5. CONCLUSION

Lianas (woody vines) are the important components of tropical forests, contributing approximately 25% of the species diversity of woody stems. Despite their prevalence in tropical forests and their strong impact on forest dynamics, lianas have received relatively little attention compared to trees. Though they are an important constituent of forest ecosystem, histological studies on their cambial activity have always been neglected on this major component of forest ecosystem (Putz and Holbrook 1991; Isnard *et al.* 2003; Lopes *et al.* 2008; Isnard and Silk 2009; Rajput *et al.* 2010b). The underlying reason for this may be their lesser economic importance when compared to timber trees (Carlqist 2001a; Rajput *et al.* 2008; Patil *et al.* 2011).

In the present study; out of 34 species, 28 species were climbers and only seven species were either herbs or shrubs. Therefore, present study indicates that occurrence of cambial variant is more common than other growth forms. Prevalence of cambial variants in climbers is associated with shift from self supporting to climbing habit is resulted in the development of several interesting structures such as formation of successive cambia, interxylary phloem, dissected or compound xylem, furrowed xylem and so on. That could be the reason that the complexity of anatomical construction in many lianas is known to arise after the development of climbing architecture. This is however, not a universal correlation for similar variant types occurring in plants that are not lianas and conversely there are some lianas in which secondary thickening confirm the normal type.

During this growth form, the cambium changes its activity in one or many aspects, leading to the production of soft-walled tissues mixed with thick-walled lignified tissues, which presumably provide higher flexibility to climbing stems, which allow them twisting without damaging the secondary xylem. The relative amount of parenchyma, fibres, vessels and sieve tubes may be correlated with the plant habit. Alternatively, these structures might also play a role in photosynthate storage and wound repair. Frequent occurrence of "anomalous" disposition of secondary tissues might increase the flexibility of the stem, augmenting its resistance to mechanical damage caused by twisting. Thus it seems to be associated with the protection of vessels from damage during torsion in stems of lianas. Moreover, thin-walled parenchyma cells may be playing an important role in the storage of reserve food material as well as in storage of water. Usually *Coccinia* grows in scrub forest and sprouting of new leaves occurs during the dryer part of the year before the arrival of rains in the month of June. Thus, abundance of axial parenchyma in the stem of *Coccinia* may be helpful to store enough water as well as reserve food material to produce new a crop of leaves during the drier part of the year. Formation of successive cambia with abundance of parenchyma in *Spinacia* may be a modification of roots in favour of storage function, as seen in the case of sugar beet (Artschwager, 1926). Therefore, if correlated with evolution of roots towards storage habit, *Spinacia* may be the beginning of root modification for storage habit and ending with sugar beet. Structural similarity in the vasculature of both species and occurrence of multiple active cambia at a time is additional evidence towards the increase in more parenchyma for storage of food material.

Presence internal phloem seems to be associated rapid and safe conduction of photosynthate. Usually herbaceous plants and climbers are most susceptible to herbivory and insect attack. If the external phloem is damaged the internal phloem will play an important role in translocation of sugars. Formation of secondary xylem and phloem from the internal cambium is additional evidence in support of role of internal phloem in photosynthate translocation. Development of secondary xylem may associated with the additional mechanical support in climbing habit, as there was no development of secondary xylem in herbaceous plants like *Cressa* and *Solanum*. In the present study, all the plants studied not only showed development of internal cambium but some members also showed development of secondary xylem and phloem from the internal cambium while other members showed only development of intraxylary/internal secondary phloem. Differentiation of internal phloem is not synchronised, internal phloem may develop before, after or simultaneously with the development of external normal phloem. Structurally the intraxylary phloem is similar to the external phloem and except the length of the sieve tube elements were relatively longer in internal phloem than in the external ones.

Development of included phloem in *Calycopteris floribunda* Lamk., deviates from the pattern of phloem (included) formation reported so far in some members of the Combretaceae. In small segments of the cambium, cells in the middle of cambial zone differentiated into their derivatives, which resulted splitting of the cambial zone into outer and inner segments. The outer segment joined with existing cambial ring and restored the cambial cylinder while the inner one became encircled by differentiating xylem. This process is repeated several times thus, resulting into formation of several phloem islands embedded in the secondary xylem. Heavy accumulation of phenolic compounds and starch in parenchyma cells of all the plants with included phloem in the present study may be associated with their habit and paucity of storage tissue. Therefore, to compensate paucity of storage parenchyma cells xylem fibres retained their living protoplast and nucleus and perform duel function as storage as well as mechanical tissue. Phloem anastomoses of axial included phloem strands in tangential and radial directions are common in occurrence in most of the plant species. These strands establish three dimensional network of secondary included phloem and considered to be the main assimilate transporting system of the stem. In the present investigation, interconnecting strands of either thin walled parenchyma or radially arranged sieve tube elements running parallel with the xylem rays were noticed. Development of radially arranged sieve tube elements are also reported in some species which do not have included phloem.

The various features of the wood in plants with cambial variant are related with their habit. Presence of wide vessels in climbing plants is considered to compensate for the small transactional area of secondary xylem. However, wider vessels are more vulnerable to the formation of air embolism, whereas fibriform vessels are probably as effective as tracheids in resisting the formation of air embolism in vessels because air embolisms form far less commonly in narrow vessels than wide ones. Therefore, fibriform vessels may give a high degree of conductive safety, similar to tracheids, by the presence of perforation plates. The presence of fibriform vessels is considered to be an adaptive feature towards greater potential for conductive efficiency and resistance to air embolism. Different modes of cambial origins have been reported in the literature, and successive cambia may originate from cortical parenchyma, endodermis, pericycle or irregular activity of a normal cambium. In the present study also origin of successive cambia was observed from all the cell types mentioned above.

FIGURE - 1

Transverse sections of young stem showing development of internal phloem and procambium in *Ipomoea hederifolia* Linn.

A. Second visible internode showing initiation of internal phloem development (arrow). Arrowhead indicates external protophloem.

B. Enlarged view of second internode. Arrow showing darkly stained internal protophloem mother cells with distinct nucleus. Note the well differentiated external protophloem (arrowhead) while small arrow indicates procambial cells.

C. Partially developed internal protophloem (arrow) in the third internode while arrowhead indicates external protophloem. Note the well-developed procambium (small arrow) and protoxylem elements (small arrowhead).

D. Well-developed internal protophloem in the sixth internode (arrows). Note the differentiating metaxylem elements (arrowheads).

E. Distinct patches of internal protophloem (arrows) where arrowhead indicates lignifying metaxylem elements. Note the nature of vascular bundle.

F. Group of relatively small cells (arrowhead) that acts as a site for internal cambium formation. Note the completely formed vascular cambium with few lignified xylem elements, arrow shows internal phloem.

Scale bars: A-F: 75 μm.

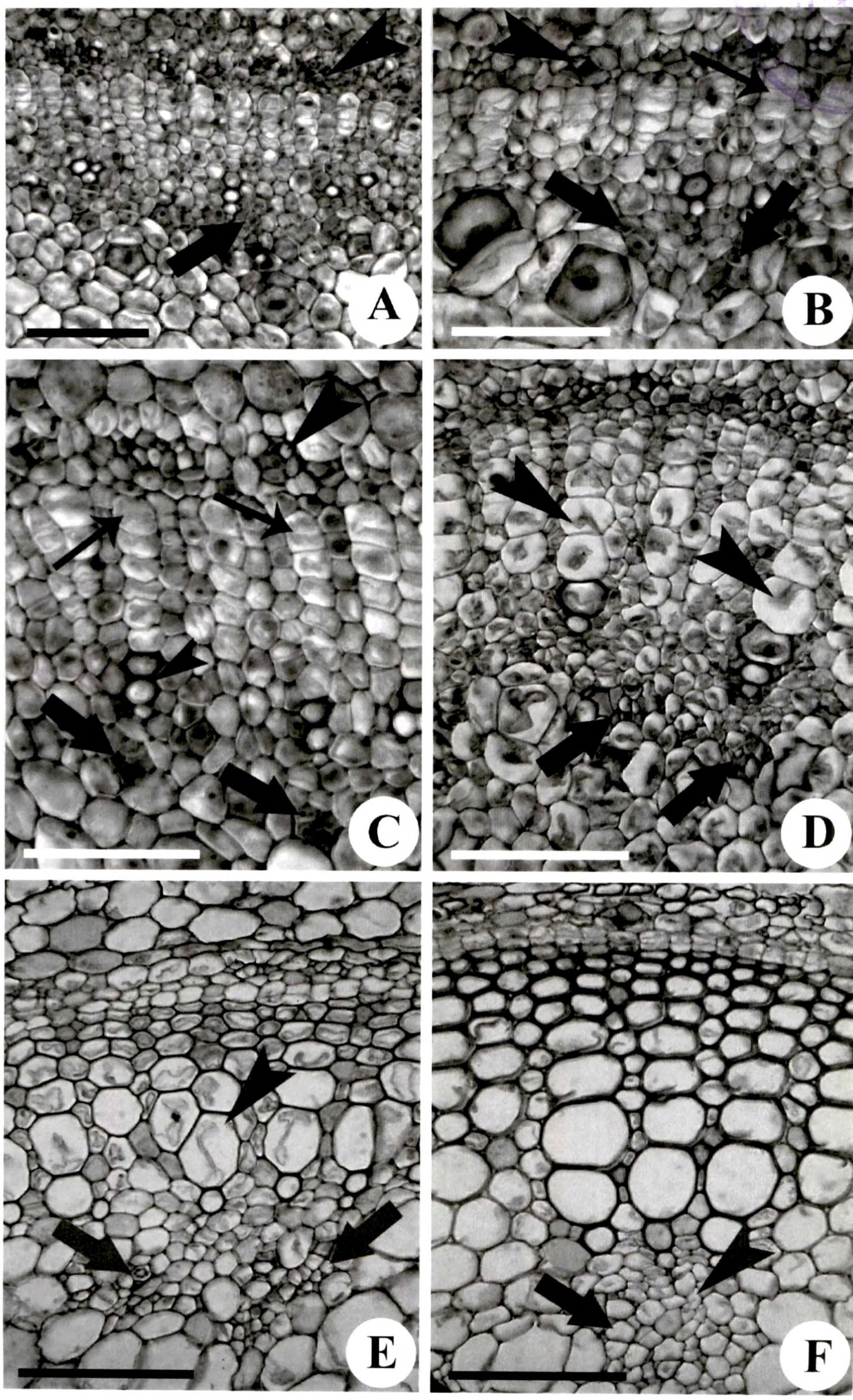

FIGURE-1

FIGURE - 2

Transverse view of young stem showing development of internal cambium and procambium in the pith region of *Ipomoea hederifolia* Linn.

A. Bulk of internal secondary phloem formed by the internal cambium (arrowheads).

B. Prior to the development of internal cambium, radial and tangential expansion of parenchyma cells between protoxylem and internal phloem (arrowhead). Arrow indicates internal phloem.

C. Development of internal cambium from the procambially derived cells between protoxylem and internal phloem. Note the tangential divisions in some of the cells (arrowheads).

D. Development of internal cambium from the procambially derived cells (arrowhead).

E. Well-developedinternal cambium (arrowhead) with secondary internal phloem (arrows). Small arrow indicates phloem ray.

F. Secondary xylem derivatives formed by the internal cambium. Note the large diameter of vessel element (arrow). Note the distinct arrangement of cambial cells in radial files.

Scale bars: A-D, F: 75 μm; E: 50 μm.

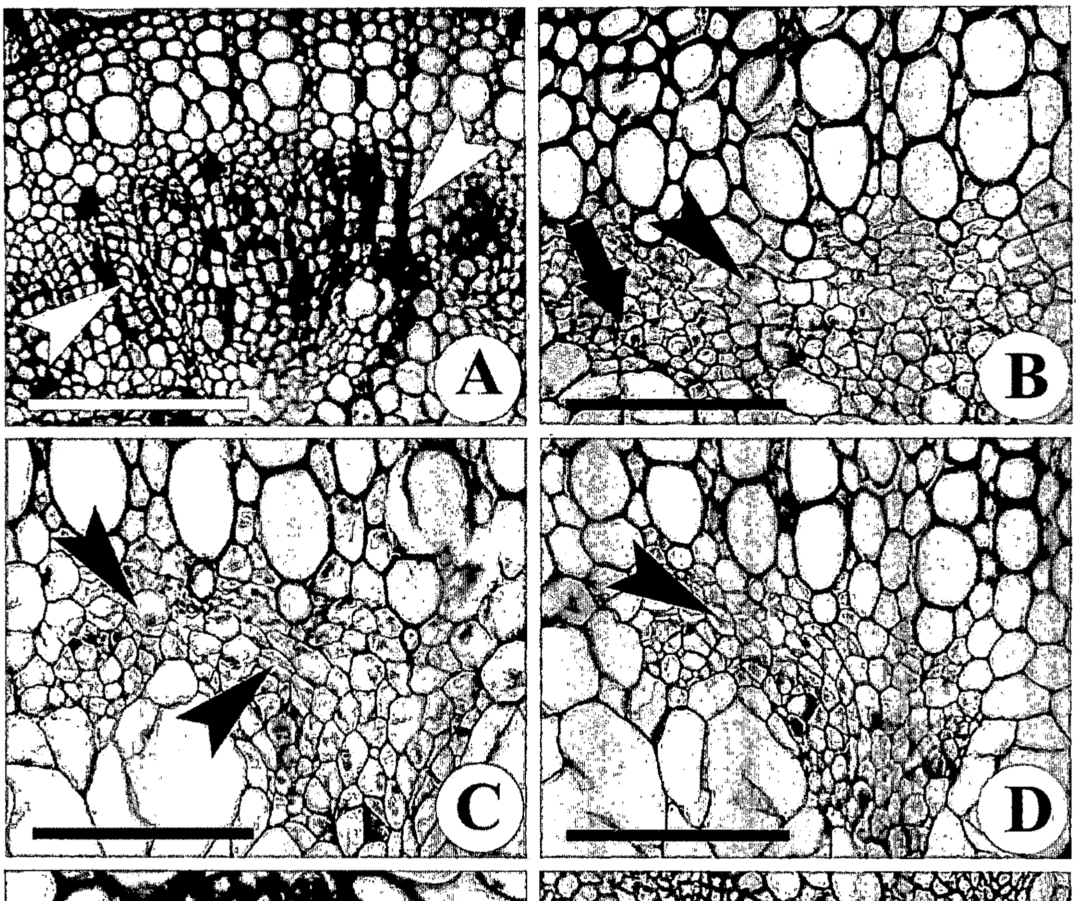

FIGURE-2

FIGURE - 3

Transverse sections of mature stem showing internal cambium and its derivatives in the pith region of *Ipomoea hederifolia* L.

A. Mature stem showing two opposite segments of the relatively more active internal cambium with secondary xylem and phloem. Arrowheads indicate vessel elements.

B. Enlarged view of one of the internal cambial segment (arrowhead) with secondary phloem (arrow) and vessel elements. Note the diameter of the vessel elements as compared to protoxylem elements on the upper part of the photograph.

C. Another stem segment showing internal cambium. Arrowhead showing radially arranged cambial cells.

D. Thick stem showing two large vascular bundles developed by the internal cambium (arrow).Note the inverted arrangement of the bundles showing formation of xylem in centrifugal direction.

E. Enlarged view of pith region from old stem showing structure and arrangement of secondary xylem and phloem formed by the internal cambium. Note the crushed pith cells in the centre (arrow). Arrowhead indicates internal cambium while small arrow shows xylem rays. V- vessel.

Scale bars: A, D: 100 µm; B-C, E: 75 µm.

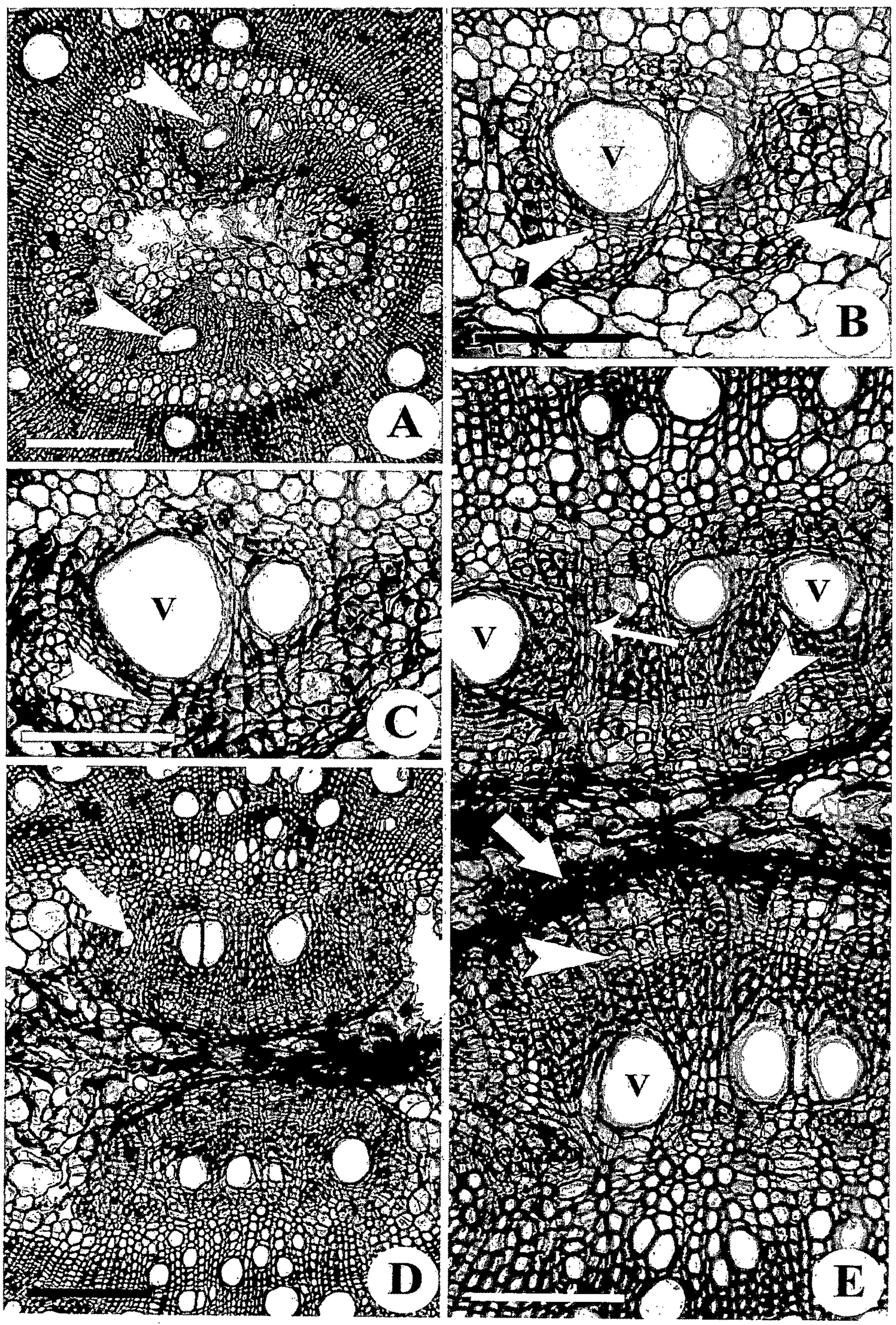

FIGURE-3

FIGURE - 4

Transverse view of young stem (A-F) showing development various stages of internal phloem, procambium and vascular bundles development in *Ipomoea aquatica* Forssk.

A. Second visible internode showing initiation of internal phloem development (arrow). Arrowhead indicates external protophloem, small arrow indicates secretary ducts.

B. Partially developed internal protophloem (arrow) and external protophloem (arrowhead) in the third internode. Note the recently formed protoxylem elements (small arrow).

C. Distinct patch of internal protophloem (arrow) whereas arrowhead indicates lignified metaxylem elements. Note the interfascicular region parenchyma cells acquired meristematic activities which results into formation of interfascicular cambium.

D. Group of relatively small cells (arrows) that acts as a site for internal cambium formation. Note the completely formed vascular cambium with lignified xylem elements, arrowhead shows internal phloem.

E. Mature stem showing well developed secondary xylem with large vessels (V) and internal phloem (arrowhead). Note the absence of secondary xylem on either side of the internal cambium.

F. Development of internal cambium from the procambially derived cells between protoxylem and internal phloem. Note the tangential divisions in some of the cells (arrowheads) and small arrow indicates phloem ray.

Scale bars: A-C, E: 75 µm; D: 25 µm; F: 75 µm.

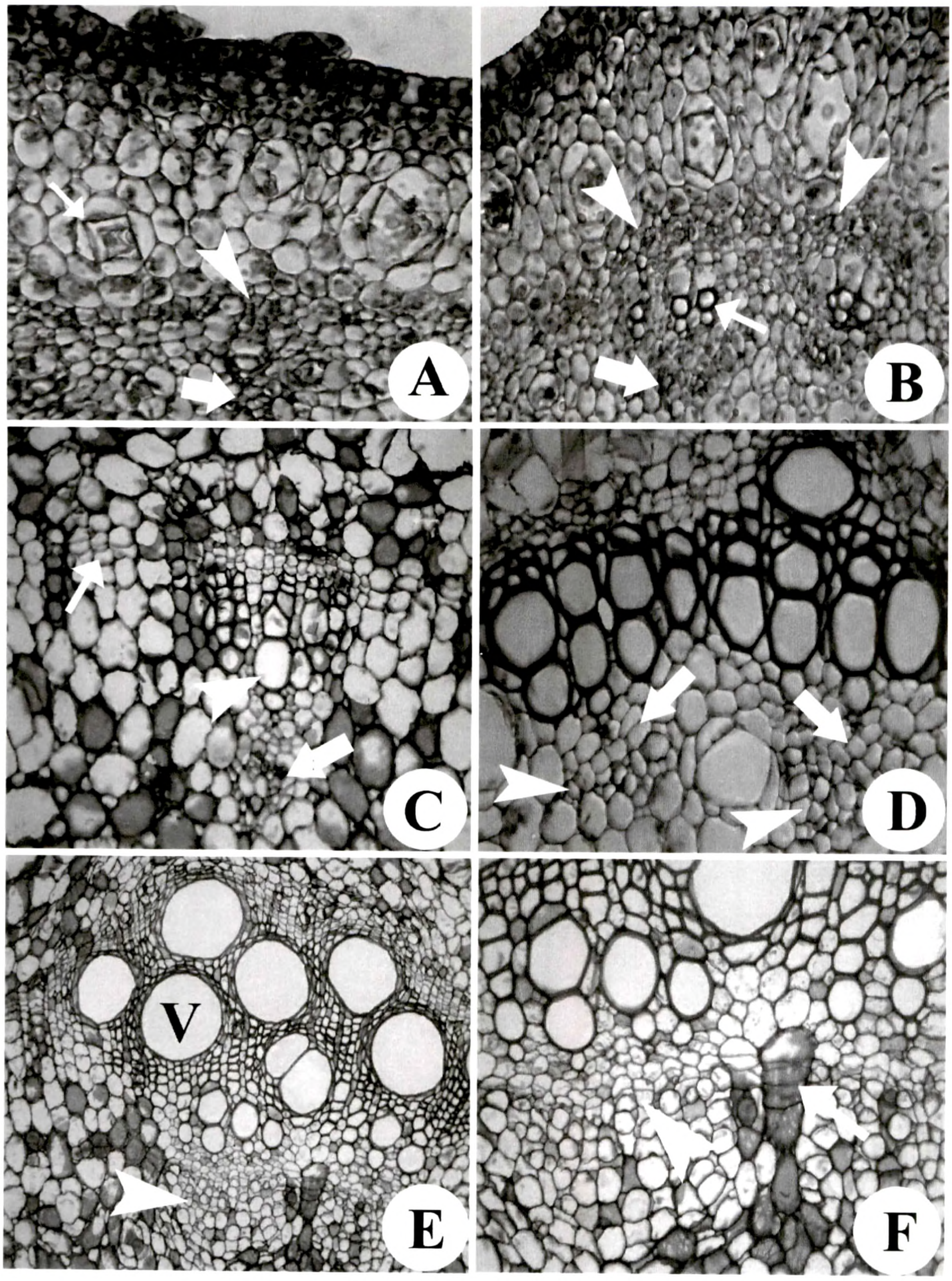

FIGURE-4

FIGURE - 5

Transverse section of young stem showing origin of internal phloem in *Leptadenia reticulata* (Retz.) Wight & Arn..

A. Young stem with procambial tissue. Second internode showing well-differentiated discrete strands of external (arrowhead) and internal (arrow) phloem.

B. Strands of external (arrowhead) and internal (arrow) phloem in the next node, showing recently differentiated protoxylem elements (small arrow). Note the tangential division and radial arrangement of procambial cells.

C. Radially arranged procambial cells (arrowhead) separating external and internal phloem strands. Arrow shows recently formed protoxylem elements.

D. Metacambium with differentiating metaxylem elements (arrows). Arrowhead indicates internal phloem strands.

E. Mature stem, showing distribution of internal phloem beneath the protoxylem.

F. Enlarged view of mature stem, showing small perforation plates on suddenly tapering end walls (arrowheads). Arrow indicates obliterated internal protophloem. PC – procambium.

Scale bars: A-D, F: 75 μm; E: 100 μm.

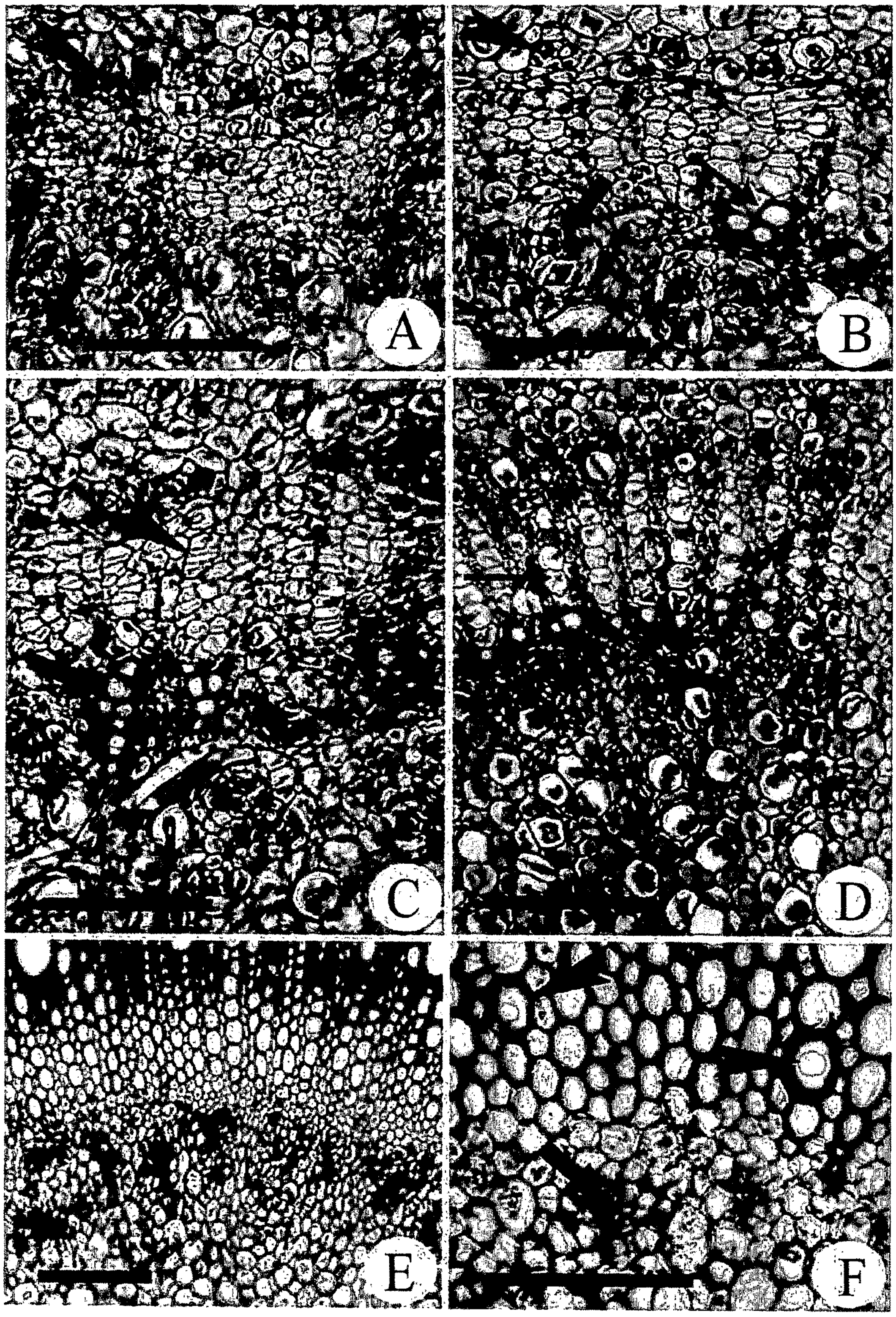

FIGURE-5

FIGURE - 6

Transverse section of mature stem of *Leptadenia reticulata* (Retz.)Wight & Arn., showing development of secondary internal phloem.

A. Obliteration of non-functional internal protophloem and newly formed sieve tube elements (arrow). Note parenchyma at upper left, showing recently formed tangential wall.

B. Enlarged view of Fig. 2A. Arrow indicates sieve tube elements with companion cell and obliterating protophloem (arrowhead).

C. Obliteration of protophloem (arrowhead) and enlargement of adjacent parenchyma followed by periclinal division (arrow).

D. Internal cambium (arrowhead) with functional internal phloem on its lower side.

Scale bars: A-C: 75 μm; D: 100 μm.

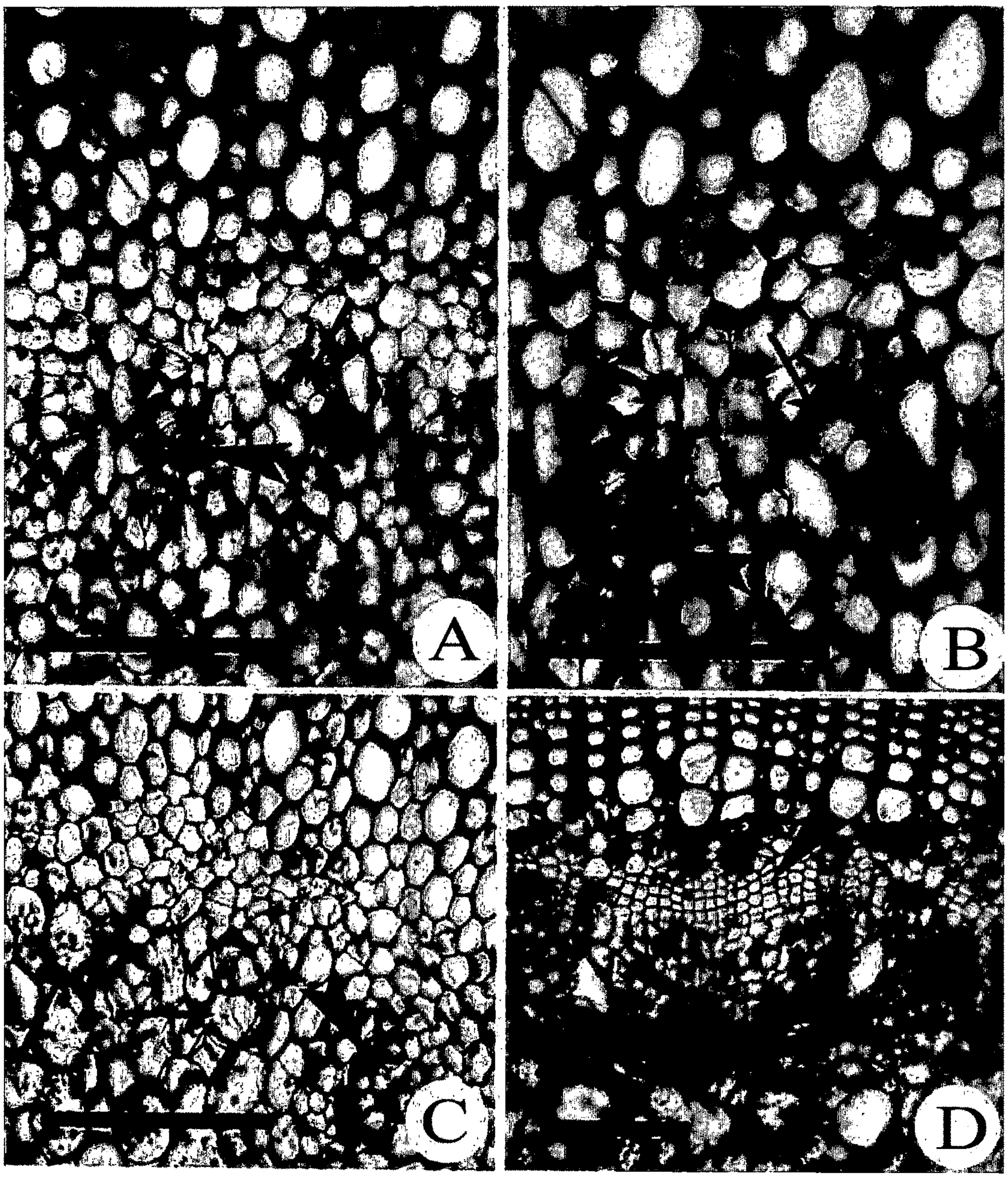

FIGURE-6

FIGURE - 7

Transverse section of young stem and mature stem of *Cressa cretica* Linn., showing structure, development of internal phloem and internal cambium.

A. Young stem showing partially developed bands of internal phloem. Note thick cuticle and chlorenchymarous hypodermis.

B. Mature stem showing well developed secondary xylem and compressed pith parenchyma with triangular shape.

C. Mature stem, showing well developed internal phloem in the pith region.

D. Distribution of external phloem.

E. Group of relatively small cells (arrows) that acts as a site for internal cambium formation. Note the arrowhead showing small arch showing division in parenchymatous cells well established internal cambium.

F. Internal cambium with functional internal phloem showing darkly stained sieve plate with callose deposition (arrow). Arrowhead showing uniseriate phloem ray.

Scale bars- A-F: 100 μm.

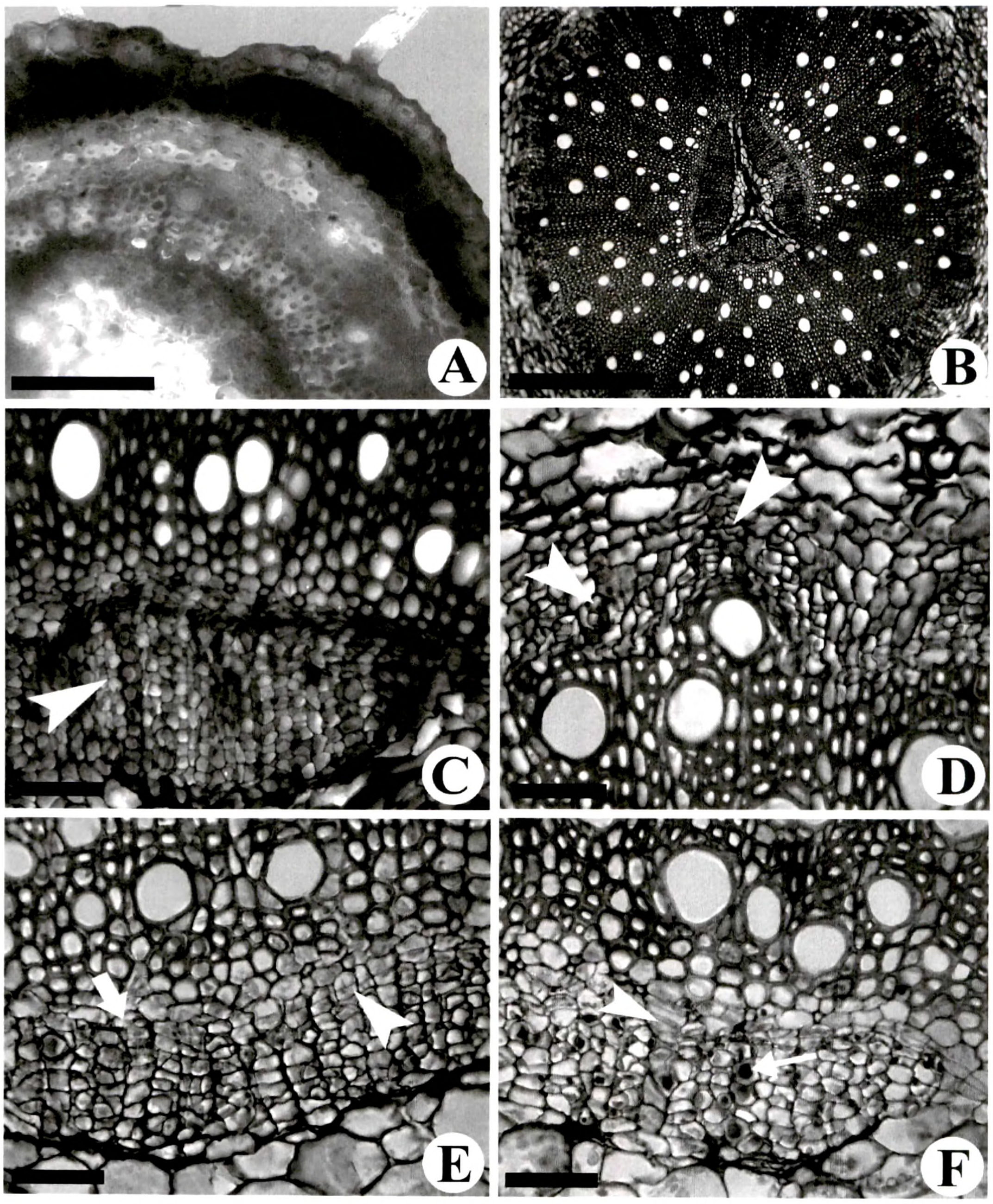

FIGURE-7

FIGURE - 8

Transverse section of young stem of *Solanum pseudocapsicum* L., showing origin of internal phloem.

A. Second internode of the young stem showing well-differentiated discrete strands of external (arrow) and internal (arrowhead) phloem.

B. Internal phloem strands (arrowhead) in the 3rd internode. Arrow showing developing procambium.

C. Enlarged view of procambium with differentiating protoxylem elements (arrows).
D. Well established metacambium (thin arrow). Arrowhead shows internal phloem and arrow shows pith parenchyma cells.

E. Radially arranged procambial cells, with differentiating xylem elements, arrow showing parenchyma cells between protoxylem and internal phloem.

F. Mature stem, showing internal phloem (arrowheads) arranged at the margin of pith. PC - procambium.

Scale bars- A-C: 75 µm, D: 50 µm, E: 25 µm, F: 100 µm.

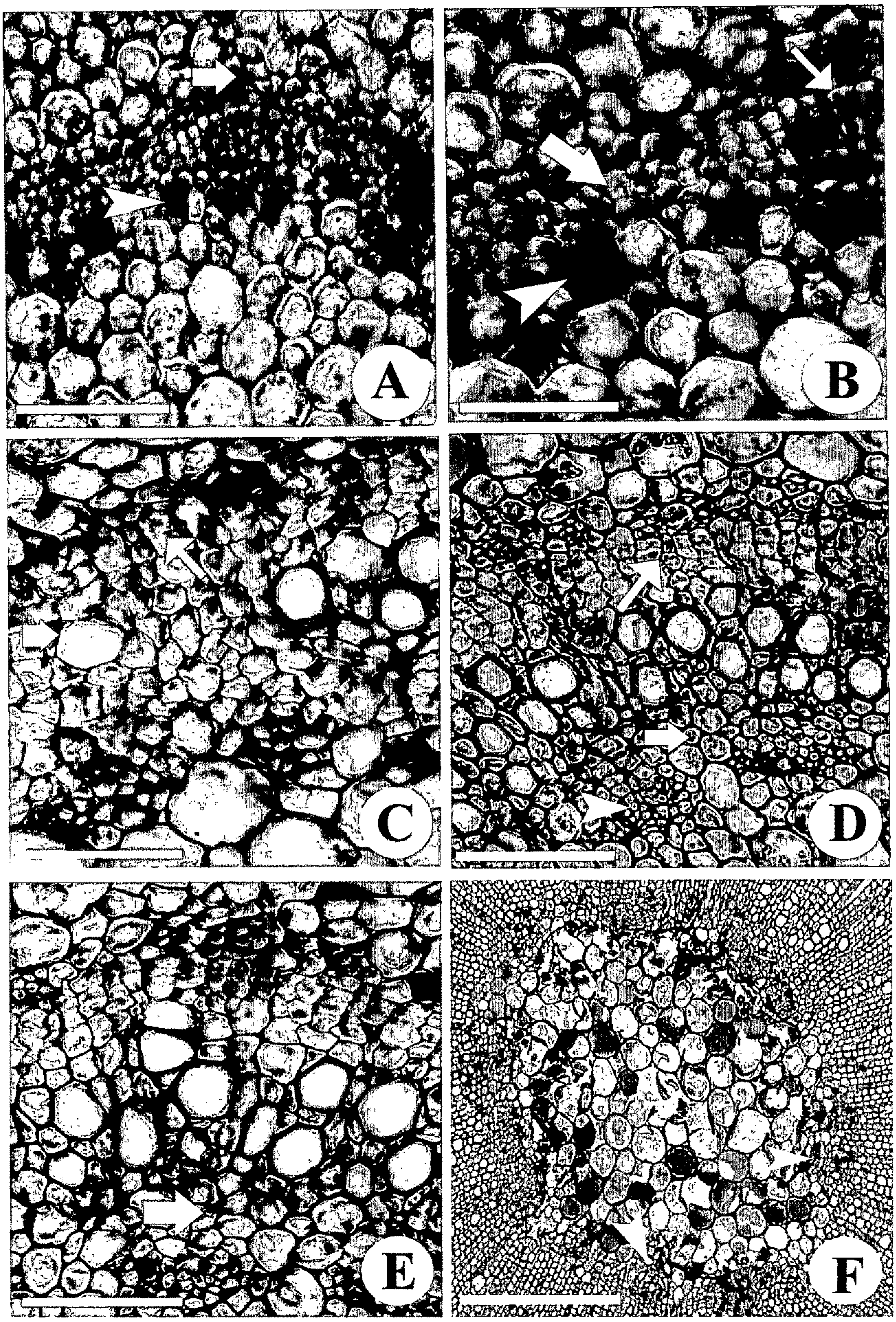

FIGURE-8

FIGURE - 9

Transverse sections of mature stem of *Solanum pseudocapsicum* L., origin of internal cambium as well internal phloem.

A. Obliterated internal phloem (arrowhead). Note presence of stone cells near to crushed phloem (arrow).

B. Well developed bands of internal phloem (arrowhead). Note the crushed protophloem elements (arrow).

C. Enlargement of marginal pith parenchyma prior to initiation of internal cambium (arrows) followed by division in them.

D. Small segment of internal cambium formed next to protoxylem (arrow), which differentiated later on in to internal phloem.

E. Newly originated internal sieve tube (black arrowhead). Thin arrow showing obliterated protophloem. Arrowhead indicates recently formed internal phloem.

F. Marginal pith cells differentiated into internal cambium (arrow). Note the secondary internal phloem (arrowhead) formed by the internal cambium. Small arrow showing obliterated internal protophloem.

Scale bars- 9A-F: 100 μm.

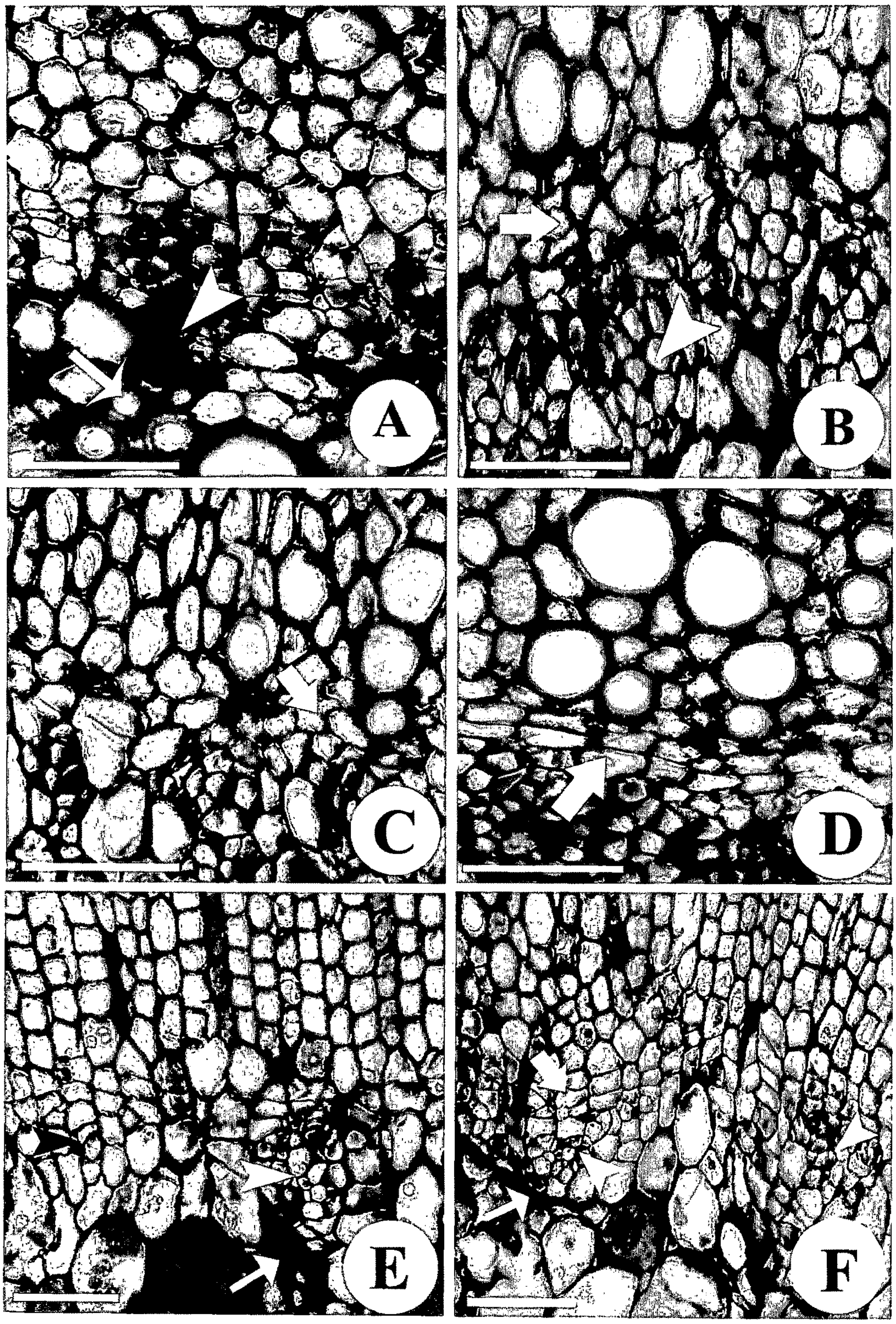

FIGURE-9

FIGURE -10

Transverse (A-D) and tangential longitudinal (E, F) view of secondary xylem of *Strychnos bicolour* Prog.

A. Mature stem showing islands of interxylary phloem (arrowheads). Arrow indicates predominance of uniseriate rays while multiseriate rays are rare.

B. Gross structure of stem showing, periderm, cortex (arrowhead) and part of the cambial segment that ceased to form xylem (lower arrow). Arrow on upper right corner indicates part of the functionally normal cambium.

C. Pith flecks in the mature stem showing deformed xylem derivatives as compared to other part (arrowhead).

D. Enlarged view of pith fleck showing cell morphology (arrowhead).

E. Xylem fibres with bordered pits (arrowheads).

F. Xylem fibres with bordered pits (arrowheads).

Scale bars- A-D: 100 μm; E, F: 75 μm.

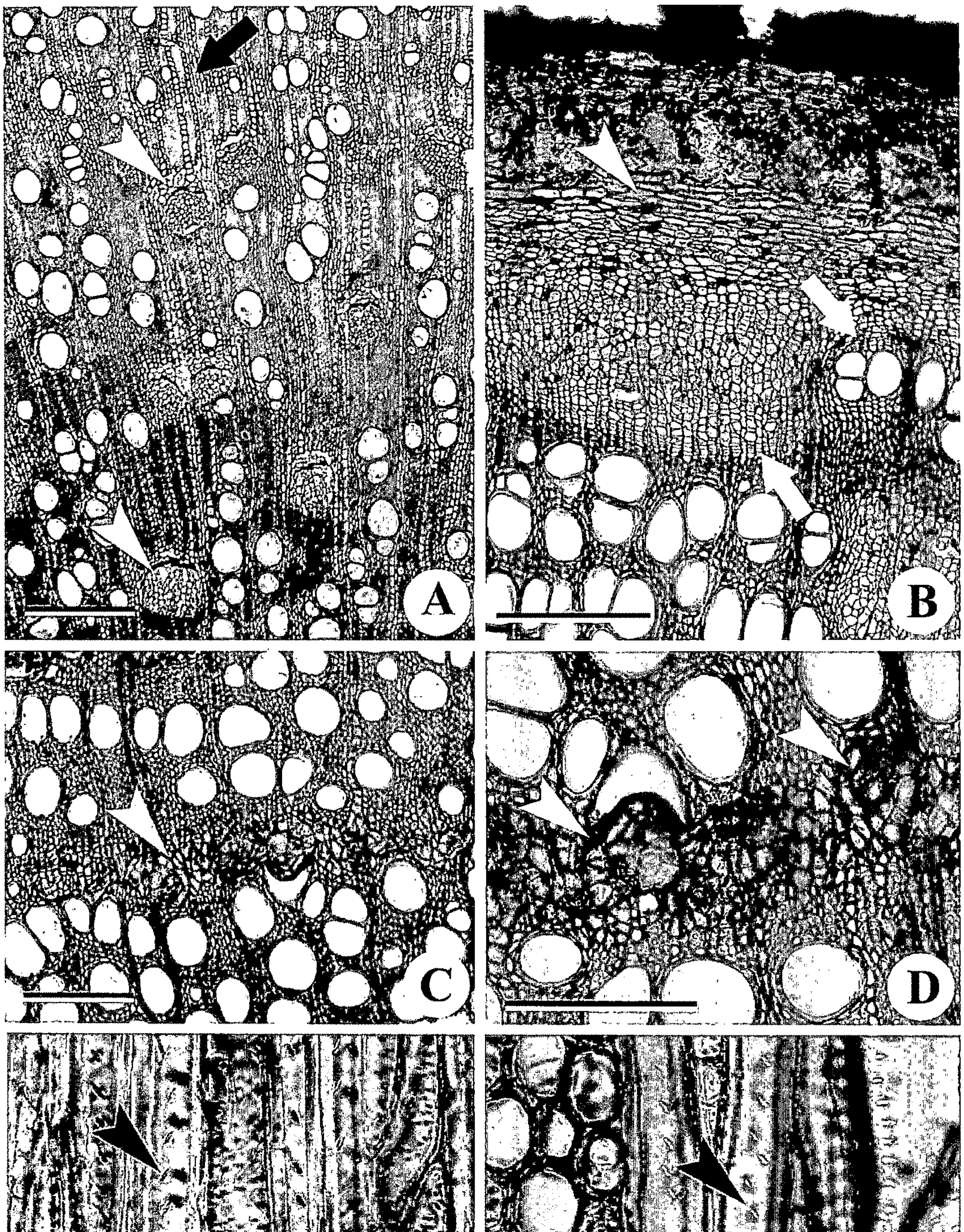

FIGURE-10

FIGURE - 11

Transverse view of *Strychnos bicolour* Prog stem showing development of cambium, and structure of interxylary phloem and secondary xylem.

A. Development of new cambial segment (arrowheads) outside to the cambium that stopped producing secondary xylem (arrows). Arrow on the upper right corner shows disconnected part of the functionally normal cambium.

B. Recently formed interxylary phloem island showing functional phloem (arrowhead).

C. Interxylary phloem island in the inner part of the stem showing obliterated phloem (arrow) that form a cap above functional phloem (arrowhead).

D. Portion of the pith in the mature showing intraxylary phloem. Note the non-functional obliterated phloem cap (arrow). Arrowhead indicates functional intraxylary phloem.

E. Development of internal cambium on the periphery of the pith (arrowhead). Arrow indicates functional sieve tube elements. Note the uni-multiseriate rays developed from the internal cambium (small arrowheads).

Scale bars- A-C, E: 75 μm; D: 100 μm.

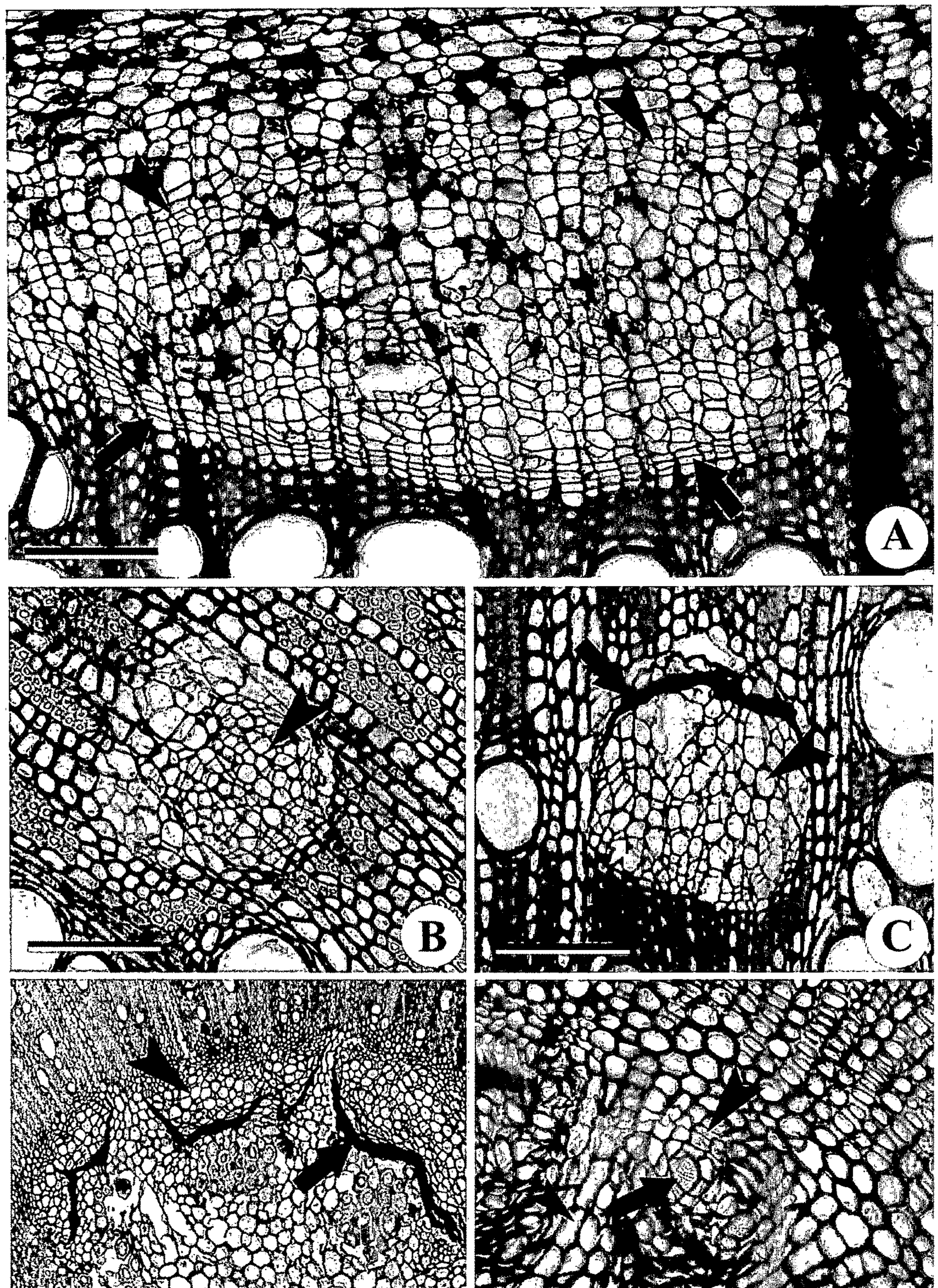

FIGURE-11

FIGURE - 12

Transverse view of young stems showing origin and development of medullary bundles in the pith region of *Argyreia nervosa* (Burm. f.) Bojer.

A. Young stem showing procambium, protoxylem (thin arrow) with differentiating metaxylem elements. Note the well-differentiated discrete strands of phloem (arrow) while arrowhead indicates presence of secretary ducts (arrowheads).

B. Origin of cortical bundles in pith region (arrowheads). Arrows indicate developing cortical bundles. Note the secretary duct adjacent to differentiating cortical bundle (thin arrow).

C. Differentiation of phloem elements in newly developing cortical bundle (arrowhead).

D. Well-developed cortical bundle with xylem and phloem elements. Arrowhead indicates metaxylem elements while arrow shows sieve tubes elements.

E. Origin and development of cortical bundles outside the pith region. Initiation of phloem development (arrowhead) while arrow indicates radial divisions in the cells to differentiate into cambium (arrow).

F. Well-developed cortical bundle with inverse orientation (arrow), differentiating xylem elements facing towards periphery. Arrowhead indicates newly developing cortical bundle, note that differentiation of phloem elements precedes that of xylem (arrowheads).

Scale bars- A-C: 25 µm; D-F: 50 µm.

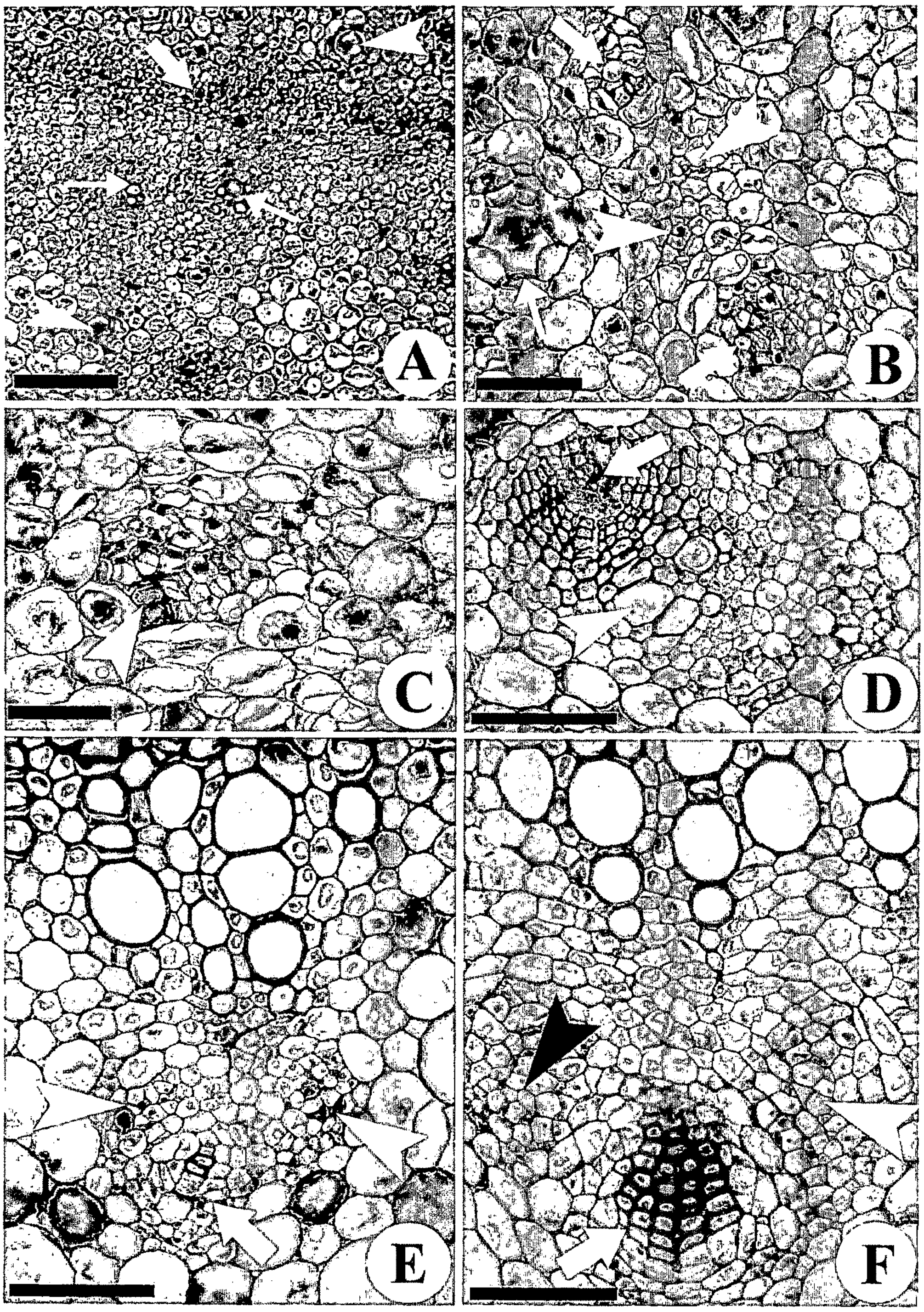

FIGURE-12

FIGURE - 13

Transverse view of mature stems showing development of medullary bundles in *Argyreia nervosa* (Burm. f.) Bojer.

A. Mature stem showing distribution of medullary bundles in the pith (arrowheads).

B. Crushed internal phloem. Arrows indicate medullary bundles.

C. Enlarged view of medullary bundle showing arrangement of xylem elements (arrowhead) and secretary duct (arrow).

D. Well-developed cortical bundle showing xylem and phloem and another newly developing cortical bundle (arrowhead).

E. Enlarge view of developing cortical bundle initially showing phloem differentiation and arrowhead showing sieve tube element with compound sieve plates.

Scale bars- A, B, D & E: 75 µm; C: 50 µm

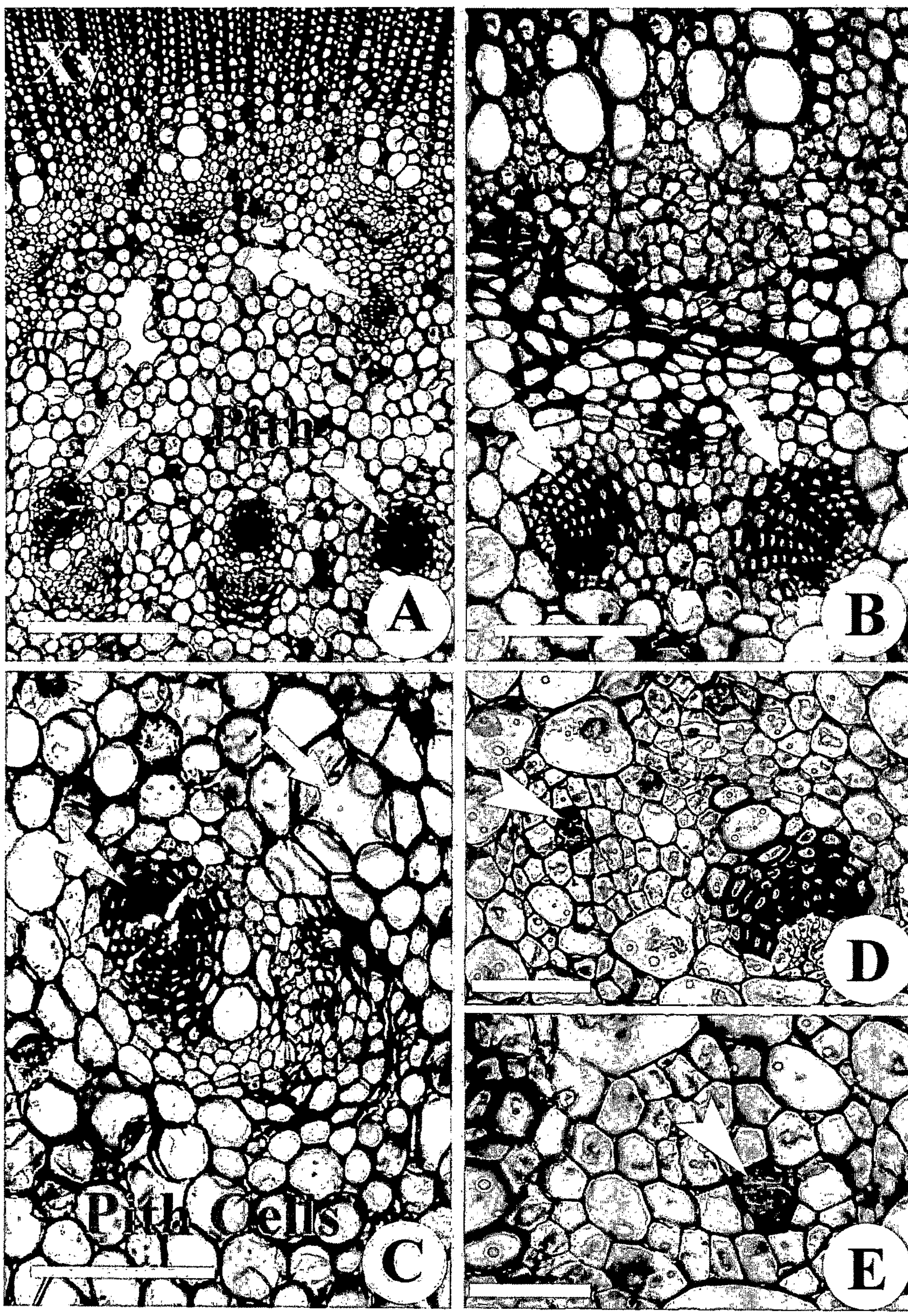

FIGURE-13

FIGURE - 14

Tangential longitudinal view of cambium (D) and Transverse view of young and mature stems of *Mirabilis jalapa* L. (A-D) *and Boerhaavia diffusa* L. (E-F), showing development of medullary bundles in the pith region

A. Distribution of medullary bundles in young stem with relatively less xylem derivatives. Arrowhead indicates medullary bundle.

B. Relatively mature stem showing more secondary xylem and larger medullary bundles (arrowhead).

C. Well developed medullary bundles in fully matured stem.

D. Semi-storied arrangement of cambial cells exclusively composed of fusiform cells.

E. Young stem showing successive rings of cambia and medullary bundles (arrowhead).

F. Successive rings of cambia in fully grown thick stem. Note that the entire pith is occupied by the medullary bundles (arrowhead).

Scale bars- A-F: 100 μm.

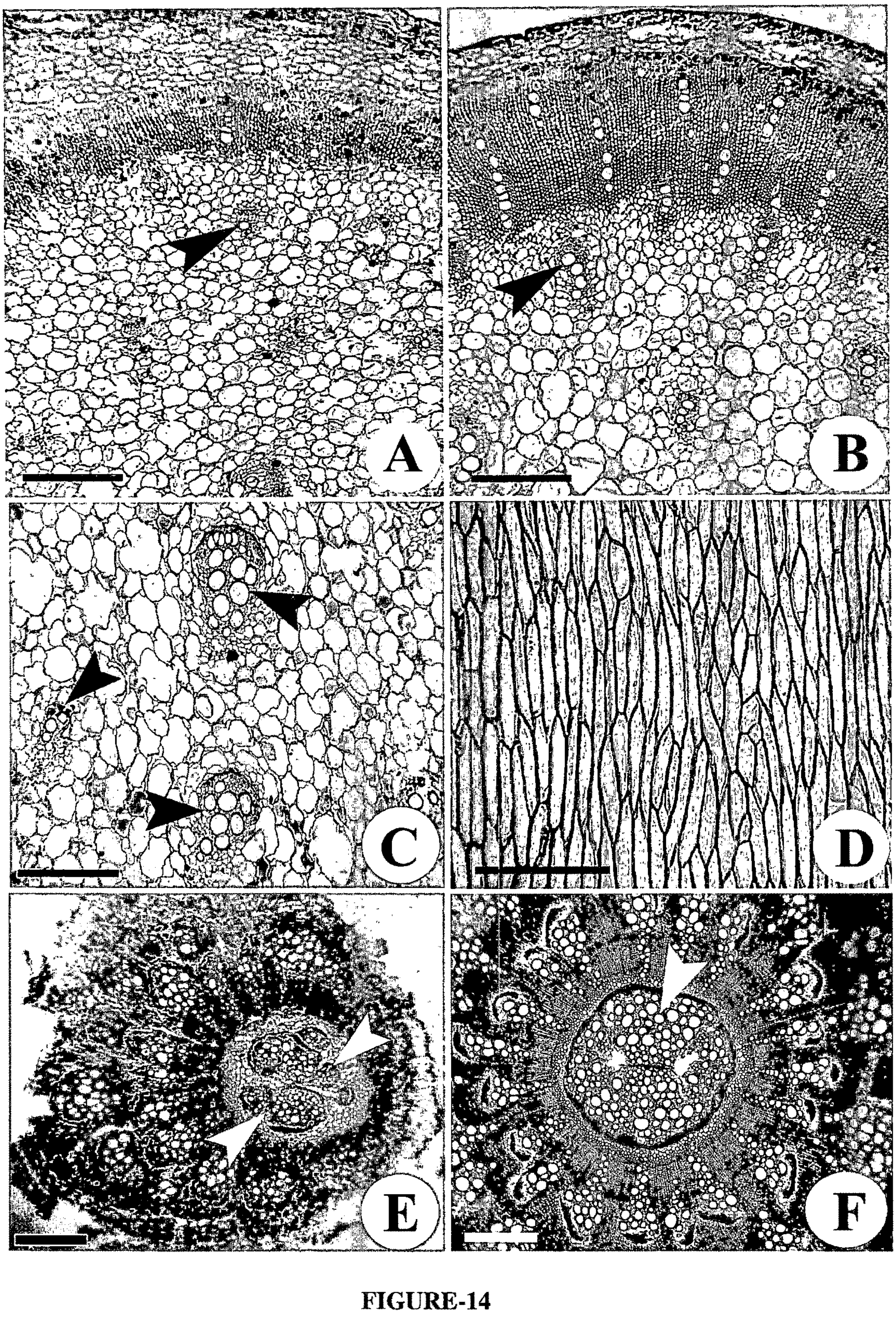

FIGURE-14

FIGURE - 15

Transverse sections of peduncle branches of *Couropita guianensis* Aubl., shows different types of cortical bundles and their arrangements.

A. Inverse orientation of cortical bundle (arrow) and indicating laterally arranged cortical bundle (thin arrow).

B. Newly differentiated cortical bundle (arrow) and thin arrow determines origination of new cortical bundle.

C. Concentric ring like cortical bundle showing recently formed vessel elements (arrow) and thin arrow shows bast fibres encircling the cortical bundle.

D. Bicollateral type of arrangement of phloem, where thin arrow shows cambium and arrow shows vessel.

E. Well established and newly developing cortical bundle showing cambium arranged opposite to each other (thin arrow) which results in production of xylem elements in opposite direction. In mature stem these bundles get separated gradually from each other.

F. Thin arrow showing cortical bundle which is in stage of division and forming two cortical bundles while adjacent bundle showing differentiating xylem elements (arrow).

Scale bars- A-B: 75 μm; C-D: 50 μm.

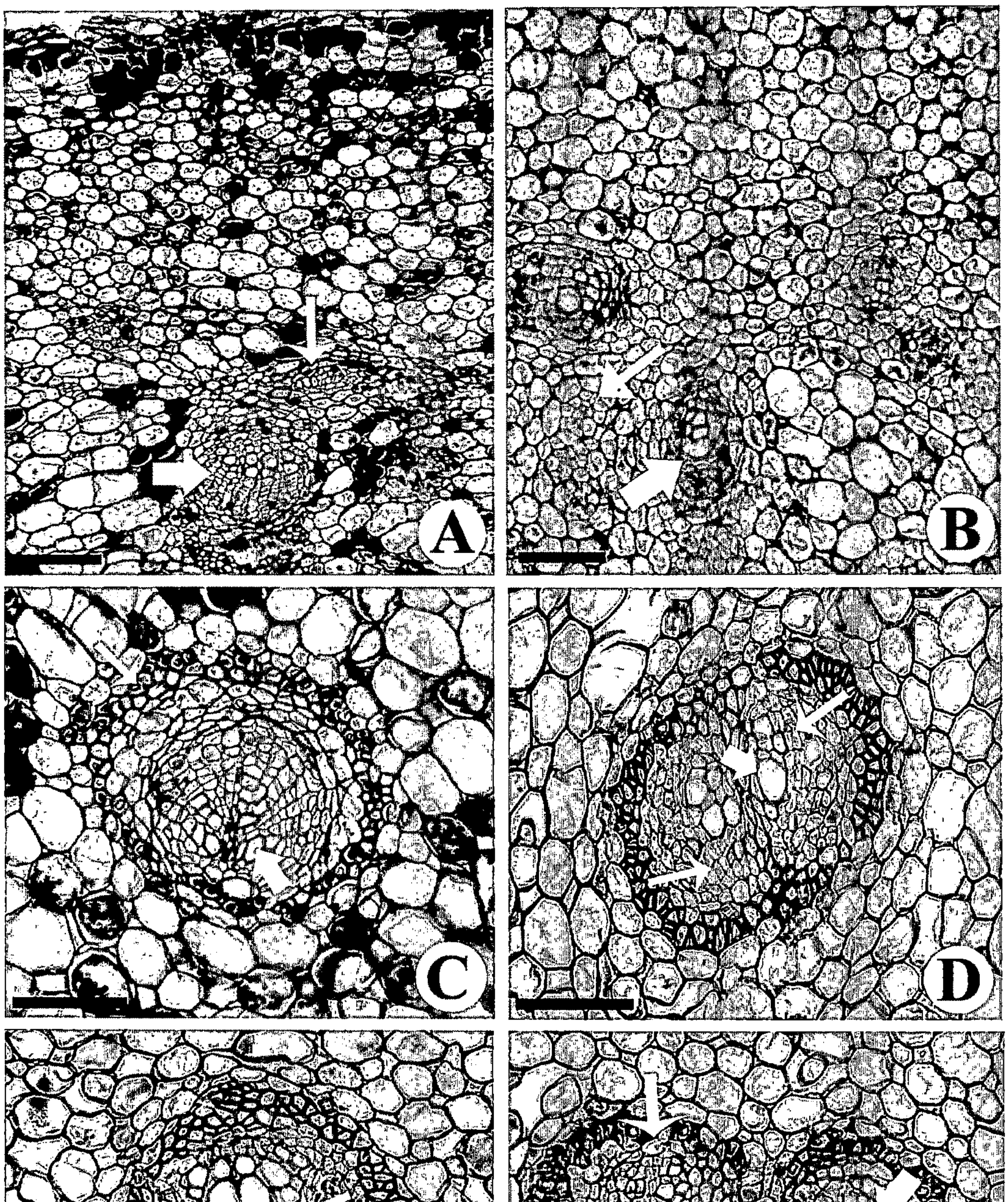

FIGURE-15

FIGURE – 16

Transverse sections of *Couropita guianensis* Aubl. showing different stages of cortical bundle development.

A. Enlarged view of cortical bundle getting separated from the main vascular ring.

B and C. Transverse sections shows main vascular bundle gradually gets separated from main vascular cylinder and pushing towards wide cortex.

D. Young stem showing newly originating, irregularly distributed cortical bundles (arrows).

E. Various stages of cortical bundles development, note the development of sieve tube elements (arrow). Note the adjacent pith cells free from tannin accumulation.

F. Relatively thick peduncle showing accumulation of tannin in adjacent pith cells.

Scale bars- A-F: 50μm.

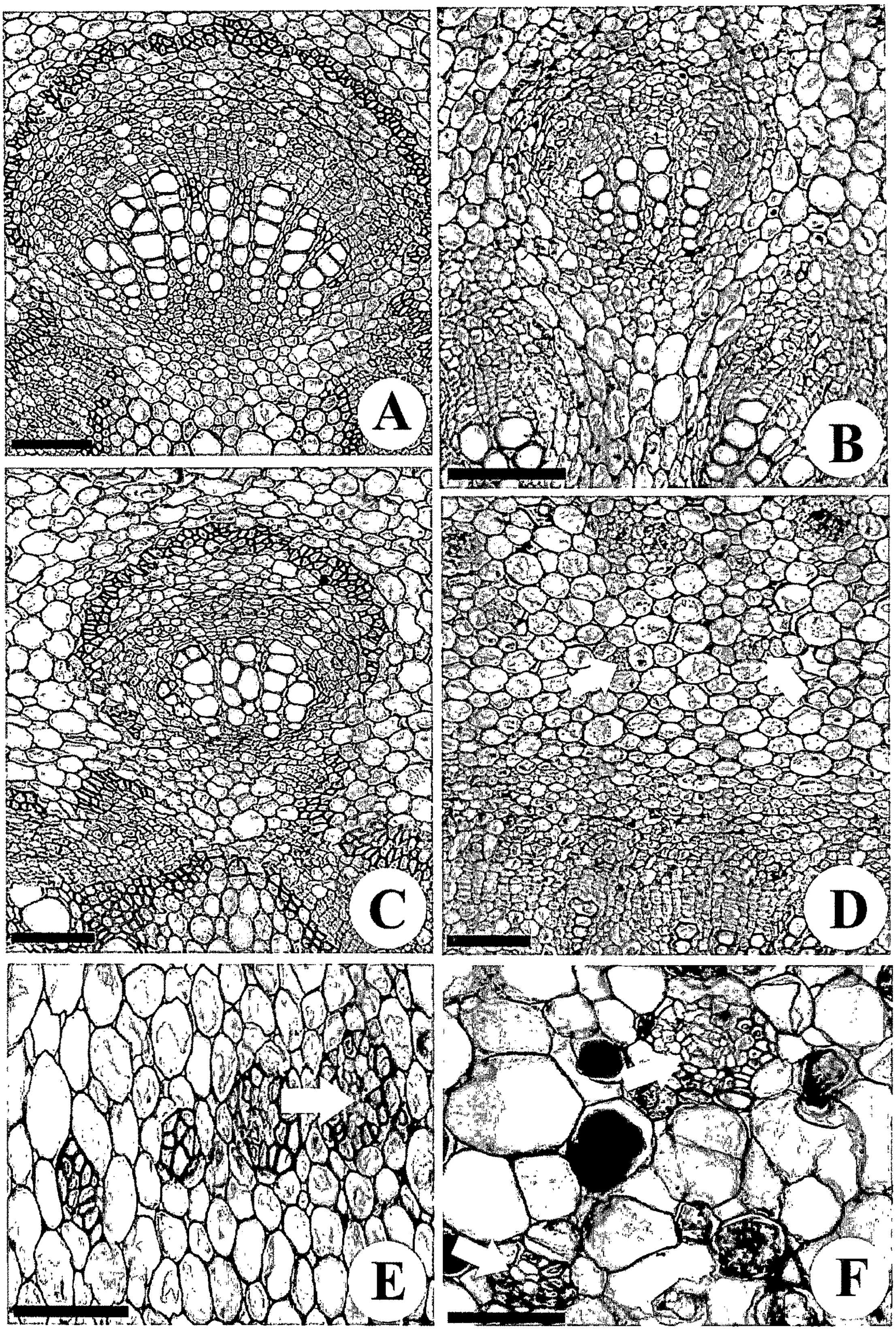

FIGURE-16

FIGURE - 17

Transverse views of young and matured stem of *Nyctanthes arbortristis* L.

A. Quadrangular young stem showing epidermis and trichomes. Note presence of cortical bundles at four corners of stem.

B. Young stem showing simultaneous origin of vascular cambium and cortical bundles. Arrowhead indicates development of protoxylem and protophloem (arrow) in cortical bundle and main vascular cylinder.

C. Relatively mature stem showing completely developed cortical bundle.

D. Thick mature stem showing well developed secondary xylem with vessel elements.

E. Developing cortical bundle showing radially arranged procambium (small arrow), sieve tubes elements strands (arrow) and differentiating metaxylem elements.

F. Enlarged view of well-developed cortical bundle. Note the well-developed xylem elements (arrowhead), phloem elements (arrow) and "C" shaped sclerenchymatous cap encircled the phloem (small arrow).

Scale bars- A-F: 100 μm.

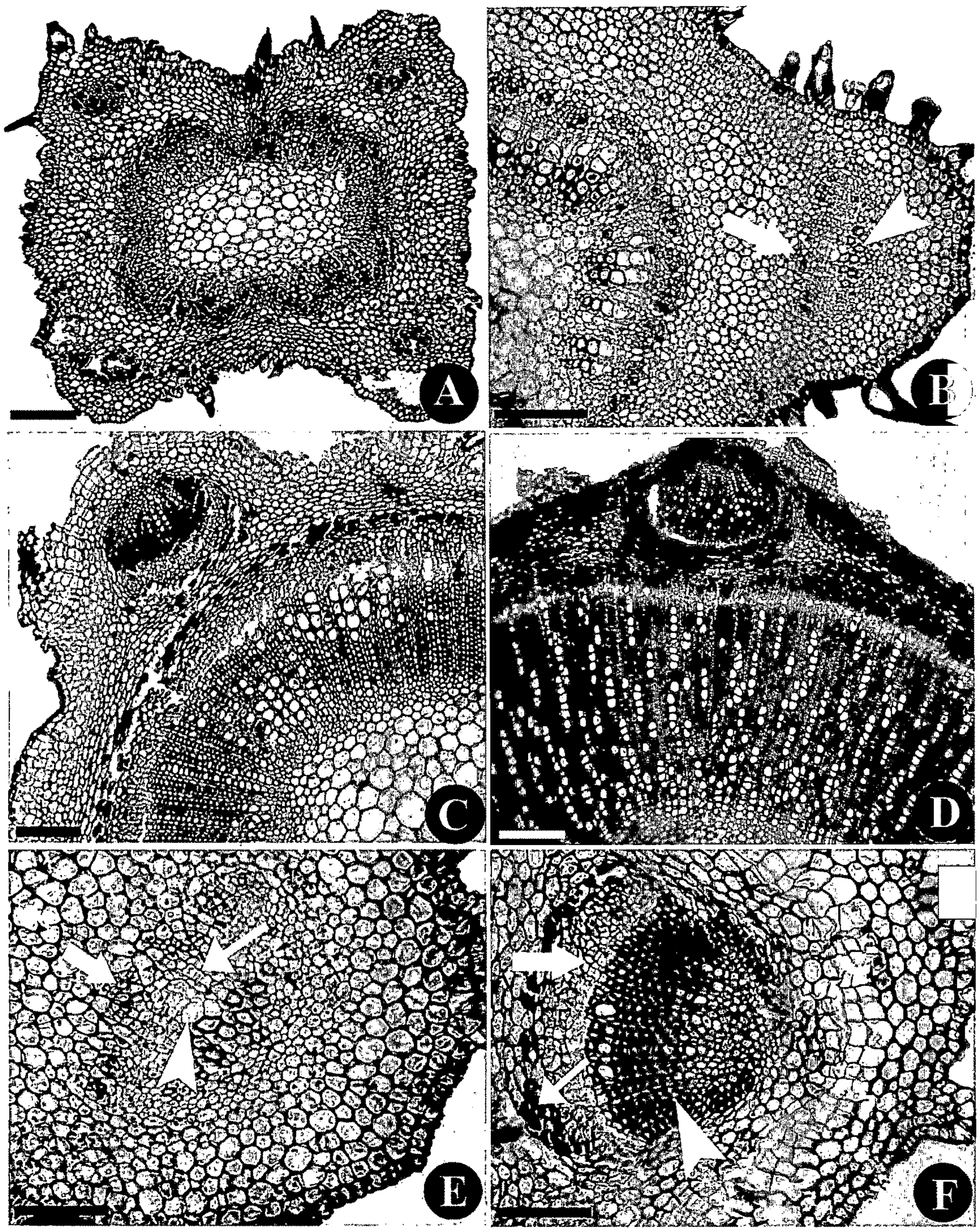

FIGURE-17

FIGURE - 18

Transverse (A, D, E) and tangential (B, C) view of stem and roots of *Spinacia oleracea* Linn., showing xylem structure and development of vascular cambium.

A. Mature stem showing successive rings of xylem embedded in parenchymatous groundmass of conjunctive tissue. Note the distinct vascular bundles in first ring of secondary xylem (arrowhead) while no such distinction was observed in outer rings.

B. Structure of xylem showing absence of rays in root.

C. Semi-storied arrangement of fusiform cambial cells showing absence of rays in the stem.

D. Development of a new ring of vascular cambium in stem. Arrowheads indicate origin of cambium from parenchyma cells outside the phloem produced by the previous cambium. Note the differentiating vessel element in the second ring of cambium (arrow).

E. Enlarged view of root showing origin of new cambium (arrow) and differentiation of phloem precedes that of xylem. Arrowheads indicate differentiated sieve tube element.

Scale bars- A-B: 150 µm; C-E: 100 µm.

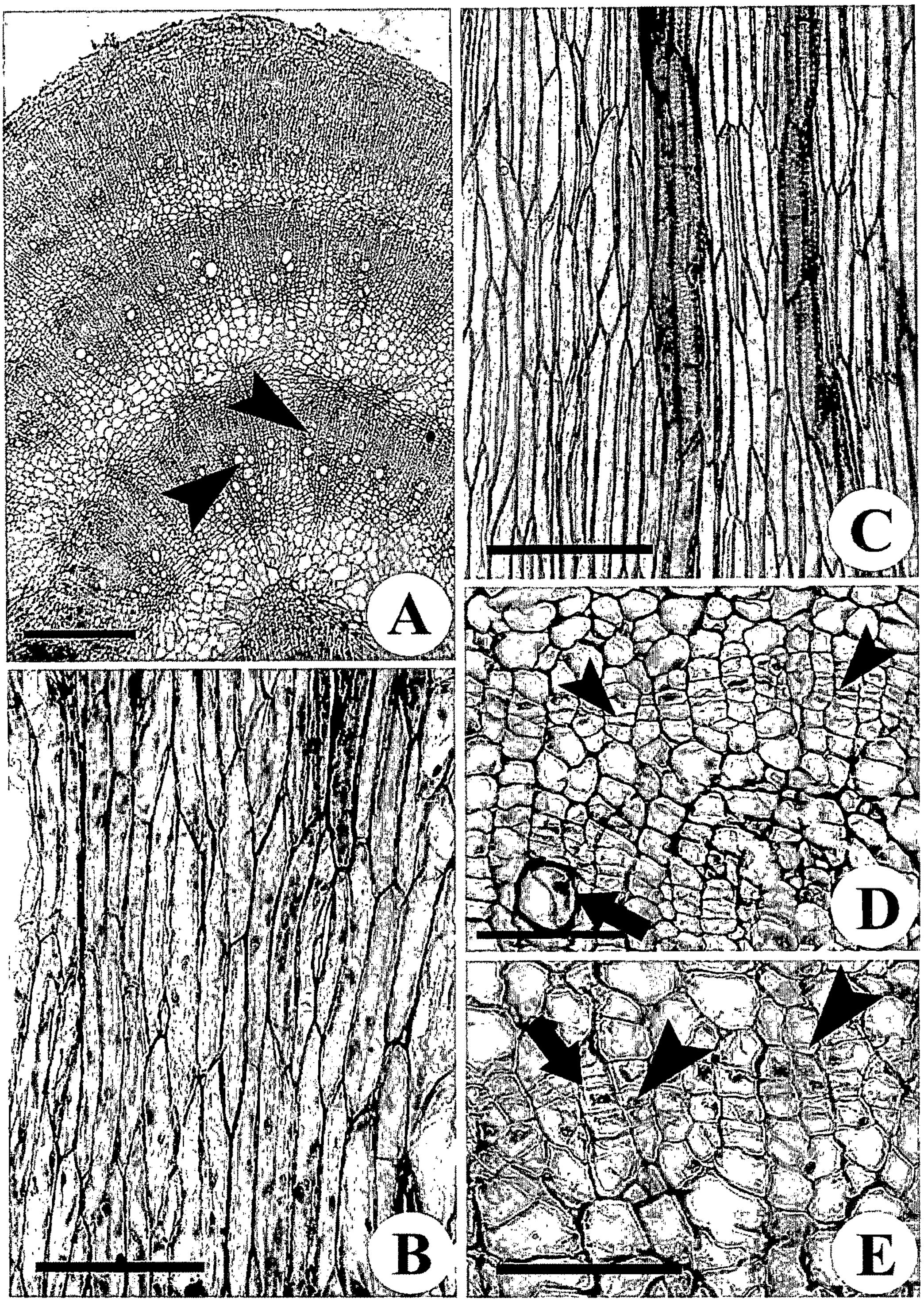

FIGURE-18

FIGURE - 19

Transverse view of roots of *Spinacia oleracea* Linn., showing xylem structure and development of vascular cambium.

A. Enlarged view of stem showing initiation of periclinal divisions (arrowheads) and development of new cambium. Arrows indicate cortical parenchyma between two successive rings of cambium that differentiate into conjunctive tissue.

B. Enlarged view of the root showing development of new cambial rings. Arrowhead indicates development of new cambial ring before the differentiation of enough number of xylem derivatives from the previous cambial ring. Arrows indicate cortical parenchyma between two successive rings of cambium that differentiated into conjunctive tissue.

C. Mature stem showing simultaneously active multiple cambial rings.

D. Part of the innermost ring of xylem showing differentiating vessel elements (arrowhead) in stem.

E. Enlarged view of Fig 2D showing mature vessels element (arrow) and differentiating vessel element (arrowhead).

Scale bars- A-E: 100 μm.

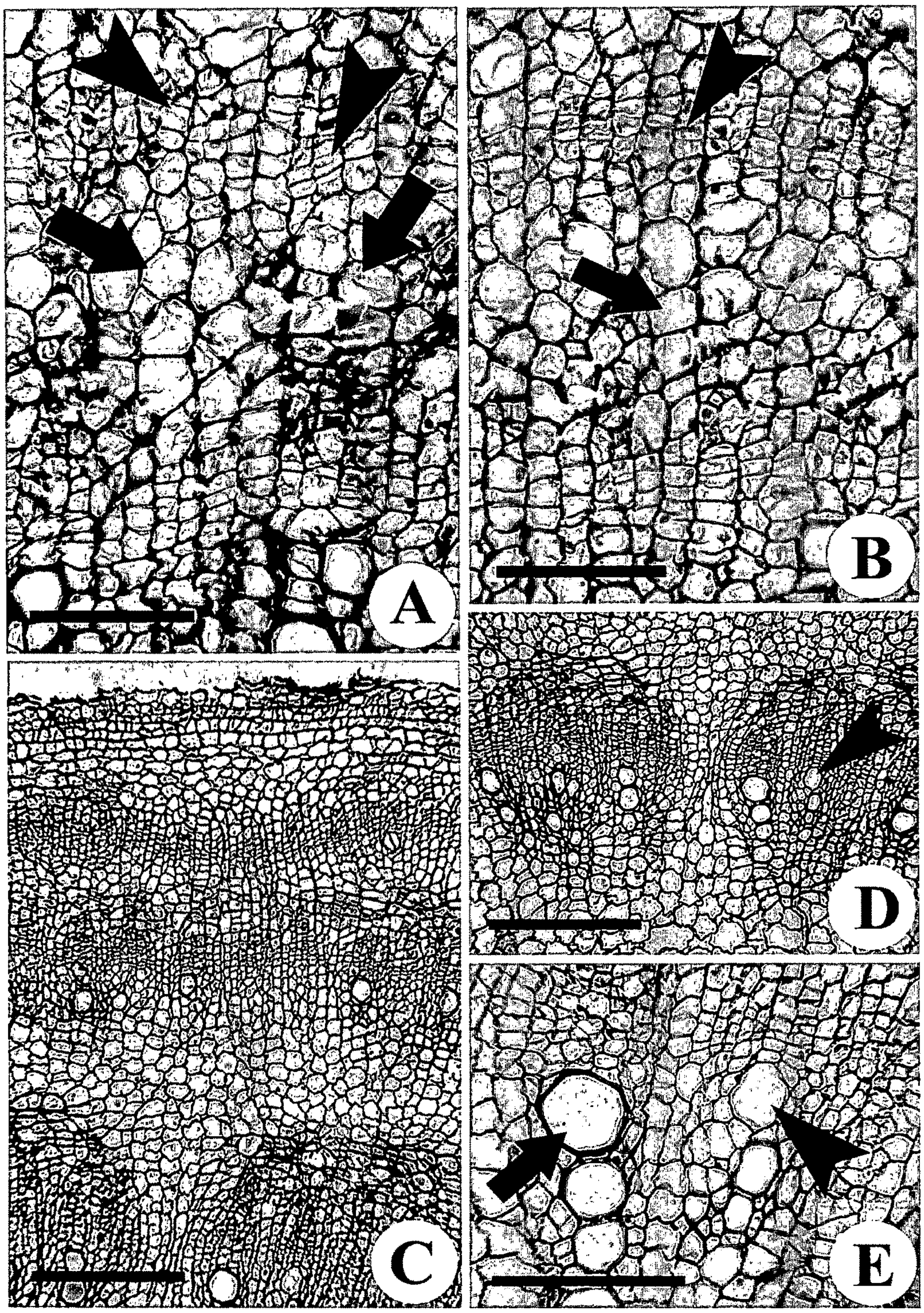

FIGURE-19

Figure – 20

Schematic diagrams showing the transverse view of *Cocculus hirsutus* (L.) Diels., stems.

A. Young stem showing first formed vascular elements (stem diameter 8 mm).

B. Stem showing two successive rings of xylem and phloem (stem diameter 15 mm).

C. Mature stem with three complete successive rings of xylem and phloem and a fourth incomplete ring (stem diameter 23 mm).

D. Flattened stem with eccentric successive cambia. Note lines represent successive cambia.

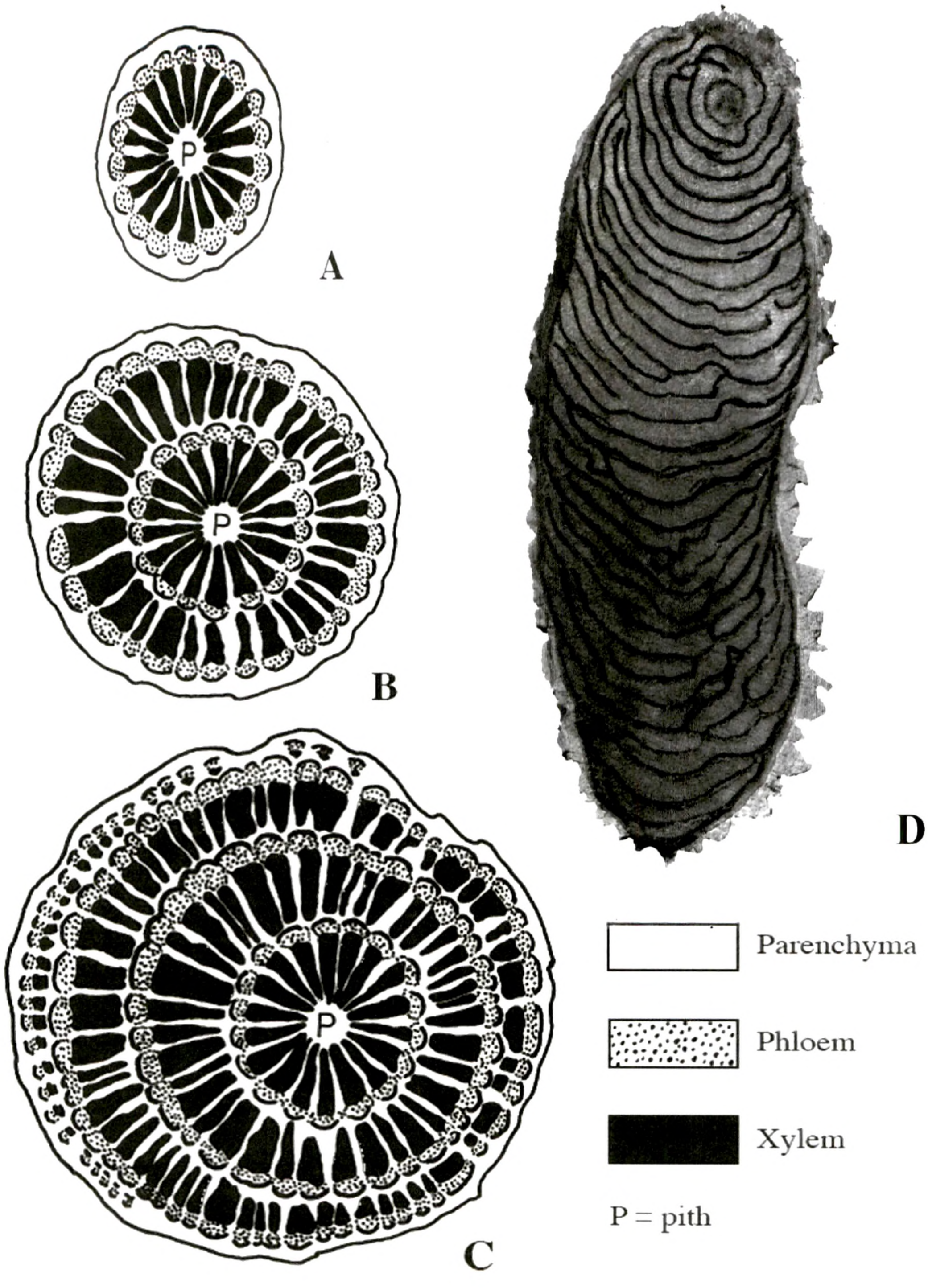

FIGURE-20

FIGURE - 21

Transverse (A-D) and tangential (E) stem sections of *Cocculus hirsutus* (L.) Diels.

A. Young stem section showing complete vascular cambium ring. Arrow shows pericyclic fibres which forms bundle cap of vascular bundle

B. Mature stem showing development of successive cambia.

C. Development of new vascular bundles from cortical parenchyma cells. Note the periclinally dividing cells developing into a complete ring of vascular cambium (arrowhead) and development of new cambium (arrow).

D. Newly formed cambium, showing development of a vessel element (arrowhead) and development of wide ray cells between two bundles.

E. Wide rays produced in the beginning of new cambium development in the fourth ring of vascular bundles. Note the width of rays and the small area occupied by axial elements.

Scale bars- A, C-E: 50 µm; B: 100 µm.

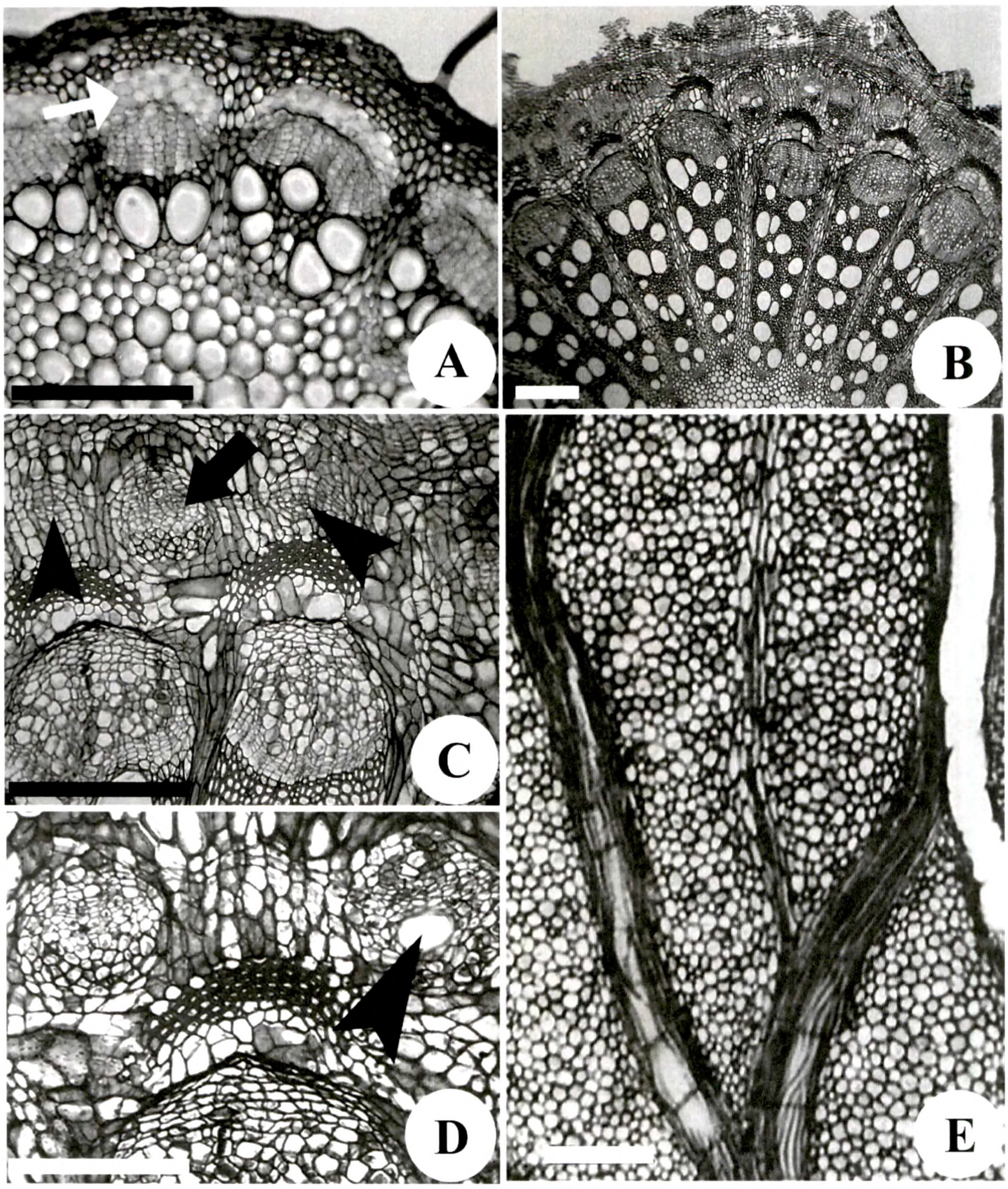

FIGURE-21

FIGURE - 22

Transverse (A-D) and tangential (E) stem sections of *Diploclisia glaucanscens* (Bl.) Diels.

A. Young stem showing complete ring of vascular cambium. Arrow shows pericyclic fibres which forms bundle cap of vascular bundle.

B. Mature stem showing development of successive cambia.

C. Development of new vascular bundles from cortical parenchyma cells. Note the periclinally dividing cells developing into a complete ring of vascular cambium (arrowhead).

D. Newly formed cambium, showing development of a vessel element (arrowhead) and development of wide ray cells between two bundles.

E. Secondary growth of plant shows sclereids formation in pith.

F. Vessel shows tyloses and note pits on sclerosed tyloses are oval oblong (arrowhead).

Scale bars- A, C-E: 50 µm; B: 100 µm.

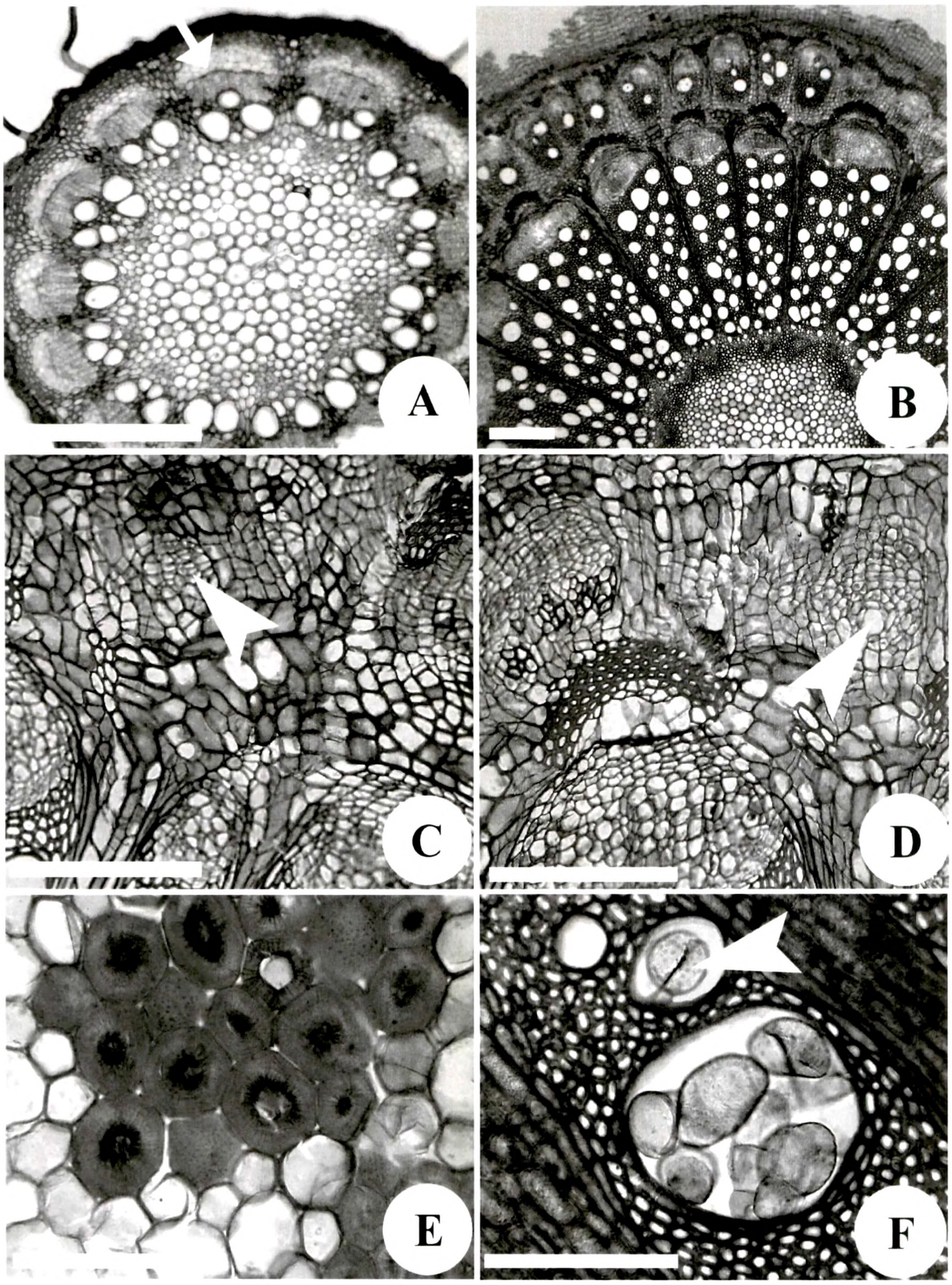

FIGURE-22

FIGURE - 23

Tangential (A, D, E) and transverse (B, C) stem sections of *Cocculus hirsutus* (L.) Diels.

A. Deformed circularly arranged fibres (arrows) among the ray cells.

B. Elongated thick walled cells at the margin of ray cells appearing like fibres (arrows). Note the relatively short and wide ray cells.

C. Isolated band of xylem fibres in one of the rays (arrow).

D. Narrow thick walled cells along the margins of rays (arrows) in tangential view.

E. Isolated band of fibres in xylem ray (arrow).

Scale bars- A-E: 150 µm.

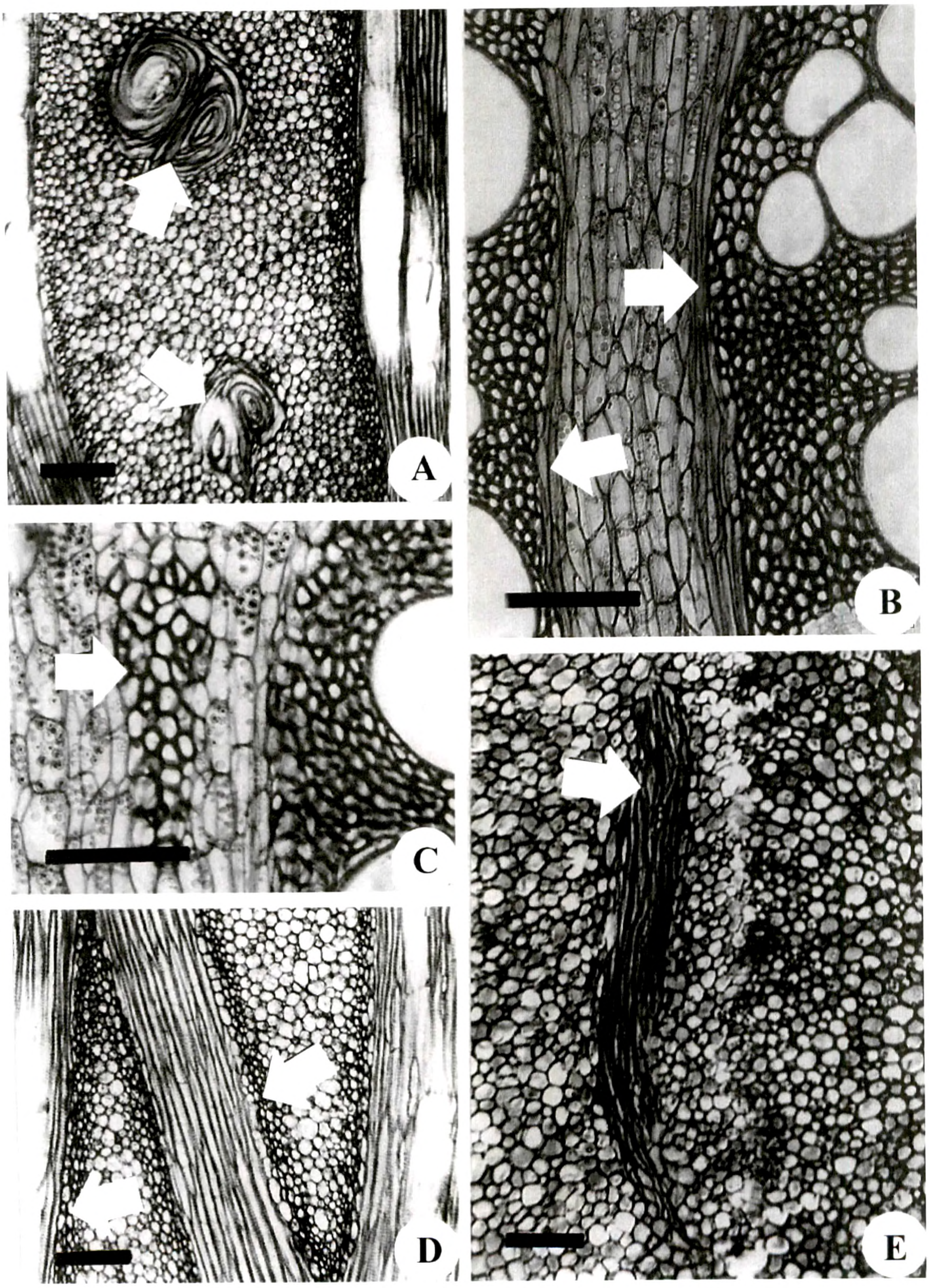

FIGURE-23

FIGURE - 24

Schematic diagrams (A-C) and transverse sections of young and mature stem (D, E) of *Antigonon leptopus* Hook. & Arn.

A. Young stem showing first formed vascular elements with developing successive ring (stem diameter 5 mm).

B. Stem showing three successive rings of xylem and phloem (stem diameter 9 mm).
C. Mature stem with three complete successive rings of lignified and unlignified xylem derivatives and phloem and a fourth incomplete ring (stem diameter 20 mm).

D. Young stem showing pentangular shape, primary vascular bundles forms a ring and epidermis covered with unicellular trichomes.

E. 5-6 mm stem showing development of successive cambia. Note star shaped pith region and cortical parenchyma accumulation of tannins.

Scale bars- D, E: 100 μm.

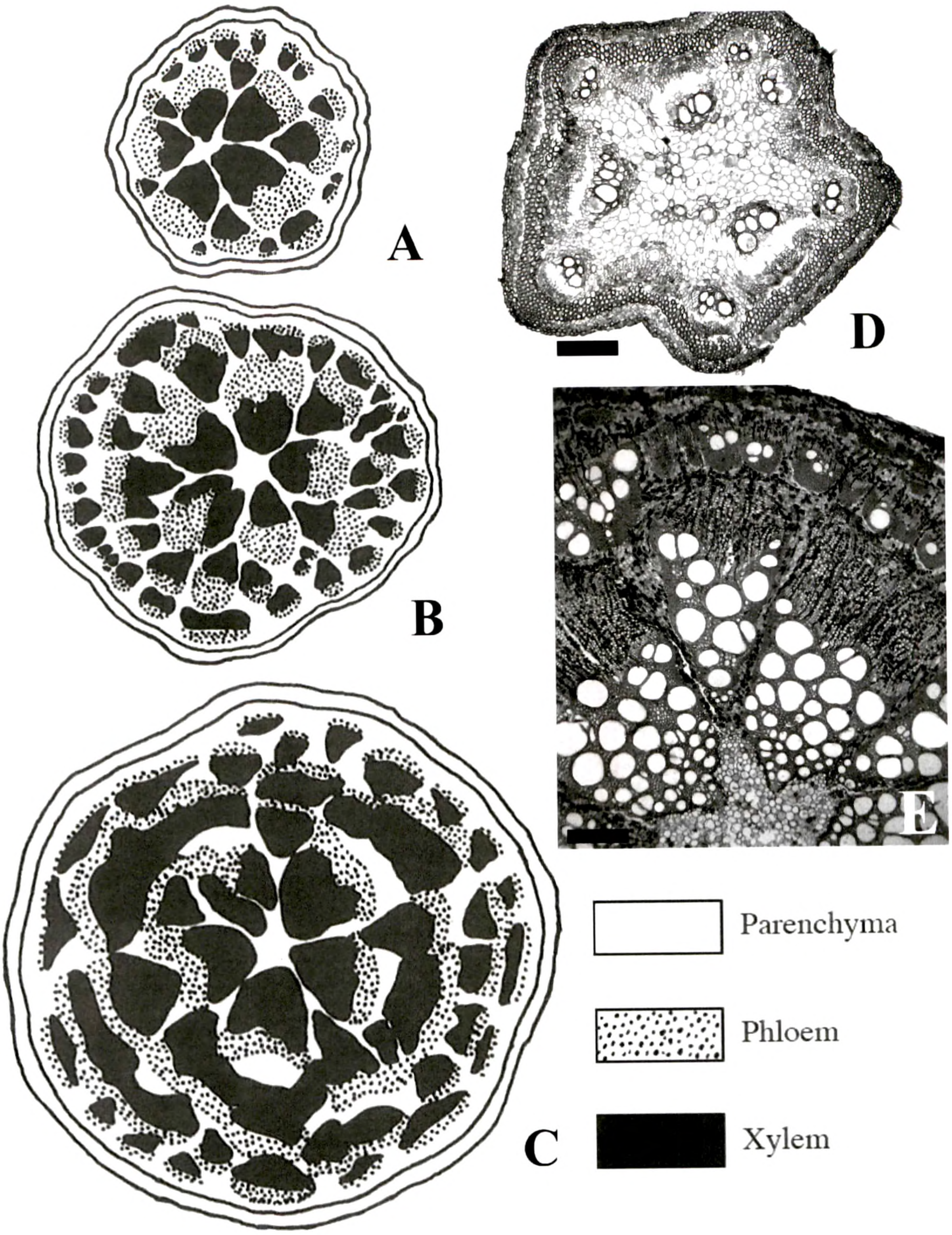

FIGURE-24

FIGURE - 25

Transverse sections of thick stem of *Antigonon leptopus* Hook. & Arn.

A. Outer part of the stem showing successive rings of xylem alternating with phloem.

B. Vessels are formed in the middle of xylem ring while there are no vessels in the early and later part of the secondary growth.

C. Xylem structure. Arrowhead indicates ground parenchyma.

D. Origin of cambium from the parenchyma cells located outside to the primary phloem (arrow) and newly developed successive bundle shows differentiating xylem parenchyma (arrowhead).

E. Development of new cambium (arrow) from cortical parenchyma cells. Note that phloem development starts first (arrowhead).

Scale bars- A-C: 100 μm; D, E: 50 μm.

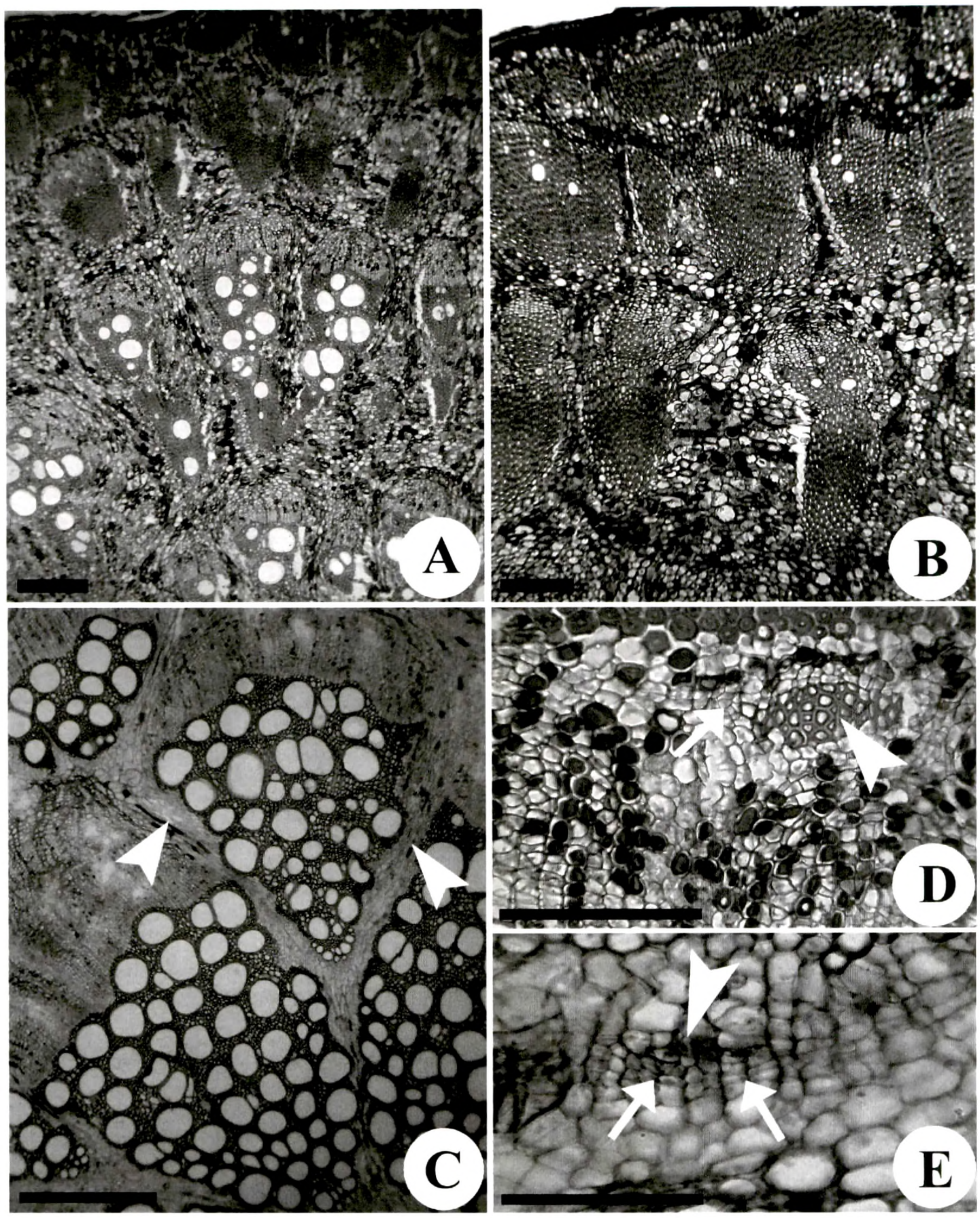

FIGURE-25

FIGURE - 26

Transverse section of *Dolichos lablab* L., stem segments showing the structure of the secondary xylem and different stages of cambium development.

A. Structure of the secondary xylem in mature stem. Note that exclusive differentiation of thin walled xylem derivatives from the cambium after the formation of few thick-walled xylem elements.

B. Formation of a new vascular bundle after repeated divisions in the secondary cortical parenchyma cells. The arrow shows a newly developed vascular bundle.

C. Enlarged view of the secondary cortical parenchyma showing the development of a new cambial segment. The arrowhead indicates newly formed sieve tube elements and radially arranged two-three layers of cambial cells (arrow). Small arrows indicate differentiating xylem elements.

D. Development of a vascular bundle from dilatating ray parenchyma cells (arrowhead). The arrow indicates dilatation of the ray. Note the orientation of vascular bundle.

E. Enlarged view of a dilatating ray parenchyma showing the development of a vascular bundle. Note the meristematic centre (arrows) formed from the ray parenchyma cells. Arrowheads show sieve tube elements indicating that development of phloem starts first followed by the xylem.

Scale bars- A-E: 25 µm.

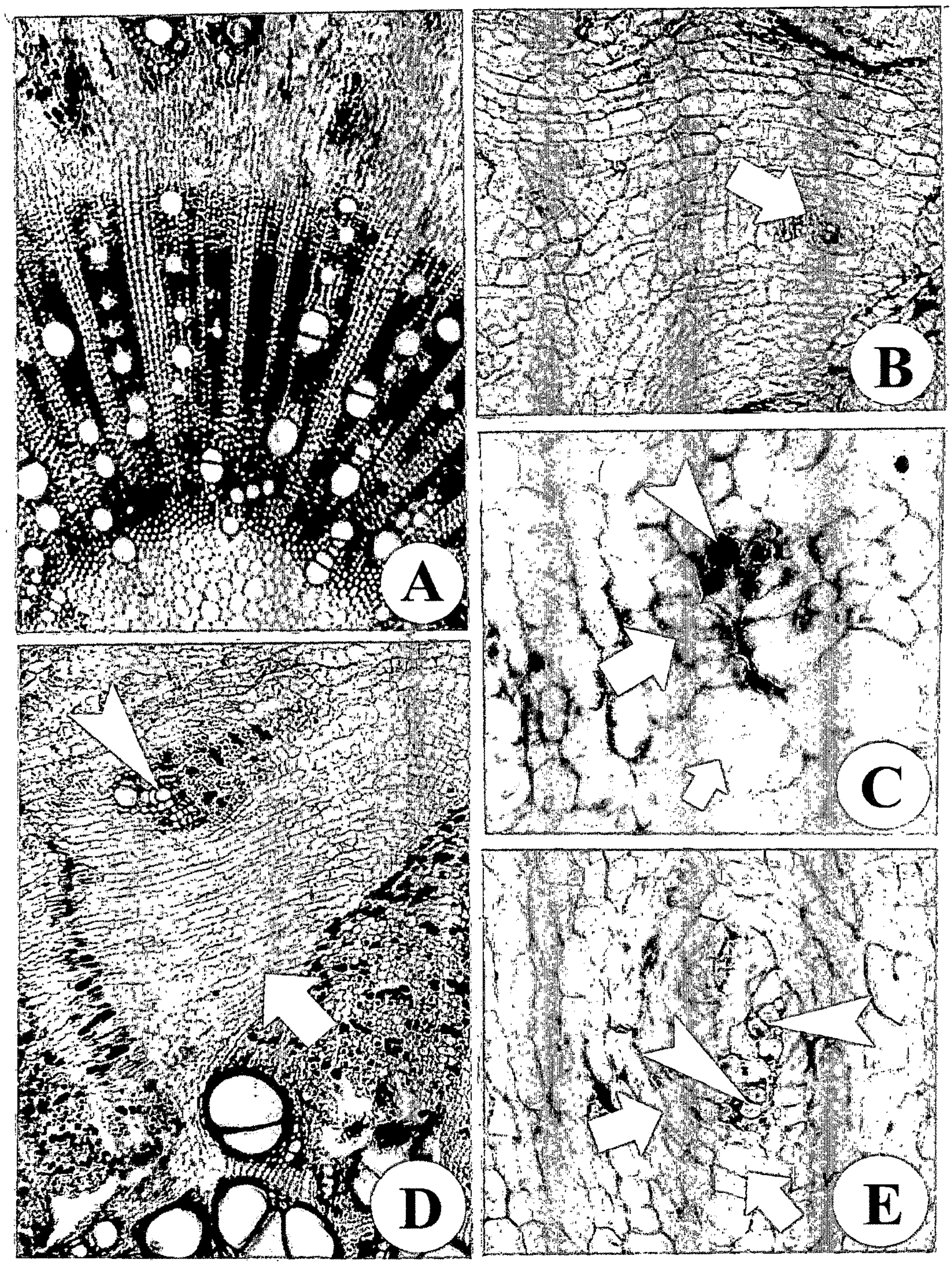

FIGURE-26

FIGURE - 27

Schematic diagram of *Dolichos lablab* L., showing the origin and distribution of normal and functionally reverse vascular bundles in transverse view.

A. Relatively young stem showing two rings. Note that the first normal ring of xylem is continuous while the second ring shows alternate bands of lignified and unlignified xylem derivatives.

B. Distribution of functionally normal and inverse vascular bundles. Note the reverse vascular bundles next to the first continuous ring of xylem.

C. Lobed stem showing a more dissected xylem and the distribution of isolated vascular bundles.

D. Mature stem showing the overall distribution of vascular bundles. Note the relatively more dissected nature of the xylem.

Scale bars- A: 8 mm; B: 12 mm; C: 15 mm D; 22 mm.

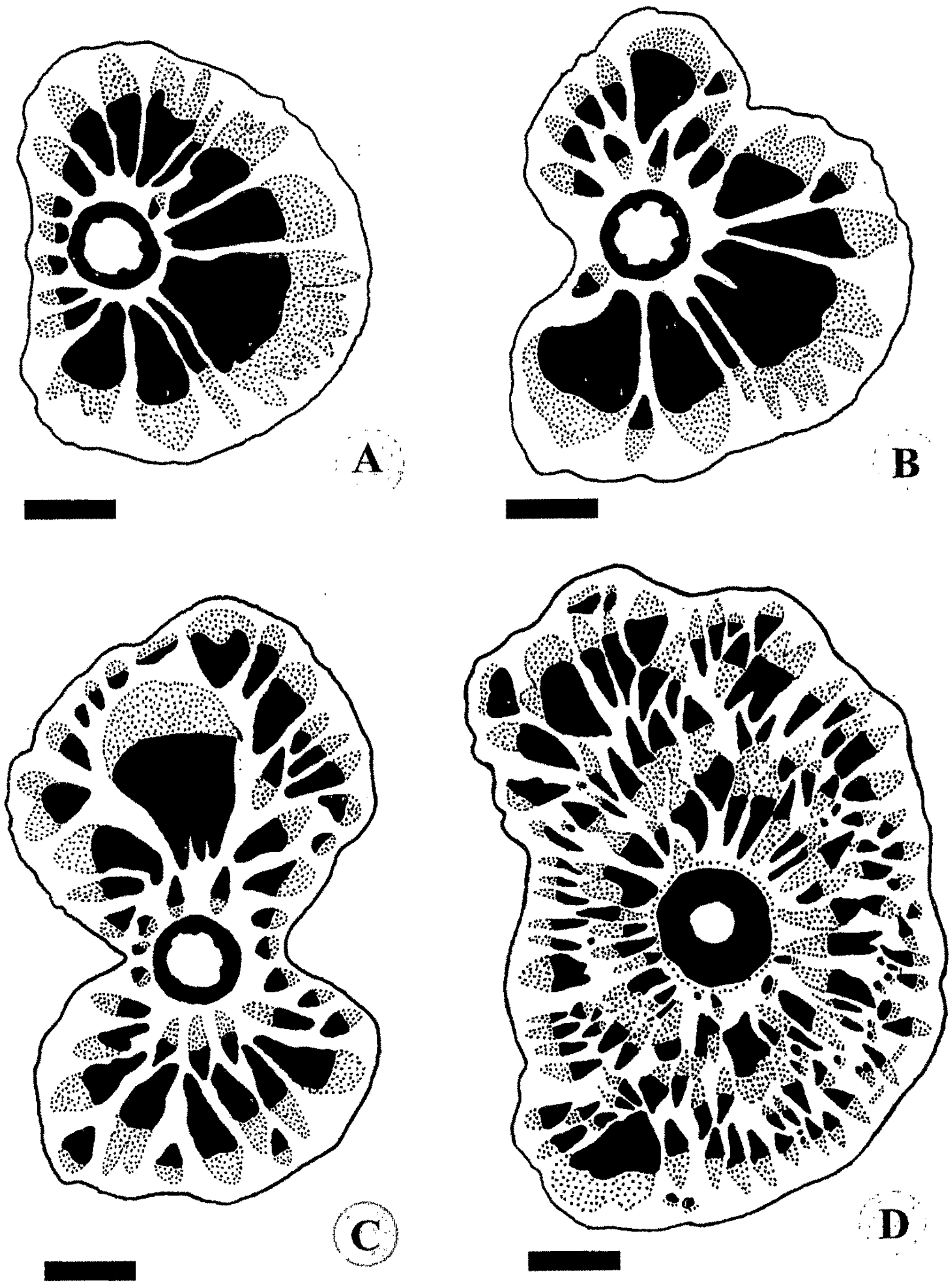

FIGURE-27

FIGURE - 28

Transverse view of the secondary xylem of a mature *Dolichos lablab* L. stem.

A. Secondary xylem showing the inverse orientation of vascular bundles (arrowhead) with the secondary xylem facing towards outside and the secondary phloem oriented towards the inner side. Note the adjacent normal vascular bundles (arrows). Square: following photograph.

B. Enlarged view of one of the vascular bundle from the previous (A) photograph showing the xylem oriented towards the periphery (arrowhead) and the phloem towards the centre (arrow).

C. Portion of a stem showing the phloem of two vascular bundles, one normal (arrow) and one reverse (arrowhead) facing each other.

D. Mature stem showing the irregular distribution of several vascular bundles.

Scale bars- A-D: 25 μm.

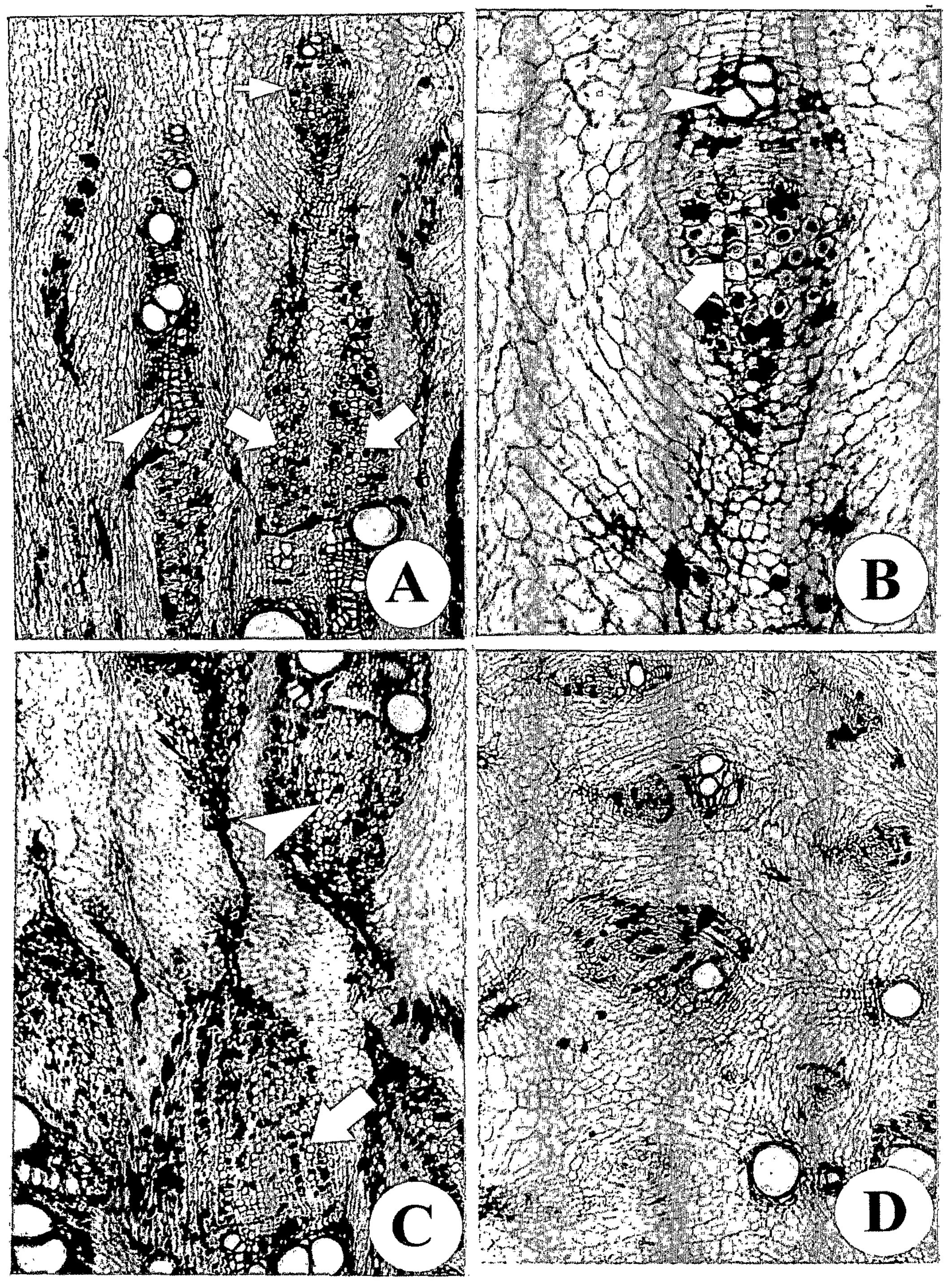

FIGURE-28

FIGURES - 29

Transverse section of stem showing origin of cambium in *Ipomoea hederifolia* L.

A. Parenchyma cells external to the phloem showing irregular divisions (arrow) that lead to the formation of a wide meristematic band. Arrowhead indicates the initiation of cell division in the parenchyma cells external to the phloem.

B. Repeated periclinal divisions in a wide meristematic band differentiating into radially arranged cambial cells (arrowheads). Note the recently developed sieve tube element (arrow).

C. Development of new cambial segment (showing reverse orientation) from the conjunctive tissue located at the base of the secondary xylem. Arrow and arrowhead indicate position of secondary xylem and phloem, respectively. V-vessel.

D. Enlarged view of Fig. 29C showing reverse orientation of secondary xylem (arrow) and phloem (arrowhead).

E. Recently differentiated cambium from the secondary cortex showing secondary xylem in upper right-hand corner (arrow) and, on the left, differentiating cambial segment (arrowhead).

F. Outermost two successive rings of secondary xylem showing normal secondary xylem and phloem.

Scale bars- A-E: 75 μm; F: 225 μm.

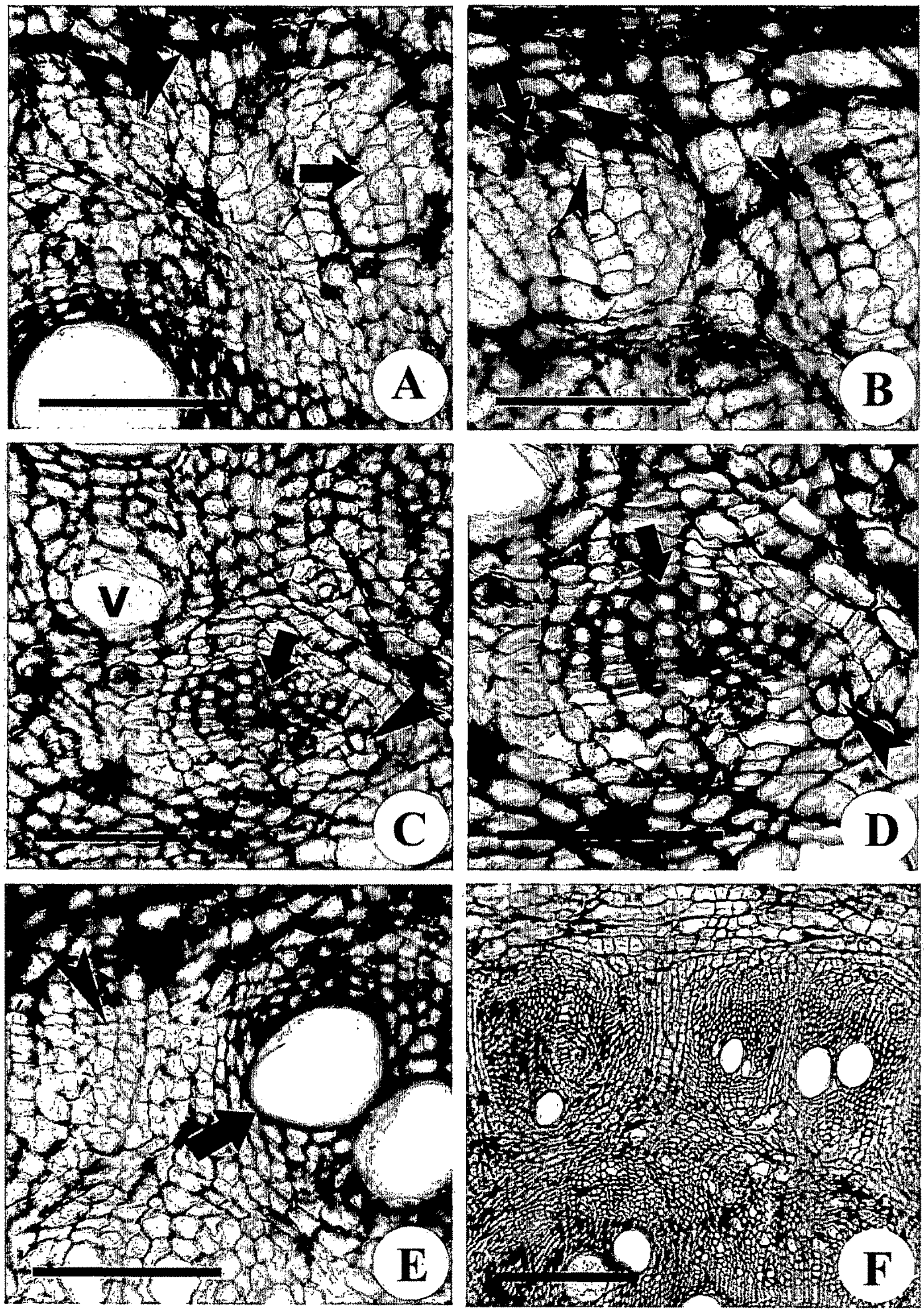

FIGURE-29

FIGURES - 30

Transverse view of secondary xylem in the stem of *Ipomoea hederifolia* L.

A. Successive rings of secondary xylem alternating with phloem. Note the discontinuous segments of xylem in the second ring (from lower side) showing xylem with reverse orientation (also see Fig. B).

B. Enlarged view of small portion from Figure A showing xylem with reverse orientation.

C. Origin of functionally reverse cambium (arrowhead) from the conjunctive tissue at the base of the xylem produced by previous cambium. Arrow indicates recently differentiated secondary phloem. Note the relatively large sized conjunctive tissue in the left corner. V, vessel.

D. Xylem showing the junction between two opposite xylem regions. Note the conjunctive tissue between the two opposite xylem regions.

Scale bars- A, B: 225 µm; C, D: 75 µm.

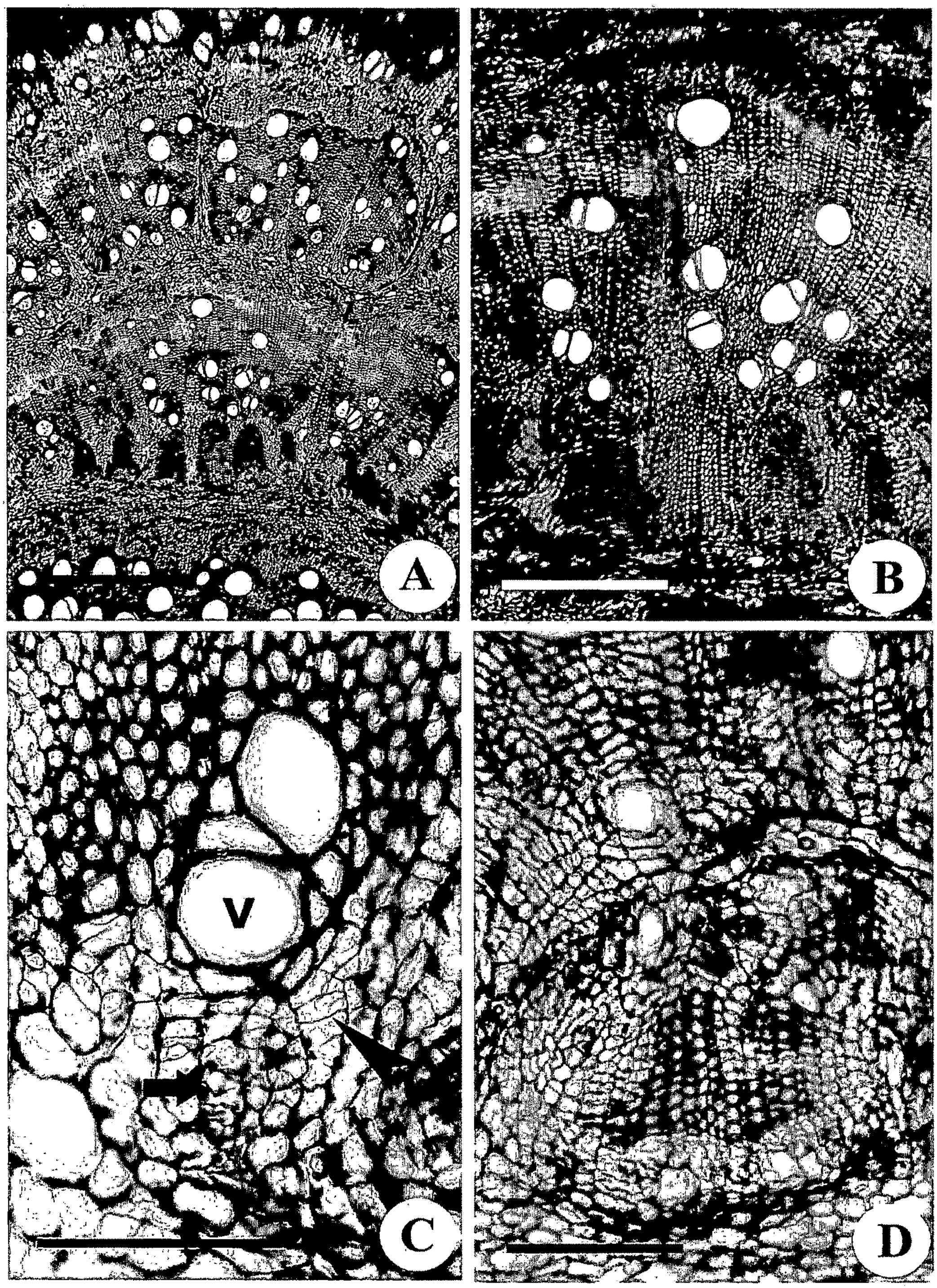

FIGURE-30

FIGURES - 31

Transverse view of secondary xylem in the stem of *I. quamoclit* Linn. (A, B) and *I. biloba* Forsk. (C-E).

A. Successive rings of secondary xylem alternating with phloem.

B. Development of inversely oriented cambium (arrowhead) from the conjunctive tissue at the base of the xylem produced by previous cambium Note the recently differentiated vessel element from inverse cambium (arrow).

C. Arrow shows differentiated vessel elements from reversely oriented cambium in *I. biloba.*

D. Lateral marginal calls of wide rays underwent repeated periclinal division differentiating into radially arranged cambial calls (arrowhead). Note recently developed vessel elements (arrows).

E. Repeated periclinal divisions in a wide meristematic band differentiating into radially arranged cambial cells (arrowheads) at the base of xylem produced by normal cambium. Note the recently developed vessel elements (arrow).

Scale bars- A, C: 150 μm; B, D, & E: 50 μm.

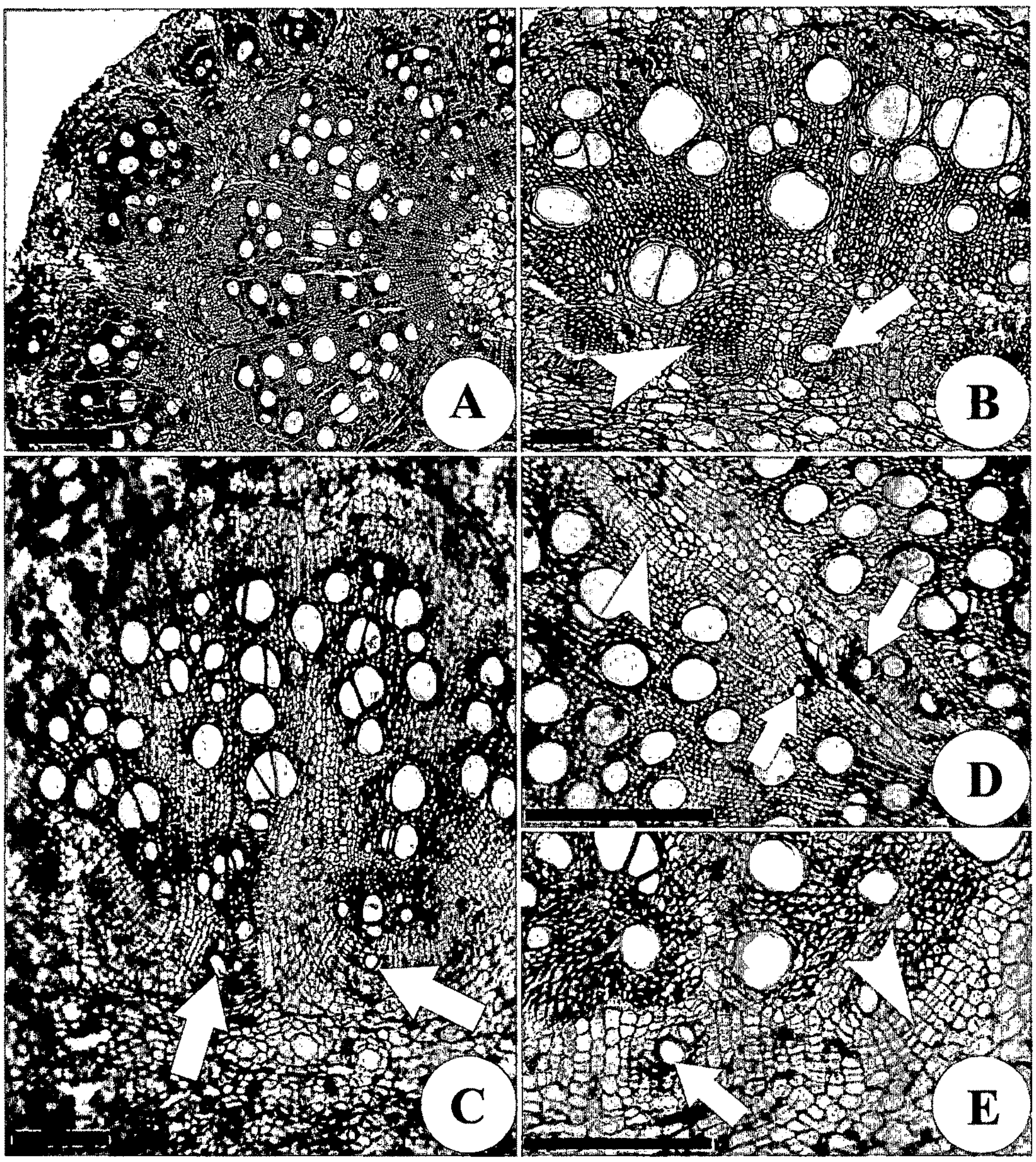

FIGURE-31

FIGURE - 32

Transverse section of mature stem of *Leptadenia reticulata* (Retz.) Wight &Arn., showing included phloem.

A. Distribution of included phloem in mature stem (arrowheads). Note the increase in size of included phloem islands from pith towards the periphery.

B. Newly differentiated sieve tube elements internal to and adjacent to the active cambium (arrowhead). Note the difference in sieve tube element diameter between external and included phloem.

C. Differentiating sieve tube elements internal to and adjacent to the active cambium (arrowheads).

D. Included phloem island surrounded with thick-walled lignified xylem elements. Arrowheads indicate fully differentiated sieve tube elements.

E. Distribution of included phloem in mature stem. Arrowhead indicates fully differentiated sieve tube elements.

F. Obliteration of non-functional included phloem (arrowhead). Note the radial and tangential expansion of adjacent parenchyma cells (arrow). CZ - cambial zone.

Scale bars- A-F: 100 μm.

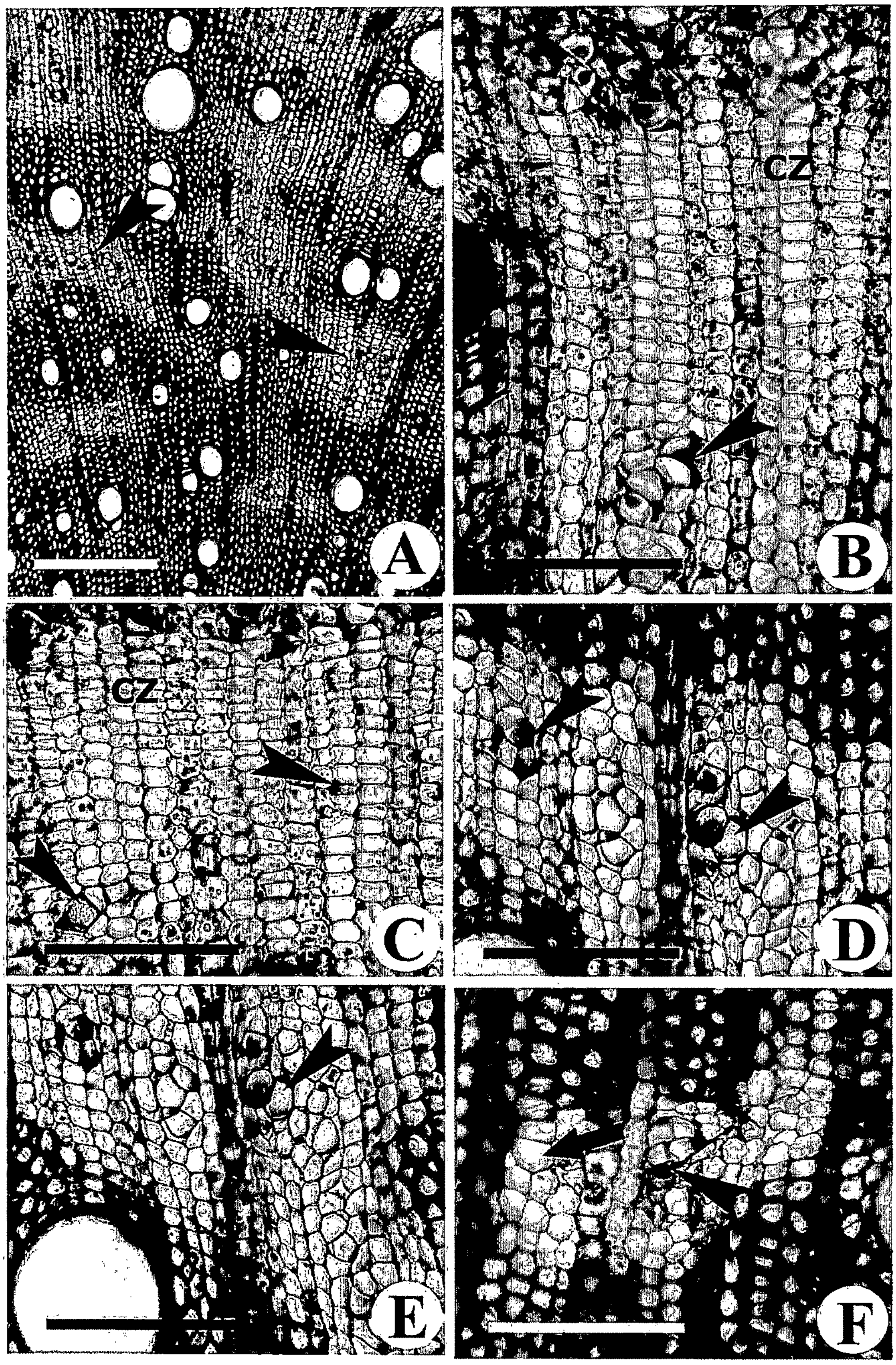

FIGURE-32

FIGURE - 33

Transections of stem secondary xylem (A, C-E) and tangential section (B) of *Salvadora persica* L.

A. Secondary xylem showing distribution of interxylary phloem strands of various sizes (arrowheads), axial parenchyma present as wide aliform ellipses. Note darkly staining patches in each island shows crushed old sieve tubes elements (arrows).

B. Storied arrangement of fusiform cambial cells and cambial rays shows uni-multiseriate arrangement.

C. Some places cambium differentiated into parenchyma cells instead xylem elements (arrows), otherwise some places cambial activity normal produces xylem elements (arrowhead). Note recently produced phloem islands (Black arrowheads).

D. Meristematic parenchyma cells behave like cambium, differentiated into new sieve tubes elements (arrows) while older sieve elements degenerated shows more darkly staining patches in each island (arrowhead).

E. Enlarge view of secondary xylem shows axial parenchyma with embeded islands of interxylary phloem. Arrowheads shows developing interxylary sieve tubes elements and companion cells and arrow showing parenchymatous cells which later become meristematic leads to interxylary phloem development.

Scale bars- A-E: 75 µm.

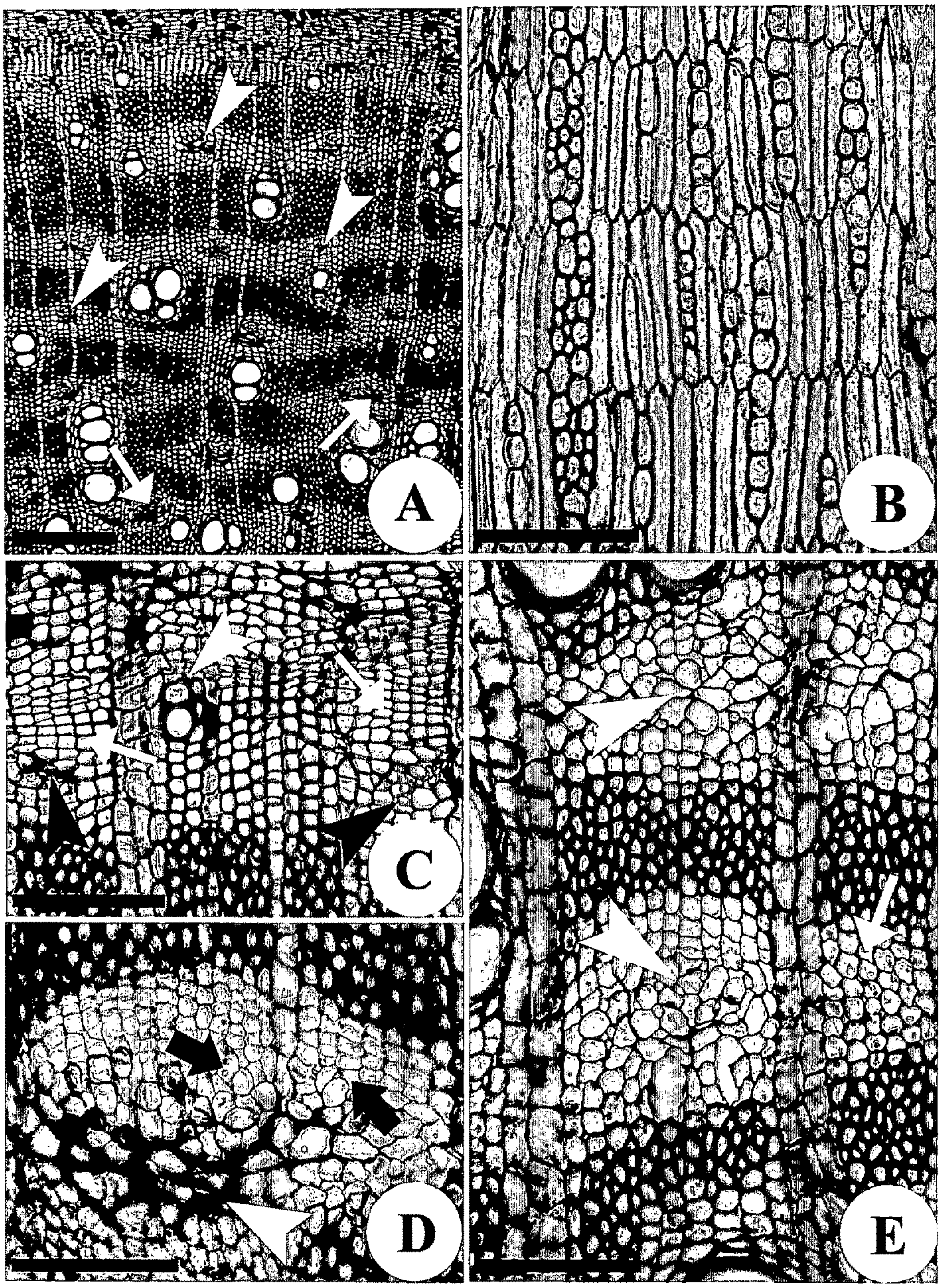

FIGURE-33

FIGURE - 34

Transverse views of secondary xylem in the mature stem of *Coccinia indica* L.

A. Enlarged view of part of Fig. 34B. Note the sheathing of xylem fibres (arrowheads) around the vessels and bands of axial parenchyma (arrows) in the back ground.

B. Bicollateral vascular bundle in one of the wide rays (arrow) and arrowhead indicates ray concentric cambia in the pith region (arrows).

C. Enlarged view of Fig. 34B showing bicollateral vascular bundle with large vessels (arrow) and phloem elements on either side of it (arrowheads).

D. Enlarged view of pith region of Fig.34B with concentric rings of cambia (arrowheads).

Scale bars- A-D: 150 μm.

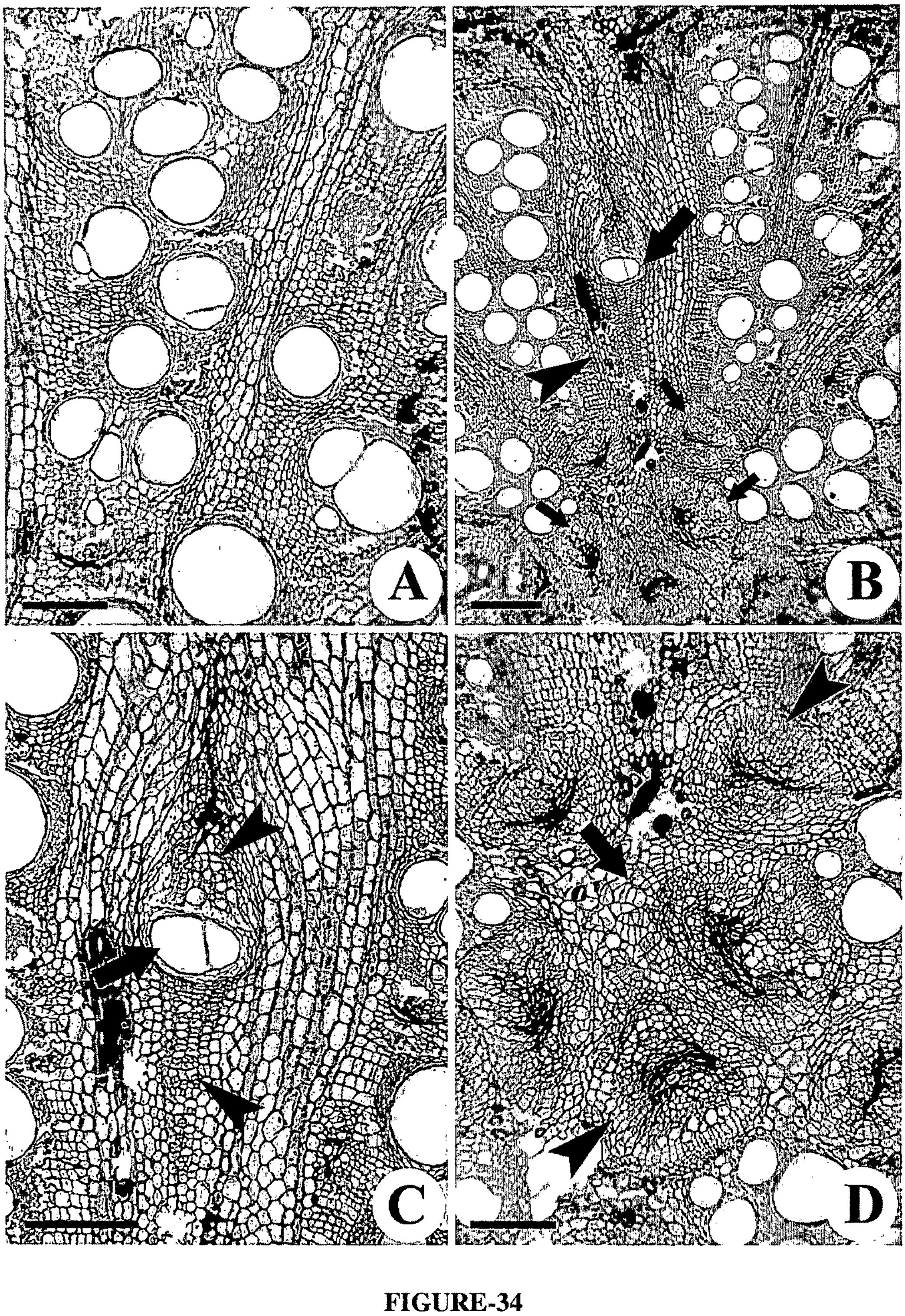

FIGURE-34

FIGURE - 35

Macerated xylem fibres (A), transverse (B) and tangential longitudinal view (C-E) of vessel elements of *Coccinia indica* L.

A. Fibre dimorphism. Arrowheads indicate relatively narrow septate fibres with thick walls and arrows indicate non-septate fibres with relatively wide lumina and larger simple pits.

B. Vessel with tyloses (arrowhead). Note the minute starch grains in the tyloses.

C. Vessel elements with simple to bordered pits (arrowheads).

D. Vessel wall showing pseudo-vestured pits (arrowhead).

E. Enlarged view of figure 2D showing pseudovestures (arrowheads) in the bordered pits.

Scale bars- A-D: 150 μm; E: 50 μm.

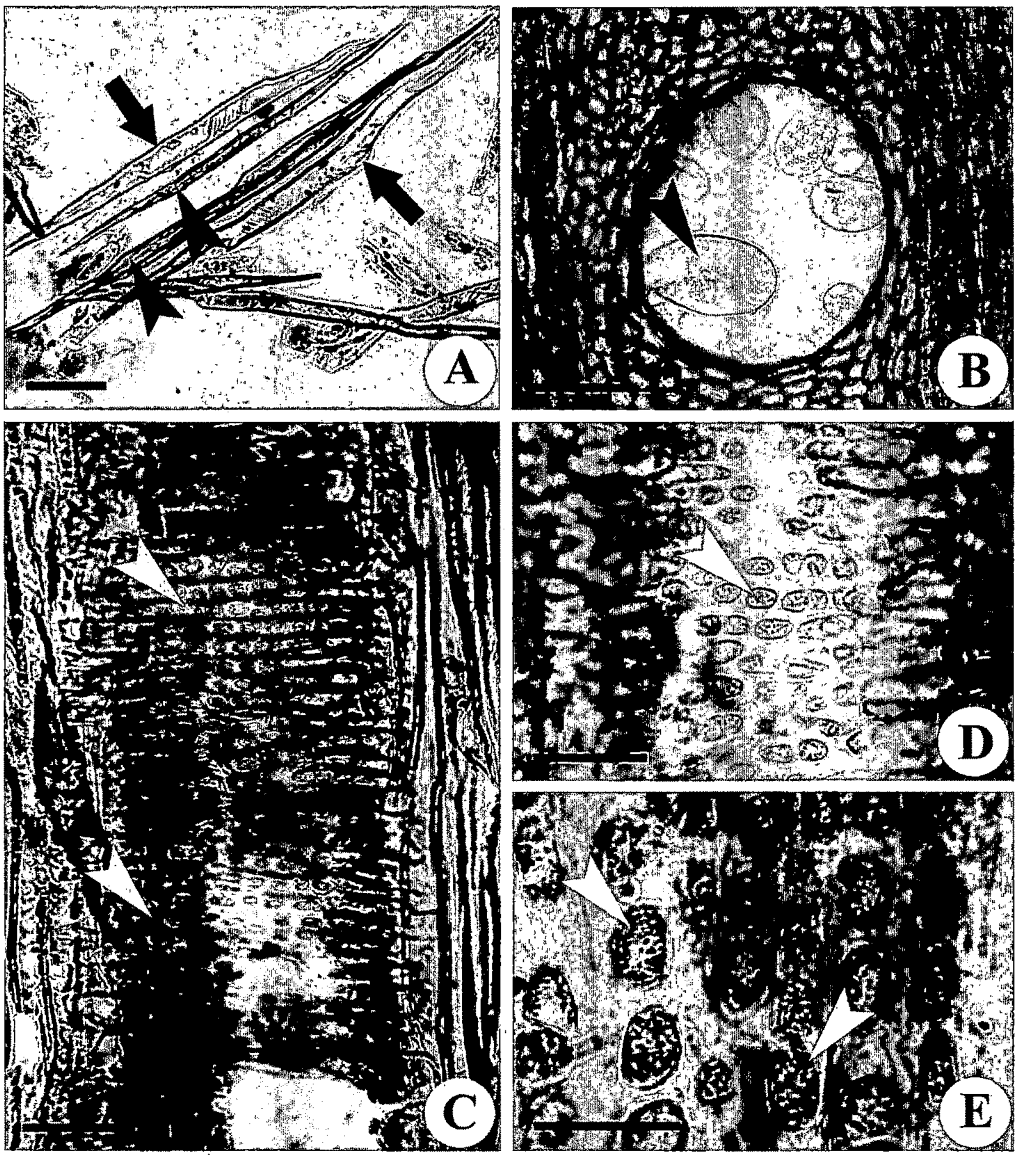

FIGURE-35

FIGURE - 36

Transverse views of mature stem of *Coccinia indica* L.

A. Parenchymatous ground tissue showing development of interxylary phloem (upper arrowhead) and concentric rings of cambia (lower arrowhead). Also note the development of interxylary phloem from the parenchyma cells on either side of the vessel (small arrows).
B. Enlarged view of the Fig. 36A showing development of concentric ring of cambium adjacent to one of the vessel element (arrow). Arrow indicates obliterated nonfunctional phloem.
C. Axial parenchyma cells undergo repeated cell division to form meristematic regions that differentiate into sieve tube elements of interxylary phloem (arrowhead).
D. Enlarged view of Figure 36C (upper vessel with astirisk) showing interxylary meristematic regions (arrowheads) with interxylary phloem (arrow).
E. Enlarged view of Figure 36C (lower vessel with asterisk) showing interxylary meristematic region (arrowhead) with interxylary phloem (arrows).

Scale bars- A-E: 150 μm.

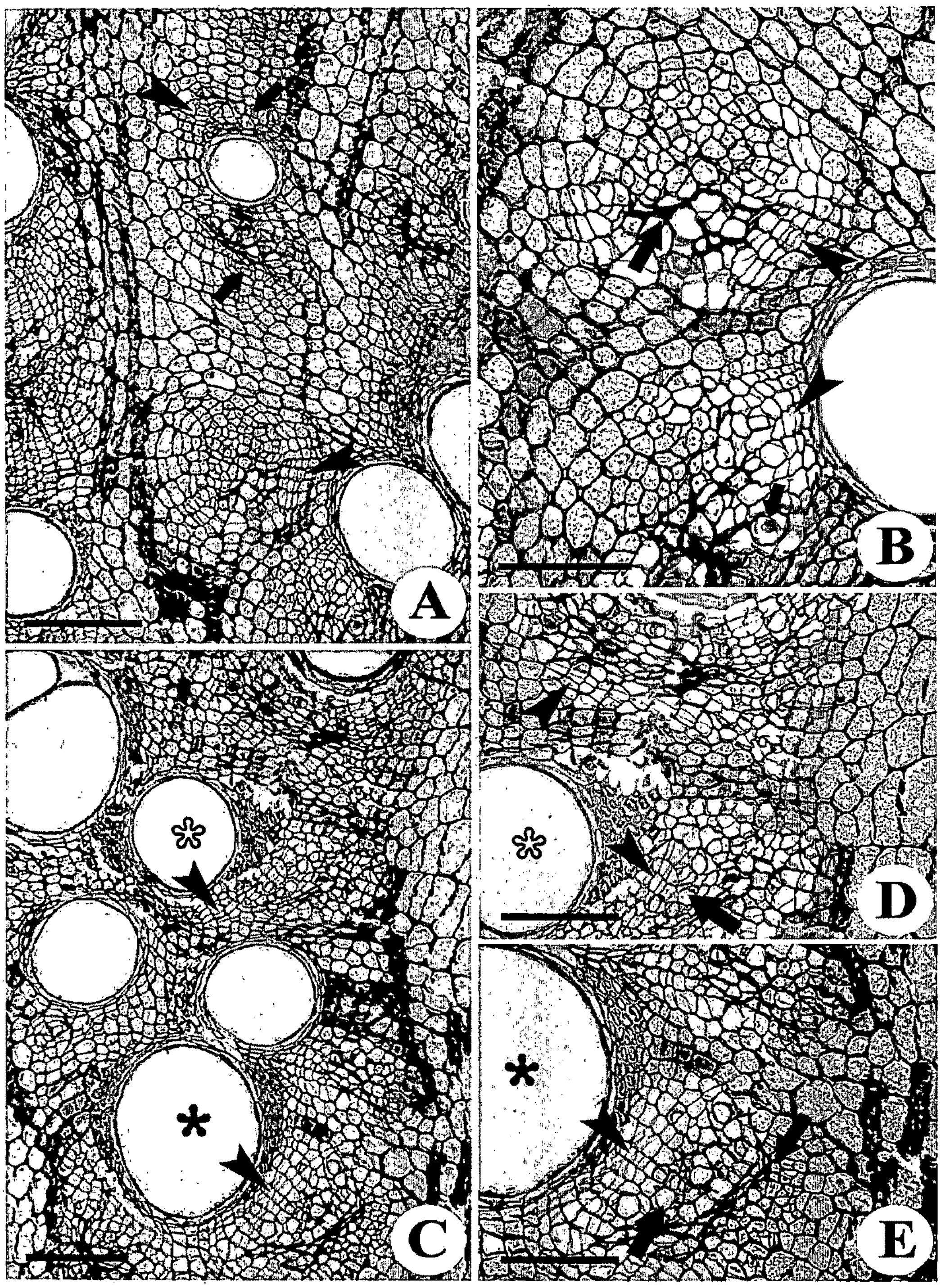

FIGURE-36

FIGURE - 37

Transverse view of mature stem of *Coccinia indica* L., showing interxylary phloem and ray cambium.

A. Parenchyma cells between two vessel elements differentiate into interxylary meristem (arrowheads) that produced phloem on opposite sides (arrow).

B. Differentiation of ray cambium on either side of the xylem rays (arrowheads). Arrows indicates central ray cells.

C. Development of phloem from ray cambium. Note that newly formed phloem encircles the nonfunctional and crushed phloem (arrowhead).

D. Origin of ray cambium. Note the development of ray cambium (arrowheads) and differentiating sieve elements (small arrow).

E. Differentiation of phloem on all the sides from the ray cambium, thus nonfunctional phloem becomes crushed in the centre (arrowhead).

F. Absence of callose from the nonfunctional sieve tube elements with open sieve pores on the crushed sieve plate (arrowhead).

Scale bars- Figs. 37A-E: 150 µm, Fig. 37F: 50 µm.

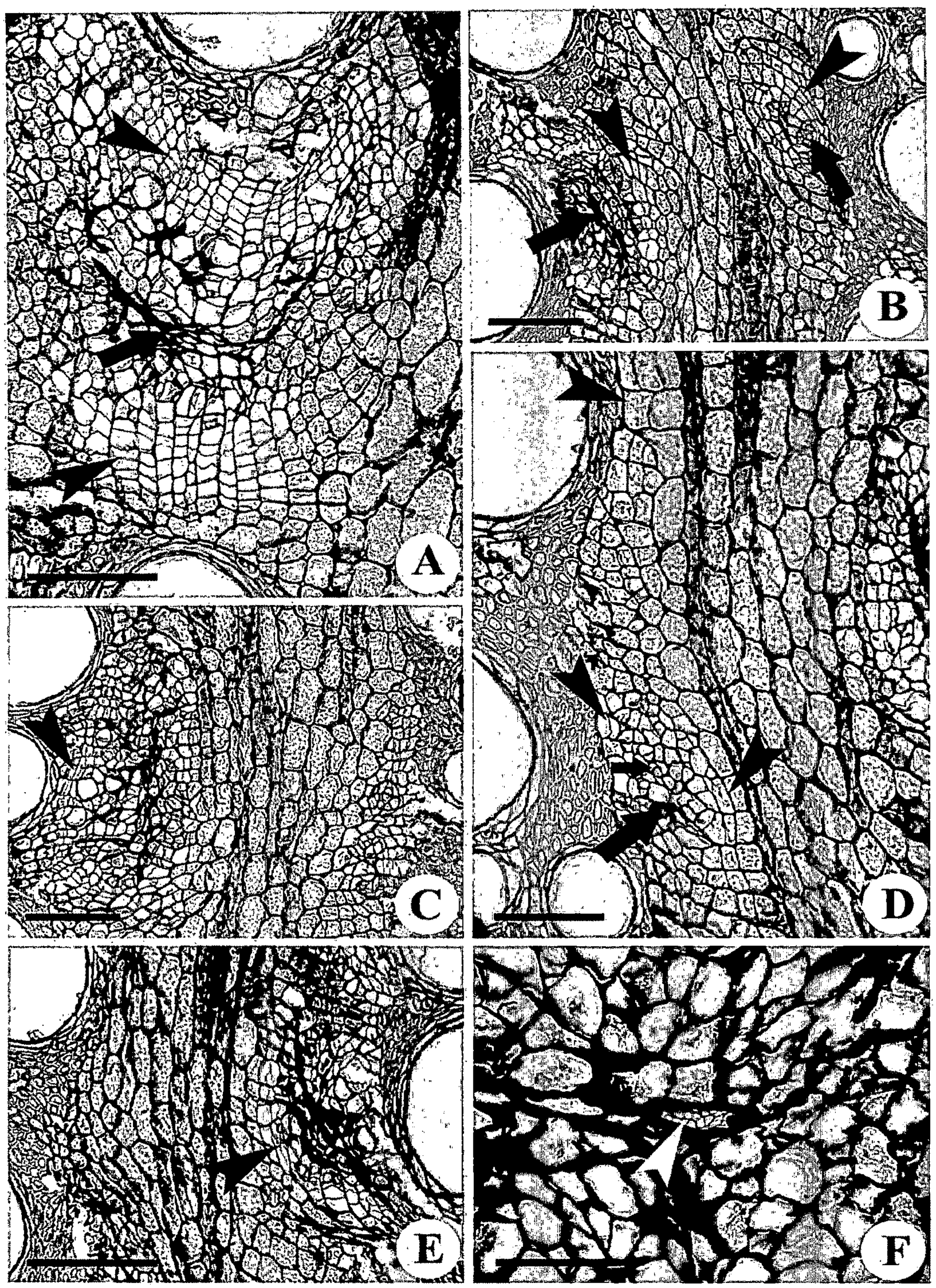

FIGURE-37

FIGURE - 38

Mature stem (A), radial (B) and tangential (C, D) view of secondary xylem of *Coccinia indica* L.

A. Mature stem (6-7 cm in diameter) showing continuation of rays from pith outward (arrowhead).

B. Portion of a ray showing upright cells (arrowhead).

C. Vessel element wall showing compound pits.

D. Arrangement of pits on the lateral walls of the vessel elements.

Scale bars- B-D: 150 μm.

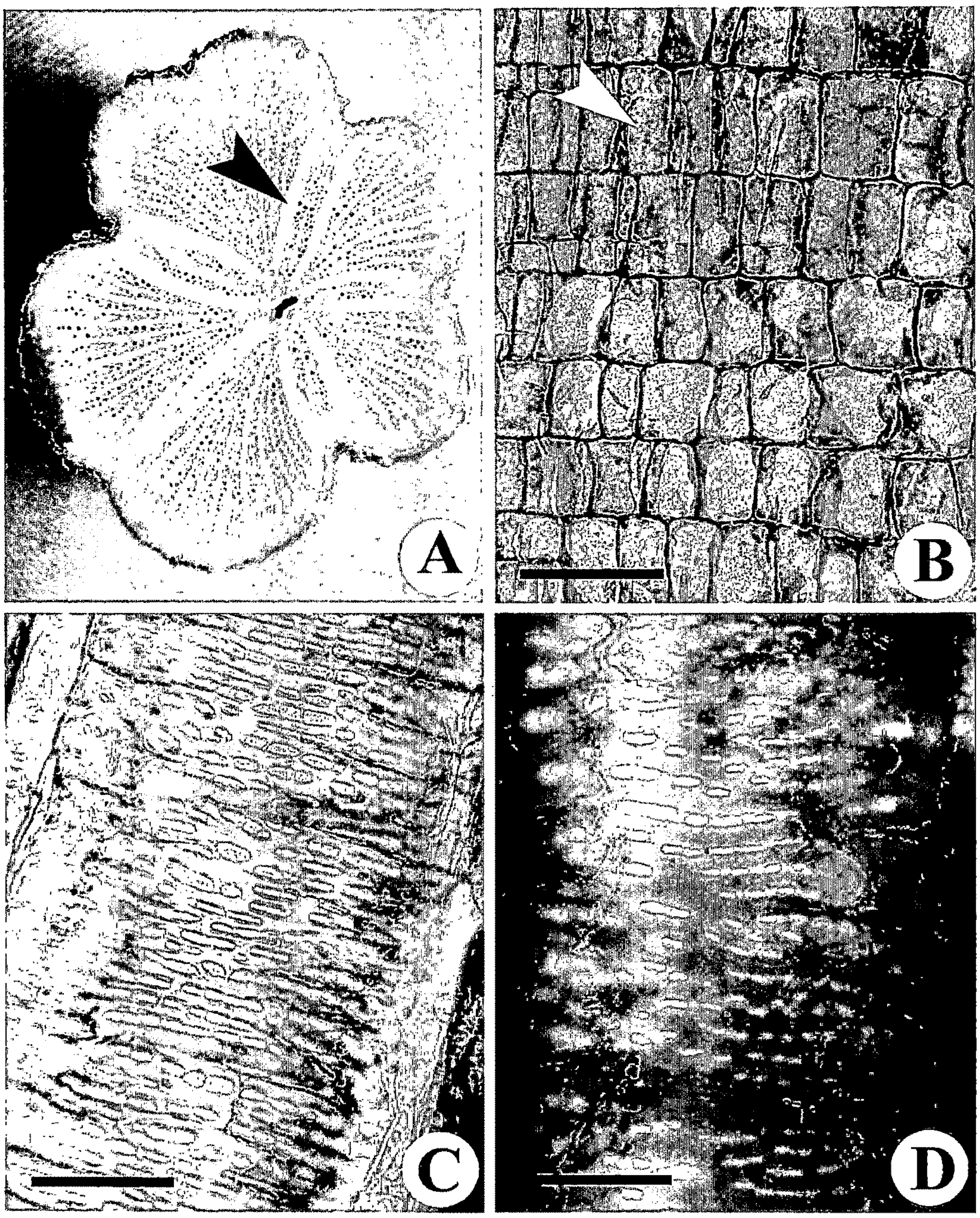

FIGURE-38

FIGURE - 39

Transverse (A, C-F) and radial longitudinal (B) view of the secondary xylem in the mature stem of *Ipomoea hederifolia* L.

A. Part of the secondary xylem showing both large (LV) and fibriform vessel elements (arrowheads).

B. Structure of the secondary xylem produced by the first ring of cambium.

C. Enlarged view of xylem showing pattern of parenchyma distribution. Arrowhead indicates included phloem islands towards the pith.

D. Islands of interxylary phloem (arrowheads) embedded in thick walled xylem derivatives.

E. Islands of axial parenchyma (arrow) embedded in thick walled xylem derivatives.

F. Enlarged view of phloem island showing transversely arranged sieve plates (arrowheads).

Scale bars- A, C, F: 50 μm; B, C: 100 μm; D: 75 μm.

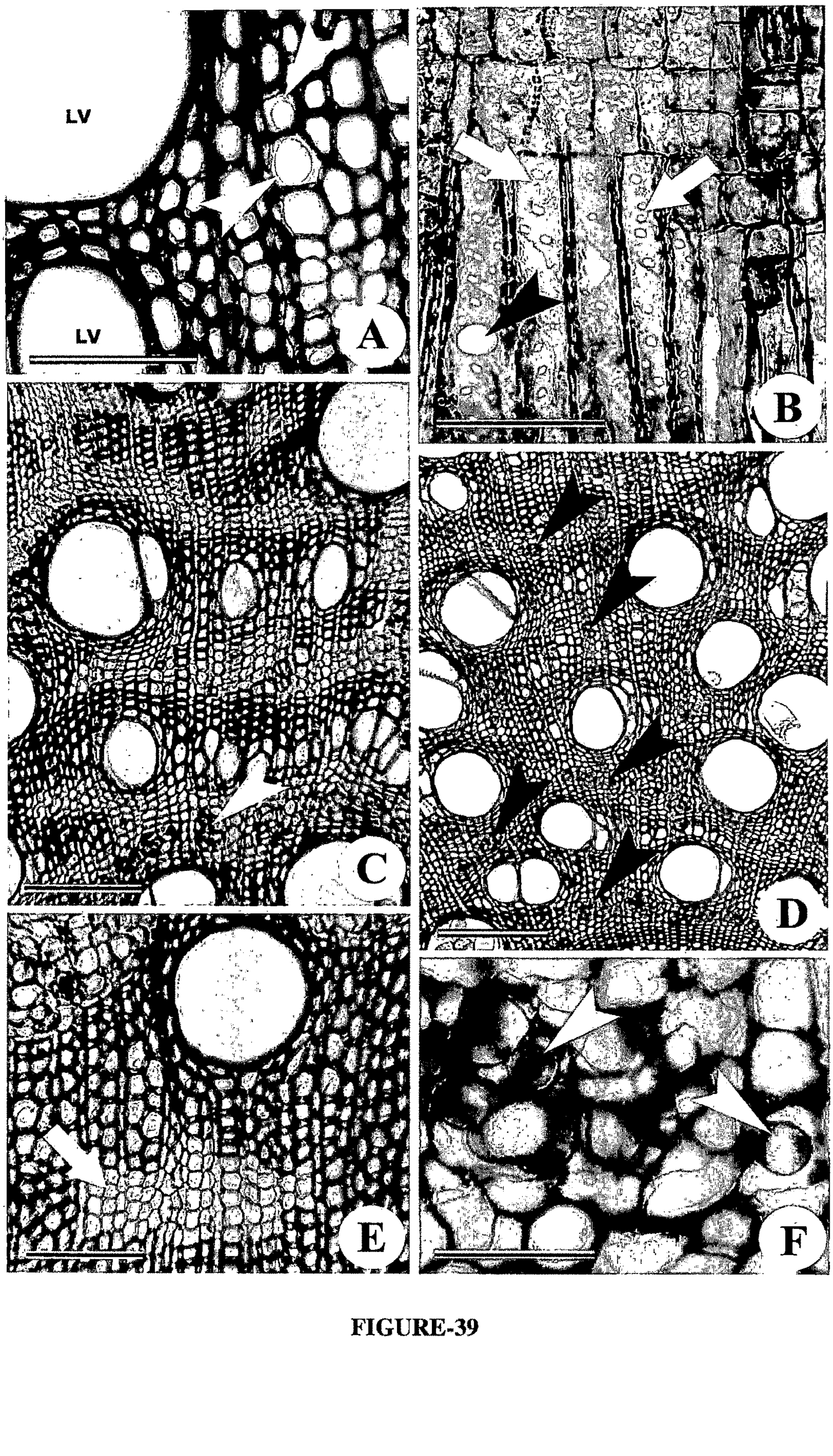

FIGURE-39

Figure - 40

Transverse (A-F) view of the secondary xylem in the mature stem of *Ipomoea hederifolia* L.

A. Thick walled parenchyma in the young stem. Arrows showing the location of thick walled parenchyma that differentiates into included phloem in the later part of secondary growth.

B. Enlarged view of the young stem showing thick walled parenchyma formed in the beginning by the cambium (arrows).

C. Mature stem showing dedifferentiated thick walled parenchyma into thin walled parenchyma (arrows). Arrowhead indicates re-differentiation of these parenchyma cells into included phloem islands.

D. Enlarged view of included phloem formed by re-differentiation of de-differentiated parenchyma cells showing sieve tube elements (arrowheads).

E. Dedifferentiated thick walled parenchyma showing thin walls while tracheids are the only thick walled elements (arrow) embedded in it. Arrowhead indicates initiation of periclinal divisions for further differentiation into sieve tube elements

F. De-differentiated parenchyma cells showing re-differentiation into sieve tube elements (arrowhead). Note the radial arrangement of parenchyma cells due to repeated periclinal divisions (arrow). Arrowhead indicates differentiated phloem elements, small arrow showing loosening of the cell wall during the dedifferentiation of parenchyma cells.

Scale bars- A: 100 µm; B-F: 50 µm.

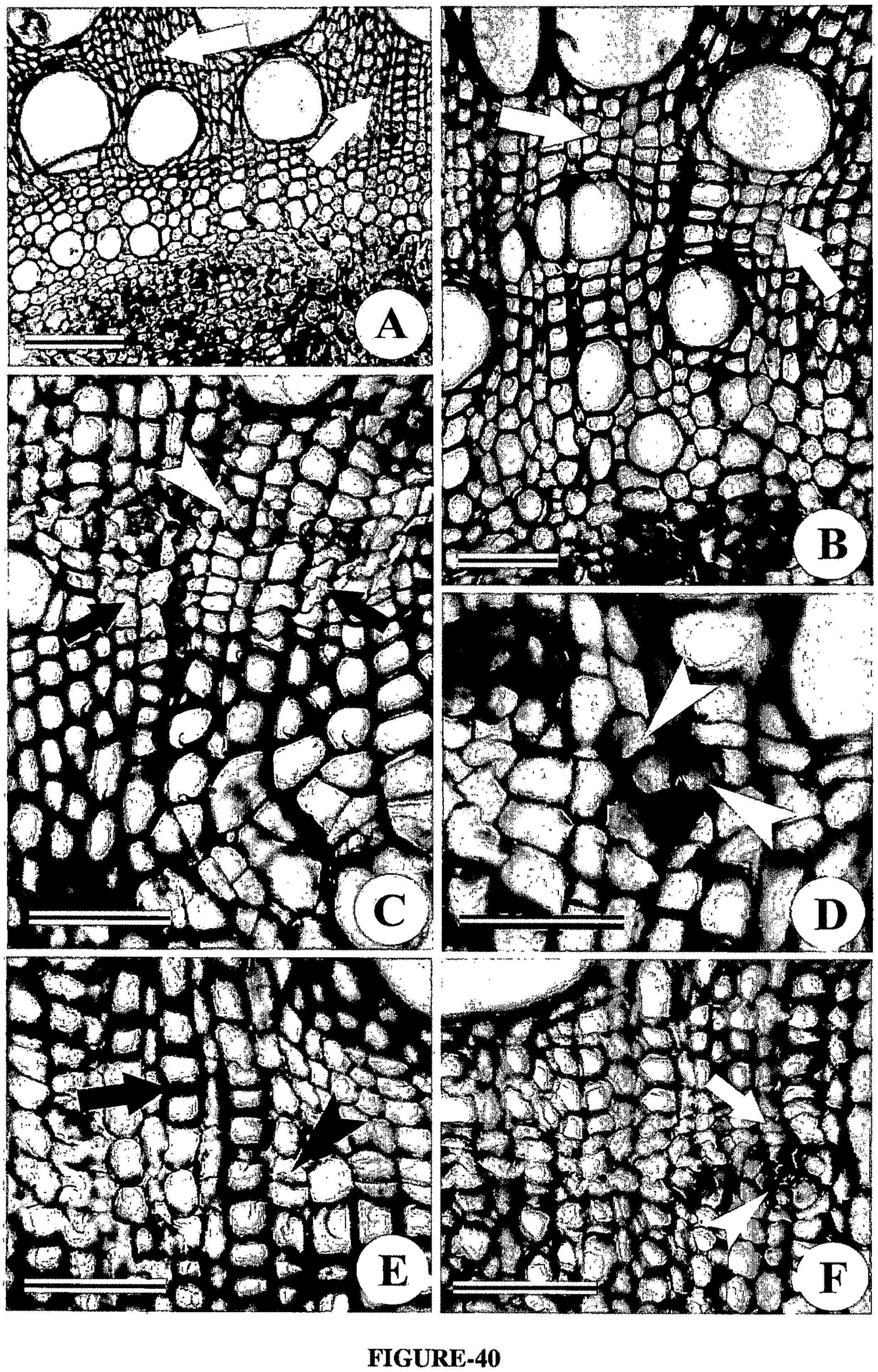

FIGURE-40

FIGURE - 41

Transverse (A, C-E) and tangential longitudinal (B) view of xylem, included phloem and cambium of *Canavalia ensiformis* (L.) DC.

A. Structure of xylem shows ensheathing lignified element restricted only to the vessel elements.

B. Storied arrangement of fusiform cambial cells. Note the compound (tall) heterocellular cambial rays.

C. Arrowhead showing well developing interxylary sieve tubes elements while arrows indicate obliterating sieve tubes elements while repeated divisions in the surrounding parenchyma resulted into radial arrangement of newly formed parenchyma.

D. Periclinaly dividing cells (arrowheads) results into sieve tubes differentiation. Note arrow indicates newly developed sieve tube with companion cell.

E. Arrowhead showing included sieve tube element with simple sieve plate.

Scale bars- A-C, E: 75 µm; D: 25 µm.

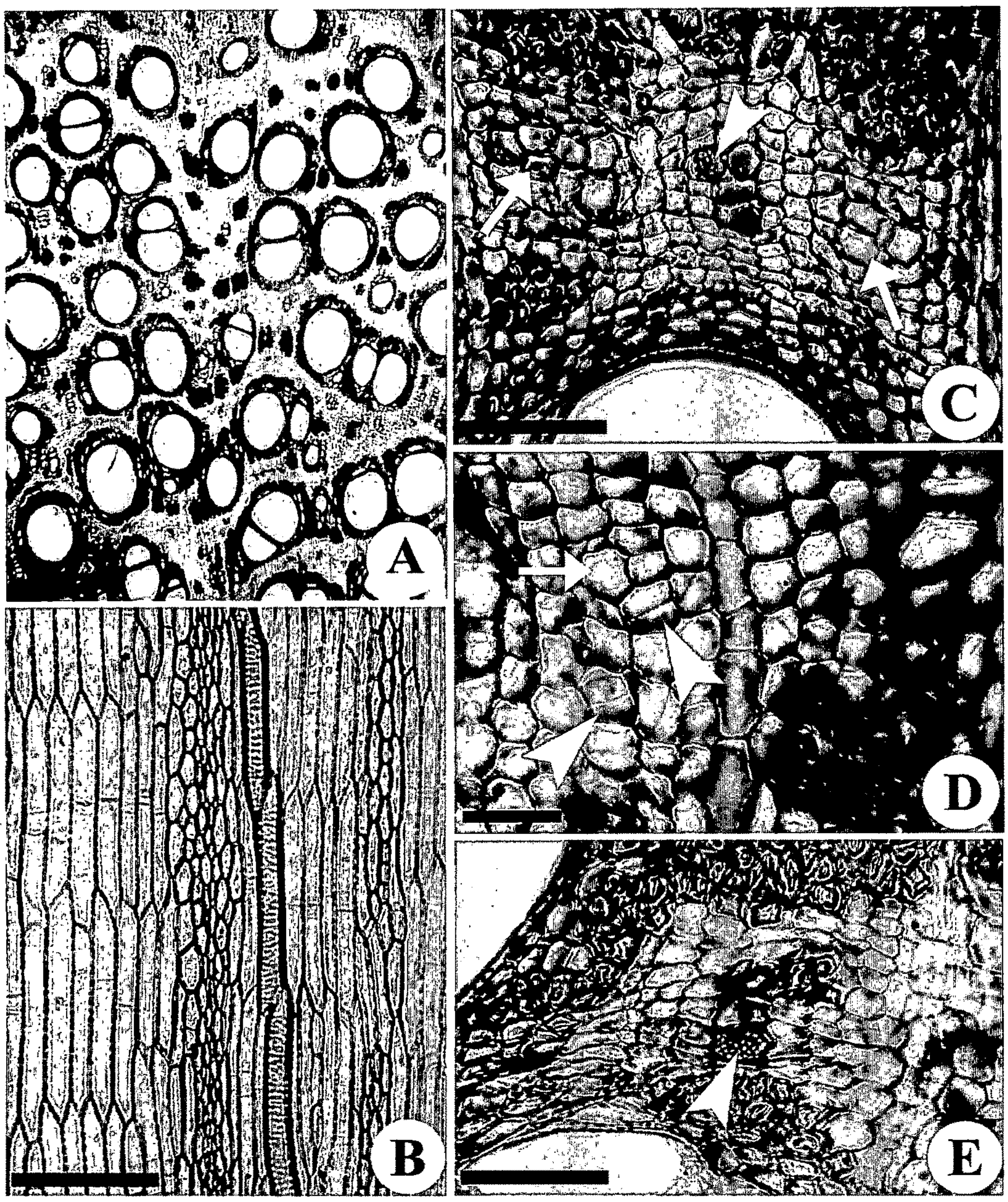

FIGURE-41

FIGURE - 42

Transverse view of main stem showing development of included phloem in *Mucuna pruriens var. pruriens* (Linn.) DC.

A. Structure of xylem showing patches of lignified element restricted only to the vessel elements. Arrowheads showing included phloem islands and narrow vessels surrounding to large vessels (arrows).

B. Embedded included phloem islands in unlignified xylem parenchyma (arrowheads). Note lignified patch of xylem fibres (arrow).

C. Enlarge view of secondary xylem showing in between large vessels periclinal division of parenchyma results into development of included phloem islands (arrowheads) while repeated division of parenchyma resulted into radial arrangement of newly formed parenchyma.

D. Enlarge view of included sieve tube elements shows circular, simple perforation plates.

E. Some places of secondary xylem shows obliterating phloem elements represented by darkly stained area (aroowheads) and arrow shows lignified fibres.

Scale bars- A-E: 75 µm.

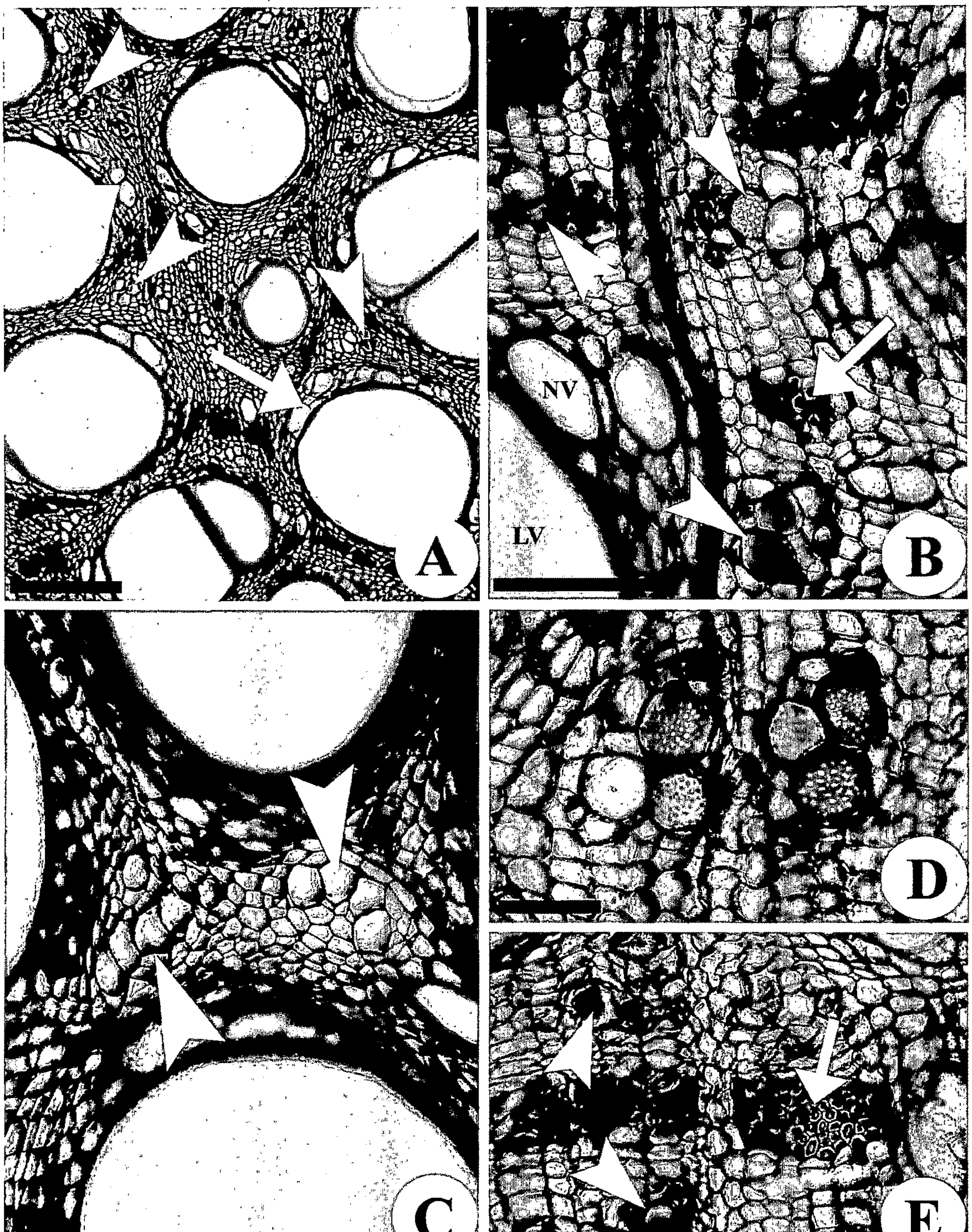

FIGURE-42

FIGURE - 43

Transverse view of stem showing development of interxylary phloem in *Strychnos bicolour* Prog.

A. Cessation of secondary xylem formation in small segment of cambium (arrow). Note the sunken part of the cambium as compared to other ends of the cambium.

B. Disconnected cambial segment. Arrowhead indicates functionally normal cambium on upper right corner. Arrowhead on lower side showing functionally retarded segment of cambium that ceased to produce secondary xylem.

C. Cessation of secondary xylem formation in small segment of cambium (arrow). Note the other ends of the cambium. Arrowhead indicates newly developing cambial segment outside to the portion that ceased to divide.

D. Part of the cambial segment that stopped production of secondary xylem. Arrowheads indicate phloem parenchyma that dedifferentiates into new segment of the cambium.

E. Development of new cambial segment (arrowhead) outside to the cambium that stopped producing secondary xylem.

F. Development of new cambial segment (arrowhead) outside to the cambium that stopped producing secondary xylem.

Scale bars- A-D: 100 µm; E, F: 75 µm.

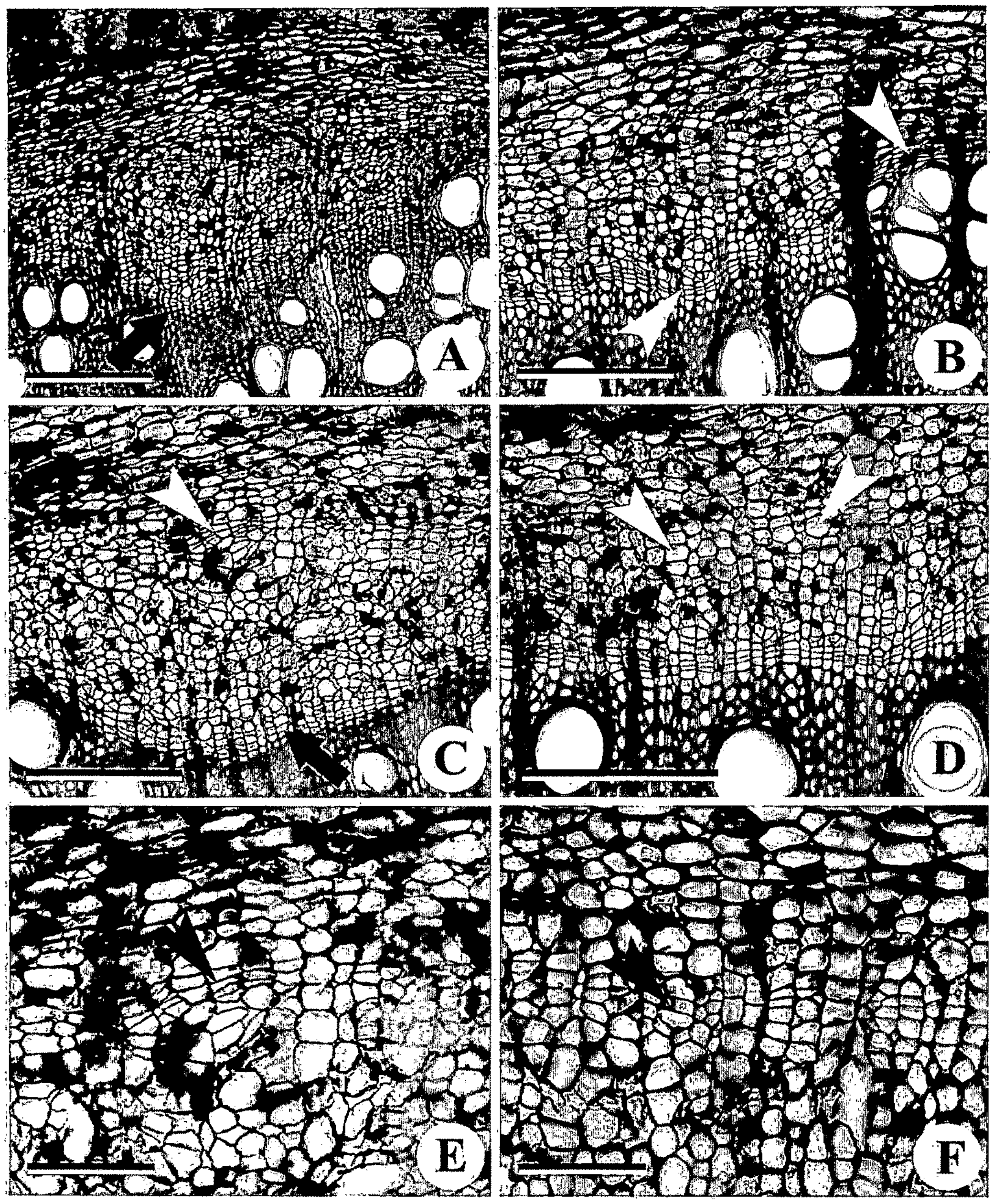

FIGURE-43

FIGURE - 44

Transverse view of main stem showing development of included phloem in *Calycopteris floribunda* Lamk.

A. A relatively wider cambial zone prior to separation of the vascular cambium into outer and inner segment. Note that phloem parenchyma, ray cells and vessel associated parenchyma cells filled with tannin.

B. Initiation of separation of cambium into outer and inner cambial segment (arrowheads). Note the differentiation and enlargement of parenchyma in the middle of the cambial zone. Small arrow indicates transformation of cambial cells into thick walled xylem derivatives.

C. Separation of the cambium into outer and inner segment. Note the cambial zone from left corner of the photograph to right corner showing all the stages of separation.

D. Outer and inner segment of the cambium (arrowhead) and differentiating thin walled cambial derivatives (arrow). Note that cambial cells transformed into thick walled xylem derivatives (small arrow).

E. Recently formed included phloem island, also note the shape of the ray parenchyma in it. Arrowhead indicates differentiating sieve elements.

Scale bars- A, C: 75 μm; B, D-E: 50 μm.

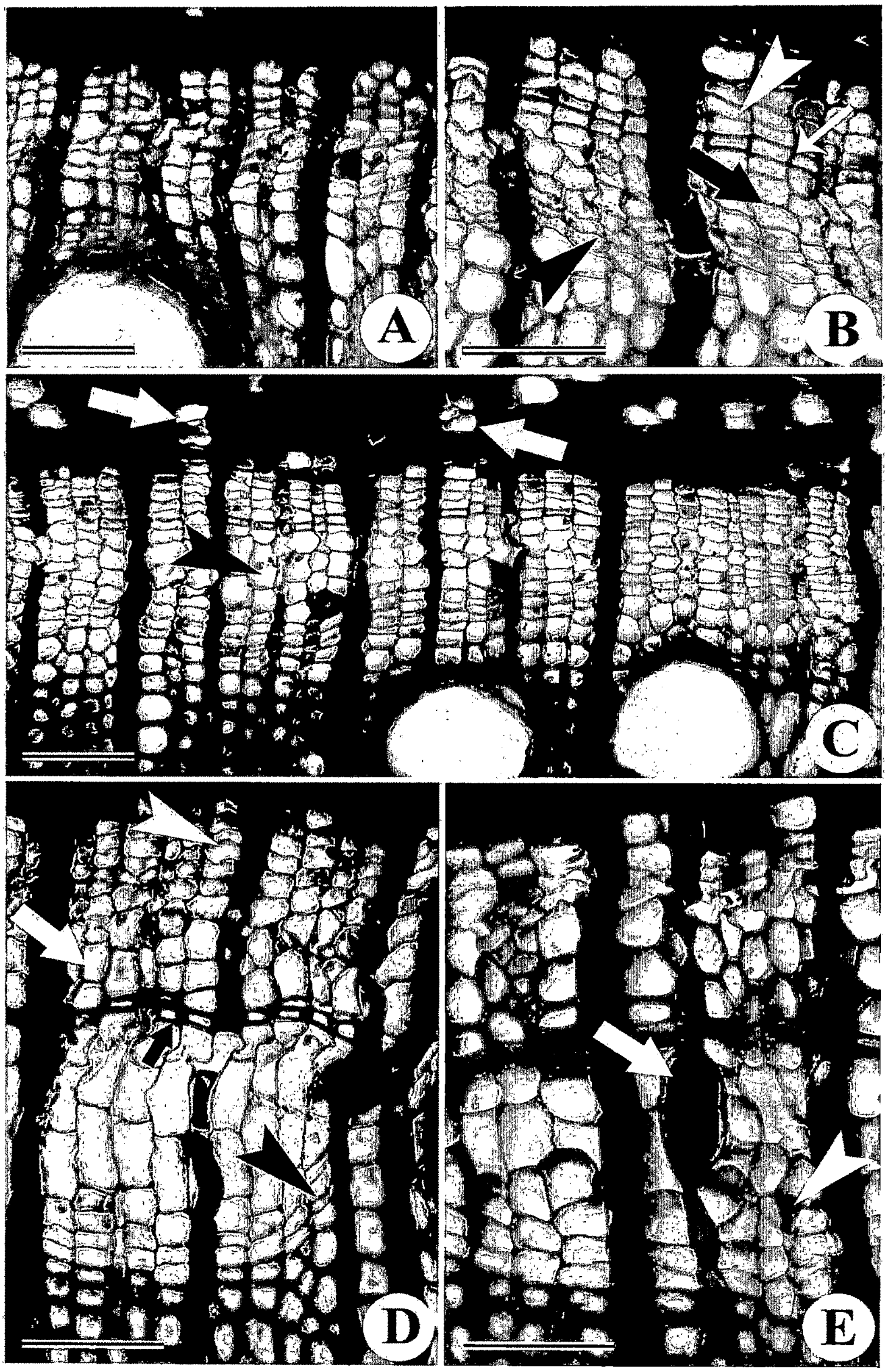

FIGURE-44

FIGURE - 45

Transverse view of secondary xylem showing included phloem islands in *Calycopteris floribunda* Lamk.

A. Initiation of phloem differentiation in newly forming phloem island (arrowhead). Note the differentiating xylem derivatives on the upper right corner of the photograph.

B. Recently formed included phloem island showing radially elongated parenchyma cells (arrowhead) with few differentiating phloem elements.

C. The phloem island some distance away from the cambial ring showing fully differentiated sieve tube elements and elliptic oblong rays (arrowhead). Note the shape of the ray cells in the phloem island.

D. Structure of secondary xylem with phloem islands. Note the tangentially flattened phloem island (arrowhead).

E. Two adjacent phloem islands connected by thin walled parenchyma cells (arrowhead). Note that adjacent uniseriate rays are filled with tannins.

F. Obliterated older phloem elements (arrow) along with the rays passing through the island. Arrowhead indicates cambial cells are arranged in radial files.

Scale bars- A: 50 μm; B, C, F: 75 μm; D, E: 100 μm.

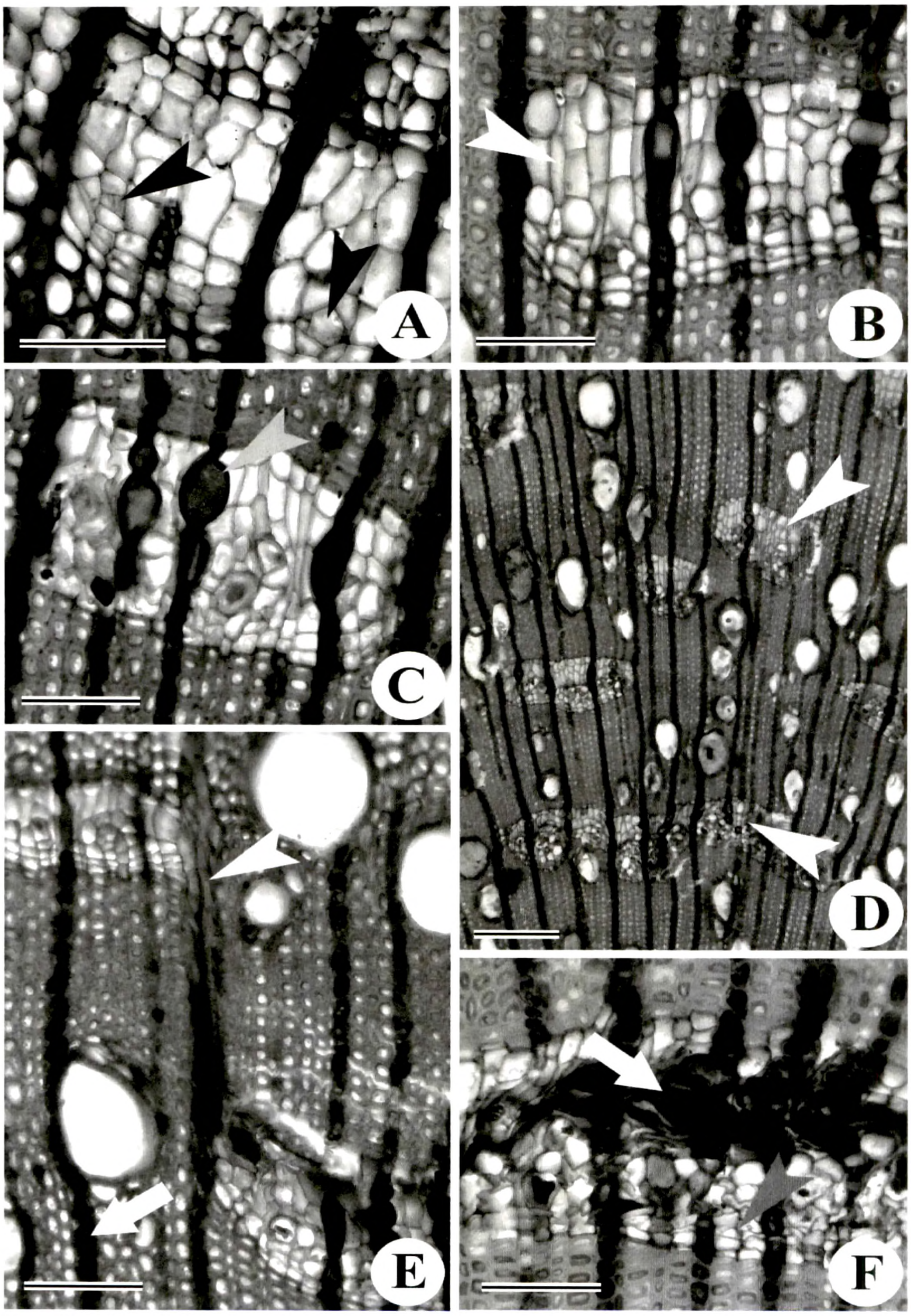

FIGURE-45

FIGURE - 46

Transverse (A), tangential (B and C) and radial (D-F) longitudinal view of secondary xylem of *Calycopteris floribunda* Lamk.

A. Innermost phloem island showing completely crushed and obliterated phloem elements (arrowhead). Note the complete loss of ray cell alignment. Arrow indicates complete differentiation of cambium into its derivatives.

B. Xylem fibres with nuclei (arrows). Note that fibre lumen is filled with oval to elliptic starch grains (arrowheads).

C. More or less oval to circular shape of the nuclei (arrowheads).

D. Perforated ray cell (arrowhead).

E. Perforated ray cell is relatively larger in size as compared to adjacent ones (arrow).

F. Vertically elongated perforated ray cells (arrow) formed at the terminal end of the ray.

Scale bars- A: 75 μm; B-F: 50 μm.

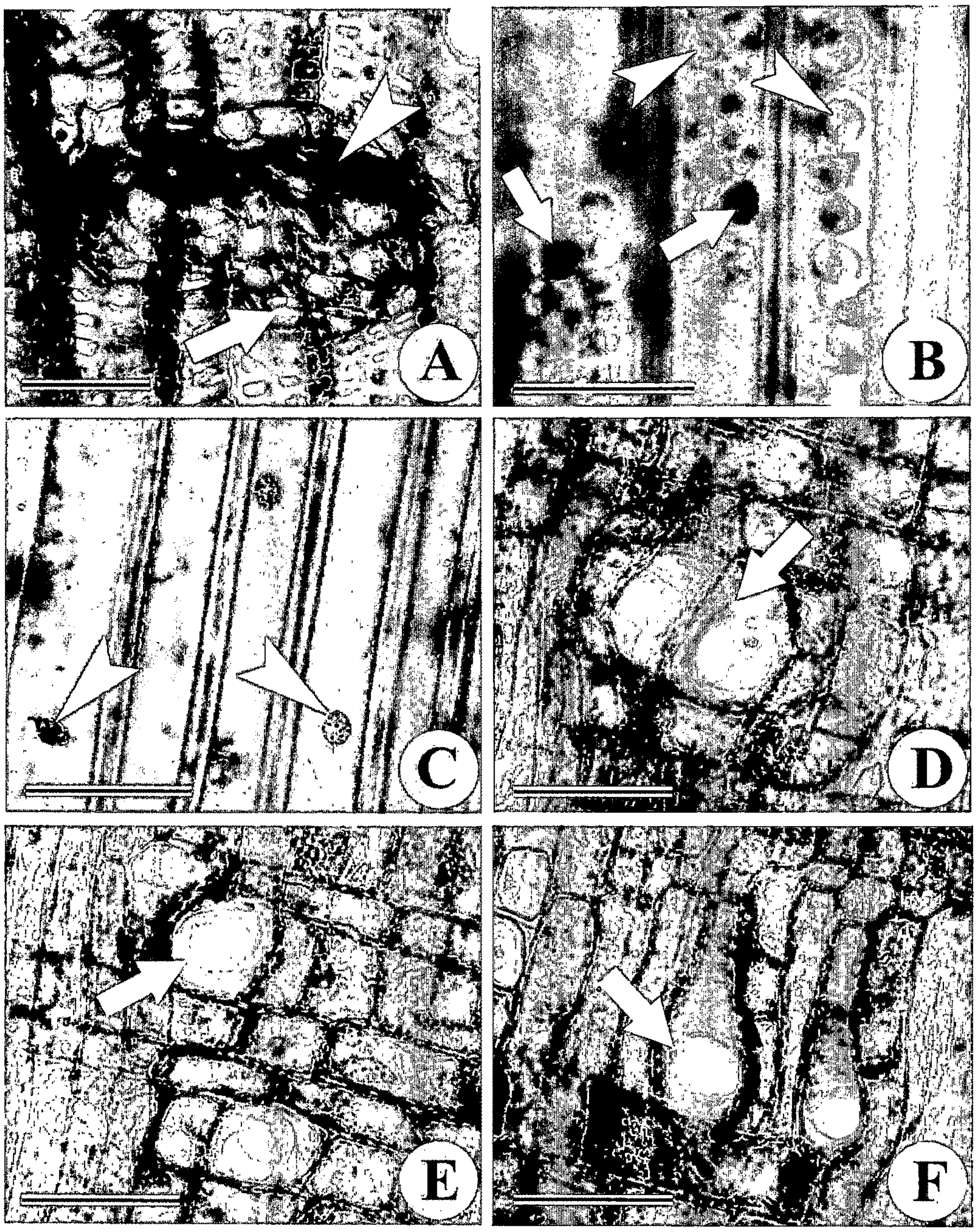

FIGURE-46

FIGURE - 47

Transverse (A-F) and tangential (G and H) longitudinal view of secondary xylem of *Camptosema isopetalum* (Lam.) Taub.

A. Young stem of *Camptosema* shows circular in outline with normal vascular cylinder.

B. Transverse section of stem (5 mm in diameter) showing increased in production of xylem tissue and major vessels at the tips.

C. Cross-section of cylindrical stem showing outer layers of the periderm (thin arrow), pericycle (arrow), phloem rays (asteriks); idioblasts cluster (circle) forming concentric bands. Note the amount phloem produced on proximal side of the flattened stem.

D. Transverse section of flattened stem showing amount of phloem produced on distal side of the flattened stem. Asteriks indicates phloem rays.

E. Transverse section of flattened stem showing lateral side.

F. Transverse view of flattened stem showing sieve tube elements and companion cells; phloem rays (PhR), fibres, parenchyma cells (P) and idioblasts (asteriks).

G. Longitudinal section of cylindrical stem showing storied arrangement of sieve tube elements companion cells (thin arrow) and parenchyma cells (P); simple sieve plate (arrow) and lateral sieve areas on sieve tube element (asterisk).

H. Longitudinal section of flattened stem showing sieve tubes elements. Note the phloem ray (PhR), and lateral areas on sieve tube element (arrowhead).

Scale bars- A & B: 400 μm; C-E: 100 μm; F-H: 50 μm.

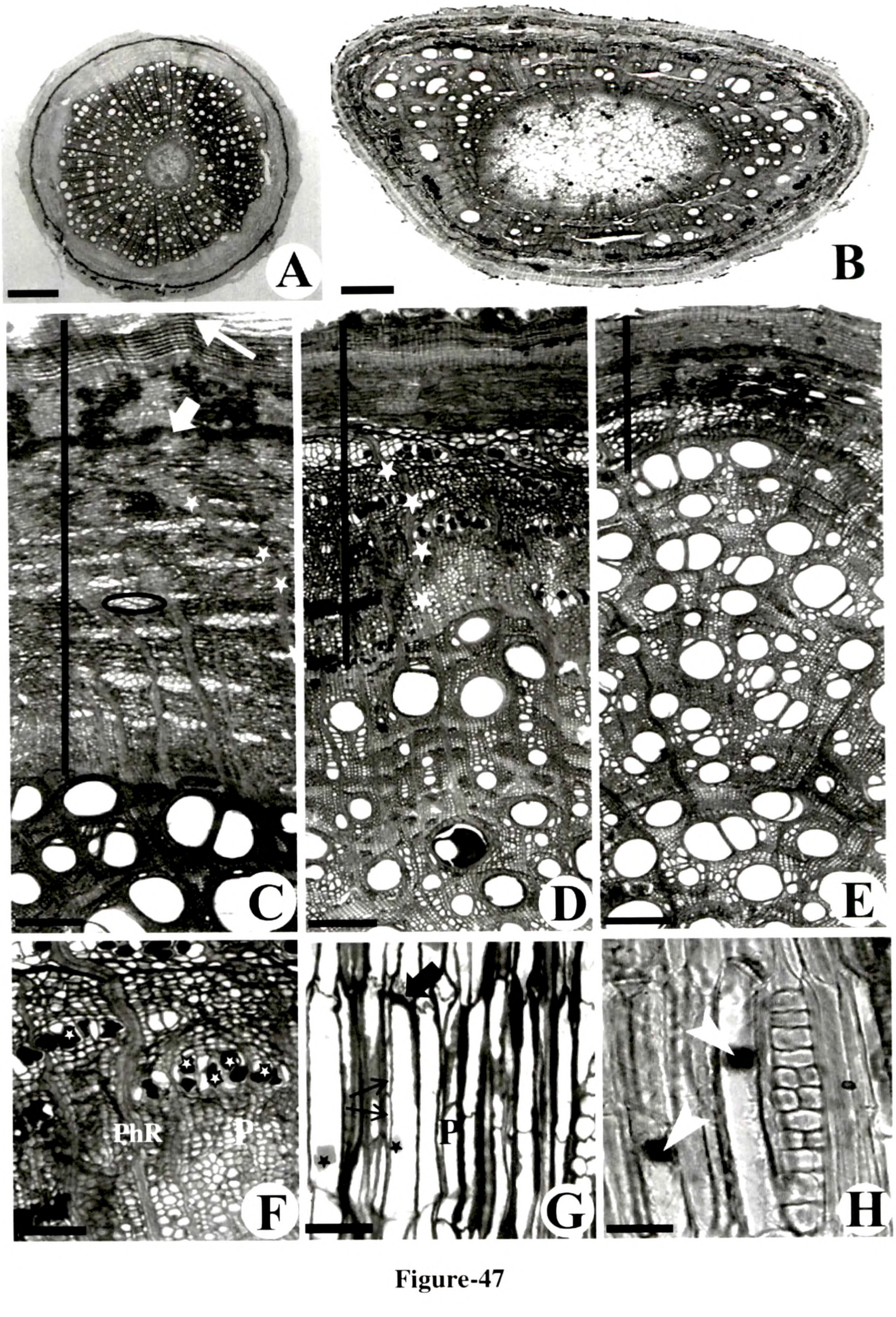

Figure-47

FIGURE - 48

Tansverse view of stem *Phanera glabra* Jacq. (A-C, E-H) showing flattened stem development and lobed stem in *Phanera outimouta* (Aubl.) Queiroz (D).

A-C Various stages of branch flattening (stem diameter 5mm-18mm).

D: Lobbed stem of *Phanera outimouta.*

E: Central portion of young stem showing rectangular pith.

F: Lateral portion if stem showing different size of vessel elements. Note vessel elements near pith are smaller compared to lateral side of stem.

Scale bar- A: 5 mm; B: 9 mm; C: 18 mm; D: 20 mm; E, F: 100 μm.

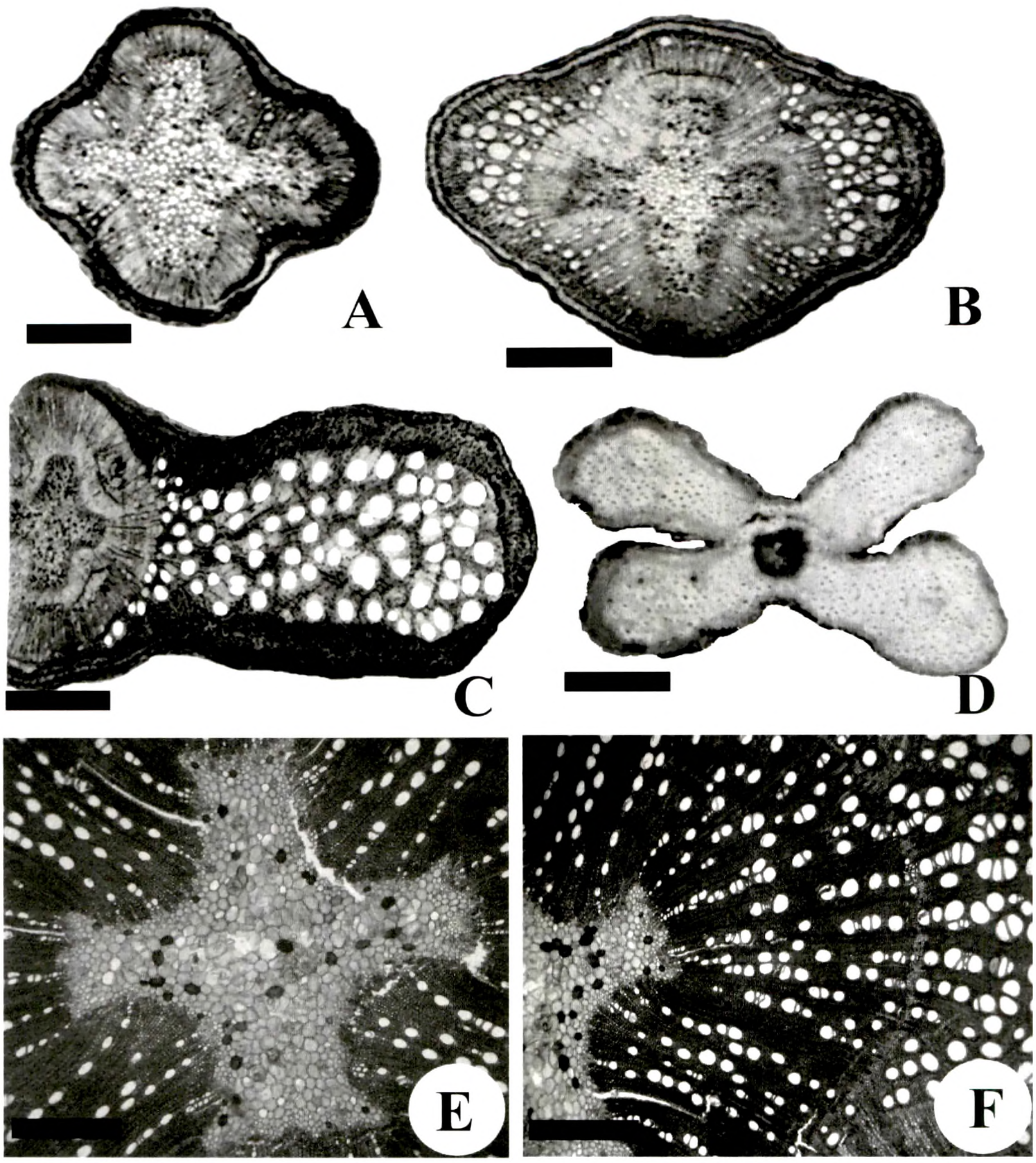

FIGURE-48

FIGURE - 49

Transeverse view of young and mature thick stem of *Begnonia alliacea* L. showing developmental stages of phloem wedges.

A. Young stem (4^{th} internode) showing initiation of groove formation and production of only phloem elements (arrowhead). Note arrow showing pericyclic fibres bands.

B. Entire stem portion showing four grooves (arrows).

C. 12^{th} internode showing deep groove (arrows).

D. Relatively enlarged view of thick stem showing well developed and wide phloem wedge (arrow).

E. Enlarge view of phloem wedge that shows phloem (arrowhead) bands of fibres (small arrow). Note multiseriate rays passing through phloem wedge (arrow).

F. Arrowheads showing unidirectional cambium. Arrow indicates multiseriate rays and differentiation of fibres, which usually start from the bordering rays of the furrows toward the centre of the furrow (small arrow).

Scale bars- A-E: 100 μm; F: 50 μm.

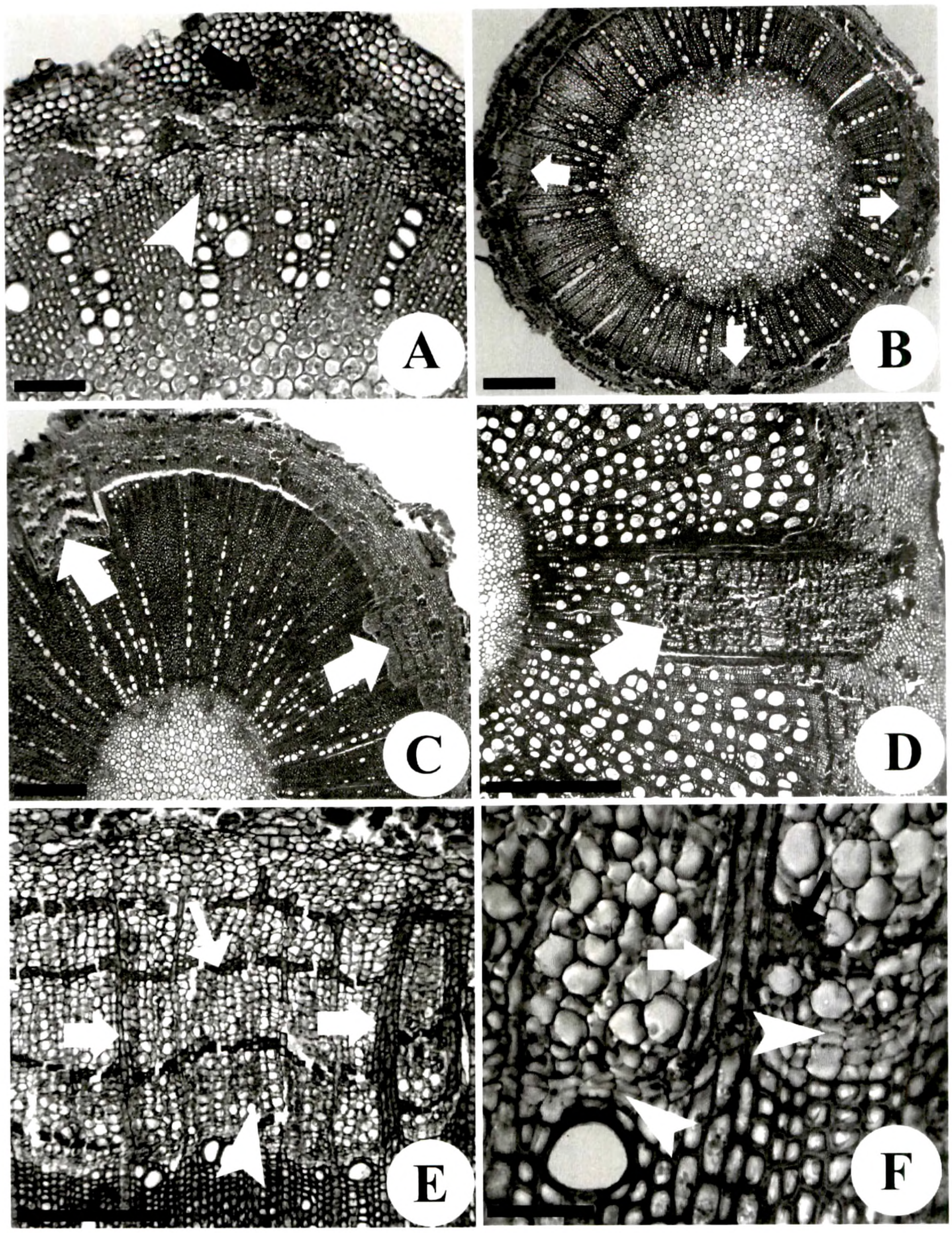

FIGURE-49

Figure - 50

Transverse sections of young and matured stem of *Aristolochia indica* Linn. (A-D) and *Tinospora cordifolia* (Thunb.) Miers.(E, F).

A. Young stem showing eight conjoint collateral open vascular bundles joined by the interfascicular cambium and forming the complete cylinder. Epidermis covered with trichomes.

B. Xylem appearing as plates embedded in thin walled parenchymatous background.

C. Mature stem showing wider rays (arrowheads). Arrow indicates multiseriate medullary ray.

D. Mature stem showing arrangement of thick walled and thin walled elements. Arrows showing medullary rays while other rays are vascular rays.

E. Structure of secondary xylem. Note the large vessels and multiseriate and wider rays (arrow) in *Tinospora*.

F. Arrow shoeing developing vessel element in wider rays.

Scale bars- A, B, D-E: 100 μm; C: 50 μm.

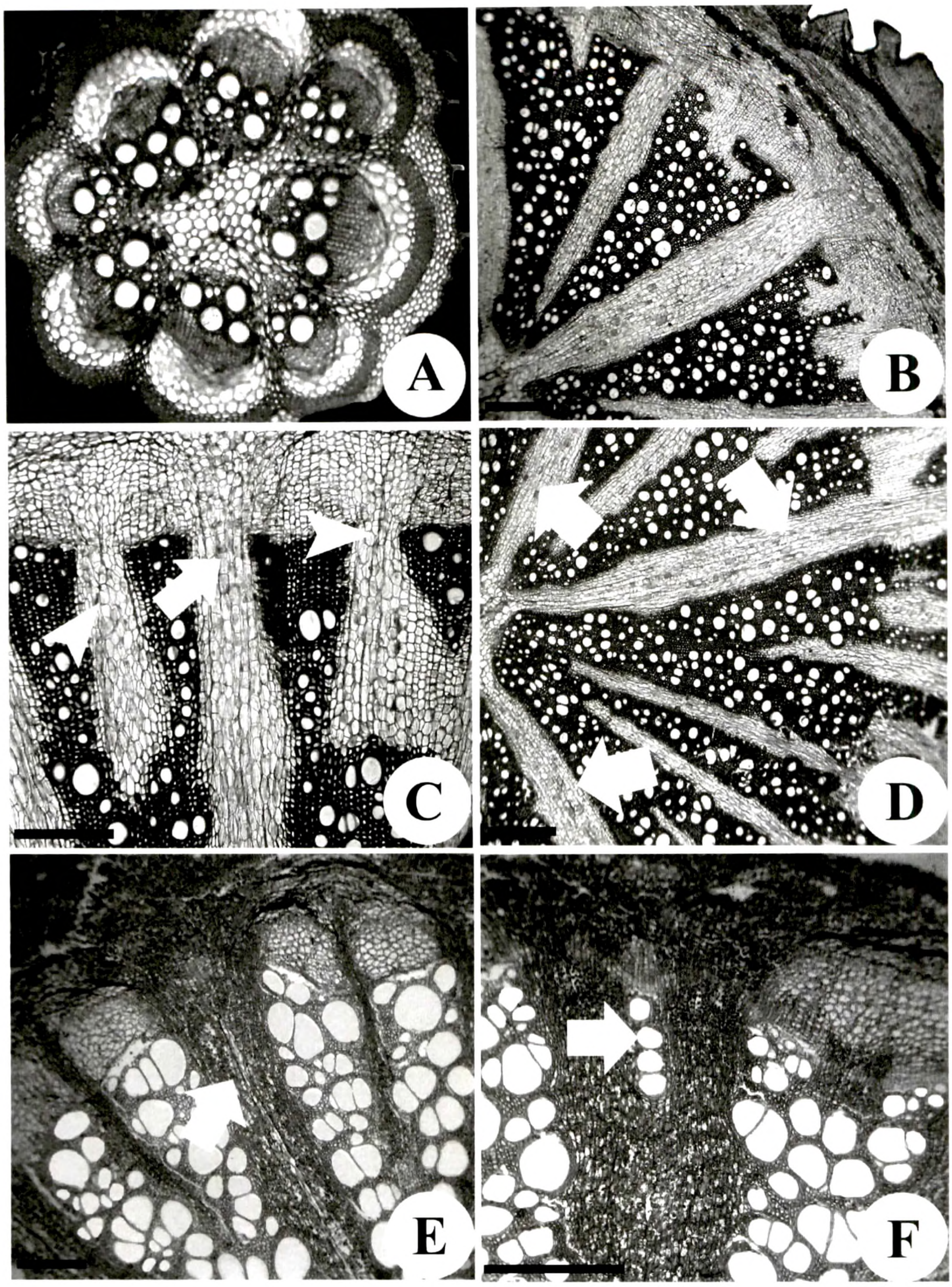

FIGURE-50

Figure - 51

***Serjania corrugata* Radlk. (Sapindaceae) and *Serjania caracasana* (Jacq.) Willd**

A: Adult stem composed of five vascular cylinders. Note that all the cylinders are separated by thin walled cells.

B: Apical shoot (tip portion) showing five lobes alternating with grooves.

C: Enlarged view of Fig. 51B showing structural details of groove.

D: Portion of the grove in the relatively thick stem showing vascular cambium and secondary phloem.

E: Detailed structure of one of the lobe showing structure of secondary xylem, and the pericyclic sclerenchyma ring (arrowhead).

F: Central portion of the stem showing the junction of five cylinders (P-Pith).

G: Origin of peripheral cylinder (arrowhead).

H: Macromorphology of the *Serjania caracasana* stem showing central cylinder surrounded with eight vascular cylinders.

Scale bars- C-G: 100 μm.

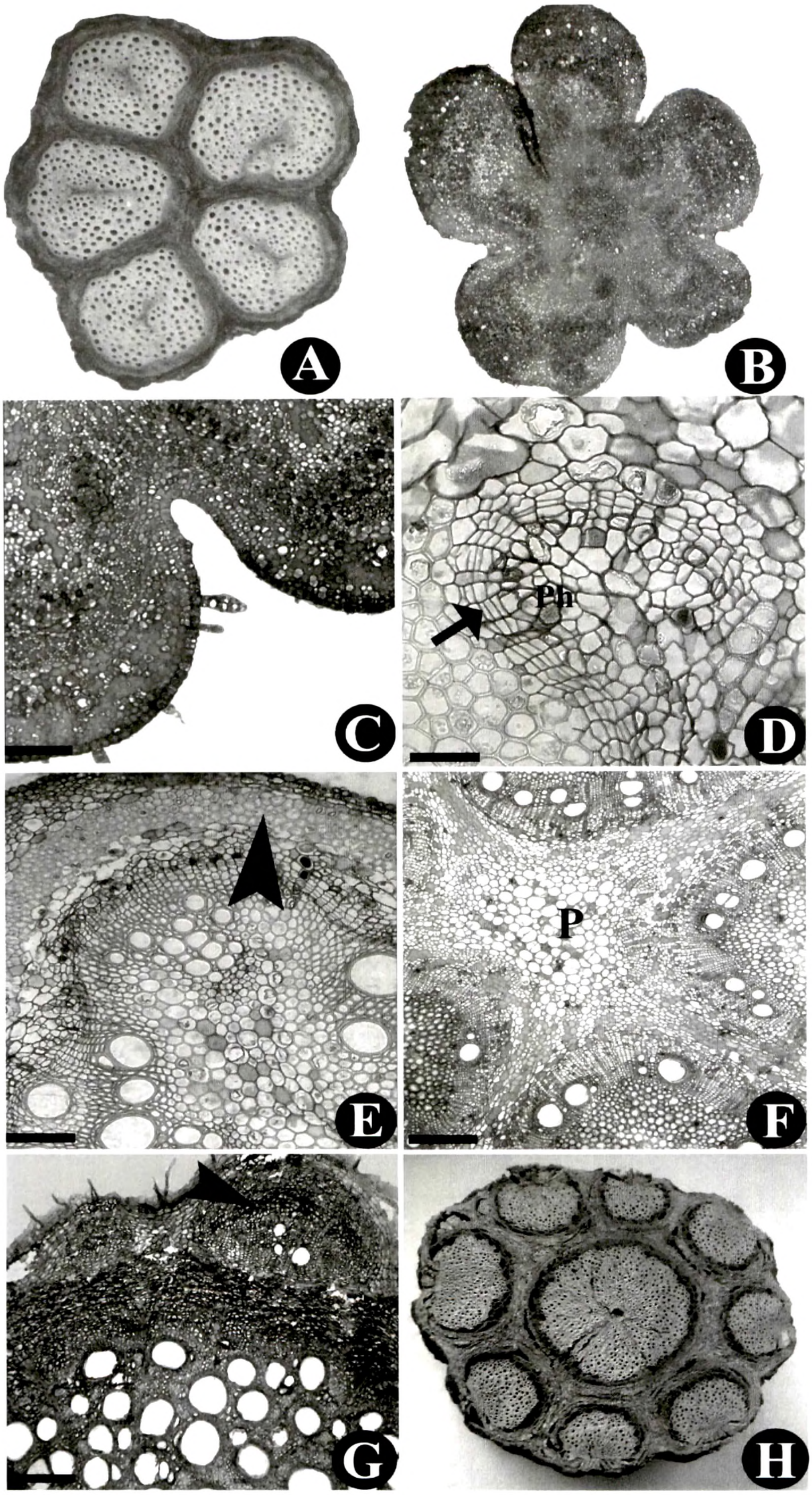

FIGURE-51

FIGURE - 52

Transverse sections of thick stem *Ipomoea triloba* L. successive rings of secondary xylem alternating with phloem.

A. Structure of stem showing first ring of secondary xylem while second ring is in the form of individual bundles.

B. Thick stem showing three successive rings of xylem alternating with phloem. Note the vascular bundles embedded in ground mass of parenchyma cells.

C. Internal cambium showing xylem and phloem in the pith region. Arrowheads indicate vessel elements. Note the crushed pith due to pressure exerted by differentiating cambial derivatives.

D. Enlarge view of internal cambium with secondary xylem (arrowhead) and secondary phloem (arrow).

Scale bars- A-D: 100 μm.

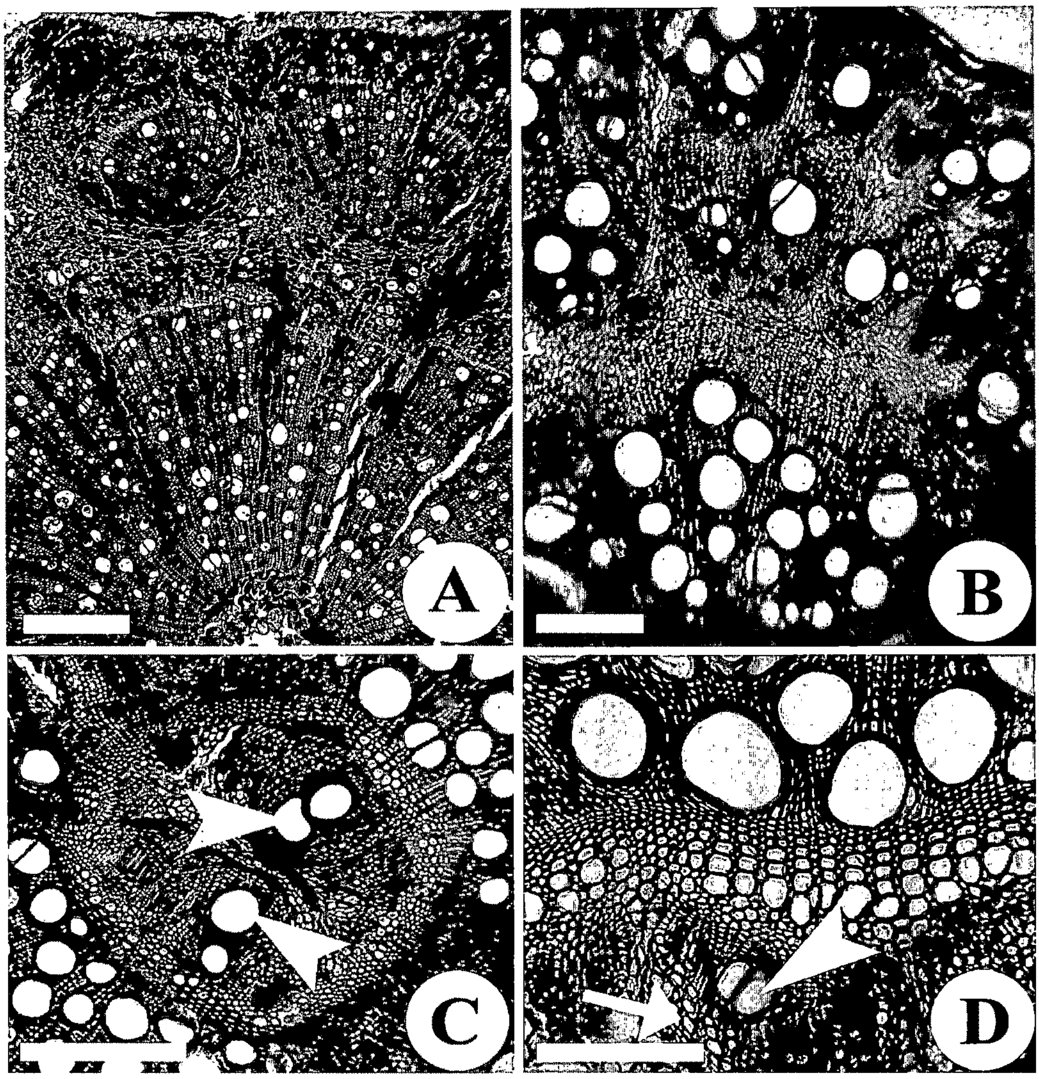

FIGURE-52

FIGURE - 53

Transverse view of *Macherium aculeatum* Raddi. Lantana aff. Fulcata Lindl., stem.

A-C. Various stages of stem showing flattening of the stem.

D. Stem portion on adjacent lateral side (proximal end) of the stem showing relatively more phloem production. Arrow indicates unicellular phloem ray.

E. Distal end of the stem showing less phloem as compared to proximal end. Arrow indicates the cambium.

F. Origin of second ring of cambium from the cortical parenchyma cells (arrows). Arrowhead indicates recently formed xylem derivatives.

G. Enlarged view of stem showing newly developing cambium (arrowhead).

Scale bar- D, E & F: 100 μm; G: 50 μm.

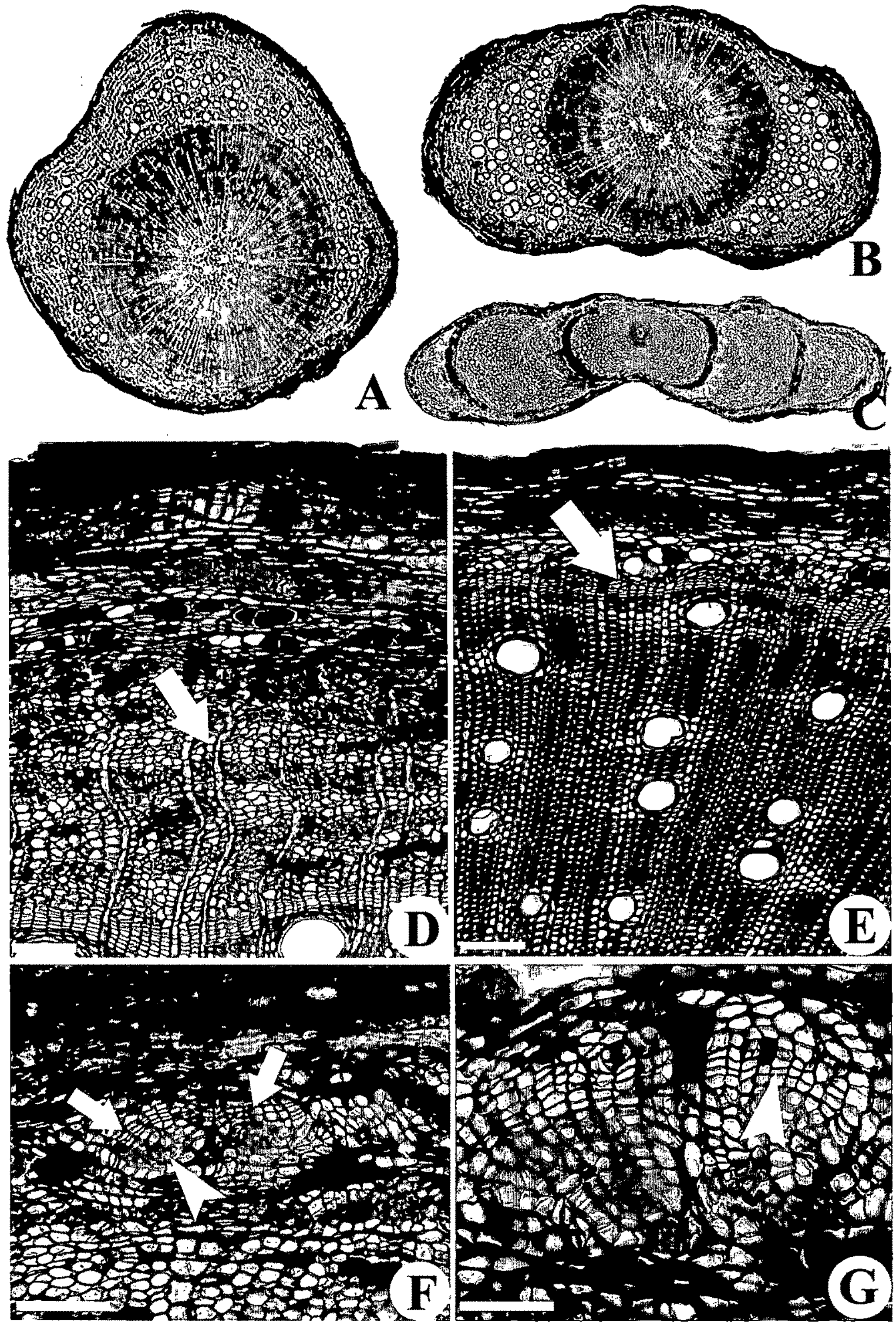

FIGURE-53

FIGURE - 54

Transverse view of young and mature stem of *Securidaca rivinaefolia* A. St.-Hill & Moq.

A. Young stem showing thick cuticle (arrowhead), note the tangentially elongated epidermal cell and few layered hypodermis.

B. Flanged cuticle showing multilayered thickening of lignin material in the mature stem (arrowhead).

C. Mature stem showing thick cuticle, epidermis, hypodermis and part of the cortex. Note that epidermal cells undergo anticlinal divisions (arrowhead) and they become vertically elongated as compared to young stem.

D. Tangential elongation of hypodermal cells (arrowhead) in the relatively mature stem. Note multilayered hypodermis.

E. Origin of phelloderm in the mature stem (arrowhead). Note the broken epidermal cells.

Scale bar- A-C: 75 μm; D, E: 100 μm.

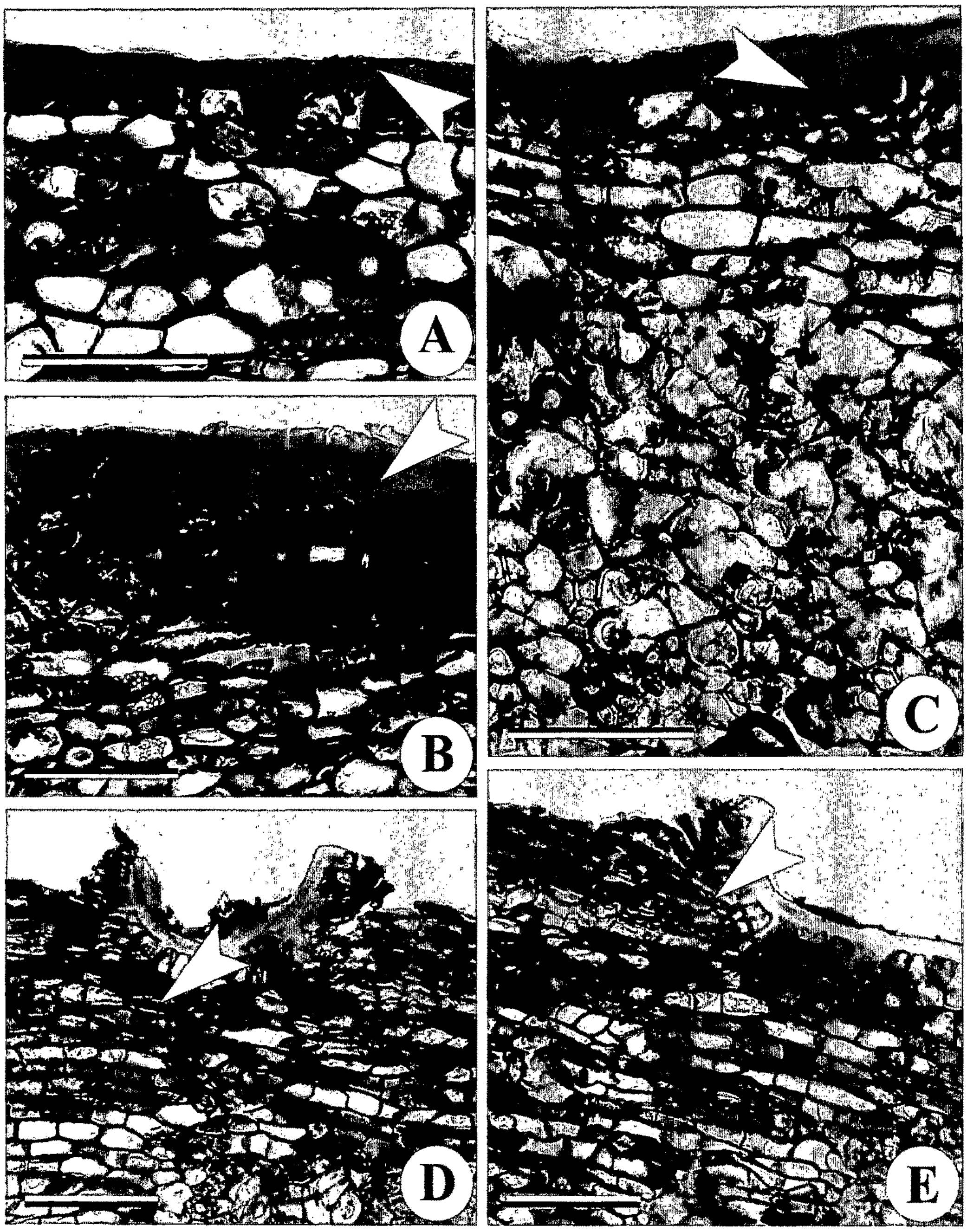

FIGURE-54

FIGURE - 55

Transverse view of young and mature stems of *Securidaca rivinaefolia* A. St.-Hill & Moq., showing different stages of cambial origin.

A. Origin of first cambial ring from the pericyclic parenchyma located outside to the phloem of previous cambium (arrowhead).

B. Enlarged view of newly developing cambium. Note the wide band of parenchyma cells that develops into cambium and conjunctive tissue (arrow).

C. Enlarged view of newly developing cambium. Arrowheads indicate newly formed sieve element.

D. Parenchyma cells located outside to the phloem formed by previous cambium (arrowhead).

E. Tangential spreading of the newly developed cambium. Note differentiated fibers on the xylem side (arrowheads).

Scale bar- A: 100 μm; B-E: 75 μm.

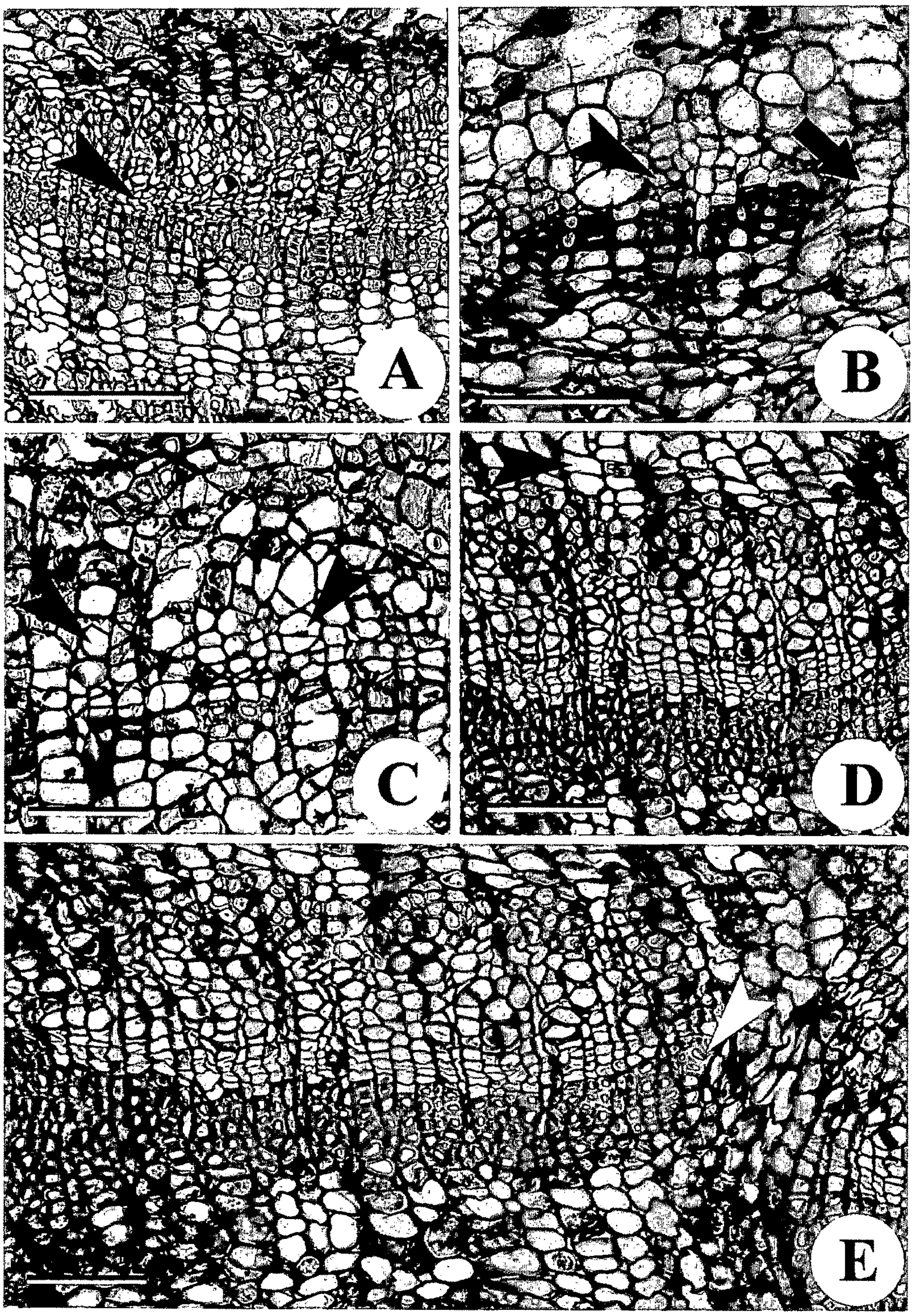

FIGURE-55

FIGURE - 56

Macroscopic (A) transverse view (B-D) of mature stems of *Securidaca rivinaefolia* A. St.-Hill & Moq., showing different stages of cambial origin.

A. Macroscopic view of mature stem showing dumbbell shaped configuration with eccentric successive ring of cambia (arrowhead) and xylem rings (arrow).

B. Formation of only xylem fibres by the newly developed cambium. Arrowhead showing well developed new cambium while arrow indicates conjunctive tissue, XY- secondary xylem.

C. Newly developed cambium showing recently formed xylem fibres (arrowhead) and occasionally formation of vessel elements. Note the development of new cambium occurs only after the formation of some xylem by previous cambium.

D. Macroscopic view of growth rings.

Scale bar- B, C: 75 µm; D: 100 µm.

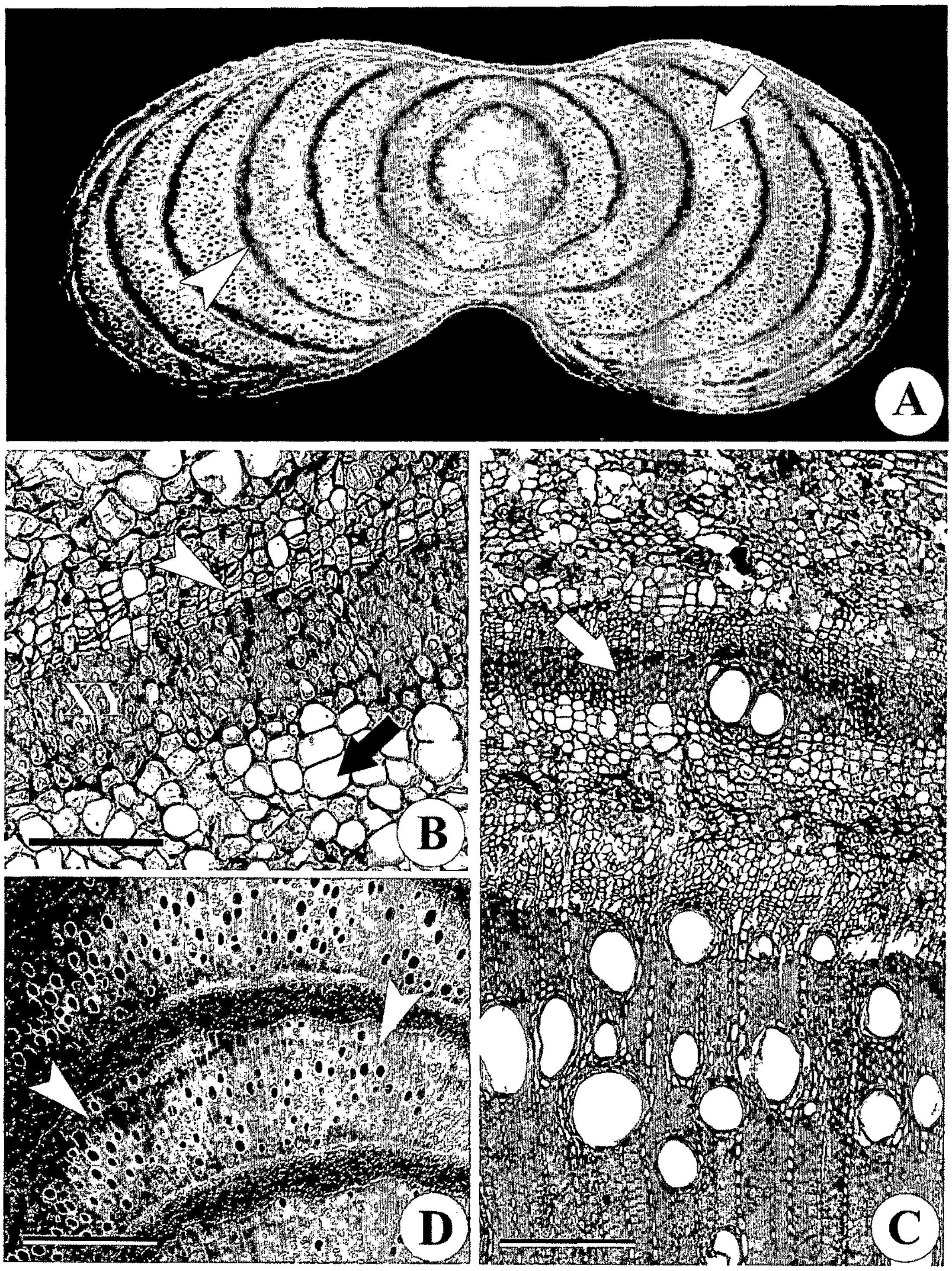

FIGURE-56

FIGURE - 57

Transverse (A-C) and tangential longitudinal (D-F) view of secondary xylem of *Securidaca rivinaefolia* A. St.-Hill & Moq.

A. Secondary xylem of formed by two successive cambial rings showing growth ring markers (arrowheads).

B. Enlarged view of growth ring marker (arrowhead) showing thicker fibers in latewood, and relatively wider lumened vessel elements in early wood.

C. Ray cells in the limit of the growth ring. Note the ray cells dimensions, latewood ray cells are isodiametric (arrow) and radially elongated early wood ray cell (arrowhead).

D. General structure of secondary xylem. Note that rays are mostly uniseriate with 1-2 celled rays at some places.

E. Xylem fibres with bordered pits (arrowheads).

F. Enlarged view of xylem fibre showing bordered pits.

Scale bar- A, B: 100 μm; C, D: 75 μm; E: 50 μm.

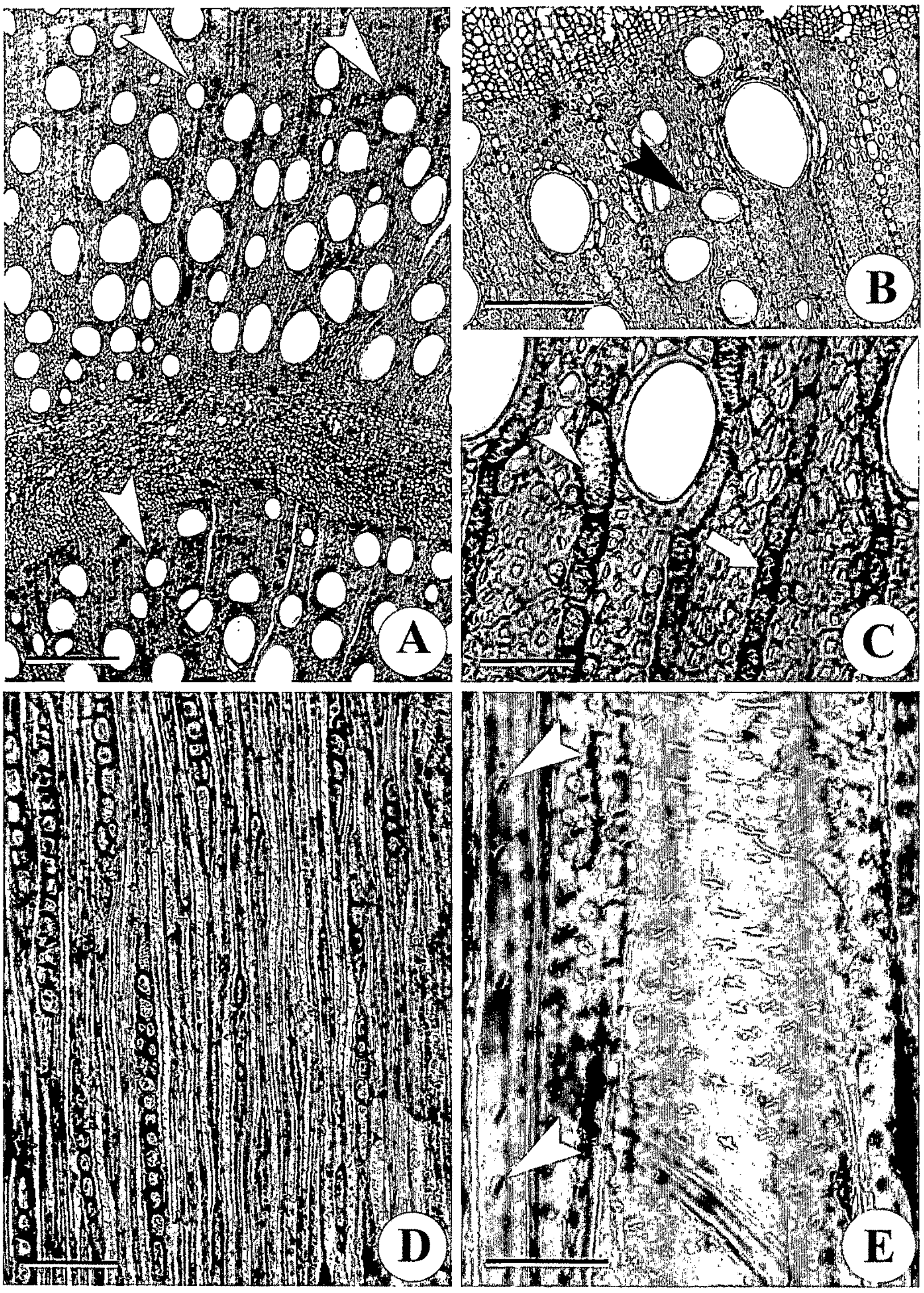

FIGURE-57

Table 2: Dimensional details of fusiform cambial cells and its derivatives (with standard deviation) of plants showing internal phloem. Values in parentheses indicate range (minimum-maximum) of variation in length and width (µm).

Sr. No	Name	Fusiform Cambial Cell	Vessel Element		Xylem Fibre		Sieve tube (Internal)		Sieve tube (External)	
		Length	Length	Width	Length	Width	Length	Width	Length	Width
1.	*Ipomoea hederifolia* L.	321 ±4.885 (320-360)	352 ±3.624 (228-438)	181 ±3.004 (134-248)	1205 ±11.945 (1062-1400)	28 ±0.500 (25-37)	350 ±9.282 (346-362)	28 ±2.780 (25-31)	326 ±9.892 (323-368)	25 ±0.120 (23-27)
2.	*Ipomoea aquatica* Forssk.	169 ±3.323 (124-249)	209 ±3.332 (148-275)	245 ±5.048 (225-375)	1625 ±34.329 (1250-1937)	26 ±0.333 (25-35)	248 ±3.306 (240-270)	29 ±1.228 (25-31)	199 ±23.108 (157-231)	25 ± 0.298 (22-27)
3.	*Leptadenia reticulata* (Retz.) W. & A.	179 ±15.177 (150-265)	345 ±4.965 (275-375)	247 ±4.574 (235-300)	822 ±11.097 (750-937)	28 ±1.685 (25-34)	221 ±26.804 (210-250)	21 ±3.218 (20-25)	209 ±14.007 (200-225)	20 ±1.806 (18-24)
4.	*Cressa cretica* Linn.	196 ±16.496 (140-249)	352 ±5.512 (250-438)	67.5 ±1.040 (50-88)	573 ±10.757 (500-760)	16 ±0.458 (13-25)	206 ±10.085 (200-268)	13 ±0.862 (12-16)	145 ±12.343 (140-187)	19 ±1.194 (17-24)
5.	*Solanum pseudocapsicum* L.	221 ±17.068 (171-225)	403 ±7.068 (300-437)	63 ±0.928 (50-78)	589 ±7.238 (550-623)	20 ±4.055 (18-23)	230 ±16.369 (229-280)	20 ±1.806 (23-28)	216 ±20.779 (220-269)	26 ±3.579 (19-27)
6.	*Strychnos bicolor* Prog.	259 ±20.514 (240-312)	370 ±6.525 (273-571)	122 ±4.381 (79-176)	983 ±18.017 (730-1200)	15 ±0.186 (7-16)	380 ±16.804 (375-389)	29 ±3.218 (26-30)	369 ±12.107 (364-374)	28 ±2.006 (22-28)

Table 3 (a): Dimensional details of fusiform cambial cells and its derivatives (with standard deviation) of plants showing medullary bundles. Values in parentheses indicate range (minimum-maximum) of variation in length and width (µm).

Sr. No	Name	Fusiform Cambial Cell	Vessel Element		Xylem Fibre		Sieve Tube	
		Length	Length	Width	Length	Width	Length	Width
1.	*Argyreia nervosa* (Burm. f.) Bojer	312 ±29.200 (280-445)	481 ±10.100 (257-487)	462 ±7.620 (420-620)	1380 ±14.901 (1187-1437)	30 ±0.758 (29-47)	215 ±11.550 (156-312)	29 ±1.276 (24-34)
2.	*Mirabilis jalapa* L.	234 ±1.255 (220-260)	212 ±3.247 (230-255)	75 ±2.208 (70-91)	662 ±7.467 (580-695)	26 ±0.653 (22-30)	197 ±11.752 (156-265)	21 ±1.965 (16-28)
3.	*Boerhaavia diffusa* L.	209 ±3.323 (207-219)	139 ±1.032 (134-225)	105 ±5.048 (72-125)	392 ±9.185 (260-465)	26 ±0.333 (25-35)	178 ±13.306 (157-231)	19 ±1.468 (18-23)

(b) Dimensional details of fusiform cambial cells and its derivatives (with standard deviation) of plants showing cortical bundles. Values in parentheses indicate range (minimum-maximum) of variation in length and width (µm).

Sr. No	Name	Fusiform Cambial Cell	Vessel Element		Xylem Fibre		Sieve tube	
		Length	Length	Width	Length	Width	Length	Width
1.	*Couroupita guianensis* Aubl.	394 ±26.633 (296-468)	478 ±9.480 (350-625)	115 ±1.877 (87-137)	873 ±20.165 (625-987)	20 ±0.595 (15-25)	352 ±15.622 (280-374)	31 ±1.384 (29-35)
2.	*Nyctanthes arbortristis* L.	225 ±16.072 (240-384)	578 ±10.517 (375-600)	73 ±1.351 (60-100)	1125 ±8.988 (1000-1250)	21 ±0.410 (19-30)	160 ±12.007 (125-192)	15 ±0.617 (12-18)

Table 4: Dimensional details of fusiform cambial cells and xylem derivatives in each successive ring of cambium and xylem from the centre towards the periphery in *Cocculus hirsutus* (sizes in µm except when stated otherwise)

Successive Ring No.	Fusiform Cambial Cell		Vessel Element		Vessel Frequency Per mm^2	Fibre Tracheid Length	Xylem Ray		Xylem Ring Width (mm)
	Length	Width	Length	Width			Height	Width	
1.	232 ± 6.63	22 ±1.68	211 ±8.73	193 ±10.53	23 ± 8.57	850 ± 8.22	3818 ± 11.59	365 ± 8.77	2.6
2.	235 ± 4.89	20 ± 0.89	228 ± 6.89	176 ± 7.06	39 ± 6.31	1018 ± 7.72	3984 ± 10.30	472 ± 9.38	4
3.	290 ± 5.78	24 ±1.31	274 ± 8.18	173 ± 10.13	45 ± 4.53	1120 ± 9.11	3998 ± 12.65	523 ± 7.83	7.4
4.	300 ± 7.21	21 ± 1.47	279 ± 6.02	171 ± 7.25	47 ± 6.46	1157 ± 7.37	4911 ± 11.53	560 ± 8.28	10
5.	300 ± 5.39	22 ±1.04	288 ± 8.08	152 ± 8.67	46 ± 8.35	1220 ± 8.70	5183 ± 8.66	640 ± 9.90	13.4
6.	313 ± 6.29	22 ± 0.98	297 ± 8.41	138 ± 9.24	50 ± 7.58	1286 ± 8.71	6018 ±13.58	679 ± 10.01	13.7

Table 5: Dimensional details of fusiform cambial cells and its derivatives (with standard deviation) of plants showing successive cambia with normal orientation. Values in brackets indicate range (minimum-maximum) of variation in length and width (μm).

Sr. No	Name	Fusiform Cambial Cell	Vessel Element		Xylem Fibre		Sieve tube		Rays	
		Length	Length	Width	Length	Width	Length	Width	Height	Width
1.	*Spinacia oleracea* Linn.	178 ±10.496 (159-210)	170 ±5.512 (98-178)	69 ±1.040 (61-73)	1020 ±10.757 (1000-1600)	31 ±0.450 (30-40)	170 ±7.540 (160-220)	21 ±0.687 (15-24)	- - -	- - -
2.	*Cocculus hirsutus* (L.) Diels.	321 ±4.856 (232-323)	346 ±8.290 (312-450)	275 ±2.280 (125-300)	1100 ±26.686 (850-1286)	28 ±0.711 (20-30)	324 ±7.228 (280-430)	29 ±0.957 (24-31)	4855 ± 18.550 (3818-6018)	390 8.780 (365-697)
3.	*Diploclisia glaucanscens* (Bl.) Diels.	341 ±5.743 (299-364)	420 ±7.622 (320-650)	115 ±4.007 (87-250)	899 ±9.238 (750-978)	20 ±0.200 (19-25)	468 ±30.340 (260-565)	28 ±0.708 (22-35)	1150 ± 14.460 (988-1169)	456 ± 9.460 (365-697)
4.	*Antigonon leptopus* Hook. & Arn.	186 ±15.000 (187-342)	168 ±2.905 (73-165)	260 ±6.202 (80-265)	512 ±6.379 (395-578)	25 ±0.611 (19-30)	183 ±12.920 (148-258)	24 ±1.129 (22-29)	1298 ±75.850 (1020-1800)	198 ± 2.730 (128-340)

Table 6: Dimensional details of fusiform cambial cells and its derivatives (with standard deviation) of plants showing successive cambia with inverse orientation. Values in parentheses indicate range (minimum-maximum) of variation in length and width (µm).

Sr. No	Name	Fusiform Cambial Cell Length	Vessel Element		Xylem Fibre		Sieve Tube		Rays	
			Length	Width	Length	Width	Length	Width	Height	Width
1.	*Dolichos lablab* L.	222 ±19.056 (210-245)	292 ±9.935 (250-350)	199 ±23.408 (150-300)	1290 ±20.289 (1062-1950)	19.5 ±0.509 (17-25)	246 ±4.561 (230-295)	19 ±3.064 (18-26)	3009 ±17.957 (65-4586)	655 ±5.575 (25-897)
2.	*Ipomoea hederifolia* L.	321 ±4.885 (320-360)	352 ±3.624 (237-476)	181 ±3.004 (134-260)	1205 ±11.945 (1062-1400)	28 ±0.500 (25-37)	326 ±9.892 (323-368)	25 ±0.120 (23-27)	247 ±9.892 (90-350)	51 ±0.120 (9-71)
3.	*Ipomoea biloba* Forsk.	311 ±10.894 (271-399)	231.5 ±6.832 (150-337)	208.2 ±5.742 (162-325)	1080 ±12.612 (875-1175)	30 ±0.610 (25-35)	391.4 ±14.454 (277-419)	30 ±1.855 (24-35)	980 ±7.942 (457-1048)	180 ±0.484 (67-189)
4.	*Ipomoea quamoclit* L.	198.4 ±9.873 (171-249)	199 ±4.768 (125-312)	175 ±4.040 (225-250)	632 ±7.450 (562-750)	19 ±0.500 (13-25)	196 ±14.094 (150-250)	27 ±1.417 (21-30)	495 ±6.901 (182-570)	90 ± 0.232 (20-117)

Table 7: Dimensional details of fusiform cambial cells and its derivatives (with standard deviation) of plants showing included phloem. Values in brackets indicate range (minimum-maximum) of variation in length and width (μm).

Sr. No	Name	Fusiform Cambial Cell Length	Vessel Element		Xylem Fibre		Sieve tube (Included phloem)		Sieve tube (External)	
			Length	Width	Length	Width	Length	Width	Length	Width
1.	*Leptadenia reticulata* (Retz.) W. & A.	179 ±15.177 (150-265)	345 ±4.965 (275-375)	247 ±4.574 (235-300)	822 ±11.097 (750-937)	28 ±1.685 (25-34)	238 ±26.804 (210-250)	22 ±3.218 (20-25)	209 ±14.007 (200-225)	20 ±1.806 (18-24)
2.	*Salvadora persica* L.	265 ±6.288 (218-298)	246 ±2.478 (135-312)	255 ±1.408 (250-360)	540 ±5.913 (500-890)	28 ±0.489 (20-30)	260 ±8.246 (220-280)	20 ±1.806 (19-31)	253 ±7.942 (210-268)	27 ±1.484 (19-31)
3.	*Coccinia indica* L.	220 ±15.663 (190-228)	225 ±7.767 (186-269)	326 ±5.923 (250-385)	1025 ±30.450 (687-1125)	26 ±0.333 (23-30)	224 ±9.976 (190-296)	25 ±2.208 (22-27)	195 ±6.978 (180-225)	40 ± 2.732 (29-43)
4.	*Strychnos bicolor* Prog.	259 ±20.514 (240-312)	370 ±6.525 (273-571)	122 ±4.381 (79-176)	983 ±18.017 (730-1200)	15 ±0.186 (7-16)	383 ±16.804 (372-385)	27 ±3.218 (26-32)	369 ±12.107 (364-374)	28 ±2.006 (22-28)
5.	*Ipomoea hederifolia* L.	321 ±4.885 (320-360)	352 ±3.624 (237-476)	181 ±3.004 (134-260)	1205 ±11.945 (1062-1400)	28 ±0.500 (25-37)	299 ±9.282 (151-350)	21 ±2.780 (15-28)	326 ±9.892 (323-368)	25 ±0.120 (23-27)
6.	*Canavalia ensiformis* (L) DC.	290 ±19.511 (288-310)	298 ±5.050 (68-271)	152 ±7.154 (150-300)	1225 ±12.933 (1800-2500)	20 ±3.109 (18-30)	280 ±2.600 (270-295)	23 ±2.133 (21-30)	250 ±16.565 (249-295)	24 ±2.344 (20-28)
7.	*Mucuna pruriens var. pruriens* (Linn.) DC.	285 ±13.177 (258-343)	198 ±4.367 (150-275)	281 ±9.287 (150-300)	1442 ±21.280 (1062-1750)	19 ±0.509 (13-25)	245 ±16.077 (225-280)	36 ±1.789 (25-40)	240 ±16.012 (218-280)	37 ±1.290 (30-45)
8.	*Calycopteris floribunda* Lamk.	478.6 ±3.971 (471-490)	136 ±8.686 (210-310)	210 ±3.917 (150-235)	908 ±4.523 (883-927)	19.4 ±0.973 (18-22)	477.5 ±4.719 (467-489)	26.2 ±0.945 (23-28)	473.3 ±6.238 (470-489)	23.7 ±1.247 (18-27)