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Anatomy of the Rachis of the Inflorescence of Pigeonpea (*Cajanus cajan*)

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Abstract: The anatomical investigation of the rachis has been made on the basis of flower removal. Two different types of rachis have been investigated. One type of rachis is normal (control) which develops naturally up to maturity and another type is deflowered (treated) where flowers and buds have been removed from the basal 3 nodes and then allows the rachis to develop naturally up to maturity. After removal of flowers and buds, pods are found to be set in 4-6 nodes of the same rachis. The internal structure of rachis is more or less similar to that of the stem. Epidermis bears multicellular hairs and glandular trichomes. The vascular tissue decreases gradually from base upward. The vascular tissue become highly developed in the deflowered rachis. The cambium is highly active on its adaxial side and produces a large amount of secondary xylem adaxially and well developed sieve tube elements abaxially. Some large vessels are formed in the abaxial region of the xylem. In the middle and upper parts of the deflowered rachis, the radial dimension of xylem is several times higher than the corresponding part of the normal rachis. The vascular tissue is poorly developed in the apical part of the normal rachis. The xylem is mainly composed of fibre cells with ray parenchyma which is uniseriate or multiseriate. Pericycle is discontinuous at the basal part and gradually it forms a more or less continuous ring towards the apical part around the vascular cylinder. Tanniniferous cells are more in the normal rachis compared to that of the deflowered rachis.

Key words: Pigeonpea, *Cajanus cajan*, anatomy, rachis

INTRODUCTION

Pigeonpea (*Cajanus cajan* (L.) Millsp.) belongs to the sub-family Papilionaceae under the family Leguminosae. In Bangladesh, pigeonpea is gaining popularity to the farmers due to its more feasibility than any other possible pulses. This pulse crop has some special characteristics such as, it can tolerate drought condition, it can grown as mixed crop, fallow crop and it is able to grow in unconventional lands like homesteads, roadsides, border of crop fields and other unutilized public places. The rural people of Bangladesh are largely depends on this pulse crop to meet up their protein requirement. Recently, some attention has been given to increase the production rate of pigeonpea in Bangladesh. Pre-mature abscission of flowers is one of the most serious problem in pigeonpea (Fakir, 1997) and other legumes (Wiebold *et al*., 1981). About 70-96% floral abcission occurs in pigeonpea (Sheldrake *et al*., 1979; Fakir, 1997). Yield of pigeonpea remains low due to high level of floral abscission (Sheldrake *et al*., 1979; Fakir, 1997). So, the low yield of pigeonpea is due to poor pod set resulting from high flower and pod drops. Available literature shows that there are some research have been carried out on the genotypic variation of floral abscission of pigeonpea by Fakir (1997) in Trinidad.

The flowers and pods of the inflorescence may not receive enough assimilates from the leaf due to inadequate phloem or tissue development in case of mustard (Haque and Prodhan, 1987) and in soybean (Wiebold and Panciera, 1990). There are no studies, to our knowledge, the anatomical bases of floral abscission in pigeonpea, especially on the limitation of vascular capabilities to carbohydrate transport to the inflorescence.

However, information on the anatomy of different tissues of the rachis of the inflorescence of pigeonpea is lacking. Therefore, the present piece of research has been undertaken to investigate the anatomical barriers related to floral abscission within the inflorescence of pigeonpea (*Cajanus cajan* (L.) Millsp.).

MATERIALS AND METHODS

The experiment was carried out in the university farm and as well as in the Department of Crop Botany during

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the study period between July 2003 and May 2004. The seeds were sown in polybags that were transplanted in pits of plots.

The pigeonpea plants were allowed to grow in natural condition. Two different types of inflorescence has been investigated. At the time of flowering, one type of inflorescence kept normal condition which develops naturally up to maturity, that were tagged as control inflorescence. Some inflorescences were deflowered up to third node from the base of the inflorescence and the upper flowers in the same rachis were as it is that was tagged as deflowered rachis. After this treatment both of this inflorescences were grown in natural condition. After removal of flowers and buds, pods are found to be set in 4-6 nodes of the same rachis. This pod bearing inflorescence samples were collected from both control and deflowered pigeonpea plants. Then immediately fixed in Craf III (Sass, 1958) after making three pieces such as basal, middle and apical portion of the rachis. Some samples were fixed in FAA after making three pieces. The materials fixed in Craf III and FAA were dehydrated through the Tertiary Butyl Alcohol (TBA) series on the general principle of Johansen (1940) and Sass (1958). The materials fixed in FAA were washed in running water for 2-3 h before dehydration. The materials fixed in Craf III were very succulent. They were dehydrated gradually more grades of alcohol to avoid more shrinkage (Ali *et al*., 1999; Haque and Prodhan, 1991; Prodhan and Haque, 1986; Begum and Prodhan, 2003; Begum *et al*., 2006).

The dehydrated materials were gradually infiltrated with paraffin oil and low melting point paraffin wax (51°C) for 1-3 days. The succulent materials were dehydrated for a longer period. Finally, the materials were embedded in high melting point paraffin wax (61°C). Repeated trial showed that there was less shrinkage when the materials were infiltrated for a longer period (Haque and Prodhan, 1987; Prodhan and Haque, 1986; Begum and Prodhan, 2003; Begum *et al*., 2006). Serial transverse sections were made at 10-15 μ by a rotary microtome. The sections were stained with safranin and fast green and mounted in Canada balsam after proper dehydration with ethyl alcohol and clearing with xylene (Johansen, 1940). Free hand sections were also made from fresh and fixed materials (Begum and Prodhan, 2003; Bari and Prodhan, 2001; Prodhan and Haque, 1986). Olympus binocular compound microscope (Japan) has been used to investigate the anatomical sections.

RESULTS AND DISCUSSION

Epidermis: The epidermis of the rachis is single layered and it bears a thick cuticle on its abaxial side. The cells are more or less round, oval or slightly rectangular in appearance as seen in transverse sections (Fig. 2, 4 and 6). The epidermis bears lots of multicellular hairs and glandular trichomes (Fig. 1-6). The outer circumference of the epidermis is more or less smooth in the basal part and wavy or irregular in middle and upper parts (Fig. 1-6). The epidermis of the normal rachis is similar to that of the deflowered rachis.

Cortex: There are 5-6 layers of cortical cells in the rachis (Fig. 2, 4 and 6). The cortical cells are round, oval, irregular or tangentially elongated in appearance as seen in transverse section. The outermost layer of the cortex below the epidermis is compact and there was no intercellular spaces. The cells of this layer are not uniform in size. The cell wall thickness is similar to that of epidermis. The cortical cells are thin with small intercellular spaces. The tanniniferous cells are present in the cortical region of the middle and upper parts of the rachis (Fig. 3-6). The radial thickness of the cortex is more or less uniform in deflowered rachis (Fig. 2b, 4b and 6b).

However, the cortical region of the normal rachis is not uniform in thickness. It is wider in different regions as seen in middle and upper parts of the normal rachis or specially in the ridges of the middle part of the rachis (Fig. 3a-6a). There are lots of tanniniferous cells in the normal rachis specially in the upper part compared to that of the deflowered rachis (Fig. 3-6).

Pericycle: The pericycle lies beneath the endodermis (Fig. 1-6) and it consists of sclerenchymatous cells. It forms a discontinuous ring at the basal part of the rachis and gradually it forms a more or less continuous ring towards the apical part around the vascular cylinder (Fig. 1-6). A continuous ring of sclerenchymatous cells constituting pericycle has been reported for pigeonpea stem (Bisen and Sheldrake, 1981) and discontinuous pericycle in the pigeonpea stem has been reported by Begum *et al*. (2006). The individual band is connected to each other by one to two layers of sclerenchyma or thick-walled parenchyma cells as seen in the middle and upper parts of the rachis. The band is closely placed to the normal rachis and apart in deflowered rachis as seen in the middle and upper parts. The walls of the cells are very thick with small lumen. The pericycle is not uniformly thick. In some places 4-5 layered thick and in others it is 1-2 layered thick. The pericycle is wavy in appearance (Fig. 3-6) in the middle and upper parts of the rachis.

Vascular tissue: The amount and size of vascular tissue gradually decreases from the base to the upper part of the rachis. Similar results have been reported for the rachis of lignosus bean (Bari and Prodhan, 2001). The vascular tissue arranged in a ring. In the basal part of the normal

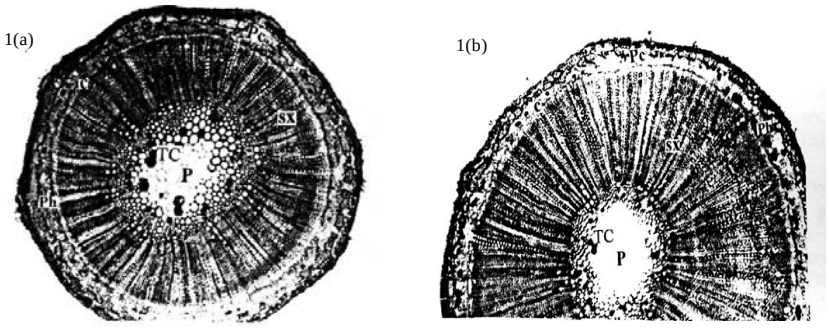

Fig. 1: T.S. of the basal part of the (a) Normal (Control) and (b) Deflowered (Treated) rachis showing epidermis with hairs, pericycle (Pc), phloem (Ph), cambium (c), secondary xylem (Sx) and pith (P). Tanniniferous cells (Tc) are present in cortical, phloem and pith regions. X 90

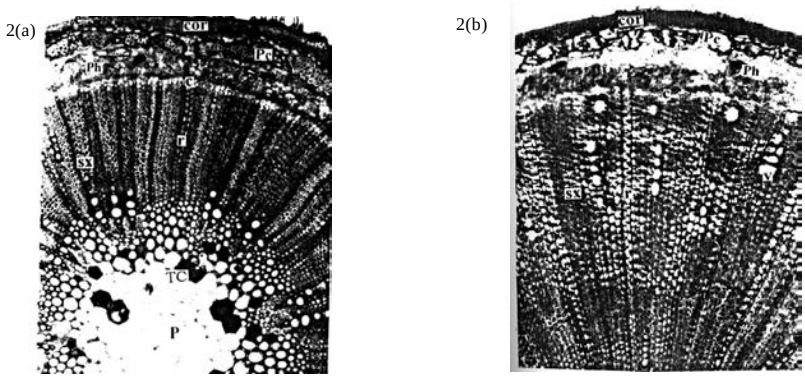

Fig. 2: T.S. of the basal part of the (a) Normal (Control) rachis showing epidermis with hairs, cortex (cor), pericycle (Pc), phloem (Ph), cambium (c), secondary xylem (Sx), ray parenchyma (r) and pith (P). (b) Deflowered (Treated) rachis showing epidermis with hairs, pericycle (Pc), phloem (Ph), cambium (c), secondary xylem (Sx), secondary xylem vessel (V) and ray parenchyma (r). Tanniniferous cells (Tc) are present in cortical, phloem and pith regions. X 240

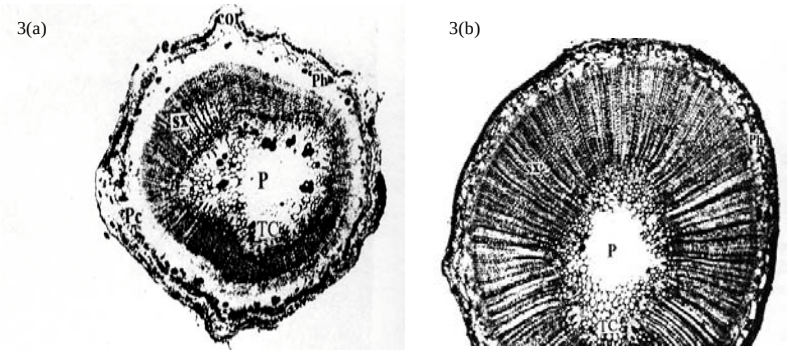

Fig. 3: T.S. of the middle part of the (a) Normal (Control) rachis showing epidermis with hairs, cortex (cor), pericycle (Pc), phloem (Ph), secondary xylem (Sx) and pith (P). (b) Deflowered (Treated) rachis showing epidermis with hairs, pericycle (Pc), phloem (Ph), cambium (c), secondary xylem (Sx) and pith (P). Tanniniferous cells (Tc) are present in cortical, phloem and pith regions. X 90

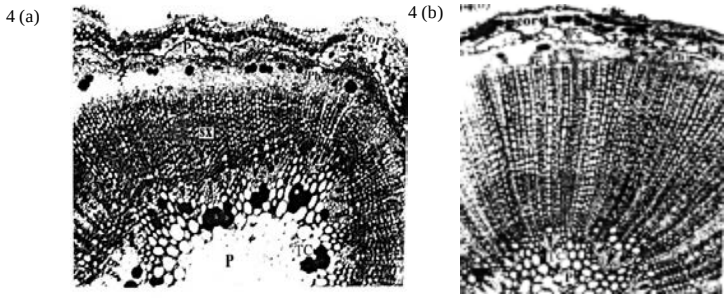

Fig. 4: T.S. of the middle part of the (a) Normal (Control) and (b) Deflowered (Treated) rachis showing epidermis with hairs, pericycle (Pc), phloem (Ph), cambium (c), secondary xylem (Sx) and pith (P). Tanniniferous cells (Tc) are present in cortical, phloem and pith regions. X 240

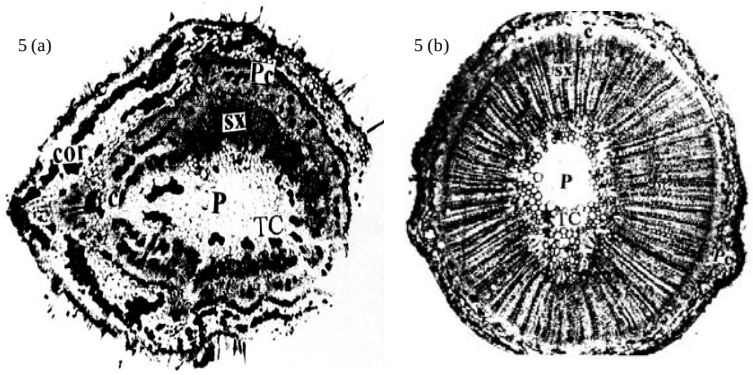

Fig. 5: T.S. of the apical part of the (a) Normal (Control) rachis showing epidermis with hairs, cortex (cor), pericycle (Pc), cambium (c), secondary xylem (Sx) and pith (P). (b) Deflowered (Treated) rachis showing epidermis with hairs, cortex, pericycle (Pc), phloem (Ph), cambium (c), secondary xylem (Sx) and Pith (P). Tanniniferous cells (Tc) are present in cortical, phloem and pith regions. X 90

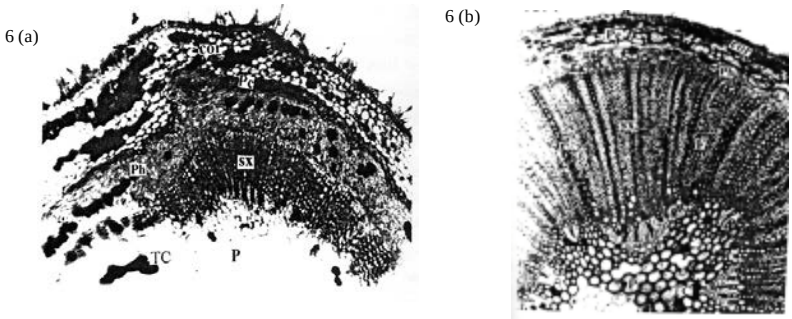

Fig. 6: T.S. of the apical part of the (a) Normal (Control) rachis showing epidermis with hairs, cortex (cor), pericycle (Pc), phloem (Ph), secondary xylem (Sx) and pith (P). (b) Deflowered (Treated) rachis showing epidermis with hairs, cortex, pericycle (Pc), phloem (Ph), cambium (c), secondary xylem (Sx), ray parenchyma (r), fibre cells (F) and Pith (P). Tanniniferous cells (Tc) are present in cortical, phloem and pith regions. X 240

rachis, a few tanniniferous cells have been observed in the phloem region during the present investigation. The tanniniferous cell gradually increases from base to upper part of the normal rachis (Fig. 1-6a). Reverse in case of deflowered rachis where the tanniniferous cell gradually decreases from base upward (Fig. 1-6b).

A complete cambial ring has been found at the basal parts of the normal rachis and gradually it extends upward. The ring is interrupted in few places where the cortex is connected with pith by parenchyma cells. The cambium has been found to be more active on its adaxial side and as such it gives more secondary xylem than secondary phloem. The vessels of the secondary xylem are few in number and arranged radially (Fig. 1) as seen in basal part of the normal rachis. The adaxial vessels are round, oval, polygonal or hexagonal in shape while the abaxial vessels are radially elongated. Adaxial to the secondary xylem, primary xylem vessels are found with protoxylem towards the center and metaxylem towards the periphery (Fig. 2a).

The ray cells are radially elongated and thick walled. They are uniseriate and multiseriate (Fig. 2-4a). The secondary xylem is mainly composed of fibre and parenchyma cells. The fibre cells are hexagonal, pentagonal, triangular, rectangular or square in shape and thick walled with small lumen. Similar results have been reported for lignosus bean by Bari and Prodhan (2001). The fibre cells in the upper part are smaller in size and thick walled. The middle and upper parts of the normal rachis are also composed of mainly fibre and parenchymatous cells (Fig. 3-6a). The tracheary elements of the upper part of the rachis are poorly developed compared to that of the basal part (Fig. 1a and 6a). Similar results have been reported for the lignosus bean (Bari and Prodhan, 2001). The size and number of vessels gradually decreases towards the upper parts of the rachis. In the upper part of the normal rachis the xylem areas is not radially uniform. It is wider in some places and almost nil in few places (Fig. 5-6a).

The cambium is less active on its abaxial side and as a result secondary phloem becomes narrow gradually towards the upper parts of the rachis (Fig. 5-6a). At the basal part of the rachis, the phloem is both primary and secondary in origin. In the rachis, undifferentiated or partially differentiated sieve elements fail to mature. This is prominent in upper part of the normal rachis. The amounts of sieve elements decreases from base upward. Sieve tube members also become narrower towards the apex.

It is assumed that the reduction in the phloem tissues on the apex of inflorescence probably allows translocation of insufficient photosynthates to support few or no flower to set pods i.e., insufficient photosynthates supply in the top of the inflorescence contributed sheeding of flowers and buds. Similar results have been reported in soybean (Wiebold *et al*., 1981), mustard (Haque and Prodhan, 1987) and lignosus bean (Bari and Prodhan, 2001). Therefore, it has been observed in the rachis that most of the pods are set in the basal 3 nodes.

The vascular tissue becomes highly developed in the deflowered rachis (Fig. 1-6). The cambium is very active on its adaxial side and produces a large amount of secondary xylem adaxially and well developed secondary phloem abaxially. The basal parts of the deflowered rachis is more or less similar except the radial dimension of xylem which is greater than that of the normal rachis. The vessels are oval or radially elongated. The vascular tissue gradually decreases from base upward. In the middle and upper parts of the deflowered rachis, the radial dimension of xylem is several times higher than corresponding part of the normal rachis (Fig. 1-2).

Pith: The pith is prominent in the rachis (Fig. 1-6). The parenchymatous cell constituting the pith are round, oval or polygonal in shape as seen in transverse sections. Similar results have been reported in lignosus bean (Bari and Prodhan, 2001). A central mass of large and thin walled cells shows prominent intercellular spaces and the surrounding abaxial cells are comparatively thick and small walled with small intercellular spaces. Tanniniferous cells are present in both normal and deflowered rachis except the upper part of the deflowered rachis where the tanniniferous cells are very few in number (Fig. 5-6b).

CONCLUSIONS

After removal of flowers and buds from the basal three nodes, the pod sets in 4-6 nodes of the same rachis. For the upper formed pods, it needs mechanical support which is related to the economic yield. Therefore, the mechanical tissue becomes highly developed in the deflowered rachis. Large vessels and prominent sieve tube elements are found to be developed in the deflowered rachis to conduct water and food materials for the growth and development of upper formed pods. It may be concluded that the removal of buds and flowers enhances the development of mechanical and conducting tissues in the rachis for the support, growth and development of the upper formed pods.

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