OBSERVATIONS

The present study is confined to the anatomy, fibre macerates and cell wall substances of the stalk internodes of five different varieties of *S. bicolor*. Figures pertaining to morphology of vegetative and reproductive structures in the text are shown for comparison of varieties investigated viz., IS 18164 (sweet sorghum) (Fig.1), IS 32265 (Fig.5) and IS 5487 (Fig.9) (salt tolerant) and E 36-1 (Fig.12) and M 35-1 (Fig.16) (drought resistant).

VARIETY IS 18164

ANATOMY

In transectional view, the mature stalk internode shows an outer rind region composed of an epidermis made of thick-walled cells and externally covered by a thick cuticle. Inner to the epidermis, a hypodermal zone is present. It is composed of two layers of thick-walled cells and the fibro-vascular bundles are arranged in two or three rings (Fig.2A & B). Based on the size, three types of vascular bundles viz., very small, small and large are recognised in the rind region. Very small and small bundles are arranged alternately (Fig.2A) and are followed by large bundles. The R/T ratio of fibro-vascular bundles is 1.153. In the small and very small bundles, protoxylem is reduced or absent (Fig.3A). Metaxylem is rarely partitioned (Fig.3B). Each vascular strand is surrounded by a complete and continuous fibrous sheath (Fig.3C). The bundle sheath fibres found close to the vascular strand are very thick-walled and the ones present at the periphery are thick-walled. In larger
A - D: Morphology of vegetative and reproductive structures of var. IS 18164

A  Grams

B  Earhead with boot leaf

C  Stalk internode entire, split halves and leaf

D  Portion of the stalk with basal roots
bundles, metaxylem is surrounded by fibres in a continuous ring. The fibres closer to the metaxylem are thick-walled and the ones away from the metaxylem are thin-walled.

At the core region, the vascular strands are surrounded by a common fibrous sheath. Fibres adjoining the vascular strands are thick-walled and those at the periphery are thin-walled (Fig.2D). Parenchyma cells of the ground tissue are thin-walled. The average size of fibro-vascular bundles in terms of R/T ratio is 1.008.

**FIBRE MACERATES**

The rind region shows the presence of very thick-walled and thick-walled fibres (Fig.4A - E & J). The fibres are much longer and have pointed tips (Fig.4E). The average length of fibres is 2273.95 µm, the diameter is 16.19 µm and wall thickness is 4.375 µm. Fibre wall lamellation is very distinct (Fig.4A - E). The number of wall lamellae varies from 4-6. Septate fibres are rarely found and the septal wall is very thin (Fig.4C). Pitting is biseriate in thick-walled (Fig.4A) and uniseriate in very thick-walled fibres (Fig.4D). Pit orientation is oblique.

At the core region, thin-walled and very thin-walled fibres are predominant in occurrence (Fig.4F & G). Thick-walled fibres are rarely found (Fig.4H). Pitting is multiseriate in thin and very thin-walled fibres and biseriate in thick-walled fibres. Fibre tips are blunt. The fibres are 1922.55 µm long, and 14.70 µm wide with a wall thickness of 2.845 µm.
FIGURE - 2

A - D: Transectional views of stalk internode of var. IS 18164

A Distribution of fibro-vascular bundles in rind and core regions

B Enlarged portion of the rind region

C Enlarged view of a rind bundle

D Enlarged view of a core bundle
FIGURE - 3

A - D: Transectional views of stalk internode of var. IS 18164 as seen with light (A & B) and polarisation microscopes (C & D).

A  Rind portion showing wall thickening of epidermis, hypoderma, sclerenchyma and fibro-vascular bundle with single metaphylen

B  Fibro-vascular bundle of the rind showing partitioned metaphylen

C  Polarised view of the rind region

D  Polarised view of a rind bundle showing a continuous fibrous sheath
**FIGURE - 4**

Fibre macerates of rind and core regions of var. IS 18164 as seen with light (A-H) and polarisation microscopes (I & J)

A - E & J: Rind Fibres; F - I: Core Fibres

A  Thick-walled fibre showing wall lamellation and biseriate alternate pitting

B  Thick-walled fibre showing uniseriate pitting

C  Thick-walled fibre showing septation

D  Very thick-walled fibre

E  Thick-walled fibre and a fibre with pointed tip

F  Thin-walled fibre with a broad lumen

G  Very thin-walled fibre

H  Thick-walled fibre with blunt tip

I  Polarised view of a thin-walled fibre

J  Polarised view of a very thick-walled fibre
Both the rind and core fibres show distinct lamellation. The outermost wall lamella appears pink and the innermost lamella appears greenish blue in colour in response to toluidine blue 'O' stain (Fig.4A - H).

VARIETY IS 32265

ANATOMY

Transsectional view of the mature stalk internode shows that the rind region is composed of an epidermis of thick-walled cells covered by a thick cuticle. There is a hypodermal zone consisting of thick-walled cells in 2 layers. The fibro-vascular bundles are arranged in 2-3 rings (Fig. 6A & B). Based on the size, three types of bundles are recognised viz., very small, small and large bundles. Very small and small bundles are arranged alternately beneath the hypodermis followed by large sized vascular bundles. The R/T ratio of fibro-vascular bundles is 1.106. Just above the small sized bundles, the hypodermal zone is thick consisting of 3-4 layers of cells. The fibrous sheath that surrounds the vascular strand adjoins the hypodermis (Fig.6C). In very small bundles, protoxylem is reduced or absent (Fig.7A).

The fibrous sheath surrounding the vascular strand is continuous and complete. The bundle sheath fibres found close to the vascular strand are thick-walled and the ones towards the periphery are thin-walled similar to variety IS 18164 (Fig.6C). Fibres surrounding metaxylem form a continuous ring. The fibres closer to the xylem vessel are thin-walled and the ones away from it are thick-walled.
A - D: Morphology of vegetative and reproductive structures of var. IS 32265

A  Grains

B  Earhead

C  Stalk internode entire, split halves and leaf

D  Basal portion of the stalk with roots and tiller buds
The fibro-vascular bundles in the core region are surrounded by a fibrous sheath. The R/T ratio of fibro-vascular bundles is 1.003. Fibres close to the vascular strand are thick-walled and those at the periphery are thin-walled (Fig.6D). Bundle sheath fibres are well developed on the tangential and adaxial side of the vascular strand. Ground parenchyma cells are thin-walled.

**FIBRE MACERATES**

Three types of fibres are present in the rind region viz., thick-walled, thin-walled and very thin-walled. The fibres are longer with either pointed or blunt tips and the wall lamellation is distinct (Fig.8A - E). The number of wall lamellae is 3 or 4. Pitting is multiserrate in thin-walled fibres and uniseriate in thick-walled fibres (Fig.8C). Thin-walled fibres generally have a wide lumen (Fig.8A, B, G & H). The fibres are 1935.80 µm long, 13.65 µm broad with a wall thickness of 2.58 µm.

In the core region both thin and thick-walled fibres are present (Fig.8D, E, M & I). Fibre tips are pointed (Fig.8D). Pitting is multiserrate in thin-walled fibres. Some of the thin-walled fibres retain their nucleus (Fig.8E). The average length of fibres is 879.69 µm diameter is 9.96 µm wide and wall thickness is 1.87 µm. The outermost wall lamella of both rind and core fibres appear pinkish and the innermost wall lamella greenish blue in colour in response to toluidine blue staining (Fig.8A - E).
FIGURE - 6

A - D: Transectional views of stalk internode of var. IS 32265

A  Distribution of fibro-vascular bundles in rind and core regions

B  Enlarged view of the rind region

C  Enlarged view of a rind bundle

D  Enlarged view of a core bundle showing typical bundle organisation
FIGURE - 7

A - D: Transectional view of stalk internode of var. IS 32265 as seen with light (A & B) and polarisation (C & D) microscopes

A  Rind bundle with a narrow and partitioned metaxylem

B  Rind region showing wall thickening of epidermis and sclerenchymatous hypodermis

C  Polarised view of rind region

D  Enlarged view of a rind bundle in polarised view
FIGURE - 8

A - I: Fibre macerates of rind and core regions of var. IS 32265 as seen with light (A-E) and polarisation microscopes (F-I)

A & B  Very thin-walled rind fibres with multiseriate pitting

C  Narrow and thick-walled fibre in rind region

D  Narrow and thick-walled core fibre with pointed tip

E  Very thin-walled core fibre with the nucleus being retained

F & G  Polarised view of thin-walled rind fibres

H  Thin-walled and wide lumened core fibre

I  Very thin-walled core fibre
Variety IS 5487

ANATOMY

Transectional view of the stalk internode shows a single layered epidermis covered by a thick cuticle (Fig.10D). Epidermis is followed by a sclerified hypodermis of 2 or 3 layers. Beneath the hypodermis small and large sized vascular bundles are present. Very small sized vascular bundles are absent. The average R/T ratio of fibro-vascular bundles is 1.081. In the small sized vascular bundles single metaxylem is present and the protoxylem is absent or reduced (Fig.10E, F and H). Metaxylem in some vascular strands is surrounded by a complete fibrous sheath. The fibres are thick-walled at the close proximity and thin-walled at the periphery of the vascular strand.

Fibro-vascular strands in the core region show typical bundle organisation with well developed phloem, large metaxylem elements and a well developed protoxylem lacuna (Fig.10B & C). The average R/T ratio of fibro-vascular bundles is 0.973. The fibrous sheath surrounding the vascular strand is discontinuous and incomplete. Fibres form a continuous sheath only around the xylem leaving the phloem sheath fibres as a distinct and isolated patch (Fig.10B). Fibres lying at the close proximity of xylem are thin-walled and away from it are thick-walled.

FIBRE MACERATES

In the rind region, three types of fibres are recognised viz., very thin, thick and very thick-walled. In very thick-walled fibres, wall lamellation is not
FIGURE - 9

A - D: Morphology of vegetative and reproductive structures of var. IS 5487

A  Grams

B  Stalk internode entire, split halves and leaf

C  Earhead with boot leaf

D  Portion of the stalk with extensive base roots extending upto the third node
A - H  Transectional views of stalk internode of var. IS 5487 as seen with light (A, B, D, E, F & H) and polarisation (C & G) microscopes

A  Distribution of fibro-vascular bundles in rind and core regions

B  Enlarged view of core bundle with a distinct phloem cap

C  Polarised view of core bundle with large metaxylem vessels

D  Rind region showing epidermal wall thickening and selerenchymatous hypodermis

E  Abnormal rind bundle with single metaxylem

F  Enlarged view of a rind bundle showing a continuous fibrous sheath

G  Polarised view of a rind bundle

H  Rind bundle with partitioned metaxylem
FIGURE - 11

A - J: Fibre macerates of rind and core regions of var. IS 5487 as seen with light (A-E) and polarisation (F-J) microscopes

A - C & F - H Rind Fibres; D & E and I & J Core Fibres

A  Very thick walled fibre with a very narrow lumen
B  Very thin walled fibre with multiseriate pitting
C  Thin walled fibre with blunt tip
D  Thick walled fibre with biseriate pitting
E  Very thick walled fibre
F  Polarised view of thick-walled fibre
G  Very thick walled fibre with uniseriate pitting under polarised view
H  Narrow thick walled fibre showing pointed tip and pit canals
I  Thick walled fibre showing wall striations in polarised view
J  Polarised view of a very thick-walled fibre
distinctly seen (Fig.11A). In the thin-walled fibres, the number of wall lamellae is 2 or 3 (Fig.11B & C). The fibres are 1742.50 μm long, 16.07 μm broad having a wall thickness of 5.79 μm. The fibre tips are blunt (Fig.11C) or pointed (Fig.11G). Pitting is uniseriate in thick-walled fibres and multiseriate in thin-walled fibres. Some thick-walled fibres show pit canals (Fig.11M).

In the core region, thick, very thick and thin-walled fibres are present (Fig.11D, E, I & J). The fibres are shorter as compared to the rind fibres. They are 12.18.30 μm long, 12.50 μm wide with a wall thickness of 3.41 μm. Wall lamellation is not very distinct. Thick-walled fibres show uniseriate pitting. Pits show an oblique orientation (Fig.11D). Thin-walled fibres show multiseriate pitting. Fibres are generally broader in diameter.

VARIETY E 36-1

ANATOMY

In transectional view, the mature stalk internode shows a rind region composed of an uniseriate epidermis with cells showing massive thickening on the outer tangential wall (Fig.14B). Externally the epidermis is bound by a thick cuticle and interrupted by stoma in certain regions (Fig.14A). Following the epidermis, a hypodermal zone composed of 2 or 3 layers of thick-walled cells is present. These cells show prominent thickening towards the inner tangential walls and pit connections (Fig.14B).

The fibro-vascular bundles in the rind region are arranged in 2 or 3 rings (Fig.13A). Two types of bundles viz., small sized and large sized bundles
A - D: Morphology of vegetative and reproductive structures of var. E 36-1

A  Grains

B  Stalk internode entire, split halves and leaf

C  Earhead with boot leaf

D  Portion of stalk with basal roots
are present. Average size of vascular bundles in terms of R/T ratio is 1.084. In small sized bundles, protoxylem is reduced. Each vascular strand is surrounded by a continuous and complete massive fibrous sheath (Fig. 13B). All the bundle sheath fibres are uniformly thick-walled. Isolated fibre strands are present (Fig. 13D). These fibres are thick-walled without prominent pit connections.

In the core region all the bundles are uniformly larger in size. The R/T ratio of fibro-vascular bundles is 1.025. The fibrous sheath surrounding the vascular strand is discontinuous. The fibrous sheath around the xylem is continuous and the phloem sheath fibres form an isolated patch.

**FIBRE MACERATES**

In the rind region, all the four types of fibres viz., thin, very thin, thick and very thick-walled are present. Very thick-walled fibres are longer with pointed tips. The average fibre length is 2211.70 µm, diameter is 16.11 µm and wall thickness is 3.68 µm. Wall lamellation is very distinct (Fig. 15A - C) and the number of lamellae varies from 2-4. In the thick-walled fibres, pitting is biseriate (Fig. 15A) and is multiseriate in thin-walled fibres (Fig. 15B). Pit orientation is oblique. Very thick-walled fibres have a narrow lumen (Fig. 15F). Some fibres are very broad with a wide lumen (Fig. 15G).

In the core region, thin, thick and very thick-walled fibres are present (Fig. 15D, E, M & I). The fibres are 1205.6 µm long, 11.02 µm wide having a wall thickness of 2.39 µm. Wall lamellation is also distinct (Fig. 15D & E). The
FIGURE - 13

A - D: Transectional views of stalk internode of var E 36-1

A  Distribution of fibro-vascular bundles in the rind and core regions

B  Enlarged view of rind bundle with a continuous massive fibrous sheath

C  Enlarged view of core bundle with a distinct phloem sheath

D  Isolated fibre strand in the rind region
A - D: Transectional views of stalk internode of var. E 36-1 as seen with light (A & B) and polarisation (C & D) microscopes

A  Rind region showing a single stoma at the epidermis

B  Epidermal cells showing massive thickening on the outer tangential walls and thick-walled hypodermal cells with prominent pit connections

C  Polarised view of the rind region

D  Enlarged view of rind bundle showing thick-walled sheath fibres
**FIGURE - 15**

A - I: Fibre macerates of rind and core regions of var. E 36-1 as seen with light (A-E) and polarisation (F-I) microscopes

A - C and F - I Rind Fibres; D & E - Core Fibres

A  Thick walled fibre showing biseriate alternate pitting

B  Thin walled fibre

C  Very narrow and thin-walled fibre

D  Thin walled fibre showing multiseriate pitting

E  Thick walled fibre with blunt tip

F  Very thick walled rind fibre

G  Thin walled rind fibre with broad lumen

H  Thin walled core fibre

I  Very thick walled fibre with a narrow lumen
number of lamellae varies from 2-4. Pitting is multiseriate in thin-walled fibres and biseriate in thick-walled fibres (Fig.15E).

**VARIETY M35-1**

**ANATOMY**

The transectional view of the stalk internode shows an outer rind region consisting of an uniseriate epidermis and two layers of hypodermis followed by fibro-vascular bundles arranged in three rings. Hypodermal cells are thick-walled and show striated thickening (Fig.17E). Small and large sized vascular bundles are present. The R/T ratio of fibro-vascular bundles is 1.163. The protoxylem elements in small sized bundles are much reduced or absent. Some of the large sized bundles are conjoint (Fig.17A). The bundle sheath fibres are uniformly thick-walled and completely surround the vascular strand (Fig.17C & F).

Vascular bundles at the core region are sparsely distributed and well developed. The R/T ratio of fibro-vascular bundles is 1.004. The sheathing fibres of bundles are discontinuous around the entire vascular strand. The phloem sheath is distinct and separate (Fig.17B). Metaxylem and protoxylem elements are large (Fig.17D).
FIGURE - 16

A - D: Morphology of vegetative and reproductive structures of var. M 35 - 1

A  Grains

B  Stalk internode entire, split halves and leaf

C  Ear head

D  Portion of the stalk with basal roots
FIGURE - 17

A - F: Transectional views of stalk internode of var. M 35-1 as seen with light (A-C & E) and polarisation (D & F) microscopes

A  Distribution of fibro-vascular bundles in rind and core regions, the rind region showing conjoint fibro-vascular bundles

B  Enlarged view of the core bundle with a distinct phloem cap

C  Enlarged view of the rind bundle

D  Polarised view of a core bundle with large metaxylem vessels

E  Rind region showing thick-walled epidermis and sclerenchymatous hypodermis

F  Polarised view of a rind bundle with a continuous sheath of thick walled fibres
FIGURE - 18

A-H: Fibre macerates of rind and core regions of var. M 35-1 as seen with light (A-D) and polarisation (E-H) microscopes

A-C, E & F - Rind fibres; D, G & H - Core fibre

A  Thin-walled rind fibre showing alternate biseriate pitting
B  Very thin-walled rind fibre
C  Thick-walled rind fibre
D  Thin-walled core fibre showing pointed tip and pit canals
E & F  Polarised view of thin-walled fibres
G  Polarised view of very thin-walled fibre
H  Thin-walled, narrow lumened fibre in polarised view
FIBRE MACERATES

Fibres in the rind region are very thin and thick-walled (Fig.18A-C,E&F). The fibres are 1750.65 μm long, 15.50 μm wide with a wall thickness of 3.68 μm. Wall lamellation is very distinct (Fig.18A - C). The number of lamellae varies from 2-5. Pitting is uniseriate in thick-walled fibres, biseriate and multiseriate in thin-walled and very thin-walled fibres respectively (Fig.18A & B). The outermost layer is pinkish and the innermost lamella is greenish blue in colour in response to toluidine blue ‘O’ staining (Fig.18A).

Core fibres are mostly thin and thick-walled (Fig 18D,G&H) and very thick-walled fibres are rare in occurrence. Average fibre length is 1129.32 μm, diameter is 13.13 μm and wall thickness is 2.39 μm. Pitting is multiseriate and the fibre tips are mostly pointed. Some fibres show pit canals (Fig 18D).

HISTOCHEMICAL STUDIES ON WALL SUBSTANCES

Lignin

Phloroglucinol method employed to localise lignin distribution in fibro-vascular bundles, shows that sheath region takes up red stain (Fig.31&34 - C&D; 32,33&34 - C,D&E). The sheath region adjoining the vascular elements is darkly stained, while the peripheral region is lightly stained. In variety E 36-1 the fibrous sheath showed maximum staining owing to the thick and massive sheath surrounding the vascular elements (Fig.34C & D).
Cellulose

Fluorescent technique employed for the localisation of cellulose in fibrovascular bundles shows high intensity of fluorescence in the sheath fibres. In general the ground parenchyma and phloem elements also exhibit fluorescence (Figs. 31-35 A & B).

On staining with Acridine orange, a fluorescent dye, the cell walls showed fluorescence in green and yellow depending on the wall thickness (Fig. 31 & 33-35, E & F; 32, E,F & G).