

Scales and phyllopodia of some Indian species of *Isoetes* L.*

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The present paper describes for the first time the scales and phyllopodia of some Indian species of *Isoetes* L. Their taxonomic and phylogenetic significance are also discussed.

Key-Words- *Isoetes*, scales and phyllopodia.

THE genus *Isoetes* is one of the most enigmatic genera of pteridophytes thriving luxuriantly in varied geographical conditions. The plants are perennial but their leaves die out by the end of the season. The shoot apex is situated in the centre of the corm which is protected by the scales and phyllopodia.

Braun (1864) can be accredited to have given the first ever report on presence of phyllopodia occurring in *I. durieui* Bory and *I. histrix* Bory & Dur. from the Mediterranean. This initial discovery was followed by Pfeiffer (1922) who reported phyllopodia in *I. nutalli* A.Br. and *I. melanopoda* Gay & Dur., from Central United States. Subsequently, Wanntorp (1970) reported phyllopodia in *I. kersii* Wanntorp from South west Africa.

Scales in *Isoetes* were initially reported by Braun (1868) in *I. drummondii* A.Br. from Australia and *I. mexicana* Underwood from north central Mexico, respectively. However, the first description of scales was given by Duthie (1929) in *I. stephansenii* Duthie, *I. capensis* Duthie, and *I. stellenbosiensis* Duthie, from South Africa. Lately, Stolze and Hickey (1983), described the scales of *I. montezumae* Eaton from central Mexico. Hickey (1985), further described scales in a number of species viz., *I. pringlei* Underwood from west central Mexico, *I. hieronymii* Weber from Argentina, *I. triangula* Weber from Venezuela and Mexico, *I. weberi* Herter from Brazil and Uruguay, *I. eshbaughii* Hickey from Bolivia and others.

Hickey (1986) for the first time not only dwelt in extension on the structure and occurrence of these structures but also discussed their evolutionary significance.

However, the scales and phyllopodia associated with the plants of Indian species of *Isoetes* have neither been described nor studied till to date. Hence, this paper appears to be the first such report from the Indian sub-continent. It embodies the gross morphological and structural attributes of the scales and phyllopodia encountered in some Indian species of *Isoetes*, viz., *I. coromandelina* L.f., *I. dixitei* Shende, *I. panchananii* Pant & Srivastava, *I. tuberculata* Gena & Bhardwaja, *I. reticulata* Gena & Bhardwaja, *I. rajasthanensis* Gena & Bhardwaja, *I. mahadevensis* Srivastava, Pant & Shukla and *I. panchganiensis* Srivastava, Pant & Shukla, with a view to elicit as to how these structures may be of assistance in establishing an evolutionary trend among the diverse Indian species of *Isoetes*.

MATERIAL AND METHOD

Diverse species figuring in the present investigation were collected from their type localities barring *I. coromandelina* which enjoys a wide distribution in India. Different species were identified by the authors with the aid of descriptions and illustrations given by respective authors. The herbarium sheets and prepared slides have been deposited in the Botany Department, Allahabad University.

Mature plants of different species exhibiting scales and phyllopodia at different stages of development were gleaned from plants for detailed study, but only the mature ones were preferred for the present investigation.

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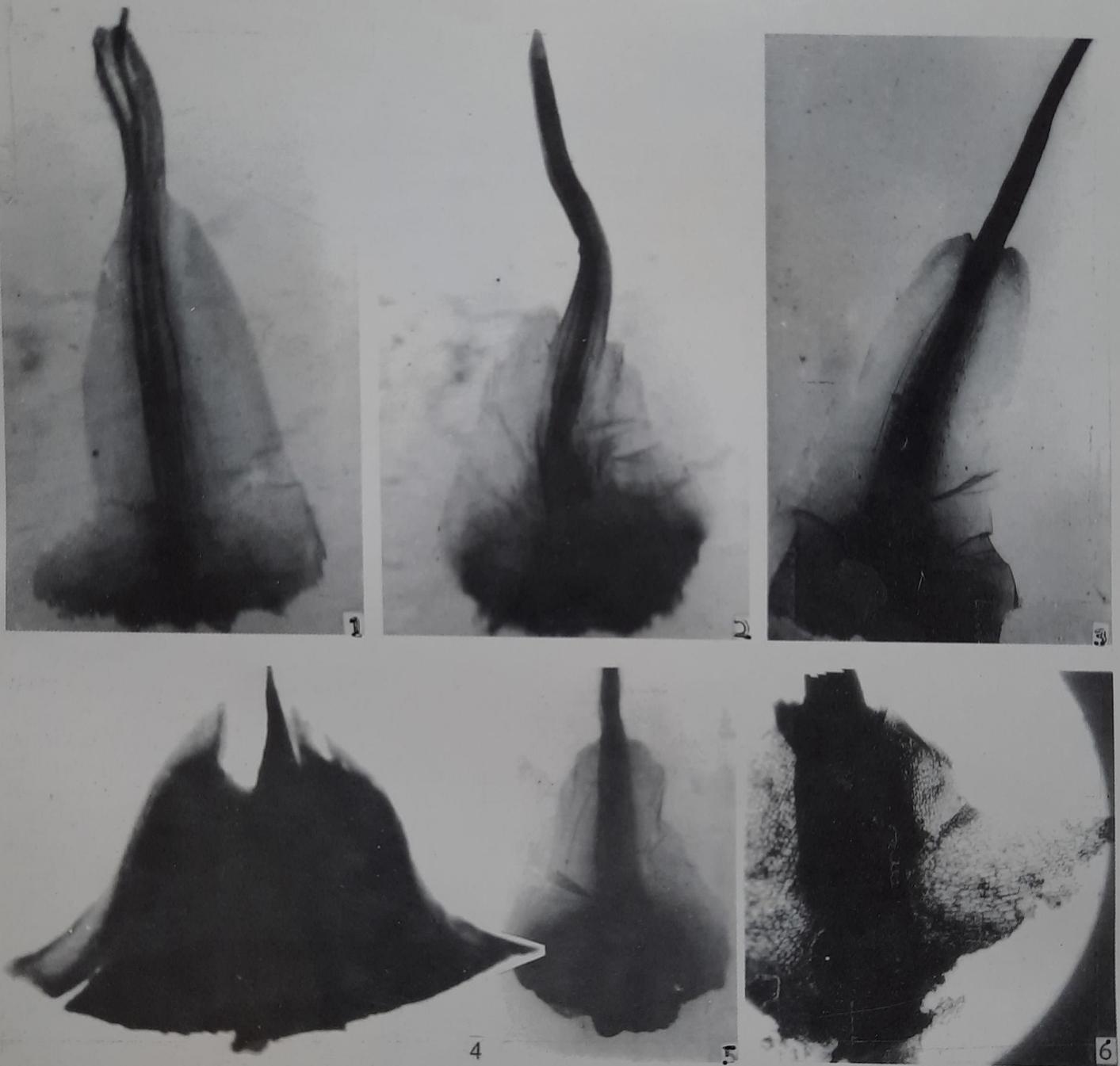


Plate 1

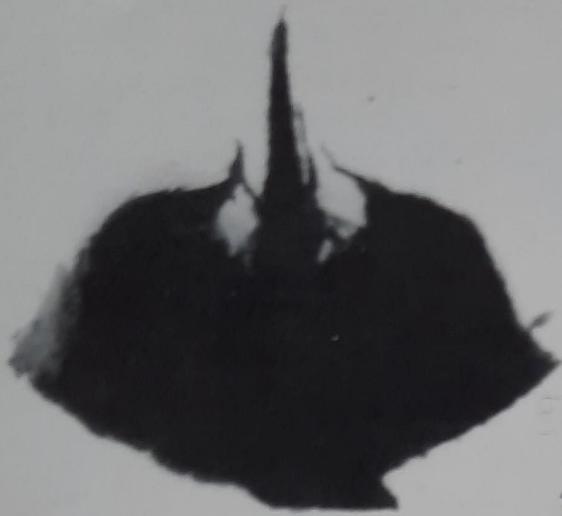
Figures 1-5. *Isoetes coromandelina*; 6. *Isoetes rajasthanensis*; 1,2,3,4,5, Membranous scale; 4. Completely sclerified scale 1,4, X8; 2,3,5, X10; 6 X15.

The mature scales and phyllopodia which encircle the corm were carefully pulled out with the help of a forcep after excising them from the base using a sharp razor blade.

LM and SEM microphotographs were taken in transmitted light using Wild Stereobinocular, Leitz and Stereoscan 430, Leica Cambridge respectively in Botany Department, Allahabad University, Allahabad.

OBSERVATION

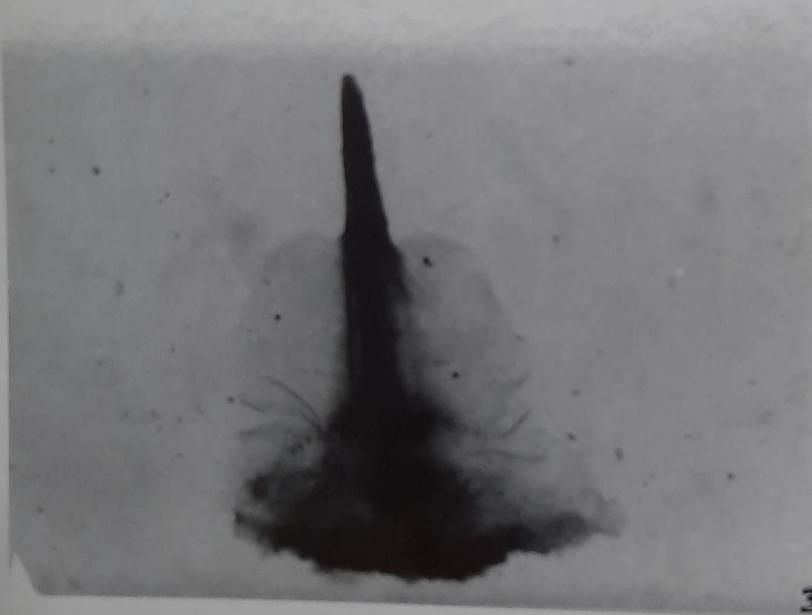
Scales and phyllopodia are most conspicuous on the outer surface of the corm. Generally they exist as tightly overlapped and well appressed structures below the spirally arranged sporophylls and sometimes intermingled with them. In old corms they form two to three whorls. The lower or the outermost whorls of scales and



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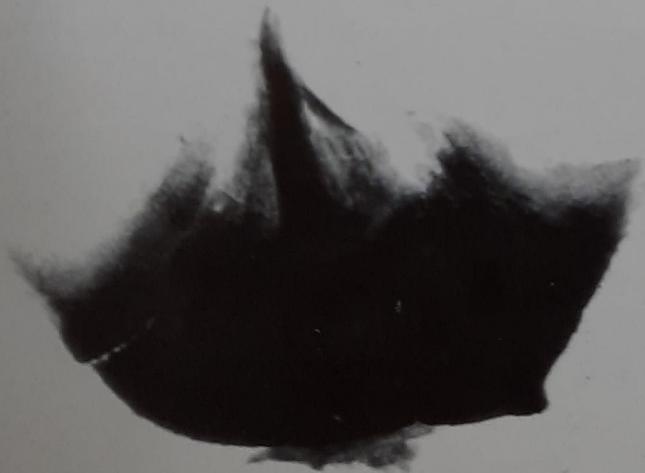
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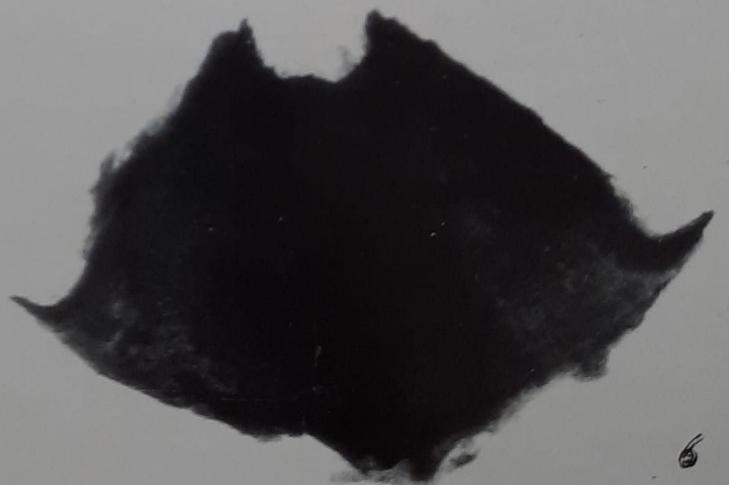
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6

Plate 2

Figures 1-4, *Isoetes tuberculata*; 5&6, *Isoetes dixitei*; 1. completely sclerified scale; 2,3,4, membranous scale; 5. completely sclerified, dhow-shaped scale; 6. phyllopodium. 1-4X10; 5-6X12.

phyllopodia are in most cases dark-brown to tan, less appressed, randomly distributed and persistent.

Generally a scale is a complete leaf primordia which has become arrested early in its development and partially or entirely sclerified. This is evidenced by the presence of ligular pits, aborted sporangia and alae. Phyllopodia are the remnant of bases of fully developed leaves and which are only noticeable after the disintegration of the surrounding softer tissues (see Hickey, 1986). A typical scale is characterised by an apex which is drawn out like a spine. The bases of these spines are usually strong and thick. Their lengths vary within the different populations of the same species. The curvature of the spines sometimes show a more or less consistent character within a given species. In general the bases of scales and phyllopodia varies in their widths and shapes. Broader bases are mostly found in those scales and phyllopodia that are broad and long. On the other hand the margins of the scales and phyllopodia are generally entire and the attachment of most of these structures to the corm is by the length of their basal edges. The basic organization of the scales of different species is the same but they differ in their finer details which are given below:

I. coromandelina L.f.

Pl.1, figs 1-5; Text-fig. 4

Scales are of two types, (i) membranous forms which are somewhat narrowly triangular, thus appearing longer than wide (Pl.1, figs 1-5), and (ii) completely sclerified bonnet-shaped scales (Pl.1, fig.4.). Their sizes vary within a single plant: length 10.0 (7.0-13.0) mm, base width, 5.0(4.0- 6.0)mm, apice length, 4.0(2.0-6.0)mm. Phyllopodia are of intermediate forms. They do not possess any clear-cut distinction from the scales, but unlike scales, they do possess normal elliptical or circular sporangia. The thin translucent membranous scales are delicate and have more or less flabelloid margins. However, the completely sclerified scales are firm in texture, tough and dark coloured (Pl.1, fig.4).

Majority of the cells constituting the margins of the membranous scales exhibit square-like shapes with a few being rectanguloid (Pl.4, fig.5). Towards the central middle region, most of the cells are elongated and rectangular, except few ones which are hexagonal. Stomata are present (Pl.4, fig.6) close to the central mid region.

Occasionally the scale margins are drawn out into a hair-like outgrowth (Pl.4, fig.5).

Scale apices are either caudate, i.e. drawn out like a tail (Pl.1, fig 2), or cuspidate, i.e. pointed and ending in a spine (Pl.2, figs 3-5). The central middle to basal areas of the membranous, translucent scales are highly sclerified and thus appearing dark colored. However, in some it is marked by a mixture of light-brown and black stripes running from the tips to the base (Pl.1, figs 1-2). Scales and phyllopodia which are bent and well appressed to the corms get attached by the entire length of their basal edges (Pl.1, figs 1 & 4).

I. tuberculata Gena & Bhardwaja

Pl.2, figs 1-4

Scales and phyllopodia are large sized. Their sizes vary within a plant. Measurements; length 7.4 (5.0-9.0) mm, base width, 5.8 (5.0-7.0)mm, and apice length, 2.6 (2.0-4.0)mm. They are generally longer than broad. Both completely sclerified scales (Pl.2, fig.1) and the papery, membranous scales which exhibit flabelloid margins (Pl.2, figs 1,3 & 4) are present. Phyllopodia are of intermediate forms. They do not exhibit any clear-cut distinction from the scales. Scale apices may be caudate or cuspidate. These may either be straight or curved. Some apices emerge from a slight depression (Pl.2, fig.1). Bases of the scales are generally broad with a few exceptions being narrow (Pl.2, fig.2). The attaching tissues or flanges are narrow and short.

I. dixitei Shende

Pl.2, figs 5 - 6; Pl.3, figs 1-3; Text-fig. 1

Scales and phyllopodia are medium sized, with lengths and widths varying within the same plant: Scale measures: length, 4.7 (3.0-6.0) mm, base width, 5.5 (4.0-8.0) mm, and apice length, 1.4 (0.5-3.0) mm. phyllopodia measures: length, 3.0 (2.0-4.0) mm, and base width, 6.5 (5.0-8.0) mm. Typically the scales and phyllopodia are wider than long. Scales are either dhow-shaped (Pl.2, fig.5), dome-shaped or somewhat triangular. Majority of the scales are completely sclerified with only a few being partially sclerified. However, completely sclerified scales and phyllopodia are firm, tough in texture and tan coloured. Scale apices are stout and straight in majority of the specimens. Phyllopodia possess no apices but instead the upper end consists of a 'U'-shaped depression (Pl.2, fig.6). The extreme ends of the basal

Plate 3

Figures 1-3. *Isoetes dixitei*; 4. *Isoetes mahadevensis*; *mahadevensis*; 5,9, *Isoetes rajasthanensis*; 6. *Isoetes reticulata*; 7. *Isoetes panchananii*; 8. *Isoetes panchanganiensis*; 1,3,5,7,8, partially sclerified scales. 4,5, membranous

scales. 6,9, completely sclerified scales; 2. a portion of base of scale magnified to show position of abortive sporangium and glosopodium; 1,3,5,6,9x10; 2,4,x20; 7,8 x 15.

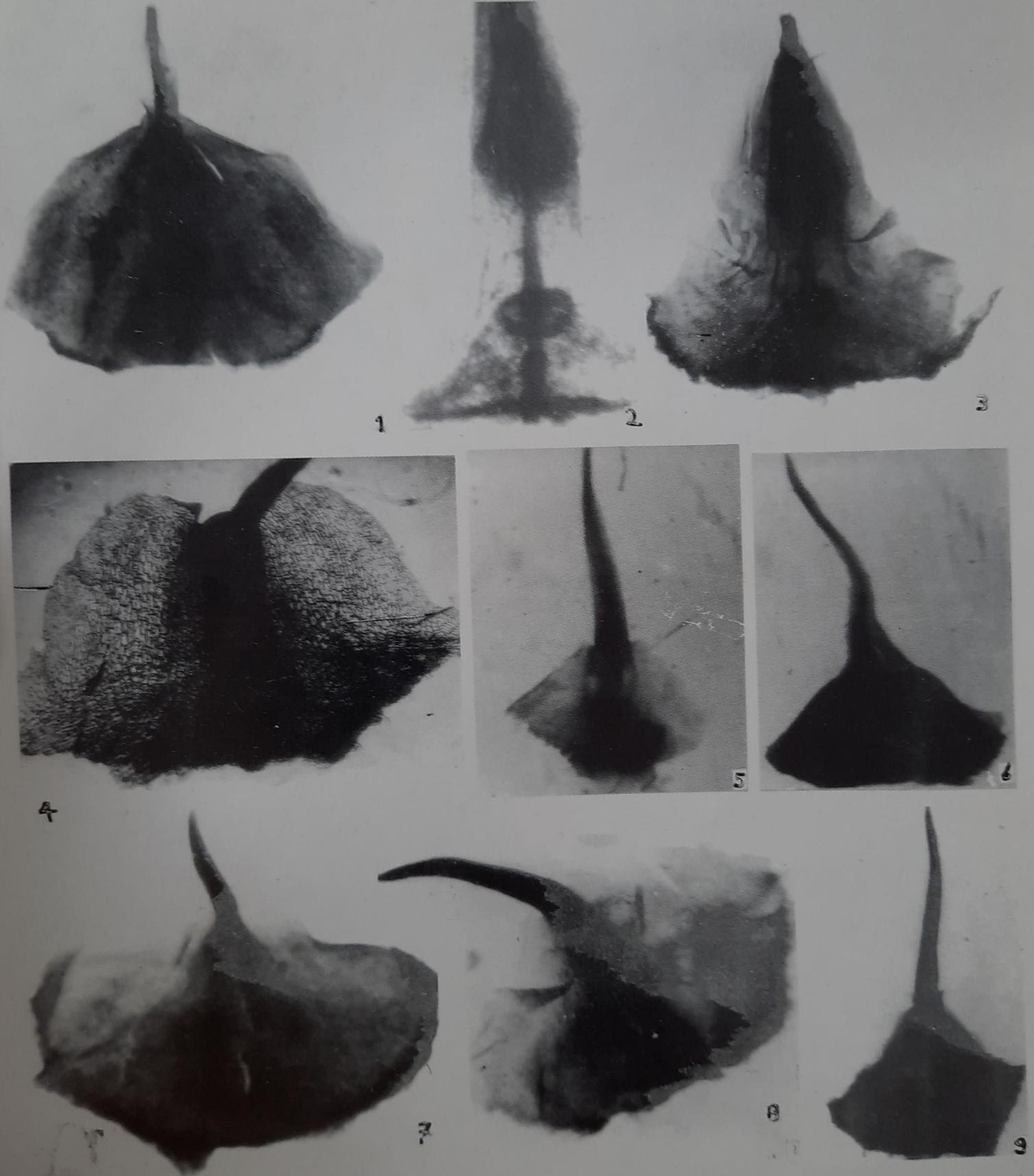


Plate 3

margins of both the scales and phyllopodia bear distinction upwardly pointed spur-like structure (Pl.2, figs 5-6), which appear to be a consistent character of this species. Scale margins are entire. Attachment to the corm is by means of a small flange (Pl.2, figs 5-6). Bases may be ovate, cordate or flat. The position of glossopodium and the abortive sporangium are seen in the basal region of the scale (Pl.3, fig.2).

I. mahadevensis Srivastava, Pant & Shukla
Pl.3, fig.4; Text-fig. 3

Size of scales varies within the same plant : length, 3.0 (2.0-4.0)mm, base width, 4.2 (3.0-6.0) mm, and apice length, 1.2 (1.0-2.0) mm. They are generally wider than long and appear winged (Pl.3, fig.4.). The wing-like flaps are positioned on the opposite sides of the middle region of the scales. Translucent, papery or membranous scales are soft, and delicate. Scale apices are generally mucronate, i.e., appearing as spur-like outgrowths and emerges suddenly from an almost rounded region. They may be straight or curved. The membranous scales consists of elongated cells towards their margins, but the cells in basal region consists of mixed cells which may be rounded or hexagonal in shapes. The dark central middle area consists of more or less square-like cells. This region appear brownish-dark due to a lesser degree of sclerification. The basal margins of the scales are broadened and have attachment tissues which are not conspicuous.

I. reticulata Gena & Bhardwaja
Pl.3, fig.6

The scales are generally small sized. Their sizes vary within the same plant: length, 4.2 (2.0-6.0) mm, base width, 1.4 (1.0-2.0) mm, apice length, 1.8 (1.0-2.0)mm. They appear as slightly compressed equilateral triangle. Majority of the scales are firm, tough in texture and uniformly tan coloured. Their apices are mostly caudate and drawn out to form an elongated curved spines. The scales are longer than broad. They are sessile, i.e., attachment tissues or flanges are absent. The scales therefore get attached to the corms through the broadened area of their basal margins.

I. panchananii Pant & Srivastava

Pl.3, fig. 7

Size of scales vary within a plant: length, 4.4 (4.0-5.0) mm, base width, 2.2 (1.0-3.0)mm, and apice length, 4,8 (4.0-5.0) mm. They are longer than wide. The scales are more or less rectangular in shape. Apices are drawn out as straight or curved sharp spines. The central middle to basal areas of the scales are sclerified and thus appearing darker than the rest of the regions. Scales are sessile and thus get attached to the corm by the entire lengths of their basal margins.

I. panchganiensis Srivastava, Pant & Shukla

Pl.3, fig. 8; Text-fig. 2

Scales are small sized: length 2.8(2.0-3.5)mm, base width, 3.8 (3.0-4.2) mm, and apice length, 0.9 (0.5-1.0) mm. their sizes vary within a plant. They are brown to light tan in colour. They are not completely sclerified. However, they are firm in texture. The scale apices are mucronate. The scales are either sessile or possess an attachment flange (Pl.5, fig.2), and thus get attached to the corms by means of these flanges or by their somewhat rounded basal margins.

I. rajasthanensis Gena & Bhardwaja

Pl.3, figs 5 & 9

Scales are small sized: length, 3.0(2.0-4.0) mm, base width, 1.6 (1.0-2.0) mm, and apice length, 1 mm. They resemble *I. reticulata* in their outward morphology. Apex is cuspidate. Scales are longer than broad and more or less triangular in shape. Majority of the scales are partially sclerified. Attachment flange is absent and thus the scales get attached to the corm by the entire length of their basal margins.

FUNCTIONS OF SCALES AND PHYLLOPODIA

On the onset of unfavourable conditions such as extreme drying of the ponds, the aerial shoots of the plants die and the corms perennate. Since the corm possesses the delicate meristematic tissues at the apex and also being an important food store of the plants, it warrants all the necessary protection from dessication, ravaging insects, pests and some minor mechanical injuries.

Plate 4

Figures 1-6: SE Micrographs of *Isoetes coromandelina*: 1. complete scale; 2. position of glossopodium; 3. cells around the sporangial region; 4. sporangium at the base of the scale; 5. margin of the scale

showing shapes of cells and presence of a hair-like outgrowth; 6. magnified stoma.

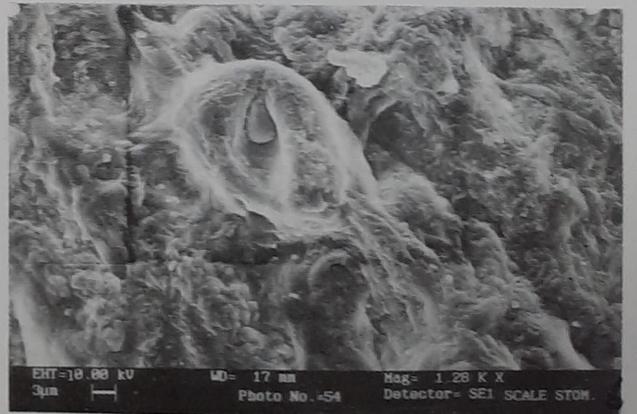
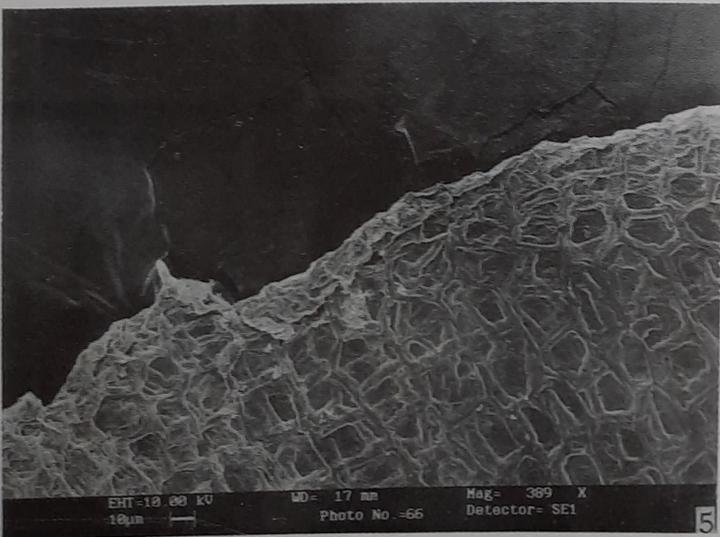
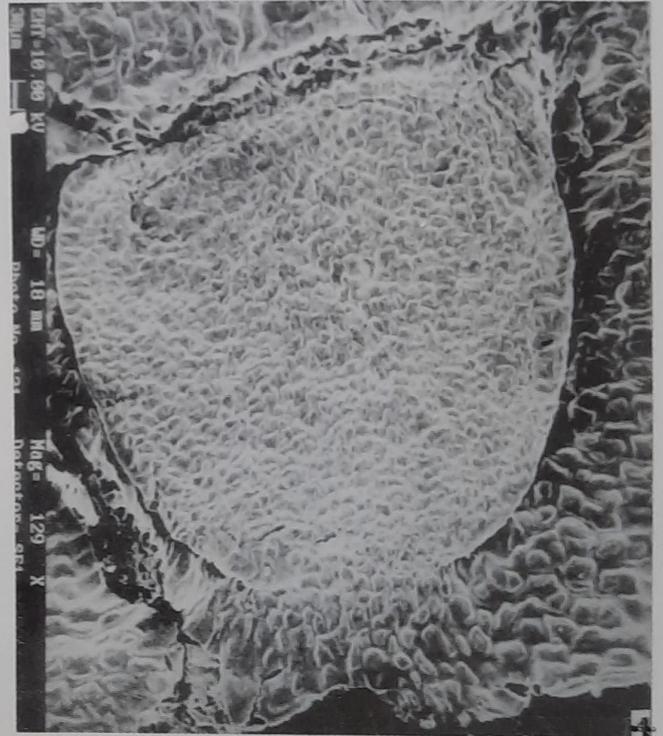
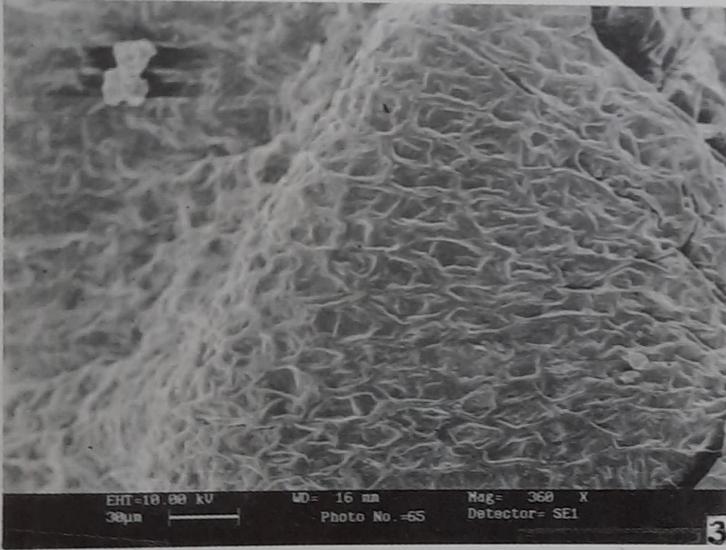
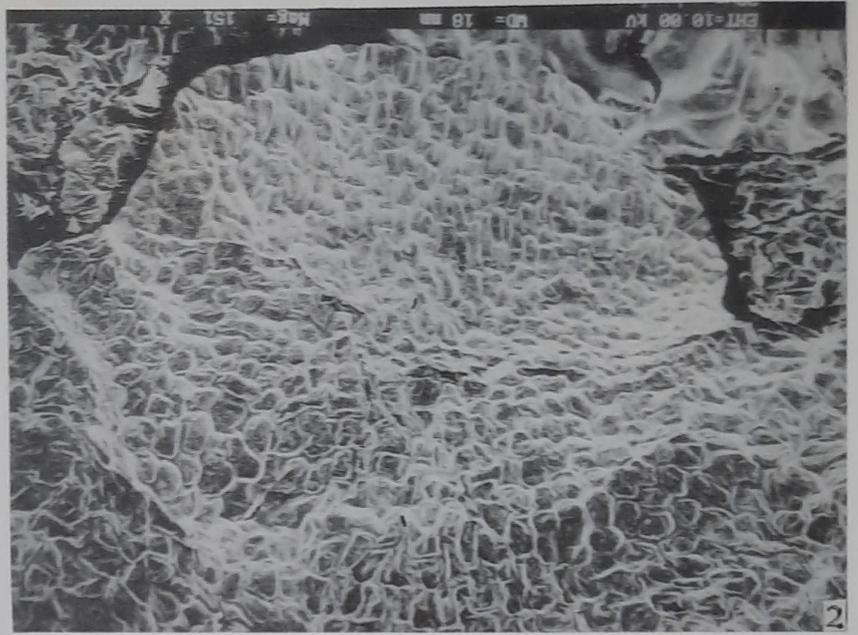
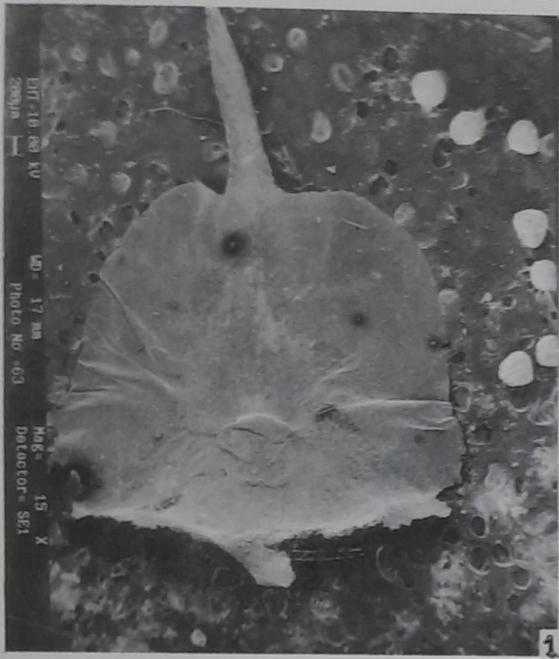
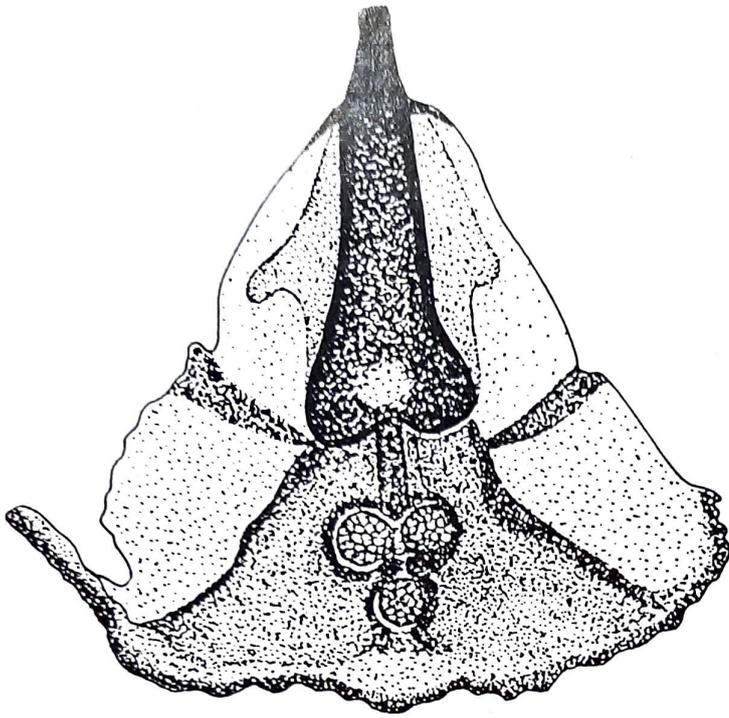
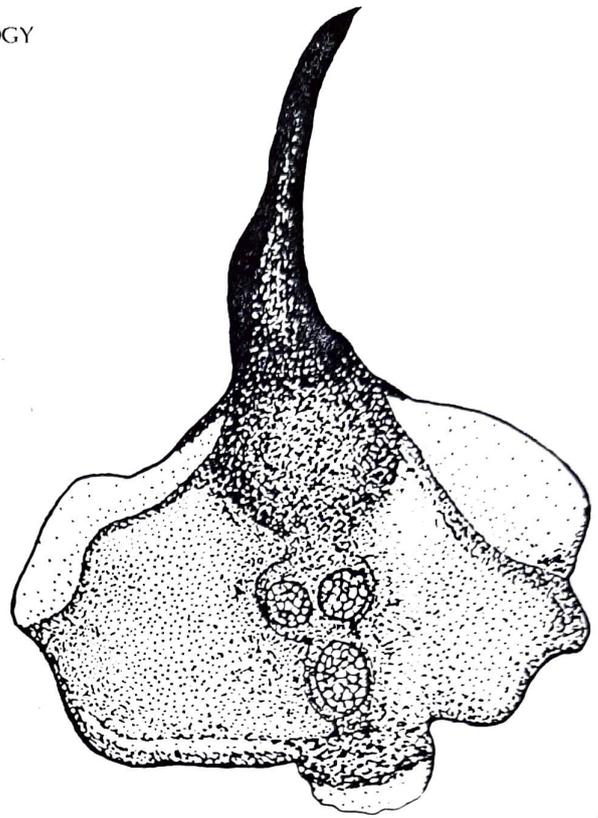


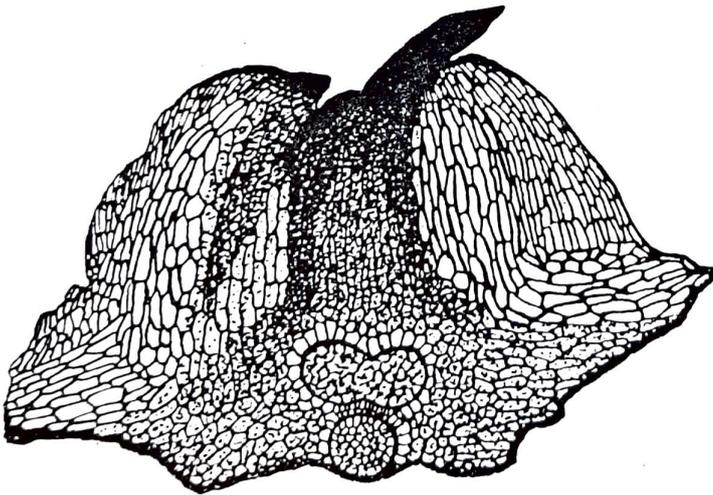
Plate 4



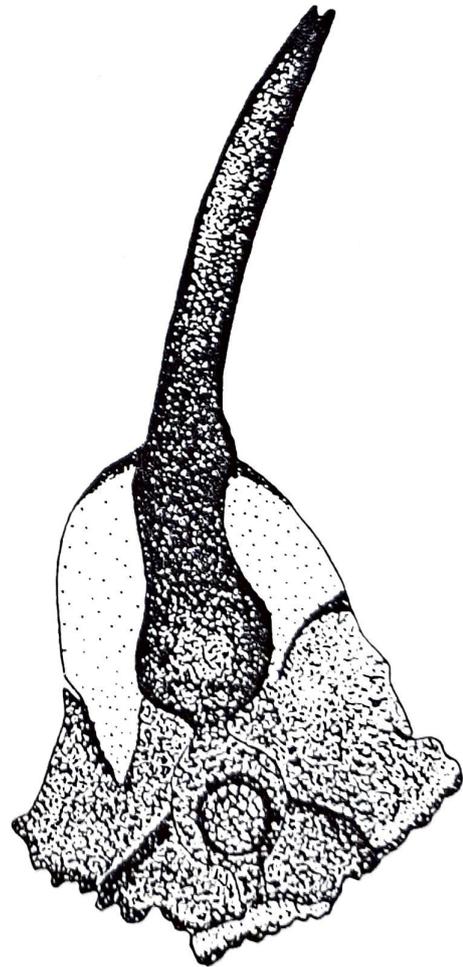
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Text-figures 1-4. Camera Lucida diagrams of Scales: 1. *Isoetes dixitei* showing position of glossopodium and abortive sporangium, X15. 2. *I. panchganiensis* showing position of glossopodium, abortive sporangium and an attachment flange on the basal margin, X20. 3. *I. mahadevensis* showing position of glossopodium, abortive sporangium and the cellular details, X28. 4. *I. coromandelina* X13.

The present investigation reveals an evidence of beetles and weevils attacking the corms especially when the ponds dry out. However, the tough and firm nature of scales and phyllopodia, protects the corms from such external forces. Since these structures do not cover the whole surface of the corms, the exposed parts are generally protected by the rough and tough nature of the corm surfaces. The insect pests seemingly attack the corms through the soft, delicate apical meristematic zone which is not well protected by the scales and phyllopodia. However, phyllopodia always persist at the base of the plants during the dormant stage and retain spores for one year or more.

The corms also act as a place of habitation for earthworms and snails, majority of which invade the corms after weevils have bored their passages through them. They use the corms either as a source of food, shelter or for laying their eggs. Our observations also reveal intact megaspores from the droppings of the earth-worms. Evidently this suggests that the corms serve as a source of food for these insects. Uprooted corms by cattles, buffaloes and wild boars lie dormant in the dried ponds, being protected by the scales and phyllopodia. On the onset of rain water that fills the ponds, the new plants emerge from the dormant apical meristematic tissues.

DISCUSSION AND CONCLUSION

The investigation of scales and phyllopodia in Indian species has revealed that scales are present invariably in all the investigated species, but typical as well as distinct phyllopodia are only found in *I. dixitei*, whereas phyllopodia like-intermediate structures have been noticed in *I. coromandelina* and *I. tuberculata*.

The scales of different species of *Isoetes* are distinguishable from one another on the basis of their size and shapes. In *I. coromandelina*, *I. tuberculata* and *I. dixitei* both papyraceous as well as sclerified scales are found. The scales of *I. coromandelina* and *I. tuberculata* are longer than their width, while those of *I. dixitei* are wider than their length. The scales of *I. panchganiensis* and *I. panchananii* are almost similar in look, but in the former the membranous wing forms an almost round circle, while in the latter it is somewhat rectangular. The scales of *I. mahadevensis* resemble those of *I. panchganiensis* and *I. panchananii* but they form a bird-like membranous wing. The scales of *I. reticulata* and *I. rajasthanensis* are smaller and more or less completely sclerified.

Most of Indian species of *Isoetes* are amphibious found mostly in shallow ponds or in rice fields which dry up after the rainy season except *I. panchganiensis* which is an obligately submerged aquatic species. The maximum number of scales are found in *I. coromandelina*, *I. tuberculata*, *I. dixitei*, *I. panchganiensis*, *I. panchananii*, *I. rajasthanensis* and *I. reticulata* and the minimum number of scales are found in *I. panchganiensis*.

Our study corroborates the observation made by Duthie (1929), that, "there was a strong correlation between the presence of these structures and a terrestrial habit". Hickey (1986) too, has expressed almost a similar opinion that, "the loss of sclerified tissue in aquatic and strongly amphibious taxa supports the premise that scales are an adaptation to drought conditions. He also expressed the view that, "The only austral, terrestrial species group which lacks scales and /or phyllopodia are those species originating in the Indian subcontinent". According to him, "the Indian species form the second set or clade". The subulate clade as result of additional divergence formed two distinct lineages as mentioned below:

- (i) Lineages which are characterized by papyraceous leaf bases surrounding the dormant apex, and
- (ii) Lineages which are characterised by production of scales, phyllopodia and sporangial wall pigmentation.

Hickey (1986), contended that it is only the members of first clade that are present in the Indian subcontinent. However, our present investigation has revealed that both these clades are present. It may be that in the past only papyraceous scales were present but later as a result of increased environmental stress such as drought and dessication, sclerification may have taken place in order to protect the growing apex of these plants.

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