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STRUCTURAL DESIGN OF THE DEVELOPING FRUIT WALL OF *TERMINALIA ARJUNA* (ROXB. EX DC.) WT. & ARN. (COMBRETACEAE)

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The pericarp of *T. arjuna* is differentiated into epicarp, mesocarp and endocarp. The multilayered epicarp develops from the outer epidermis and outer hypodermis of the ovary wall. The mesoderm of the ovary wall forms the mesocarp which is further differentiated into outer, middle, and inner zones. The outer and inner mesocarpic zones are fibrous, while the middle mesocarp is parenchymatous. The vascular bundles and secretory cavities are found mostly in the middle mesocarp. The inner hypodermis and inner epidermis of ovary wall collectively contribute the endocarp. The inner hypodermal cells are meristematic and they undergo frequent periclinal divisions. As a result, multilayered endocarp is formed. Due to the meristematic activity of middle mesocarp, a dome-shaped projection is formed which ultimately develops into a wing.

Key Words : Combretaceae, fruit, pericarp, *Terminalia.*

Anatomical features of the family Combretaceae have been investigated by Metcalfe and Chalk (1950). A recent survey of literature reveals that *Terminalia,* a genus of Combretaceae, has attracted the attention of some researchers (e.g. Rao and Ramayya, 1984; Ramassamy and Kannabiran, 1996 etc.) due to its world wide distribution and economical and medicinal value. However, except cursory references made by Iyengar and Dwivedi (1989) and Roth (1977), the due consideration was not given to explore the structural and developmental details of fruits of *Terminalia.* Keeping all these facts in view an attempt has been made to study the structure and development of pericarp of *Terminalia arjuna.*

MATERIALS AND METHODS

The fruits collected at different stages of development were fixed in FAA. Customary methods were adopted for dehydration and infiltration. The sections cut between 8-12 µm thickness were stained with Safranine and Fast-green FCF or Toluidine blue O. For Scanning Electron Microscopic (SEM) studies materials were dehydrated through a graded acetone series and mounted on aluminum stubs. They were then coated with a thin conducting film of Gold-Palladium using sputter coater BALTEO SCD 005 and observed under Philips XL 20 Scanning Electron Microscope at N.B.R.I., Lucknow.

OBSERVATIONS

Ovary wall : The undulated ovary wall is hairy and stomatic. The trichomes are unicellular, eglandular and papillate. The stomata are of anomocytic and cyclocytic types. The scanning electron microscopic studies on the outer surface of the ovary wall reveal that the trichomes are oriented in all directions (Fig. J). The outer epidermal cells of ovary wall appear polygonal and isodiametric in surface view while they are columnar or rectangular in transection and possess thick tangential walls. Beneath the outer epidermis, 4-5 layers thick hypodermis is present. The cells of hypodermis are more or less similar to that of outer epidermis (Fig. A). The cells of outer epidermis undergo anticlinal divisions while the hypodermal cells divide periclinally as well as anticlinally. The mesoderm can be further classified into outer, middle and inner zones. The tangentially elongated cells with spindle shaped nuclei in 4 or 5 layers thick constitute the outer mesoderm. The polygonal or spherical cells of middle mesoderm in 20 to 24 layers thick embed secretory cavities and vascular bundles. The cells of inner mesoderm resemble the cells of outer mesoderm in size and shape. The cells of inner hypodermis which possess dense cytoplasm show frequent periclinal divisions. The inner epidermis is single layered and its cells undergo anticlinal divisions. The tangential walls of these inner epidermal cells also appear thick (Fig. B).

Epicarp : The outermost zone of the pericarp is the epicarp which develops from the outer epidermal and outer hypodermal layers of the ovary wall. The

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SEM studies on the outer surface of young fruit shows that the trichomes are smooth walled. However, they are shed off during subsequent growth leaving only the scar on the outer surface of the fruit wall. In the initial stage of fruit development the cuticle is smooth but during the course of development it becomes thick due to deposition of more cuticular wax. As a result of such an accumulation of wax the stomatal pore appears to be closed. In early stages of fruit development the outer epidermal cells undergo anticlinal while hypodermal cells show anticlinal and periclinal divisions. The derivatives of such periclinal divisions subsequently elongate radially and contribute to the developing epicarp (Fig. C). As the fruit grows the frequency of divisions is ceased but the cells of outermost layer of epicarp contain tanniniferous contents (Fig. F).

Mesocarp : It develops from the mesoderm of the ovary wall. Like mesoderm, the mesocarp is also differentiated into three zones viz. (i) outer mesocarp (ii) middle mesocarp and (iii) inner mesocarp. The outer mesocarp is 5 or 6 layers thick and it is derived from the tangentially elongated cells of the outer mesoderm of the ovary wall. In the course of fruit development, the tangentially elongated cells attain thick walls, become vacuolated and eventually they transform into fibres. The cells of parenchymatous middle mesocarp appear polygonal or spherical (Fig. E). In the early stage of fruit development these cells are meristematic but their meristematic activity ceases as the growth of fruit progresses. Thus the middle mesocarpic cells undergo the process of enlargement. However, increment in the diameter of fruit is more due to cell divisions rather than cell enlargement. Meristematic activity is more in ridge region than in the furrow region in which secretory cavities and vascular bundles are present. As the fruit matures the cells increase in size and become vacuolated. Occurrence of calcium oxalate crystals is also noticed in the middle mesocarp.

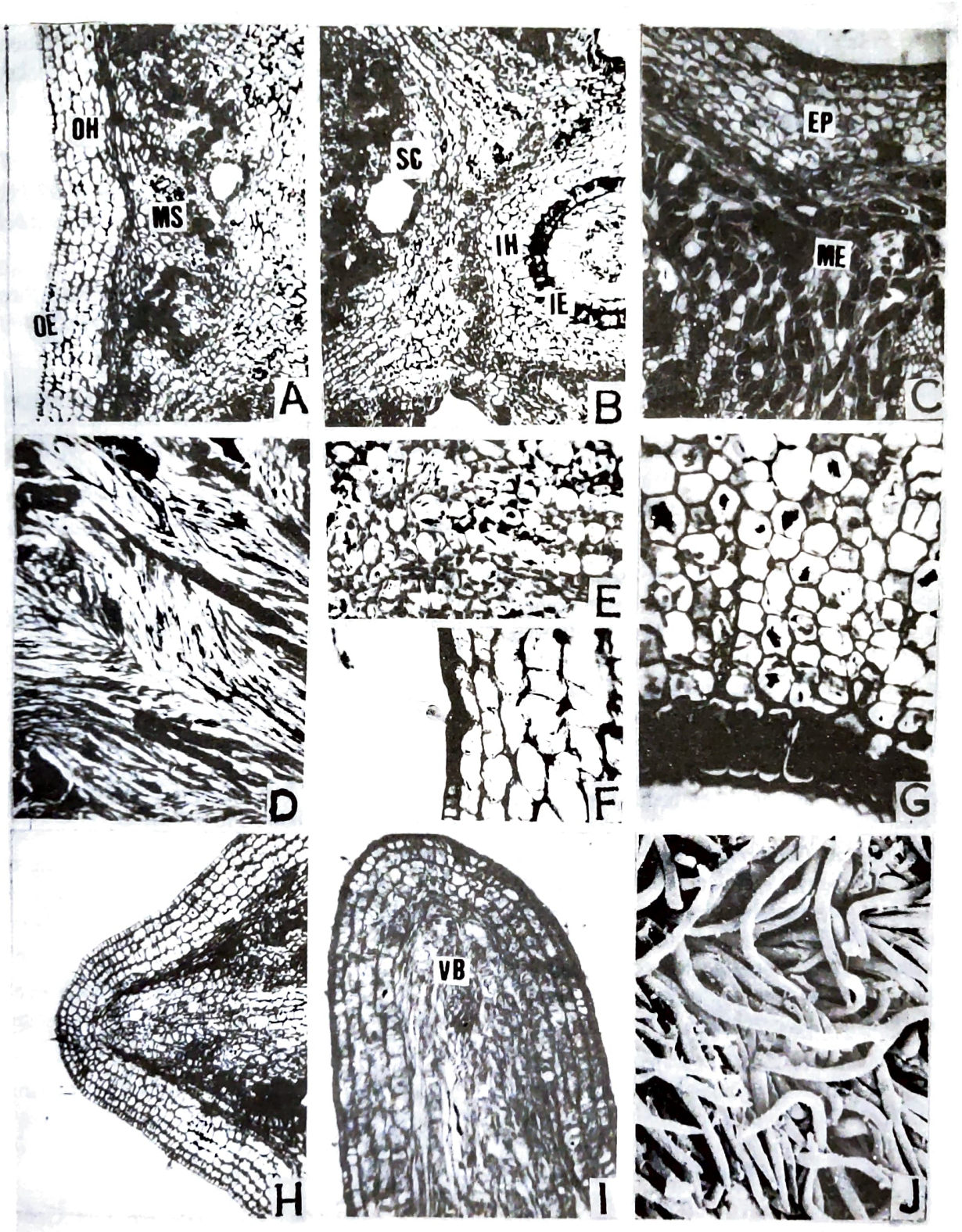
The inner mesocarp is the product of a zone of tangentially elongated inner mesodermal cells. They contain dense cytoplasm and prominent nuclei and undergo periclinal divisions. As the growth proceeds towards the maturity of fruit, the cells of inner mesocarp elongate further in tangential direction and gradually transform into fibres (Fig. D).

Anatomy of wing : Wing develops due to the meristematic activity of the middle mesocarpic cells situated in the ridge region. The meristematic cells of ridge contain dense cytoplasm and prominent nuclei. The cells of middle mesocarp undergo periclinal divisions, as a result of which wing develops. As the fruits undergo the process of maturation, the frequency of cell divisions is ceased and it is replaced by the process of elongation and vacuolation. The cells of outer epidermis and outer hypodermis of wing elongate at right angle to the vertical axis of the fruit. The tangentially elongated cells of outer and inner mesocarp also extend into the wing and gradually they transform into fibers. The occurrence of vascular bundle is found in the parenchymatous cortical-like zone of the wing (Figs. H, I.).

Endocarp : The cells of inner epidermal and inner hypodermal layers of the ovary wall collectively contribute the endocarp. The cells of inner hypodermis are meristematic and show frequent periclinal divisions. Thus the number of endocarpic layers increase in the subsequent stages of fruit development. However, eventually the cell division is replaced by cell enlargement. The innermost layer of endocarp consists of tabular or columnar cells with thick tangential walls. During the process of maturation the cells of inner epidermis do not exhibit any significant structural changes (Fig. G).

DISCUSSION

The pericarp of *T. arjuna* is histologically differentiated into three zones viz. epicarp, mesocarp and endocarp. Esau (1965) and Fahn (1982) expressed more or less similar opinion that these layers do not represent separate tissue from the point of view of their origin. Contrary to this opinion, Roth (1977) could show the ontogeny of each pericarpic layer from a definite zone in the ovary wall. The present study on the development of pericarp of *T. arjuna* also supports the view of Roth (1977). The 5-7 layered epicarp of *T. arjuna* develops from the outer epidermis and outer hypodermis. Thus the formation of epicarp in *T. arjuna* shows close resemblances with that of *Terminalia bellerica* (Bhatnagar *et al.*, 1997) and *Combretum coccineum* (Communicated). Moreover, Dave *et al.* (1980, 1982) also reported similar type of epicarp formation in *Solanum tuberosum* and *Lycopersicon esculantum* respectively. The waxy coating on the cuticle of the outer epidermis of developing pericarp of *T. arjuna* forms an



Figures A-J. A. Transversesection of the ovary wall showing outer epidermis, outer hypodermis and mesoderm. B. Transversesection of ovary wall showing mesoderm, inner hypodermis and inner epidermis. C. Epicarp and mesocarp of developing fruit in transversesection. D. Transversesection of the fruit showing fibrous inner mesocarp. E. Middle mesocarp of developing fruit. F. Epicarp of the mature fruit. G. Endocarp of mature fruit in transection. H, I. Longitudinal section of wing (A-I : X 120). J. Scanning electron micrograph of the surface view of ovary wall X 390. EP Epicarp; IE Inner epidermis; IH Inner hypodermis; ME Mesocarp; MS Mesoderm; OE Outer epidermis; VB Vascular bundle; SC Scretory cavity.

additional protective layer of the fruit. Besides, the developing epicarp of *T. arjuna* is also found to possess anomocytic and cyclocytic types of stomata while Rao & Ramayya (1984) reported anomocytic and tricytic types of stomata on the leaf of *T. arjuna.*

The mesocarp of *T. arjuna* is heterogeneous and it is made up of fibrous and parenchymatous zones. Its outer and inner mesocarpic zones are fibrous while the middle mesocarp is parenchymatous. Iyengar and Dwivedi (1989) and Bhatnagar *et al.* (1997) reported the occurrence of outer sclerenchymatous and inner parenchymatous mesocarpic zones in *T. bellerica.* However, secretory cavities are found to occur in the middle mesocarp of *T. arjuna.* Metcalf and Chalk (1950) also reported the presence of secretory cavities in the foliar parts of *Terminalia.* But neither Iyengar and Dwivedi (1989) nor Bhatnagar *et al.* (1997) found such cavities in the mesocarp of *T. bellerica.*

The fibers of outer and inner mesocarp of *T. arjuna* extend into its wing and provide tensile strength to the wing. A similar kind of fiber-like cells were reported in the glochid of *Urena* (Rao *et al.*, 1986). Moreover, the middle mesocarp of *T. arjuna* forms a cortical-like zone in the wing. Besides, the vascular bundle which is located in the middle mesocarp also extends into the wing. Roth (1977) also reported the occurrence of vascular bundle embedded inside the sclerenchyma of wing of *Terminalia modesta.* In contrast, the fruit of *Combretum* whose wings consists of loose parenchyma in which sclerenchyma is embedded, since vascular bundles are absent (Roth, 1977). The well differentiated ramifications of vascular bundles coming from the mesocarp entering into the spine has been observed in *Ricinus* (Sharma, 1964) and *Datura* (Dave *et al.*, 1980).

The multilayered endocarp of *T. arjuna* is formed by the inner epidermis and inner hypodermis of its ovary wall. The endocarp of *T. catappa* is heterogenous and contain floating tissue while in *T. arjuna* it is homogenous. Roth (1977) has proposed a scheme concerning the topography of composing endocarpic layers. According to her scheme the endocarp of *T. arjuna* comes under the fifth category (i.e. The inner hypodermis become multilayered by meristematic activity and transformed into endocarp together with inner epidermis).

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