ROOT AND STEM ANATOMY OF *SESBNIA ROSTRATA*

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ABSTRACT

Anatomical investigation were made on the stem and root of *Sesbania rostrata* at different stages of growth. Xylem was found to be the first vascular tissue to differentiate. The root was tetrarch with four strands of xylem and four strands of phloem. One strand of xylem alternated with one strand of phloem. The epidermis was single layered. Beneath the epidermis there were cortex with some tannin cells. The cambium appeared at the basal part of the root and gradually it extending towards the root apex. The phellogen appeared in the deeper cortex and produced 4-5 layers of cork cells and 2-4 layers of phelloderm. In the stem, the epidermis was single layered. Beneath the epidermis there were 10-12 layers of cortex with lots of tanniniferous cells. The vascular bundles were of two types, small and large with bundle caps. In the large vascular bundle, the primary phloem consisted of a number of sieve elements while in the small bundle there were parenchymatous tissue with or without functional sieve element. The large vascular bundle contained 5-7 strands of xylem while the small bundle contained 1 or 2. The cambium differentiated in between xylem and phloem of the primary structures of the stem. It became active and gave rise to secondary phloem and secondary xylem. The vessels were small and big. The smaller vessels lay in between or among the big vessels. Most of the vessels were solitary. Among the elements of secondary phloem, axial parenchyma was found to occupy the major area. The periderm developed one after another from deeper cortex.

INTRODUCTION

The species, *Sesbania rostrata* belongs to the sub-family Papilionoideae of the family Leguminosae. It is a fast growing nitrogen fixing plant. It is used as fencing materials, fodder, fuel wood as well as in making paper pulp, green manure and many useful medicines (Evans and Macklin, 1990). It plays vital roles in conserving soil moisture, checking soil erosion, improving quality of soil and in protecting crops from wind, strong sunshine and low humidity if the plants are grown following suitable system of agroforestry. It is widely used in farm-forestry in many countries of the world (Mulongoy, 1986).

*Sesbania rostrata* has recently been introduced in Bangladesh from Africa. It is widely cultivated in the farms, fallow lands, roadsides and many other vacant or less utilized lands. It is fast gaining popularity with the growers due to its habit of rapid growth and high efficiency in fixing atmospheric nitrogen and for production of net biomass. Agronomical features, growth behaviour, nitrogen fixing ability and external morphology of *Sesbania rostrata* are fairly known. A number of workers have studied the nodulation and nitrogen fixing ability of *Sesbania* at a depth (Goethals et al., 1994; Ndoye et al., 1994; Harris et al., 1949) while others have reported gross morphological characters, adaptive qualities and growth features of *Sesbania* species (Burbidge, 1960, 1965; Prain, 1981). Anatomical characters of this species are not clearly known and as such, the present piece of research work has been designed to investigate the gross anatomical features of root and stem of *Sesbania rostrata* at different stages of growth.

MATERIAL AND METHODS

Mature seeds of *Sesbania rostrata* were collected from the Agroforestry Germplasm Research Centre of Bangladesh Agricultural University, Mymensingh. The experiment was carried out in the Agroforestry Germplasm Research Centre as well as in the Department of Crop Botany during 1996. The experimental plot was prepared following standard proce-
procedure of land preparation. The plot was divided into three parts each of which was 2 m x 1 m in size. The seeds were sown in lines. The spacing of the plants was 50 cm x 30 cm. The seeds were also sown in earthen pots (top diameter 30 cm) which were filled with thoroughly prepared soil of the plots. The earthen pots were kept exposed to the normal weather condition so that the plants of both earthen pots and plots got more or less similar weather condition.

Some seeds were also placed on moist filter paper in large petri dishes in the laboratory at room temperature of about 26-28°C. The germination of the seeds had been found to be about 40% in petri dishes and 30% in both earthen pots and plots in about 48 hours. The sprouting is considered as the zero hour of age of the plant. The seedlings were obtained from petri dishes, earthen pots and plots. Young seedlings as produced in petri dishes were mostly used to study the initial structure of the plumule and radicle of the plant. The older seedlings of pots and plots were studied to investigate anatomical structures of root and stem of the plant. In the Germplasm Centre there were about 3 years old trees of Sesbania rostrata. Anatomical studies of stem and root of these plants were also made during the present investigation.

The following samples were collected and fixed in Craf III and FAA solution (Johansen, 1940; Sass, 1958) for anatomical studies: (a) basal, middle and apical (about 2 cm away from the tip) parts of the young and older roots of the plants at different stages of growth; (b) basal, middle and apical parts of the stem while the plants were 1 week, 2 weeks, 1 month, 4 months and 3 years old.

For anatomical investigation both free hand sectioning and paraffin methods of microtechniques were followed. The paraffin sections were made mostly on the results of hand sections. For hand section the materials were fixed and preserved in FAA (Johansen, 1940). The fresh and fixed materials were sectioned by hand with the help of razor blades. The sections were stained in safranin and mounted in 70% glycerine temporarily. The specimens were studied immediately or temporarily preserved by sealing with nail polish or varnish.

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 hrs before dehydration. The succulent materials were dehydrated gradually making more grades of alcohol to avoid severe shrinkage (Prodhan and Haque, 1986).

The dehydrated materials were gradually infiltrated with paraffin oil and low-melting point (51°C-53°C) paraffin wax for 1-3 days (Haque and Prodhan, 1987; Prodhan and Haque, 1986). After infiltration the materials were embedded in high-melting point (61°C) paraffin wax. There was less shrinkage when the materials were infiltrated for a longer period (Haque and Prodhan, 1987). Serial transverse sections were made at 10 micron 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; Prodhan and Haque, 1986).

RESULTS AND DISCUSSION

STEM

Gross anatomical structures of apical, middle and basal part of the Sesbania rostrata were studied while the plants were 7 days, 15 days, 1 month, 4 months and 3 years old. The apical part of the 7 days old and 1 month old plants showed mostly primary structures. The remaining part of the 7 days old plants, and middle and distal part of 1 month old plants exhibited moderate secondary growth while basal part of 1 month old plant and almost the entire part of stem and branches (except the
Primary structures of the stem

Epidermis: There is a single layer of epidermis as seen in transverse section of the stem of *Sesbania rostrata* at different stages of growth (Fig. 1). The epidermal cells are more or less square or slightly rectangular in shape at apical portion (Fig. 1) but rectangular and tangentially flattened towards the basal part as seen in transverse section (Fig. 3). The young epidermal cells, as found in the apical part of older stem or soft stem of young seedling, contain lots of protoplasm within the boundary of thin or slightly thickened cell wall. The older epidermis is devoid of protoplasm and the cell walls are thickened. The abaxial wall of the epidermis is thicker than the adaxial and lateral walls. On the outer wall of the epidermis a cuticle is formed. In the older stem the cuticle is thick but in the soft elongating young stem it is very thin or even absent. In plants the cuticularization depends on the age of the plant part concerned (Esau, 1965). Due to the stress of secondary growth, the epidermis is ruptured here and there, and ultimately replaced by periderm.

Cortex: Beneath the epidermis there is cortex. The number of cortical layers varies according to the age, size and level of secondary growth of the organ concerned. The number of cortical tissue has been found to be 10-12 layers in the shoot apex of *Sesbania rostrata* (Fig. 1). The number of cortical tissue has been reported to be 9-10 layers in the shoot apex of *Sesbania sesban* (Sarkar, 1996). At the young seedling stage the cortex shows clear morphological variations in its radial rows of cells. The outer and inner cortical cells, 2-4 radial rows in each, are small, thick walled and compact while the remaining middle rows contain large but thin walled loosely arranged oval or round shaped cells with large intercellular spaces (Fig. 1, 2 and 3). Lots of tanniniferous

Fig. 1. T.S. of the shoot tip of *Sesbania rostrata* showing one layer epidermis (e), 10-12 layers cortex with big intercellular space, small and big vascular bundles. Each vascular bundle consists of phloem, cambial zone (c) and xylem (metaxylem towards the periphery and protoxylem towards the centre). Pith is composed of thin walled parenchymatous cells with big intercellular spaces x 40

Fig. 2. T.S. through the middle part of the stem of *S. rostrata* showing one layer epidermis with thick cuticle, cortex, sclerenchymatous bundle cap, phloem, cambial zone, metaxylem, protoxylem and pith. x 80
Fig. 3. T.S. through the basal part of the stem of *S. rostrata* showing epidermis (e), cortex, sclerenchymatous bundle cap, phloem, cambial zone and secondary xylem with big vessels along with radial rows of tracheary elements and xylem fibres. x 80

Fig. 4. T.S. of the shoot tip of *S. rostrata* showing one layer epidermis, cortex with enormous amount of tannin cells, sclerenchyma in wedge shaped structure, phloem, cambial zone and xylem. x 120

Fig. 5. T.S. through the middle part of the stem of *S. rostrata* showing epidermis, cortex with tannin cells, endodermis, sclerenchymatous bundle cap, phloem, cambium, xylem and pith with tannin cells. x 120

cells are found in the middle zone of cortex. (Fig. 4 and 5). Tanniniferous cells have also been reported by Sarkar (1996) in the middle zone of cortex in *Sesbania sesban* but the number is very few. Secretory cells are common in the cortex of many plants (Yarbrough, 1957). The cortex is disorganized and disintegrated due to the stress of secondary growth.

Primary vascular tissue: The vascular bundles are arranged in a ring as seen in transverse section of the apical part of the stem. The vascular bundles are of two types, small and large. There are one or two small vascular bundles in between two large bundles (Fig. 1). On the abaxial side of the vascular bundle there is bundle cap consisting of sclerenchymatous cells (Fig. 1). Both large and small bundles contain bundle caps (Fig. 1). Bundle cap has also been reported by Sarkar (1996) in *Sesbania sesban*.

Primary phloem: Adaxial to the bundle cap there is primary phloem as seen in
the transverse sections of the apical part of the stem (Fig. 1). In the large vascular bundle, the primary phloem consists of a number of sieve elements and lots of parenchymatous cells while in the small bundle there are parenchymatous tissue with or without functional sieve element.

Primary xylem: The large vascular bundle at the apical part of the stem contains 5-7 strands of xylem (Fig. 1). The number of xylem strands in the small vascular bundle has been found to be one or two (Fig. 1). The xylem strand consists of protoxylem and metaxylem vessels. Protoxylem vessel remains towards the centre while metaxylem vessel towards the periphery. The vessels are arranged radially. The vessels are round or oval in shape with prominent secondary thickening (Fig. 1 and 2).

Secondary structures of the stem

Secondary vascular tissue: The initial stage of secondary growth has been found at the apical region of the stem near the tip. The secondary vascular tissue is described here in the sequence of cambium, secondary xylem and secondary phloem.

Cambium: The cambium differentiates in between xylem and phloem of the primary structures of the stem. At the very young seedling stage the cambium becomes active and gives rise to secondary phloem and secondary xylem. In the active state of growth, the cambial zone consists of 4-6 layers of cells consisting of cambial initials, and their derivatives. The cambium in the stem shows activities in the same way as in the root. The cambial activities seen to be more in the stem compared to that in the root.

Secondary xylem: The secondary xylem lies just beneath the cambial zone. The vessels are arranged randomly as seen in transverse section of the middle part of young stem (Fig. 2). Most of the vessels are solitary. Sarkar (1996) has reported that the vessels of *Sesbania sesban* are mostly in pairs. Most of the xylem rays are uniseriate but few are biseriate. Similar results have been reported by Sarkar (1996) in *S. sesban*. The xylem fibres are prominent and scattered. There are two types of vessels, small and big. The smaller vessels lie in between or among the big vessels. The walls of both small and big vessels are thick and lignified. The lumen of big vessels are much more larger than the thickness of their wall. The thickness of the wall of small vessel may be less, equal or more than the lumen. The older stem exhibits more thickened vessels than the younger part. No attempt was made to identify tracheids, fibres and sclerified xylem parenchyma in the secondary wood. It appears that lignification and sclerification, as revealed from the thickness of wall, are more prominent in *Sesbania rostrata* compared to those in *S. sesban* (Sarkar, 1996). The axial xylem parenchyma of *S. rostrata* has been found to be more in number with thinner walls as compared to those in *S. sesban* (Sarkar, 1996). The increase in secondary xylem, as a result of secondary growth, as revealed from radial diameter at the basal part of the stem has been found to be more in *S. rostrata* (Fig. 3) than that in *S. sesban* (Sarkar, 1996).

Secondary phloem: The secondary phloem lies abaxial to the cambial zone. The secondary phloem consists of sieve elements, phloem parenchyma and phloem fibre. Among the elements of secondary phloem, axial parenchyma has been found to occupy the major area. Similar result has been reported for *Sesbania sesban* (Sarkar, 1996). The parenchyma cells of the phloem are thin walled compared to those of the secondary xylem. The area, that is, the radial diameter of secondary phloem is more in *S. rostrata* as compared to *S. sesban* (Sarkar, 1996). The number of sieve elements seems to be more per unit area in *S. rostrata* than that in *S. sesban* (Sarkar, 1996).

Periderm: Periderm has been found to from in the stem of *Sesbania rostrata*. A well developed periderm is observed at the basal
part of the stem of 3 years old plant. The periderm develops one after another from deeper cortex. As a result, cortex is eliminated due to the formation of periderm. In general the periderm is formed in the outer part of the cortical zone of stem (Esau, 1965; Haque and Hossain, 1978). The periderm in the stem has been found to be similar in origin, development, structure and pattern as that of root. As in root, the number of cork cells depends on the age of plant part concerned. The origin, development and activity of phellogen have been reported for many woody plants (Arzee et al., 1970):

Pith: The pith is the central core of the stem and is composed of thin walled parenchymatous cells. Due to the stress of secondary growth, secondary xylem in particular, the pith is obliterated.

ROOT

Anatomical structures of the basal, middle and apical part of the root of *Sesbania rostrata* are described here as seen in transverse section. In the older plants, the basal part of the root exhibits a typical secondary structures, the apical part shows mainly primary structures while the middle part exhibits moderately secondary growth. In young seedling stage, the younger roots exhibit primary structures while the older root shows primary structures at the distal end and slight secondary growth at the basal end.

Primary structures of the root

Epidermis: The epidermis is single layered in the root of *Sesbania rostrata*. The walls of the epidermal cells are more thickened in the older parts of the roots and less thickened in the younger ones (Fig. 6 and 7). In the same root, the thickening has been found to increase towards the basal region. Near the root tips there are root hairs. The young epidermal cells are slightly rectangular in shape as seen in transverse section and contain plenty of protoplasm while the older roots are tangentially

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Fig. 6. T.S. through the basal part of the root of *S. rostrata* showing disorganised cortex with small amount of tannin cells, phloem (primary and secondary), cambial zone (c), secondary xylem with big vessels along with tracheary elements, xylem and phloem rays. x 120

Fig. 7. T.S. of the root tip of *S. rostrata* showing cortex, phloem, cambial zone secondary xylem with big vessels along with tracheary elements (T). Protoxylem vessels can be seen at the centre. x 240
flattened showing little protoplasm with big vacuoles. Morphological features of the epidermis of *Sesbania* root resembles a typical dicotyledonous one (Esau, 1965).

**Cortex:** The cortex lies beneath the epidermis. The cortical cells are thin walled and round, oval or polygonal in shape (Fig. 6 and 7). The abaxial and adaxial cells are small and somewhat polygonal in shape while those of the middle ones are large, and round or oval in shape having big intercellular spaces. These features are prominent in the older roots. The cortical cells of *S. rostrata* are larger than those of *S. sesban* (Sarkar, 1996). There are some tanniniferous cells in the cortex. They are more in *S. rostrata* than in *S. sesban* (Sarkar, 1996). Feher (1924) has reported lots of tannin cells in the roots of *Robinia*.

**Primary vascular tissue:** The root of *Sesbania rostrata* is tetrarch. There are four strands of xylem alternating with four strands of phloem. Towards the distal end of the young roots, four poles of xylem consisting of a few vessels of metaxylem along with 1 or 2 protoxylem vessels, and four poles of phloem with sieve elements and parenchyma can be seen. Protoxylem and metaxylem sieve elements could not be identified because no ontogenic studies were made during the present investigation. Towards the basal part of the root, large metaxylem vessels have been found to occupy the central part of the root leaving a small pith. Metaphloem with lots of axial phloem parenchyma with a few sieve elements has been found to extend adaxially but the differentiation of phloem is very slower than that of xylem. In the primary growth of the root, the number of tracheary and sieve elements seemed to be less in *Sesbania rostrata* than in *S. sesban* (Sarkar, 1996).

**Secondary structures of the root**

**Secondary vascular tissue:** The initial stage of secondary growth has been found at the basal part of tap and branch roots of young seedlings. The secondary vascular
tissue is described here in the sequence of cambium, secondary xylem and secondary phloem.

Cambium: In *Sesbania rostrata*, the active cambium is first detected at the basal part of tap and branch roots when they become 7 days old. The cambium gives rise to secondary xylem towards the centre and secondary phloem towards the periphery (Fig. 6, 7 and 9). In the fascicular region the activities of cambium seem to be more at the initial stage but vigorous activities can easily be detected in the interfascicular region soon after the formation of cambial ring.

Secondary xylem: In *Sesbania rostrata* the secondary xylem has been found to contain less tracheary elements and more xylem parenchyma. Abundance of xylem fibres has not been observed during the present investigation (Fig. 8). The secondary wood of the root is soft due to less number of tracheary elements and fibre cells, and more number of less thickened or unthickened xylem parenchyma (Fig. 8). The tracheary elements have been found to be thinly distributed among the large mass of xylem parenchyma (Fig. 6). As compared to *S. Sesban*, the species of *S. rostrata* shows less thickened vessels, less number of vessels per unit area and less thickened axial xylem parenchyma (Sarkar, 1996). Most of the vessels are distributed randomly throughout the xylem area (Fig. 6 and 9). The secondary xylem vessels are smaller in *S. rostrata* than in *S. sesban* (Sarkar, 1996). The rays are uniseriate. The number of vessels are more in middle portion than those of basal portion (Fig. 6 and 9). The mature vessels contain small amount of protoplasm.

Secondary phloem: Secondary phloem, as appeared from the cambium, is slow in differentiation compared to secondary xylem (Fig. 6 and 9). The phloem rays are more in number at radial rows which do not traverse the same path as those of secondary xylem (Fig. 9). Secondary phloem stands on the adaxial side of the primary phloem. It consists of sieve tube members, companion cells, phloem parenchyma and phloem fibres.

Periderm: The periderm has been found in the root of *Sesbania rostrata*. Development of different components of periderm has not been studied. The periderm can easily be detected in the 3 years old plant. It consists of 4-5 layers of cork cells. The number of phelloderm is 2-4 layers (Fig. 6 and 9). The periderm has been found to form in the deeper layer of cortex and extended outwards. In early stage, the periderm is similar in structure in both *S. rostrata* and *S. sesban*, but later on their morphological features vary considerably. In *S. sesban*, the periderm is composed of 6-8 layers of cork cells and 4-5 layers of phelloderm with a narrow zone of differentiating phellogen (Sarkar, 1996). This type of periderm is seen in most woody species (Esau, 1965; Haque and Hossain, 1978).

REFERENCES


