

LEAF EPIDERMAL ANATOMY OF SELECTED *DIGITARIA* SPECIES, TRIBE PANICEAE, FAMILY POACEAE OF PAKISTAN

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Abstract

Anatomical studies of both the abaxial and adaxial surfaces of leaf epidermis of the selected *Digitaria* species showed variations in size and shapes of prickles, short cells, silica bodies, microhairs with basal and distal cells, hooks, stomates and long cells. Leaf epidermal anatomy was found to be an important tool for identification of *Digitaria* spp. The average lengths of the organelles of leaf epidermises were more clear difference between the species than considering their full ranges of length and breadth. Cross shaped silica bodies were found in *D. abludens* (av. length less than 15 μ m), *D. setigera* and *D. violascens* (av. length less than 20 μ m), dumb-bell to cross shaped in *D. nodosa* and *D. sanguinalis* ssp. *vulgaris* var. *glabra* while dumb-bell shaped in *D. ciliaris*, *D. ischaemum* and *D. radicata*.

The comparative lengths of distal cell and basal cell of microhairs i.e., shorter, longer or equal to each other, were found to be useful in identifying *Digitaria* spp. Basal cell was longer than the distal cell of microhairs in *D. abludens*, it was equal to the distal cell in *D. nodosa* and shorter than the distal cell in *D. sanguinalis* and *D. ciliaris*. Low or tall domed shaped, parallel and triangular subsidiary cells were also observed to be helpful in identification. Cross shaped silica bodies were found in *D. abludens*, *D. setigera* and *D. violascens*, dumb-bell to cross shaped in *D. nodosa* and *D. sanguinalis* subsp. *vulgaris* var. *glabra* while dumb-bell shape in *D. ciliaris*, *D. ischaemum* and *D. radicata*.

Introduction

The genus *Digitaria* belongs to the tribe Paniceae of the family Poaceae (Gramineae). It is fairly large genus with c. 200 species, mostly distributed in tropical and warm temperate regions. It is represented in Pakistan by 12 species (Cope, 1982). Heister (1748) gave the name *Digitaria* for the first time and separated it from the genus *Panicum*. Haller, in 1768, validated the genus and gave a detailed description (Henrard, 1950). Metcalfe (1960) studied abaxial epidermal anatomy of *Digitaria borbonica* Desv., *D. brazzae* (Franch.) Stapf, *D. horizontalis* Willd., *D. milanijana* (Rendle) Stapf and *D. wallichiana* (Wight & Arn.) Stapf. Webster (1983) revised the genus *Digitaria* of Australia. He studied morphological as well anatomical characters of 38 species of *Digitaria*. While studying the leaf epidermal anatomy of the genus, he examined abaxial leaf surface only.

Materials and Methods

Leaves from living and dried specimens of eight species of *Digitaria* were used for anatomical studies. Dried leaves were placed in boiling water for few minutes to

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soften the leaf until they became unfolded and were ready for epidermal scrapping. Fresh leaves were used directly for anatomical studies. Leaf samples were prepared according to the modified method of Cotton (1974) who followed Clark's (1960) technique. The fresh or dried leaves were placed in a tube filled with 88% lactic acid kept hot in boiling water bath for about 50-60 minutes. Lactic acid softens the tissue of leaf due to which its peeling off is made possible.

To prepare the abaxial surface, the leaf was placed keeping its adaxial surface upward and then it was flooded with 88% cold lactic acid. The adaxial epidermis was cut across the leaf using a sharp scalpel blade and scrapped away together with the mesophyll cells until only the abaxial epidermis of the leaf remained on the tile. The epidermis was placed outside uppermost and mounted in clean 88% lactic acid.

Same procedure was followed to prepare the adaxial epidermis but the leaf was placed abaxial surface uppermost instead of adaxial surface uppermost. The photographs of these mounted materials were taken using a camera (35mm.) mounted on the microscope.

Anatomical observations were made on available representative specimens for the taxa. The specimens of 8 species of the genus *Digitaria* are preserved in the herbarium of Quaid-i-Azam University, Islamabad. Length and width characters were found to be highly variable, therefore the typical size is given. To obtain the typical size, numerous measurements were made on each of the representative specimens.

Results

Key to the species of *Digitaria* on the basis of leaf epidermal anatomical characters

- | | | |
|----|---|---|
| 1a | Prickles absent on margins of costal zone of abaxial surface | 2 |
| 1b | Prickles present on margins of costal zone of abaxial surface | 3 |
| 2a | Silica bodies cross shaped and average length < 15 μm , basal cell of microhairs > the distal cell | <i>D. abludens</i> |
| 2b | Silica bodies dumb-bell shaped and average length > 15 μm , basal cell of microhairs equalling the distal cell | <i>D. ischaemum</i> |
| 3a | Basal cell of microhairs equalling the distal cell | <i>D. nodosa</i> |
| 3b | Basal cell of microhairs longer or shorter the distal cell | 4 |
| 4a | Basal cell of microhairs longer than the distal cell | 5 |
| 4b | Basal cell of microhairs shorter than the distal cell | 7 |
| 5a | Average length of silica bodies < 20 μm | 6 |
| 5b | Average length of silica bodies > 20 μm | <i>D. radicata</i> |
| 6a | Average length of prickles on abaxial surface < 40 μm , stomates with tall domed shaped subsidiary cells | <i>D. sanguinalis</i> subsp. <i>vulgaris</i> var. <i>glabra</i> |
| 6b | Average length of prickles on abaxial surface > 40 μm , stomates with low domed shaped subsidiary cells | <i>D. ciliaris</i> |
| 7a | Hooks present on both the abaxial and adaxial surfaces | <i>D. setigera</i> |
| 7b | Hooks not present on both the abaxial and adaxial surfaces | <i>D. violascens</i> |

1. *Digitaria abludens*

A. Adaxial Side (Figs. 1 & 2)

Costal Zone: Average number of rows 2-5. Prickles absent. Short cells $20-50\ \mu\text{m} \times 5-15\ \mu\text{m}$, arrangement of silica bodies and short cells is alternative, margins slightly wavy. Silica bodies $10-12.5\ \mu\text{m} \times 5-7.5\ \mu\text{m}$ (Table 1).

Intercostal Zone: Micro hairs $20\ \mu\text{m} \times 5\ \mu\text{m}$, knife like, short, bicelled. Basal cell $12.5\ \mu\text{m}$ long, distal cell $7.5\ \mu\text{m}$ long. Hooks absent. Stomata $30-32.5\ \mu\text{m} \times 17.5-22.5\ \mu\text{m}$, parallel shaped subsidiary cells. Number of rows of cells between two costal zones 8-10. Number of stomatal rows between two costal zones 3-4. Long cells $25-112.5\ \mu\text{m} \times 20-40\ \mu\text{m}$, margins slightly wavy, irregular and rectangular in shape (Table 1).

B. Abaxial Side (Figs. 3 & 4)

Costal Zone: Average number of rows 2-5. Prickles absent. Short cells $20-50\ \mu\text{m} \times 5-15\ \mu\text{m}$, arrangement of silica bodies and short cells is alternative, margins slightly wavy. Silica bodies $10-12.5\ \mu\text{m} \times 5-7.5\ \mu\text{m}$ (Table 2).

Intercostal Zone: Micro hairs and hooks absent. Stomata $30-32.5\ \mu\text{m} \times 17.5-22.5\ \mu\text{m}$, low dome shaped, parallel or tall dome shaped subsidiary cells. Number of rows of cells between two costal zones 8-10. Number of stomatal rows between two costal zones 3-4. Long cells $25-112.5\ \mu\text{m} \times 20-40\ \mu\text{m}$, margins slightly wavy, irregular and rectangular in shape (Table 2).

2. *Digitaria ciliaris*

A. Adaxial Side (Figs. 5 & 6)

Costal Zone: Average number of rows 3-5. Prickles $20-30\ \mu\text{m} \times 8-12\ \mu\text{m}$, 3-7 cells between the two prickles. Short cells $7.5-30\ \mu\text{m} \times 10-12.5\ \mu\text{m}$. Silica bodies $5-25\ \mu\text{m} \times 7.5-12.5\ \mu\text{m}$ (Table 1).

Intercostal Zone: Micro hairs $57.5-65\ \mu\text{m} \times 5-7.5\ \mu\text{m}$, knife like, bicelled. Basal cell $25-35\ \mu\text{m}$, distal cell $27.5-30\ \mu\text{m}$. Hooks $30-50\ \mu\text{m} \times 25-27.5\ \mu\text{m}$. Stomata $30-40\ \mu\text{m} \times 30-35\ \mu\text{m}$ low domed shaped to parallel subsidiary cells. Number of rows of cells between two Costal zones 8-22. Number of stomatal rows between two costal zones 1-2. Long cells $45-80\ \mu\text{m} \times 20-30\ \mu\text{m}$, margins slightly wavy (Table 1).

B. Abaxial Side (Figs. 7 & 8)

Costal Zone: Average number of rows 3-5. Prickles $37.5-70\ \mu\text{m} \times 17.5-20\ \mu\text{m}$, 7-30 cells between every two prickles. Short cells $10-12.5\ \mu\text{m} \times 7.5-10\ \mu\text{m}$. Silica bodies $12.5-20\ \mu\text{m} \times 7.5-10\ \mu\text{m}$ (Table 2).

Intercostal Zone: Micro hairs $55-62.5\ \mu\text{m} \times 5-7.5\ \mu\text{m}$, knife like, bicelled. Hooks $17.5-25\ \mu\text{m} \times 12.5-15\ \mu\text{m}$. Stomata $35-42.5\ \mu\text{m} \times 5-7.5\ \mu\text{m}$, low domed shaped to parallel subsidiary cells. Number of rows of cells between two costal zones 2-8. Number of stomatal rows between two costal zones 2-3. Long cells $30-82.5\ \mu\text{m} \times 15-22.5\ \mu\text{m}$ margins wavy (Table 2).

Table 1. Average lengths of organelles of leaf epidermis at adaxial surface of *Digitaria* spp.

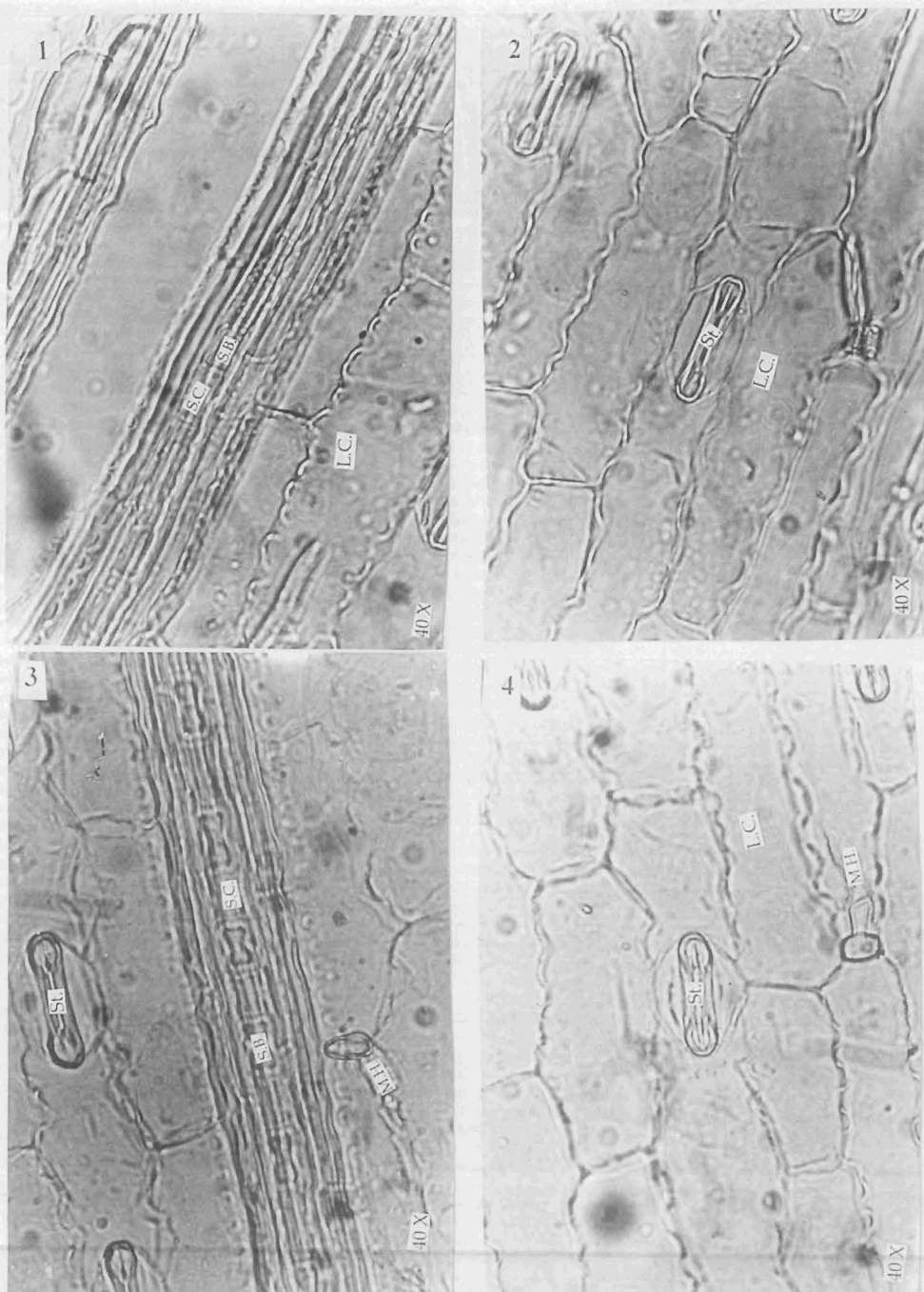
Parameters	<i>D. abludens</i>	<i>D. ciliaris</i>	<i>D. ischaemum</i>	<i>D. nodosa</i>	<i>D. radicata</i>	<i>D. sang. ssp. vulg. var. glabra</i>	<i>D. setigera</i>	<i>D. violascens</i>
<u>Costal Zone</u>								
No. of Rows	2-5	3-5	2-3	2-3	3	2-3	3	3-5
P. (L.) μm	0	25	0	42.5	43.75	0	26.25	23.75
P. (B.) μm	0	10	0	21.25	18.75	0	11.25	11.25
No. of Cells bet. 2 Ps.	0	3-7	0	2-9	7-36	0	6-32	25-36
S.C. (L.) μm	35	18.75	15	12.5	8.75	45	43.75	27.5
S.C. (B.) μm	10	11.25	8.75	8.75	27.5	7.5	6.25	10
S.B. (L.) μm	11.25	15	35	16.25	16.25	17.5	13.75	12.5
S.B. (B.) μm	6.25	10	6.25	8.75	8.75	6.5	8.75	10
<u>Intercostal Zone</u>								
M.H. (L.) μm	20	56.25	77.5	75	97.5	32.5	53.75	58.75
M.H. (B.) μm	5	6.25	6.25	6.25	7.5	6.25	6.25	6.25
Broader cell of M.H. (L.) μm	12.5	30	38.75	38.75	55	32.5	22.5	25
Smaller cell of M.H. (L.) μm	7.5	28.75	38.75	38.75	45	6.25	31.25	33.75
Hooks (L.) μm	0	40	0	31.25	33.75	20	11.25	0
Hooks (B.) μm	0	26.25	0	6.25	12.5	10	10	0
St. (L.) μm	31.25	35	43.75	27.5	38.75	15	30	30
St. (B.) μm	20	32.5	17.75	15	38.75	28.75	18.75	30
No. of Cells bet. C.Zs.	8-10	8-22	2-5	2-5	7-8	6-8	4-7	5-6
No of St. rows bet CZs	3-4	1-2	1-3	2	2-3	2-3	1-2	1-2
L.C. (L.) μm	68.75	62.5	108.75	82.5	103.75	16.25	70	68.75
L.C. (B.) μm	30	25	17.5	18.75	22.5	75	17.5	17.5

Key: B. = Breadth, bet. = between, C.Zs. = Costal zones, L. = Length, L.C. = Long Cells, M.H. = Micro Hairs, No. = Numbers, P = Prickles, S.B. = Silica Bodies, S.C. = Short Cells, St. = Stomata.

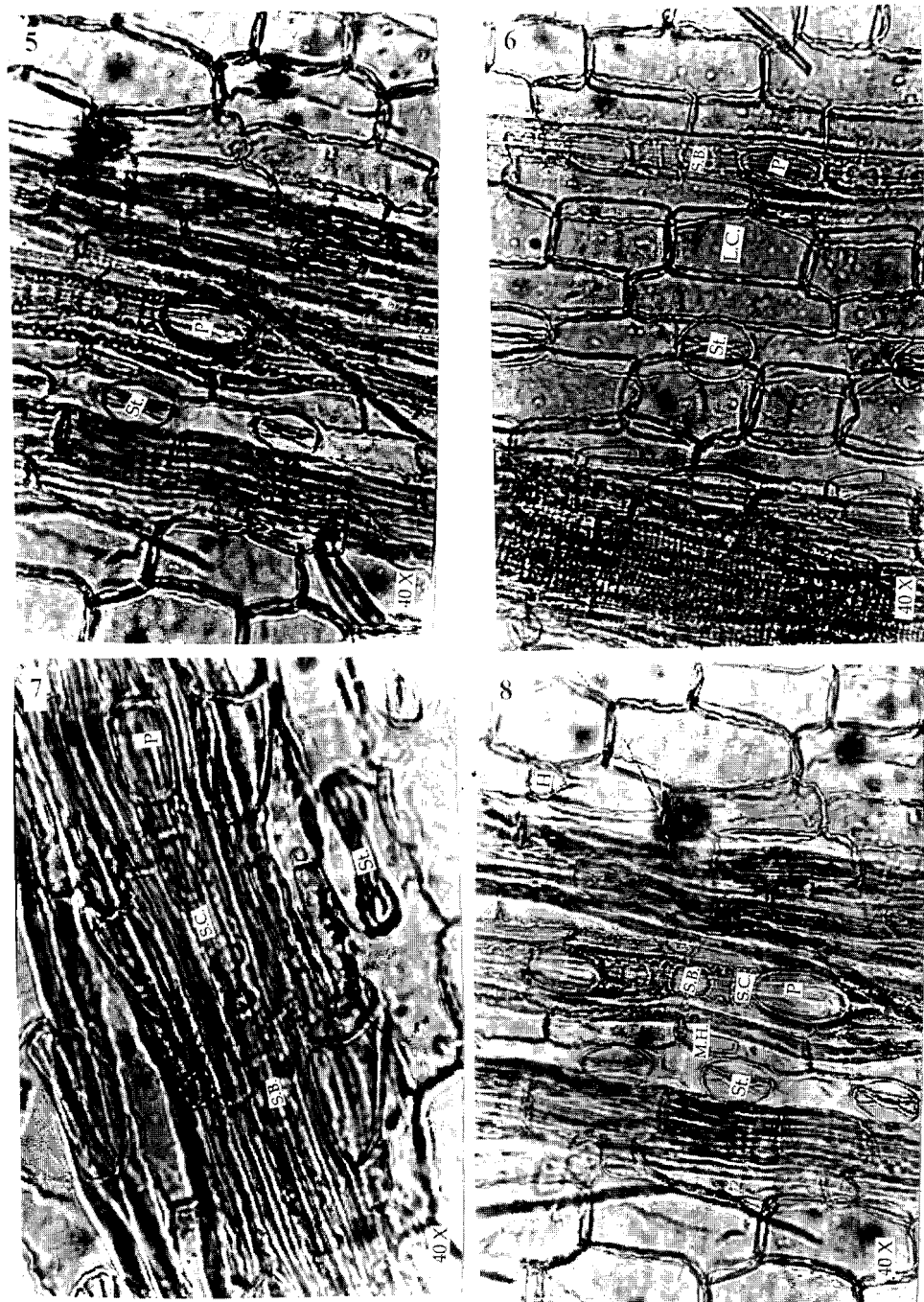
Table 2. Average lengths of the organelles of leaf epidermis abaxial surface of *Digitaria* spp.

Parameters	<i>D. abludens</i>	<i>D. ciliaris</i>	<i>D. ischaemum</i>	<i>D. nodosa</i>	<i>D. radicata</i>	<i>D.sang. ssp. vulg. var.glabra</i>	<i>D. setigera</i>	<i>D. violascens</i>
<u>Costal Zone</u>								
No. of Rows	2-5	3-5	2-3	2-3	3	2-3	3	2-3
P. (L.) μm	0	53.75	0	48.75	32.5	31.25	26.25	40
P. (B.) μm	0	18.75	0	17.5	18.75	15	11.25	18.75
No. of Cells bet. 2 Ps.	0	7-30	0	3-5	16-55	7	6-32	9-20
S.C. (L.) μm	35	11.25	15	26.25	21.25	22.5	43.75	26.25
S.C. (B.) μm	10	8.75	8.75	6.25	10	8.75	6.25	8.75
S.B. (L.) μm	11.25	16.25	35	13.75	22.5	17.5	29.5	12.5
S.B. (B.) μm	6.25	8.75	6.25	7.5	11.25	8.75	8.75	8.75
<u>Intercostal Zone</u>								
M.H. (L.) μm	0	0	0	0	0	0	0	0
M.H. (B.) μm	0	0	0	0	0	0	0	0
Broader cell of M.H. (L.) μm	0	0	0	0	0	0	0	0
Smaller cell of M.H. (L.) μm	0	0	0	0	0	0	0	0
Hooks (L.) μm	0	21.25	0	38.75	20	0	11.25	0
Hooks (B.) μm	0	13.75	0	13.75	16.25	0	10	0
St. (L.) μm	31.25	38.75	43.75	35.25	42.5	26	30	35
St. (B.) μm	20	6.25	18.75	17.5	23.75	26	18.75	23.75
No. of Cells bet. C.Zs.	8-10	2-8	5-6	2-3	9-11	25-40	4-7	3-15
No of St. rows bet CZs	3-4	2-3	1-3	2	3-5	7-8	1-2	2-5
L.C. (L.) μm	68.75	56.25	108.75	71.25	96.25	62.5	70	125
L.C. (B.) μm	30	18.75	17.5	12.5	30	26.25	17.5	23.75

Key: B. = Breadth, bet. = between, C.Zs. = Costal zones, L. = Length, L.C. = Long Cells, M.H. = Micro Hairs, No. = Numbers, P = Prickles, S.B. = Silica Bodies, S.C. = Short Cells, St. = Stomata.



Figs. 1-2. Leaf epidermal anatomy of adaxial surface of *Digitaria abludens*. Figs. (3-4). Leaf epidermal anatomy of abaxial surface of *Digitaria abludens*. These taxa show short cells (S.C.), silica bodies (S.B.) in the costal zone and stomata (St.), microhairs (M.H) and large cells (L.C.) in intercostal zone.



Figs. 5-6. Leaf epidermal anatomy of adaxial surface of *D. ciliaris*. Figs. 7-8. Leaf epidermal anatomy of abaxial surface of *D. ciliaris*. These taxa show short cells (S.C.), silica bodies (S.B.) and prickles (P) in the costal zone and stomata (St.), microhairs (M.H) and large cells (L.C.) in intercostal zone.

3. *Digitaria ischaemum*

A. Adaxial Side (Figs. 9 & 10)

Costal Zone: Average number of rows 2-3. Prickles absent. Short cells $12.5-17.5\ \mu\text{m} \times 7.5-10\ \mu\text{m}$. Silica bodies $20-50\ \mu\text{m} \times 5-7.5\ \mu\text{m}$, dumb-bell shaped (Table 1).

Intercostal Zone: Micro hairs $75-80\ \mu\text{m} \times 5-7.5\ \mu\text{m}$. Basal cell $37.5-40\ \mu\text{m}$, distal cell $37.5-80\ \mu\text{m}$. Hooks absent. Stomata $42.5-45\ \mu\text{m} \times 17.5-20\ \mu\text{m}$. Number of rows of cells between two costal zones 2-5. Number of stomatal rows between two costal zones 1-3. Long cells $87.5-130\ \mu\text{m} \times 10-25\ \mu\text{m}$, wavy (Table 1).

B. Abaxial Side (Figs. 11 & 12)

Costal Zone: Average number of rows 2-3. Prickles Absent. Short cells $12.5-7.5\ \mu\text{m} \times 7.5-10\ \mu\text{m}$. Silica bodies $20-50\ \mu\text{m} \times 5-7.5\ \mu\text{m}$, dumb-bell shaped (Table 2).

Intercostal Zone: Micro hairs absent. Hooks absent. Stomata $42.5-45\ \mu\text{m} \times 17.5-20\ \mu\text{m}$. Number of rows of cells between two costal zones 5-6. Number of stomatal rows between two costal zones 1-3. Long cells $87.5-130\ \mu\text{m} \times 10-25\ \mu\text{m}$, wavy (Table 2).

4. *Digitaria nodosa*

A. Adaxial Side (Fig. 13)

Costal Zone: Average number of rows 2-3. Prickles $35-80\ \mu\text{m} \times 17.5-25\ \mu\text{m}$ with a long beak which emerges from the centre, length of a beak is $10-30\ \mu\text{m}$ and the cell is $25-50\ \mu\text{m}$, 2-9 cells between 2 prickles. Short cells $7.5-17.5\ \mu\text{m} \times 7.5-10\ \mu\text{m}$. Silica bodies $7.5-25\ \mu\text{m} \times 7.5-10\ \mu\text{m}$, dumb-bell-cross shaped (Table 1).

Intercostal Zone: Micro hairs $70-85\ \mu\text{m} \times 5-7.5\ \mu\text{m}$, bicelled, knife like. Basal cell $35-42.5\ \mu\text{m}$, distal cell $35-42.5\ \mu\text{m}$. Hooks $25-37.5\ \mu\text{m} \times 5-7.5\ \mu\text{m}$. Stomata $25-30\ \mu\text{m} \times 12.5-17.5\ \mu\text{m}$. Number of rows of cells between two costal zones 2-5. Number of stomatal rows between two costal zones 2. Long cells $50-115\ \mu\text{m} \times 17.5-20\ \mu\text{m}$, margins wavy (Table 1).

B. Abaxial Side (Figs. 14 & 15)

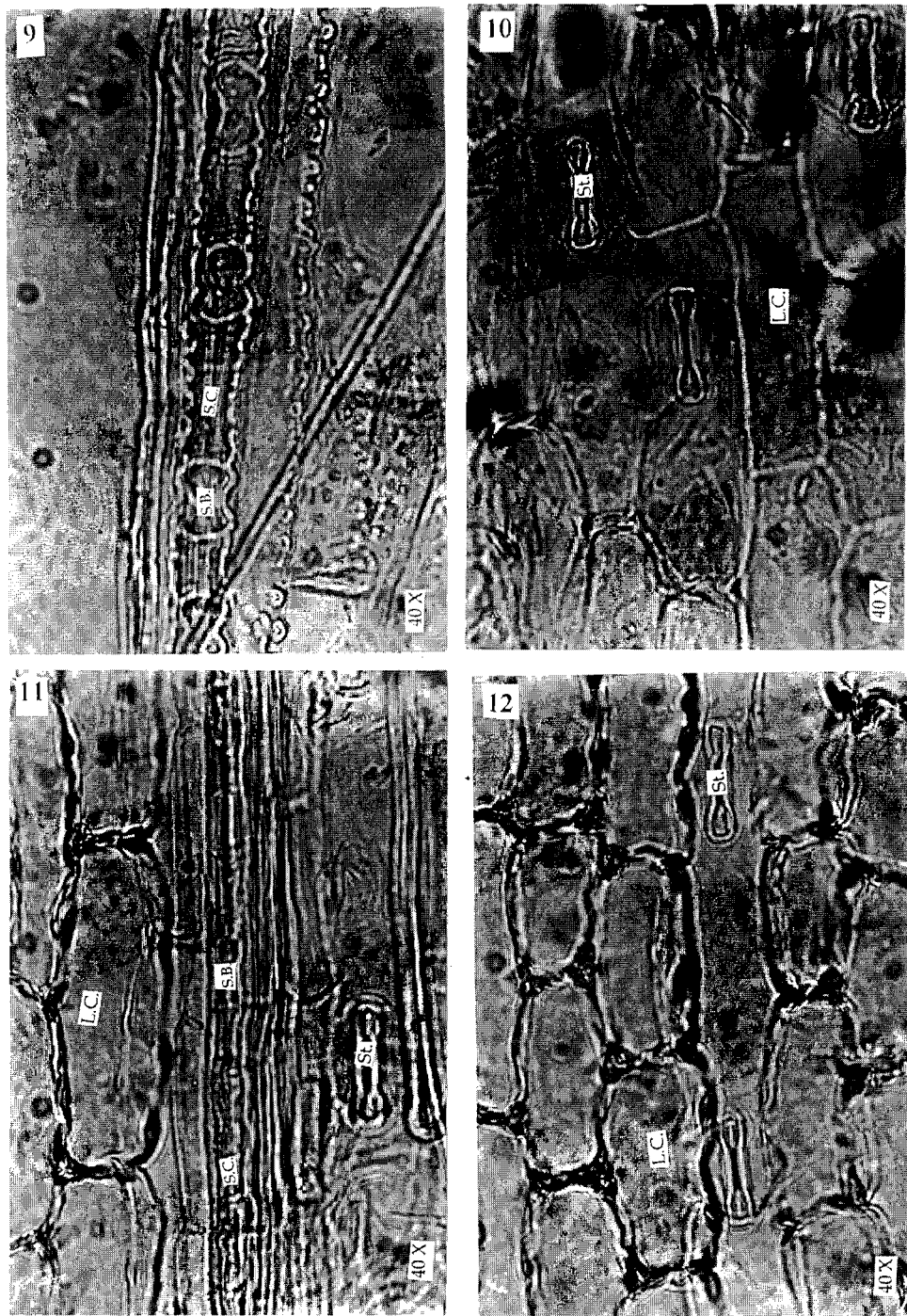
Costal Zone: Average number of rows 2-3. Prickles $35-62.5\ \mu\text{m} \times 15-20\ \mu\text{m}$, 3-5 cells between two prickles. Short cells $15-37.5\ \mu\text{m} \times 5-7.5\ \mu\text{m}$, margins wavy. Silica bodies $10-17.5\ \mu\text{m}$, dumb-bell or cross shaped (Table 2).

Intercostal Zone: Micro hairs absent. Hooks $35-42.5\ \mu\text{m} \times 12.5-15\ \mu\text{m}$. Stomata $32.5-40\ \mu\text{m} \times 15-20\ \mu\text{m}$, tall domed shaped subsidiary cells. Number of rows of cells between two costal zones 2-3. Number of stomatal rows between two costal zones 2. Long cells $45-97.5\ \mu\text{m} \times 10-15\ \mu\text{m}$ (Table 2).

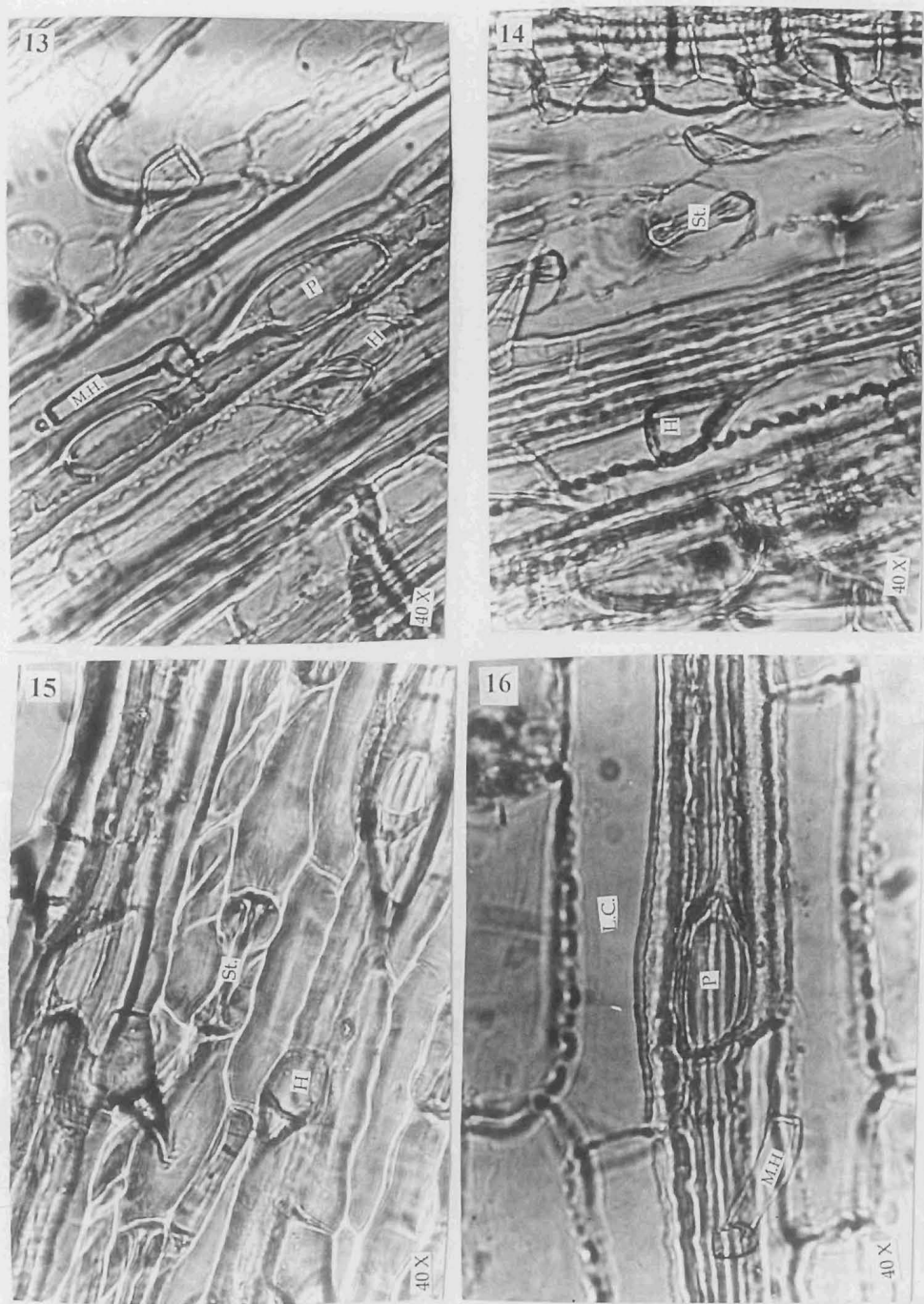
5. *Digitaria radicata*

A. Adaxial Side (Figs. 16 & 17)

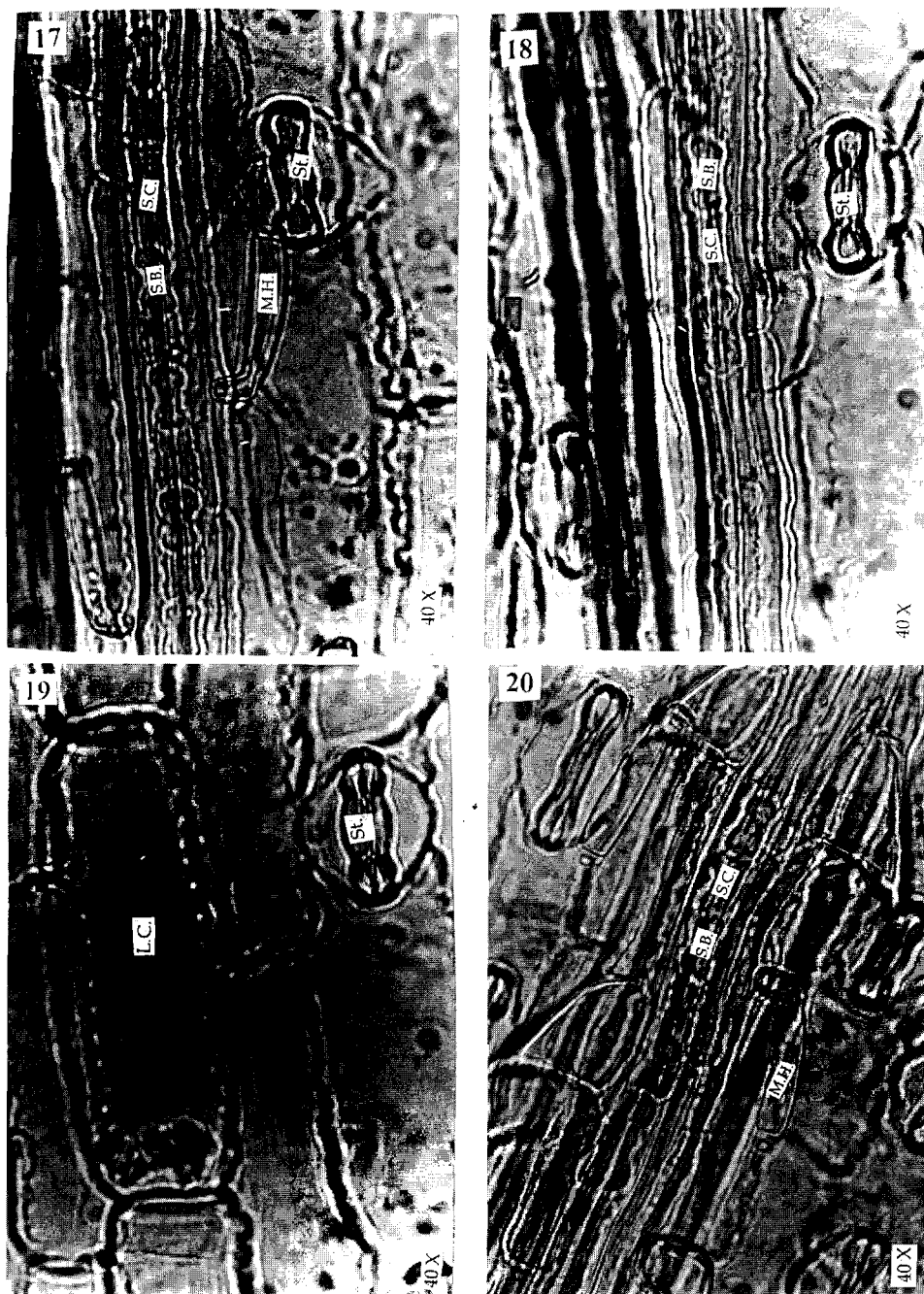
Costal Zone: Average number of rows 3. Prickles $42.5-45\ \mu\text{m} \times 17.5-20\ \mu\text{m}$, 7-36 cells between two prickles. Short cells $7.5-10\ \mu\text{m} \times 12.5-42.5\ \mu\text{m}$, margins slightly wavy. Silica bodies $10-22.5\ \mu\text{m} \times 7.5-10\ \mu\text{m}$, dumb-bell shaped (Table 1).



Figs. 9-10. Leaf epidermal anatomy of adaxial surface of *Digitaria ischaenum*. Figs. 11-12. Leaf epidermal anatomy of abaxial surfaces of *Digitaria ischaenum*. These taxa show short cells (S.C.), silica bodies (S.B.) in the costal zone and stomata (St.), microhairs (M.H.) and large cells (L.C.) in intercostal zone.



Figs. 13-14. Leaf epidermal anatomy of adaxial (13) and abaxial (14) surfaces of *D. nodosa*. Figs. 15-16. Leaf epidermal anatomy of abaxial surface (15) of *D. nodosa* and adaxial surface (16) of *D. radicata*. These taxa show short prickles (P) in the costal zone and stomata (St.), microhairs (M.H.), hooks (H) and large cells (L.C.) in intercostal zone.



Figs. 17-18. Leaf epidermal anatomy of adaxial (17) and abaxial surfaces (18) of *Digitaria radicata*. Figs. 19-20. Leaf epidermal anatomy of abaxial surfaces (19) of *Digitaria radicata* and adaxial (20) surface of *D. sanguinalis* spp. *vulgaris* var. *glabra*. These taxa show short prickles (P) in the costal zone and stomata (St.), microhairs (M.H), hooks (H) and large cells (L.C.) in intercostal zone.

Intercostal Zone: Micro hairs 90-105 $\mu\text{m} \times 5-10 \mu\text{m}$. Basal cell 50-55 μm , distal cell 40-50 μm . Hooks 25-42.5 $\mu\text{m} \times 10-15 \mu\text{m}$. Stomata 37.5-40 $\mu\text{m} \times 37.5-40 \mu\text{m}$, low domed shaped subsidiary cells. Number of rows of cells between two costal zones 7-8. Number of stomatal rows between two costal zones 2-3. Long cells 57.5-150 μm , margins deeply wavy (Table 1).

B. Abaxial Side (Figs. 18 & 19)

Costal Zone: Average number of rows 3. Prickles 30-35 $\mu\text{m} \times 17.5-20 \mu\text{m}$, 16-55 cells between two prickles. Short cells 12.5-30 $\mu\text{m} \times 7.5-12.5 \mu\text{m}$. Silica bodies 15-30 $\mu\text{m} \times 10-12.5 \mu\text{m}$ (Table 2).

Intercostal Zone: Micro hairs absent. Hooks 15-25 $\mu\text{m} \times 15-17.5 \mu\text{m}$. Stomata 37.5-47.5 $\mu\text{m} \times 22.5-25 \mu\text{m}$, tall domed shaped or triangular subsidiary cells. Number of rows of cells between two costal zones 9-11. Number of stomatal rows between two costal zones 3-5. Long cells 55-137.5 $\mu\text{m} \times 17.5-42.5 \mu\text{m}$, broader rectangular (Table 2).

6. *Digitaria sanguinalis* ssp. *vulgaris* var. *glabra*

A. Adaxial Side (Figs. 20 & 21)

Costal Zone: Average number of rows 2-3. Prickles absent. Short cells 40-50 $\mu\text{m} \times 7-8 \mu\text{m}$, arrangement of short cells and silica bodies is alternative, margins wavy. Silica bodies 15-20 $\mu\text{m} \times 6-7 \mu\text{m}$ (Table 1).

Intercostal Zone: Micro hairs 35-42.5 $\mu\text{m} \times 5-7.5 \mu\text{m}$, knife like, bicelled. Basal cell 30-35 μm , distal cell 5-7.5 μm . Hooks 10-20 μm , long beaked. Stomata 17.5-22.5 $\mu\text{m} \times 27.5-30 \mu\text{m}$, tall domed shaped subsidiary cells. Number of rows of cells between two costal zones 6-8. Number of stomatal rows between two costal zones 2-3. Long cells 12.5-20 $\mu\text{m} \times 55-95 \mu\text{m}$, margins wavy (Table 1).

B. Abaxial Side (Figs. 22 & 23)

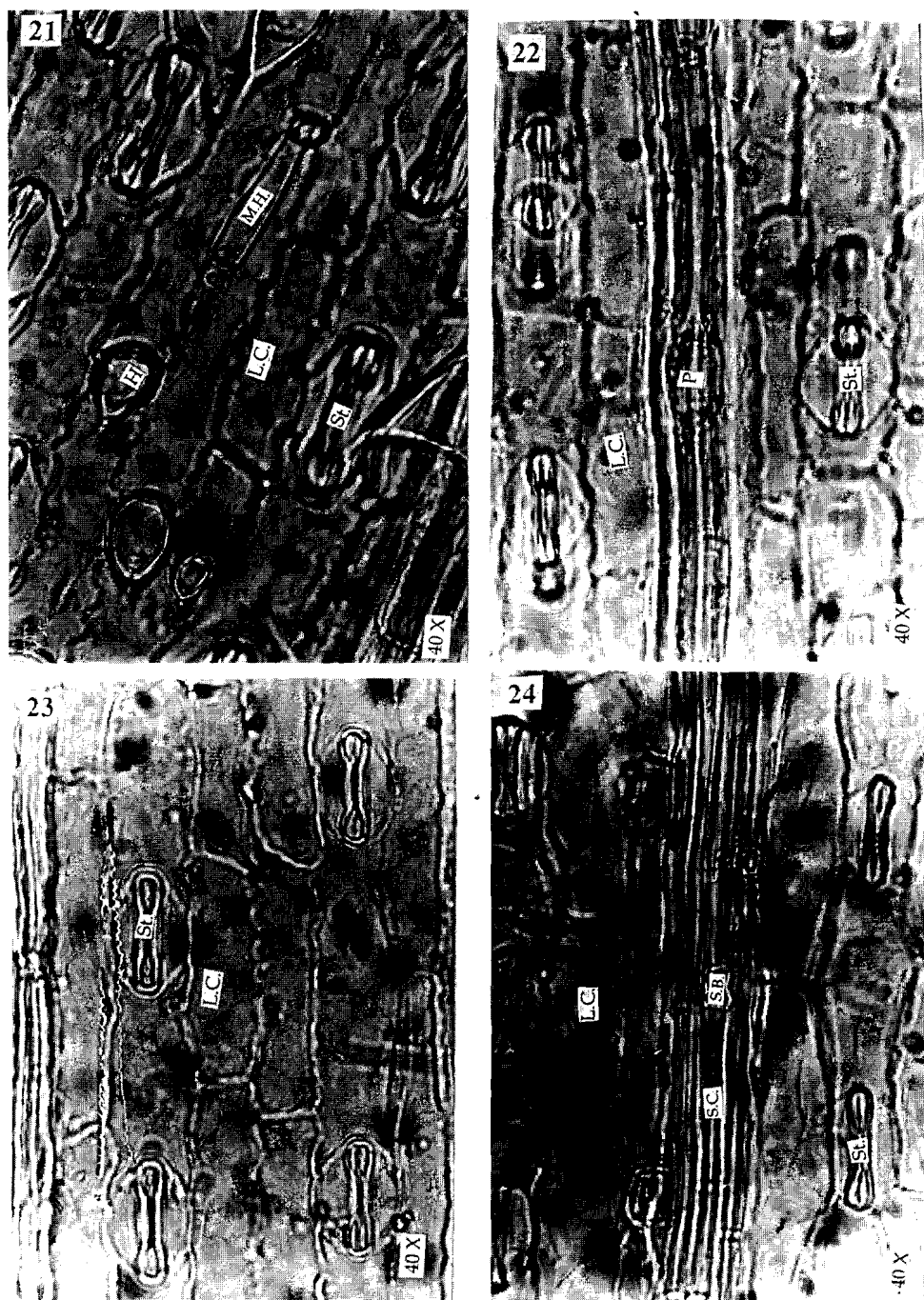
Costal Zone: Average number of rows 2-3. Prickles 25-37.5 $\times 12.5-17.5 \mu\text{m}$, 7 cells are found between every two prickles. Short cells 20-25 $\mu\text{m} \times 7.5-10 \mu\text{m}$. Silica bodies 15-20 $\mu\text{m} \times 7.5-10 \mu\text{m}$ (Table 2).

Intercostal Zone: Micro hairs absent. Hooks absent. Stomata 25-27 $\mu\text{m} \times 25-27 \mu\text{m}$, tall domed shaped subsidiary cells. Number of rows of cells between two costal zones 25-40. Number of stomatal rows between two costal zones 7-8. Long cells 25-100 $\mu\text{m} \times 17.5-35 \mu\text{m}$, margins smooth not wavy (Table 2).

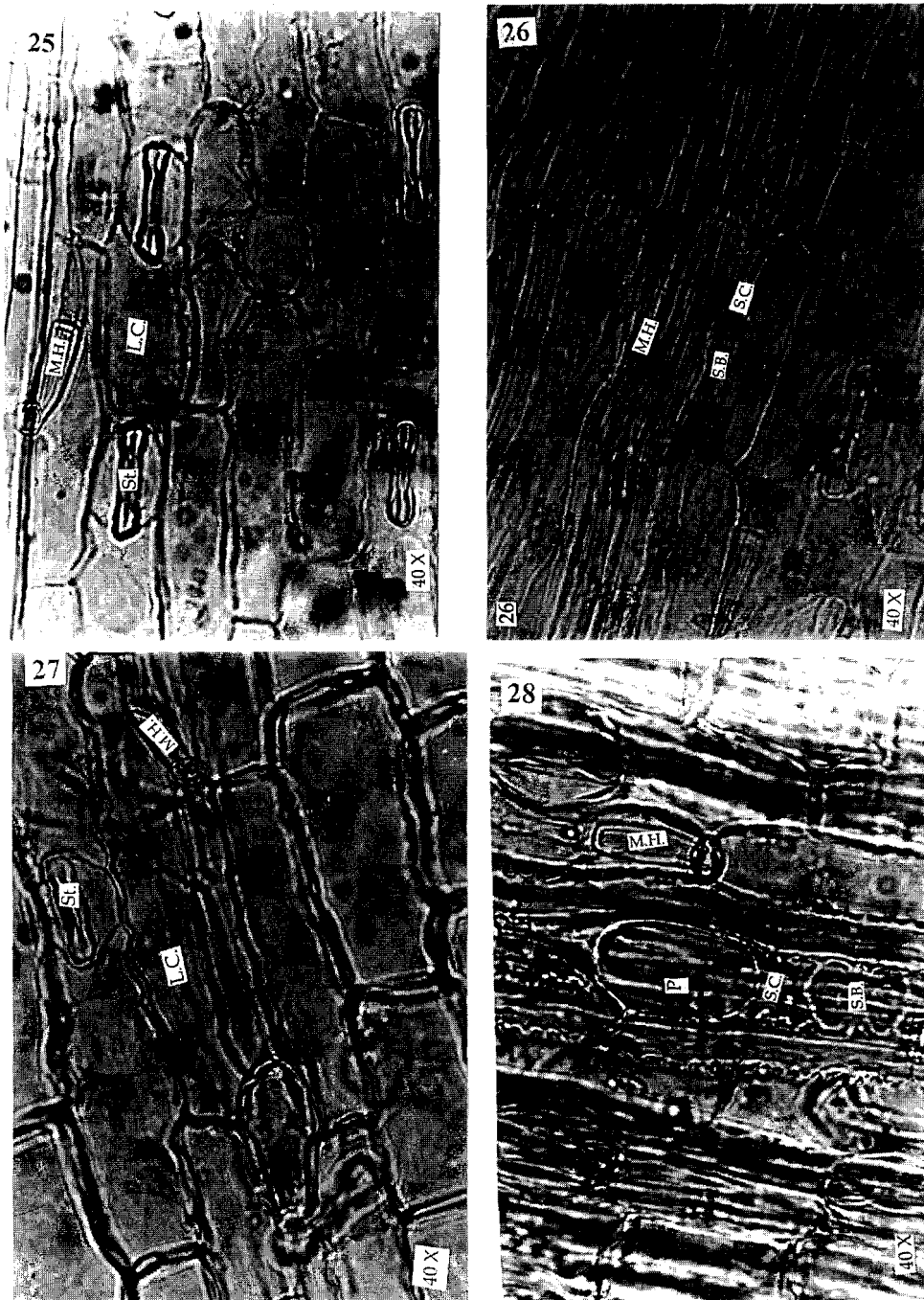
7. *Digitaria setigera*

A. Adaxial Side (Figs. 24 & 25)

Costal Zone: Average number of rows 3. Prickles 22.5-30 $\mu\text{m} \times 10-12.5 \mu\text{m}$, 6-32 cells between two prickles, arrangement of silica bodies and short cells is alternative or silica bodies are after every two short cells. Short cells 37.5-50 $\mu\text{m} \times 5-7.5 \mu\text{m}$. Silica bodies 12.5-15 $\mu\text{m} \times 7.5-10 \mu\text{m}$ (Table 1).



Figs. 21-22. Leaf epidermal anatomy of adaxial (21) and abaxial (22) surfaces of *D. sanguinalis* spp. *vulgaris* var. *glabra*. Figs. 23-24. Leaf epidermal anatomy of abaxial (23) surface of *D. sanguinalis* spp. *vulgaris* and adaxial (24) surface of *D. setigera*. These taxa show short cells (S.C.), silica bodies (S.B.) and prickles (P) in the costal zone and stomata (St.), microhairs (M.H), hooks (H) and large cells (L.C.) in intercostal zone.



Figs. 25-26. Leaf epidermal anatomy of adaxial (25) and abaxial surfaces (26) of *Digitaria setigera*. Figs. 27-28. Leaf epidermal anatomy of abaxial surface (27) of *Digitaria setigera* and adaxial (28) surface of *D. violascens*. These taxa show short cells (S.C.), silica bodies (S.B.) and prickles (P) in the costal zone and stomata (St.), microhairs (M.H), hooks (H) and large cells (L.C.) in intercostal zone.

Intercostal Zone: Micro hairs $50-57.5\ \mu\text{m} \times 5-7.5\ \mu\text{m}$, bicelled, knife like. Basal cell $20-25\ \mu\text{m}$, distal cell $30-32.5\ \mu\text{m}$. Hooks $10-12.5\ \mu\text{m} \times 10\ \mu\text{m}$. Stomata $30\ \mu\text{m} \times 17.5-20\ \mu\text{m}$, low domed shaped subsidiary cells. Number of rows of cells between two costal zones 4-7. Number of stomatal rows between two costal zones 1-2. Long cells $25-115\ \mu\text{m} \times 10-25\ \mu\text{m}$ (Table 1).

B. Abaxial Side (Figs. 26 & 27)

Costal Zone: Average number of rows 3. Prickles $22.5-30\ \mu\text{m} \times 10-12.5\ \mu\text{m}$, 6-32 cells between two prickles, arrangement of silica bodies and short cells is alternative or silica bodies is after every two short cells. Short cells $37.5-50\ \mu\text{m} \times 5-7.5\ \mu\text{m}$. Silica bodies $12.5-15\ \mu\text{m} \times 7.5-10\ \mu\text{m}$ (Table 2).

Intercostal Zone: Micro hairs absent. Hooks $10-12.5\ \mu\text{m} \times 10\ \mu\text{m}$. Stomata $30\ \mu\text{m} \times 17.5-20\ \mu\text{m}$. Number of rows of cells between two costal zones 4-7. Number of stomatal rows between two costal zones 1-2. Long cells $25-115\ \mu\text{m} \times 10-25\ \mu\text{m}$ (Tables 2).

8. *Digitaria violascens*

A. Adaxial Side (Fig. 28)

Costal Zone: Average number of rows 3-5. Prickles $22.5-25\ \mu\text{m} \times 10-12.5\ \mu\text{m}$, 25-36 cells between two prickles. Short cells $17.5-37.5\ \mu\text{m} \times 5-15\ \mu\text{m}$. Silica bodies $10-15\ \mu\text{m} \times 7.5-12.5\ \mu\text{m}$, cross-shaped (Table 1).

Intercostal Zone: Micro hairs $55-62.5\ \mu\text{m} \times 5-7.5\ \mu\text{m}$, bicelled, knife like. Basal cell $25\ \mu\text{m}$, distal cell $30-37.5\ \mu\text{m}$. Hooks absent. Stomata $27.5-32.5\ \mu\text{m} \times 27.5-32.5\ \mu\text{m}$. Number of rows of cells between two costal zones 5-6. Number of stomatal rows between two costal zones 1-2. Long cells $25-112.5\ \mu\text{m} \times 10-25\ \mu\text{m}$ (Table 1).

B. Abaxial Side

Costal Zone: Average number of rows 2-3. Prickles $35-45\ \mu\text{m} \times 17.5-20\ \mu\text{m}$, beak is as long as the cell, 9-20 cells between two prickles. Short cells $17.5-35\ \mu\text{m} \times 7.5-10\ \mu\text{m}$. Silica bodies $10-15\ \mu\text{m} \times 7.5-10\ \mu\text{m}$, cross shaped (Table 2).

Intercostal Zone: Micro hairs absent. Hooks absent. Stomata $32.5-37.5\ \mu\text{m} \times 22.5-25\ \mu\text{m}$. Number of rows of cells between two costal zones 3-15. Number of stomatal rows between two costal zones 2-5. Long cells $100-150\ \mu\text{m}$, $17.5-30\ \mu\text{m}$ (Table 2).

Discussion

Anatomical studies have been used successfully to clarify taxonomic status and help in the identification of species. Anatomical studies showed differences in size and shapes of prickles, short cells, silica bodies, micro hairs with basal and distal cells, hooks, stomates and long cells of *Digitaria* species.

The size and shapes of organelles were different on both the abaxial and adaxial surfaces of leaf epidermis because of the bifacial leaf which also confirmed the findings of Webster (1983) and Shouliang *et al.*, (1996) but it was the first time that both the abaxial and adaxial surfaces were studied in detail in the present study.

The prickles were found to be absent on both the abaxial and adaxial surfaces of leaf epidermis in *D. abludens* and *D. ischaemum*. *D. sanguinalis* subsp. *vulgaris* var. *glabra* had prickles only on an abaxial surface but absent on adaxial surface of leaf epidermis, thus distinguishing these species from the rest of the genus *Digitaria*. The rest of the species of *Digitaria* had prickles on both the abaxial and adaxial surfaces.

Three types of silica bodies i.e., dumb-bell, dumb-bell-cross shaped and cross shaped were observed in *Digitaria* spp. The evolutionary trend in silica bodies is from dumb-bell to cross shape (Shouliang *et al.*, 1996). Cross shaped silica bodies were found in *D. abludens*, *D. setigera* and *D. violascens*, dumb-bell to cross shaped in *D. nodosa* and *D. sanguinalis* subsp. *vulgaris* var. *glabra* while dumb-bell shape in *D. ciliaris*, *D. ischaemum* and *D. radicata*.

The other characteristic organelle of leaf epidermis were microhairs which were found to be present only on adaxial surface of leaf epidermis of all the species. These microhairs were two celled and knife like. The basal cell was either shorter, longer or equal to the distal cell of microhairs. Basal cell was longer than the distal cell of microhairs in *D. abludens*, it was equal to the distal cell in *D. nodosa* and shorter than the distal cell in *D. sanguinalis* and *D. ciliaris*. The average length of microhairs was also an important character in identification, which is also in conformation with the findings of Webster (1983) and Shouliang *et al.*, (1996). However, the comparative lengths of basal and distal cells, either shorter, longer or equal to each other, were also useful in delimiting *Digitaria* spp. This character was not considered previously by any of the taxonomists.

Stomates had low or tall dome shaped, parallel or triangular subsidiary cells. Triangular subsidiary cells were observed in *Digitaria radicata* which also contained tall dome shaped subsidiary cells. *D. ciliaris* consisted of parallel along with low dome shaped subsidiary cells in the same epidermis which is also in conformity with the findings of Metcalfe (1960) that two types of subsidiary cells may be found in the same epidermis of the *Digitaria* spp. Shouliang *et al.*, (1996) considered, the tall dome shaped subsidiary cells as primitive while parallel and triangular subsidiary cells as advanced characters.

Considering the arrangement of characters for evolutionary series, the *D. abludens*, *D. setigera* and *D. violascens* may be the advanced species on the basis of shape of silica bodies but these species contain dome shaped subsidiary cells of stomata which is the primitive character while *D. radicata* and *D. ciliaris* may be the advanced one due to the presence of triangular and parallel subsidiary cells of stomatas but they also contained the dome shaped subsidiary cells along with the primitive character, the dumb-bell shaped silica bodies. Thus the evolutionary trend simply on these characters may not be sketched out because of the combination of different primitive and advanced characters in the same species.

The presence of both the primitive and advanced characters of the same organelle for example domed shaped and triangular subsidiary cells of stomata in *D. radicata* may lead to the conclusion that this taxon may occupy an intermediate position in evolutionary hierarchy. However, full range of morphological and cytological range of *Digitaria* species is unknown. Their cytological and karyological studies are required to find the relationships between the species.

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(Received for publication 31 May 2002)