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VARIATION IN STEM ANATOMY OF RICE CULTIVARS

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Abstract

Anatomical investigations on 8 cultivars of rice (*Oryza sativa* L.), four from each of the traditional (local) and modern (high yielding) cultivars, were carried out to study the variation among the cultivars. The epidermis is single layered having cuticle of varying thickness. The number of hypodermal layer is more in modern cultivars compared to traditional ones. The vascular bundles are of two types, outer (small) and inner (large), in all the cultivars except Madhabshail-boro where additional median (medium) type is present in between outer and inner bundles. The number, position and arrangement of vascular bundles vary among the cultivars. The outer vascular bundles are embedded in the hypodermis and found to push outwards forming outgrowth of different shapes in all the cultivars except BR7 and BR3 where the wavy appearance in outer circumference of the stem is present. Some of the inner vascular bundles are attached or nearer to the hypodermis while the rest are away from it. The hollow pith is found to be smaller in modern cultivars compared to traditional ones. The higher number of mechanical tissues (hypodermal cells and inner vascular bundles) in modern cultivars imparts resistance to lodging.

Introduction

Rice (*Oryza sativa* L.) is the staple food of Bangladesh. Two types of rice cultivars viz., modern and traditional, are cultivated in the country. Traditional cultivars are susceptible to lodging that causes lower yield while the modern cultivars are lodging resistant and give higher yield. These two types of rice cultivars may differ anatomically. A series of anatomical investigations on the stem of rice plant have been made (Chalam, 1942; Chang, 1964; Chaudhuri *et al.*, 1971; Fukuyama & Takayama, 1995; Hedayetulla & Chakravarty, 1942, 1947; Holm, 1896; Joarder & Eunus, 1981; Roy, 1985). However, information on the variation in stem anatomy of rice cultivars is lacking. In the present paper the gross anatomy of the stem of traditional (local and lodging susceptible) and modern (high yielding and lodging resistant) rice cultivars with special emphasis on varietal differences has been presented.

Materials and Methods

Eight rice cultivars, four from traditional (local), viz., Hapa, Kaliboro, Kachliboro and Madhabshail-boro, and four from modern (high yielding), viz., BR7, BR29, Iratom24 and BR3, were used. Mature seeds of all the rice cultivars were collected from the Bangladesh Rice Research Institute, Joydebpur, Gazipur. The experiment was carried out in the Bangladesh Agricultural University Farm as well as in the Department of Crop Botany. The crop was grown following standard method of cultivation (Anon., 1995). The samples were collected at late tillering stage (30-45 days after transplanting) from the 3rd internode (from the top) and were fixed separately in Craf III and FAA (Johansen, 1940; Sass, 1958). For anatomical investigation both hand sectioning and paraffin methods of microtechnique were followed. The paraffin sections were made mostly on the results of hand sections. With the fresh and fixed materials, free hand cross sections were made using sharp razor blades. The sections were stained in safranin, mounted in 50% glycerine and examined under light microscope.

The fixed materials 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 hours before dehydration. Small and delicate specimens were kept in TBA grades, one hour in each grade, while the large and hard materials were kept for two hours. The materials were then gradually infiltrated with heavy duty paraffin oil and low melting point paraffin wax (51-53°C) for 1-3 days depending on the size of the specimen (Prodhan & Haque, 1986). Finally, the specimens were embedded in high melting point paraffin wax (61°C). Transverse sections of the specimens made at 10 micron with the help of a rotary microtome were stained with safranin and fast green and mounted in Canada balsam after proper dehydration with ethyl alcohol and clearing with xylene (Haque & Prodhan, 1987; Johansen, 1940; Prodhan & Haque, 1986).

Results and Discussion

Epidermis: The epidermis of the stem is single layered in all the rice cultivars. The epidermis bears cuticle on its abaxial side. The cuticle is thick in Hapa (Fig. 1), Madhabshail-boro (Fig. 4), BR7 (Fig. 5) and BR3 (Fig. 8), moderately thick in BR29 (Fig. 6) and Iratom 24 (Fig. 7), and thin in Kaliboro (Fig. 2) and Kachliboro (Fig. 3). As a whole, modern cultivars possess relatively thicker cuticle compared to traditional ones. The epidermal cells are more or less tangentially elongated as seen in transverse sections of all the cultivars except BR3 where the cells are found to be somewhat square in outline (Fig. 8). The walls of the epidermal cells are thick which is conspicuous in the inner wall. The thickening in the epidermal cell wall has been reported for rice (Hector, 1936; Mia, 1978; Shibuya, 1958).

Hypodermis: Hypodermis which lies beneath the epidermis, consists of sclerenchymatous cells. The number of hypodermal layers varies among the cultivars with 2-3 in Kaliboro (Fig. 2) and Kachliboro (Fig. 3), 3-4 in Hapa (Fig. 1), Madhabshail-boro (Fig. 4), BR29 (Fig. 6) and BR3 (Fig. 8), and 4-5 in BR7 (Fig. 5) and Iratom24 (Fig. 7). Mia (1978) has reported 4-5 layers of sclerenchyma cells in the hypodermis of BR3 and Iratom24. However, in the present investigation the number of hypodermal layer varies from 3-4 in BR3. At a particular internode the number of hypodermal layer varies radially. Such a variation in the number of sclerenchymatous cells in the hypodermal zone rarely exceed one. The number of sclerenchymatous tissue constituting the hypodermis is quite variable in rice (Hector, 1936). Chaudhuri *et al.*, (1971) and Joarder & Eunus (1981) have also found different numbers of sclerenchymatous layers in different cultivars of rice.

During the present investigation, the width of hypodermal zone is found to vary among the cultivars. Similar results have been reported in different strains of rice (Chaudhuri et al., 1971; Hector, 1936). The width of the hypodermis depends on the number of layers, size and orientation of the sclerenchyma. Joarder & Eunus (1981) have observed that the different mechanical cells in the lodging susceptible varieties are significantly larger than those of the lodging resistant varieties. During the present investigation it has been observed that the modern cultivars possess higher number of sclerenchymatous cells in hypodermis compared to traditional ones which imparts resistance to lodging in modern cultivars.

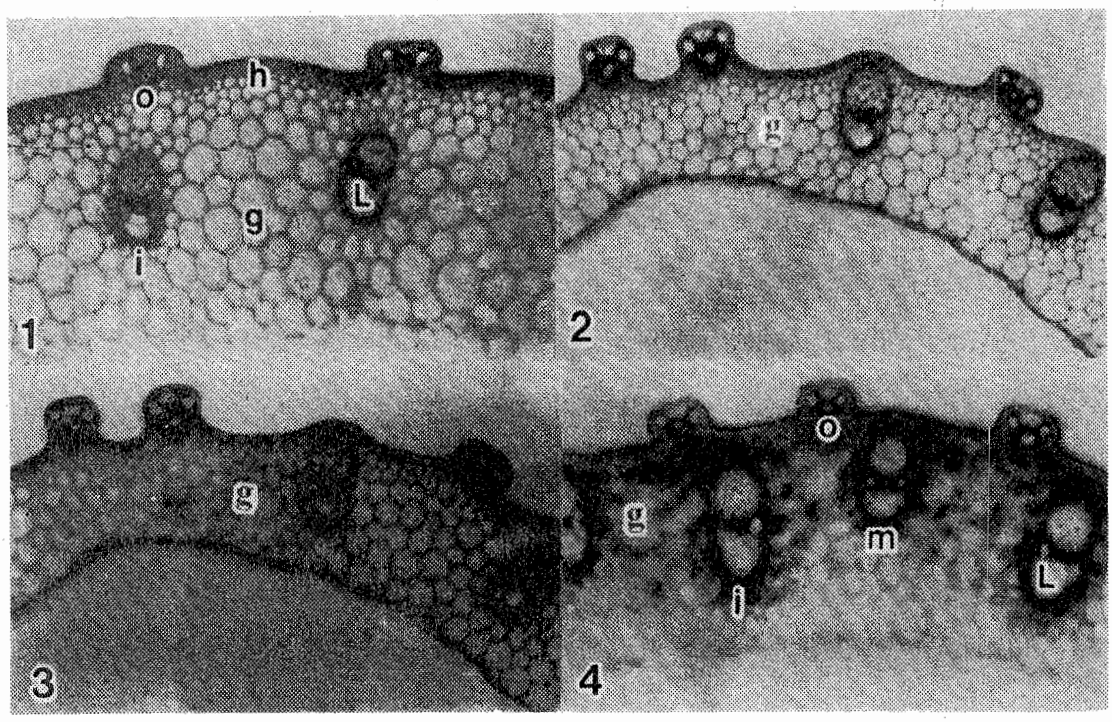

Fig. 1. T.S. through the 3rd internode (from the top) of the stem of Hapa showing epidermis with thick cuticle, hypodermis (h) consisting of 3-4 layers of sclerenchymatous cells, outer (o) and inner (i) vascular bundles, and ground tissue (g). The inner and outer vascular bundles are in the same radius. Inner vascular bundle shows prominent protoxylem lacuna (L). Other vascular bundles are embedded in the hypodermis forming outgrowth in the stem. X 80

Fig. 2. T.S. through the 3rd internode (from the top) of the stem of Kaliboro showing epidermis, hypodemis consisting of 2-3 layers of sclerenchymatous cells, outer and inner vascular bundles, and ground tissue (g). The inner and outer vascular bundles are not in the same radius. Inner vascular bundle is attached to the hypodermis and shows prominent protoxylem lacuna. The outer vascular bundles are embedded in the hypodermis forming outgrowth in the stem. X 80.

Fig. 3. T.S. through the 3rd internode (from the top) of the stem of Kachliboro showing epidermis, hypodermis consisting of 2-3 layers of sclerenchymatous cells, outer and inner vascular bundles, and ground tissue (g). The outer vascular bundles are embedded in the hypodermis forming outgrowth in the stem. The inner vascular bundle is attached to the hypodermis and shows prominent protoxylem lacuna. The inner and outer vascular bundles are not in the same radius. X 80.

Fig. 4. T.S. through the 3rd inter node (from the top) of the stem of Madhabshail-boro showing epidermis with thick cuticle, hypodermis consisting of 3-4 layers of sclerenchymatous cells, outer (o), inner (i) and median (m) vascular bundles, and ground tissue (g). The outer, inner and median vascular bundles are smaller, larger and medium in size respectively. The outer vascular bundles are embedded in the hypodermis forming outgrowth in the stem. The inner and median vascular bundles are attached to the hypodermis showing prominent protoxylem lacuna (L). The outer, inner and median vascular bundles are not in the same radius. X 80.

Vascular bundle: The vascular bundles are found in two rows, the outer (abaxial) and the inner (adaxial), in all the cultivars except Madhabshail-boro which bears three rows of vascular bundles, inner, outer and median. Chaudhuri *et al.*, (1971) and Joarder & Eunus (1981) have reported two rows of vascular bundles in different rice varieties. However, three rows of vascular bundles have been observed in rice varieties by Hector (1936) and Wada (1965). The outer vascular bundles are smaller and the inner bundles are larger

while the median ones are medium in size. The inner vascular bundles of Madhabshail-boro are the largest among the cultivars investigated.

The number, arrangement and position of vascular bundles differ among the cultivars. The numbers of outer vascular bundles are 22, 25, 22, 30, 21, 27, 26 and 21, and inner vascular bundles are 23, 26, 24, 30, 23, 29, 30 and 25 in Hapa, Kaliboro, Kachliboro, Madhabshail-boro, BR7, BR29, Iratom24 and BR3, respectively. The number of inner vascular bundles was greater than outer vascular bundles (Chaudhuri *et al.*, 1971) and while equal number of inner and outer vascular bundles has been reported by Joarder & Eunus (1981) in different rice varieties. The difference in number between inner and outer vascular bundles is greater in modern cultivars compared to traditional ones. Relatively higher number of vascular bundles in inner circle probably gives resistance to lodging in modern cultivars.

In all the cultivars, the outer vascular bundles are embedded in the hypodermis. All the outer vascular bundles in all the cultivars except BR7 (Fig. 5) and BR3 (Fig. 8) have been found to push outwards forming outgrowth of different shapes in the stem. In BR7 and BR3 (with small outgrowth), the outer circumference of the stem is wavy in appearance. The outgrowths are more or less oval with narrow base (Fig. 2 and 3), rectangular or tangentially flattened (Fig. 1, 6 and 7) or square (Fig. 4). The shape of the outgrowth varies within the cultivar. The outgrowths have also been observed by Hector (1936) and Mia (1978) in different rice varieties. All the inner large vascular bundles are embedded in ground tissue towards the hypodermis. Some of the inner vascular bundles are attached to the hypodermis (Fig. 2-4) and some are nearer (2 or 3 cells apart) to it (Fig. 5 and 8) while the rest are away from it. Some of the inner vascular bundles attached to the hypodermis form wavy circumference in the stem (Fig. 2 and 3). In Madhabshail-boro, both inner and median vascular bundles, alternating with each other, are attached to the hypodermis (Fig. 4). Well developed bundle sheath has been found in the outer vascular bundles while it is poorly developed in the inner vascular bundles in all the cultivars investigated except Madhabshail-boro where it is well developed (Fig. 4).

The protoxylem lacuna is commonly observed in each of the inner vascular bundles of all the cultivars investigated. The lacuna is found in most of the outer vascular bundles of traditional cultivars (Fig. 1-4) and in some of the outer vascular bundles of modern cultivars (Fig. 5-8). The protoxylem lacuna is the largest in Madhabshail-boro (Fig. 4). Protoxylem lacuna may be present in the large vascular bundle but may be absent in the small bundle (Esau, 1965). Degeneration of protoxylem has been reported for rice (Kawata *et al.*, 1962).

Ground tissue: In the ground tissue, the abaxial parenchymatous cells are smaller and more compact than the adaxial parenchyma. The parenchymatous cells of the ground tissue in Kaliboro (Fig. 2) and Kachliboro (Fig. 3) are smaller in size and more compact compared to other cultivars. In Hapa (Fig. 1), the parenchymatous cells of the middle region of ground tissue are larger in size compared to the abaxial and adaxial ones. The cells are round or polygonal in shape with large intercellular spaces. Iratom 24 possesses the largest parenchymatous cells on the adaxial side of the ground tissue (Fig. 7). The cells lining the margin of hollow pith are tangentially elongated. Similar observations have been made in different rice strains (Mia, 1978). No air spaces were found in the ground tissue during the present investigation. However, Mia (1978) has reported air spaces in BR3 and Iratom24 during the aman season. This difference in stem anatomy is probably due to the seasonal variation which needs investigation.

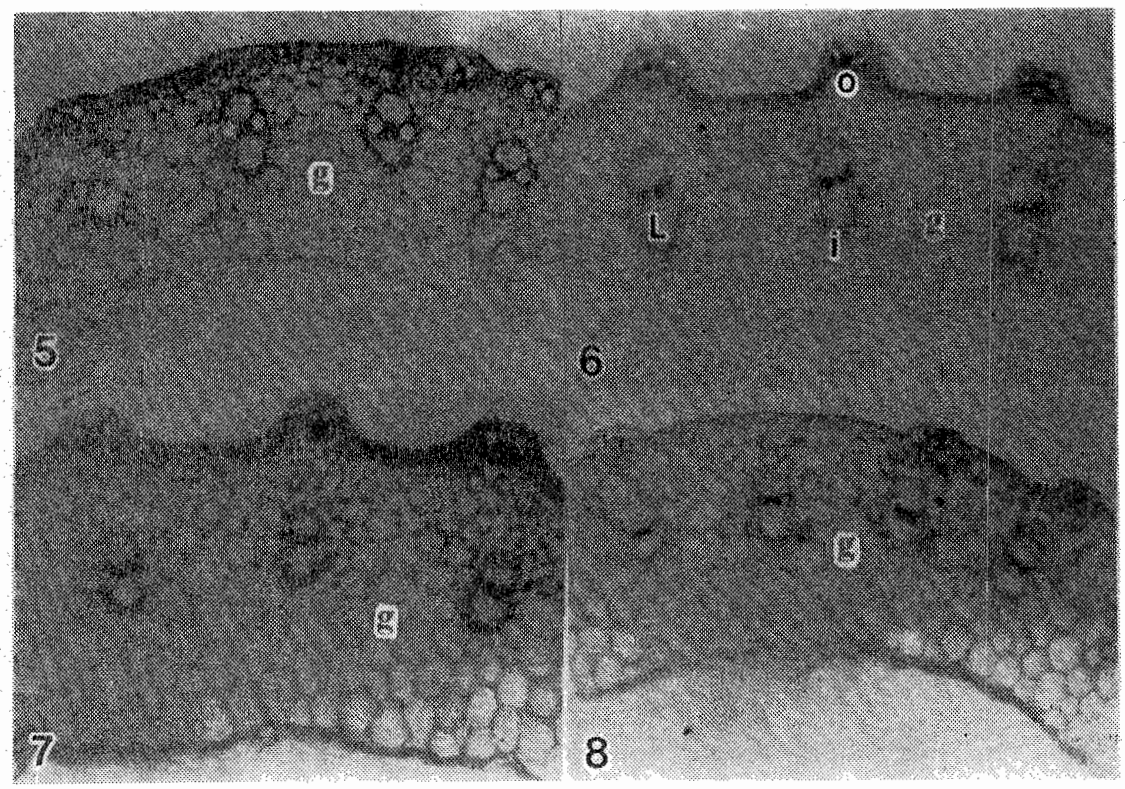

Fig. 5. T.S. through the 3rd internode (from the top) of the stem of BR7 showing epidermis with thick cuticle, hypodermis consisting of 4-5 layers of sclerenchymatous cells, outer and inner vascular bundles, and ground tissue (g). The outer vascular bundles are embedded in the hypodermis. The inner vascular bundle is nearer (2 or 3 cells apart) to hypodermis with prominent protoxylem lacuna. Each of the inner vascular bundles with corresponding outer bundle remains in the same radius and the rest of the inner and outer vascular bundles remain scattered. X 80.

Fig. 6. T.S. through the 3rd internode (from the top) of the stem of BR29 showing epidermis, hypodermis consisting of 3-4 layers of sclerenchymatous cells, outer (o) and inner (i) vascular bundles, and ground tissue (g). The outer vascular bundles are embedded in the hypodermis forming outgrowth in the stem. The inner and outer vascular bundles are in the same radius. The inner vascular bundle shows prominent protoxylem lacuna (L). X 80.

Fig. 7. T.S. through the 3rd internode (from the top) of the stem of Iratom24 showing epidermis, hypodermis consisting of 4-5 layers of sclerenchymatous cells, outer and inner vascular bundles, and ground tissue (g). The outer vascular bundles are embedded in the hypodermis forming outgrowth in the stem. The inner and outer vascular bundles are in the same radius. The inner vascular bundle shows prominent protoxylem lacuna. X 80.

Fig.8. T.S. through the 3rd internode (from the top) of the stem of BR3 showing epidermis with thick cuticle, hypodermis consisting of 3-4 layers of sclerenchymatous cells, outer and inner vascular bundles, and ground tissue (g). The outer vascular bundles are embedded in the hypodermis forming wavy circumference in the stem. The inner vascular bundle is nearer (2 or 3 cells apart) to hypodermis with prominent protoxylem lacuna. Each of the inner vascular bundles with corresponding outer bundle remains in the same radius and the rest of the inner and outer vascular bundles remain scattered. X 80.

Pith: The hollow pith is found to be smaller in modern cultivars compared to that of traditional ones. The hollow pith of traditional cultivars occupies the major part of the culm which is one of the important factors of lodging susceptibility. Mia (1978) has also reported similar results in traditional deep water strains.

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