

1. Introduction



Anatomical studies of grasses have provided some important diagnostic features in coastal and inter-coastal parts (Metcalf, 1960; Ogundipe and Olatunji, 1992; Keshavarzi et al, 2002).

Leaf anatomy has proved to be a good phylogenetic tool for grass systematic. Typically grass leaf consists mainly two parts, a base i.e. leaf sheath and a blade i.e. leaf lamina, and joint portion of these two parts called ligule. Leaf sheath is generally amplexicaul which may be open to the base or closed and tubular for all much of its length. The lamina is bifacial and possesses series of vascular bundles.

Metcalf (1960) work on “Anatomy of the monocotyledons, I. Gramineae” and several papers have appeared, those dealing with the anatomy of grasses and anatomical peculiarities such as root, culm and leaf anatomy and epidermal characteristics etc. have been used in grass systematic at generic and specific level. He described the anatomy of 206 genera and 413 species based on his own observations. After that, in addition the literature has been compiled with author’s own results thus bringing the total number of genera that have been treated up to 345. That means out of 898 genera 345 genera worked out by Metcalf (1960).

Kaufman *et al* (1956), Stebbins and Jain (1960), De Wet (1960), Stebbins and Shah (1960), Stebbins and Khush (1961), Brown (1958, 1960, 1974a, 1974b, 1975), Deshpande and Sarkar (1962), Chakravarty and Verma (1965), Picket-Heaps and Northcote (1966), Jauhar (1967), Hitch and Sharman (1968, 1971), Blackman (1969), Paliwal (1969), Sanster and Parry (1969), Kok (1972), Crookston and Moss (1973) and Kuo and O’Brien (1974) have contributed to the anatomy of the Gramineae.

Patel (1976) studied anatomy of root, culm, leaf, mature node and leaf epidermal surfaces of 51 species. In the present study 101 species have been studied and out of that 30 species have been worked out by Patel. The work includes few microphotographs and camera lucida drawings detailed photographs for anatomical characterisation was not given.

Kesar *et al.* (2003) studied morphology and anatomy of *Aristida stricta* and conclude a reassessment of the disjunction in the species ranges *A. stricta* and *A. begrichiana* are conspecific. Keshavarzi *et al.* (2007) studied anatomy of five species of *Eremopyrum* and they concluded that on the basis of anatomical observations these species can be differentiated/identified easily and classify *E. confusum* as a separate subgroup of *E. bonaepartis*. Abbasi *et al.* (2010) studied anatomical features of *Puccinellia dolicholepis* and compared with *P. bulbosa*.

The parts of the grass leaf are variously interpreted by morphologists. Burgon (1921) concluded that the blade is equivalent to the leaf base of the dicotyledon and that the sheath of the grass leaf is a new structure, having no equivalence with

dicotyledonous plants. Arber (1918, 1923) upholds the phyllode theory which states that the blade and sheath of the grass leaf correspond to the petiole and base of the dicotyledonous leaf. According to Hitchcock (1922), is that the sheath, petiole, ligule and blade of the grass leaf are homologous to the leaf base, petiole, stipules and blades, respectively, of the dicotyledonous leaf.

Grass leaf anatomy as revealed by transverse sections, has been emphasized as a very fundamental character (Avdulov, 1931; Brown and Emery, 1957; Brown *et al.*, 1957; Hubbard, 1934; Yakovlev, 1950; Tateoka, 1956; 1957; Stebbins, 1956; Reeder, 1957; Row and Reeder, 1957). Duval-joyve (1857) was the first to attempt to use it for systematic studies. The character used was the position of the bands of bulliform cells in relation to the nerves. In Paniceae and Andropogoneae bulliform cells are present over the tertiary nerves and these bulliform cells are present on both the epidermis of Paniceae. Schwendener (1896) discussed the nature of the two bundle sheaths which surrounds the vascular bundle. The inner, the mestome sheath which has characters of the endodermis, has been reported to be present in all grasses (Duval-joyve, 1857) or present in some grass groups but absent from others (Schwendener, 1896). Apart from that chlorenchymatous tissue shows various cellular arrangements, which are present external to parenchyma sheath.

Finally Avdulov (1931) recognized two basic types of leaf anatomy in grass family.

Type 1: which has a thick walled mestome sheath, connected by sclerenchyma to the upper and lower epidermises, a poorly developed parenchyma sheath, and irregularly arranged chlorenchyma? This type is mostly found in Festuceae, Agrostideae, Hordeae, Aveneae, Phalarideae. Prat (1936) this type of anatomy called “festucoid” type of leaf anatomy.

Type 2: this is characterized by the large size of the parenchyma sheath cells which separate the xylem from the sclerenchyma next to the upper epidermis and by the radial arrangement of the chlorenchyma cells. This type of anatomy is mostly found in Paniceae, Andropogoneae, Maydeae, Chlorideae and Zoysieae. Prat (1936) represented this type of anatomy as “panicoid” type of leaf anatomy.

These two basic types of anatomy has been accepted by almost all (Vickery, 1935; Prat, 1937; Burbridge, 1946; Tateoka, 1956; 1956; 1957) but Stebbins (1956) illustrated four types of anatomy. He added “bambusoid” and “chloridoid” to the “panicoid” and “festucoid” of Avdulov and Prat.

Some other anatomical characters have been used in phylogenetic studies are: kranz sheath, patterns in vascular bundles (Columbus, 1996; Cerros-Tlatilpa, 1999), sclerenchyma patterns (Siqueiros and Herrera, 1996), position and form of the

chloroplasts (Columbus, 1996), shape and position of bulliform cells (Columbus, 1996; Cerros-Tlatipla, 1999).

Based on the characteristics of the parenchyma sheath, Brown (1958) proposed six types of leaves while Nikolaevskic (1972) shows that only three types of structure are present in Poaceae. But Clayton and Renvoize (1989) gives more realistic subtypes of leaves structure and also introducing a new (kranz) crown type of structure.

Hsu (1965) in his extensive survey of the anthecial epidermis of the Paniceae recognized four basic patterns, two of which are included in *Brachiaria* (sensu Stapf). His findings led him to question spikelet orientation as a primary generic delimitator in *Brachiaria*. However, his survey of *Brachiaria* was restricted to only six species. Brown (1977) conducted a comparative study of foliar vascular anatomy and photosynthetic pathway in the Paniceae. He recognized a group, including *Brachiaria*, with a Kranz sheath derived from a parenchyma sheath and exhibiting the C₄, PEP-carboxykinase photosynthetic pathway.

Anatomy is related to biochemistry and C₄ type grasses usually have kranz anatomy. Radiate mesophyll is characteristics of C₄ grasses, but C₄ photosynthesis has multiple independent origins in the Poaceae (Kellogg, 2000; Giussani et al, 2001).

Grass ligules are small outgrowths at the junction of the leaf sheath and the blade. Their morphology and anatomy may be important for identification of some critical grass species (Judziewicz and Clark, 1993; Zuloaga *et al.*, 1998; Fuente and Ortunez, 2001). Study of the ligule anatomy provides information on the evolutionary relationships among certain species (Chaffey, 1984), contributing to a more natural taxonomic system. Ligule anatomy is a relatively constant feature, it is also important for identifying individuals living in non-optimal environments (Neumann, 1938). Chaffey (1994) demonstrated the functional anatomy of ligules of 49 grass species from ten tribes.

Generally grasses have been stated to have a hollow internode (Hitchcock, 1914; Bews, 1929; Arber, 1934; Armstrong, 1937). But the members of Andropogoneae and Paniceae internodes are or may be solid (Brown *et al.*, 1959). Canfield (1934) reported, 74% of the grasses examined from the Jornada experimental Range station, New Maxico, to have solid internodes relating the solid stem structure to the environment and concluded that hollow stemmed grasses are not well adapted to arid regions. He studied nearly 133 species in 80 genera. Their study revealed that a large number of Panicoideae grasses have thick walls and small hollows where the fescucoid grasses have thin walls and large hollows. He arranged tribes with respect to

% of species with solid internodes. For ex., Maydeae have 100% solid culm while Paniceae have 49% solid culm, Andropogoneae and Chlorideae have 78% solid stem.

For the culm anatomy features like incomplete bundle sheath which is forming an arc external to the vascular bundles, Kranz arc, radial chlorenchyma, culm outline and chloroplast shape and position are suggested to be useful for inferring phylogenies (Siqueiros and Herrera, 1996).

Except in bamboos, culm anatomy in grasses (Grosor and Liese, 1971; Liese, 1980, 1998; Balsubramanian, 1994; Agrasar and Rodriguez, 2002; Londoño et al. 2002; Sekar and Yao et al, 2002) has been little explored, as it is very useful in phylogenetics (Cenci et al, 1984; Gasser et al, 1994; Siqueiros and Herrera, 1996; Ramos et al, 2002).

Siqueiros and Herrea (1996) pointed out that culm anatomy at the epinodal culm region in *Bouteloua* has restricted phylogenetic value. Ramos *et al.* (2002) found most important variations in the culm components in *Bromus aleuticus* are cortical and medular parenchyma, the development and position of the vascular bundles and the development of the sclerenchyma ring associated with these bundles.

Delgado (2007) studied culm anatomy of 55 taxa of *Boutelouinae* (Chlorideae) and conclude that culm anatomy does not display the same degree of variation as leaf anatomy does, there are several culm anatomy characters that can be useful for inferring relationships at higher levels. And the most important phylogenetic culm anatomy features are kranz structures, number and position of the vascular bundles and sclerenchyma girders.

Caryopsis is a basic dispersal unit in the grasses. It simply consists of embryo and endodermis surrounded by several different structural layers which are contributed by the flower of the parent plant. Reeder (1957) has used unique characters like coleoptiles, epiblast, colelrhiza and scutellum as a basis to classify grass taxa. The growth of the endosperm causes expansion, modification and compaction of their enveloping layers. This study may contribute to dormancy in several species (Thornton 1966a, 1966b; Rost, 1971) and is also known to contain nutritionally important materials in certain food grains. Seed coat has anatomical and agricultural importance, since it may contribute to dormancy in several weed species (Thornton, 1966a; 1966b; Rost 1971). These weed species known to contain

nutritionally important materials (eg. Nicotinic acid and Vitamin B₁) in certain food grains (Hinton, 1948; Hinton and Shaw, 1954).

Few representative studies, have been conducted on barley (Mann and Harlan, 1915), corn (Kiesselbach, 1949; Wolf et al., 1952), Indian millets (Narayanaswami, 1953, 1955a, 1955b, 1955c, 1956), Johanson grass (Harrington and Crocker, 1923), sorghum (Sanders, 1955), sugar cane (Artschwager, Brandes and Starrett, 1929) and other Poaceae (Guerin, 1899).

The coat is continuous around the entire caryopsis except at the point where it is connected to the axis of the inflorescence. The outer most layers is covered by the thick cuticle layer. The pericarp, derived from the ovary of the flower, may be a thin membrane, or it may be composed of one or several cell layers. General structure of caryopsis coat comprised of the adnate layers of the pericarp, seed coat and nucellus surrounds the endosperm and embryonic axis (Izaguirre de Artucio and La-guardia, 1987).

The embryo of Poaceae presents characteristics that are common to other poales, such as lateral disposition, the presence of coleoptiles, mesocotyl formation and the complete reduction of the primary root (Tillich, 2007). Structures of the Poaceae embryo that are characteristics used in the taxonomy of this group include the presence or absence of the scutellum slit, the epiblast, vascularization and the overlap of the plumule margins (Reeder, 1957).

Eichemberg and Scatena (2013) studied morphology and anatomy of the diaspores and seedlings of *Paspalum*. They observed that the caryopsis involves the seed that presents the differentiated embryo and disposed laterally, an elliptical hilum in all the studied species.

Wleaherwax (1930) studied the endosperm of *Zea* and *Coix* and he summarized that the embryo of *Zea* and *Coix* is embedded in one side of the endosperm but surrounded by the latter except at the base. Endosperm shows at maturity a higher degree of differentiation than is ordinarily attributed to it. Rost (1973) studied caryopsis coat in mature caryopses of the *Setaria lutescens*. Rost *et al.* (1990) studied caryopsis anatomy of the *Briza maxima*. They observed that seed coat cuticle extends all around the caryopsis, except in the placental pad region.

In present study attempt to describe the anatomical features of culm, leaf parts and caryopses have been carried out for 100 different grass species. Key to the

identification of these grass species have been prepared to identify the species based on anatomical features of these parts individually.