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HISTO-ARCHITECTURE OF THE PERICARP AND SEED LIBERATION IN THE SCHIZOCARPIC FRUIT OF *SIDA RHOMBIFOLIA* L. (MALVACEAE)

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Abstract

The schizocarpic fruit of *Sida rhombifolia* has been examined for its histo-architectural features and their functional relationship with the dehiscence of the fruit. The multicarpellary syncarpous ovary grows into a schizocarpic fruit. The outer epidermis, mesoderm and inner epidermis of the ovary wall differentiate into the epicarp, mesocarp and endocarp respectively. The cells of mature epicarp become elongated and vacuolated and their outer tangential walls possess thick and corrugated cuticle. The growth of the parenchymatous mesocarp is due to the increment in the volume of its constituent mesodermal cells. The tangentially elongated cells of inner epidermis of the ovary wall under go periclinal divisions and constitute four to five layered thick endocarp. The thick walled cells of mature endocarp resemble more or less narrowly elongated fibers. Due to the disorganization and decay of the cells situated in the lateral walls and in the central axis, the ripe mericarps with awn-like apices become free and depart from the central axis. The scattered dry mericarps later dehisce marginicidally.

Introduction

According to Willis (1973) the genus *Sida* comprises 200 species having worldwide distribution, especially in warmer regions. In India the species of *Sida* grow wild and common in open and shady places. A perusal of literature reveals that Sivarajan *et al*., (1992) studied mature mericarps of 18 taxa of *Sida* with respect to their surface characters, size, shape, and relative length with calyx etc., in relation to taxonomy. Surprisingly, in contrast to the anatomy of other organs of *Sida* species, their fruits are badly neglected (Rao, 1985). Thus the present study was undertaken with a view to elucidate the structure and development of the fruit of *Sida rhombifolia* and mode of its dehiscence.

Sida rhombifolia is a small erect under shrub. This plant yields a good fiber. Because of this reason the cultivation of *Sida rhombifolia* has been encouraged in India (Bailey, 1958). In addition, the plant has considerable medicinal value (Kirtikar & Basu, 1933; Chopra *et al*., 1956; Jain, 1968).

It is also envisaged that the data generated from the present study, besides supplementing the studies carried out in our laboratory on the morpho-histogenesis of the capsular fruits (Dave *et al*., 1987, Inamdar *et al*., 1989 and Rao *et al*., 1986, 1987a, 1987b) and a schizocarpic fruit (Rao *et al*., 1993) of Malvaceae, would provide a stimulus to initiate this kind of studies on the carcerules of several other species of *Sida*, which may be useful for systematic purposes as well as for genetic diversity analysis for conservation purposes.

Materials and Methods

The fruits of *Sida rhombifolia* were collected at their sequential developmental stages from the local fields and after measuring their length and diameter they were fixed in F. A. A. (Berlyn & Miksche, 1976). Customary methods were followed for the dehydration, infiltration and embedding of these materials. The transverse and longitudinal sections of 8 – 10 µm thickness were cut from the paraffin embedded fruit materials with AO Spencer's Rotary Microtome and these sections were stained with Safranin and Fast Green. Besides employing the Carl – Zeiss's Polarization Microscope, the method of Pizzolato (1964) was also followed for the detection of calcium oxalate crystals. Photomicrographs were taken with Carl – Zeiss's Photomicroscope – I. The methodology followed for the preparation of the fruit materials for their Scanning Electron Microscopic (SEM) study was followed as given by Dave *et al*., (1987) and these materials were scanned under the Cambridge Stereoscan S_4 –10 Microscope at Physical Research Laboratory (PRL), Ahmedabad.

Observations

Ovary: The syncarpous, superior, ovate or widely obovate ovary of *Sida rhombifolia* (Fig. 1A) consists of 9 or 10 locules, each consisting of a single ovule borne on axile placentum (Fig. 1C). The ovary wall is a five or six cell layer thick. It comprises of a single layered outer and inner epidermis each, which encompass three or four layers of mesoderm or ground tissue in between (Fig. 1D). An inward folding, which appears in the median portion of each ovary wall, extends acropetally from the upper middle to apical region of the ovary (Fig. 1E). The apices of fused ovary walls at their extreme tip region appear as small awn-like projections with tapering ends. (Fig. 1A).

Structure of the developing and mature pericarp: The principal growth phenomenon involved in *Sida rhombifolia* fruit development is growth in thickness, which causes an increment in the circumference of the fruit, rather than its elongation, hence the cup-shaped mericarps (Figs. 1B; 2F). The pericarp of each developing mericarp differentiates into epicarp, mesocarp and endocarp (Fig. 1G, H).

Epicarp: It develops from the outer epidermis of the ovary wall. The isodiametric or columnar cells with dense cytoplasm and moderately thick tangential walls constitute the outer epidermis of the ovary wall (Fig. 1D). The outer tangential walls of these epidermal cells do not possess cuticle, but there the development of anisocytic and anomocytic types of stomata, and eglandular stellate and glandular capitate trichomes are observed.

The epicarpic cells of young mericarp do not exhibit much remarkable structural change, except a reduction in the frequency of their anticlinal divisions. However, the tangential enlargement of cells is noticed in the developing epicarp (Fig. 1G). During the subsequent growth, the deterioration of cytoplasm is found concomitant with the deposition of cuticle on the outer tangential walls of maturing epicarpic cells. Thus the elongated, enlarged and vacuolated cells of mature epicarp possess thick and corrugated cuticle (Fig. 1H). Similar phenomenon of cutinization is noticed extending towards the tip of the developing mericarp. Therefore, when fruit reaches the mature stage, the outer epidermal cells, including that of awn-like projection, appear highly vacuolated (Fig. 2C, D). As the eglandular trichomes attain thick walls they remain persistent on the mature mericarp and even on the awn (Fig. 2D), but the thin walled glandular trichomes (Fig. 2C) are shed off at maturity.

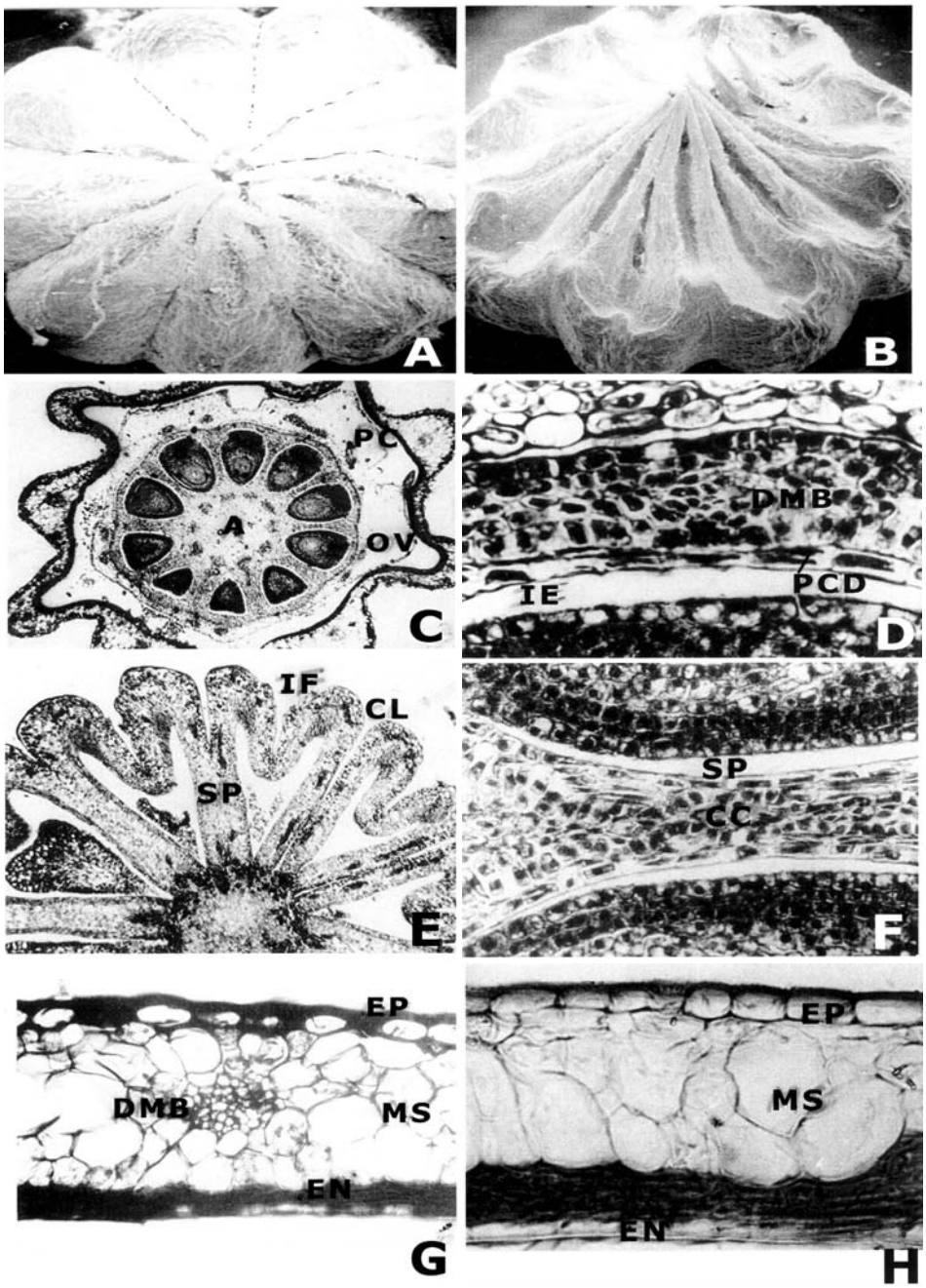

Fig. 1. A&B. Scanning electron micrographs of an ovary from unopened flower bud and developing fruit respectively showing the pointed carpel apices (60X); C. Transverse section of ovary (40X); D. A transectional portion of ovary wall showing structural details of carpel wall and the differentiation of dorsal median bundle (625X); E. Transection showing the formation of an inward folding in the apical region of carpel wall (45X); F. Structural details of a portion of septum in the ovary (400X); G & H. A portion of mericarp in transectional view at its two successive developmental stages. (400X)

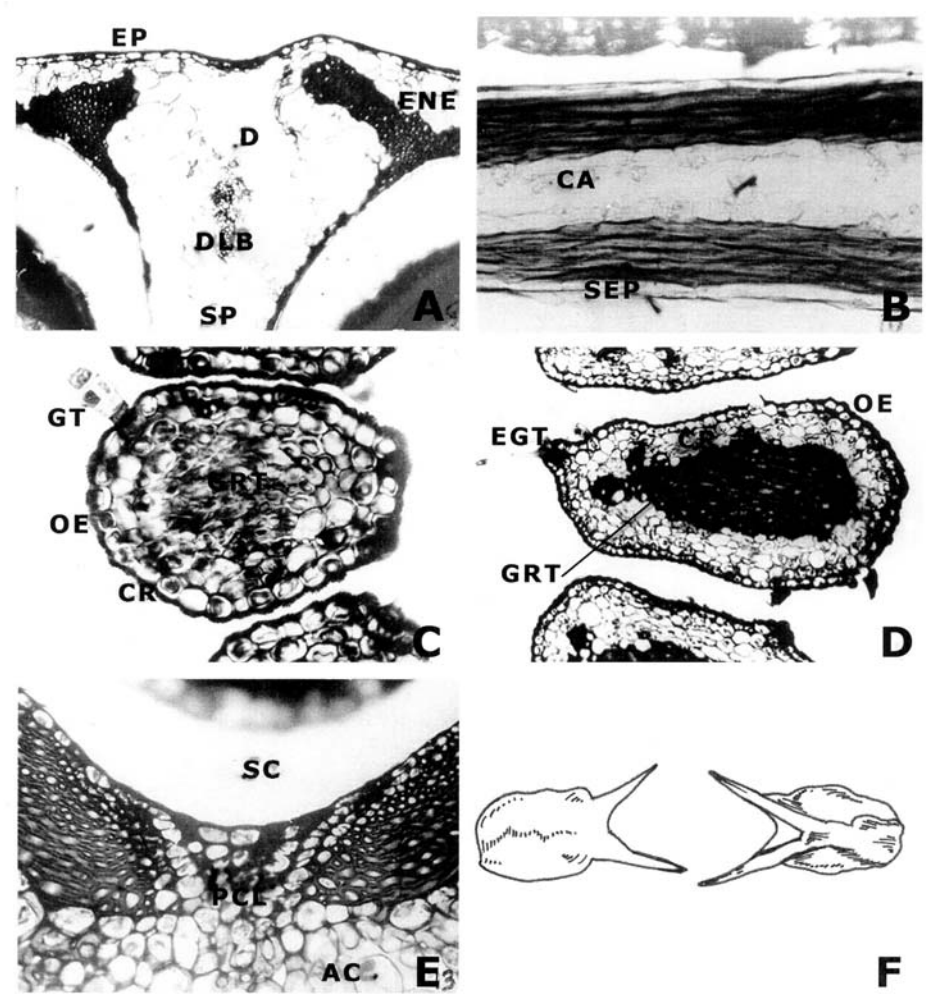

Fig. 2. A. Transectional view of the splitting of mericarp from its dorsal side with still intact epicarp. Note the structure of endocarpic ridge (150X); B. Septum in transection showing multilayered septal epidermis, calcium oxalate crystals and decaying central cells of septum (400X); C&D. Transectional structure of awns (at 3rd & 4th developmental stages respectively) formed at the apices of fused carpels. Note the presence of thick walled eglandular stellate trichome in Fig. D (C: 465X; D: 345X); E. Transectional structural details of seam in the ventral side of seed chamber (270 X); F. Dry mericarps of *Sida rhombifolia* (4X).

Abbreviations used in Figs. 1 (A–H) & 2 (A–F)

A - Axis**; AC** - Axile cells; **CA**- Calcium oxalate crystals; **CC** - Central cells of the septum; **CL** - Cleavage in the septum; **CR** - Cortex; **D** - Decay of septal cells; **DLB** - Dorsal lateral bundle; **DMB** - Dorsal median bundle; **EGT** - Eglandular trichome; **EN** - Endocarp; **ENE** - Endocarp elevation; **EP** - Epicarp; **GRT** - Ground tissue; **GT** - Glandular trichome; **IE** - Inner epidermis; **IF** - Inward folding; **M** - Mesoderm; **MC** - Mucilage containing cell; **MS** - Mesocarp; **OE** - Outer epidermis; **OV** - Ovule; **PC** - Parenchyma cluster; **PCD** - Periclinal divisions; **PCL** - Parenchyma cells; **SC** - Seed chamber; **SEP** - Septal epidermis; **SP** - Septum.

Mesocarp: The mesoderm or ground tissue of each of the ovary wall develops into the mesocarp of the developing mericarp. The isodiametric or slightly tangentially elongated cells of mesoderm in which anticlinal divisions are predominant contain dense cytoplasm (Fig. 1D). The druses of calcium oxalate crystals occur in the mesodermal cells lying below the outer epidermis. Towards apical region, the mesodermal cells in the fused ovaries form the cortical region of awn-like projections (Fig. 2C, D).

Following the anthesis, no significant structural changes are noticed to occur in the cells of young mesocarp. However, the mesocarpic cells of developing mericarp enlarge rapidly, but the frequency of anticlinal divisions is reduced considerably. Consequently, like in epicarp, the mesocarpic cells of mature mericarp also become vacuolated (Fig. 1H). The process of enlargement and vacuolation extends upward. As a result of which, the cortical cells of awn appear highly vacuolated (Fig. 2C, D). The dorsal median vascular bundle of developing mesocarp (Fig. 1G) also enlarges due to the further differentiation of xylem and phloem. Nevertheless, the xylem is slender. As the mericarp approaches maturity all the tracheary elements of these vascular bundles become sclerosed.

Endocarp: The inner epidermis of the ovary wall is composed of tangentially elongated cells with dense cytoplasm (Fig. 1D), from which the multilayered endocarp develops. Unlike in outer epidermis, neither stomata nor trichomes are noticed in the inner epidermal layer. The modes of both anticlinal and periclinal divisions are recorded in the inner epidermal cells, but at dorsal marginal region these divisions are found to confine mostly to the periclinal fashion. Due to centripetal inward folding of the ovary wall, the inner epidermis of ovary wall at its apical region comes in contact with the peripheral layer of lateral wall (Fig. 1E) and collectively form ground tissue of the awn (Fig. 2C, D).

In contrast to the epicarp and mesocarp, the degree of differentiation of endocarp is quite remarkable. The cells of young endocarp continue their anticlinal and periclinal divisions, but the frequency of anticlinal divisions decreases significantly during their subsequent growth. As a result of continued periclinal divisions, the endocarp of developing mericarp becomes 4 or 5-layered thick (Fig. 1H). The cells of developing endocarp elongate tangentially (Fig. 1G, H), except in the dorsal margin region, where an elevation or ridge is found facing the mesocarp due to the non-stretching nature of these endocarpic cells (Fig. 2A).

As the fruit matures, the cells of endocarpic layers undergo vacuolation. The walls of endocarpic cells, excluding those of the inner most endocarpic cells, become thickened. Thus the cells of mature endocarp resemble narrowly elongated fibers (Fig. 1H), while the cells of dorsal endocarpic ridge (Fig. 2: A) and ground tissue of awn attain lignified walls (Fig. 2D).

The splitting of schizocarp and the dehiscence of the mericarp: The ripe mericarps simultaneously become free and go away from the short central axis. The splitting of mericarps from each other is due to the disorganization and decay of thin walled and largely vacuolated parenchyma cells situated in the central layers of lateral wall of adjoining carpels (Figs. 1F; 2A, B). Nevertheless, the cells of peripheral layers on either side of lateral wall simulate the cells of mature endocarp (Fig. 2B). Thus, a multilayered protective zone is found around the seed except on its ventral side, where the vacuolated thin walled parenchyma form a seam-like zone (Fig. 2E).

The process of disorganization of central cells is simultaneous with that of cells of ground tissue of central axis. As a result, a cleavage formed in the entire length of lateral wall (Fig. 2B) extends into the axis. Therefore, the ripe mericarps concurrently separate from each other and also they separate from the axis. The scattered dry mericarps (Fig. 2F) later dehisce marginicidally due to the splitting of thin walled cells of the seam (Fig. 2E) and allow the seed to go off. Thus, the schizocarp of *Sida rhombifolia* (Fig. 1B) may be regarded as separatic and its mericarps are marginicidally dehiscent.

Discussion

The syncarpous ovary of *Sida rhombifolia* develops into a schizocarpic fruit of cup-shaped mericarp. The pericarp of each developing mericarp differentiates into epicarp, mesocarp and endocarp. The development of epicarp of *Sida rhombifolia* is similar to that of *Hibiscus* species (Dave *et al*., 1987; Rao *et al*., 1987a) as it develops from the outer epidermis of ovary wall. The participation of outer sub-epidermis in *Abelmoschus esculentus* (Inamdar *et al*., 1989) and outer sub-epidermis and a portion of ground tissue are also recorded in the formation of epicarp of *Thespesia populnea* (Rao *et al*., 1987a) together with their outer tangential walls of epicarpic cells of *Sida rhombifolia* possess thick and corrugated cuticle. The deposition of such cuticle is reported in the epicarps of mature capsules of *Gossypium hirsutum* (Rao & Dave, Communicated), *Hibiscus micranthus* (Rao *et al*., 1987a) and *Thespesia populnea* (Rao *et al*., 1987b). Roth (1977) is of the opinion that the cuticle plays significant part as protective layer in berries and drupes. It may serve the similar purpose even in schizocarps.

The mesoderm or ground tissue of ovary wall of *Sida rhombifolia* forms the mesocarp as it has been observed in the capsular fruits of *Hibiscus* species (Dave *et al*., 1987, Rao *et al*., 1987a) and *Abelmoschus esculentus* (Inamdar *et al*., 1989). The structural changes of developing meoscarp of *Sida rhombifolia* appear more or less similar to those of other investigated pericarps of Malvacean taxa (Dave *et al*., 1987; Rao *et al*., 1987a, b; Inamdar *et al*., 1989; Rao *et al*., 1993).

The multilayered endocarp of *Sida rhombifolia* differentiates from the inner epidermis of ovary wall. During the course of fruit development, the endocarpic cells, excluding those of the innermost layer, transform into fibers. The endocarps of similar composition are observed in *Hibiscus* species (Dave *et al*., 1987; Rao *et al*., 1987a) and *Gossypium hisrsutum* (Rao & Dave, Communicated). The fibrous endocarp may serve as a supporting tissue, which, in turn, protects the seed from injuries (Roth, 1977).

The formation of two awn-like sharply pointed projections as the apex of each mericarp of *Sida rhombifolia* is observed due to the acropetal extension of an inward folding in the median portion of ovary wall. According to Rao *et al*., (1993) the horns of *Pavonia sepium* develop either due to outward projection or vertical growth of ovary wall, while the glochid of *Urena lobata* differentiates from the outer sub-epidermis and outer layers of ground tissue (Rao *et al*., 1986). The presence of vascular tissue is recorded in the horns of *Pavonia sepium* (Rao *et al*., 1993), but the glochid of *Urena lobata* does not possess vascular tissue. Likewise, the awns of *Sida rhombifolia* are also without any vascular tissue, but they remain persistent and help in dispersal of dry mericarps which later open to liberate the seeds.

Like in *Abutilon indicum* (Rao, 1985), *Urena lobata* (Rao *et al*., 1986) and *Pavonia sepium* (Rao *et al*., 1993), the mericarps of *Sida rhombifolia* also separate from each

other and also from the central axis of the fruit. The anatomical details of present investigation reveal that the decay of central cells of lateral walls and the ground parenchyma of axis causes the separation of mericarps. Thus the placement of schizocarp of *Sida rhombifolia* under the dehiscent category of fruit is fully justified. Following the rupture of thin walled parenchymatous cells in the seam, the dry mericarps dehisce in their ventral side. Considering the view of Roth (1977) regarding the terminology for ventral dehiscence, the splitting of dry mericarps of *Sida rhombifolia* is designated as marginicidal dehiscence of the mericarps.

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