ISSN 0376-5156
Geophytology 54(2): 171–190
November 2024

Global records of fossil *Staurosporae*

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Manuscript received: 12 June 2024
Accepted for publication: 05 August 2024

ABSTRACT

Saxena R.K. 2024. Global records of fossil *Staurosporae*. Geophytology 54(1): 171–190.

Fungal spores exhibit a variety of morphological variations and are divided into: *Amerosporae*, *Didymosporae*, *Phragmosporae*, *Dictyosporae*, *Helicosporae*, *Staurosporae* and *Scolecosporae*. The present paper deals with the global diversity and distribution of fossil *Staurosporae* only. These spores are pluricellate, with more than one axis, or stellate (star-shaped). Altogether, this group is represented by 8 genera and 18 species, viz. *Eoglobella* W.H. Bradley1931 (1 sp.), *Mossopisporites* Kalgutkar & Janson. 2000 (1 sp.), *Pesavis* Elsik & Janson. 1974 (2 spp.), *Spegazzinites* Félix 1894 (3 spp.), *Tetraploa* Berk. & Broome 1850 (5 spp.), *Tribolites* W.H. Bradley 1964 (2 spp.), *Trihyphites* Kalgutkar & Janson. 2000 (1 sp.) and *Triporicellaesporites* P. Ke & Z.Y. Shi 1978 (3 spp.). Of these, *Tetraploa* Berk. & Broome and *Spegazzinites* Félix are most commonly found. *Staurosporae* have been recorded from Canada, China, France, Germany, India and U.S.A. In India, these have been recorded from the Tertiary sediments of Andhra Pradesh, Assam, Bengal Fan, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Kerala, Maharashtra, Mizoram, Tamil Nadu and West Bengal.

Keywords: Fossil fungi, fungal spores, *Staurosporae*, global diversity and distribution, Indian records.

INTRODUCTION

Studies on fossil fungi gained importance all over the world during the last fifty years. Kalgutkar and Jansonius (2000) published a synopsis of fossil fungi and tried to streamline taxonomic status of almost all fossil fungal genera and species published till then. Lakhanpal et al. (1976) and Saxena (1991, 2006) published catalogues in order to document all records of fossil fungal remains from the Indian Tertiary sediments. Saxena and Tripathi (2011) published a monographic study with the objective to synthesize the available information on Indian fossil fungi. Saxena et al. (2021) presented diversity in dispersed fossil fungal spores recorded so far and attempted to trace affinity of fossil fungi with the living ones. Saxena and Wijayawardene (2022) attempted to establish fossil-extant relationship in Fungi and their significance in palaeoenvironmental interpretation.

In the present paper, fossil fungal spores have been treated according to Saccardoan system of grouping the spores (e.g. *Amerosporae*, *Didymosporae*, *Phragmosporae*, *Dictyosporae*, *Helicosporae*, *Staurosporae* and *Scolecosporae*). This is based mainly on number and arrangement of cells. Here, in this paper, only *Staurosporae* are dealt with, which includes pluricellate spores with more than one axis, or stellate (star-shaped) spores. This group is represented by 8 genera and 18 species, viz. *Eoglobella* W.H. Bradley 1931 (1 sp.), *Mossopisporites* Kalgutkar & Janson. 2000 (1 sp.), *Pesavis* Elsik & Janson. 1974 (2 spp.), *Spegazzinites* Félix 1894 (3 spp.), *Tetraploa* Berk.

& Broome 1850 (6 spp.), *Tribolites* W.H. Bradley 1964 (2 spp.) and *Triporicellaesporites* P. Ke & Z.Y. Shi 1978 (3 spp.).

Berkeley and Broome (1850) instituted the extant genus *Tetraploa* (Type: *T. aristata* Berk. & Broome 1850) for quadriarticulate oblong spores growing together in foures and perfectly connate, each crowned with an articulate seta as long as itself from *Poaceae* plant of Great Britain. According to Nuñez Otaño et al. (2022), *Tetraplosphaeria* Kaz. Tanaka & K. Hiray. in Tanaka et al. 2009 and *Frasnacritetrus* Taug. 1968 are later taxonomic synonyms of *Tetraploa*. Félix (1894) described *Spegazzinites* (Type: *S. cruciformis* Félix 1894) from the Tertiary sediments of Germany. Bradley (1931) instituted *Eoglobella* (Type: *E. longipes* W.H. Bradley 1931) from the Middle Eocene sediments of Garfield County, Colorado, U.S.A. Bradley (1964) described *Tribolites* (Type: *T. tetrastonyx* W.H. Bradley 1964) from the Eocene sediments of Wyoming, Colorado, U.S.A. According to Kalgutkar and Jansonius (2000), *Trihyphaecites* Peppers 1970 is a later taxonomic synonym of *Tribolites*. Elsik and Jansonius (1974) instituted the genus *Pesavis* (Type: *P. tagluensis* Elsik & Janson. 1974) from the Palaeocene-Eocene sediments of Washington State, British Columbia, Alaska, U.S.A., and the Mackenzie Delta, Northwest Territorries, Canada. Ke and Shi (1978) instituted *Triporicellaesporites* (Type: *T. triangulus* P. Ke & Z.Y. Shi 1978) from the Eocene-Oligocene sediments of Panshan, Liaoning Province, Coastal region of Bohai, China. Kalgutkar and Jansonius (2000) proposed *Mossopisporites* [Type: *M. multicellulus* (P. Ke & Z.Y. Shi) Kalgutkar & Janson. 2000] from the Eocene-Oligocene sediments of Gangzhou, Hebei Province, Coastal region of Bohai, China. Kalgutkar and Jansonius (2000) instituted *Trihyphites* [Type: *T. fractus* (Z.C. Song & Liu Cao in Song et al. 1989) Kalgutkar & Janson. 2000] from the Shahejie Formation (Late Eocene-Middle Oligocene) of Shenxian county of Shandong Province, China.

DIVERSITY IN FOSSIL *STAUROSPORAE*

1. Genus: ***Eoglobella*** W.H. Bradley1931

Index Fungorum Registration Identifier: 637509.

Type species: *Eoglobella longipes* W.H. Bradley 1931.

Original Diagnosis (combined description): Thallus of definite shape, radially symmetrical, consisting of a single spherical cell to which are attached four equally spaced, greatly elongated, cylindrical appendages. These are apparently single cells that are enlarged and flattened where they join the globular cell and tapered to a rather blunt conical point at the distal end. They arise from the globular cell a little below the equator and diverge slightly downward. The globular cell is about 38 μm in diameter; the appendages are about 6 μm in diameter and range in length from 115 to about 145 μm. The characters of the genus will also serve to define the species (Bradley 1931, p. 44). Monotypic.

Number of species known: One.

Remarks: According to Kalgutkar and Jansonius (2000), *Eoglobella* has four appendices that are growing from one corner or side whereas *Tribolites* W.H. Bradley 1964 has four (or three) well developed filaments, each coming from opposite corners (and one of which, according to Bradley (1931), tends to be truncated, and possibly served as an attachment). *Frasnacritetrus* (now *Tetraploa*) is similar to *Eoglobella*, but is larger, and lacks a distinct hilate scar.

1.1. Species: ***Eoglobella longipes*** W.H. Bradley 1931

Figure 1

Index Fungorum Registration Identifier: 637510.

Original Description (combined description):

Figure 1. *Eoglobella longipes* W.H. Bradley 1931, Scale bar = 8 μm.

As for the genus (Bradley 1931, p. 44).

Location: Garfield County, Colorado, U.S.A.

Age: Middle Eocene.

2. Genus: ***Mossopisporites*** Kalgutkar & Janson. 2000

Index Fungorum Registration Identifier: 28621.

Type species: ***Mossopisporites multicellulus*** (P. Ke & Z.Y. Shi) Kalgutkar & Janson. 2000.

Original Diagnosis: Multicellate medium-sized triporate fungal spores with a (concave) triangular outline. The pores occur at the distal ends of three radial extensions of the outline, where a series of squat transverse cells are stacked to form short, broad arms. The interior of the spore is filled with similar cells, that are interlocking to form a kind of mosaic. One of the arms may be more strongly developed than the other two (Kalgutkar & Jansonius 2000, p. 183). Monotypic.

Number of species known: One.

Remarks: The overall shape of *Trihyphites* Kalgutkar & Janson. 2000 is triradiate, rather than triangular; this genus also has a single (large) central cell. *Tribolites* is inaperturate, and has a very large central cell. The genus name honours Dr. G.D. Mossop, Calgary Office of the Geological Survey of Canada.

2.1. Species: ***Mossopisporites multicellulus*** (P. Ke & Z.Y. Shi) Kalgutkar & Janson. 2000

Figure 2

Index Fungorum Registration Identifier: 483444.

Basionym: *Triporicellaesporites multicellulus* P. Ke & Z.Y. Shi 1978, p. 50, plate 5, figure 16, Index Fungorum Registration Identifier: 115651.

Original Description: Spores 43.5 μm in diameter. Outline triangular, sides straight or slightly convex. Cells at least 20 in number, each cell oblong or flattened, 8 × 5.8 μm in size. Triporate, pores situated at corners of triangle, diameter of pores 4 μm. Spore wall up to 1 μm thick. Surface scabrate-psilate (Kalgutkar & Jansonius 2000, p. 183).

Figure 2. *Mossopisporites multicellulus* (P. Ke & Z.Y. Shi 1978) Kalgutkar & Janson. 2000, Scale bar = 10 μm.

Location: Gangzhou, Hebei Province, Coastal region of Bohai, China.

Age: Eocene-Oligocene.

Remarks: According to Ke and Shi (1978), high number of cells observed in the spores of this species serves to distinguish them from the spores in *Triporicellaesporites triangulus*.

3. Genus: ***Pesavis*** Elsik & Janson. 1974

Index Fungorum Registration Identifier: 21231.

Type species: *Pesavis tagluensis* Elsik & Janson. 1974.

Original Diagnosis: Multicellular fungal fruiting body consisting of a stalked central cell and two lateral arms consisting of some 5–10 cells each. Lateral arms may be straight or curved, widely spread or closely appressed. Two planes of symmetry present. Cells of the primary structure may or may not have secondary septate hyphae-like filaments (Elsik & Jansonius 1974, p. 955).

Number of species known: Two.

Remarks: According to Elsik and Jansonius (1974), it is not clear whether these particular fungal structures represent principally spores, fruiting bodies, or snaring mechanisms of predatory parasitic fungi. The staurospores of some aquatic fungi (*Tribolites* W.H. Bradley 1964) are characterized by short arms diverging from the centre, but these lack the short stalk that is always present in *Pesavis*. Funk (1973) illustrated conidia of *Engelhardtiella alba*, a mycoparasite fungus; the blastoconidia are hyaline, four-celled, composed of a basal ("stalk") cell, a central cell, and two superior, lateral, biconiform cells, about 28–36 μm. The two lateral cells are diverging in a similar manner as the lateral arms in *Pesavis*. Mature specimens of *P. tagluensis* have paired septate projections (hyphae?) originating from each cell of the primary structure and converging towards the center as if in search of a food source. Kalgutkar & Sweet (1988) described the morphology, taxonomy and phylogeny of species of this genus from northwestern Canada, and discussed its biostratigraphic significance. The smaller and simpler new species *P. parvus* is essentially restricted to Maastrichtian and Early Palaeocene. *Pesavis tagluensis*, the type species, typically occurs in Late Palaeocene and Eocene strata; intermediate forms identified as *P.* cf. *P. parvus* and *P.* cf. *P. tagluensis* are indicative of Early to Middle Palaeocene age. The name of the genus is derived from Latin *pes*, foot, and *avis*, bird; for the similarity of the structure to that of a contracted bird's foot in the type species.

3.1. Species: ***Pesavis parvus*** Kalgutkar & Sweet 1988

Figure 3

Index Fungorum Registration Identifier: 637511.

Original Description: Fungal body made up of closely appressed or little extended, two to five lateral arm cells arising on either side of the central cell. Central cavity lacking, or small; secondary hyphal cells may be present, arising only from older cells through pores. In very young specimens, the central cell and lateral arm cells are broad and irregular in shape with conspicuously thick transverse walls and a comparatively thin and elongated outer wall. In slightly older and developing specimens, the lateral arm cells become separated on the inner side forming in profile or outline a small opening between the two lateral arms. Specimens mostly between 21 and 31 μm in overall size (Kalgutkar & Sweet 1988, p. 123).

Figure 3. *Pesavis parvus* Kalgutkar & Sweet 1988, Scale bar = 10 μm.

Location: Big Fish River area on the Yukon Coastal Plain, the Bonnet Plume Basin in Central Yukon, the central Alberta Foothills and southwestern Saskatchewan, Canada.

Age: Maastrichtian.

Remarks: According to Kalgutkar and Sweet (1988), *Pesavis parvus* is characterized by its small size and low number of developmental stages. Its restriction to the Maastrichtian and Early Palaeocene has biostratigraphic significance. It may be argued that in the Maastrichtian, conidia of *Pesavis parvus* did not advance to the full, mature forms of their geologically younger relatives, and continued to exist as small specimens. *Pesavis parvus* therefore represents the ancestral state in which the genetic capacity for development was more limited than in the more evolved species *Pesavis tagluensis* Elsik & Janson. 1974.

3.2. Species: ***Pesavis tagluensis*** Elsik & Janson. 1974

Figure 4

Index Fungorum Registration Identifier: 319409.

Original Description: Pluricellular fungal sporelike body; from a central cell with a short stalk two lateral crescentic branches of five or six (rarely up to eight) cells curve around, their tips meeting or briefly overlapping, enclosing a circular area; from each of the primary cells of the two crescentic branches and the stalked central cell two (rarely one), usually thinner-walled hyphae-like projections, each of some two to four cells, stretch toward the center of the enclosed area; often a dark, thickened membrane separates the primary cell from the secondary hypha. The flat end of the central stalk usually has a circular peripheral thickening, indicating that at one time it was attached to another structure. Dimensions of holotype about 32 × 38 μm; each lateral arm with five cells; secondary hyphae only slightly thinner-walled, two- or three celled, about 4 μm wide at proximal end, in pairs immediately straddling the inner median line (Elsik & Jansonius 1974, p. 956).

Figure 4. *Pesavis tagluensis* Elsik & Janson. 1974, Scale bar = 10 μm.

Location: Washington state, British Columbia, Alaska, U.S.A., and the Mackenzie delta, Northwest Territorries, Canada.

Age: Palaeocene-Eocene.

Remarks: Elsik and Jansonius (1974) stated that occasionally small specimens without secondary "hyphae" are found; these are at present interpreted as immature or juvenile stages. According to Kalgutkar and Jansonius (2000), small specimens without, or with short, secondary hyphae were interpreted as earlier stages in the course of evolution, and differentiated as a separate species, *Pesavis parvus*, by Kalgutkar and Sweet (1988).

4. Genus: ***Spegazzinites*** Félix 1894

Index Fungorum Registration Identifier: 21303.

Type species: *Spegazzinites cruciformis* Félix 1894 (lectotype was designated by Jansonius & Hills 1976, card no. 2630).

Number of species known: Three.

Original Diagnosis (Combined description): The remains are the conidia of a hyphomycete. Their shape and size varies more than is usually the case with such structures. However, the morphology is the same in all of them as far as the somewhat thick polished sections disclose: they consist of 4 partial cells. In the smaller conidia, these partial cells are of a slightly elongated shape, and their narrow sides are oriented towards a point in such a way that together they form a regular, equal-armed cross (figures 8a–c). In the larger specimens, the individual cells are more roundish, the arms of the cross therefore shortened, so that the entire structure approaches the shape of a tightly tied, cube-shaped parcel, a shape found, for instance, in the body of the genus *Sarcina*. The size of the smaller conidia is 12–15 μm, that of the larger ones 21–24 μm; in between occur numerous transitional forms. Some of the conidia are spinose, and not only the larger ones as was claimed by Hoffmann, but rather small conidia as well. The spines are of various lengths, in the larger conidia they are generally shorter than in the smaller specimens. The dimensions specified above refer to asetose specimens. In addition to conidia, the respective polished sections also contain numerous mycelial remains. A connection between them and the conidia could not be definitely established, but there is one case where a conidium appears to sit at the end of a hyphal branch. The mycelium is sparsely ramified, septa were not observed. The thicker filaments are 0.003–0.006 mm (3–6 μm) in

diameter (Félix 1894, translated English version in Kalgutkar & Jansonius 2000, p. 270).

Number of species known: Three.

Remarks: Félix (1894) stated that the fossil conidia resemble very closely to those of an extant hyphomycete described by Saccardo as *Spegazzinia ornata* which belongs to the family *Tuberculariеae*. *Spegazzinia* also displays partly parcel-shaped and partly cruciform conidia which consist of 4 cells and are partly covered with spines. Jansonius & Hills (1976, card no. 2630) designated the lectotype.

4.1. Species: ***Spegazzinites cruciformis*** Félix 1894

Figure 5

Index Fungorum Registration Identifier: 197021.

Original Description: As for the genus (combined description) (Kalgutkar & Jansonius 2000, p. 271).

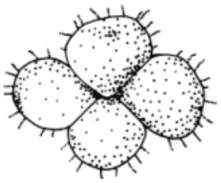

Figure 5. *Spegazzinites cruciformis* Félix 1894, Scale bar = 10 µm.

Location: Germany.

Age: Tertiary.

4.2. Species: ***Spegazzinites indicus*** Ramanujam & Srisailam 1980

Figure 6

Index Fungorum Registration Identifier: 109246.

Original Description: Spores melanin colored, inaperturate, 18–23.8 µm in diameter, cruciately or squarishly septate to form 4 subcircular or obovoid cells, studded all over with sharply pointed spines up to 2.5 µm long. Spore wall 2–layered, 1.5 µm thick (Ramanujam & Srisailam 1980, p. 120).

Figure 6. *Spegazzinites indicus* Ramanujam & Srisailam 1980, Scale bar = 10 µm.

Location: Kannur Beach area, Palayangadi and Cheruvattur (southern side of Karingottu River), Kerala, India.

Age: Miocene.

Remarks: According to Ramanujam & Srisailam (1980), the present species strikingly resemble the conidia of the modern dematiaceous taxon *Spegazzinia* (Ellis 1971, Subramanian 1971, Kendrick & Carmichael 1973). *Spegazzinia* is a common element of the tropical humid regions.

4.3. Species: ***Spegazzinites tetradus*** (Rouse 1962) Kalgutkar & Janson. 2000

Figure 7

Index Fungorum Registration Identifier: 483549.

Basionym: *Inapertisporites tetradus* Rouse 1962, p. 210, plate 5, figure 17. Index Fungorum Registration Identifier: 109865.

Original Description: Spores in a linear tetrad configuration. Individual spores subtriangular to circular in outline, deep melanin brown in color.

Figure 7. *Spegazzinites tetradus* (Rouse 1962) Kalgutkar & Janson. 2000, Scale bar = 10 µm.

Size-range of tetrads 16–20 µm (Rouse 1962, p. 210).

Location: Terminal Dock, the city of Vancouver, British Columbia, Canada.

Age: Late Cretaceous-Middle Eocene (Burrard Formation).

Remarks: According to Rouse (1962), these specimens look, at first glance, like pollen grains of the *Ericaceae*, but they have a much smaller size and are of melanin color and in a linear rather than tetrahedral configuration. Kalgutkar and Jansonius (2000) stated that similar morphology is seen in *Quadrisporites* Hennelly 1959 and *Spegazzinites* Félix 1894. *Quadrisporites* now is considered to belong to the blue green algae (Batten, 1996, vol. 1, p. 191).

5. Genus: ***Tetraploa*** Berk. & Broome 1850

Index Fungorum Registration Identifier: 10199.

Type species: *Tetraploa aristata* Berk. & Broome 1850. Index Fungorum Identifier: 148113.

Synonyms: 1. *Tetraplosphaeria* Kaz. Tanaka & K. Hiray., in Tanaka et al., Stud. Mycol. 64, p. 177 (2009). Index Fungorum Registration Identifier: 515254; 2. *Frasnacritetrus* Taug., Cahiers de Micropaléontologie, Série 1, no. 10, Archives originales du Centre de Documentation du C.N.R.S. no. 452, p. 3. 1968. Index Fungorum Registration Identifier: 519771.

Original Diagnosis: Quadriarticulate oblong spores growing four together and perfectly connate, each crowned with an articulate seta as long as itself (Berkeley & Broome 1850, p. 459).

Number of fossil species known: Five.

Classification: Phylum: *Ascomycota*, Subphylum: *Pezizomycotina*, Class: *Dothideomycetes*, Subclass: *Pleosporomycetidae*, Order: *Pleosporales*, Family: *Tetraplosphaeriaceae*.

Remarks: Taugourdeau (1968, p. 3) described *Frasnacritetrus* from the Late Devonian (Frasnian) sediments of France with the following diagnosis: "Organic-walled microorganisms, generally of subcylindrical shape tending to a rounded or slightly bell-shaped parallelepiped, in transversal section nearly circular at one pole, becoming rectangular with rounded corners at the opposite pole which carries four hollow horns (or "processes") that extend the ribs of the body." Taugourdeau (1968) stated that this single specimen does not resemble any microfossil already described. He also did not rule out possibility of contamination. He speculated possibility of this specimen being either a broken Diacrodian or half an organism of some *Conjugales* (*Desmidiales*) or linear colony such as certain *Desmochitina* or hydrozoans. But he rejected all the above possibilities and could not reach to any conclusion.

Saxena and Sarkar (1986) emended the generic diagnosis as follows: "Microfossils having two to four processes. Body subrectangular, unicellular or divided into chambers by septa, smooth or variously sculptured. Processes mostly smooth but may also be sculptured, unicellular or septate. Main body of the microfossils generally rectangular-subrectangular but variously shaped; either unicellular or divided into longitudinal chambers by vertical septa or multichambered, being divided by both vertical and transverse septa; septa may be complete or incomplete, sometimes septa faintly developed; body either smooth or ornamented with grana, verrucae or coni, etc., sculpturing elements may be closely or sparsely or evenly distributed. Two to four processes arising from one end of the body (although in *Frasnacritetrus* sp. 4, three processes are attached at the end of the body while the fourth one comes out from the middle of the body); generally broader at the base and tapering towards the apices; cylindrical or ribbon-like; either aseptate-unicellular or septate, septa one to many in each process; apex of processes pointed or blunt. *Frasnacritetrus* is not comparable to any of the known fossil palynogenera". This diagnosis allows inclusion of a number of fungal conidia

that show a general similarity to the morphology of *Tetraploa*. This fungus generally grows on *Poaceae*, and the fossil species occur in association with grass pollen. Saxena & Sarkar (1986) adduced this to support their suggestion that *Frasnacritetrus* should not be considered an acritarch but a fossil genus with affinity to *Tetraploa.*

The generic diagnosis of *Frasnacritetrus* as originally proposed by Taugourdeau, only accommodates microfossils with four processes, whereas Saxena & Sarkar (1986) also recovered specimens with three processes. Specimens with only two processes have also been recorded by Sharma (1976, plate 1, figure 3). Except for the difference in number of processes, there is no major morphological difference between the specimens which could justify the erection of a new genus.

Saccardo (1880, 1886) classified similar forms under the *Staurosporae*, which include spores having a forked or star-shaped appearance (Subramanian 1971). Kendrick and Carmichael (1973) published a list of staurosporous genera and their illustrations. A comparison of the present microfossils with these genera reveals a close resemblance with *Tetraploa*, a genus belonging to the family *Tetraplosphaeriaceae*, and in all probability they belong to it; hence their placement under Acritarcha *incertae sedis* by Taugourdeau (1968) does not seem justified. It is interesting to note that in all the seven assemblages wherefrom Saxena and Sarkar (1986) recovered these microfossils, poaceous pollen grains occur. Since *Tetraploa* mainly grows on *Poaceae*, the association of *Frasnacritetrus* with graminaceous pollen grains may be considered as supporting evidence for the affinity of *Frasnacritetrus* with *Tetraploa*.

According to Li et al. (2020, p. 182) "The asexual morph genus *Tetraploa* s. str. is characterized by micronematous or no conidiophores, monoblastic conidiogenous cells and tetraploid conidia composed of 4–euseptate, short-cylindrical, brown, vertical columns which are verrucose at the base, and with 4 setose, divergent, short or long septate appendages at the apex". Thus, no arguments sustain the use of the two generic names, then *Frasnacritetrus* is considered a later synonym for *Tetraploa*. After performing detailed morphological analysis and comparisons, Nuñez Otaño et al. (2022) assigned fossil species to extant *Tetraploa*. Nuñez Otaño et al. (2022) proposed new combinations of several accepted species in *Frasnacritetrus* to *Tetraploa*.

5.1. Species: ***Tetraploa conata*** (R.K. Saxena & S. Sarkar 1986) Nuñez Otaño et al. 2022

Figure 8

Index Fungorum Registration Identifier: 900104.

Basionym: *Frasnacritetrus conatus* R.K. Saxena & S. Sarkar, Review of Palaeobotany and Palynology 46: 215, plate 1, figure 4 (1986). Index Fungorum Registration Identifier: 519773.

Taxonomic synonym: *Frasnacritetrus jamtahensis* A. Gupta, Tertiary Research 21(1–4): 148, plate 5, figure 1 (2002). Index Fungorum Registration Identifier: 540509.

Original Description: Fungal conidia with four processes. Main body rectangular in shape, dark brown in color, unicellular, surface closely beset with small-sized coni. Processes arise from one end of the body, are tubular, wider at the base and gradually taper towards the apices, aseptate; wall of processes smooth. Dimensions: length of the conidia: 98–110 µm; size of the body: 25–38 × 18–20 µm; size of the processes: 62–84 × 2–6 µm (Saxena & Sarkar 1986, p. 215).

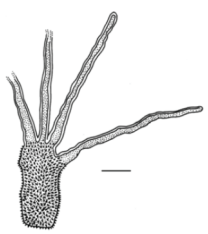

Figure 8. *Tetraploa conata* (R.K. Saxena & S. Sarkar 1986) Nuñez Otaño et al. 2022, Scale bar = 10 µm.

Location: Lower Siwalik, Nalagarh-Ramshahr Road section, Solan District, Himachal Pradesh, India.

Age: Middle-Late Miocene.

Remarks: *Frasnacritetrus josettae* Taug. 1968 resembles this species but can be differentiated by its verrucate body wall. The present species differs from *F. taugourdeaui* in having a rectangular body ornamented with coni while in the latter the body is biconvex, spindle-shaped and granulose. Nuñez Otaño et al. (2022). considered that the specimen described as *Frasnacritetrus jamtahensis* (Figure 2A) belongs to *Tetraploa conata*.

5.2. Species: ***Tetraploa indica*** (R.K. Saxena & S. Khare 1992) Nuñez Otaño et al. 2022

Figure 9

Index Fungorum Registration Identifier: 900105.

Basionym. *Frasnacritetrus indicus* Saxena & Khare, Geophytology 21(1), p. 42, plate 1, Figure 17 (1992). Index Fungorum Registration Identifier: 483898.

Original Description: Fungal conidia with four processes. Main body rectangular to oval, 23–28 × 13–17 µm, multicellular, being divided by longitudinal and transverse ridges/furrows, spore wall up to 1 µm thick, conate, coni uniformly distributed. Processes septate, 35–117 µm long and 3–4.5 µm wide, number of septa in each process 2 to 5, psilate (Saxena & Khare 1992, p. 42).

Figure 9. *Tetraploa indica* (R.K. Saxena & S. Khare 1991) Nuñez Otaño et al. 2022, Scale bar = 10 µm.

Location: Jayamkondacholapuram well–12 (JC–12), 45 km south of Neyveli, Tiruchirappalli District, Tamil Nadu, India.

Age: Tertiary.

Remarks: The present species is distinguished from *Tetraploa taugourdeaui* and *T. conatus* by its septate processes and multicellular conidial body.

5.3. Species: ***Tetraploa josettae*** (Taug.) Nuñez Otaño et al. 2022

Figure 10

Index Fungorum Registration Identifier: 900102.

Basionym: *Frasnacritetrus josettae* Taug. 1968. Cah. Micropaléontol. 10, p. 3, plate 1, figures 1–4 (1968). Index Fungorum Registration Identifier: 519772.

Original Description: Total length ca. 100 µm, width 18–20 µm; body about twice as long as it is wide; one pole truncated, apparently circular and provided with a pylome; opposite pole with four spreading hollow horns, about 1 1/2 times as long as the body, open [sic.] at their slightly rounded, truncated ends but barred by thin membranes or septa, of which one is located in each of the horns at about 1/3 of their length; wall brown, verrucate, the sculpture aligned longitudinally (Jansonius & Hills 1987, card no. 4429).

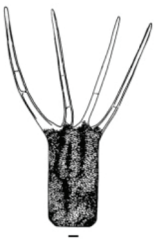

Figure 10. *Tetraploa josettae* (Taug. 1968) Nuñez Otaño et al. 2022, Scale bar = 5 µm.

Location: France.

Age: Late Devonian (Frasnian).

5.4. Species: ***Tetraploa siwalika*** (R.K. Saxena et al. 1988) Nuñez Otaño et al. 2022

Figure 11

Index Fungorum Registration Identifier: 900106.

Basionym: *Frasnacritetrus siwalikus* R.K. Saxena et al., Geophytology 17(2), p. 277, plate 2, figure 31. (1988). Index Fungorum Registration Identifier: 519774.

Original Description: Fungal conidia with four processes. Main body oval in shape, dark brown, ornamented with sparsely placed coni and grana, divided into 4 columns, each column terminating into a process. Processes tubular, wider at the base and gradually tapering at the apices, aseptate, smooth. Dimensions: length of the conidia: 50–60 µm; size of the body: 25–35 µm; size of the processes: 32–45 µm (Saxena et al., 1988, p. 277).

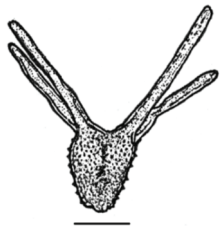

Figure 11. *Tetraploa siwalikus* (R.K. Saxena et al.) Nuñez Otaño et al. 2022, Scale bar = 10 µm.

Location: Between Masol and Kiratpur in Ambala District, Haryana, India.

Age: Miocene-Pliocene (Upper Siwalik, Tatrot and Pinjor formations).

Remarks: Spore with a triangular outline, obovoid, L/W: 2–2.69. The base of the spore could be deflated probably due to taphonomic processes. If that is the case *T. siwalika* could be comparable with *T. taugourdeaui* but the lack of more spores assignable to *T. siwalika* difficult to synonymize it. *Tetraploa josettae* Taug. 1968 differs from *T. siwalikus* by its verrucate body. *Tetraploa conata* Saxena & Sarkar 1986 can be differentiated by its unicellular and rectangular body. *Frasnarcitetrus taugourdeaui* Saxena & Sarkar 1986 can be distinguished by its spindle-shaped, unicellular and granulose body.

5.5. Species: ***Tetraploa taugourdeaui*** (R.K. Saxena & S. Sarkar 1986) Nuñez Otaño et al. 2022

Figure 12

Index Fungorum Registration Identifier: 900103.

Basionym: *Frasnacritetrus taugourdeaui* R.K. Saxena & S. Sarkar, Review of Palaeobotany and Palynology (Amsterdam) 46: 213 (1986).

Synonym: *Frasnacritetrus* sp. Sarkar & Singh 1988, p. 61, plate 5, figure 21; plate 6, figure 18.

Original Description: Fungal conidia with four processes. Main body biconvex, spindle-shaped, unicellular, surface granulose; grana small in size, closely placed and evenly distributed throughout the surface. Processes arise from one end of the body, tubular, slightly wider at base; all processes uniform in shape; wall of processes smooth; septa present in the basal part of few processes. Dimensions: length of the conidia: 66–112 µm; size of the body: 30–35 × 15–20 µm; size of the processes: 35–75 × 2–5 µm (Saxena & Sarkar 1986, p. 213–215).

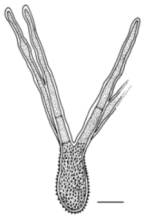

Figure 12. *Tetraploa taugourdeaui* (R.K. Saxena & S. Sarkar 1986) Nuñez Otaño et al. 2022, Scale bar = 10 µm.

Location: Near Banethi, Sirmaur District, Himachal Pradesh, India.

Age: Eocene (Subathu Formation).

Remarks: According to Saxena and Sarkar (1986), *Tetraploa taugourdeaui* resembles *Frasnacritetrus josettae* Taugourdeau 1968 in having a similar body size but can be readily distinguished by its granulose ornamentation and spindle-shaped structure. The body of *F. josettae*

is ornamented with verrucae. Nuñez Otaño et al. (2022) described it as: Ovoid outline, with the base strongly narrower than the medium conidial body (L/W: 1.5: 0.5). It could be comparable with *Tetraploa aristata* (original description).

6. Genus: ***Tribolites*** W.H. Bradley 1964 emend. Kalgutkar & Janson. 2000

Index Fungorum Registration Identifier: 21338.

Type species: *Tribolites tetrastonyx* W.H. Bradley 1964.

Synonym: *Trihyphaecites* Peppers, Illinois State Geological Survey Bulletin 93, p. 135, plate 14, figure 13 (1970). Index Fungorum Registration Identifier: 21343.

Original Diagnosis (combined description): Conidia consisting of four tapered arms that end in an abruptly tapered sharp point and that radiate from a large central, polyhedral cell; apices of the arms corresponding to the apices of a more or less regular tetrahedron; arms subdivided by thick septa into three to five nearly equidimensional cells; one arm tip generally flattened, which presumably represents the point of attachment to the conidiophore; overall dimensions 60–90 μm (Bradley 1964, p. 415).

Emended Diagnosis: Inaperturate, medium to large-sized conidia consisting of a large, inflated polyhedral (generally triangular or tetrahedral) central cell, the corners of which are extended into tapered arms consisting of some two to six nearly equidimensional cells; the radial arms closed terminally, rounded to pointed, but one arm generally with a flat (hilar?) end (Kalgutkar & Jansonius 2000, p. 298).

Number of species known: Two.

6.1. Species: ***Tribolites tetrastonyx*** W.H. Bradley 1964

Figure 13

Index Fungorum Registration Identifier: 340260.

Original Description: As for the genus (combined description).

Figure 13. *Tribolites tetrastonyx* W.H. Bradley 1964, Scale bar = 15 μm.

Location: Wyoming, Colorado, U.S.A.

Age: Eocene.

Remarks: According to Bradley (1964), the conidia resemble in structure and general form the conidia of extant *Tetrachaetum elegans* and *Lemonniera aquatica,* but the arms are much shorter, stockier, and the cell walls much thicker.

6.2. Species: ***Tribolites triangulatus*** (Peppers 1970) Kalgutkar & Janson. 2000

Figure 14

Index Fungorum Registration Identifier: 483562.

Basionym: *Trihyphaecites triangulatus* Peppers, Illinois State Geological Survey Bulletin 93, p. 135, plate 14, figure 13. 1970. Index Fungorum Registration Identifier: 325019.

Original Description: The plant microfossils are made up of radially symmetrical, triangular to roundly triangular bodies that possess septate hyphae at each of the corners, which also are septate. The hyphae may consist of a single segment with a well rounded terminal end, or numerous segments in which the terminal segment is rounded or broken. The hyphae are unbranched and the septa are thick and pronounced. The triangular body and hyphae are about 1 μm thick, levigate under oil immersion objective, and possess minor folds. Dimensions (19 specimens): size range of triangular body 32.5 to 48.8 μm in maximum diameter (median 41.3 μm); width of hyphae at corners 10.4 to 26 μm (median 15.6 μm) (Peppers 1970, p. 135).

Figure 14. *Tribolites triangulatus* (Peppers 1970) Kalgutkar & Janson. 2000, Scale bar = 10 μm.

Location: North eastern part of the Illinois Basin, Illinois. U.S.A.

Age: Carboniferous-Pennsylvanian (Carbondale and Spoon formations).

7. Genus: ***Trihyphites*** Kalgutkar & Janson. 2000

Index Fungorum Registration Identifier: 28625.

Type species: *Trihyphites fractus* (Z.C. Song & Liu Cao in Song et al. 1989) Kalgutkar & Janson. 2000.

Original Diagnosis: Fungal spores triradiate; from a small triangular central cell, three arms radiate out, each consisting of up to a dozen cells, and each terminating with a wide pore-like structure (Kalgutkar & Jansonius 2000, p. 305). Monotypic.

Number of species known: One.

Remarks: Spores of *Alleppeysporites* are triradiate, each arm comprising three to five cells, and distally narrowing into a solid? club-like structure. *Mossopisporites* has no differentiated central cell, and all cells are very broad and short. The arms in *Tribolites* are distally closed. The specific epithet is a contraction of *Trihyphaecites*, of which the type species, *T. triangulatus*, was transferred to *Tribolites*.

7.1. Species: ***Trihyphites fractus*** (Z.C. Song & Liu Cao in Song et al. 1989) Kalgutkar & Janson. 2000

Figure 15

Index Fungorum Registration Identifier: 483569.

Basionym: *Trihyphaecites fractus* Z.C. Song & Liu Cao in Song et al., p. 46, plate 4, figure 21 (1989). Index Fungorum Registration Identifier: 485274.

Original Description: Spore consists of Triradiate hyphae. Hyphal arms generally incomplete; lengths of hyphal projections may be unequal [due to fragmentation?]. Longest hypha of holotype about 60 μm, short one about 20 μm, 10–16 μm in breadth. Spores multicellular, most cells nearly square in shape, contact areas between cells with slight indistinct constriction. Septa with septal folds, but without pores. Spore wall composed of two layers, about 1–1.5 μm in thickness, surface smooth or dotted (Song et al. 1989, p. 46).

Figure 15. *Trihyphites fractus* (Z.C. Song & Liu Cao 1994) Kalgutkar & Janson. 2000, Scale bar = 10 μm.

Location: Shenxian county of Shandong Province, China.

Age: Late Eocene-Middle Oligocene (Shahejie Formation).

Remarks: The holotype, though nearly opaque, shows the presence of septa right to the base of the hyphal projections, leaving a relatively small triangular central cell. In this, the structure differs from *Mossopisporites multicellulus*, in which the hyphal cells are very squat, the central area is subdivided into many shallow cells, but the hyphal projections appear to end in an open "pore." In *Alleppeysporites*, the hyphal arms end in characteristic narrow extensions, and there is no differentiated central area. In *Tribolites*, the central cell is much larger than the cells in the hyphal projections.

8. Genus: ***Triporicellaesporites*** P. Ke & Z.Y. Shi 1978 emend. Kalgutkar & Janson. 2000

Index Fungorum Registration Identifier: 21344.

Type species: *Triporicellaesporites triangulus* P. Ke & Z.Y. Shi 1978.

Original Diagnosis: Spores triangular-lenticular in shape, outline triangular in polar view. Triporate, pores situated at corners of triangle, prominent, might be vestibulate. Multicellular, cells in triangulate (triaxial?) arrangement. Spore wall of medium thickness, surface psilate or provided with granulate to indistinct finely reticulate sculpturing (Ke & Shi 1978, p. 50).

Emended Diagnosis: Pluricellate fungal spores with triangular to inverted V-shaped outline, with a central (stalked) hilum; the two lateral wings or appendages may be closed terminally, but commonly are preserved with the distalmost cells lacking; spore wall smooth (Kalgutkar & Jansonius 2000, p. 306).

Number of species known: Three.

Remarks: This genus is distinguished from all other genera of fossil fungal spores by the fact that its members are both multicellular and triporate and exhibit a triangular to chevron-shaped outline. According to Kalgutkar and Jansonius (2000), the spores of *Triporicellaesporites elongatus* and *Triporicellaesporites simplex* are very similar to spores of the extant *Ceratosporella bicornis* (Morgan) Höhnel 1923.

8.1. Species: ***Triporicellaesporites elongatus*** P. Ke & Z.Y. Shi 1978

Figure 16

Index Fungorum Registration Identifier: 115699.

Synonym: *Pesavis elongatus* (P. Ke & Z.Y. Shi) Z.C. Song in Song et al. 1999, Index Fungorum Registration Identifier: 483850.

Original Description: Spore about 50 μm in size, longest extension measuring 35 × 11 μm. Spore outline elongated triangular, sides of triangle of unequal length. The end of the spore that is entire consists of 7 cells, the shortest end has only one cell (i.e., one cell remains), while the third end is observed to have four cells (i.e., four cells remain). The cells gradually diminish in size from the base to the ends of the spore. Spore triporate, pores situated at apex of each end (pore indistinct at four-celled end of spore). Pores 2.5 μm in diameter. Most of the septa hyaline. Spore wall about 1 μm thick, stratification obscure. Surface psilate (Ke & Shi 1978, p. 50).

Figure 16. *Triporicellaesporites elongatus* P. Ke & Z.Y. Shi 1978, Scale bar = 10 μm.

Location: Cangxian, Hebei Province, Coastal region of Bohai, China.

Age: Eocene-Oligocene.

Remarks: This species is distinguished from the other two species of this genus by the fact that the spores have elongated corners, giving them a trifurcate shape. *Triporicellaesporites elongatus* seems to be almost identical in appearance to *T. simplex* (Elsik & Jansonius) Kalgutkar & Jansonius 2000, having a central cell and two straight lateral arms.

8.2. Species: ***Triporicellaesporites simplex*** (Elsik & Janson. 1974) Kalgutkar & Janson. 2000

Figure 17

Index Fungorum Registration Identifier: 483570.

Basionym: *Pesavis simplex* Elsik & Janson. 1974, Index Fungorum Registration Identifier: 319408.

Original Description: Central cell wedge-shaped to rhomboid (attached to a narrow cylindrical hyphal cell in holotype); two straight

lateral arms, wide at their base, tapering distally, slightly asymmetrically developed; septa indistinctly perforate or whole; secondary hyphae-like projections normally lacking (at least in known material). Dimensions: Span about 70 µm; complete arm 45 µm, 13 µm wide at base.

Figure 17. *Triporicellaesporites simplex* (Elsik & Janson. 1974) Kalgutkar & Janson. 2000, Scale bar = 10 µm.

Location: Mackenzie Delta, Northwest Territories, Canada.

Age: Palaeogene.

Remarks: Elsik and Jansonius (1974) stated that in some specimens the lateral arms have hinged around the central cell and are more or less tightly appressed. The species may be morphologically intermediate between *Ctenosporites* and *Pesavis tagluensis*. Pirozynski (1976) suggested an affinity between *Pesavis simplex* and species of the dematiaceous fungus *Ceratosporella*, e.g. *C. bicornis* (Morgan) Höhnel 1923 (Ellis 1971). Smith and Crane (1979) proposed that *Pesavis simplex* probably was a dematiaceous hyphomycete, closely similar to the living counterpart *Ceratosporella bicornis*, which occurs on dead or dying plant material. *Pesavis tagluensis*, however, they thought to be aero-aquatic, and belonging to a different group of fungi.

8.3. Species: ***Triporicellaesporites triangulus*** P. Ke & Z.Y. Shi 1978

Figure 18

Index Fungorum Registration Identifier: 115650.

Original Description: Spores about 35 µm in size. Outline scalene triangular, with sides of triangle either straight or slightly convex. Composed of about 8 cells, cell shape somewhat trapezoidal or rectangular, cells smaller near aperture. Triporate, pores circular or oblate, 1.5–2.5 µm in diameter. Spore wall 1.5 µm thick, two-layered, outer layer thicker than the inner layer, provided with granulate to indistinct to finely reticulate sculpturing. Outer contour line smooth (Elsik & Jansonius 1974, p. 956).

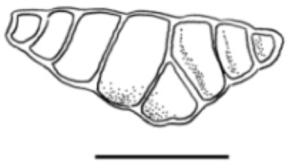

Figure 18. *Triporicellaesporites triangulus* Ke & Shi 1978, Scale bar = 15 µm.

Location: Panshan, Liaoning Province, Coastal region of Bohai, China.

Age: Eocene-Oligocene.

DISTRIBUTION

It has been observed that *Staurosporae* have been recorded from widespread areas, e.g. Canada, China, France, Germany, India and U.S.A. (Table 1). In Canada, staurospores (*Pesavis parvus*) were recorded from the Maastrichtian sediments of Big Fish River area on the Yukon Coastal Plain, the Bonnet Plume Basin in Central Yukon, the central Alberta Foothills and south-western Saskatchewan (Kalgutkar & Sweet 1988). Elsik and Jansonius (1974) recorded them (*Pesavis tagluensis* and *Triporicellaesporites simplex*) from the Palaeocene-Eocene sediments of Mackenzie delta, Northwest Territorries and Washington state, British Columbia, Alaska, U.S.A. In addition, *Spegazzinites tetradus* was recorded from the Burrard Formation (Late Cretaceous-Middle Eocene) of Terminal Dock, the city of Vancouver, British Columbia, U.S.A. (Rouse 1962). In China, Ke and Shi (1968) recorded *Mossopisporites multicellulus* from the Eocene-Oligocene sediments of Gangzhou, Hebei Province, Coastal

region of Bohai; *Triporicellaesporites elongates* from the from the Eocene-Oligocene sediments of Cangxian, Hebei Province, Coastal region of Bohai; and *Triporicellaesporites triangulus* also from the Eocene-Oligocene sediments of Panshan, Liaoning Province, Coastal region of Bohai. Song and Cao (1994) recorded *Trihyphites fractus* from the Shahejie Formation (Late Eocene-Middle Oligocene) of Shenxian county of Shandong Province, China. Taugourdeau (1968) reported *Frasnacritetrus josettae* from the Late Devonian (Frasnian) sediments of Boulonnais, France. Nuñez Otaño et al. (2022) considered *Frasnacritetrus* a later taxonomic synonym of extant *Tetraploa* and transferred species of *Frasnacritetrus* to *Tetraploa*. Félix (1894) described *Spegazzinites cruciformis* from the Tertiary of Germany. In U.S.A., Bradley (1931) recorded *Eoglobella longipes* from the

Table 1. Showing global distribution of various species of fossil *Staurosporae* and their occurrences in India.

Country	Location	Species	Reference	Age
Canada	Big Fish River area on the Yukon Coastal Plain, the Bonnet Plume Basin in Central Yukon, the central Alberta Foothills and south-western Saskatchewan.	*Pesavis parvus* Kalgutkar & Sweet 1988	Kalgutkar & Sweet 1988	Maastrichtian
	Washington state, British Columbia, Alaska, U.S.A., and the Mackenzie delta, Northwest Territorries.	*Pesavis tagluensis* Elsik & Janson. 1974	Elsik & Jansonius 1974	Palaeocene-Eocene
	Terminal Dock, the city of Vancouver, British Columbia.	*Spegazzinites tetradus* (Rouse) Kalgutkar & Janson. 2000	Rouse 1962	Late Cretaceous-Middle Eocene (Burrard Formation)
	Mackenzie Delta, Northwest Territories.	*Triporicellaesporites simplex* (Elsik & Janson.) Kalgutkar & Janson. 2000	Elsik & Jansonius 1974	Palaeogene
China	Gangzhou, Hebei Province, Coastal region of Bohai.	*Mossopisporites multicellulus* (P. Ke & Z.Y. Shi) Kalgutkar & Janson. 2000	Ke & Shi 1978	Eocene-Oligocene
	Shenxian county of Shandong Province, China.	*Trihyphites fractus* (Z.C. Song & Liu Cao) Kalgutkar & Janson. 2000	Song & Cao 1994	Late Eocene-Middle Oligocene (Shahejie Formation)
	Cangxian, Hebei Province, Coastal region of Bohai.	*Triporicellaesporites elongatus* P. Ke & Z.Y. Shi 1978	Ke & Shi 1978	Eocene-Oligocene
	Panshan, Liaoning Province, Coastal region of Bohai.	*Triporicellaesporites triangulus* P. Ke & Z.Y. Shi 1978	Ke & Shi 1978	Eocene-Oligocene
France	Boulonnais, France	*Tetraploa josettae* (Taug. 1968) Nuñez Otaño et al. 2022	Taugourdeau 1968	Late Devonian
Germany.	Germany	*Spegazzinites cruciformis* Félix 1894	Félix 1894	Tertiary
India	Kannur Beach area, (southern side of Karingottu River), Kerala.	*Spegazzinites indicus* Ramanujam & Srisailam 1980	Ramanujam & Srisailam 1980	Miocene
	Lower Siwalik, Nalagarh-Ramshahr Road section, Himachal Pradesh.	*Tetraploa conatus* (R.K. Saxena & S. Sarkar 1986) Nuñez Otaño et al. 2022	R.K. Saxena & S. Sarkar 1986	Middle-Late Miocene
	Jayamkondacholapuram well–12 (JC–12), 45 km south of Neyveli, Tamil Nadu.	*Tetraploa indicus* (R.K. Saxena & S. Khare 1991) Nuñez Otaño et al. 2022	R.K. Saxena & S. Khare 1991	Tertiary
	Upper Siwalik exposed between Masol and Kiratpur, Haryana.	*Tetraploa siwalikus* (R.K. Saxena et al. 1988) Nuñez Otaño et al. 2022	Saxena et al. 1988	Miocene-Pliocene (Tatrot and Pinjor formations)
	Near Banethi, Sirmaur District, Himachal Pradesh.	*Tetraploa. taugourdeaui* (R.K. Saxena & S. Sarkar 1986) Nuñez Otaño et al. 2022	Saxena & Sarkar 1986	Early Miocene (Kasauli Formation)
U.S.A.	Garfield County, Colorado.	*Eoglobella longipes* W.H. Bradley 1931	Bradley 1931	Middle Eocene
	Wyoming, Colorado.	*Tribolites tetrastonyx* W.H. Bradley 1964	Bradley 1964	Eocene
	North eastern part of the Illinois Basin, Illinois.	*Tribolites triangulatus* (Peppers) Kalgutkar & Janson. 2000	Peppers	Carboniferous-Pennsylvanian (Carbondale and Spoon formations).

Table 2. Representation of species of fossil *Staurosporae* in various states of India.

Geographical area	Species recorded (References)
Andhra Pradesh	*Spegazzinites indicus* Ramanujam & Srisailam: Miocene, Godavari-Krishna Basin, Andhra Pradesh (Mallesham et al. 1989).
Assam-Meghalaya	*Tetraploa siwalika* (R.K. Saxena et al.) Nuñez Otaño et al.: Lower Bhuban and Bokabil formations (Early-Middle Miocene), Silchar-Haflong Road Section, Assam (Kumar & Takahashi 1991); Lower Bhuban Formation (Early Miocene), Silchar-Haflong Road Section, Assam (Kumar 1994). *Tetraploa* spp.: Barail and Surma Groups (Oligocene-Early Miocene), Sonapur-Badarpur Road Section, Jaintia Hills, Meghalaya and Cachar District, Assam (Singh et al. 1986); Jenam, Renji, Bokabil and Dupitila formations (Middle-Late Oligocene, Middle Miocene and Plio-Pleistocene), Silchar-Haflong Road Section, Assam (Kumar 1994); Kopili Formation (Late Eocene), Umrongso-Haflong Road near Umrongso, North Cachar Hills District, Assam (Trivedi & Saxena 2000).
Bengal Fan	*Tetraploa* sp.: Late Tertiary, Site 218, Deep Sea Drilling Project Leg 22, Bengal Fan, Indian Ocean (Chandra & Kumar 1998).
Gujarat	*Tetraploa conata* (R.K. Saxena & S. Sarkar) Nuñez Otaño et al.: Intertrappean Beds (Early Palaeocene), 5 km west of Naredi, on Naliya-Narayan Sarovar Road, Kutch District, Gujarat (Saxena & Ranhotra 2009). *Tetraploa indica* (R.k. Saxena & S. Khare) Nuñez Otaño et al.: Intertrappean Beds (Early Palaeocene), 5 km west of Naredi, on Naliya-Narayan Sarovar Road, Kutch District, Gujarat (Saxena & Ranhotra 2009). *Tetraploa* sp.: Quaternary, Malvan, Surat District, Gujarat (Sharma 1976).
Haryana	*Tetraploa siwalika* (R.K. Saxena et al.) Nuñez Otaño et al.: Tatrot and Pinjor formations (Pliocene), Masol-Kiratpur Section, Ambala District, Haryana (Saxena et al. 1988). *Tetraploa* sp.: Pinjor Formation (Late Pliocene), Nadah, Panchkula, Haryana (Rao & Patnaik 2001).
Himachal Pradesh	*Tetraploa conata* (R.K. Saxena & S. Sarkar 1986) Nuñez Otaño et al.: Kasauli Formation and Lower Siwalik (Miocene), near Banethi, Sirmaur District, Himachal Pradesh, and Nalagarh-Ramshahr Road Section, Solan District, Himachal Pradesh (Saxena & Sarkar 1986); Subathu Formation (Eocene), 20 km south-east of Bilaspur on Shimla-Bilaspur Highway, Bilaspur District, Himachal Pradesh (Sarkar 1997); Subathu and Dagshai formations (Late Palaeocene-Early Oligocene), Dadahu Road Section, Sirmaur District, Himachal Pradesh (Gupta 2002). *Tetraploa siwalika* (R.K. Saxena et al.) Nuñez Otaño et al.: Kasauli Formation (Early Miocene), Kasauli, Solan District, Himachal Pradesh (Singh & Sarkar 1994). *Tetraploa taugourdeaui* (Saxena & Sarkar) Nuñez Otaño et al.: Kasauli Formation and Lower Siwalik (Miocene), near Banethi, Sirmaur District, Himachal Pradesh and Ramshahr Well no.1, Solan District, Himachal Pradesh (Saxena & Sarkar 1986); Subathu Formation (Eocene), Banethi-Bagthan area, Sirmaur District, Himachal Pradesh (Sarkar & Singh 1988). *Tetraploa* spp.: Upper Siwalik (Plio-Pleistocene), Gagret-Bharwain Road Section, Una District, Himachal Pradesh (Singh & Saxena 1981); Upper Siwalik (Pliocene), Hoshiarpur-Una Road Section, Hoshiarpur District, Punjab and Una District, Himachal Pradesh (Saxena & Singh 1982a); Lower Siwalik (Middle-Late Miocene), Bhakra-Nangal Section, Bilaspur District, Himachal Pradesh (Saxena et al. 1984); Miocene, Ramshahr Well-1, Solan District, Himachal Pradesh (Singh & Sarkar 1984a); Subathu Formation (Eocene), Jhimroti-Banethi Section, Sirmaur District, Himachal Pradesh, Lower Siwalik (Middle-Late Miocene), Bhakra -Nangal Section, Bilaspur District, Himachal Pradesh and Ramshahr Well no.1, Solan District, Himachal Pradesh (Saxena & Sarkar 1986); Upper Siwalik (Plio-Pleistocene), Hoshiarpur-Una Section, Hoshiarpur District, Punjab and Una District, Himachal Pradesh, Gagret-Bharwain Section, Una District, Himachal Pradesh; Subathu Formation (Eocene), Banethi-Bagthan area, Sirmaur District, Himachal Pradesh (Sarkar & Singh 1988); Kundlu and Nalagarh formations (Miocene), Kundlu and Ramshahr, Solan District, Himachal Pradesh (Sarkar & Singh 1994).
Jharkhand	*Tetraploa* sp.: Neogene, Rampur Nala, Mahuadanr Vally, Latehar District, Jharkhand (Singh & Chauhan 2008).
Kerala	*Spegazzinites indicus* Ramanujam & Srisailam: Warkalli Beds (Miocene), Kannur District, Kerala (Ramanujam & Srisailam 1980). *Tetraploa* sp.: Quilon Beds (Miocene), clay mine section near Kanjantheria House, Padappakkara, Kollam district, Kerala (Kumar 1990); Tertiary, Alleppey and Kannur districts, Kerala (Rao 1995).
Maharashtra	*Tetraploa conata* (R.K. Saxena & S. Sarkar) Nuñez Otaño et al.: Sindhudurg Formation (Miocene), Mavli Mine at Redi, Sindhudurg District, Maharashtra (Saxena 2000). *Tetraploa* sp.: Sindhudurg Formation (Miocene), Kalviwadi, Sindhudurg District, Maharashtra (Rao 2004).
Mizoram	*Eoglobella* sp.: Bhuban Formation (Miocene), Rengte Anticline near Kolasib, Aizwal District, Mizoram (Banerjee & Nandi 1992). *Tetraploa* sp.: Late Holocene, Demagiri, Mizoram (Mandaokar et al. 2008). *Triporicellaesporites* sp.: Bhuban Formation (Miocene), Rengte Anticline near Kolasib, Aizawl District, Mizoram (Banerjee & Nandi 1992).
Tamil Nadu	*Spegazzinites indicus* Ramanujam & Srisailam: Miocene, Palk Bay area in Cauvery Basin, Tamil Nadu ((Mallesham et al. 1989). *Tetraploa indica* (Saxena & Khare) Nuñez Otaño et al.: Late Palaeocene-Middle Eocene, Jayamkondacholapuram Well 12, Tiruchirapalli District, Tamil Nadu (Saxena & Khare 1992). *Tetraploa* spp.: Quaternary, Pykara, Ootacamund, Tamil Nadu (Rao & Menon 1970); Miocene, Godavari-Krishna Basin, Andhra Pradesh and Palk Bay area in Cauvery Basin, Tamil Nadu (Mallesham et al. 1989); Late Palaeocene-Middle Eocene, Jayamkondacholapuram Well 12, Tiruchirapalli District, Tamil Nadu (Saxena & Khare 1992).
West Bengal	*Tetraploa aristata* Berkley & Broome: Pleistocene, Sankrail, Howrah District, West Bengal (Gupta 1970). *Tetraploa ellisii* Cooke: Pleistocene, Sankrail, Howrah District, West Bengal (Gupta 1970).

Table 3. Distribution of species of fossil *Staurosporae* in India with stratigraphic unit (age) and area of their occurrence.

Genus	Species	Stratigraphic unit, age and area (References)
Eoglobella W.H. Bradley1931	*Eoglobella* sp.	Bhuban Formation (Miocene), Rengte Anticline near Kolasib, Aizwal District, Mizoram (Banerjee & Nandi 1992, p. 84).
Spegazzinites Félix 1894	*Spegazzinites indicus* Ramanujam & Srisailam 1980	Warkalli Beds (Miocene), Kannur District, Kerala (Ramanujam & Srisailam 1980, p. 120, plate 1, figure 1); Miocene, Godavari-Krishna Basin, Andhra Pradesh and Palk Bay area in Cauvery Basin, Tamil Nadu (Mallesham et al. 1989, p. 16, plate 1, figure 22).
Tetraploa Berk. & Broome 1850	*Tetraploa conata* (R.K. Saxena & S. Sarkar) Nuñez Otaño et al. 2022	Kasauli Formation and Lower Siwalik (Miocene), near Banethi, Sirmaur District, Himachal Pradesh, and Nalagarh-Ramshahr Road Section, Solan District, Himachal Pradesh (Saxena & Sarkar 1986, p. 215–216, plate 1, figures 4–5, text-figure 3); Subathu Formation (Eocene), 20 km south-east of Bilaspur on Shimla-Bilaspur Highway, Bilaspur District, Himachal Pradesh (Sarkar 1997, p. 102, 104, 108); Sindhudurg Formation (Miocene), Mavli Mine at Redi, Sindhudurg District, Maharashtra (Saxena 2000, p. 163); Subathu and Dagshai formations (Late Palaeocene-Early Oligocene), Dadahu Road Section, Sirmaur District, Himachal Pradesh (Gupta 2002, p. 148, plate 5, figures 1–3); Intertrappean Beds (Early Palaeocene), 5 km west of Naredi, on Naliya-Narayan Sarovar Road, Kutch District, Gujarat (Saxena & Ranhotra 2009, p. 692, figure 3.18).
	Tetraploa indica (R.K. Saxena & S. Khare) Nuñez Otaño et al. 2022	Late Palaeocene-Middle Eocene, Jayamkondacholapuram Well 12, Tiruchirapalli District, Tamil Nadu (Saxena & Khare 1992, p. 42, plate 1, figure 17); Intertrappean Beds (Early Palaeocene), 5 km west of Naredi, on Naliya-Narayan Sarovar Road, Kutch District, Gujarat (Saxena & Ranhotra 2009, p. 692, figure 3.23).
	Tetraploa siwalika (R.K. Saxena et al.) Nuñez Otaño et al. 2022	Tatrot and Pinjor formations (Pliocene), Masol-Kiratpur Section, Ambala District, Haryana (Saxena et al. 1988, p. 277, plate 2, figures 31–33); Lower Bhuban and Bokabil formations (Early-Middle Miocene), Silchar-Haflong Road Section, Assam (Kumar & Takahashi 1991, p. 609, plate 7, figure 6, plate 16, figure 11); Lower Bhuban Formation (Early Miocene), Silchar-Haflong Road Section, Assam (Kumar 1994, p. 55, plate 27, figure 6); Kasauli Formation (Early Miocene), Kasauli, Solan District, Himachal Pradesh (Singh & Sarkar 1994, p. 52).
	Tetraploa taugourdeaui (R.K. Saxena & S. Sarkar 1986) Nuñez Otaño et al. 2022	Kasauli Formation and Lower Siwalik (Miocene), near Banethi, Sirmaur District, Himachal Pradesh and Ramshahr Well no.1, Solan District, Himachal Pradesh (Saxena & Sarkar 1986, p. 213–215, plate 1, figures 1–3, text-figure 2); Subathu Formation (Eocene), Banethi-Bagthan area, Sirmaur District, Himachal Pradesh (Sarkar & Singh 1988: 61, plate 5, figure 21, plate 6, figure 18).
	Tetraploa spp.	Quaternary, Pykara, Ootacamund, Tamil Nadu (Rao & Menon 1970, p. 75, plate 1, figure 13); Quaternary, Malvan, Surat District, Gujarat (Sharma 1976, p. 79, plate 1, figures 1–4); Upper Siwalik (Plio-Pleistocene), Gagret-Bharwain Road Section, Una District, Himachal Pradesh (Singh & Saxena 1981, p. 177, plate 1, figure 13); Upper Siwalik (Pliocene), Hoshiarpur-Una Road Section, Hoshiarpur District, Punjab and Una District, Himachal Pradesh (Saxena & Singh 1982a, p. 295–296, plate 2, figure 30); Lower Siwalik (Middle-Late Miocene), Bhakra-Nangal Section, Bilaspur District, Himachal Pradesh (Saxena et al. 1984, p. 189, plate 2, figure 38); Miocene, Ramshahr Well-1, Solan District, Himachal Pradesh (Singh & Sarkar 1984a, p. 98, plate 2, figure 37); Subathu Formation (Eocene), Jhimroti-Banethi Section, Sirmaur District, Himachal Pradesh, Lower Siwalik (Middle-Late Miocene), Bhakra-Nangal Section, Bilaspur District, Himachal Pradesh and Ramshahr Well no.1, Solan District, Himachal Pradesh, Upper Siwalik (Plio-Pleistocene), Hoshiarpur-Una Section, Hoshiarpur District, Punjab and Una District, Himachal Pradesh, Gagret-Bharwain Section, Una District, Himachal Pradesh (Saxena & Sarkar 1986, p. 216–221, plate 1, figures 6–7, plate 2, figures 1–8, text-figures 4–8); Barail and Surma Groups (Oligocene-Early Miocene), Sonapur-Badarpur Road Section, Jaintia Hills, Meghalaya and Cachar District, Assam (Singh et al. 1986, p. 102, plate 2, figure 9); Subathu Formation (Eocene), Banethi-Bagthan area, Sirmaur District, Himachal Pradesh (Sarkar & Singh 1988, p. 61, plate 5, figure 21, plate 6, figure 18); Miocene, Godavari-Krishna Basin, Andhra Pradesh and Palk Bay area in Cauvery Basin, Tamil Nadu (Mallesham et al. 1989, p. 16, plate 1, figure 23); Quilon Beds (Miocene), clay mine section near Kanjantheria House, Padappakkara, Kollam district, Kerala (Kumar 1990, p. 25, plate 1, figures 24, 26); Late Palaeocene-Middle Eocene, Jayamkondacholapuram Well 12, Tiruchirapalli District, Tamil Nadu (Saxena & Khare 1992, p. 42, plate 1, figure 11); Jenam, Renji, Bokabil and Dupitila formations (Middle-Late Oligocene, Middle Miocene and Plio-Pleistocene), Silchar-Haflong Road Section, Assam (Kumar 1994, p. 42, 48, 88, 97, plate 21, figure 8, plate 41, figure 6); Kundlu and Nalagarh formations (Miocene), Kundlu and Ramshahr, Solan District, Himachal Pradesh (Sarkar & Singh 1994, p. 99, plate 1, figures 4–5); Tertiary, Alleppey and Kannur districts, Kerala (Rao 1995, p. 234, plate 1, figure 10); Late Tertiary, Site 218, Deep Sea Drilling Project Leg 22, Bengal Fan, Indian Ocean (Chandra & Kumar 1998, p. 60, plate 1, figure 13, plate 3, figure 10); Kopili Formation (Late Eocene), Umrongso-Haflong Road near Umrongso, North Cachar Hills District, Assam (Trivedi & Saxena 2000, p. 273, plate 1, figure 13); Pinjor Formation (Late Pliocene), Nadah, Panchkula, Haryana (Rao & Patnaik 2001, p. 272, plate 3, figures 7–8); Sindhudurg Formation (Miocene), Kalviwadi, Sindhudurg District, Maharashtra (Rao 2004, p. 128, plate 3, figure 11). Neogene, Rampur Nala, Mahuadanr Vally, Latehar District, Jharkhand (Singh & Chauhan 2008, p. 76, plate 2, figure 10); Late Holocene, Demagiri, Mizoram; Late Palaeocene-Middle Eocene (Mandaokar et al. 2008, p. 198, plate 1, figures 1–2)
Triporicellaesporites P. Ke & Z.Y. Shi 1978	*Triporicellaesporites* sp.	Bhuban Formation (Miocene), Rengte Anticline near Kolasib, Aizawl District, Mizoram (Banerjee & Nandi 1992, p. 84, plate 1, figure 9).

Middle Eocene sediments of Garfield County, Colorado whereas Bradley (1964) recorded *Tribolites tetrastonyx* from the Eocene sediments of Wyoming, Colorado (Table 1).

Distribution in India: In India, staurosporous spores have been recorded from Andhra Pradesh, Assam, Bengal Fan, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Kerala, Maharashtra, Mizoram, Tamil Nadu and West Bengal. Distribution of 4 genera and 7 named species of fossil *Staurosporae* in India and their stratigraphic unit (geologic age) and areas of occurrence, along with citation of relevant References is shown in Tables 2 and 3.

ACKNOWLEDGEMENTS

The author is grateful to the authorities of the Birbal Sahni Institute of Palaeosciences, Lucknow, India for library facilities.

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