GENERAL ASPECTS OF GRASS ANATOMY

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Anatomical features especially those of grass leaves are of considerable significance in taxonomy, phylogeny and evolutionary aspects of grasses. Anatomical characters especially that of vascular bundles, abaxial and adaxial epidermis of leaf, silica cells, stomata, macrohairs and microhairs, papillae etc. and terminology used are of prime importance in understanding anatomical features of grasses and their significance in systematics of the group. Therefore a general account of anatomical features of grasses is provided in following paragraphs.

Anatomy of grass leaf:

Anatomical features are very specific to all categories of grasses. Microscopical characters are more important in taxonomic and systematic study of Gramineae. The surface view of both abaxial and adaxial epidermis provides a set of diagnostic characters of grass leaf. Transverse section of leaf also provides characters of diagnostic value. The characteristic features of vascular bundle, distribution of vascular bundles, girders and mesophyll are of significant value in taxonomy of grasses.

Epidermis in surface view:

The surface view of epidermis presents an architectural characterstics of the taxon. Epidermis is usually distinguishable into costal and intercostal zones.

Epidermal cells:

The epidermis consists of two types of cells, long cells and short cells. The long cells which are usually much longer horizontally than vertically. They lie parallel with the long axis of the leaf. The long cells vary in their lengths. The cell walls of long cells vary in thickness as well as in the extent to which they are sinuous or pitted. Variations in thickness and nature of wall are often of specific diagnostic value and species specific. Short cells are often much more nearly equidimentional but in some species they are some what longer horizontally than vertically; in other species their vertical lengths exceed horizontal lengths. Short cells occur in horizontal row, they are either in solitary or in pairs. The arrangement and distribution of short cells varies in costal and intercostals zones. Short cells are

generally classified into silica cells, when each of them is more or less completely filled with a single silica body or cork cells when their cells walls are corky. Cork cells are commonly silicified. The silica bodies in the silica cells assume very characteristic form of diagnostic value. They are dumbbell, crescent, saddale, cubical or elliptical in shape. Although long cells and short cells usually occur together in rows in some grasses but the short cells are infrequent or absent.

Stomata:

Stomata are opening in the epidermis each bounded by two guard cells, which by change in shape brings about the opening and closing of the pore. In some species, the stomata are surrounded by cells that do not differ from other ground cells of the epidermis. These cells are called neighboring cells. In other, the guard cells are bordered by one or more cells that differ in size, shape, arrangement and some times in content from the ordinary epidermal cells. These distinct cells are called subsidiary cells.

In grass leaves, stomata are confined to the intercostals zones. In some grasses of exposed or dry localities, they are sometime restricted to the sides or bases of the furrows in the leaf surface. In most grasses, they occur in horizontal bands in the intercostals zones, and each intercostal zone may include one or more stomatal bands according to the species. In the Poaceae, the guard cells are dumbbell shaped that is they are narrow in the middle and enlarged at both ends.

Grass stomata can be classified according to shape of these subsidiary cells as seen in surface view. Four types of subsidiary cells according to Metcalfe's (1960) system are recognized: parallel- sided, low dome, triangular, high dome or tall dome.

Interstomatal cells:

The long cell that occurs in the same horizontal row as the stoma and that separates individual stoma are termed interstomatal cells. They vary in size and shape.

Dermal appendages:

In grasses the dermal appendages are classified as i) Macro-hair, ii) Micro-hair, iii) Prickle-hairs and iv) Papillae.

i) Macro-hair:

Macro-hairs have been so designated because they are nearly always much longer than the microhair. They can easily be seen with the nacked eyes or simple hand lense. Macro-hair differs from micro in being unicellular. Macro-hairs vary in length, in flexibility, in thickness of the cell wall, and their bases are superficial or penetrated between adjacent epidermal cells, when the bases of the hairs are sunken and surrounded by epidermal cells. In *Indopoa papurcula* the epidermal cells surrounding the bases of the growing hairs grow up around the hair themselves.

Macro-hairs are generally of no more than specific diagnostic value in taxonomy. They may occur in intercostal zones, but on the whole, are more commonly to be found over the vein or at the leaf margins. Intercostal macro-hairs are often cushion hairs, or at least have sunken bases.

ii) Micro-hairs:

Micro-hairs are generally much smaller than macro-hairs. They are commonly two celled. They are either distinctive or very often not very distinct or absent in section because the distal cell is very thin walled and is easily damaged and hence commonly missing. They do not take up the stains very readily either. It is being suggested that the hair serve for the secretion of some undetermined substances.

Micro-hairs commonly occur either in the stomata bands, or in those parts of the intercostals zones that lie between the stomatal band and the vein. They are found elsewhere on the leaf surface in certain grasses.

The various types of microhairs present in grasses are given below; all these types are given by [Metcalf.C.R. (1960)]

***Sporobolus* type** -Unicellular, rounded to dome shaped.

***Chloris* type**-Two-celled, with rounded to dome shaped distal cells.

Zea type - With a short basal cell and usually much longer distal cell having a broadly rounded apex.

***Panicoid* type**-With a short basal cell and a longer distal cell tapering to a pointed apex.

***Echinochloa* type**-With distal and basal cells about equal in length, the distal cell usually having a broadly rounded apex unless distorted.

***Loudetia* type**- With basal and distal cells long and narrow and both uniform in diameter throughout their lengths unless distorted.

***Arundo* type** -With the basal cell usually longer than the apically tapered distal cell.

***Zizania* type**-With basal and distal cells both short and about equal in lenght, the distal cell being apically tapered.

***Eragrostis* type**-With the basal cell very much longer than the dome-shaped distal cell.

iii) Prickle hairs:

Prickle hairs are robust, sharply but shortly pointed structure with swollen bases. They are found above or between the veins. Their short points are usually directed towards the apex of the leaf .They are pointed with thick, lignified walls. Prickle hairs are divided into two types on the basis of size, i.e. prickle and hook.

Prickles and hooks may occur alone or together in the same grass leaf or may both be absent. Prickles commonly occur above the veins and hooks between the veins.

iv) Papillae:

Papillae are variously shaped protrusions from the outer walls of epidermal cells. Papillae occur mostly on the long cells, particularly in the intercostal zones and there may be one or a number of papillae on a single cell. In some grasses, there are several rows of papillae on the individual cells and sometime the papillae on single cell are of two distinct sizes. The papillae are conical or inflated in appearance. In some species they are highly cutinized. Papillae which are on the epidermal cells next to the stomata often overarch and serve to protect the stomatal pores. Papillae occur sporadically throughout the Gramineae. They are especially numerous and characteristic of certain taxonomic groups. The types recognized for descriptive purpose are as follows:

i) Globose papillae in chains overlying the veins.

ii) Oblique, with thickened distal ends.

iii) Unthickened, globose, and often somewhat oblique.

iv) Combination of small cuticular and larger inflated papillae on the same cell.

v) Small, variously shaped, thickened, cuticular papillae

vi) Large, thin papillae.

Transverse section of Lamina:

In grasses, midrib may be prominent or not and the midrib is seen from the abaxial than from the adaxial surface forming keel. The portions of the lamina on either side of the midrib are relatively thin and the lamina frequently becomes still thinner towards the margins. The adaxial surface of the leaf may be either flat or longitudinally ribbed. The ribs varying in height in different species. The ribs are separated from one another by wide or narrow grooves. Ribs are generally more fully developed on the adaxial than abaxial surface.

Epidermis:

The epidermis does not exhibit any important diagnostic character in transverse section, but is necessary to examine it in section as well as in surface view to study the nature of papillae, attachment of macrohair to the epidermis and to interpret the structure of microhair.

Mesophyll:

The ground tissue between the adaxial and the abaxial epidermis consists of the assimilatory tissue or chlorenchyma, but is often partly composed of translucent cells, which are arranged in different pattern. The chlorenchyma and translucent cells occupy all of the space in the leaf that is not taken up by the sclerenchyma or the vascular bundles and their surrounding sheath.

In many grasses from temperate regions the assimilatory tissues is more or less homogeneous and the cells are not arranged in any definite pattern in relation to the vascular bundle. Such type of chlorenchyma is commonly known as festucoid.

In many tropical grasses, the assimilatory cells are oriented in a radiating manner around the vascular bundle. These types of chlorenchyma are referred as panicoid. The distinction between the chlorenchyma as radiate and non radiate is useful for taxonomic purpose.

Arm-cells and fusoid cells are especially the characteristics of the mesophyll of bamboos as distinct from other grasses, although they vary considerably in size in different species and genera.

The types of chlorenchyma that have proved to be valuable for diagnostic purpose are as follows:

i) Chlorenchyma not radiate.

ii) Chlorenchyma radiate.

iii) Chlorenchyma indistinctly or incompletely radiate.

iv) Chlorenchyma radiate, but radiating cells long and narrow – (the ***Isachne*** **type)**

v) Chlorenchyma composed of arm cells, i.e. with inwardly directed projection from the cell- walls.

vi) Mesophyll containing fusoid-cells-(the ***bamboo*** **type.)**

Bundle-sheaths:

Every vascular bundle is surrounded completely or partly by one or two bundle-sheaths, consisting of a single layer of cells. It consists of parenchymatous cells with thin or slightly thickened walls. The transerverse section shows that the cells are inflated and conspicuous, contain chlorophyll, the granules are of larger size and darker in colour.

The cells of the inner sheath (I.S.) are nearly always smaller in diameter and with thicker walls than those of outer sheath, as viewed in transverse section.

Vascular Bundles:

Vascular bundles, apart from those in the midrib, are generally arranged in a single row. They are embedded more or less in the middle of the mesophyll, closer to the abaxial surface. Vascular bundles are of different sizes and different orders, the biggest being the midrib bundle. The individual vascular bundles are more or less circular or elliptical in outline or angular specially the smaller vascular bundles. In grass leaves, the vascular bundle observed is of basic type. The xylem in each bundle of this type is usually characterized by a single, conspicuously large metaxylem vessel to the right and left of the protoxylem.

Following types of vascular bundles are recognized for descriptive purpose:

i) Bundles small, xylem and phloem not easy to distinguish from one another in transverse section.

ii) Bundles relatively small; xylem and phloem easy to distinguish but no conspicuously large vessels present; xylem and phloem not angular in outline.

iii) Bundles tall, narrow and somewhat angular in outline: no conspicuously large vessels present; vertical sides of the bundle sheath straight and parallel to one another.

iv) Bundles of basic type, i.e with at least one, and sometimes two, metaxylem vessels to the right and left of the protoxylem.

v) Large basic type bundles exhibiting varying degrees of sclerosis of the phloem.

Sclerenchyma:

Support is provided by fibrous and other types of thick walled cells that collectively constitute the sclerenchyma. Sclerenchyma is especially well developed in grasses of dry or arid localities. The amount of sclerenchyma that is present varies from species to species. The distribution pattern of sclerenchyma associated with vascular bundles is of ecological and taxonomic interest. There are two type of sclerenchyma present in grasses. In first type, sclerenchyma appears as 'island' of lignified tissue lying above and below or on one side only of each vascular bundle and in second type sclerenchyma appears as girder extending from epidermis to the vascular bundles. This type of sclerenchyma is referred as 'strand' and 'girder' respectively. Strand and girders often occur together in association with different bundles in single leaf.

The various types of sclerenchyma used for descriptive purpose are as follow:

i) Vascular bundle not accompanied by sclerenchyma.

ii) Vascular bundle accompanied by an adaxial strand only.

iii) Vascular bundle with a well –developed abaxial girder only.

iv) Vascular bundle accompanied by adaxial and abaxial girders.

v) Vascular bundle with adaxial T- and abaxial I-girders.

Bulliform and colourless cells:

Transverse section of the lamina nearly always exhibits certain cells that stand out in marked contrast to their neighbors because they are translucent and coloureless.The very specialized fusoid cells occur particularly in the mesophyll of bamboo leaves. The leaves of few common grasses with groups of colourless cells that form part of the epidermis but differ from neighboring cells in being larger and more inflated. These are often referred to as bulliform cells. They were at one time known as 'hinge cells' or 'motor cell' in the belief that by inflation and deflation, due to change of turgor, they controlled the rolling or folding of the leaves in which they occur. They occur most commonly in grasses. Bulliform cells appear as variously shaped groups when viewed in transverse section. The various types of bulliform and colourless cells useful for diagnostic purpose are as follows:

i) Bulliform cells in irregular group.

ii) Bulliform cells in well-defined regular group, but cells not very much larger than the remaining epidermal cells.

iii) Bulliform cells especially large, in regular groups.

iv) Bulliform cells in fan shaped groups at the bases of furrows.

v) Bulliform and associated colourless cells in narrow groups penetrating deeply into the mesophyll.

vi) Bulliform and associated colourless cells forming arches over the small vascular bundle.

vii) Adaxial half of the mesophyll consisting of colourless cells

Anatomy of culm:

Culm is usually solid or become loose and spongy without actually breaking down to become hollow in the central ground tissue. It is completely solid at the node (solid nature helps to withstand bending stress). Sheathing leaf bases protect the portion of the culm that is in most need of mechanical support.

Component tissue of the culm:

Transverse section of the culm is made essentially of parenchymatous ground tissue, some of which contains chloroplast and serves for photosynthesis while the mechanical support is provided by fibers and other cells with thickened walls.

Mechanical tissue:

Ring of sclerenchymatous cells are present below the chrolorenchymatous region or below the epidermis. They provide support in resisting the stress and strains. The inner ground tissue consists of large thin walled parenchymatous cells with intercellular spaces and these occupy the centre of the culm.The central ground is loose and spongy.

Chlorenchyma:

Culms of grasses are usually green owing to the presence of chlorenchyma. Chlorenchyma is in the form of continuous or discontinuous cylinders sub adjacent to the epidermis or the traversed at intervals by sclerenchyma of the next region extending up to the epidermis. Chlorenchyma cells are arranged in single row. The cells of the chlorenchyma are frequently irregular in shape and arrangement and exhibit no characteristic pattern.

Vascular bundles:

Vascular bundles are scattered but spaced towards the center than the periphery of the culm. Vascular bundles toward the center of the culm are much larger than those are next to the epidermis. The outermost vascular bundles are embedded in the peripheral sclerenchyma. The individual vascular bundles are usually more or less circular or oblong in transverse section, but their shapes vary considerably in grasses of various affinities. The bundles are collateral with the phloem at the pole of the bundle towards the periphery of the culm, where it is usually embedded in fibrous tissue. The phloem is made up of sieve elements and phloem parenchyma. Phloem lies between the metaxylem elements. In small vascular bundles the metaxylem vessels are neither conspicuously larger in diameter nor properly developed. In most of the other larger vascular bundles the metaxylem is usually characterized by two (or occasionally more) vessels with greater diameter. The protoxylem elements usually breakdown and are usually replaced by longitudinal intercellular cavities.