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Angiospermous fossil fruits/seeds during Tertiary in India

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ABSTRACT

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A number of fossil fruits/seeds are known from the different Tertiary sediments in India ranging from the Maastrichtian-Danian (Palaeocene) to the Pliocene-Pleistocene. Present account embodies the listing of some well known fossil fruits/ seeds from the Indian Tertiary and an attempt has been made to throw light on their palaeoecological, palaeophytogeographical and the evolutionary significance. Most of the known monocot fossils belong particularly to the family Arecaceae from the Maastrichtian-Danian Deccan Intertrappean beds of India. In the dicots, quite a few fossil fruits/seeds of family Lythraceae are described only from the Maastrichtian-Danian, while the fabaceous fruits/seeds are described in a large number mostly from the Oligocene to Miocene. The families viz., Arecaceae, Burseraceae, Combretaceae, Nyssaceae, Polygonaceae, Rhamnaceae, Rubiaceae and Sapindaceae occur in the Neogene sediments. However, the paucity of fossil fruits/seeds precludes any definite analysis or comments on their palaeobotanical characteristics. Most of the fossil fruits are drupaceous or capsular while fabaceous fruits are lomentum or legume. types. The fibrous nature of mesocarp in Arecaceous fruits suggests their dispersal through water, such plants might be growing in the coastal areas or near the other water bodies. The capsular or the other fruits with thin pericarp might belong to the inland terrestrial zones. Many fruits of uncertain affinities, e.g. *Sahniocarpon*, *Wingospermocarpon*, *Enigmocarpon* and *Viracarpon* pose interesting questions about the evolution of angiosperms during the Tertiary in India. Further investigations are needed to ascertain the taxonomy of fossil fruits/seeds, to ascribe them to respective families.

Key-words—Tertiary, India, Angiosperms, Fossil fruits/seeds.

भारत में टर्शियरी के दौरान आवृतबीजीय जीवाश्म फल/बीज

अनिल अग्रवाल

सारांश

भारत में मास्ट्रीच्टियन-डेनियन (पुरानूतन) से अतिनूतन-अत्यंनूतन तक विभिन्न टर्शियरी अवसादों से अनेक जीवाश्म फल/बीज ज्ञात हैं। वर्तमान लेखा-जोखा भारतीय टर्शियरी से कुछ सुप्रसिद्ध जीवाश्म फलों/बीजों को सुनिश्चित रुप से व्यक्त करता है तथा उनकी पुरापारिस्थितिक, पुरापादपभौगोलिक एवं विकासात्मक सार्थकता पर प्रकाश डालने का प्रयास किया गया है। अधिकांश प्रसिद्ध एकबीजी जीवाश्म विशेष रूप से एरेकैसी कुल के हैं जो भारत के मास्ट्रीच्टियन-डेनियल दक्कन अंतरट्रापीन संस्तरों से प्राप्त हुए हैं। द्विबीजियों में, मास्ट्रीच्टियन-डेनियन से लिथ्रासीए परिवार के निश्चित रुप से कुछ जीवाश्म फलों/बीजों को वर्णित किया गया है, जब कि ज्यादातर सेमाभ फलों/बीजों को बड़ी संख्या में अल्पनूतन से मध्यनूतन से वर्णित किया गया है। नियोजीन अवसादों में एरेकैसी, बर्सेरसी, कॉम्ब्रेटेसी, नाय्सासी, पॉलीगोनीसी, रह्म्नासीए, रुबीआसी तथा सेपिनडासी कुल प्राप्त होते हैं। फिर भी, जीवाश्म फलों/बीजों की कमीं उनकी पुरावानस्पतिक विशेषताओं पर स्पष्ट विश्लेषण अथवा समीक्षा को बाधित करती है। ज़्यादातर जीवाश्म फल गुठलीदार या संपुटी हैं जब कि सेमाभ फल लोमेंटम या फली जैसा है। एरेकेसीमय फलों में मध्य फल-भितृति की रेशेदार प्रकृति जल से उनका परिक्षेपण सुझाती है, इस तरह की वनस्पतियां तटीय क्षेत्रों या अन्य जलाशयों के नज़दीक उग रहे होंगे। संपुटी या तनु फल-भितृति सहित अन्य फल अंतःस्थलीय स्थलीय क्षेत्रों का रहा होगा। भारत में टर्शियरी के दौरान आवृतबीजी के विकास के बारे में अनिश्चित बंधुता के बहुत से फल जैसे कि साहानियोकार्पन, विंगोस्पर्मोकार्पन, एनीग्मोकार्पन तथा वीराकार्पन कुछ रोचक प्रश्न प्रस्तुत करते हैं। अपने कुलों के नाम देने के लिए, जीवाश्म फलों/बीजों की वर्गिकी को सिद्ध करने के लिए आगे अन्वेषणों की आवश्यकता है।

संकेत-शब्द—टर्शियरी, भारत, आवृतबीजी, जीवाश्म फल/बीज।

Challenges in Indian Palaeobiology: Current Status, Recent Development and Future Directions
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INTRODUCTION

THE dominance of gymnosperms began to decline during Cretaceous and made way for a new group of plants, the angiosperms. The angiosperms underwent major diversification during the Mid–Cretaceous as evidenced by abundance of the angiosperm fossils at this stratigraphic level (Crane & Lidgard, 1989; Lidgard & Crane, 1990; Wing *et al.*, 1993). Although the precise location of the centre of origin of the angiosperms is uncertain, Takhtajan (1969, 1987) proposed that the "Cradle of the Angiosperms" lies somewhere between Assam and Fiji in South- eastern Asia and considered south-east Asia (including Myanmar, Thailand, Indo-China and Malaysia) to be the most likely region where angiosperms originated but the proposal could not be justified.

The question of time and the geographical region of angiosperm evolution and diversification can be best tackled by palaeobotanical studies. Indian palaeobotanical records indicate sudden appearance of angiosperms profusely in the Deccan Intertrappean sediments of Maastrichtian-Danian age. No reliable older angiosperm fossils are known so far from India though a few angiospermous fruits of uncertain affinities and a questionable flower described from the Lower Cretaceous sediments of Rajmahal Hills, deserve to be seriously questioned (Mehrotra, 2003).

It is generally believed that angiosperms appeared in India during Maastrichtian-Danian, spreading and diversifing rapidly thereafter throughout the Tertiary. According to Chatterjee and Scotese (1999), Greater India established contact with Africa via Greater Somalia during the Campanian-Early Maastrichtian (Fig. 1). This might have paved way for the influx of angiosperms from Africa into India after the KT extinction. Megafossil assemblages recorded from various Tertiary sediments in India are mostly based on wood and leaf records. Comparatively, very small number of fossil fruits/seeds have been described from the Indian Tertiary. Critical studies of the characteristics of fossil woods and leaves and their comparison with the corresponding living species have provided valuable insights into the dispersal and diversification of angiosperms in India. However, critical studies of the fossil fruits/seeds are still lacking. The dispersal of fruits/seeds from the source areas through various abiotic and biotic agencies would have played a crucial role in the evolution of new ecosystems in India throughout the Tertiary. In the present study, reliable records of fossil fruits/seeds from various Palaeogene and Neogene sediments of India are listed and discussed (Figs 2, 3).

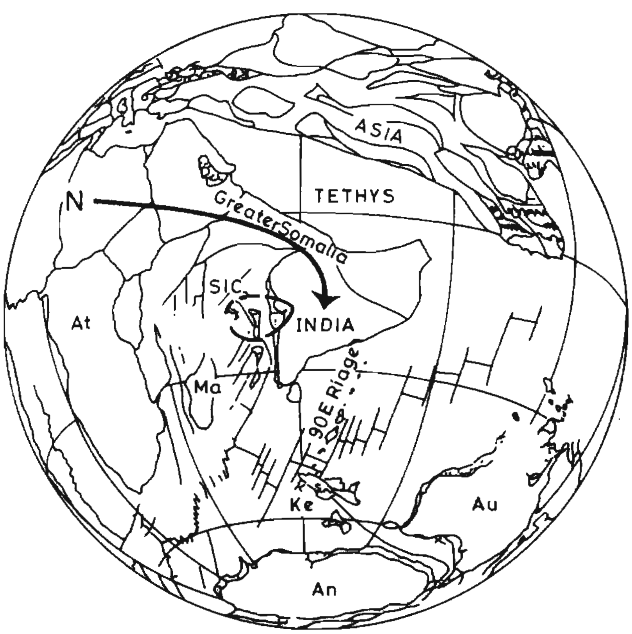

Fig. 1—Palaeogeographic reconstruction showing the positions of Gondwana continents during the Cretaceous Tertiary (KT) Boundary (Chatterjee & Scotese, 1999).

OBSERVATIONS AND DISCUSSION

Most of the fossil fruits from the Palaeogene have been recorded from the Deccan Intertrappean localities of Mohgaonkalan and Mandla in M.P.; Nawargaon and Nagpur in Maharashtra. These localities are considered Upper Maastrichtian to Danian in age (Venkatesan *et al.*, 1993; Shukla *et al.*, 1997; Salis & Saxena, 1998; Khosla, 1999). Other Palaeogene localities are Barmer (Rajasthan) of Middle Eocene age; Champai (Mizoram), Dagashi Formation, Solan (Himachal Pradesh) and Makum Coalfield (Assam) of Oligocene age; Garo hills, Rongrenggiri and Nangwalbilra (Meghalaya) of Upper Palaeocene age (Rajarao, 1981). The Neogene fossil fruits/seeds have been collected from Ratnagiri and Sindhudurg (Maharashtra), Payangadi (Kerala), Darjeeling (West Bengal), Aizwal and Sesawng (Mizoram), Solan (Himachal Pradesh), Kathgodam (Uttarakhand), Goyla-Mokra (Gujarat) and Garo hills (Assam). These localities have been assigned Upper to Lower Miocene ages. Palamu and Katni (Bihar) and Saketri (Chandigarh) localities have been assigned Miocene to Pleistocene and subsequent Quaternary ages.

A total of 57 fossil fruits/seeds species are described here from Palaeogene. Thirty belong to monocots, 26 belong to dicots and 1 is incertae-sedis. Most of the monocot fossils belong to Arecaceae (19). Palm fruits occur quite commonly in the Indian Tertiary, especially in the Deccan Intertrappean beds of Mohgaonkalan. However, identification of these fruits with any extant taxa of Arecaceae has usually not been possible. Kulkarni and Pande (1980) have grouped palm fruits into six major types on the basis of endocarp features. Among the fossil fruits of Arecaceae only *Areca*, *Cocos* and *Hyphaene* could be identified with reasonable certainty. A number of palm fruits not comparable with living species have been placed

Fossil taxon	Comparable modern taxon	Locality	Age	References
Monocotyledons				
Arecaceae				
Areca intertrappea	*Areca*	Mohgaonkalan/M.P.	Maastrichtian-Danian	Paradkar & Senad, 1981; Senad & Paradkar, 1989
Arecoidocarpon kulkarnii	*Areca*	Mohgaonkalan/M.P.	Maastrichtian-Danian	Bonde, 1990b
Cocos intertrappeansis	*Cocos*	Mohgaonkalan/M.P.	Maastrichtian-Danian	Patil & Upadhya, 1984
Cocos sahnii	*Cocos*	Mohgaonkalan/M.P.	Maastrichtian-Danian	Kaul, 1951
Cocos nucifera like fruit	*Cocos nucifera*	Champai/Mizoram	Oligocene	Tripathi *et al.*, 1999
Hyphaenocarpon indicum	*Hyphaenea*	Mohgaonkalan/M.P.	Maastrichtian-Danian	Bande *et al.*, 1982
Palmocarpon sp.	Palm	Mohgaonkalan/M.P. Mandla/M.P.	Maastrichtian-Danian	Sahni, 1934; Mehrotra, 1988
Palmocarpon arecoides	*Arecoid* palm	Mandla/M.P.	Maastrichtian-Danian	Mehrotra, 1988
Palmocarpon bracteatum	Palm	Mohgaonkalan/M.P.	Maastrichtian-Danian	Sahni, 1934
Palmocarpon cocoides	*Cocoid* palm cf. Fruit	Mandla/M.P.	Maastrichtian-Danian	Mehrotra, 1988
Palmocarpon coryphoidium	*Coryphoid* palm	Nawargaon/Maharashtra	Maastrichtian-Danian	Shete & Kulkarni, 1985
Palmocarpon compressum	Palm	Mohgaonkalan/M.P.	Maastrichtian-Danian	Sahni & Rode, 1937
Palmocarpon indicum	Palm	Mohgaonkalan/M.P.	Maastrichtian-Danian	Prakash, 1960
Palmocarpon intertrappea	Palm	Mohgaonkalan/M.P.	Maastrichtian-Danian	Yawale & Chitaley, 1979
Palmocarpon insigne	Palm	Mohgaonkalan/M.P.	Maastrichtian-Danian	Mahabale, 1950
Palmocarpon mohgaoense	Palm	Mohgaonkalan/M.P.	Maastrichtian-Danian	Prakash, 1955
Palmocarpon splendidum	Palm	Mohgaonkalan/M.P.	Maastrichtian-Danian	Trivedi & Chandra, 1973
Palmocarpon sulcatum	Palm	Mohgaonkalan/M.P.	Maastrichtian-Danian	Prakash, 1960
Palmocarpon umariense	Palm	Mohgaonkalan/M.P.	Maastrichtian-Danian	Bonde, 1988
Nypaceae				
Nipa hindi	*Nypa*	Mohgaonkalan/M.P.	Maastrichtian-Danian	Sahni & Rode, 1937
Nipa	*Nypa*	Mohgaonkalan/M.P.	Maastrichtian-Danian	Chitaley, 1960; Nambudiri, 1966
Nipa sahni	*Nypa fruticans*	Rongrenggiri/Meghalaya	Eocene	Bhattacharyya, 1983
Nipa fruiticans Wurmb	*Nypa fruiticans* Wurmb	Makum & Dilli-Jeypore coalfields (Assam); Kolasib stone quarry (Mizoram)	Oligocene and Lower Miocene	Mehrotra *et al.*, 2003
Musaceae				
Musa cardiosperma	*Musa*	Mohgaonkalan/M.P.	Maastrichtian-Danian	Jain, 1964b; Bande *et al.*, 1993
Monocotyledonae				
Triloculocarpon mahabalei	?	Mohgaonkalan/M.P.	Maastrichtian-Danian	Kapgate & Sheikh, 1988
Viracarpon hexaspermum	?	Mohgaonkalan/M.P.	Maastrichtian-Danian	Sahni, 1944; Chitaley, 1958
Pandanaceae	*Pandanus*	Mandla/M.P.	Maastrichtian-Danian	Bonde, 1990a
Pandanusocarpon umariense				
Tricoccites trigonum	*Pandanus*	Mohgaonkalan/M.P	Maastrichtian-Danian	Rode, 1933; Sahni & Rode, 1937; Shukla , 1950; Chitaley, 1957; Patil, 1974; Bonde, 1985
Poaceae				
Graminocarpon mohgaoense	Wheat/Maize/ Jowar	Mohgaonkalan/M.P	Maastrichtian-Danian	Chitaley & Sheikh, 1971
Graminocarpon stellatus	Poaceae	Mohgaonkalan/M.P	Maastrichtian-Danian	Dutta & Ambwani, 2005
Dicotyledonae				
Cremocarpon deccanii	?	Mohgaonkalan/M.P	Maastrichtian-Danian	Karanjekar, 1984
Deccanocarpon arnoldii	?	Mohgaonkalan/M.P	Maastrichtian-Danian	Paradkar, 1975

Sahniocarpon harrisii	?	Mohgaonkalan/M.P	Maastrichtian-Danian	Chitaley & Patil, 1973; Patil & Karekar, 1986; Nambudiri *et al.*, 1987; Karekar, 1989
Wingospermocarpon mohgaonse	?	Mohgaonkalan/M.P.	Maastrichtian-Danian	Sheikh & Kapgate, 1984
Caryophyllaceae				
Centrospermocarpon chitaleyi	Caryophyllaceae	Mohgaonkalan/M.P.	Maastrichtian-Danian	Sheikh *et al.*, 1982
Combretaceae				
Terminalia precatappa	*T. catappa*	Champhai/Mizoram	Oligocene	Tewari & Mehrotra, 2002
Clusiaceae				
Indocarpa intertrappea	Clusiaceae	Mohgaonkalan/M.P.	Maastrichtian-Danian	Jain, 1964a
Euphorbiaceae				
Euphorbiocarpon drypeteoides	*Drypetes*	Mandla/M.P	Maastrichtian-Danian	Mehrotra *et al.*, 1983
Fabaceae				
Entada palaeoscandens	*E. scandens*	Makum/Assam	Oligocene	Awasthi & Mehrotra, 1995
Leguminocarpon albizoides	*Albizia*	Garo hills/Meghalaya	Upper Palaeocene	Bhattacharyya, 1985
Leguminocarpon derrisoides	*Derris*	Garo hills/Meghalaya	Upper Palaeocene	Bhattacharyya, 1985
Leguminocarpon desmoides	*Desmodia*	Garo hills/Meghalaya	Upper Palaeocene	Bhattacharyya, 1985
Leguminocarpon millettioides	*Millettia*	Garo hills/Meghalaya	Upper Palaeocene	Bhattacharyya, 1985
Leguminocarpon mizoramensis	*Delonix regia/Albizia*	Champhai/Mizoram	Oligocene	Tewari & Mehrotra, 2002
Leguminocarpon pongamoides	*Pongamia*	Garo hills/Meghalaya	Upper Palaeocene	Bhattacharyya, 1985
Lythraceae				
Enigmocarpon parijai	Lythraceae	Mohgaonkalan/M.P.	Maastrichtian-Danian	Sahni, 1943; Dwivedi, 1956
Enigmocarpon parijai mohgaonse	Lythraceae	Mohgaonkalan/M.P	Maastrichtian-Danian	Patil, 1974
Enigmocarpon parijai intertrappea	Lythraceae	Mohgaonkalan/M.P	Maastrichtian-Danian	Patil, 1974
Enigmocarpon sahnii	Lythraceae	Mohgaonkalan/M.P	Maastrichtian-Danian	Chitaley & Kate, 1977
Malvaceae				
Daberocarpon gerhardii	?	Mohgaonkalan/M.P	Maastrichtian-Danian	Chitaley & Sheikh, 1973
Harrisocarpon sahnii	?	Mohgaonkalan/M.P	Maastrichtian-Danian	Chitaley & Nambudiri, 1973
Oleaceae				
Oleocarpon nagpurii	Oleaceae	Nagpur/Maharashtra	Maastrichtian-Danian	Sheikh *et al.*, 1989
Tiliaceae				
Grewia mohgaoenensis	*Grewia*	Mohgaonkalan/M.P.	Maastrichtian-Danian	Paradkar & Dixit, 1984
Triumfetta rhomboideocarpa	*Triumfetta rhomboidea*	Nangwalbibra/Meghalaya	Palaeocene	Bhattacharyya, 1983
Trapaceae				
Trapa mohgaoensis	*Trapa*	Mohgaonkalan/M.P.	Maastrichtian-Danian	Paradkar & Patki, 1987
Urticaceae				
Boehmeria intertrappea	*Boehmeria*	Mohgaonkalan/M.P.	Maastrichtian-Danian	Ambwani *et al.*, 2004
Incertae -sedis				
Carpolithus sp. 1	?	(Dagashi Formation) Solan/H.P.	Oligocene	Mathur *et al.*, 1996

Fig 2—Fossil fruits/seeds from Palaeogene of India.

Fossil taxon	Comparable modern taxon	Locality	Age	References
Arecaceae				
Eugeissonocarpon indicum	*Eugeissona*	Ratnagiri (Maharashtra)	Miocene	Shinde & Kulkarni, 1989
Palm fruit	cf. *Cocos plumosa/coronata*	Pangadi (Andhra Pradesh)	Oligocene-Eocene-Miocene	Mahabale & Rao, 1968
Nypaceae				
Nipa sahnii	*Nypa fruticans*	Garo Hills (Assam)	Miocene	Lakhanpal, 1952
Boraginaceae				
Boraginocarpon lakhanpalii	Boraginaceae	Saketri (Chandigarh)	Pliocene-Pleistocene	Mathur, 1974
Burseraceae				
Bursera serratoides	*Bursera serrata*	Darjeeling (West Bengal)	Miocene	Antal & Awasthi, 1993
Canariocarpon ratnagiriensis	*Canarium*	Sindhudurg (Maharashtra)	Miocene	Agarwal & Ambwani, 2000
Combretaceae				
Terminalia sesawngensis	*Terminalia belerica*	Sesawng (Mizoram)	Lower Miocene	Agarwal & Mandaokar, 2007
Terminalia praechebula	*Terminalia chebula*	Sindhudurg (Maharashtra)	Miocene	Agarwal, 2005
Euphorbiaceae				
Euphorbiocarpon payangadiensis	Euphorbiaceae	Payangadi (Kerala)	Miocene	Awasthi & Srivastava, 1992
Fabaceae				
Derrisocarpon prakashii	*Derris trifoliatus*	Kathgodam (Uttarakhand)	Middle Miocene	Prasad *et al.*, 2004
Derrisocarpon miocenicum	*Derris*	Darjeeling (West Bengal)	Miocene	Mitra & Banerjee, 2004
Entada palaeoscandens	*Entada phaseoloides* (syn. *E. scandens)*	Suraikhola & Koilabas (Nepal), Darjeeling (West Bengal), Sindhudurg (Maharashtra)	Miocene	Awasthi & Prasad, 1990; Prasad, 1994a; Antal & Awasthi, 1993; Agarwal, 2003
Leguminocarpon khariensis	Fabaceae	Goyla- Mokra (Gujarat)	Lower Miocene	Lakhanpal & Guleria, 1982
Leguminocarpon cassioides	*Cassia fistula*	Aizawl (Mizoram)	Lower Miocene	Mehrotra & Mandaokar, 2002
Leguminosites khariensis	Fabaceae	Goyla- Mokra (Gujarat)	Lower Miocene	Lakhanpal & Guleria, 1982
Pongamia kathgodamensis	*Pongamia pinnata (*syn. *P. glabra* Vent*)*	Kathgodam (Uttarakhand)	Middle Miocene	Prasad, 1994b; Prasad *et al.*, 1999, 2004
Dicot Fruit Type- 4 cf. *Dalbergia sissoo*	*Dalbergia*	Palamu (Bihar)	Miocene- Quaternary	Bande & Srivastava, 1990
Rhamnaceae				
Dicot Fruit Type-2 cf. *Zizyphus xylopyrus*	*Zizyphus xylopyrus*	Palamu (Bihar)	Miocene- Quaternary	Bande & Srivastava, 1990
Dicot Fruit Type-3 cf. *Zizyphus mauritiana*	*Zizyphus mauritiana*	Palamu (Bihar)	Miocene- Quaternary	Bande & Srivastava, 1990
Dilleniaceae				
Dicot Fruit Type-1 cf. *Dillenia*	*Dillenia*	Palamu (Bihar)	Miocene- Quaternary	Bande & Srivastava, 1990
Nyssaceae				
Nyssa brandoniana	*Nyssa brandoniana*	Ratnagiri (Maharashtra)	Miocene	Shinde & Kulkarni, 1989
Polygonaceae				
Rumex acetosella	*Rumex acetosella*	Katni (Bihar)	Mio-Pliocene	Yadekar & Pitchai Muthu, 1988
Rubiaceae				
Amberiwadiocarpon devgarhensis	*Randia/ Psychotria*	Sindhudurg (Maharashtra)	Miocene	Agarwal & Ambwani, 2002
Mitragyna parviflora	*Mitragyna parviflora*	Solan (Himachal Pradesh)	Lower Miocene	Guleria *et al.*, 1999
Sapindaceae				
Euphoria longanoides	*Euphoria longanoides*	Darjeeling (West Bengal)	Miocene	Antal & Awasthi, 1993
Incertae- sedis				
Carpolithus sp. II	?	(Kasauli Formation) Solan/H.P.	Lower Miocene	Mathur *et al.*, 1996
Carpolithus sp. III	?	(Kasauli Formation) Solan/H.P.	Lower Miocene	Mathur *et al.*, 1996
Carpolithus sp. IV	?	(Kasauli Formation) Solan/H.P.	Lower Miocene	Mathur *et al.*, 1996
Carpolithus sp. V	?	(Kasauli Formation) Solan/H.P.	Lower Miocene	Mathur *et al.*, 1996

Fig. 3—Fossil fruits/ seeds from Neogene of India.

Fossil Fruit Species	Fruit	Fruit Wall	Seed	Embryo
Grewia mohgaoensis (*Grewia asiatica* of Tiliaceae)	Round, 2-pyrened, drupaceous, 4.4 x 4 mm axile placentation.	3-layered; mesocarp lacunose with slime canals. Endocarp stony, warty.	Elliptic, bitegmic, albuminous, crassinucillate with hypostase present. One seed in each pyrene.	Straight. Two foliaceous cotyledons. Short curved radicle.
Deccanocarpon arnoldii	Stalked, oblong rounded, 4 x 3 mm; Stalk 7 mm long & branched. Axile placentation, eight locular capsule.	Smooth with cutinised epidermis having stomata. Undifferentiated into zones.	Reniform, nine seeds in one row in each locule non-endospermic, bitegmic, warty muricate testa.	Curved dicotyledonous.
Tricoccites trigonum	Aggregate fruit, 3.4-4.5 x 2.5-4.0 cm triangular, sessile, 1-3 large pyrenes in centre surrounded by 20-22 abortive pyrenes in a ring, each pyrene is a drupe.	3-layered epicarp has 1-layered epidermis & 1-3 layered hypodermis. Mesocarp fibrous with numerous layers of fibrous bundles. Endocarp composite with horizontally & vertically interwoven fibrous strands and fibrovascular bundles endocarp of all pyrenes fuses compactly and forms aggregate fruit.	Basally attached elongated, cylindrical, 2.5-3.0 cm long & 1.0-1.4 cm in diameter. Seed coat 3 layered. Endosperm present.	Present in basal apical or middle region of seed. Monocotyledonous. Straight, flat, ribbon-like. Seed coat & cotyledon remaining within seed. Only plumule & radicle come out through a small hole at base of seed during germination, polyembryony and abortive embryos in abortive pyrenes.
Wingospermocarpon mohgaoense	2.5 x 4.6 mm, ovoid, unilocular, capsule with apical slit. Many seeded.	3-layered. Epicarp has epidermis & hypodermis. Mesocarp fibrous. Endocarp-1 layered parenchymatous.	Seed winged. Wing has pointed ends. Surface has spiny parenchymatous projections. Seed coat 1-layered parenchymatous. Endosperm present.	-
Trapa mohgaoensis	Indehiscent drupaceous. Coriaceous, turbinate. 2-3 spines with barbs.	3- layered. Outer zone parenchymatous Middle-sclerenchymatous with air cavities, inner layer parenchymatous.	One large seed, non-endospermous. Seed coat not fused with pericarp and has testa & tegmen.	Embryo has one well developed and other scaly cotyledon. Hypostase present.
Euphorbiocarpon drypeteoides	Oval to elliptical drupe. Usually 3, rarely 2 to1- locular. 2.1 x 1.9 cm.	Epicarp thin-walled parenchymatous. Mesocarp fleshy parenchymatous. Endocarp stony. Sclereids in mesocarp present thick-walled radially elongated cells in inner zone of endocarp absent.	Elliptical, 1.2-1.5 cm long, 7-8 mm in diameter One-seed in each locule. Enderspermous. Seed coat 4-6 layers of thin walled cells	Rod-shaped, dicotyledonous.
Enigmocarpon	8-locular loculicidal capsule.	Externally & internally smooth.	Non-endospermic.	
E. parijai	Ellipsoidal, 16 mm long 14 mm broad, septae not attached to placenta.	Externally & internally smooth.	Non-endospermic.	
E. sahnii	Globular, 11 mm long, 13 mm broad, septae attached to placenta.	Inner lining of loculi & Septa have glandular outgrowths Epidermis thin-walled 4-8 layers of thick-walled cells, 4-5 layers of compact parenchyma, rest of wall spongy.		
Indocarpon intertrappea	4-locular, septifragal capsule with columella 3.0 x 2.3 cm.	Pericarp of parenchyma cells.	Testa fleshy.	

Harrisocarpan sahnii	5-locular, loculicidal capsule.	Pericarp parenchymatous with intercellular spaces. Multicellular & multiseriate scaly hairs on fruit wall.	2- seeds per locule, oval, anatropous. Seed coat 3-layered middle layers thick walled parenchymatous, endosperm present.	Embryo straight dicotyledonous.
Rumex acetosella			seed rounded triangular pointed tip, 0.41 mm diameter shiny smooth surface, wall thin.	
Sahniocarpon harrisii	5-locular, loculicidal capsule.		One seed per locule.	
Daberocarpon gerhardii	10-locular, capsule.		One seed per locule.	
Leguminocarpon	1-locular lomentaceous legume.			
Cremocarpon deccanii	2-chambered cremocarp, 2 mericarps attached to biforked carpophore on commnisural sides Mericarp 1-locular, smooth elongated.	Pericarp of two zones.	One unitegmic anatropous pendulous.	
Musa cardiosperma	Elongated berry with axile placentation.		Seeds in rows in each locule, arillate?	
Boehmeria intertrappea	Achene/drupe.	Perianth persistent.	Seed with only endosperm.	Embryo straight.
Graminocarpon mohgaoense	Caryopsis, long, spheroidal, 1.5 x 2 mm, has longitudinal furrow.	Exocarp without scales, mesocarp 2-3 layered in concentric rings, endocarp thin.	Endosperm present.	
Graminocarpon stellatus	Caryopsis, oval, 1 x 1.6 mm, lateral ridge present, without furrow, transluscent.	Exocarp covered with stellate scales, mesocarp thick parenchymatous, endocarp thin.	Abundant endosperm.	Embryo marginal, enclosed in papery membrane.
Eugeissona	One seeded drupe.	Mesocarp fibrous. Endocarp hard.	Seed endospermous, seed coat well developed.	
Palmocarpon	One seeded drupe.	Mesocarp fibrous. Endocarp hard.	Seed endospermous, seed coat well developed.	
Areca	One seeded drupe.	Mesocarp fibrous .Endocarp hard.	Seed endospermous, seed coat well developed.	
Arecoideocarpon	One seeded drupe.	Mesocarp fibrous. Endocarp hard.	Seed endospermous, seed coat well developed.	
Nipa	One seeded drupe.	Mesocarp fibrous. Endocarp hard.	Seed endospermous, seed coat well developed.	
Nypa fruticans	One seeded drupe.	Mesocarp fibrous. Endocarp hard.	Seed endospermous, seed coat well developed.	
Cocos	One seeded drupe.	Mesocarp fibrous. Endocarp hard.	Seed endospermous, seed coat well developed.	

Fig. 4—Important characteristics of the fossil fruits/seeds from Tertiary of India.

under artificial genus *Palmocarpon* Miquel (1853). In such palm fruits also characteristics of Coryphoid, Arecoid and Cocoid palm fruits could be identified. The fruits of *Nipa* are representsed by 3 species. Fossil species of *Nipa* fruits described from India are simply instituted on the basis of variations in the size and shape. However, the size and shape of fruits considerably vary even in the same living *Nipa* plant. Thus, the identification of fossil *Nipa* fruits on this ground may not be secure enough. Further, morphological studies of the fruits of both living and fossil may resolve the problem (Singh, 1999). All the species of fossil *Nipa* have been merged into one *Nipa fruticans* by Mehrotra *et al.* (2003). Other monocot families represented are, Musaceae, Pandanaceae and Poaceae. Bonde (1985) showed close affinity of *Tricoccites* with *Pandanus* and suggested that the fruit might belong to an extinct member of Pandanaceae very close to *Pandanus*. Another fossil fruit showing affinities with *Pandanus* is *Pandanusocarpon umariense* (Bonde, 1990a). *Callistemonites indicus* after reinvestigation has been merged with *Musa cardiosperma* Jain (1964b) by Bande *et al.* (1993). Two species, viz. *Triloculocarpon mahabalei* and *Viracarpon hexaspermum* from Mohgaonkalan (M.P.) are fruits that could not be assigned to any living monocot species or family. *Graminocarpon mohgaoense* Chitaley and Sheikh (1971) and *G. stellatus* Dutta and Ambwani (2005) from Mohgaonkalan (M.P.) are caryopsis fruits of Poaceae.

Among the dicots, 4 fossil fruits/seeds species could not be assigned to any living family. These are *Cremocarpon deccani*, *Deccanocarpon arnoldii*, *Sahniocarpon harrisii* and *Wingospermocarpon mohgaoense*. Fossils *Daberocarpon gerhardii* and *Harrisocarpon sahnii* of Malvaceae as well as *Enigmosarpon parijai* and *E. sahnii* of Lythraceae could not be reliably compared with modern taxa. Other fossil fruits have been assigned to definite living species *Terminalia catappa* (Combretaceae), *Entada scandens* (Fabaceae), *Grewia* and *Triumfetta rhomboidea* (Tiliaceae), *Trapa* (Trapaceae) and *Boehmeria* (Urticaceae). The largest number of dicot fruits from Palaeogene belong to Fabaceae. In addition to *Entada*, the other 7 fruits showing affinities with modern *Albizzia*, *Derris*, *Desmodia*, *Millettia*, *Pongamia*, etc. have been assigned to artificial genus *Leguminocarpon*. Other dicot families represented in Palaeocene are Caryophyllaceae, Clusiaceae, Euphorbiaceae and Oleaceae. The fruit genus *Enigmocarpon* (Sahni, 1943) is unique as it could be associated with its flower *Sahnianthus* (Shukla, 1944). Numerous specimens of both these forms have been discovered from the Upper Maastrichtian-Danian beds of Mohgaonkalan, Chhindwara District (M.P.) and some specimens have also been found at Bharatwada near Nagpur (Shukla, 1950). Two species of the fruit *E. parijai S*ahni and *E. sahnii* Chitaley and Kate differ only slightly. These 8 locular capsular fruits however, show affinities with Lythraceae and might belong to some extinct taxon of this family. Fruits of *Enigmocarpon parijai* have been analysed biostatistically and grouped by Patil (1974) into two varieties *E. parijai mohgaonense* (fruit wall less than 2 mm for 12 x 10 mm fruit size) and *E. parijai intertrappea* (fruit wall more than 2 mm for 12 x 10 mm fruit size). One seed from Dagashi Formation in Himachal Pradesh has been placed in the artificial genus *Carpolithus*.

About 29 fossil fruits/seeds have been described from Neogene sediments. Only 3 monocot (palm) fruits have been recorded, 22 fruits/seeds belong to 11 dicot families and 4 are incertae-sedis. The monocot fruits have been compared with *Nipa fruiticans* (Nypaceae), *Cocos* and *Eugeissona* (Arecaceae). Seven fruits belonging to family Fabaceae have been described. Among these the fruits of *Pongamia, Entada* and *Derris* have been identified with reasonable certainty and others have been placed in the artificial genus *Leguminocarpon*. The other species represented among the fossil fruits/seeds record are *Bursera* and *Canarium* (Burseraceae), *Terminalia* (Combretaceae), *Zizyphus* (Rhamnaceae), *Dillenia* (Dilleniaceae), *Nyssa* (Nyssaceae), *Rumex* (Polygonaceae), *Randia/Psychotria, Mitragyna* (Rubiaceae) and *Euphoria* (Sapindaceae). In Himachal Pradesh, 4 seeds described from Kasauli Formation have been placed under artificial genus *Carpolithus*.

The long-term survival of an angiosperm species in an area as well as its migration to new areas depends upon the successful dispersal of its fruits/seeds through various agencies such as air, water, birds or animals. In modern angiosperms, the fruits/seeds have particular adaptations to aid their successful dispersal. Thus, it seems reasonable to assume that structural features of the fruits/seeds of the past angiospermous species would also show features suitable for their dispersal in the conditions of their habitat. The structural features of the fossil fruits/seeds (Fig. 4) may be helpful in deducing the mode of their dispersal and related conditions of the past environment.

The fossil Palm fruits are drupe having single well developed seed with copious endosperm. They have characteristic fibrous mesocarp and hard endocarp suited for their dispersal through sea-water currents in coastal area like modern palm fruits. The indehiscent drupaceous fruit of *Trapa* has a middle layer of parenchymatous pericarp with air cavaties. Such fruits are also suited for dispersal through water. *Musa cardiosperma* is many-seeded berry fruit. *Pandanusocarpon umariense, Viracarpon hexaspermum* and *Tricoccites trigonum* are aggregate fruits. Dispersal of such fruits and their seeds might have taken place through animals. The structure of *Tricoccites trigonum* shows that the seed coat and cotyledon remain adhered in the seed. Only plumule and radicle come out through a small hole at the base of the seed during germination. A large number of capsular fruits having few to numerous small seeds have been recorded from Palaeocene such as *Daberocarpon gerhardii* (10-locular capsule), *Deccanocarpon sahnii* (8-locular, stalked capsule), *Wingospermocarpon sahnii* (1-locular capsule with apical slit and winged seeds), *Enigmocarpon* (8-locular loculicidal capsule), *Indocarpon intertrappea* (4-locular septifragal capsule), *Harrisocarpon sahnii* and *Sahniocarpon harrisii* both (5-locular loculicidal capsule). Seeds from such capsular fruits might have been dispersed by air. Caryosis fruits *Graminocarpon mohgaoense* and *G. stellatus* were probably dispersed by animals.

Pollination in angiosperm is an event of fundamental importance in the life cycle of angiosperms. The co-evolution between insects and plants (i.e. insect pollination) has been suggested as an influential process in the origin and divergence of angiosperms (Dilcher, 2000; Labandeira, 1988; Labandeira *et al.*, 1994; Takhtajan, 1969). Stewart (1993) noted that evolution of seeds had to be closely related with evolution of pollens. Production of fruits/seeds, their dispersal and germination of seeds are other important aspects of the life cycle of angiosperms. The plant invests considerable energy to ensure successful reproduction. A lot of energy is invested in developing such characteristics that may ensure the successful dispersal of fruits and seeds through suitable agencies and subsequent germination. In all the studies of fossil fruits/seeds from the Indian Tertiary, the emphasis has been focussed on their description and affinities with modern living species. Not much attention has been paid on relating their morphological/anatomical features with the environmental conditions or their suitability for a particular mode of dispersal. These aspects require further attention. Concerted efforts for collection of fossil fruits/seeds from various localities and sediments of India are also required.

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