3. **Momordica dioica** Roxb. ex Willd.

**Momordica dioica** is a dioecious climber, found throughout India. It grows wild in the hedges but often cultivated for its fruits which are used as a vegetable. Its roots are tubrous. The stem is glabrous. Leaves are ovate, and deeply 3-5 lobed. Flowers are solitary and yellow.

Fruit is ovoid or ellipsoid, shortly beaked and densely achinate with spine. The mature fruit is green but it turns yellowish-orange when ripe. Seeds are slightly compressed, 6.0-7.0 mm long and irregularly corrugated. Different developmental stages are studied from the young unfertilised ovary to the mature fruit. Two major dimensions of the fruit
of each stage were measured, circumference at the widest point, and length from the point of attachment of fruit with the stalk to the apex. Table 3.1 shows data regarding the length and circumference of the fruit at different stages of its development.

**MORPHOLOGY**

The young ovary selected for the study is about 0.5-1.2 cm long, oblong, soft light green and densely covered with young soft spines (Fig.3.1A). Macroscopically the ovary appears only covered by the spine but its surface is also covered with minute hairs which are also present on the mature fruit.

At the second stage of the development the circumference increases at the basal region (Fig.3.1B, C). Therefore, a developing fruit appears broad at the base and narrow towards the apex (Fig.3.1D). Later, radial growth in the middle portion also causes an increase in the circumference of the fruit in that region, so ultimately fruit remains only narrow at the upper end (Fig.3.1E, F). Thus, increase in the circumference of the fruit takes place from the base to the apex.

Spines on young ovary are soft and small. The number of spines per unit area of the surface is not much affected
at various stages of fruit development (Table 3.3). This shows that the development of the spine continues for a long time. Spines are comparatively shorter in the upper region of the fruit (Table 3.3). Thus, the surface of the mature fruit appears densely covered with spines (Fig.3.1F). As the fruit development proceeds, size and stiffness of the spines increase (Table 3.3). Longest spines are observed from the 4th stage of the fruit development.

**GROSS ANATOMY**

Two broad regions can be identified in the longitudinal transactions of the fruit (Fig.3.1G, H). The outermost region is the skin. It is moderately thick and covered with spines. The soft region is of the flesh occupying the major part of the fruit. Seeds are embedded in the interior part of the flesh.

**DEVELOPMENTAL ANATOMY**

The young ovary at the base is distinguished into three main regions, (1) a single layered epidermis, (2) ground tissue, and (3) vascular tissues (Fig.3.2A, B). A few outer layers of the ground tissue are chlorenchymatous. Vascular bundles are embedded in the peripheral ground tissue and arranged in a ring (Fig.3.2A, B). Three distinct
Placental cavities are present in the middle region of the ground tissue (Fig. 3.2C, D). Ovules arise from the cells situated near the two ends of the inner side of the placental cavity (Fig. 3.2D, F). The cells lining the placental cavity are rectangular, densely stained and compactly arranged. They mostly divide anticlinally to form the endocarp of the mature fruit. Few vascular meristem strands develop from the inner tissue (Fig. 3.2B). Three vascular bundles having inverse orientation of xylem and phloem are present in the centre. They are ventral bundles (Fig. 3.3A).

At the 2nd stage, cells lying between the two adjacent placenta enlarge (Fig. 3.3B) which ultimately contributes to the tangential growth.

**Development of skin**

The skin of *M. dioica* is a composite structure and consists of (1) a single layer of epidermis, (2) a few layers of chlorenchymatous hypodermis, and (3) a few layers of lignified cells of the outer mesocarp. The epidermis and hypodermis constitute the epicarp. At the 1st and 2nd developmental stage of the fruit development, the skin is soft and it consists of the epidermis and hypodermis (Fig. 3.2A).
Epidermis

Epidermal cells are polygonal in surface view. During the development of fruit they divide anticlinally, thus contributing to its surface growth. Fig. 3.13A substantiates that the cell divisions in the epidermis continue up to late fruit development. Compared to the other regions of the fruit, cell enlargement in the epidermis is not marked (Fig. 3.13A). Along with the fruit development the thickness of the cuticle increases. At the 5th and 6th stage of the fruit development lipid bodies are identified in some epidermal cells (Fig. 3.3D). Their diameter varies from 6.2 to 7.6 micron. In the ripe fruit, occasionally, a few scattered cells show phenolic substances (Fig. 3.3C). They are without plastids, nucleus and vacuoles (Fig. 3.3C). During 6th stage of the fruit development the nuclei in several epidermal cells degenerate. During the ripening of the fruit, chromoplasts in the epidermal cells give yellowish-orange colour to the skin.

Hairs

Hairs of M. dioica are glandular and eglandular.

Glandular hair

Glandular hair is simple and consists of a unicellular foot and a body. The body has a multicellular uniseriate stalk
and a 6-8-celled clavate head (Fig. 3.9A).

**Development of eglandular hair**

A papillate epidermal cell acts as a hair initial (Fig. 3.9B). It divides periclinally to form a basal cell and a terminal cell (Fig. 3.9C). The terminal cell divides periclinally to form a head cell and a stalk cell (Fig. 3.9D). The stalk cell by further periclinal divisions gives rise to a uniseriate stalk. The head cell divides in various planes and forms the clavate head (Fig. 3.9E, F). The basal cell becomes the foot cell.

**Eglandular hair**

Eglandular hair is simple and filiform (Fig. 3.9G). The foot is unicellular or bicellular, and a multicellular body is not differentiated into a stalk and a head.

**Development of eglandular hair**

A papillate hair initial divides periclinally to form a basal cell and a terminal cell. The terminal cell undergoes successive periclinal divisions (Fig. 3.9G) to form a multicellular filiform hair. The cell above the foot may divide anticlinally to form a biseriate base of the body. One or two terminal cells may enlarge. The basal cell differentiates as a unicellular foot or divides anticlinally to form a bicellular foot (Fig. 3.9H).
Stomata are present at all stages of fruit development. However, their developmental stages are normally observed during early fruit development. As the fruit develops the frequency of stomata decreases (Table 3.2) because new stomata do not develop though epidermal cells continue to divide. Anomocytic (aperigenous), haploecytic (hemiparamesoperigenous), paracytic (diaperigenous) and teracytic (tetramesogenous) stomata are present.

Development of stomata

A meristemoid is a small, more or less oval cell with densely stained cytoplasm and a prominent nucleus (Fig.3.9I). Anomocytic (Aperigenous) stomata

The guard cells originate from the meristemoid (Fig.3.9J). The mature stoma is surrounded by 4-6 normal epidermal cells (Fig.3.9K).

Haploecytic (Hemiparamesoperigenous) stomata

The meristemoid divides only twice to produce one subsidiary and two guard cells. Both divisions are parallel to each other so that the position of the subsidiary cell is lateral (Fig.3.9L, M). Guard cells are surrounded by one subsidiary and a few epidermal cells (Fig.3.9M).

Occasionally, a second division of the meristemoid is perpendicular to the first division. Then the subsidiary
cell has a polar position (Fig.3.9N, O).

**Paraepityc (paramesopercigenous) stomata**

Two subsidiary cells are present on the lateral side while epidermal cells have polar position (Fig.3.9P). Occasionally, a subsidiary cell divides perpendicular to the long axis of the pore (Fig.3.9Q).

Rarely, a stoma has three subsidiary cells parallel to each other and flanking the lateral side of the guard cell (Fig.3.9R). It is hexaperigenous.

**Tetrapytic (tetramesopercigenous) stomata**

Five divisions of a meristemoid, each at right angles to the previously divided plane of division result into the formation of a stoma with four subsidiary cells. First four unequal divisions result in the development of the subsidiary cells (Fig.3.9S) and the last division leads to the development of two guard cells. Therefore, the first formed subsidiary cell is the largest and the last formed cell is the smallest (Fig.3.9S). This is helicocytic type of Pyne (1970).

**Contiguous stomata**

Rarely, contiguous stomata at the polar ends are observed (Fig.3.9U).

**Degeneration of guard cells**

The degeneration of guard cells is normally observed
in the mature fruit, they, with scanty cytoplasm, appear collapsed, possibly due to loss of turgidity (Fig. 3.9V). Nuclei and chloroplasts also degenerate.

**Plasmodesmata**

Fine cytoplasmic connections passing through the anticlinal walls of the epidermal cells are present (Fig. 3.3F). The average number of plasmodesmata per 100 micron long wall was fourteen.

**Hypodermis**

The hypodermis of the mature fruit has 15-20 layers of chlorenchymatous cells. They are partly responsible for the colour of the fruit. Chromoplasts develop during the ripening of the fruit in these cells. During the early fruit development a few hypodermal cells divide anticlinally and periclinally (Fig. 3.3F, 3.4B) and the subsequent growth in this region is mostly by cell enlargement (Fig. 3.13A). As the fruit further develops, these cells elongate radially. This pattern of cell growth is partly responsible for the ovoid shape of the fruit. Peripheral cells elongate earlier than those of the inner side. Hypodermal cells external to the ring of lignified cells present in the skin show the least elongation (Fig. 3.4A).

**Spiny projection**

The skin of the young and mature fruit is densely covered with spiny projections. They are filiform with
broad base and sharply pointed apex. The multicellular filiform eglandular hair is present at the spine tip.

Structure of the spine

It has a single layered epidermis and ground tissue of a few layers of chlorenchymatous cells (Fig. 3.10C, 3.11A). Epidermal cells are polygonal in surface view. The continuity of the epidermis is interrupted by stomata (Fig. 3.11A). Anomocytic (aperigenous), heliocytic (hemipermesoperigenous) and paraocytic (paramesoperigenous) stomata are observed. Their structure and development are similar to those of the fruit epidermis. Glandular and eglandular hairs are present (Fig. 3.11). Their structure and development are similar to those of the fruit epidermis.

Development of the spine

The spine develops below the base of the young eglandular hair. But all eglandular hairs are not associated with the formation of the spine. It is also difficult to distinguish morphologically the hairs that are likely to be associated with the formation of the spine. Cells of the hypodermis below the hair divide (Fig. 3.11B) to initiate the spine. They are small and densely stained prominent nuclei. Epidermal cells adjacent to the foot cell also divide anticlinally. The foot cell may divide anticlinally (Fig. 3.11C). Thus, a few hypodermal cells along with the
associated foot cells of the hair and their contiguous epidermal cells enlarge to form a spine primordium (Fig.3.11D). Further divisions in the epidermal and hypodermal derivatives occur and their subsequent growth takes place. The hair along with its foot tops the spine primordium. The basal cells of the spine primordium are meristematic (Fig.3.11E). The differential divisions and growth in the epidermal and inner layers bring the elongation of the spine. Cells situated above the foot of the hair may also further divide and elongate (Fig.3.10C). Fine cytoplasmic connections through the common wall of the two adjacent body cells of the hair are present (Fig.3.4D).

Most of the cells of the spine enlarge more or less parallel to its long axis (Fig.3.10). Rarely, periclinal divisions are observed in the epidermal cells (Fig.3.11E).

The spine lacks any vascular tissue. The entire spine develops from the epidermal and hypodermal cells of the young fruit. Therefore, the spine is a superficial outgrowth of the fruit skin.

**Outer mesocarp**

The outer mesocarp of the mature fruit is a complete ring of isodiametric sclereids subjacent to the hypodermis (Fig.3.4A, 3.10A). This constitutes a hard layer of the skin. It protects the inner soft flesh of the fruit.
The development of the outer mesocarp begins from the 3rd stage of the fruit development. The parenchyma cells of the ground tissue of the ovary subjacent to the chlorophyllous layers undergo sclerosis (Fig. 3.10A). In the early fruit development, as the sclerosis is not continuous, isolated groups of sclereids below the hypodermis are first observed. The parenchyma cells between such adjacent groups divide radially (Fig. 3.4C). Some of these cells develop into sclereids and others continue to divide till the late fruit development. Thus, the pattern of the development of the sclereids is commensurate with the growth in circumference of the fruit. The sclereid initial enlarges first with increased vasuolation (Fig. 3.4E) and subsequent heavy deposition of the wall material. Fine cytoplasmic threads through the common wall between two adjacent sclereids are present (Fig. 3.5E). The nuclei in many sclereids degenerate during fruit ripening. At the 6th stage of the fruit development, a complete ring of sclereids is formed.

Development of Flesh

The flesh is a soft region of the fruit beneath the skin. It consists of middle and inner mesocarp, endocarp and the placental regions.
Middle and Inner mesocarp

During the early fruit development, the mesocarp is homogenous and not differentiated into outer, middle and mesocarp. The parenchyma cells of the ovary near the vascular bundles (Fig. 3.2A, B) form the middle mesocarp (Fig. 3.10A, B). The parenchyma cells, external to the placental cavity, undergo periclinal and anticlinal divisions, and their subsequent enlargement contributes in forming the inner mesocarp (Fig. 3.5A, B). Their periclinal divisions contribute to the growth in the circumference of the fruit. Later, the middle mesocarp becomes distinct from the inner mesocarp because of the uneven wall thickening in the former (Fig. 3.5C, D). The cell walls of the inner mesocarp cells are comparatively thin (Fig. 3.5D). This difference in the cell wall thickening between the middle and inner mesocarp cells is observed during the 3rd stage of the fruit development. During the 4th stage initially a few scattered cells show small starch grains. Subsequently, many of them, 8-13 micron in diameter, are observed in the cells of middle and inner mesocarp (Fig. 3.5C, D).

In the middle and inner mesocarp the fruit growth predominantly takes place by cell enlargement from the 3rd stage (Fig. 3.13A, B). During fruit ripening, intercellular spaces in the middle and inner mesocarp cells enlarge.
Physiological and biochemical changes during fruit ripening result into the separation of the flesh cells. Chromoplasts also develop.

Major vascular strands, arranged in a ring below the outer mesocarp (Fig.3.10A), are prominent and bicolateral (Fig.3.6B). The fruit stalk has nine vascular strands at the first stage of the fruit development (Fig.3.11F). They branch in the fruit extending vertically up in the middle mesocarp and the tip of the fruit. During fruit development, major strands appear slightly towards the inner side because of the increase in the number of cell layers in the hypodermis, their cell enlargement, and formation of the sclereid ring. Other minor strands develop from the vascular meristem-procambium which differentiates from the parenchyma cells of the flesh. They are collateral or rarely bicolateral. They may have abnormally oriented tracheary elements.

Minor strands show definite pattern of orientation in the different parts of the flesh. In the middle mesocarp, they may be horizontal, i.e., parallel to the circumference of the fruit or vertical, i.e., parallel to the long axis of the fruit (Fig.3.6C, D). In the middle mesocarp they may anastomose to form an irregular pattern. In the inner mesocarp, most of the strands run
parallel to the long axis of the fruit (Fig. 3.6F). A few ones are horizontal and radial. Some of them may anastomose with those of the middle mesocarp in the peripheral region and with those of the placental region in the inner side. In the placental region most of the bundles are radially oriented except a few minute upward strands (Fig. 3.6E).

**Development of minor strands**

As stated earlier minor strands are derived from the vascular meristem developed from the parenchyma cells of the flesh. Initially one or two parenchyma cells divide. These derivatives form a small strand of vascular meristem (Fig. 3.7A). Such strands are scattered in the flesh. A few sieve elements develop earlier than the tracheary elements (Fig. 3.7B, C). Xylem may be endarch (Fig. 3.7B, D) or exarch (Fig. 3.7C). Occasionally, inner phloem also develops (Fig. 3.7E). Some isolated strands of phloem are present in the flesh. Occasionally, very minute strands with only a few conducting elements are observed in a mature fruit (Fig. 3.7G). During the 4th stage of the fruit development many minor strands with irregularly arranged xylem cells are observed (Fig. 3.8A, B). In Fig. 3.8D xylem is present at the two ends of the bundle while in Fig. 3.8A, B xylem is peripheral. Because of such an abnormal arrangement of the xylem, it can be presumed that such a small vascular complex is formed by
the union of minute strands. They have joined at their phloem regions and their xylem is directed away from each other. During the late stage of the fruit development parenchyma cells of the mesocarp surrounding the minor bundles contain starch grains (Fig. 5.7f).

Endocarp

It is a single layer of tubular cells surrounding the seeds (Fig. 3.6f). As stated earlier it is derived from rectangular cells surrounding the placental cavity of the ovary (Fig. 3.10A, B). Their frequent anticlinal divisions and subsequent enlargement in the tangential direction contribute to the formation of the endocarp of the mature fruit (Fig. 3.6f). In the endocarp, cell enlargement is prominent over the cell divisions from the 4th stage of the fruit development (Fig. 3.13B).

Stomata of endocarp

The stomata are anomocytic (aperigenous), haplocytic (hemiperamesoperigenous) and paraeystic (diaperigenous). A wide aperture with more or less circular outline in the surface view is the characteristic feature of the endocarpic stomata. The diameter of the aperture varies from 20-26 micron.

Development of the stomata

A triangular meristemoid is cut off by an unequal
division of the endocarpic cell.

Anomooytic (aperigenous)

Figures 3.12A, B, C and D illustrate the development of the anomocytic stomata.

Haplocytic (hemiparamesopogenous)

The development is illustrated in figs. 3.12E, F and G. Sometimes a common subsidiary cell between two adjacent stomata is observed in which its position is lateral for one stoma, while for the other it is polar (Fig. 3.12H).

Parepic stomata (diaperigenous)

Two lateral subsidiary cells are derived from the surrounding endocarpic cells (Fig. 3.12I). The polar side is flanked by normal endocarpic cells.

Occasionally, two stomata and two subsidiary cells are placed alternately (Fig. 3.12J). It appears that subsidiary cells are mesogenous.

Sometimes the meristemoid behaves as a guard mother cell after two divisions (Fig. 3.12K, L). Here two subsidiary cells are lateral while the third one is polar (Fig. 3.12M).

Stoma with three subsidiary cells

The meristemoid directly behaves as a guard mother cell. The adjacent endocarpic cell divides twice to produce three subsidiary cells arranged in a raw on one side of the guard cell. The subsidiary cell adjacent to the guard cell is
flanked in such a manner that it partly occupies the polar side. The other sides of the guard cells are flanked by the normal endocarpic cells (Fig. 3.12N). Because of such abnormal position of subsidiary cells, it is difficult to classify this type of stomata.

**Abnormal Stoma**

Rarely, an abnormal stoma is found with two apertures and three guard cells. Two of them are parallel with each other having a wider aperture. The polar side of this stoma is flanked by the other guard cell forming an aperture along the point of meeting of two large guard cells. Such a stoma is surrounded by normal endocarpic cells (Fig. 3.12O).

**Placental Region**

This region is also soft, homogenous and delicate. It is parenchymatous. It develops from the central ground tissue of the ovary (Fig. 3.6A and 3.10A, B). Their differential divisions and subsequent enlargement result in the formation of the placental region of the mature fruit. Cells of this region and also of the mesocarp undergo similar changes during the ripening of the fruit. In this region cell divisions continue up to 3rd stage of the fruit development, and later the growth of this region is predominantly by cell enlargement (Fig. 3.13B).
Structure of phloem

Phloem is present on either side of the major vascular strand (Fig. 3.6B) and on one or rarely both sides of the minor strands (Fig. 3.7E). Isolated scattered strands of the phloem are also observed.

The inner cambium of the major strand is inert, but at the 4th stage of the fruit development new phloem elements develop from the derivatives of the mesocarpic parenchyma (Fig. 3.8A).

Sometimes, a large mesocarpic parenchyma cell adjacent to the inner phloem is thin walled with dense cytoplasm (Fig. 3.8C). A group of phloem cells differentiate from its daughter cells.

There is hardly any phloem tissue formed by the outer cambium, but a few phloem elements differentiate from the mesocarpic parenchyma (Fig. 3.8D).

Sieve tube elements are 90-120 micron long and 20-30 micron broad. Sieve plates are simple on transverse to oblique end walls. The number of pores in the sieve plate varies from 72-112. Isolated sieve tube elements are not observed.

ANATOMICAL STRUCTURE OF THE FRUIT

The mature fruit is distinguished into two main parts
(1) skin and (2) flesh (Fig. 3.10A).

Skin It is of two regions (1) epicarp and (2) outer mesocarp.

Epicarp Epidermis and hypodermis constitute the epicarp.

Epidermis of the mature fruit is single layered and consists of compactly arranged rectangular cells. A moderately thick and smooth layer of cuticle is present. Stomata, spines, glandular and eglandular hairs are also present.

Hypodermis It consists of radially elongated chlorenchymatous cells.

Outer mesocarp It consists of 6-12 layers of thick walled, isodiametric sclereids giving a hard texture to the skin. This is a protecting region of the skin.

Flesh

Flesh of the mature fruit consists of the following regions.

Middle mesocarp: It is a soft homogenous region of parenchyma cells containing many starch grains. Cell walls show uneven thickening. Inter cellular spaces are wide.

Inner mesocarp: This region differs from the middle mesocarp by its comparatively thin walled cells.

Endocarp: It is an innermost layer of compactly arranged rectangular cells. Stomata with wide apertures are present. Hairs are absent.
Placental region: It is the parenchymatous region of the flesh extending centripetally from the placental cavity. Seeds are embedded in this region.

Vascular tissue: Major biocollateral strands are at the periphery of the middle mesocarp. Minor collateral (rarely biocollateral) strands are of varying patterns in the different parts of the flesh. They anastomose with each other forming a complex vascular system.

The ventral bundles are in the center. Isolated phloem strands are present but isolated sieve tube elements are absent.

THE RELATION BETWEEN CELL SIZE AND FRUIT SIZE

The relation between cell size and fruit size is graphically presented (Fig.3.13A, B). For various regions of the fruit, the graph is linear at the early stage of the fruit development indicating rapid increase in the fruit size in comparison to the cell size. From the 3rd stage, the linear graph bends upwards. This shows that the fruit size increases with the cell enlargement. Before the inflection point the increase in the fruit size is prominent over the increase in the cell size but after the inflection point cell expansion is marked with the fruit development.
Thus, the fruit growth is a result of the two main factors: (1) cell multiplication and (2) cell enlargement. Before the inflection point, the linear graph shows that the fruit growth is by cell multiplication. After the inflection point, the vertical line of graph indicates that the growth of the fruit is mainly due to cell enlargement (Fig.3.13A, B).

Different parts of the developing fruit show varying behaviour in the cell multiplication and enlargement (Fig.3.13A, B). The cells in the inner region of the fruit, i.e. placental region and inner part of the mesocarp, show more cell enlargement after the inflection point. For epidermal cells inflection point is not sharp. This indicates that their growth is mainly due to cell divisions as cell enlargement is not marked (Fig.3.13A). Hypodermal cells undergo conspicuous cell enlargement (Fig.3.4A). Like the inner parts of the fruit this region of the skin has growth mainly due to cell enlargement after inflection point.
<table>
<thead>
<tr>
<th>Stage</th>
<th>Length in cm</th>
<th>Circumference in cm</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>0.5-1.2</td>
<td>0.8-1.5</td>
<td>Ovary of the flower bud</td>
</tr>
<tr>
<td>2nd</td>
<td>1.5-2.0</td>
<td>2.0-2.5</td>
<td>Ovary of the flower</td>
</tr>
<tr>
<td>3rd</td>
<td>2.3-2.8</td>
<td>2.6-3.0</td>
<td></td>
</tr>
<tr>
<td>4th</td>
<td>3.0-3.8</td>
<td>4.0-4.5</td>
<td>Developing stages of fruit</td>
</tr>
<tr>
<td>5th</td>
<td>4.0-4.5</td>
<td>6.0-7.0</td>
<td></td>
</tr>
<tr>
<td>6th</td>
<td>5.0-6.0</td>
<td>7.5-8.0</td>
<td>Mature fruit</td>
</tr>
</tbody>
</table>
Table 3.2. Frequency of stomata per mm$^2$ for different developing stages. The frequency is calculated for the middle region of the fruit.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Frequency/mm$^2$</th>
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<tbody>
<tr>
<td>1st</td>
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<tr>
<td>2nd</td>
<td>102.6</td>
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<tr>
<td>3rd</td>
<td>94.0</td>
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<tr>
<td>4th</td>
<td>78.4</td>
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<tr>
<td>5th</td>
<td>64.4</td>
</tr>
<tr>
<td>6th</td>
<td>56.0</td>
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</table>
Table 3.3. The number of spines per cm$^2$ area and their range of length for the different region of the fruit.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Number of spines</th>
<th>Spine length in basal region in mm</th>
<th>Spine length in middle region in mm</th>
<th>Spine length in upper region in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>70</td>
<td>0.5-2.5</td>
<td>0.5-2.5</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>2nd</td>
<td>70</td>
<td>0.5-2.5</td>
<td>0.5-2.5</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>3rd</td>
<td>68</td>
<td>0.5-2.5</td>
<td>0.5-2.5</td>
<td>0.5-1.5</td>
</tr>
<tr>
<td>4th</td>
<td>66</td>
<td>0.5-3.0</td>
<td>0.5-3.0</td>
<td>0.5-2.0</td>
</tr>
<tr>
<td>5th</td>
<td>64</td>
<td>1.0-3.5</td>
<td>1.0-3.5</td>
<td>0.5-2.0</td>
</tr>
<tr>
<td>6th</td>
<td>63</td>
<td>1.5-3.5</td>
<td>1.2-3.5</td>
<td>1.0-2.3</td>
</tr>
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</table>
Fig.3.1.A-H.
A. Developing fruit in 1st stage.
B. Developing fruit in 2nd stage.
C. Developing fruit in 3rd stage.
D. Developing fruit in 4th stage.
E. Developing fruit in 5th stage.
F. A mature fruit.
G. Longisection of the fruit in 6th stage.
H. Transection of the fruit in 6th stage.
( pl - placental region; white line indicates scale of 3 cm ).
Fig. 3.2A-F. All transections.
A. Basal portion of the fruit in 1st stage, X 65.
B. Enlarged view of A, X 130.
C. Placental region in the middle portion of the fruit in 1st stage, X 130.
D. Enlarged view of C, X 350.
E. Middle portion of the fruit in 1st stage showing inner part of the placental region, X 130.
F. Ovular primordium in the placental region of the fruit in 1st stage, X 350.
XXXII

Fig. 3.3A-F.

A, B. Transections.

A. Middle portion of the fruit in 2nd stage showing inner part of the placental region, X 350.

B. Middle portion of the fruit in 2nd stage showing region between two placentae, X 350.

C. Epidermis from the middle portion of the fruit in 6th stage showing a cell with phenolic contents, X 650.

D. Epidermis from the middle portion of the fruit in 5th stage, X 500.

E. Epidermis from the middle portion of the fruit in 6th stage showing plasmodesmata, X 1200.

F. A transection of the middle portion of the fruit in 2nd stage showing epicarp, X 350.

( ad - anticlinal division; lb - lipid body; vb - ventral bundle ).
Fig. 3.4A-E.
A-C,E. Transsections.

A. Middle portion of the fruit in 6th stage showing epicarp, X 36.
B. Middle portion of the fruit in 2nd stage showing epicarp, X 350.
C. Middle portion of the fruit in 4th stage showing outer and middle mesocarp, X 350.
D. A portion of the hair of spine showing plasmodesmata between two adjacent cells, X 1400.
E. A transection of the middle portion of the fruit in 3rd stage showing outer mesocarp, X 650.

( pe - periclinal division; rd - radial division; v - vacuole ).
Fig. 3.5A-F. All transactions.

A. Middle portion of the fruit in 1st stage showing inner mesocarp, X 350.

B. Middle portion of the fruit in 2nd stage showing inner mesocarp, X 560.

C. Middle portion of the fruit in 5th stage showing middle mesocarp, X 350.

D. Middle portion of the fruit in 5th stage showing inner mesocarp, X 350.

E. Middle portion of the fruit in 6th stage showing outer mesocarp, X 1200.

F. Parenchyma cells of the inner mesocarp of the fruit in 6th stage, X 1400.

( ad - anticlinal division; ics - intercellular space; pd - plasmodesmata; pe - periclinal division; sg - starch grains ).
Fig. 3.6A-F. All transections.

A. Basal portion of the fruit in 1st stage showing placental region, X 350.

B. A vascular bundle from the basal region of the fruit in 3rd stage, X 560.

C,D. Middle portion of the fruit in 4th stage showing middle mesocarp, X 130.

E. Upper portion of the fruit in 5th stage showing placental region, X 130.

F. Middle portion of the fruit in 4th stage showing inner mesocarp, X 350.

(ec - endocarp; hs - horizontal strand;
rs - radial strand; vs - vertical strand).
Fig. 3.7A-G. All transections.
A-E. Developing stages of vascular strand in the middle mesocarp of the fruit in 3rd stage, X 500.
F. Middle portion of the fruit in 4th stage showing a vascular strand in the middle mesocarp, X 400.
G. Upper portion of the fruit in 6th stage showing inner mesocarp, X 500.

(ip - inner phloem; op - outer phloem; ph - phloem; vm - vascular meristem; xy = xylem)
Fig. 3.8A–E. All transections.

A. Middle portion of the fruit in 5th stage showing a major and a minor strand in the middle mesocarp, X 350.

B. Enlarged view of minor strand from A, X 500.

C. A portion of the inner phloem of a major strand in the middle mesocarp, X 560.

D. Middle portion of the fruit in 6th stage showing a major strand in the middle mesocarp, X 185.

E. Enlarged view of outer phloem from D, X 560.

(mp - mesocarpic parenchyma with dense staining; ph - phloem; php - phloem derived from parenchyma; XX - Xylem).
Fig. 3.9A-V. Epidermal structures.

A. Glandular hair.
B-F. Developing stages of eglandular hair.
G, H. Filiform eglandular hair.
I. A meristemoid.
J. Division of the meristemoid.
K. Anomocytic stoma.
L-O. Developing stages of haploctyic stoma.
P-Q. Paracytic stoma with two, three and six subsidiary cells, respectively.
S. Developing stage of tetracytic stoma.
T. Tetracytic stoma.
U. Contiguous stomata.
V. Stoma with degenerated guard cells.

(BC - basal cell; HC - head cell; HI - hair initial; M - meristemoid; SC - stalk cell; TC - terminal cell).
Fig. 3.10A-C.

A, B. Diagrammatic sketch from transections representing correlation between ovary and mature fruit.

C. Longisection of a mature spine.

( CG - central region of the guard tissue; 
  EC - endocarp; GA - ground tissue above vascular bundles; HY - hypodermis; IM - inner mesocarp; 
  MG - middle region of the ground tissue; 
  MM - middle mesocarp; OG - outer region of the ground tissue; OM - outer mesocarp; PL - placental region; SE - seed; VB - ventral bundle ).
Fig. 3.11A-F.

A. Transection of a mature spine.

B-E. Longisections of the developing stages of the spine.

F. Transection of the stalk of fruit in 1st stage.

( IP - inner phloem; OP - outer phloem; SO - stoma; XY - xylem ).
Fig. 3.12A-0. Endocarp in surface view showing developmental stages of stomata.

A. A meristemoid.
B-D. Developmental stages of anomocytic stomata.
E-G. Developmental stages of haploxytic stomata.
H. Stoma with a common subsidiary cell.
I. Paracytic stoma.
J. Stomata alternately placed with subsidiary cells.
K-M. Developing stages of a stoma with two subsidiary cells.
N. Stoma with three subsidiary cells.
O. Abnormal stoma with two pores and three guard cells.
Fig. 3.13A,B. Graph of fruit stage against cell area.
(CA - cell area; FS - fruit stage;
in A - solid circle = epidermis; hollow circle = hypodermis; triangle = middle mesocarp;
in B - solid circle = endocarp;
hollow circle = placental region;
triangle = inner mesocarp).