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Developmental Studies of Indian Laboulbeniomycetes II – *Peyritschiella* sp.

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ABSTRACT

The Laboulbeniales are a group of fungi known for their obligate ectoparasitic relationships with arthropods, primarily insects. Here we are describing the developmental studies of two species of *Peyritschiella* occurring on the rove beetle *Philonthus*.

Keywords: *Peyritschiella* , Perithecium, Antheridium, Development.

INTRODUCTION

Peyritschiella species (49 species worldwide, Santamaria, 2021) are distributed worldwide and can be found in various terrestrial ecosystems. It is well distributed in Algeria, Belgium (DeKesel 1991a, 1991b), India (Kaur,2022), Tibet (Lee et al 2006), and United states of America.(Benjamin, 1971), Korea (Lee et al 2011), Ukraine (Mishustin,2023), Taiwan (Terada et al, 2006) Indonesia (Haelewaters et al 2014). In Europe there are 15 species, of which six are in Denmark. The most recently described species is *P. heinemanniana* (De Kesel 1998). Their hosts are various ground beetles and rove beetles which occur in damp soils, decaying organic matter etc. The common host species are *Anotylus*, *Bledius*, *Manda*, *Oxytellus*, *Philonthus*, *Planeustomus* and *Strloxys* (Staphylinidae, Coleoptera).

Peyritschiella begins its life cycle by attaching to the external surfaces of the host insects, including the exoskeleton, antennae, wings, or other appendages. The thallus is multicellular, fan shaped and has four layers of cells. The sexual structures include male antheridia, which release sperm-like structures called spermatia, and female ascogonia, which contain specialized ascogenous cells. Fertilization occurs when spermatia from the male structures come into contact with ascogonia from the female structures. Following fertilization, *Peyritschiella* species form specialized structures called asci. Each ascus contains ascospores, which are the sexual spores of the fungus. These asci are arranged in clusters, ready for dispersal. Mature asci release ascospores into the environment. These spores are adapted for attachment to passing host insects, enabling them to start a new infection cycle when they encounter a suitable host.

OBSERVATIONS

Peyritschiella furcifera (Thaxter, 1896; Lee and Lee,1981; Tavares,1985; Majewski and Sugiyama, 1989; Sugiyama and Ginkgoana, 1973; Sugiyama and Shazawa, 1977).

This is a very interesting fungus, found all over the body of the staphylinid beetle *Philonthus.* It is of an unique appearance, having a narrow fan shaped receptacle. The width increases from the base of the first layer to the distal end of the fourth layer. The second, third, and fourth layer are multicellular with the cells arranged in a horizontal plate like manner. The marginal portions of the second and the third layer are black in colour. In the third layer this forms long projections, which extend beyond the fourth layer.

The fungus is monoecious. There are two compound antheridia formed per thallus. Each is a dark brown, horn-shaped structure, arising from the third layer at submarginal positions. The perithecia are two to five in number per thallus. They arise from the fourth layer. Each is oblong in shape with a broad, blunt, apex. Some perithecia may show two small blunt projections sub-apically called auricles (Santamaria,2021).

Development

The fungus forms eight bi-celled ascospores in each ascus. Each spore is surrounded by a gelatinous sheath and the two cells are unequal in size. The basal cell (b) is longer than the apical cell (a) which is much shorter.

At the beginning of the life cycle, in the first stage spore undergoes the first division. This division is a horizontal and takes place in the basal cell to cut off the foot(f) and a cell termed as ‘i’. The foot initially is a small round to conical structure and it soon begins to darken. Later it matures, darkens totally and turns black. It is a stout structure and has a broad rounded cone shape.

Cell ‘i’ divides by a single horizontal division. There are thus three cells in a longitudinal series. The cell closest to the foot is small and rectangular and is the cell of the 1st layer(I). The next cell termed ‘II’ is longer than broad and is the first cell of the second layer. The third cell is the small apical cell ‘a’ of the spore (Fig.1a).

The next division is also horizontal and it takes place in cell II and forms two cells II and III. The cell ‘II’ is separated from cell ‘I” by a black septum. Cell ‘a’

develops into the single celled appendage (Fig. 1b,Fig 2c,d).

The cell II then divides longitudinally, twice, one after the other and forms the three cells of the layer II. The cells of the IInd layer are all elongated cells with the two lateral cells darkening intensely. Gradually they darken to the extent of hiding the central hyaline cell too (Fig. 1d).

Cell 'III' is a small rectangular cell when compared with the cells of layer II. Later it also enlarges and then divides longitudinally and forms three cells initially (Fig. 1c). The cells divide horizontally and form cells of the fourth layer. Then the cells of the third layer elongate and divide longitudinally further forming a row of cells or a plate of cells (Fig 1g, 1h) The cells of the fourth layer also divide longitudinally and form a plate of long, cells (Fig 1h).

From the third layer of the receptacle arise the pair of compound antheridium. Each side of the third layer, gives rise to one compound antheridium. The submarginal cells on either side of the third layer divide obliquely and form a cell towards its distal end. The cell divides further, a number of times and forms small square to rectangular cells which constitute the horn shaped compound, antheridium (Fig. 1h, Fig 2j). The antheridial cells move towards the base of the structure and produce spermatia. The spermatia travel through the neck and finally are released out through the apical ostiole. The whole structure is dark brown in colour and opaque. Due to its opacity, it is difficult to determine the exact number of cells that take part in the formation of the compound antheridium by maturity. The marginal cells of the third layer start to darken and elongate (Fig.1d, Fig 2e). These cells form the long black projections of the third layer. The projections exceed the fourth layer of the receptacle. The projections are long and slender with blunt apices (Fig 2k). The third layer is formed of five to seven cells arranged in a plate like manner, with the submarginal compound antheridia and the marginal projections which exceed the fourth layer in height.

The fourth layer is formed by longitudinal divisions of the initial few cells. The central portion shows five cells, columnar in shape, arranged at the same level. Further divisions on both the sides are obliquely longitudinal so that the resultant cells are formed in a curvature. The total number of cells in the fourth layer varies between seventeen to nineteen cells. This layer thus forms a plate of cells, curving upwards on the sides. The cells on the sides are shorter and thinner than those in the central portion (Fig. 1k). The central region of the fourth layer also gives rise to the perithecia. Apart from the central three cells, the cells on the side give rise to the perithecia.

The initial cell of the fourth layer divides horizontally to form a stalk cell 'h' and the primordium. The stalk cell is much smaller than the other cells of the fourth layer. It is square in shape. The cell divides further, and forms three basal cells (Fig. 1j) Only one 'n' cell is visible in one focus.

The primordial cell divides at the same time and forms three cells in a longitudinal series - the basal carpogenic cell (cp), sub-basal trichophoric cell and the apical trichogyne. (Fig. 1k, Fig 2k). The trichogyne is elongated and protrudes out beyond the wall cells. With fertilization, the trichogyne regresses, and the wall layers close around it. The wall cells '0' and the parietal cells 'p' divide horizontally again to form tiers of cells which function as the outer and inner wall layers (Fig. 1k).

As the ascogonial filaments and then the asci develop, the perithecium increases in size. Along with this increase, the wall cells also divide and form upto four tiers of cells.The cell 'a' of the appendage, also divides longitudinally and forms a large number of appendages all along the distal end of the fourth layer (Fig. 1h, Fig 2k). An 'a' cell is present for each cell of the fourth layer except those taking part in the formation of perithecia. Each cell 'a' forms the single cell 'pa' of the primary appendage. The septum between them is black. The primary appendage is long, thin and single celled (Fig. 1k).

In the mature perithecium, each ascus 'ac' forms eight ascospores 'as'. In the top tier of wall cells, the outer wall cells are longer than the inner wall cells, and thus close up and form the apex. The inner wall cells or canal cells form the passage of ostiole. The perithecium at maturity is bottle shaped with a blunt apex. Some perithecia show two small projections at the subapical part ' ap' (Fig. 1l, Fig 2m). When the ascospores are mature, they are released into the perithecial cavity. From here, the spores are released out through the ostiole.

The mature thallus (Fig. 1m,n Fig 2 l,m) thus shows a stout black, conical foot at the base which is used for anchoring the fungus. Above the foot is the single celled first layer of the receptacle. The cell is rectangular, longer than broad, and hyaline. This cell leads to the three celled second layer of the receptacle. The marginal cells arc blackened and the pigmentation is so intense that it hides the central hyaline cell. The third layer is made up of seven to nine cells. The cells are all tall and thin with the marginal cells blackened. The marginal cells extend and form two long black, projections on either side. The projections exceed the fourth layer. The fourth layer of the receptacle is also multicellular, with the cell arranged in a curved plate. There are seventeen to nineteen cells, all the cells are tall and arranged parallel to each other. One appendage arises near each compound antheridium. From the distal end of the fourth layer, also, appendages arise from its basal cell. Each appendage is long, thin, and unicellular. The third layer forms the pair of horn shaped compound antheridia, at sub marginal position. The antheridia are opaque and dark brown in colour. From the fourth layer, arise the perithecia at central positions. Each perithecium is bottle shaped, and, may have two small blunt projections at subapical points. Each perithecium has four asci, which have eight ascospores. Ascospores are bi-celled and have a surrounding gelatinous sheath.

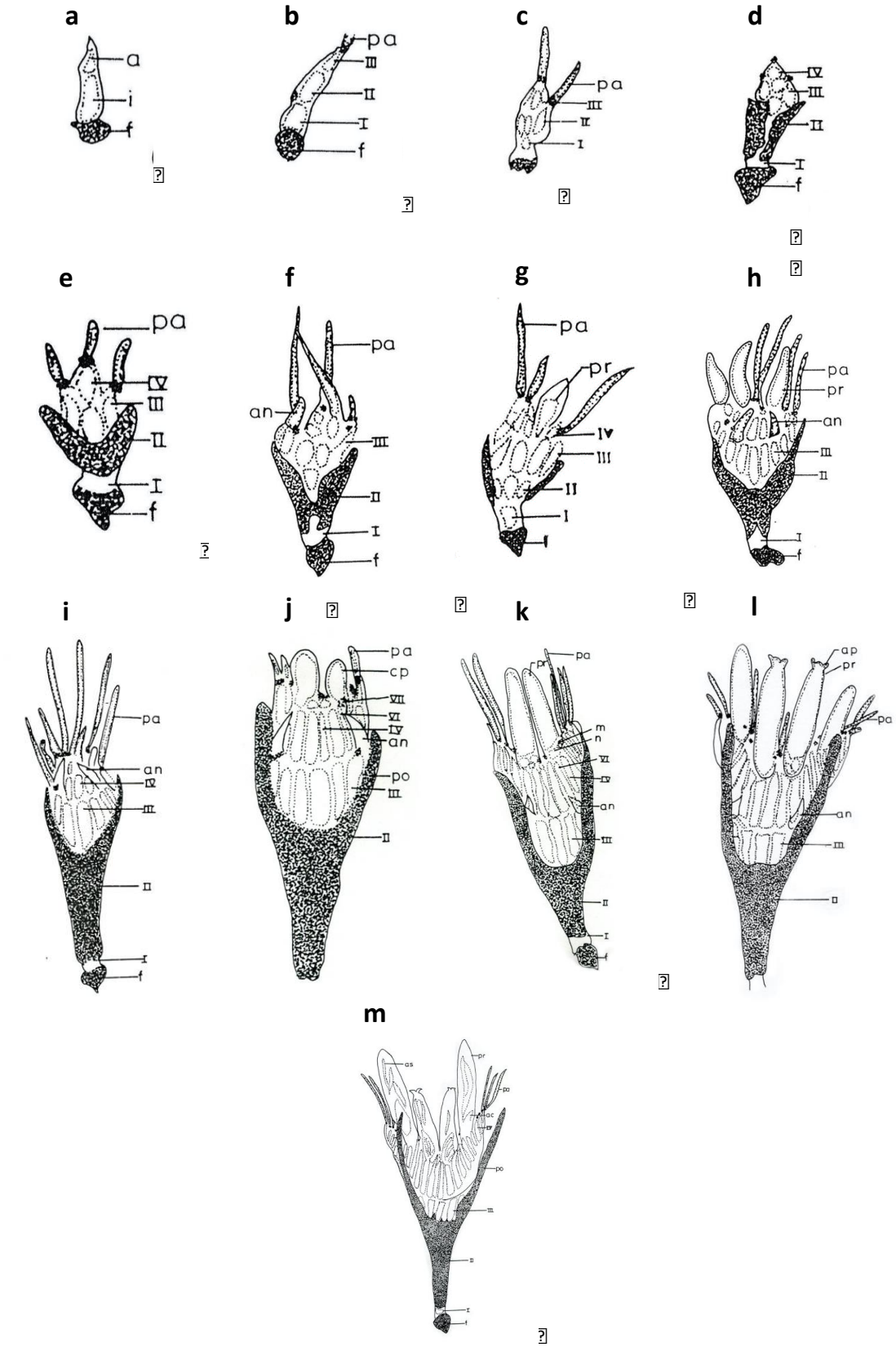

Figure 1: a-m, Developmental stages of *Peyritschiella furcifera*. Camera lucida drawings, all figures X 400. Explanation and terminology are given in the text. Abbreviations : ac: ascus, as: ascospores, an: antheridium, ap: auricles, cp : carpogyne, pa : primary appendage, po : projections, pr : perithecium.

Figure 2: a-m, Developmental stages - *Peyritschiella furcifera*- Photographic ilustrations

Peyritschiella vulgata (Thaxter 1908, Sugiyama 1973, Sugiyama and Shazawa,1977, Majewski and Sugiyama 1985, Santamaria and Girbal1987, Majewski, 1988).

The fungus is found all over the abdomen and legs of the staphylinid beetle *philonthus.* It is a very characteristically elegant looking fungus. The receptacle is fan shaped. It has four layers. The thallus thus continues to broaden from the base of the second layer to the distal part of the fourth layer.

The antheridia in this genus are of compound type. They are horn-shaped, dark brown in colour and are formed at submarginal positions on the third layer of the receptacle. The fourth layer gives rise to the perithecia. There are two perithecia per thallus. Perithecia are long, broad, bottle shaped with no projections. The fourth layer also gives rise to the appendages. The appendages arise from all cells except where the perithecia are formed. They are unicellular and are blackened and constricted at their base. A few appendages are also found at

marginal positions on the third layer, from the point of the compound antheridia outwards.

Specimens Examined: The fungus was isolated in Delhi, and deposited in the Delhi University Herbarium. 31.5.93 DU/MAP/1059; 10.8.93 **DU/MAP/1060;** 11.8.93 DU/**MAP/1061;** 18.8.93 **DU/MAP/1062;** 28.10.93 DU/MAP/1063.

Development

In each perithecium four asci are formed. The asci produce eight ascospores each. The ascospores are bicelled, with two unequal cells, and, the whole covered by a gelatinous sheath. According to the orientation, the apical cell is the smaller cell while the basal cell is the bigger cell.

After liberation the ascospore settles on the surface of the beetle at it's basal end and divides. The first division is a horizontal one and takes place at the base of the basal cell and cuts off a foot and forms the cell 'b'. The cell 'b' is a rectangular cell, longer than broad. The foot is conical in shape, black in colour and as yet small in size (Fig. 3a, Fig 4a). The cell 'b' divides horizontally to form a smaller square shaped cell 'ii' and cell I. Cell I is the single cell of the first layer and does not divide further (Fig.3b, Fig. 4b,c).

The cell 'ii' divides horizontally to form another small square shaped cell 'iii'. At the same time, the apical cell of the spore also divides horizontally once and forms the basal cell and the cell of the primary appendage. The septum between these two cells darkens and constricts (Fig.3b).The cell I remains hyaline and enlarges to form a bigger cell, but maintains the rectangular shape being slightly longer than broad. The cell 'ii' of the second layer, also enlarges and divides longitudinally and forms a cell on the side. The initial cell 'ii' again divides longitudinally, on the other side, and forms another cell. There are thus three cells formed in a horizontal row. All the cells are rectangular, longer than broad. The marginal cells of the second layer start to show blackening (Fig. 3d). While the cells of the second layer are being formed the cell 'iii' also divides vertically and forms three cells (Fig.3c).

The basal cell of the appendage divides vertically twice and forms a basal cell over each cell of the third layer. The central cell of the third layer then divides horizontally once, at its distal end, and forms a single initial cell of the fourth layer- cell 'iv' (Fig.3e). The cell 'iv' has a primary appendage above it too (Fig.3f).

The cells of the third layer then divide vertically. They undergo a large number of divisions to eventually form eleven to fifteen cells. The central five to seven cells are hyaline and rectangular, being longer than broad. The cells on the sides, get progressively shorter till they become square shaped near the margin. The cells on the sides of the central cells, darken and extend to form the very small, black projection on both the sides. The basal cells of the appendage also divide longitudinally and form the single celled appendages over the marginal cells of the third layer.

A submarginal cell on either side of the central three to four cells of the third layer, divides to form the compound antheridia. The initial cell divides by an oblique division at its distal end (Fig. 3g). The resultant cell divides further longitudinally. These two cells then divide horizontally two to three times to form two rows of three to four cells each. All these cells are small, square shaped and they constitute the compound antheridia (Fig. 3i) which are horn-shaped. The cells remain in the basal region, and, the cells function as spermatia mother cells and produce the spermatia which are released into the cavity of the compound antheridia, from here they are released outside through the ostiole at the tip of the antheridium.

The antheridium is dark brown in colour and becomes nearly opaque at maturity Thus, the exact number of cells at maturity is not clear. At the time of the formation of antheridia, the basal cell of the appendage also divides longitudinally, and forms two to three appendages near the antheridia. Each appendage has a basal cell. The septum between the two cells is narrow, blackened and constricted slightly.

While the, antheridia were developing, the initial cell of the fourth layer undergoes further divisions. It divides longitudinally a number of times. The divisions towards the sides are slightly oblique, so that the plate of cells formed curves upwards at both the sides. The five to seven cells in the centre of the fourth layer, remain in contact with the third layer. The rest of the cells which form the sides do not touch the marginal cells of the third layer over which they occur spatially. These cells of the third layer give rise to the compound antheridia and the appendage. The cells of the fourth layer are also rectangular but unlike the cells of third layer are not very long. The cells at the centre are stout looking cells being broad and long, while, the cells at the margin get progressively shorter towards the sides till they are square in shape. The marginal cells get narrower also (Fig. 3l).

The fourth layer also forms the two perithecia on the thallus. The initial cells are the cells at the sides of the three central cells. This initial cell divides obliquely at the distal end and forms a smaller, square to conical cell. The initial cell **functions** as the stalk cell VI, the smaller single cell that it cuts off divides once horizontally to form the carpogonial initial and then functions as the secondary stalk cell (Fig-3i). The stalk cell VI

divides at its distal end and forms a basal cell 'm'(Fig 3j). The secondary stalk cell VII again divides at the distal end and cuts off two basal cells. The basal cells are round in shape and small in size. The three basal cells undergo further divisions to form four outer wall cells. These four cells form the lower most tier of the wall cells. The basal cells divide again to form four parietal cells, which are placed internal to the outer wall cells. These cells enclose the carpogonial initial which undergoes further divisions to form the carpogonial apparatus. It divides, horizontally twice to form three cells, arranged in a vertical row. The basal cell is the carpogenic cell, the subbasal trichophoric cell and the apical trichogyne. As the carpogonial apparatus grows, the wall layers also divide to increase the number of tiers to keep up with it.The trichogyne is an elongated cell and projects out beyond the wall layers (Fig. 4g). After fertilization is over, the trichogyne regresses and the wall layers elongate to close up around the tip of the carpogonial apparatus (Fig. 3j). Both the cells V and 'p', divide and form the outer and inner wall cells respectively. They form upto four tiers of cells. The wall cells are all thin, elongated structures. In the top tier of wall cells, the outer wall cells are longer than the inner so that they close up to form the apex of the perithecium.

After fertilization, the carpogenic cell, forms the ascogonial filaments. These form the four asci. The asci remain at the base of the perithecium (Fig. 3k, Fig4i). Each ascus has eight bicelled ascospores, spindle shaped and covered with a gelatinous sheath. When the ascospores are mature, they are released in the perithecial cavity. From the perithecium, the ascospores are released to the outside through the apical ostiole. While the cells of the fourth layer were increasing in number, so also were the basal cells of the primary appendage. There are seven to nine basal cells found all over the distal end of the fourth layer, except at the point of the perithecia. Each basal cell gives rise to one primary appendage. Each appendage is long, slender, and unicellular. The septum between the basal cell and the appendage is slightly constricted and is black in colour.

The mature thallus, (Fig. 3l, Fig. 4 k) is made up of four layers of the receptacle, a pair of compound antheridia, a pair of perithecia, and, numerous, single celled primary appendages. The receptacle is multicellular and typically fan shaped. The base of the receptacle is conical, black foot. The foot leads to the first layer. The first layer is unicellular. The cell I is rectangular in shape, being longer than broad and is hyaline. The first layer leads to the second layer, which is made up of three cells, the central cell is hyaline, whereas the two cells on the side are blackened. All the cells are rectangular being longer than broad. The central cell is the thickest, and is broadest at the distal end. In the receptacle, the width and the number of cells, begins to increase from the second layer onwards. The third layer of the receptacle is made up of nine to twelve cells, arranged in a transverse series. Most of the cells are rectangular in shape, and longer than broad. The central five to seven cells are hyaline, the cells towards the sides blacken. The central cells are prominent and rectangular, the three central cells being the most prominent. They are stout cells with broad distal end. At submarginal position two cells of the third layer form the pair of compound antheridia.

The compound antheridia are horn shaped, brown in colour, composed of seven to eight cells. The spermatia mother cells are very small, square to round shaped cells, found at the base of the antheridium. The spermatia formed within are released through the apical ostiole of the horn shaped compound antheridium.

The marginal cells of the third layer get progressively shorter, thereby becoming square in shape at the margins. These cells darken in colour, turn black. The marginal cells also lead to the basal cells of the primary appendages. The appendages are all long, unicellular and hyaline. The septum between the appendage and basal cell is constricted, narrow and black.

The fourth layer is made up of twelve to fifteen cells. The cells are formed by slightly oblique divisions and are arranged in an upward curving plate. The cells are rectangular but as in the third layer, shorter towards the sides to become square shaped cells. The cells in the centre are stout cells, those towards the sides are narrower. Two cells at sub-central positions form the two perithecia per thallus. The perithecia have a stalk cell, a secondary stalk cell, three round basal cells and has two layers of wall cells - outer and inner. Within the oblong to bottle shaped perithecia, the ascospores are formed and are released through the ostiole at the blunt, rounded apex (Fig 4 k).

The cells of the fourth layer not taking part in the formation of the perithecia, show the presence of the primary appendages. Each appendage is long, slender and unicellular and has a basal cell. The septum between the two cells is narrow, black and slightly constricted. All the cells of the receptacle in this species are broader and shorter than *P. furcifera.* The thallus thus appears stouter and broader than the other species. The perithecia in this species appear to be as tall as the whole receptacle.

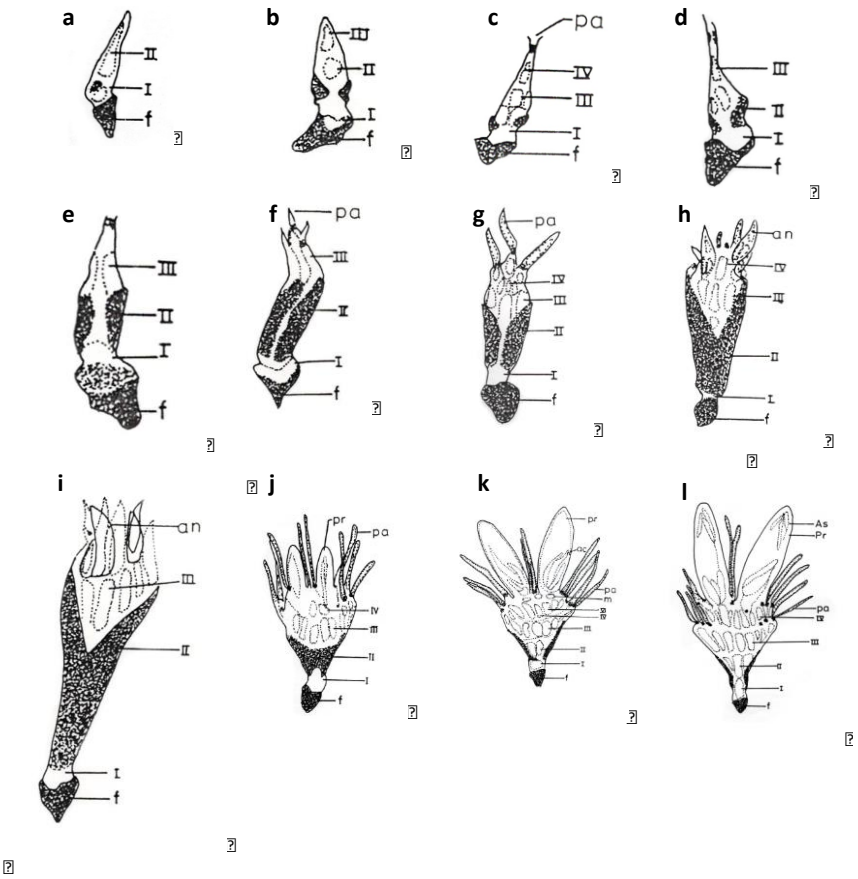

Figure 3: a-l, Developmental stages of *Peyritschiella vulgate.* Camera lucida drawings, all figures X 400. Explanation and terminology are given in the text. Abbreviations : ac: ascus, as: ascospores, an: antheridium, pa : primary appendage, pr : perithecium.

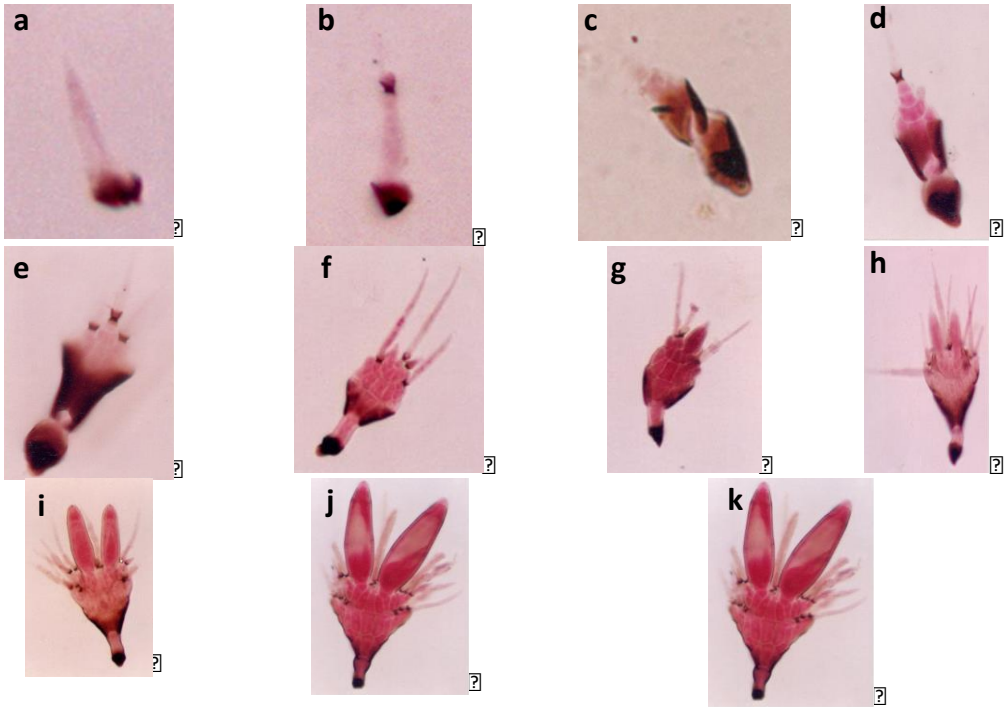

Figure 4: a-k, Developmental stages- *Peyritschiella vulgata* - Photographic ilustrations: a to k, all fiigures x 400

DISCUSSION

Both the species are found on the rove beetle *Philonthus.* Both have symmetrical thalli and similar development. However, *P. furcifera* has four perithecia rising from the fourth layer, two central ones having short apical projections (auricles) and *P. vulgate* has only two perithecia and without any projections.

The second layer forms marginal long appendages which are black and extend upto the perithecium in P. *furcifera,* these are not seen in *P. vulgata.*

In *P. furcifera,* the second layer is blackened and almost totally opaque while in *P. vulgate* only the wall at the margins is black.

As per the literature only 32 species (Thaxter 1896, 1899, 1900, 1901, 1902, 1908, 1915, 1926; Batra 1963; Kaur et al. 1993; Kaur & Mukerji 1995, 1996a,b; Pathak & Mukerji, 1997, Kaur 2022) have been added to the Indian flora and given that India is a tropical country with warm and humid climate, there is tremendous potential for the insect-borne fungi to be discovered. Therefore, there should be ongoing research in this field.

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