

Occurrence of fossil fungi in dinosaur dung and its implication on food habit

An investigation on the fossil dinosaur dung (Group A coprolite of Matley)¹ exhibits an array of fungi that live on leaves as parasites, revealing thereby that some sauropod dinosaurs ate the leaves of various types of plants as food.

Among the dinosaurs, the sauropods were the most dominant terrestrial herbivores. They were large but had weak peg-like teeth, which were thought to be suitable for chopping soft, aquatic plants².

The Lameta Formation (Maastrichtian), exposed mostly in central and western India, is rich in dinosaurs³. Of these, *Titanosaurus* Lydekker represents one-third of sauropod diversity and was widespread in India, Argentina, Madagascar, Europe and Laos and continued throughout the Cretaceous^{4,5}. However, *Titanosaurus* is an invalid genus and it has now been replaced by a new generic name *Isisaurus*⁵.

At the village Pisdura, about 13 km NNE of Warora in Nand-Dongargaon basin (Figure 1), dinosaurian coprolites commonly occur along with the remains of *Isisaurus*, and other sauropods, etc.^{1,6,7}. The coprolites found around Pisdura are generally scattered in the field; a few are also embedded in the sediments. Here, the Lameta Formation is sandwiched between the Gondwanas and the Deccan Traps (Figure 2). The formation represents mostly the over-bank red silty and sandy clays in association with planar and cross-bedded sandstone and is overlain with Deccan basalts. Fossil remains of dinosaurs, coprolites, freshwater fishes, ostracods, pelecypods and gastropods occur in a thin marl band within the red clays⁸⁻¹⁰.

The coprolitic remains constitute one of the largest global collections at a single site. Matley¹, who first studied these coprolites, divided them into Group A, Groups B and Ba and Group C according to their size and morphological characters. The bigger size of Group A coprolites along with the association of *Isisaurus* led him to advocate that these were the faeces of those animals. This was substantiated by other workers¹¹⁻¹³. This type of coprolite was also studied for its contents and it was observed that they have leaf cuticles, petioles, apical shoots, inflorescence, etc. Algal and fungal spores in the coprolites were thought to

be ingested along with water. Stable isotopic analyses of this coprolite furnished evidences of C₃ type of plant material in them¹⁴⁻¹⁶.

In the present investigation, the coprolites of Group A type of Matley¹ (Figure 3) were macerated with hydrochloric acid and the digested material was passed through a 400 mesh sieve. The residue was mixed with polyvinyl alcohol solution and spread on a slide, and after drying was mounted in Canada balsam. The slides contained cuticles, tender apical shoots, algal and fungal bodies. The fungi recorded here, except *Glomus*, are all obligatory parasites on leaves; they are held firmly on them throughout their life cycle and are not dispersed. Their presence in the coprolites could only be possible through eating of the infected leaves by the dinosaurs.

The genus *Colletotrichum* Corda causing leaf spot and red rot diseases in the extant plants, is quite common in the coprolites (Figure 4a). It has subcircular acervuli sporting the setae along its mar-

gin. The setae are strongly built, septate, slightly swollen at the base, with a pointed tip. It belongs to the family Melanconiaceae, class Deuteromycetes. They are generally obligatory parasites on the various parts of plants. This genus is responsible for the leaf spot disease on many plants, viz. *Agave* of Agavaceae, *Alstonia* of Apocynaceae, *Rhus* of Anacardiaceae, *Terminalia* of Combretaceae, etc.¹⁷⁻¹⁹. *Colletotrichum* is also known from the Deccan Intertrappean bed of Mohgaon-Kalan, Madhya Pradesh and the Neogene sediments of Darjeeling foothills^{20,21}.

A number of epiphyllous fungi of the family Microthyriaceae belonging to the order Hemisphaeriales are also observed in the coprolites (Figure 4e). These are known by the form genera *Phragmothyrites*, *Notothyrites*, etc.^{22,23}. The family has about 36 genera and 150 species and almost all of them are leaf parasites mostly in the tropical-subtropical region. They are characterized by rounded, dimidiate stromata appearing as superficial

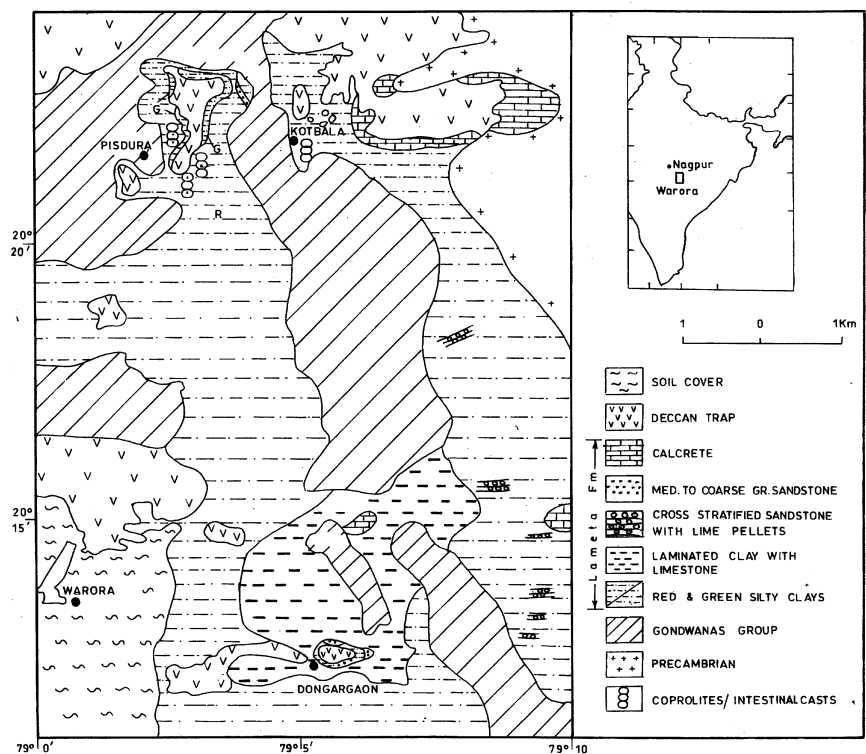


Figure 1. Map showing the locality from where the coprolites were collected (after Mohabey *et al.*¹⁰).

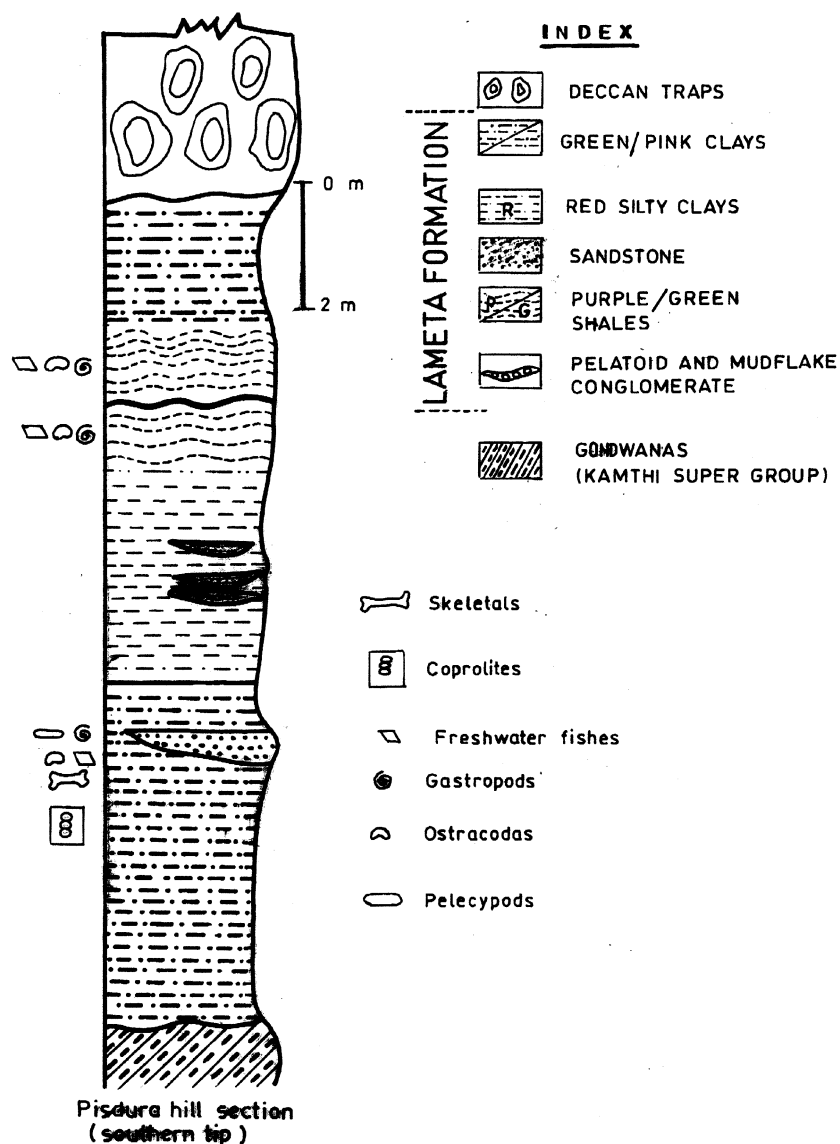


Figure 2. Lithology of the Pisdura hill section showing the position of coprolite-bearing sediments (after Mohabey³).

dots on the leaves. The hyphae are radially arranged and interconnected to form radial and transverse strands^{24,25}. The occurrence of these fungi in coprolites also points out that the dinosaurs might have lived in tropical-subtropical climatic conditions.

The genera *Uncinula* and *Erysiphe* of family Erysiphaceae, responsible for producing powdery mildew disease mostly on the leaves of angiosperms, are also present in the material (Figure 4 b and c). The mature cleistotheca of these genera are characteristic and useful in identifying them in dispersed condition. They are equipped with characteristic appendages,

which differ much in length and morphological characters. These, along with the number of asci borne on the cleistothecum, separate the different genera. In *Uncinula* the appendages are curved and circinate, whereas cleistothecum in *Erysiphe* exhibits dark, free equatorial appendages and superficial mycelium to anchor to the host^{26,27}.

The mycorrhizal fungal genus *Glomus*, family Endogonaceae is also common in the assemblage (Figure 4 d). It grows in the roots of many plants, increases the solubility of minerals in the soil and improves the uptake of nutrients. In return, it gets its nourishment from the host.

This symbiotic association of plants and endogonales is more than 400 million years old, as *Rhynia* of Devonian age exhibits micorrhizal association in the roots similar to those of the extant plants. The chlamydospores are borne on the angular hyphae projected into the soil, subcircular in shape, about 150 μm in size and commonly occur in the humid, tropical-subtropical forest floors^{26,27}.

The mycorrhizal and epiphyllous fungi enumerated here represent two phenomena – the first relates to the post voided state when the coprolite came in contact with the soil and the fungi penetrated into it. The second reflects the food habit

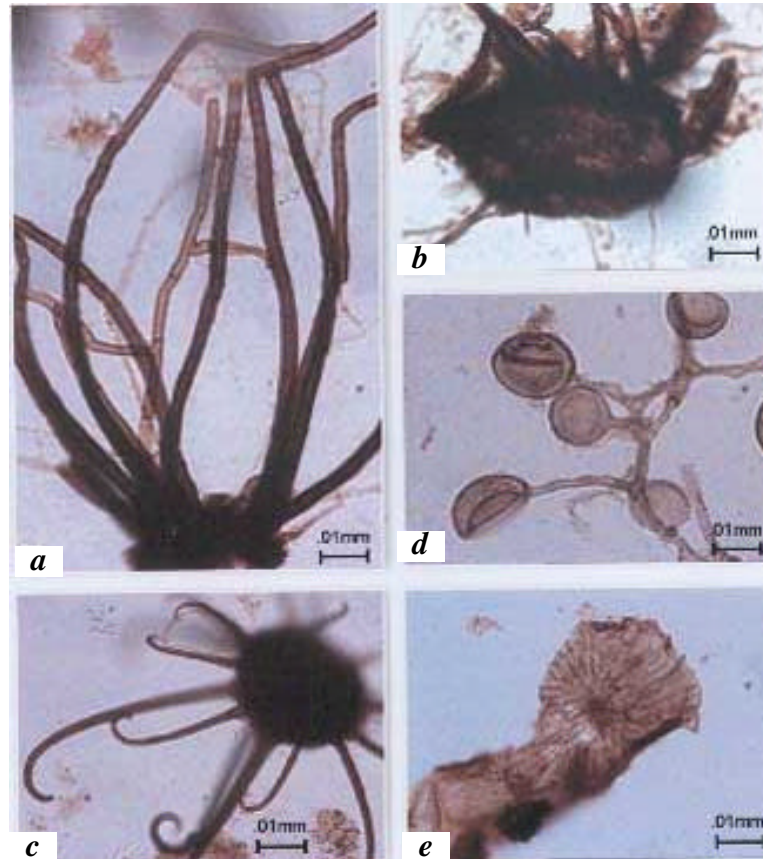


Figure 4. *a*, *Colletotrichum* cf. *capsici* (Syd.) Butler & Bisby; *b*, *Erysiphe* sp.; *c*, *Uncinula* sp; *d*, *Glomus* sp; *e*, *Phragmothryites eocaenica* Edwards emend. Kar & Saxena.



Figure 3. Two coprolites of Group A type of Matley¹.

of the dinosaurs. The diatoms (*Aulacoseira*) were recorded from the Group A-type of coprolites and their presence was explained through ingestion of water²⁸. However, the same explanation does not hold good for these fungi, as they are mostly cleistotheca and ascostromata which remain adhered on the leaves. The fungi that grow as parasites on the living leaves of plants could only be present in the coprolite through eating of these leaves. As these parasitic fungi grow on

herbaceous plants to trees, it seems possible that dinosaurs utilized their long, slender but strong neck to browse the trees like the modern camels and giraffes.

1. Matley, C. A., *Rec. Geol. Surv. India*, 1939, **74**, 535–574.
2. Ostrom, J. H., *McGraw-Hill Encyclopedia of Science and Technology*, McGraw-Hill Inc, 1977, vol. 4, pp. 219–223.
3. Mohabey, D. M., *J. Geol. Soc. India*, 1996, **37**, 363–386.
4. Lydekker, R., *Mem. Geol. Surv. India*, 1879, **4**, 1–27.
5. Wilson, J. A. and Upchurch, P., *J. Syst. Palaeontol.*, 2003, **1**, 125–160.
6. Jain, S. L. and Sahni, A., *Proc. Indian Assoc. Palynostrgr.*, Lucknow, 1983, pp. 66–83.
7. Mohabey, D. M., *J. Geol. Soc. India*, 2001, **58**, 479–508.
8. Jain, S. L., *J. Palaeontol. Soc. India*, 1977, **20**, 306–365.
9. Jain, S. L. and Sahni, A., *Geosci. J.*, 1985, **2**, 211–220.
10. Mohabey, D. M., Udhoji, S. G. and Verma, K. K., *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 1993, **105**, 83–94.
11. Chin, K., in *Encyclopedia of Dinosaurs* (eds Currie, P. J. and Padian, K.), 1997, pp. 147–150.
12. Thulborn, R. A., *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 1991, **83**, 341–366.
13. Mohabey, D. M., *Geol. Surv. India Spl. Publ.*, 2001, **64**, 605–615.
14. Mohabey, D. M. and Samant, B., *Gondwana Geol. Mag.*, 2003, **6**, 225–238.
15. Ghosh, P., Bhattacharya, S. K., Sahni, A., Kar, R. K., Mohabey, D. M. and Ambwani, K., *Cret. Res.*, 2003, **4**, 743–750.
16. Van der Merwe, N. J., *Palaeoecol. Afr. Surv. Isl.*, 1986, **17**, 123–131.
17. Kelkar, P. V. and Rao, V. G., *Sydowia*, 1962, **16**, 101–105.
18. Sharma, M. N., *Sci. Cult.*, 1970, **36**, 52–54.
19. Sarkar, A. and Chattopadhyay, S. B., *Indian J. Agric. Res.*, 1960, **30**, 162–164.
20. Kar, R. K., Sharma, N. and Verma, U. K., *Cret. Res.*, in press.
21. Mitra, S. and Banerjee, M., *J. Mycopathol. Res.*, 2000, **37**, 7–11.
22. Cookson, I. C., *Rep. B.A.N.Z. Antarctic Expedition Ser. A*, 1947, 129–142.

23. Kar, R. K. and Saxena, R. K., *Palaeobotanist*, 1976, **23**, 1–15.
24. Bessey, E. A., *Morphology and Taxonomy of Fungi*, The Blakiston Company, Philadelphia, 1950, pp. 1–790.
25. Thiessen, F. and Sydow, H., *Ann. Mycol.*, 1917, **15**, 389–491.
26. Alexopoulos, C. J., Mims, C. W. and Blackwell, M., *Introductory Mycology*, John Wiley, New York, 1996, pp. 1–632.
27. Webster, J., *Introduction to Fungi*, Cambridge University Press, Cambridge, 1993, pp. 1–669.
28. Ambwani, K., Sahni, A., Kar, R. K. and Dutta, D., *Rev. Micropaleontol.*, 2003, **46**, 67–71.

ACKNOWLEDGEMENTS. R.K.K. is grateful to the DST, New Delhi for sanctioning a project and R.K. thanks DST, New Delhi for the award of Fast-Track Young Scientist Project. We thank the Director, Birbal Sahni Institute of Palaeobotany, Lucknow for providing infrastructural facilities.

Received 20 March 2004; revised accepted 5 September 2004

R. K. KAR^{1,*}
N. SHARMA²
RATAN KAR¹

¹*Birbal Sahni Institute of Palaeobotany, Lucknow 226 007, India*

²*Department of Botany, Lucknow University, Lucknow 226 007, India*

*For correspondence.
e-mail: rk_kar@yahoo.com

Brown lacewing, *Micromus igorotus* Banks – a potential predator of sugarcane woolly aphid

Sugarcane, a major industrial crop grown over 5.9 and 3.1 lakh ha in Maharashtra and Karnataka, is being threatened by a sucking pest, sugarcane woolly aphid (SWA), *Ceratovacuna lanigera* Zehntner (Aphididae: Homoptera). Nymphs and adults of SWA congregate on the ventral surfaces of leaves along the midrib and desap resulting in drying up of the leaves. Besides, honeydew excreted by the aphid covers the upper surface of lower leaves on which sooty mould develops, making the leaf photosynthetically less or non-functional.

This pest has been reported to be widespread in the Philippines, Indonesia (Java), Taiwan, Malaysia, Japan (Ryukyu Archipelago) and India among 23 South-east Asian countries. The first report from India was in 1958 from Cooch Behar, West Bengal¹ followed by the Northeastern States and Uttar Pradesh² in 1974 and then from Assam and Nagaland³ in 1995. The woolly aphid made its sudden entry in epidemic form in Maharashtra and Karnataka in July and September 2002 respectively. After its first appearance in Athani, Belgaum district, Karnataka, it spread to Chikkodi, Raibag, Hukkeri, Gokak taluks in the same district and Mudhol and Jamakhandi taluks of Bagalkot district. By the middle of 2003 the aphid had moved down to Davanagere and Shimoga districts.

Faster rate of multiplication due to parthenogenetic reproduction by both apterous and alate forms makes it difficult to contain the pest through artificial interventions. Natural suppression factors

hold the key to the management of the pest on sustainable basis. Among the 40 natural enemies reported, 30 predators dominate the scenario followed by parasitoids (6) and pathogens (4). During our survey for composition and abundance of bio-control agents in Karnataka in 2003, a dozen predators were found preying on SWA.

Dipha aphidivora (Meyrick), a lepidopteran carnivore, was found in close association with the aphid in all sugarcane-growing areas in varying abundance. Syrphids and hemerobiids were also found preying in severe form in isolated places adjoining forest ecosystem (Sunadoli). Hemerobiid predators, in large numbers were found preying heavily on SWA at Sunadoli village (20 km from Gokak

taluk, Belgaum district) during August 2003 (Figure 1). Sugarcane that was heavily infested by the aphid was cleared-off completely by the predator in about a period of 10 days over an area of 4 ha, which was not treated with insecticides. Overwhelmed by this episode, growers dispensed with pesticide for the management of the pest. No mobile stage of the predator was seen in the invaded fields during our visit. The farmers informed us that the predator disappeared as food (aphid) was not available. However, intensive search for the predator revealed the presence of pupae in cocoons at the base of the plant that was loosely covered by dried leaf sheaths (Figure 2a and b). A large collection of cocoons was made and brought to the laboratory for emer-



Figure 1. Larvae feeding on sugarcane woolly aphid.