# A Comparative Anatomy of Mesophyll Among the Leaves of Gramineous Crops

By NOBUO CHONAN

Faculty of Agriculture, Ibaraki University

It is well known that the photosynthetic capacity of leaves is different among the gramineous crops. On the other hand, the differences are also observed in some anatomical characteristics among these leaves. Therefore, the relation between photosynthetic capacity and leaf anatomy has become of general interest recently. In discussing this problem, it will be useful to present a summary of the observations on mesophyll anatomy of the gramineous leaves.

The mesophyll is usually specialized as a photosynthetic tissue, and is differentiated into palisade and spongy parenchyma. In the leaves of gramineous crops, however, the mesophyll shows no distinct differentiation into palisade and spongy parenchyma. The arm-palisade cells from which several lateral protuberances have developed are found in the gramineous leaves. In this paper the shape, size and arrangement of the mesophyll cells are compared among the leaves of gramineous crops.

## Systematics of gramineous crops

Most of the gramineous crops are systematically classified into four subfamily groups, festucoideae, bambusoideae, panicoideae and eragrostoideae. In these groups the festucoideae is temperate origin and the other groups are of tropical origin. Main crops of cereals and grasses included in each group are as follows:

Festucoideae: wheat (*Triticum* spp.), barley (*Hordium vulgare*), oat (*Avena sativa*), rye (*Secale cereale*), orchardgrass (*Dactylis glomerata*), timothy (*Phluem pratense*), kentucky bluegrass (*Poa pratensis*), bromegrass (*Bromus* spp.), redtop (*Agrostis alba*), fescuegrass (*Festuca* spp.), ryegrass (*Lolium* spp.), reed canary grass (*Phalaris arundenacea*), tall oatgrass (*Arrhenatheum elatius*)

Bambusoideae: rice (*Oryza sativa, O. glabberrima*)

Panicoideae: maize (*Zea mays*), sorghum (*Sorghum* spp.), common millet (*Panicum miliaceum*), italian millet (*Setaria italica*), barnyard millet (*Echinochloa crus-galli*), dallisgrass (*Paspalum dilatatum*), napier grass (*Pennisetum purpureum*), teosinte (*Euchlaena mexicana*), eularia (*Miscanthus sinensis*)

Eragrostoideae: finger millet (*Eleusine coracana*), weeping lovegrass (*Eragrostis curvula*), bermuda grass (*Cynodon dactylon*), rhodesgrass (*Chloris gayana*)

## Mesophyll cell shape

In gramineous crops, most of the mesophyll cells are so-called the arm-palisade cells having several protuberances. According to the direction of cell elongation and protuberance development, the mesophyll cells of gramineous leaves are divided into the following types:

1. Tubular palisade cell (P-type): The most simple shape of the mesophyll cells, as observed in the adaxial (upper) layer of dicotyledonous leaves. These cells are oriented with their long axes at right angles to the leaf surface or to the vascular bundle sheath.
2. Longitudinally elongated arm-palisade cell

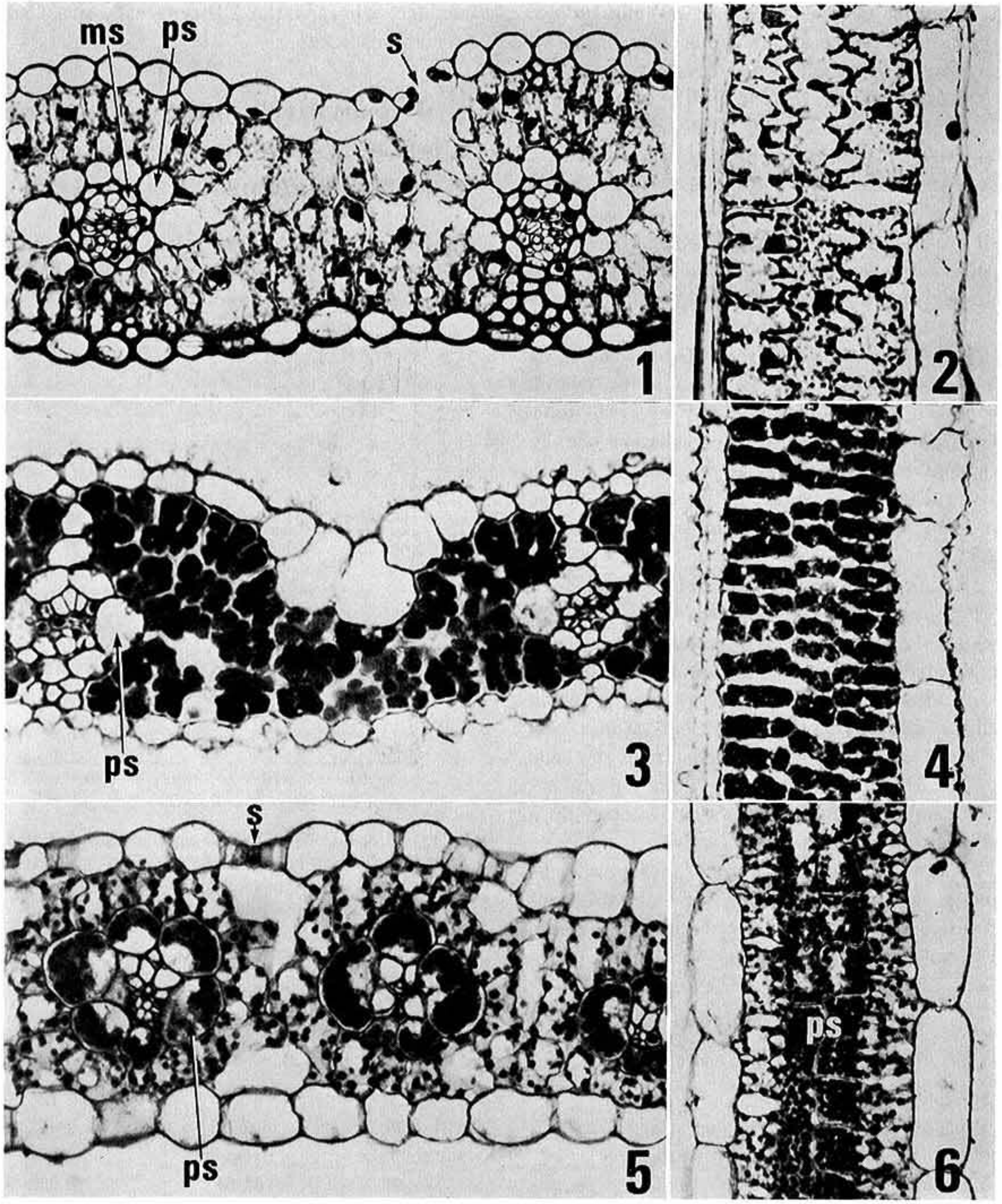


Plate 1. Transection of wheat leaf. Plate 2. Longitudinal section of wheat leaf. Plate 3. Transection of rice leaf. Plate 4. Longitudinal section of rice leaf. Plate 5. Transection of maize leaf. Plate 6. Longitudinal section of maize leaf.
PS: parenchymatous bundle sheath, MS: mestome sheath, S: Stoma

(LP-type): Cell elongation in longitudinal direction is more conspicuous than that in tangential or transverse direction. In the transection of leaf, it appears like a P-type cell (Plate 1, 5), but in the longitudinal section the protuberance development is observed on both sides of a cell (Plate 2, 6). The number of protuberances developed on one side of the cell ranges from three to twelve. There are positive linear relationships between the number of protuberances and the cell length in longitudinal direction.

The P-type cells are regarded as the most simple shape of the LP-type cells, which possess a single protuberance on both sides of a cell. The P- and LP-type cells are usually occur in the outer layer of mesophyll, but in the innear layer of mesophyll the cell shape is remarkably modified and appears like a rachis (Plate 1, 2).

3. Transversely elongated arm-palisade cell (TP-type): The cells of this type are conspicuously elongated in tangential and transverse direction, but not so much elongated in longitudinal direction. The shape of armed cell is clearly observed in leaf transection (Plate 3), but in longitudinal section the cells appear like tubular palisade cells (Plate 4). The number of protuberances developed by a cell ranges from three to twelve.

When we compare the type of mesophyll cells among the three groups of cereal crops (Table 1), the P- and LP-type cells are found in many species of festucoideae and panicoideae, whereas the TP-type cells are found in bambusoideae.

## Mesophyll cell size and its correlation with other characteristics in leaf anatomy

The surface area and volume of mesophyll cells are calculated on the assumption that the protuberances of arm-palisade cells are

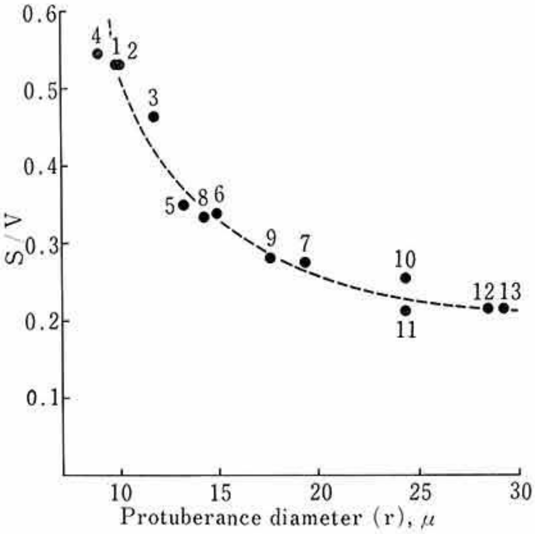


Fig. 1. Relationship between the protuberance diameter (r) and the surface/volum ratio (S/V) of mesophyll cells in the second leaves of cereal seedlings.
1–4: bambusoideae, 5–9: panicoideae, 10–13: festucoideae.

**Table 1. Comparison of anatomical characteristics in the second leaves of cereal seedlings**

| Characteristics of leaf anatomy | Festucoideae | Bambusoideae | Panicoideae |
|---|---|---|---|
| Mesophyll cell type | P, LP | TP | P, LP |
| Mesophyll cell size (protuberance diameter, μ) | 24. 4–29. 2 | 8. 9–11. 8 | 13. 3–19. 4 |
| Mesophyll cell arrangement in transection | palisade-like | irregular | radial |
| Mesophyll thickness (μ) | 141–180 | 51–64 | 78–118 |
| Number of stomata on both surfaces/mm² | 67–91 | 241–325 | 103–180 |
| Guard cell length (μ) | 68–71 | 30–37 | 30–45 |
| Vascular bundle sheath | PS, MS | PS | PS |
| Chloroplasts in PS | few | few | many |
| Interveinal distance (μ) | 360–475 | 168–205 | 122–184 |

Note: PS: parenchymatous bundle sheath, MS: mestome sheath columnar in shape. The protuberance diameter (r) represents the size of mesophyll cells, because it is negatively correlated with the surface/volume ratio (S/V) of mesophyll cells (Fig. 1). The size of mesophyll cells was compared among the second leaves of cereal seedlings (Table 1). The size becomes larger in increasing order, bambusoideae, panicoideae, and festucoideae.

The number of cell layers in the middle portion between the vascular bundles are commonly three in every cereal leaf (Plate 1, 3, 5). Thus, the size of mesophyll cells is positively correlated with thickness of the mesophyll (Table 1). A positive correlation is also observed between the mesophyll cell size and the stomatal cell (guard cell) length, but the number of stomata per unit leaf area is found to be negatively correlated with the mesophyll cell size (Table 1).

## Mesophyll cell arrangement

There are also large differences in arrangement of the mesophyll cells among the gramineous leaves. When we observe the leaf transection, the mesophyll of rice species, which is composed of the TP-type cells, shows irregular cell arrangement (Plate 3). The mesophyll of other groups, which is composed of the P- and LP-type cells, shows a palisade-like arrangement. In the leaves of festucoideae, the palisade cells are oriented with their long axes at right angles to the leaf surface (Plate 1). However, in the leaves of panicoideae and eragrostoideae, most of the mesophyll cells are in close contact with the parenchymatous bundle sheath cells with numerous chloroplasts, and show a distinct radial arrangement (Plate 5). The interveinal distance is also different among the three groups of cereal crops (Table 1).

## References

1) Chonan, N.: Studies on the photosynthetic tissues in the leaves of cereal crops. I. The mesophyll structure of wheat leaves inserted at different levels of the shoot. *Proc. Crop Sci. Soc. Japan*, **33**, 388–393 (1965) [In Japanese with English Summary].

2) Chonan, N.: Studies on the photosynthetic tissues in the leaves of cereal crops. III. The mesophyll structure of rice leaves inserted at different levels of the shoot. *Proc. Crop Sci. Soc. Japan*, **36**, 291–296 (1967) [In Japanese with English Summary].

3) Chonan, N.: Studies on the photosynthetic tissues in the leaves of cereal crops. V. Comparison of the mesophyll structure among seedling leaves of cereal crops. *Proc. Crop Sci. Soc. Japan*, **39**, 418–425 (1970) [In Japanese with English Summary].

4) Chonan, N.: Differences in mesophyll structures between temperate and tropical grasses. *Proc. Crop Sci. Soc. Japan*, **41**, 414–419 (1972) [In Japanese with English Summary].