

A COMPARATIVE STUDY OF SPORES OF *CERATOPTERIS THALICTROIDES* (L) BRONGN. AND *STRIATRILETES* VAN DER HAMMEN EMEND. KAR

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ABSTRACT

The paper deals with the morphology of spores of *Ceratopteris thalictroides* (L) Brongn. and its bearing on the taxonomy of similar fossil spores occurring in Tertiary sediments of Assam. A comparative morphological study of a number of costate trilete fossil spores and those described from the living plants of *Ceratopteris thalictroides* reveals a striking morphological similarity between the two. Spores studied from the fertile plants of *Ceratopteris thalictroides* growing in different ecological conditions have more or less similar qualitative characters but variation in different quantitative characters has been observed and represented graphically.

INTRODUCTION

Most of the Tertiary sediments of India show the presence of costate trilete spores and their frequency of occurrence is quite high, particularly in the Tertiary succession of Assam and Meghalaya. These spores have been assigned to different genera, viz., *Ceratopteris*, *Striatriletes*, *Cicatricosisporites*, *Parkeriaceasporites*, *Schizaeaceasporites*, *Magnastriatites*, by different workers.

It has been observed that characters of these taxa overlap to such a degree that it often becomes difficult to determine precisely their taxonomic status. So, the present morphological study of the spores of *Ceratopteris thalictroides* (L) Brongn. was initiated particularly to study the range of variation in spores collected from specimens growing in different ecological conditions with a view to throwing light on the taxonomic status of various corresponding fossil spores.

Parkeriaceae, the water fern family, is represented by a single genus *Ceratopteris* (L) Brongn., consisting of four species—namely, *C. thalictroides*, *C. cornuta*, *C. pteridoides* and *C. richardii*. The first species is a marshy or aquatic annual fern generally found in tropical and subtropical countries. In India *C. thalictroides* is found in swamps, ditches and rice fields of Dehradun, Haldwani, common in tanks and swamps of Bombay, Goa territory, Chhota Nagpur and Sambalpur. The plants are very common in shallow marshes and rice fields of Orissa, West Bengal and Assam. Plants growing in different localities of West Bengal were studied. Mature plants are mostly erect 50-60 cm high with a short rhizome which is rooted in mud or free floating. The foliage are diamorphic and pinnately decompose. The fertile pinnae are erect with linear, acute segments having revolute margins which cover the fructification whereas, the sterile fronds are short with spreading habit having cuneate segments which are succulent in nature. The sporangia are sessile or subsessile arranged in a seriate fashion all along the veins.

The most common and frequently available species of *Ceratopteris* in India is *C. thalictroides*. Amongst the other 3 species, *C. cornuta* is also reported from north-eastern India. One of us (SKMT) could not find it growing in the areas visited for the collection of *C. thalictroides*.

SPORE MORPHOLOGY OF COSTATE SPORES

The spores of *Ceratopteris thalictroides* are costate, trilete and resemble superficially the spores of *Anemia* and *Mohria*. The spores in these three taxa are costate and trilete but nature and disposition of the costae are different in each one of them.

In the spores of *Anemia*, costae are generally parallel to the margin of the spore and also parallel to each other. The inter-radial areas of the proximal side in the spores of *Anemia*, contrary to those of *Ceratopteris thalictroides*, are occupied by parallelly arranged costae. The distal surface is occupied by costae arranged in 2-3 concentric triangles. The corners of these triangles lie below the apices of the spores. Each apex of the spore possesses a protruding ridge which joins with the corners of the outermost triangle of the distal side.

In the spores of *Mohria*, the pattern of the costae is quite like that of *Anemia* but here the costae are paired. The closely placed pairs of costae are separated from each other by a broad groove.

SPORE MORPHOLOGY OF CERATOPTERIS THALICTROIDES

The spores of *Ceratopteris thalictroides* (L) Brongn. are trilete, tetrahedral, and without perine. They are subtriangular to subcircular with the inter-radial margins variably convex and radial apices rounded to broadly rounded. The size of the spores ranges between 78-160 μm . The exine is 3-7 μm thick and bears costae on both proximal as well as distal surfaces. The trilete ray-ends or the inter-radial areas near the commissure are generally marked with the ends of costae. The costae on the proximal surface are few in number, convex, the convexity being away from the pole of the spore.

The costae originate at or near the ray-ends and a few of them run more or less parallel to the margin of the spore ending at or near the adjacent ray-ends. The remaining costae run towards the distal side and end at or near the adjacent ray-end forming concentric rings. The distal surface of the spore possesses three concentric rings of 4-5 parallel costae. The convexity of the costae is towards the pole of the spore.

The costae are frequently bi- or trifurcated and a branch of the marginal costae may contribute to the other adjacent concentric ring. The number of costae on proximal surface varies from 1-3 in each inter-radial area and 4-8 at each ray-end but due to frequent branching their number increases at the distal surface. In some cases, the number of costae on proximal surface of the spore may not be counted due to their branched nature and subsequent fusion with the ray-ends. The costae may be 3-10 μm wide and 1-11 μm apart from each other. The ornamentation of the costae and the spaces between them is mostly laevigate but it may also be granulate or punctate. The number and width of costae are not governed by the size of the spore.

The trilete mark is generally distinct, straight, thin, sometimes slightly thickened and slightly raised or flat. The laesurae are simple and mostly extend up to more than half of the spore radius.

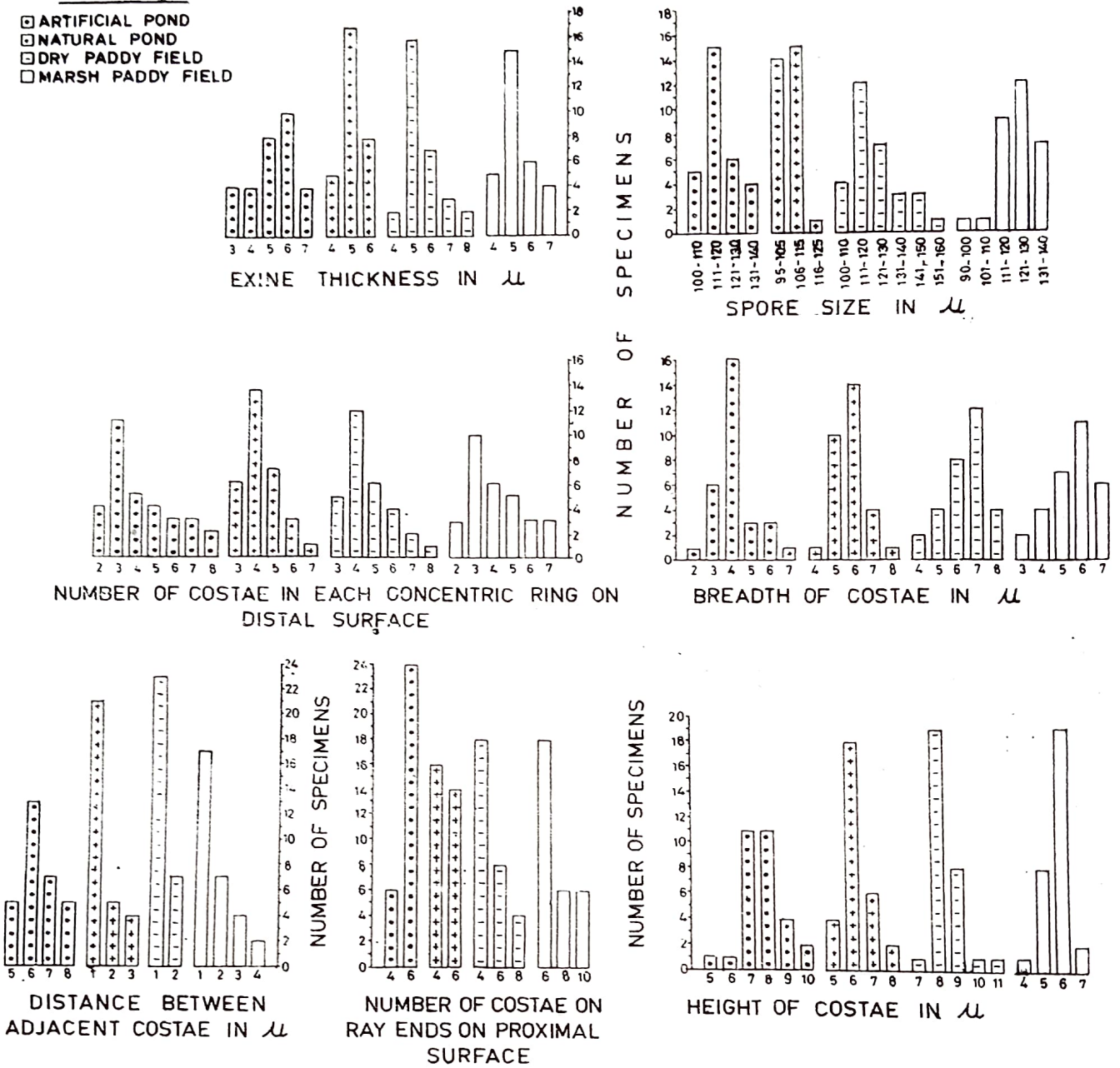
In the costae organisation and exine pattern, most of the spores are alike. They, however, differ in size, the number of costae, height and breadth of the costae, ornamentation of the costae and exine, exine thickness and the nature of trilete.

QUANTITATIVE ANALYSIS

From the frequency distribution of different quantitative characters of the spore, histograms have been plotted (Text-fig. 1). Different quantitative characters have been

HABITATS

- ARTIFICIAL POND
- ▣ NATURAL POND
- ▤ DRY PADDY FIELD
- ▥ MARSH PADDY FIELD



Text-fig. 1. Morphological variation in spores of *Ceratopteris thalictroides* under different habitats.

marked on the horizontal axis and rectangles have been erected to represent various classes. The base of the rectangle covers the range of values included in the class and area of the rectangle represents the frequency of the class.

$$\text{Area} = \text{base} \times \text{altitude}$$

In every histogram the value which is repeated for the maximum time is the mode or most fashionable value. Going away from the mode in either direction the frequency declines. Most of the spores exhibit the typical central value whereas, a few spores show comparatively rare values. This observation has been confirmed when similar picture appeared repeatedly while dealing with the different sets of quantitative characters.

FOSSIL TERTIARY COSTATE SPORES

The fossil costate trilete spores are common in the Tertiary sediments of Assam and Meghalaya. These spores show a close resemblance with the spores of *Ceratopteris thalictroides*. Generally these spores mark their first appearance in the Upper Eocene sediments and their frequency is quite high in Oligocene-Lower Miocene rocks. The frequency of these spores decreases in the Middle Miocene. The costate spores recovered from the various Tertiary horizons of the Indian subcontinent have been assigned to different genera by various workers, viz. *Ceratopteris*, *Cicatricosisporites*, *Parkeriaceasporites*, *Schizaeaceasporites* and *Magnastriatites*.

MEYER (1958, pl. 24, fig. 1) for the first time reported the occurrence of costate trilete spores in the Barail Series (Oligocene) of Assam and described them as *Ceratopteris* type spore. BISWAS (1962, pl. 2, figs. 2, 3) described costate trilete spores as *Cicatricosisporites* sp. from the Upper Cretaceous-Palaeocene sediments of Meghalaya. BAKSI (1962), while investigating the palynomorphs from the Middle Eocene-Miocene sediments of Simsang River Section, Assam, also described some costate trilete spores, viz. *Schizaeaceasporites knoxi* (BAKSI, 1962, pl. 3, fig. 41), *Ceratopteris macrocostata* (BAKSI, 1962, pl. 4, fig. 53) and *Schizaeaceasporites/Parkeriaceasporites* sp. (BAKSI, 1962, pl. 5, fig. 54). Morphologically all these forms look very similar. Unfortunately the descriptions of these forms are also poor.

BANERJEE (1964) reported some costate trilete spores from the Miocene sediments of Garo Hills, Meghalaya and described them as *Striatriletes* sp. A (BANERJEE, 1964, pl. 1 figs. 11, 16, 17) and *Striatriletes* sp. B (BANERJEE, 1964, pl. 1, fig. 18). GHOSH, JACOB AND LUKOSE (1964, pl. 1, fig. 5; pl. 2, figs. 13-20) described some fossil costate spores from Cretaceous-Tertiary rocks of India and grouped them under the following living genera: *Schizaea*, *Anemia*, *Mohria* and *Ceratopteris*. A detailed taxonomic study of these forms is required so as to understand the nature of their costae because most of the illustrations provided by the above authors are of folded specimens.

SAH AND DUTTA (1968) transferred *Ceratopteris macrocostata* BAKSI (1962) to the genus *Cicatricosisporites*. Subsequently, KAR (1979) treated it as the synonym of *Striatriletes susannae* (van der Hammen) Kar (1979). SALUJHA, KINDRA AND REHMAN (1972, 1974) described *Cicatricosisporites pudens* (SALUJHA *et al.*, 1972, pl. 1, figs. 24, 25) and *Magnastriatites venustus* (SALUJHA *et al.*, 1974, pl. 1, fig. 16) from the Palaeogene sediments of the Garo Hills, Meghalaya which, according to the present status of knowledge, belong to the genus *Striatriletes*.

The genus *Cicatricosisporites*, instituted by POTONIÉ AND GELLETICH (1933, pl. 1, figs. 1-5), is a costate, trilete spore and is reported to occur widely in Mesozoic and Tertiary sediments. It has been compared with the spores found in some members of the fern family Schizaeaceae (POTONIÉ, 1966, DETTMANN, 1963, p. 522). POTONIÉ (1966) emended the diagnosis of this genus as follows: "The muri may show a slight tendency to become cristate. This then results in a slight resemblance to the genus *Corrugatisporites* or the spores of schizaeaceous genus *Senftenbergia*. And occasionally a few roundish lumina situated in the grooves between the parallel muri indicate a relationship with the genus *Ischyosporites* or the schizaeaceous genera *Stachyopteris* and *Klukia*".

The genus *Striatriletes* was published by VAN DER HAMMEN (1956, pl. 2, fig. 5) with the following description: "Sculpture-type striate. Size of the type specimen 82 × 75 micron, but rather variable within the species. The arms of the Tetrad mark are relatively long, but in general do not reach the limits of the proximal and distal sides. Tetrad mark sometimes slightly opened. Breadth of striae 2-3 micron. The distance

between the striae is smaller than the breadth of striae. The majority of the striae leave divergating from the ends of the arms of tetrad-mark. Bifurcations and little pronounced constrictions of the striae can be observed sometimes”.

Regarding the botanical affinity of these spores VAN DER HAMMEN (*l. c.*) suggested their relationship with the genus *Anemia* but he also surmised its affinity with the family Parkeriaceae.

GERMERAAD, HOPPING AND MULLER (1968, pl. 3, fig. 1) created a genus—*Magnastriatites*, for the reception of the spores having morphological characters which resemble the spore of the family Parkeriaceae. They gave the following diagnosis for the genus *Magnastriatites*: “Spherical, trilete, coarsely striate, except on the proximal contact area which is surrounded by a circular ridge. Striae continuous, grooves about as wide as ridges, size around 100 μ ”

It might be mentioned here that VAN DER HAMMEN had already validly published the genus *Striatriletes* in the year 1956 describing spores having morphological characteristics as exhibited by *Magnastriatites*. KAR (1979), while dealing with plynomorphs from the Oligocene sediments of Kachchh has correctly treated *Magnastriatites* Germeraad *et al.* (1968) as a junior synonym of *Striatriletes* van der Hammen (1956). He emended the diagnosis of the genus *Striatriletes* as follows: “Spores triangular-subcircular in polar view, 40-140 μ m, trilete distinct-indistinct, costate, costae 3-7, generally arise at inter-radial area or at ray-ends and continue on respective distal side as successive concentric rings, costae sparsely or closely placed, laevigate or ornamented”.

The study of the spores of *Geratopteris thalictroides* (L) Brongn. clearly indicates that most of the morphological features exhibit a wide range of quantitative variation whereas, the qualitative characters of the spores collected from the plants growing in different ecological conditions remain more or less uniform. It indicates that the qualitative characters of these spores are quite conservative and are governed by the genetic make-up of the species. On the other hand, the quantitative variation in the spore morphology seems to be influenced by the ecological factors.

Considering the extent of quantitative morphological range of variation in the spores of *Geratopteris thalictroides* it is proposed here that the taxonomic designation of fossil costate spores up to the level of species should be based on more than one quantitative characters.

While studying the palynoflora recovered from Jowai-Badarpur Road Section, Lower Assam it was realised that the parkeriaceous spores, which constitute a remarkable proportion of the whole assemblage, deserves a special attention in regard to their taxonomy.

SYSTEMATIC DESCRIPTION

Anteturma SPORITES Potonié, 1893

Turma TRILETES Potonié & Kremp, 1954

Subturma AZONOTRILETES Luber, 1935

Infraturma MURORNATI Potonié & Kremp, 1954

Genus **Striatriletes** van der Hammen emend. Kar, 1979

Type species—*Striatriletes susannae* van der Hammen emend. Kar, 1979

Striatriletes susannae van der Hammen emend. Kar, 1979

Pl. 1, Figs. 7, 8; Pl. 2, Figs 9, 10

Remarks—In the emended diagnosis of *S. susannae* Kar (1979) has mentioned that the exine is more or less laevigate. During our study some forms have been recovered which have all the characters similar to *S. susannae* except the punctate exine. Such spores have also been included in the same species. This has been done on the basis of our study of living spores of *Ceratopteris thalictroides*.

Previous records—Eocene of Assam and Meghalaya (GHOSH, *et al.*, 1964; SALUJHA *et al.* 1972, 1974) and Oligocene of Kachchh (KAR, 1979).

Occurrence—Kopili Formation (Upper Eocene), Meghalaya.

Affinity—Morphologically *Striatriletes susannae* closely resembles the spores of *Ceratopteris thalictroides* (L) Brongn.

Striatriletes pseudocostatus sp. nov.

Pl. 1, Fig. 2; Pl. 2, Figs. 11, 12

Holotype—Pl. 1, Fig. 2; Slide No. 6952

Horizon—Kopili Formation

Llocality—Near 133.4 km. from Shillong on Shillong—Badarpur Road, Meghalaya.

Diagnosis—Miospores subtriangular, apices broadly rounded, interapical margins convex; trilete distinct, slightly raised, extending up to more than half of the spore radius; exine costate, costae ill-developed, flat and not evenly wide.

Description—Miospores subtriangular in shape, 76-90 μm in size (Holotype 88 μm) apices broadly rounded, interapical margins convex. Trilete distinct, labra thick, slightly raised, extending up to more than half of the spore radius. Exine 1-2 μm thick costate. Costae ill-developed, flat, originating at ray-ends, where mostly 6 in number. Above the ray ends costae runing towards the distal side. Nature of costae not clearly discernible, however, at some places their parallel nature exhibited. Costae not uniformly wide, mostly indistinct, 2-3 μm wide and 28—3 μm apart.

Comparison—*Striatriletes pseudocostatus* is distinct from other known species of the genus in exhibiting ill developed, flat and unevenly wide costae. Here, in contrast to the other species of the genus, the pattern of costae on the distal surface is also not clearly observed.

Occurrence—Lower part of Kopili Formation (Upper Eocene), Meghalaya.

Affinity—In size, shape and costate nature of exine these miospores are like the spores of *Ceratopteris thalictroides* (L) Brongn., but former is distinct from the latter in possessing a very thick trilete mark and ill-developed, flat costae. However, a relationship of these miospores with the family Parkeriaceae can not be ruled out.

Striatriletes attenuatus sp. nov.

Pl. 1, Figs. 3, 6

Holotype—Pl. 1, Fig. 3; Slide No. 6954

Horizon—Kopili Formation

Locality—At 131.25 km from Shillong on Shillong—Badarpur Road, Meghalaya.

Diagnosis—Miospores subtriangular; trilete thick, distinct, raised, provided with an ancllet near the commissure; exine 1-2 μm thick, costate; costae more or less flat, few in number, showing less curvature.

Description—Miospores subtriangular, 81-85 μm in size (Holotype 85 μm), apices rounded, interapical margin convex. Trilete distinct, laesura thickened, raised appreciably, extending up to 2/3 of the spore radius. Margin of the thickened Y-mark not

smooth. The trilete mark shows the presence of an ancllet near the commissure supporting the raised nature of the Y-mark and that the structure arises during the flattening of the spore. Exine $\pm 1 \mu\text{m}$ thick, costate. Costae 4-6 in number at each ray-end and not more than 3-4 in each concentric ring on the distal side. Costae 2-3 μm thick, 3-7 μm apart, flat, showing less curvature and possess dilated ends. The convexity of the costae, on distal side, facing towards the pole of the spore. Costae and spaces between them laevigate.

Comparison—*Striatriletes attenuatus* is distinguished from *S. susannae* (van der Hammen) Kar (1979) in possessing a thick and raised trilete mark, in having less number of costae with a lesser curvature and in possessing dilated costae ends. This species is distinguished from *S. pseudocostatus* in possessing distinct nature of costae.

Occurrence—Lower part of Kopili Formation (Upper Eocene), Meghalaya.

Affinity—Morphological features of this species suggest its affinity with the spores of the family Parkeriaceae.

DISCUSSION

The qualitative differences between the spore morphology of the family Parkeriaceae and Schizaceae are well established. It is clear from the study of the living spores of *Ceratopteris thalictroides* that most of the morphological features exhibit a wide range of quantitative variation. The qualitative characters of the spores from plants growing in different ecological conditions remain more or less uniform. So it can be inferred that the qualitative characters of spores of *Ceratopteris thalictroides* (L) Brongn. are quite conservative and are governed by the genetic make up of the species. It is only the quantitative range of variation exhibited by one or more characters which perhaps denote the effect of different ecological conditions on the spore morphology. Considering the quantitative morphological range of variation and presuming that similar conditions might have produced similar results in the fossil spores of *Ceratopteris* sp. it is suggested that the taxonomic designation of the costate fossil spores up to the level of species should be based on more than one quantitative character.

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EXPLANATION OF PLATES

(All photomicrographs ca ×500)

PLATE 1

- 1 & 5. Spores of *Ceratopteris thalictroides* collected from the plants growing in Orissa; Slide no. 6942; Coordinates; 97.1 × 11.1 and 102.5 × 14.0 respectively.
2. *Striatriletes pseudocostatus* sp. nov., Slide no. 6952; Coordinate: 77.2 × 11.8.
- 3 & 6. *Striatriletes attenuatus* sp. nov.; Slide nos. 6954 and 6955; Coordinates: 100.7 × 22.5 and 75.2 × 30.8 respectively.
4. Spore of *Ceratopteris thalictroides* collected from the plants growing in artificial tank of Kalyani University, West Bengal; Slide no. 6941; Coordinate: 105.2 × 11.1.
- 7 & 8. *Striatriletes susannae* van der Hammen emend. Kar, Slide nos. 6956 and 6957; Coordinates : 85.8 × 19.7 and 82.5 × 13.6 respectively.

PLATE 2

- 9 & 10. *Striatriletes susannae* van der Hammen emend. Kar, 1979; Slide nos. 6951 and 6950; Coordinates: 85.7 × 23.3 and 90.8 × 13.6 respectively.
- 11 & 12. *Striatriletes pseudocostatus* sp. nov.; Slide nos. 6952 and 6953; Coordinates; 80.5 × 14.0 and 105.9 × 6.2 respectively.
13. Spore of *Ceratopteris thalictroides* collected from the plants growing in natural pond of Kalyani, West Bengal; Slide no. 6938; Coordinate: 110.8 × 16.1.
14. Spore of *Ceratopteris thalictroides* collected from the plants growing in the artificial pond of Lucknow University, Lucknow; Slide no. 6939; Coordinate: 97.3 × 22.8.
5. Spore of *Ceratopteris thalictroides* collected from the plants growing in dry paddy field of Kalyani, West Bengal; Slide no. 6940; Coordinate: 100.2 × 17.8.
16. Spore of *Ceratopteris thalictroides* collected from the plants growing in marsh paddy field of Kalyani, West Bengal; Slide no. 6959; Coordinate: 108.7 × 20.7.

