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The Epidermal Characteristics of the First Seedling Leaves of Certain Grass Seedlings

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THE EPIDERMAL CHARACTERISTICS OF THE FIRST SEEDLING LEAVES OF CERTAIN GRASS SEEDLINGS

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THESIS ABSTRACT

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The epidermal characteristics of the first seedling leaves of thirty species of grasses common to the Mixed Prairie Association of West central Kansas were studied. The thirty species represent seventeen genera and six tribes of the Gramineae. Seed was gathered in the Hays, Kansas area and the seedlings grown in the Fort Hays Kansas State College greenhouse under optimum conditions.

Slides of both abaxial (lower) and adaxial (upper) leaf surfaces were made from preserved specimens by the peel method which utilizes acetone and cellulose acetate film. These slides were compared with stained mounts of the abaxial epidermis. Photomicrographs of both leaf surfaces were taken and these supplemented with line drawings of certain diagnostic epidermal elements.

The differing cell types occurring as part of the epidermis were studied and recorded. Silica bodies, cork cells, macro-hairs, micro-hairs, prickle-hairs, papillae, stomata, and certain undifferentiated cells were studied. The form or shape of these epidermal elements was emphasized rather than the number or distribution.

The form of the silica bodies and bicellular micro-hairs were found to be most useful in distinguishing or

characterizing species and other taxa. In this survey of a number of grasses of several genera and tribes, the form and arrangement of the epidermal elements were found to be more diagnostic than distribution or frequency.

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I. INTRODUCTION

The Gramineae has long been recognized as a complex and highly diversified family. Since the grass family is widespread in occurence and of such economic importance, many workers have endeavored to achieve a natural as well as utilitarian system of classification. Attention has been drawn to the fact that existing treatises which utilize the gross morphological characteristics of the floral organs are insufficient in solving the problems posed by this taxon.

During the past fifty years, the store of knowledge concerning the grasses has been greatly magnified as it has for all sciences. An important factor in this amplification has been the application of new techniques and the use of information derived from several botanical disciplines. In the past decade the science of grass systematics has served to clarify the relative positions of quite a large number of grasses. The new trend in grass systematics involves the use of a correlation of data from the fields of morphology, ecology, physiology, cytology, embryology and others. Physiological responses (Al-Aish and Brown, 1958), the meristem (Brown, et.al., 1957), leaf anatomy (Brown, 1958), chromosome numbers (Gould, 1958), and leaf epidermis (Lee, 1961), have been found to vary among species and may be utilized in the taxonomy of the group.

A study by Reeder and Ellington (1960) exemplifies the advantages of the new grass systematics. On the basis of floral morphology, the genera *Calamovilfa*, *Ammophila* and *Calamagrostis* are characterized as closely related members of the traditional tribe Agrostideae. Taxonomists and agrostologists have followed this arrangement for years. The studies of Reeder and Ellington involved comparisons of embryo structure, lodicules, leaf epidermis, leaf anatomy as revealed by transverse section, and the size and number of chromosomes of certain representatives of the three genera. Examination of the correlated data showed the genera *Ammophila* and *Calamagrostis* to be closely related, but the genus *Calamovilfa* was shown to be most closely related to the genus *Sporobolus*. *Calamovilfa* revealed few characteristics in common with the other two genera except those of the floral organs.

Among the characteristics utilized in the above study were those of the leaf epidermis. The epidermis of grass leaves exhibits one of the most highly specialized morphological aspects of the family and has been proven useful in the taxonomy of the group. The taxonomic significance of these epidermal characteristics were emphasized by the Frenchman Henri Prat in 1932. In writings since that date (1936, 1948), Prat assigned importance to epidermal patterns and cell types and stated that these were characteristic of each subfamily as well as tribes. Prat (1936) indicated that complex silica cells (i.e. silica bodies), triangular stomata, and the presence of cushion hairs are characteristic of the subfamily Panicoideae while simple silica cells, oval-shaped stomata, and the absence of cushion-hairs are characteristic of the Festucoideae. Although Prat was not correct in all his assumptions, he did foster an interest in the taxonomic application of epidermal characteristics.

Since the appearance of Prat's paper, many researchers have explored and utilized epidermal characteristics of small or isolated groups of grasses. A recent work by C. R. Metcalfe (1960) includes the greatest assemblage of facts concerning the epidermis of grass leaves published to date. However, only a limited number of grasses indigenous to the Mixed Prairie Association are described in the voluminous work.

In striving to add some measure of knowledge concerning the epidermis of grass leaves, the author chose to examine thirty species commonly found in the area surrounding Hays, Kansas and to note their epidermal characteristics. The epidermis of grass leaves varies according to position on the plant (Metcalfe, 1960) and only those characteristics of the first seedling leaves are included in this study. Before beginning research, the author consulted the texts of Esau (1958), Arber (1934), and Metcalfe (1960) for both basic and specialized information.

II. MATERIALS AND METHODS

Seeds of thirty species of native and introduced grasses were collected in the vicinity of Hays, Kansas in the Mixed Prairie Association. The identity of these selected species was determined through use of the Manual of the Grasses of the United States (Hitchcock, 1950). These species are representative of six tribes in seventeen genera. The fresh seed was vernalized according to procedures outlined in Table I. The treated seed was then placed on sterile soil to insure growth of only desired species and allowed to germinate. The soil was subjected to temperatures of approximately 180° F to render any seeds present inviable. The seedlings were grown in the college greenhouse under optimum temperature and soil moisture conditions.

Since some species, especially perennials with rhizomes, produce seed in a limited supply and with low germination percentages, it was necessary to treat another supply of seed to insure an adequate number of seedlings with which to work. These particular seeds were submitted to fluctuating temperatures of 40° to 50° F for twelve hours and 70° to 80° F for twelve hours. This alternation of temperature was continued for a period of two weeks. The treated seeds were then placed in a fine sterile sand and kept at an optimum content of nutrient solution instead of water. The nutrient solution of Shive and Robbins (1938) was used and is compounded as follows:

0.0023 Molar KH_2PO_4

0.0045 Molar $Ca(NO_3)_2$

0.0023 Molar $MgSO_4$

0.0007 Molar $(NH_4)_2SO_4$

One milliter of a 0.5% ferric tartrate solution was added per liter of culture as micrometabolic elements to "complete" the nutrient solution.

Although no records of germination percentages were kept, the use of alternating temperatures produced a higher percentage of germinating seed than those treated by constant temperatures.

The seedlings were allowed to grow until the third seedling leaf was evident. The seedlings were then washed free of sand and soil and preserved in F.A.A., a standard fixing and preserving fluid.

Slides of the abaxial (lower) and adaxial (upper) surface of the first seedling leaves were made by the peel method outlined by Lonert (1960). The preserved leaves were first excised from the seedling, washed in 70% ethyl alcohol, then placed on absorbent paper to remove excess fluid. A drop of acetone was applied to the desired surface and a piece of cellulose acetate film about the size of a standard coverslip then pressed firmly over the leaf surface. The acetate film employed was 0.021 mm in thickness, but thickness may vary without undesirable effects. After the acetate film was dry, it was directly fastened, impression side down, to a standard glass slide with masking tape. The resulting slides are permanent. The slides were observed under a compound microscope with oblique illumination of 100x and 400x powers. Both abaxial and adaxial surfaces of each species were photographed with Kodak Tri-X film. A photomicrograph lightmeter was employed to adjust the light source to six units, the film was then exposed for 1/5 second.

Comparisons of the acetate peels were made by utilizing stained mounts of the actual epidermis. The preserved specimens were washed in 70% ethyl alcohol and placed adaxial surface up on a glass slide. All but the abaxial epidermis was then scraped away with a single-edged razor blade. The specimen was then transferred to a methylene blue staining solution which serves to differentiate the cell types. The specimens were mounted in Karo syrup, one of the mounting media prescribed by Johansen (1940). The resulting slide is permanent and need not be ringed with piccolyte except in moist climates. No photomicrographs of these slides were taken.

III. OBSERVATIONS AND DATA

In an unpublished study, the author has observed that the external gross morphology of grass seedling leaves does not necessarily reflect the same characteristics found in leaves of the nature of flowering plants. For example, the pustulate hairs along the margins of mature leaves of Bouteloua curtipendula are not seen in first seedling leaves. Species within the same genus often show striking similarities and are quite difficult to distinguish on the basis of gross morphology alone.

In this present study, it was noted that the position of the first seedling leaf seems characteristic for each subfamily. Prat (1936) indicated that the first foliage leaf of grasses of the subfamily Panicoideae is rather broad and flaring and assumes a horizontal position. On the other hand, grasses of the subfamily Festucoideae have long, narrow first seedling leaves that assume a vertical position. Observations of the selected thirty species showed the position of the first seedling leaf relative to the soil surface to be characteristic of the two subfamilies Panicoideae and Festucoideae. It was also noted that the first seedling leaf is ephemeral in nature.

The microscopical epidermal characteristics of both abaxial (lower) and adaxial (upper) surfaces of the thirty selected species were examined and recorded. In all cases the leaves were examined from margin to margin. The leaves of all but a few species were observed from the ligule or collar region to the apex. Observations were made at 100X and 400X.

The abaxial surfaces, in general, were found to offer a wider assortment of characteristics than the adaxial surfaces. Only the characteristics of the abaxial surface were employed in a key to species. The key was constructed not strictly for purposes of identification, but rather to point out morphological characters and to aid in identification. More important, the key categorizes species which share epidermal characteristics and points out their differences. Descriptions and photomicrographs of both epidermal surfaces and line drawings of silica bodies and other diagnostic features accompany the key to species.

The grass seedlings studied were found to exhibit a variety of cell types as occur in leaves of mature grasses. The individual cells are orientated in rows or files with the long axis parallel with the margins of the lamina. Since C. R. Metcalfe may be considered an authority concerning epidermal characteristics, it is desirable to view these files of cells in a horizontal position so that his terminology may be understood and employed. The terms used to describe epidermal elements in this paper follow Metcalfe's rather closely in order to preserve some standardization of meaning. In general, the files of cells may be categorized as short cells, which are nearly isodiametric and usually occur over the veins, and long cells, which are much longer than broad and occur predominantly between the veins.

Short cells have been referred to in previous literature as either silica cells, which become silicified and then contain a characteristic silica body, or cork cells, which give reactions of cork. Metcalfe (1960) points out that this terminology is not entirely satisfactory since some cork cells commonly become silicified. The author has continued to use these terms, however, for the sake of convenience. The shape of the silica bodies and the relative distribution of the short cells are characteristic of species and can be employed as diagnostic characters. Of the species included in this study, fourteen exhibited dumbbell-shaped silica bodies or variations of the dumbbell shape. Five species had horizontally elongated silica bodies, and four species cruciate silica bodies. Saddle-shaped silica bodies were predominant in three species. Other species showed mixed or variable forms of silica bodies. Cubical, acutely angled, tall and narrow, nodular, and forms intermediate between cruciate and dumbbell-shaped were noted.

The position of the short cells were found to vary in relation to the veins and to each other. They may occur as solitary silica cells, in pairs consisting of a cork cell and silica cell, or in long rows the silica cells and cork cells usually alternating. The short cells occur either over the veins, between the veins, or both over and between the veins on the same leaf. The majority of species included in the study had short cells in long rows, only nine species having short cells either solitary or in pairs. Sitanion hystrix had no short cells present.

The long cells offer few characteristics in comparison with the short cells. Long cells are usually much longer than broad and may or may not have sinuous cells walls. The long cells separating the stomata are referred to as interstomatal cells and are generally shorter than other long cells. The end walls of the interstomatal cells are usually concave around the stomatal mechanism.

Bicellular micro-hairs were noted to occur on both leaf surfaces of twenty one species of the thirty species examined. An additional three species had micro-hairs on the adaxial surface only. The remaining six species were devoid of micro-hairs. On the basis of the ratio of the length of the basal cells to the distal cells and the relative width of the cells, several rather distinct types of micro-hairs can be distinguished. Although unicellular micro-hairs occur, notably in Sporobolus spp., none were seen in this study.

Macro-hairs are usually much larger structures than the micro-hairs described above and are unicellular. Macro-hairs were found to occur in ten species of those included in the study. The macro-hairs may be long, slender, and flexuous, or short and stiff. The bases of the trichomes may be swollen, or slender, and may be surrounded by a group of specialized epidermal cells.

Prickle-hairs are short, sharply-pointed structures with swollen bases. Angular prickle-hairs were present at the margins of all thirty species studied. Angular prickle-hairs, or smaller, more rounded "hooks" were found to be present, mostly over the veins, in twenty species. Although the apices of these prickle-hairs usually point toward the apex of the lamina, some were found to be retrorse, notably in *Agropyron smithii*.

Stomata occur between the veins in horizontal files with the long cells. The shape of the subsidiary cells was found to vary. Prat (1936) indicated that triangular stomata (i.e. subsidiary cells) were characteristic of grasses of the subfamily Panicoideae. Metcalfe (1960), however, emphasized that many grasses of the subfamily Festucoideae show mixed characteristics and notes the occurrence of triangular subsidiary cells in members of the Chlorideae, Festuceae, and other Festucoid tribes. Stomata of the thirty grass seedlings included in this study showed triangular, dome-shaped ("ovoid"), and parallel-sided subsidiary cells, twelve predominently triangular, and the remainder a mixture of shapes.

Other characteristics, such as papillae and certain specialized cells are included in the description of species.

A KEY TO SPECIES

1. (2) Short cells absent. . . . . . <u>Sitanion hystrix</u>

2. (1) Short cells present.

3. (12) Short cells both over and between the veins.

4. (5) Silica bodies acutely angled, saddle-shaped and cubical over the veins; tall and narrow or cubical between the veins . . . . <u>Buchloe dactyloides</u>

5. (4) Silica bodies dumbbell-shaped or variations of the dumbbell shape.

6. (7) Long, slender macro-hairs present; the cells near proximal end inflated or raised above the general level of the epidermis. . . . <u>Chloris verticillata</u>

7. (6) Macro-hairs absent.

8. (9) Stomata with predominantly triangular subsidiary cells, infrequently low dome-shaped; distal cells of micro-hairs often bearing a minute projection or papilla. . . . . <u>Eragrostis trichodes</u>

9. (8) Stomata with low dome-shaped and triangular subsidiary cells in about equal frequencies or predominantly low dome-shaped; distal cells of micro-hairs bearing no projections.

10. (11) Basal cell of micro-hairs approximately three times as long as broad; prickle-hairs over the veins near margins; long cells somewhat sinuous. . . . . <u>Sporobolus airoides</u>

11. (10) Basal cell of micro-hairs approximately as broad

as long, constricted at proximal end; prickle-hairs absent; long cells sinuous, very sinuous at margins . . . . Sporobolus asper

12. (3) Short cells over the veins, only rarely occurring between.

13. (22) Short cells solitary or in pairs, not in long rows; silica bodies horizontally elongated; stomata with parallel-sided subsidiary cells.

14. (15) Macro-hairs absent. . . . . . Bromus inermis

15. (14) Slender macro-hairs or short stiff macro-hairs abundant.

16. (19) Macro-hairs long and slender, flexuous; prickle-hairs usually absent.

17. (18) Silica bodies greatly elongated, often twice as long as stomatal mechanism; macro-hairs long, slender, and flexuous . . . . Bromus japonicus

18. (17) Silica bodies seldom longer than stomatal mechanism; macro-hairs slender, of medium length, and flexuous . . . . Bromus tectorum

19. (16) Macro-hairs short and stiff; prickle-hairs present.

20. (21) Large, angular prickle-hairs present over the veins, marginal prickles large, angular, some retrorse; small, nearly isodiametric cells with a minute papilla often in same file with long cells. . . . . Agropyron smithii

21. (20) Few hooks present over the veins, angular prickle-

hairs absent; isodiametric cells with papilla absent. . . . . Hordeum pusillum

22. (13) Short cells usually in long rows, or solitary, in pairs, and in long rows on same leaf; silica bodies not horizontally elongated (except in Shedonnardus paniculatus); stomata with low dome-shaped or triangular subsidiary cells.

23. (38) Micro-hairs with broad, hemispherical distal cell, the basal tapered at proximal end.

24. (27) Single, large, oblique papillae present at apical end of long cells; the long cells widest at apical third of cell.

25. (26) Silica bodies dumbbell-shaped, intermediate forms between cruciate and dumbbell-shaped present . . . . .Muhlenbergia racemosa

26. (25) Silica bodies horizontally elongated with acute angles. . . . . Schedonnardus paniculatus

27. (24) Single, large, oblique papilla absent; long cells widest at ends or center of cell.

28. (33) Saddle-shaped silica bodies present.

29. (32) Silica bodies predominantly saddle-shaped acutely angled or tall and narrow forms present.

30. (31) Stomata with predominantly triangular subsidiary cells, low dome-shaped forms also present; cork cells very sinuous, the folds overlapping; macro-hairs absent. . . . . Bouteloua hirsuta

31\. (30) Stomata with low dome-shaped subsidiary cells, a few near margins somewhat triangular; few long, slender macro-hairs present, the cells near proximal ends inflated or raised above general level of the epidermis. . . . Bouteloua gracilis

32\. (29) Silica bodies variable; saddle-shaped, dumbbell-shaped, and intermediate between cruciate and dumbbell-shaped forms present . . . . Bouteloua curtipendula

33\. (28) Saddle-shaped silica bodies absent.

34\. (35) Stomata with predominantly triangular subsidiary cells; silica bodies dumbbell-shaped, intermediate forms between cruciate and dumbbell-shaped forms present; long cells not sinuous . . . . Eragrostis cilianensis

35\. (34) Stomata with predominantly low dome-shaped subsidiary cells, triangular near margins.

36\. (37) Silica bodies dumbbell-shaped, acutely angled forms also present; long cells somewhat sinuous . . . . Sporobolus cryptandrus

37\. (36) Silica bodies cruciate, intermediate forms between cruciate and dumbbell-shaped present; long cells sinuous, very sinuous at margins . . . . Sporobolus neglectus

38\. (23) Micro-hairs with distal cells tapering to sharp-pointed or gently rounded apices, not hemispherical and broad; the basal cells not markedly tapered at proximal ends.

39. (40) Long cells with a single, large, oblique papilla near their apical ends; long cells widest near apical third of cell; distal cells of micro-hairs with gently rounded apices. .<u>Echinochloa crusgalli</u>

40. (39) Long cells without such papillae, widest at center or ends of cell; distal cells of micro-hairs tapered to sharp-pointed apices.

41. (50) Distal cells of micro-hairs longer than the basal cells; cruciate silica bodies usually present (except in <u>Panicum dichotomiflorum</u>).

42. (43) Silica bodies dumbbell-shaped, cruciate forms absent; conspicuous small, circular papillae present at each end of subsidiary cells on adaxial surface; the interstomatal and surrounding cells papillose . . . .<u>Panicum dichotomiflorum</u>

43. (42) Silica bodies both cruciate and dumbell-shaped, or cruciate; subsidiary cells of adaxial surface not papillose.

44. (45) Long slender macro-hairs present, the cells near proximal end of trichomes appearing raised or inflated above the general level of the epidermis . . . .<u>Panicum capillare</u>

45. (44) Macro-hairs absent.

46. (47) Silica bodies cruciate; forms intermediate between

cruciate and dumbbell-shaped also present; distal cells of micro-hairs two to two and one-half times as long as the basal cells; stomata with both triangular and low dome-shaped subsidiary cells . . . . *Cenchrus pauciflorus*

47. (46) Silica bodies both cruciate and dumbbell-shaped; distal cells of micro-hairs usually one and one-half times as long as basal cells or twice as long; stomata have triangular subsidiary cells.

48. (49) Silica bodies predominantly dumbbell-shaped, cruciate and saddle-shaped forms present; distal cells of micro-hairs one and one-half times as long as basal cells, usually bent; long cells usually three to five times longer than broad . . . . *Setaria lutescens*

49. (48) Silica bodies dumbbell-shaped and cruciate, saddle-shaped forms absent; distal cells of micro-hairs one and one-half to two times as long as basal cells, usually straight; long cells usually over five times longer than broad. . *Setaria viridis*

50. (41) Distal and basal cells of micro-hairs equal in length or the basal longer; cruciate silica bodies usually absent (rarely present in *Sorgastrum nutans* and *Panicum virgatum*).

51. (52) Silica bodies variable, tall and narrow and saddle-shaped forms present near margins, horizontally

elongated to cubical, cruciate, and variations of the dumbbell-shape present, dumbbell shapes most frequent. . . . . Panicum virgatum

52. (51) Silica bodies dumbbell-shaped (rarely cruciate in Sorghastrum nutans).

53. (54) Distal cells of micro-hairs taper slightly to blunt or gently rounded apices; stomata have triangular subsidiary cells. . Sorghastrum nutans

54. (53) Distal cells of micro-hairs taper to sharp-pointed apices; stomata have both low dome-shaped and triangular subsidiary cells.

55. (56) Silica bodies dumbbell-shaped, resembling an hourglass in form; distal cells of micro-hairs broadest just above proximal end . . Andropogon saccharoides

56. (55) Silica bodies dumbbell-shaped; distal cells of micro-hairs broadest at point of attachment to basal cells.

57. (58) Angular prickle-hairs and few hooks present over the veins; interstomatal cells inflated or appearing with single, large, dome-shaped papillae, these conspicuous; interstomatal cells are usually two to three times longer than broad and are considerably broader than other long cells. .Andropogon scoparius

58. (57) Prickle-hairs absent; interstomatal cells somewhat inflated but not conspicuous; interstomatal cells are usually five times longer than broad or more and as broad or twice as broad as other long cells . . . . Andropogon gerardi

DESCRIPTION OF SPECIES

1. Agropyron smithii Rydb. Western Wheatgrass

Abaxial Surface:

Short cells occur over the veins-usually solitary, but also in pairs. Silica bodies are predominantly horizontally elongated and sinuous. Cubical and tall and narrow forms also occur. Short, stiff hairs with swollen superficial bases are abundant between the veins. Large angular prickles occur over the veins. Marginal prickles are angular and some are retrorse. Stomata have parallel-sided subsidiary cells. The long cells are thin-walled and not sinuous. Certain cells which have been referred to as "crown cells" were found to occur in the same file with the long cells. These are nearly isodiametric cells with single, small, needle-like projections or papillae.

Adaxial Surface:

Short cells occur both over and between the veins, both solitary and in pairs. Silica bodies are horizontally elongated and sinuous. Large, angular prickles are abundant over the veins. The long cells are thin-walled and not sinuous.

2. Andropogon gerardi Vitman. Big Bluestem

Abaxial Surface:

Short cells occur over the veins in long rows. The silica bodies are dumbbell-shaped. Bicellular micro-hairs are present between the veins. Basal and distal cells are about equal in length, the distal cells tapered to sharp-pointed apices. The interstomatal cells occur inflated but are not papillose. Stomata have triangular-shaped subsidiary cells near the leaf margins, but the subsidiary cells are low dome-shaped elsewhere on the leaf surface. Long cells have thin, sinuous cell walls. The interstomatal cells are approximately twice as broad as other long cells and somewhat inflated in appearance. The interstomatal cells are mostly five times longer than broad or longer.

Adaxial Surface:

Short cells occur over the veins in long rows. The silica bodies are dumbbell-shaped. Macro-hairs are rarely present between the veins. These are slender trichomes surrounded at the base by a few specialized epidermal cells raised above the general level of the epidermis constituting a "cushion-hair". Bicellular micro-hairs are present between the veins. The basal and distal cells are about equal in length, the distal cells taper to sharp-pointed apices. Few angular prickle-hairs occur over the veins near the margins only. Subsidiary cells are predominantly low dome-shaped, a few at margins triangular. The long cells are thin-walled and sinuous only near margins and are mostly three to four times longer than broad.

3. Andropogon saccharoides Swartz. Silver Beardgrass

Abaxial Surface:

Short cells occur over the veins in long rows. The silica bodies are dumbbell-shaped, somewhat resembling an hour glass in form. Bicellular micro-hairs are present between the veins and most abundant near the margins. Basal and distal cells are about equal in length, the proximal ends of the distal cells wider than the basal cells. The distal cells are tapered to sharp-pointed apices. Few angular prickles occur over the veins near the margins and base of the blade. Stomata have low dome-shaped subsidiary cells, triangular near margins and base of blade. Long cells are thin-walled and sinuous near margins only. These are broadest at the center of the cell and considerably longer than broad. The interstomatal cells are somewhat inflated in appearance, but not papillose, and are shorter than other long cells.

Adaxial Surface:

Short cells occur over the veins in long rows. Silica bodies are dumbbell-shaped. Angular prickles are rarely present over the veins. Stomata are low dome-shaped. Long cells are thin walled, of uniform width, and considerably longer than broad.

4. Andropogon scoparius Michx. Little Bluestem.

Abaxial Surface:

Short cells occur over the veins in long rows. Silica bodies are dumbbell-shaped. Bicellular micro-hairs are present between the veins. The basal and distal cells are about equal in length. The distal cells taper to sharp-pointed apices. Angular prickles occur over the veins, and few hooks are present. Stomata are low dome-shaped to somewhat triangular-triangular near the leaf margins. The subsidiary cells have minute papillae at each end or appear swollen. Long cells have sinuous cell walls, markedly sinuous near leaf margins. The interstomatal cells are conspicuous, appearing inflated or somewhat papillose. The interstomatal cells are as broad as long to two or three times as long as broad. Other long cells appear much narrower and considerably longer.

Adaxial Surface:

Short cells occur over the veins in long rows, the silica bodies dumbbell-shaped. Bicellular micro-hairs are present between the veins, the basal and distal cells appearing equal in length. The distal cells taper to sharp-pointed apices. Angular prickles occur over the veins near the leaf margins and midrib. Stomata are mostly triangular to low dome-shaped, the guard cells appearing papillose or swollen at the ends. The long cells are thin-walled and sinuous. The interstomatal cells appear inflated and are mostly over three times longer than broad.

5. Bouteloua curtipendula Michx. Side-oats Grama.

Abaxial Surface:

Short cells occur over the veins in rows of three to five and in long rows. Silica bodies are dumbbell-shaped, saddle-shaped, and intermediate between cross and dumbbell-shaped. Bicellular micro-hairs are present between the veins. The basal cells are somewhat longer to twice as long as the distal cells and taper toward their proximal ends. The distal cells are hemispherical. Stomata usually occur in two rows with a row of micro-hairs between. Stomata have predominantly triangular subsidiary cells with low dome-shaped forms also present. The long cells are thin-walled and somewhat sinuous near the leaf margins and the longer veins.

Adaxial Surface:

Short cells are few and occur over the veins. The silica bodies are saddle-shaped and most abundant near the leaf margins. Short, stiff macro-hairs are present between the veins, often in the same file with micro-hairs. Bicellular micor-hairs are present between the veins. Basal and distal cells are nearly equal or the basal up to twice as long as distal. The basal cells are tapered toward their proximal ends, the distal cells are hemispherical. Large angular prickle-hairs are present over the veins near the margins of the leaf. The long cells are thin-walled and weakly sinuous near the margins.

6. Bouteloua gracilis (H. B. K.) Lag. ex Steud. Blue Grama.

Abaxial Surface:

Short cells occur over the veins in long rows, the silica bodies saddle-shaped. A few long, slender macro-hairs are present between the veins. The bases of these trichomes are surrounded by a few epidermal cells raised somewhat above the general level of the epidermis. Bi-cellular micro-hairs are present between the veins. The basal cells taper toward their proximal ends and are equal in length to the hemispherical distal cells. Stomata have predominantly low dome-shaped subsidiary cells, but triangular forms appear near the leaf margins. The long cells are thin-walled and sinuous.

Adaxial Surface:

Short cells occur over the veins, the silica bodies saddle-shaped and most frequent near the leaf margins. Neither macro-hairs nor bicellular micro-hairs occur on the adaxial surface. Large angular prickle-hairs are present over the veins, especially near the margins and the apex of the leaf. Those prickle-hairs near the apex appear to be prolonged into short stiff hairs. Stomata have low dome-shaped subsidiary cells. The long cells are thin-walled and not sinuous except at the leaf margins.

7. Bouteloua hirsuta Lag. Hairy Grama.

Abaxial Surface:

Short cells occur over the veins in long rows. The silica bodies are predominantly saddle-shaped. Acutely angled and tall and narrow forms are also present. Cork cells have very sinuous cell walls. Bicellular micro-hairs are present between the veins. The basal cells taper toward their proximal ends and are usually twice as long as the hemispherical distal cells. Few hooks are present over the veins near the leaf margins. Stomata have predominantly triangular subsidiary cells, others appearing low dome-shaped. Stomata occur in two rows with a row of micro-hairs between. The long cells are thin-walled and very sinuous, the folds interlacing.

Adaxial Surface:

Short cells appear over the veins in long rows. The silica bodies are saddle-shaped but tall and narrow and acutely angled forms also occur. Bicellular micro-hairs are present between the veins. The basal cells taper toward their proximal ends and are approximately twice as long as the hemispherical distal cells. Large angular prickle-hairs are abundant over the veins and appear to be projected into short stiff hairs toward the apex of the leaf. Stomata are low dome-shaped and occur in two rows. The long cells are thin-walled and somewhat sinuous.

8. Bromus inermis Leyss. Smooth Brome.

Abaxial Surface:

Short cells occur over the veins in pairs and solitary. Silica bodies are horizontally elongated with sinuous margins and often appear tall and narrow near the leaf margins. Hooks are present over the veins, a few of these retrorse. Few specialized cells referred to as "crown cells" appear over the veins. Stomata have parallel-sided subsidiary cells. The long cells are thin-walled, not sinuous, and greatly elongated. The interstomatal cells are much shorter, usually twice as long as broad.

Adaxial Surface:

Short cells are few and occur over the veins both solitary and in pairs. Silica bodies are horizontally elongated with sinuous margins. Stomata occur in rows of two and have parallel-sided subsidiary cells. The long cells are thin-walled, not sinuous, and quite long. Interstomatal cells are usually much shorter, about twice as long as broad.

9. Bromus japonicus Thunb. Japanese Brome.

Abaxial Surface:

Short cells occur over the veins both solitary and in pairs. The silica bodies are horizontally elongated with sinuous margins and are often twice as long as the stomatal mechanism. Long, slender macro-hairs with swollen bases are abundant between the veins. Stomata have parallel-sided subsidiary cells. Long cells are thin-walled, not sinuous, and are greatly elongated.

Adaxial Surface:

Short cells occur over the veins usually solitary or in pairs. The silica bodies are horizontally elongated with sinuous margins. Long, slender macro-hairs with swollen bases are abundant between the veins. Few hooks are present over the veins near the leaf margins. Stomata have parallel-sided subsidiary cells. The long cells are thin-walled, not sinuous, and are greatly elongated.

In distinguishing *Bromus japonicus* from *Bromus tectorum*, the length of the silica bodies seems diagnostic. In *Bromus japonicus*, the silica bodies are often as long to twice as long as the cells of the stomatal mechanism. On the other hand, the silica bodies of *Bromus tectorum* are only rarely longer than the cells of the stomates, usually shorter.

10. *Bromus tectorum* L. Downy Brome.

Abaxial Surface:

Short cells occur over the veins solitary, in pairs, or in rows of three. The silica bodies are horizontally elongated, sinuous in outline, and only rarely exceed the length of the stomata. Slender macro-hairs of medium length and with swollen bases are abundant between the veins. Stomata have parallel-sided subsidiary cells, rarely appearing low dome-shaped. The long cells are thin-walled, not sinuous, and greatly elongated.

Adaxial Surface:

Short cells are infrequent and are usually solitary over the veins where present. Silica bodies are horizontally elongated and may have smooth or sinuous margins. Slender macro-hairs of medium length with swollen bases are abundant between the veins. Stomata have parallel-sided subsidiary cells or may have few low dome-shaped forms. The long cells are thin-walled, not sinuous, and greatly elongated.

Bromus tectorum closely resembles *Bromus japonicus* in its epidermal characteristics.

11. *Buchloe dactyloides* (Nutt.) Engelm. Buffalo Grass.

Abaxial Surface:

Short cells occur both over and between the veins-solitary, in pairs, and in long rows. Silica bodies over the veins are frequent and are saddle-shaped, acutely angled, and cubical. Silica bodies between the veins are less frequent and tall and narrow in form. Cork cells have sinuous cell walls. Bicellular micro-hairs are present between the veins near the apex of the leaf. The basal cells taper toward their proximal ends and are approximately twice as long as the hemispherical distal cells. Hooks are present over the veins near the leaf apex and between the veins elsewhere on the leaf surface. Single small, circular papillae are usually present at the apical end of the long cells. Stomata have predominantly triangular subsidiary cells. The long cells are thin-walled and sinuous, markedly sinuous near the margins of the lamina.

Adaxial Surface:

Short cells occur both over and between the veins-solitary, in pairs, and in long rows. Silica bodies are usually saddle-shaped or acutely angled over the veins, tall and narrow or cubical between the veins. Bicellular micro-hairs are present near the leaf margins only. The basal cells taper toward their proximal ends and are usually twice as long as the hemispherical distal cells. Hooks occur over the veins, the inter-stomatal cells often appear weakly barbed. Stomata have triangular subsidiary cells, or some low dome-shaped forms also present. The long cells are sinuous, markedly sinuous near the leaf margins, and vary from two to five times as long as broad.

12. *Cenchrus pauciflorus* Benth. Field Sandbur.

Abaxial Surface:

Short cells occur solitary, in pairs, and in long rows over the veins or rarely between. Silica bodies are cruciate, but forms intermediate between cruciate and dumbbell-shaped are also present. Bicellular micro-hairs are present between the veins. The distal cells are from two to two and one-half times as long as the basal cells. The distal cells are tapered to sharp-pointed apices and usually appear bent. Hooks are abundant over the veins. Stomata have mixed shares of subsidiary cells. The subsidiary cells are markedly triangular near the leaf margins and principle veins but are low dome-shaped elsewhere. The long cells are thin-walled and sinuous only near the leaf margins.

Adaxial Surface:

Short cells occur usually over the veins in long rows. Silica bodies are few and cruciate in form. Bicellular micro-hairs are present. The distal cells are two to two and one-half times as long as the basal cells and taper to sharp-pointed apices. Hooks occur over the veins and are most numerous near the leaf margins. Stomata have both triangular and low dome-shaped subsidiary cells. The long cells are thin-walled and not sinuous except at the leaf margins.

13. Chloris verticillata Nutt. Windmill Grass.

Abaxial Surface:

Short cells occur in long rows over the veins, rarely between the veins. Silica bodies are predominantly dumbbell-shaped, few horizontally elongated acutely angled forms also present. Short cells are usually in pairs or solitary where they occur between the veins. Long, slender macro-hairs are present. The epidermal cells surrounding the bases of these trichomes appear raised or inflated above the general level of the epidermis. Bicellular micro-hairs are also present. The distal cells are hemispherical and are equal in length or somewhat longer than the basal cells. The basal cells taper at their proximal ends. Few hooks are present over the veins near the leaf margins. Stomata have both triangular and low dome-shaped subsidiary cells. The long cells are thin-walled and somewhat sinuous, being more markedly sinuous near the leaf margins and apex. The interstomatal cells are usually not concave around the stomata.

Adaxial Surface:

Short cells occur over the veins in long rows. Silica bodies are dumbbell-shaped and relatively few. Long, slender macro-hairs are present, the cells bordering proximal ends inflated as those of the abaxial surface. Relatively few bicellular micro-hairs are present near the leaf margins only. Basal and distal cells are about equal in length, the basal tapering toward proximal end, the distal hemispherical. Few hooks are present over the veins near the leaf margins. Stomata have both triangular and low dome-shaped subsidiary cells. The long cells are thin-walled and somewhat sinuous, especially near leaf margins.

14. Echinochloa crusgalli (L.) Beauv. Barnyard Grass.

Abaxial Surface:

Short cells occur over the veins in long rows. Silica bodies are predominantly dumbbell-shaped but some appear intermediate between dumbbell-shaped and nodular. Bicellular micro-hairs are present between the veins. Basal and distal cells are about equal in length. The basal cells are somewhat tapered toward their proximal ends, the distal cells have blunt or gently rounded apices. Single, large, oblique papillae are present near the apical ends of the long cells. Stomata have low dome-shaped subsidiary cells, the stomata near the leaf margins often appearing to have triangular subsidiary cells. The long cells are thin-walled and not sinuous. The cells are broadest at the upper third of the cell and taper toward the end walls. The end walls of the inter-stomatal cells are not concave.

Adaxial Surface:

Short cells occur over the veins in long rows. Silica bodies are dumbbell-shaped. Relatively few bicellular micro-hairs are present near the margins of the leaf. The basal and distal cells are equal in length. The basal cells taper somewhat toward their proximal ends, the distal cells have gently rounded apices. Single, large, oblique papillae are present on most of the long cells. Stomata have low to tall dome-shaped subsidiary cells. The long cells are thin-walled, not sinuous, and are broadest at the apical third of the cell.

15. Eragrostis ciliaensis (All.) Lutati. Stinkgrass.

Abaxial Surface:

Short cells occur over the veins and are solitary, in pairs, in rows of three, or predominantly in long rows. Silica bodies are dumbbell-shaped, but intermediate forms between cruciate and dumbbell-shaped are also present. Bicellular micro-hairs are present between the veins. The basal cells taper toward their proximal ends and are usually three times as long as the distal cells. The distal cells are hemispherical and often bear a minute projection or papilla at their apices. Stomata have triangular subsidiary cells. The long cells are thin-walled and sinuous only near the leaf margins. "Pustulate" structures composed of many cells occur at the leaf margins.

Adaxial Surface:

Short cells occur over the veins in long rows or solitary and in pairs. Silica bodies are relatively few and are dumbbell-shaped. Bicellular micro-hairs are present between the veins near the leaf margins only. Basal cells taper toward their proximal ends and are usually three times longer than the hemispherical distal cells. The distal cells usually possess a minute projection or papilla at their apex. Stomata have predominantly low dome-shaped subsidiary cells, but those near the leaf margins appear triangular. The long cells are thin-walled and somewhat sinuous near the leaf margins.

16. <u>Eragrostis</u> <u>trichodes</u> (Nutt.) Wood. Sand Lovegrass.

<u>Abaxial</u> <u>Surface</u>:

Short cells occur over the veins and rarely between the veins. Those short cells over the veins occur in long rows while those between the veins are either solitary or in pairs. Silica bodies are dumbbell-shaped over the veins. Those between the veins are dumbbell-shaped and are noticeably larger than those over the veins. The basal cells are tapered somewhat toward their proximal ends and are two to three times longer than the distal cells. The distal cells are hemispherical and often possess a minute projection or papillae at their apices. Hooks are present over the veins near the leaf margins. Stomata have predominantly triangular subsidiary cells, but some appear low dome-shaped to somewhat tall dome-shaped. The long cells are thin-walled and sinuous, markedly sinuous near the leaf margins.

<u>Adaxial</u> <u>Surface</u>:

Short cells occur over the veins usually in long rows or solitary and in pairs. Silica bodies are dumbbell-shaped. Bicellular micro-hairs are present between the veins. The basal cells taper toward their proximal ends and are two to three times longer than the hemispherical distal cells. The distal cells often possess a minute projection or papilla at their apices. Hooks are present over the veins. Stomata have mostly triangular subsidiary cells, but others appear low to tall dome-shaped. The long cells are thin-walled and sinuous near the leaf margins only.

17. Hordeum pusillum Nutt. Little Barley.

Abaxial Surface:

Short cells occur over the veins both solitary and in pairs. Silica bodies are horizontally elongated and sinuous. Short, stiff macro-hairs with swollen bases are abundant over and between the veins. Hooks are present over the veins. Stomata have parallel-sided subsidiary cells. The long cells are thin-walled and not sinuous.

Adaxial Surface:

Short cells occur over the veins in pairs and solitary. The silica bodies are horizontally elongated and sinuous. Short, stiff macro-hairs with swollen bases are present over and between the veins. Hooks occur over the veins. Stomata have parallel-sided subsidiary cells. The long cells are thin-walled and not sinuous. The interstomatal cells are shorter than other long cells and are seldom over twice as long or broad.

18. Muhlenbergia racemosa (Michx.) B.S.P. Marsh Muhly.

Abaxial Surface:

Short cells occur over the veins both in long rows and solitary and in pairs. Silica bodies are dumbbell-shaped although some forms appear intermediate between cruciate and dumbbell-shaped. Few bicellular micro-hairs are present between the veins. The basal cells taper toward their proximal ends and are two to three times longer than the hemispherical distal cells. A single, large, oblique papilla is present near the apical third of most of the long cells. Stomata have predominantly low dome-shaped subsidiary cells although others appear somewhat tall dome-shaped. The long cells are thin-walled, sinuous, and broadest at the apical third of the cell.

Adaxial Surface:

Short cells occur over the veins usually solitary and in pairs. Silica bodies are relatively few and are dumbbell-shaped. Bicellular micro-hairs are present between the veins near margins. The basal cells are two to three times as long as the hemispherical distal cells and are usually tapered toward their proximal ends. Large, angular prickles are present over the veins. Single, large, oblique papillae are present near the apical end of the long cells as on the abaxial surface. Stomata have low dome-shaped subsidiary cells, but tall dome-shaped forms are also present. The long cells are thin-walled, not sinuous, and broadest at the apical third of the cell.

19. Panicum capillare L. Witchgrass.

Abaxial Surface:

Short cells occur over the veins in long rows or rarely solitary or in pairs. Silica bodies are cruciate. Slender macro-hairs are present between the veins. The bases of the trichomes are surrounded by a few specialized epidermal cells raised above the general plane of the epidermis. Bicellular micro-hairs are most abundant over the veins near margins, only few occurring elsewhere. The distal cells of the micro-hairs taper to sharp-pointed apices and are usually twice as long as the thicker-walled basal cells. The micro-hairs usually appear bent. Stomata have predominantly triangular subsidiary cells, others appearing somewhat low dome-shaped. The long cells are thin-walled and sinuous. The interstomatal cells are shorter than other long cells and are usually three to five times longer than broad.

Adaxial Surface:

Short cells occur over the veins in long rows. Silica bodies are cruciate and few forms intermediate between cruciate and dumbell-shaped are usually present. Long, slender macro-hairs are present between the veins. The bases appear superficial and not surrounded by specialized epidermal cells as on the abaxial surface. Bicellular micro-hairs are present between the veins near margins. The distal cells are tapered to sharp-pointed apices and are twice as long as the thick-walled basal cells. Stomata have predominently low dome-shaped subsidiary cells, others appearing triangular. The long cells are from two to three times longer than broad, thin-walled and sinuous, especially at leaf margins.

20. Panicum dichotomiflorum Michx. Fall Panicum.

Abaxial Surface:

Short cells occur over the veins in long rows. Silica bodies are dumbbell-shaped. Slender macro-hairs are abundant between the veins. The bases of the trichomes are surrounded by a few specialized epidermal cells raised above the general level of the epidermis. Bicellular micro-hairs are present between the veins and are most abundant near the leaf margins. The distal cells are two to two and one-half times longer than the thicker walled basal cells. The distal cells are broadest just above the point of attachment to the basal cells and taper to sharp-pointed apices. Stomata have low dome-shaped and triangular subsidiary cells. The long cells are thin-walled and sinuous.

Adaxial Surface:

Short cells occur over the veins in long rows. Silica bodies are dumbbell-shaped. Conspicuous small, circular papillae are present on each end of the subsidiary cells. A single file of dome-shaped papillae occur on the interstomatal cells and those long cells bordering the interstomatal cells. Stomata have low dome-shaped subsidiary cells. The long cells are thin-walled and sinuous.

21. Panicum virgatum L. Switchgrass.

Abaxial Surface:

Short cells occur over the veins in long rows and often in pairs. Silica bodies are rather variable in form. Tall and narrow forms occur near the leaf margins. Horizontally elongated to cubical, nodular, saddle-shaped, cruciate, dumbbell-shaped, and intermediate between nodular and dumbbell-shaped occur elsewhere on the leaf surface. The dumbbell-shaped silica bodies occur most frequently. Bicellular micro-hairs are present near the leaf margins. The distal cells are slightly longer than the heavier-walled basal cells and taper to more or less sharp-pointed apices. Stomata have low dome-shaped and triangular subsidiary cells. The long cells are thin-walled and somewhat sinuous, especially near the leaf margins.

22. <u>Schedonnardus</u> <u>paniculatus</u> (Nutt.) Trel. Texas Crabgrass.

<u>Abaxial</u> <u>Surface</u>:

Short cells occur over the veins in long rows. Silica bodies are horizontally elongated with acutely-angled end walls. Bicellular micro-hairs occur between the veins and are often obscured by surrounding papillae. The basal cells of the micro-hairs taper toward their proximal ends and are as long or somewhat longer than the hemispherical distal cells. Single, large, oblique papillae occur at the apical third of most of the long cells. Stomata have low dome-shaped subsidiary cells and are often obscured by the papillae of the surrounding long cells. The long cells are thin-walled, not sinuous, and are broadest at the apical third of the cell.

<u>Adaxial</u> <u>Surface</u>:

Short cells occur over the veins in long rows. Silica bodies are relatively few and are horizontally elongated with acutely-angled end walls. Bicellular micro-hairs are present between the veins near margins. The basal cells are tapered at their proximal ends and are somewhat longer than the hemispherical distal cells. Hooks are present over the veins and rarely occur between the veins. Single, large, oblique papillae are present on most of the long cells. Stomata have low dome-shaped subsidiary cells. The long cells are thin-walled, not sinuous, and are widest at the apical third of the cell.

23. Setaria lutescens (Weigel) Hubb. Yellow Foxtail.

Abaxial Surface:

Short cells occur over the veins in long rows. Silica bodies are predominantly dumbbell-shaped. Bicellular micro-hairs are abundant between the veins. The distal cells are one and one-half times as long as the basal cells and taper to sharp-pointed apices. The micro-hairs usually appear bent. Hooks are rarely present over the veins near the margins of the leaf. Stomata have triangular subsidiary cells. The long cells are thin-walled and sinuous, especially near the leaf margins, and are generally three to five times longer than broad. The interstomatal cells are two to three times longer than broad.

Adaxial Surface:

Short cells occur over the veins in long rows. Silica bodies are relatively few and dumbbell-shaped. Saddle-shaped and cruciate forms are also present. Bicellular micro-hairs are present between the veins. The distal cells are about one and one-half times as long as the basal cells and taper to sharp-pointed apices. Few hooks are present over the veins. Stomata have triangular subsidiary cells. The long cells appear quite regular in size and shape and are three times as long as broad. The interstomatal cells are two and one-half times as long as broad.

24. Setaria viridis (L.) Beauv. Green Foxtail.

Abaxial Surface:

Short cells occur over the veins in long rows. Silica bodies are cruciate and dumbbell-shaped. Some nodular forms are present. Bicellular micro-hairs are present between the veins. The distal cells are one and one-half times as long as the basal cells and taper to sharp-pointed apices. The micro-hairs are usually straight. Hooks are rarely present over the veins near the leaf margins. Stomata have triangular subsidiary cells. The long cells are thin-walled, sinuous, and usually over five times longer than broad.

Adaxial Surface:

Short cells occur over the veins in long rows. Silica bodies are dumbbell-shaped to somewhat intermediate between dumbbell-shaped and nodular. Bicellular micro-hairs are present and are most numerous near the leaf margins. The distal cells are one and one-half to two times as long as the basal cells and taper to sharp-pointed apices. Hooks are present over the veins. Stomata have triangular subsidiary cells near the margins of the leaf, and low to tall dome-shaped forms elsewhere. The long cells are thin-walled and not sinuous except at the leaf margins.

25. Sitanion hystrix (Nutt.) J. G. Smith. Squirreltail.

Abaxial Surface:

Short cells are apparently absent in this species. Short, stiff macro-hairs with swollen bases are abundant between the veins and occur over the veins. Stomata have parallel-sided subsidiary cells. The long cells are thin-walled and not sinuous. The interstomatal cells are not markedly concave about the stomata.

Adaxial Surface:

Short cells are absent as in the abaxial surface. Short, stiff macro-hairs with swollen bases are abundant between and present over the veins. Stomata have parallel-sided subsidiary cells. The long cells are thin-walled and not sinuous.

26. Sorghastrum nutans (L.) Nash. Indian Grass

Abaxial Surface:

Short cells occur over the veins in long rows. Silica bodies are dumbbell-shaped and cruciate forms rarely occur. Bicellular micro-hairs are present between the veins. The basal and distal cells are equal in length or more commonly the basal cells are somewhat longer to twice as long as the distal cells. The basal cells are heavy-walled and often taper slightly at the proximal or distal ends. Few hooks are present over the veins near the apex and margins of the leaf. Stomata have triangular subsidiary cells. The long cells are thin-walled and sinuous, especially sinuous near the leaf margins.

Adaxial Surface:

Short cells occur over the veins in long rows. Silica bodies are dumbbell-shaped. Cruciate forms rarely occur. Bicellular micro-hairs are present between the veins. Basal and distal cells vary from about equal in length to the basal cells up to twice as long as the distal cells. The basal cells are often tapered slightly at their proximal or distal ends. Stomata have triangular subsidiary cells. The long cells are somewhat sinuous and those near the leaf margins are very sinuous.

27. Sporobolus airoides (Torr.) Torr. Alkali Saccaton.

Abaxial Surface:

Short cells occur over the veins in long rows and solitary or in pairs between the veins. Silica bodies are dumbbell-shaped over the veins. The silica bodies between the veins are dumbbell-shaped, cruciate, or intermediate between dumbbell-shaped and cruciate. Bicellular micro-hairs are abundant between the veins. The basal cells of the micro-hairs taper toward their proximal ends and are two and one-half to three times as long as the hemispherical distal cells. Hooks are present over the veins near the leaf margins. Stomata have both low dome-shaped and triangular subsidiary cells.

The long cells are thin-walled and somewhat sinuous.

Adaxial Surface:

Short cells occur over the veins in long rows and solitary between the veins. Silica bodies are dumbbell-shaped between the veins and dumbbell-shaped or occasionally saddle-shaped over the veins. The basal cells taper toward their proximal ends and are three to four times as long as the hemispherical distal cells. Hooks are present both over and between the veins. Stomata have both low dome-shaped and triangular subsidiary cells. The long cells are thin-walled and somewhat sinuous.

28. Sporobolus asper (Michx.) Kunth. Tall Dropseed.

Abaxial Surface:

Short cells occur over the veins in long rows and are paired or solitary between the veins when present. Silica bodies are predominantly dumbbell-shaped. Other silica bodies appear intermediate between dumbbell-shaped and nodular, or are compacted to somewhat cruciate in form. Cruciate silica bodies occur between the veins in the same file with bicellular micro-hairs. Bicellular micro-hairs are present between the veins. The basal cells are constricted at their proximal ends and are one and one-half to two times as long as the hemispherical distal cells. Stomata have predominantly low dome-shaped subsidiary cells, but those near the leaf margins are somewhat triangular in form. The long cells are thin-walled and sinuous, especially sinuous toward the margins of the leaf.

Adaxial Surface:

Short cells occur over the veins in long rows and few occur paired and solitary between the veins. Silica bodies are dumbbell-shaped. Few bicellular micro-hairs are present between the veins. The basal cells are constricted near their proximal ends and are one and one-half to two times as long as the hemispherical distal cells. Few hooks are present over the veins. Small, circular papillae occur in single rows on most of the long cells. Stomata have somewhat triangular subsidiary cells near the leaf margins. Other subsidiary cells are low dome-shaped. The long cells are thin-walled and not sinuous.

29. Sporobolus cryptandrus (Torr.) A. Gray. Sand Dropseed.

Abaxial Surface:

Short cells occur over the veins in long rows. Silica bodies are dumbbell-shaped and few acutely-angled forms may occur. Few bicellular micro-hairs are present between the veins. The basal and distal cells are about equal in length or the basal cells vary to twice as long as the distal cells. The basal cells taper toward their proximal ends and the distal cells are hemispherical.

Stomata have low dome-shaped subsidiary cells with a few appearing somewhat triangular near the leaf margins. The long cells are thin-walled and not sinuous.

Adaxial Surface:

Short cells occur over the veins mostly in pairs or solitary. The short cells occasionally occur over the veins in long rows. The silica bodies are variations of the dumbbell-shape or rarely acutely-angled in form. Bicellular micro-hairs are present over the veins. Basal and distal cells may be equal in length or the basal twice as long as the distal cells. The basal cells taper toward their proximal ends and the distal cells are hemispherical. Hooks occur over the veins and are most abundant near the apex of the leaf. A single papilla often occurs at the apical end of the long cells or one papilla at each end, the apical usually the largest. Stomata have low dome-shaped subsidiary cells. Those stomata near the leaf margins appear to have triangular subsidiary cells. The long cells are thin-walled and are sinuous near the leaf margins.

30. Sporobolus neglectus Nash. Poverty Grass.

Abaxial Surface:

Short cells occur in pairs over the veins. Silica bodies are relatively few in number and are cruciate in form. Intermediate forms between dumbbell-shaped and cruciate occur infrequently. Bicellular micro-hairs are present between the veins. The basal cells are two and one-half times as long as the distal cells. The basal cells taper toward their proximal ends and the distal cells are hemispherical. Stomata have low dome-shaped subsidiary cells or appear somewhat triangular near the leaf margins. The long cells are thin-walled and sinuous, especially sinuous near the margins of the leaf.

Adaxial Surface:

Short cells occur over the veins in pairs or rarely solitary. Silica bodies are cruciate in form and are most frequent near the leaf margins. Bicellular micro-hairs are present over the veins near the leaf margins and occur infrequently elsewhere. The basal cells are two and one-half times as long as the distal cells and taper toward their proximal ends. The distal cells are hemispherical. Numerous small papillae occur in a single row on most of the long cells. The papillae are more conspicuous and numerous near the margins of the leaf. Stomata have low dome-shaped subsidiary cells. The long cells are thin-walled and somewhat sinuous. The long cells near the leaf margins are sinuous.

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TABLE I

VERNALIZATION PROCEDURES FOR FRESH SEED

Scientific Name		Procedure
Agropyron smithii		15-30°C for fourteen days
Andropogon gerardi		5°C for fourteen days
Andropogon saccharoides		" " " " "
Andropogon scoparius		" " " " "
Bouteloua curtipendula	Light, KNO_3,	15-30°C for fourteen days
Bouteloua gracilis	" "	" " " " " "
Bouteloua hirsuta	" "	" " " " " "
Bromus inermis		5°C for five days
Bromus japonicus		" " " " "
Bromus tectorum		" " " " "
Buchloe dactyloides	KNO_3,	5°C for six weeks
Cenchrus pauciflorus		5°C for fourteen days
Chloris verticillata		" " " " "
Echinochloa crusgalli		20-30°C for four to ten days
Eragrostis cilianensis		5°C for fourteen days
Eragrostis trichodes		" " " " "
Hordeum pusillum		" " " " "
Muhlenbergia racemosa		" " " " "
Panicum dichotomiflorum		" " " " "
Panicum virgatum		" " " " "
Schedonnardus paniculatus		" " " " "
Setaria lutescens		" " " " "
Setaria viridis		20-30°C for four to ten days
Sitanion hystrix		" " " " " " " "
Sorghastrum nutans		5°C for fourteen days
Sporobolus asper	KNO_3,	5°C for fourteen days
Sporobolus airoides	"	" " " " "
Sporobolus cryptandrus	KNO_3,	5°C for four to eight weeks
Sporobolus neglectus	KNO_3,	5°C for fourteen days

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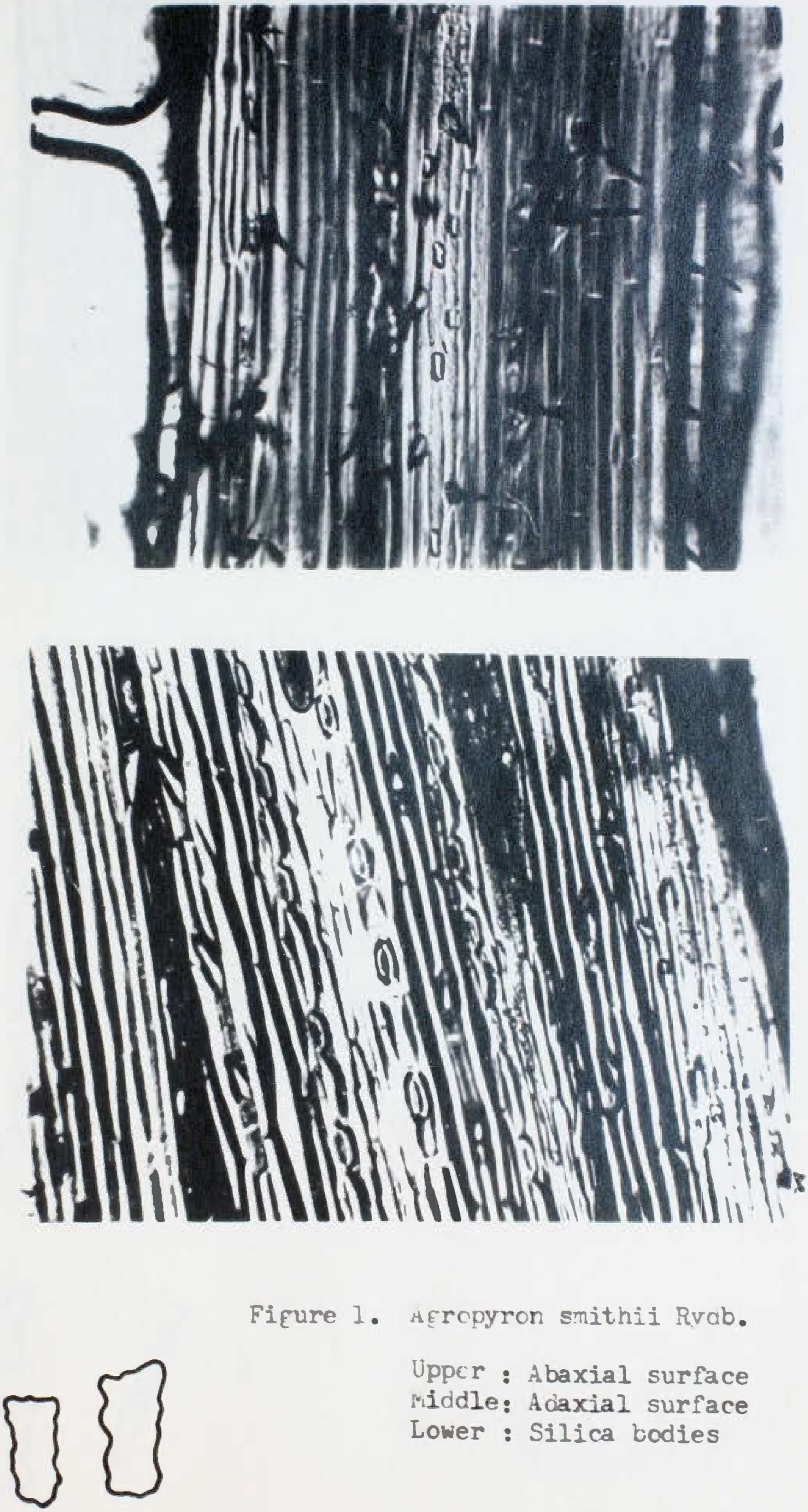
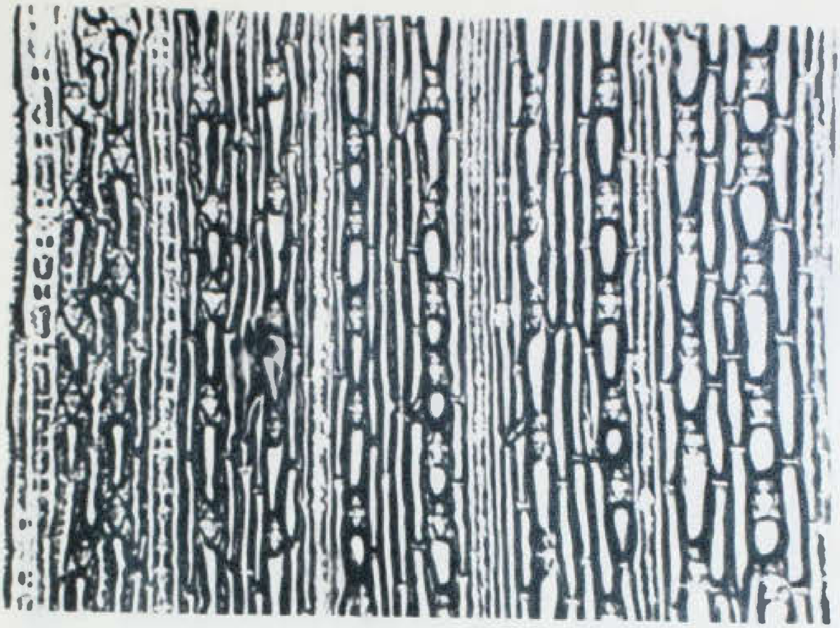


Figure 1. Agropyron smithii Rydb.

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies



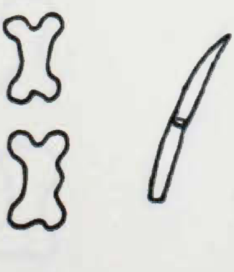
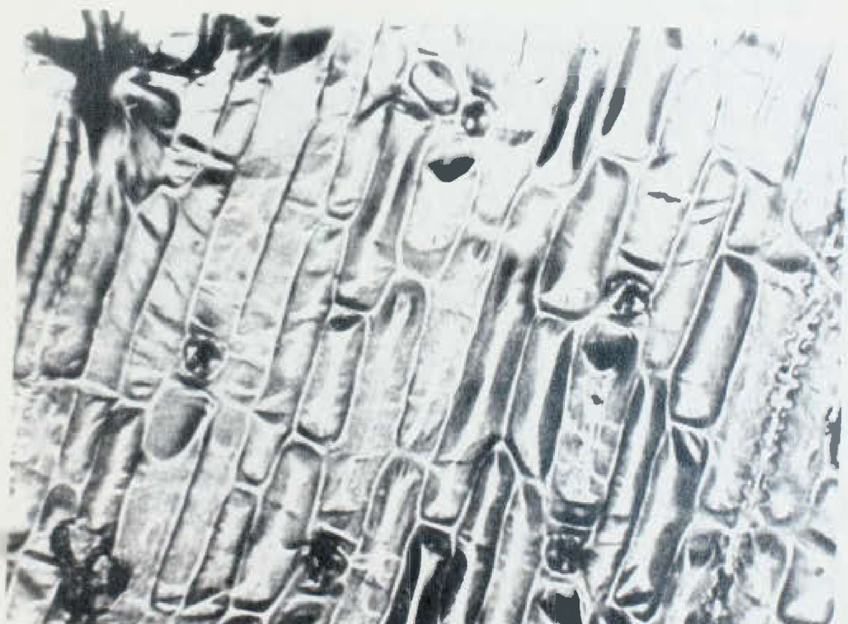


Figure 2. Andropogon gerardi Vitman.

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica body and Micro-hair



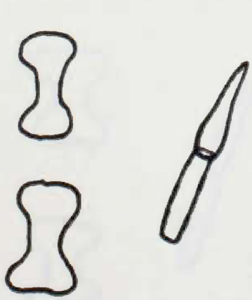


Figure 3. Andropogon saccharoides Swartz.

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies and
Micro-hair

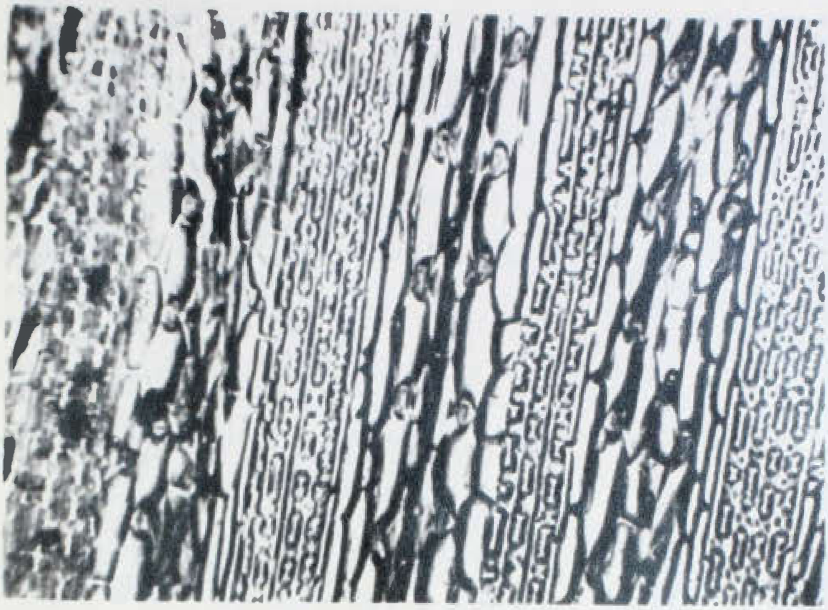


Figure 5. *Bouteloua curtipendula* Michx.

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies and
micro-hair

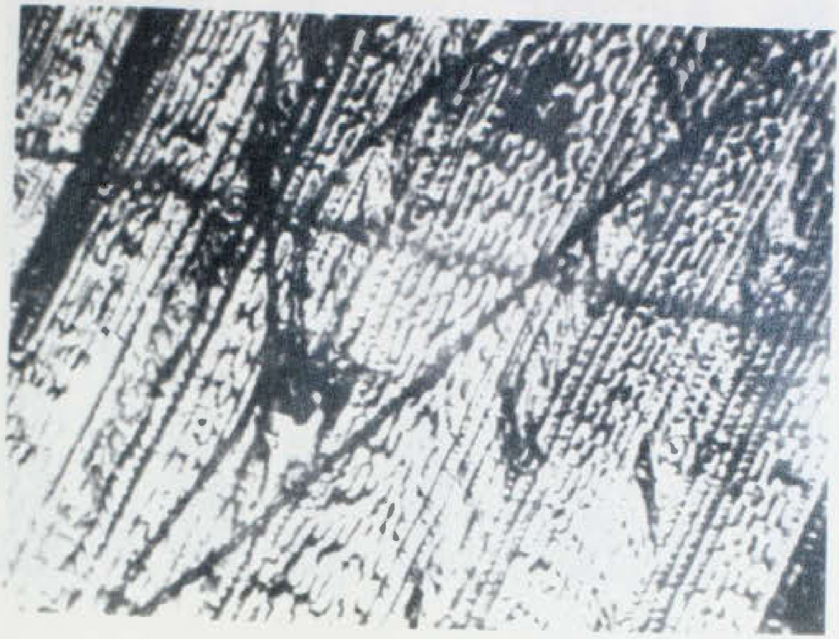
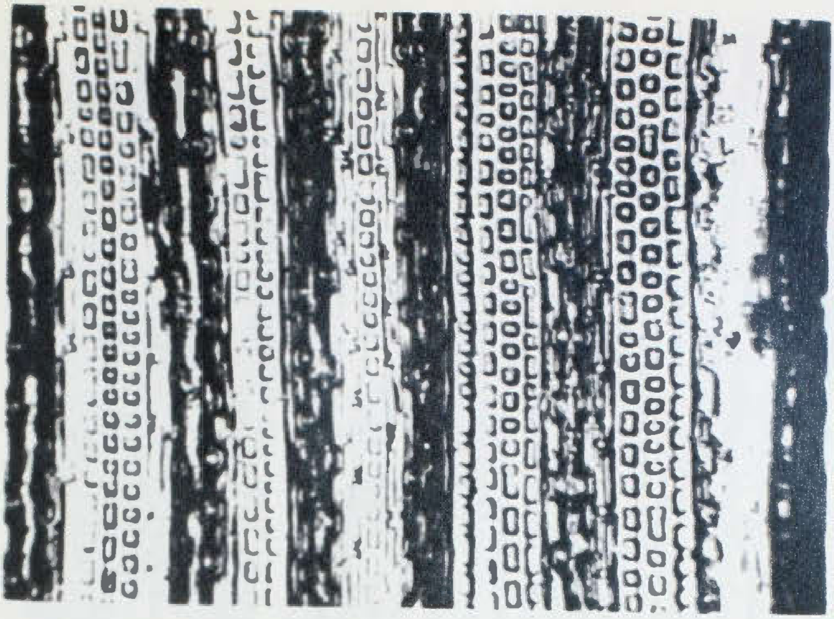


Figure 6. Bouteloua gracilis (H.B.K.)

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies and Micro-hair



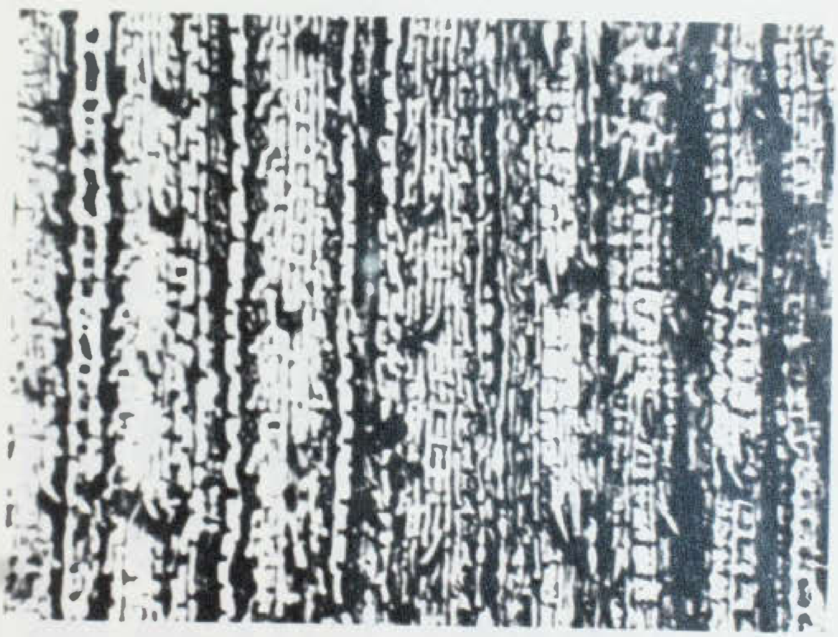
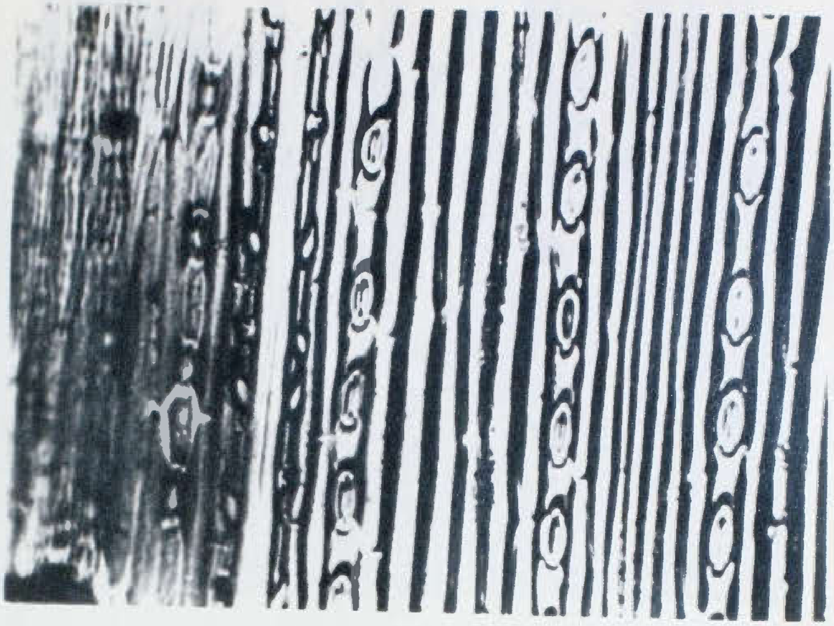


Figure 7. Bouteloua hirsuta Lag.

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Short cells and Micro-hair



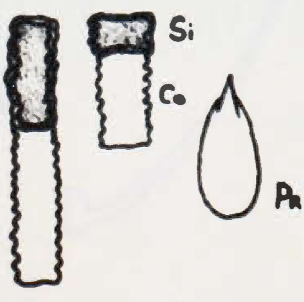
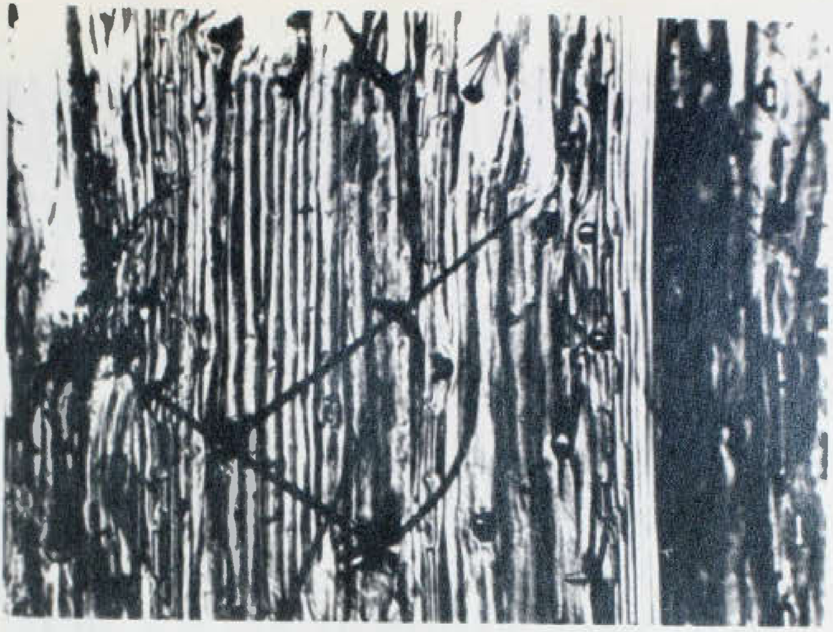


Figure 8. Bromus inermis Leyss.

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Short cells and
Prickle-hair



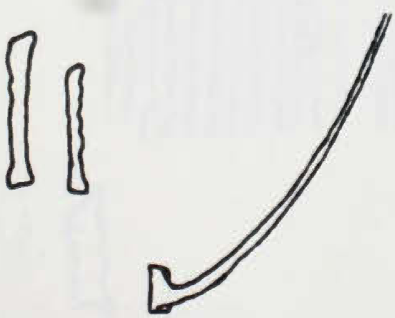
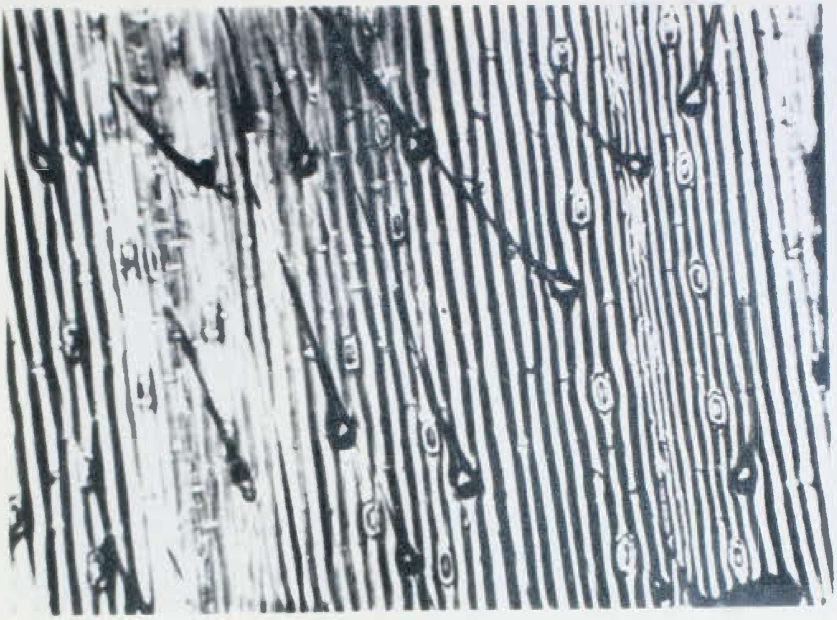


Figure 9. Bromus japonicus Thunb.

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies and Macro-hair



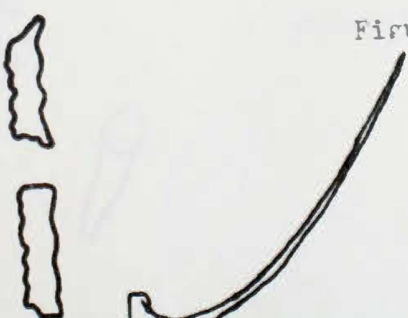
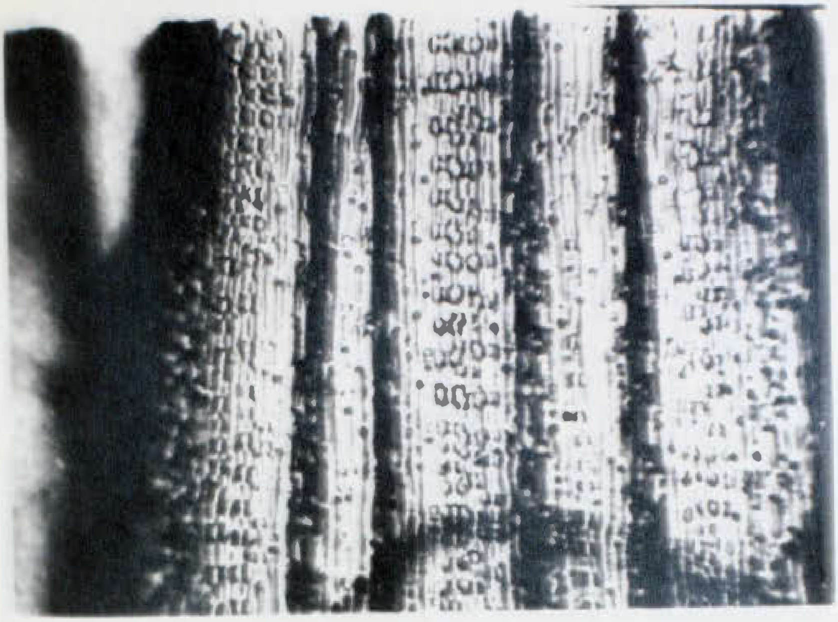


Figure 10. Bromus tectorum L.

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies and
Macro-hair



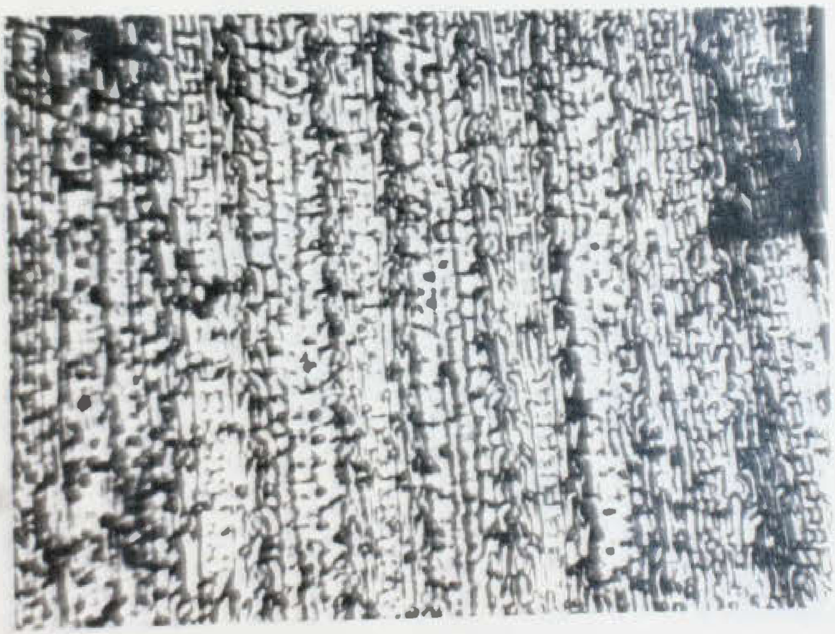


Figure 11. Buchloe dactyloides (Nutt.) Engelm.

Upper : Abaxial surface
Middle : Adaxial surface
Lower : Short cells and
Micro-hair

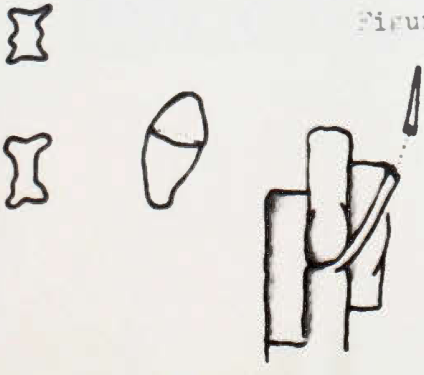


Figure 13. Chloris verticillata Nutt.

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies, Micro-
hair and Macro-hair

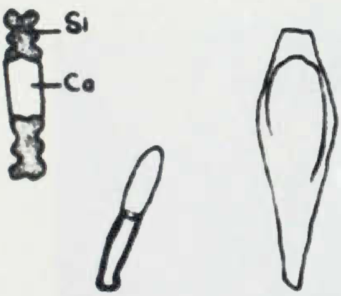
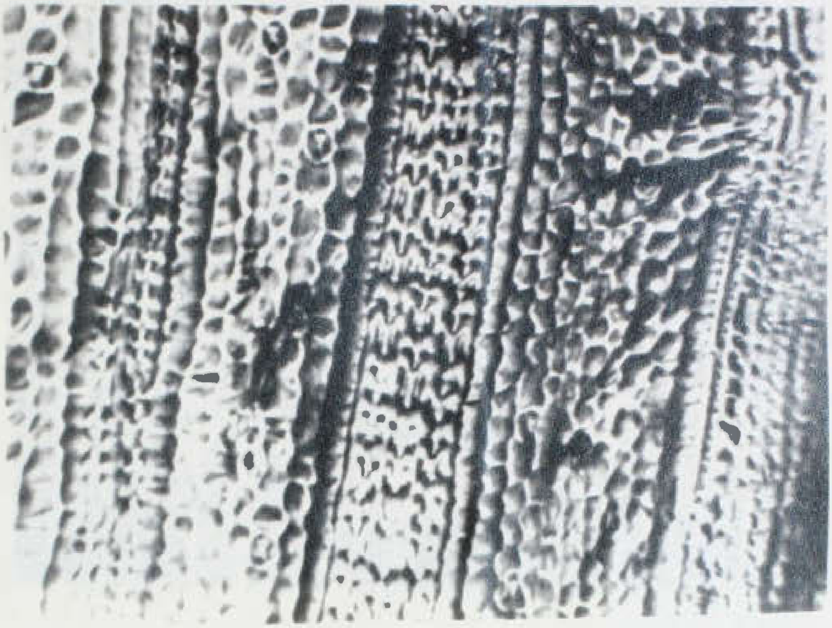


Figure 14. Echinochloa crusgalli (L.) Beauv.

Upper : Abaxial surface
Lower : Short cells, Micro-hair, and long cell with papilla



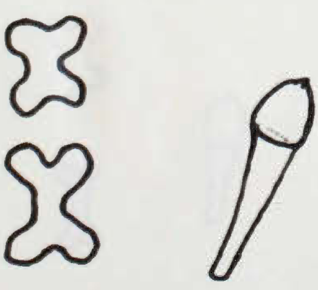


Figure 15. *Eragrostis cilianensis* (All.) Lutati.

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies and
Micro-hair

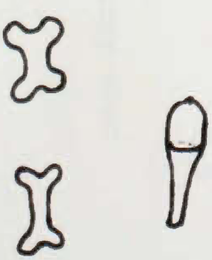


Figure 1[illegible]. Eragrostis trichodes (Nutt.) Wood.

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies and
micro-hair

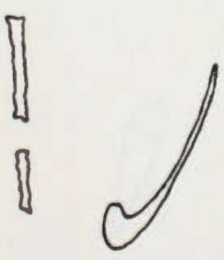
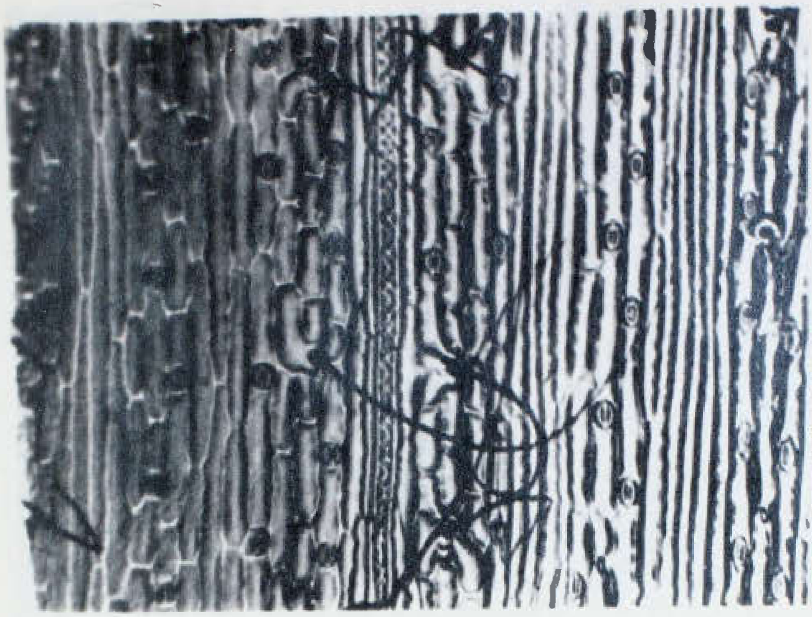


Figure 17. Hordeum pusillum Nutt.

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies and
Macro-hair



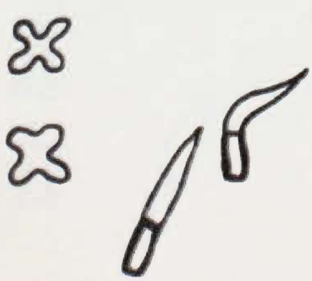


Figure 19. Panicum capillare L.

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies and Micro-hairs

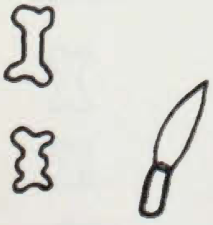


Figure 20. Panicum dichotomiflorum Michx.

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies and
Micro-hair

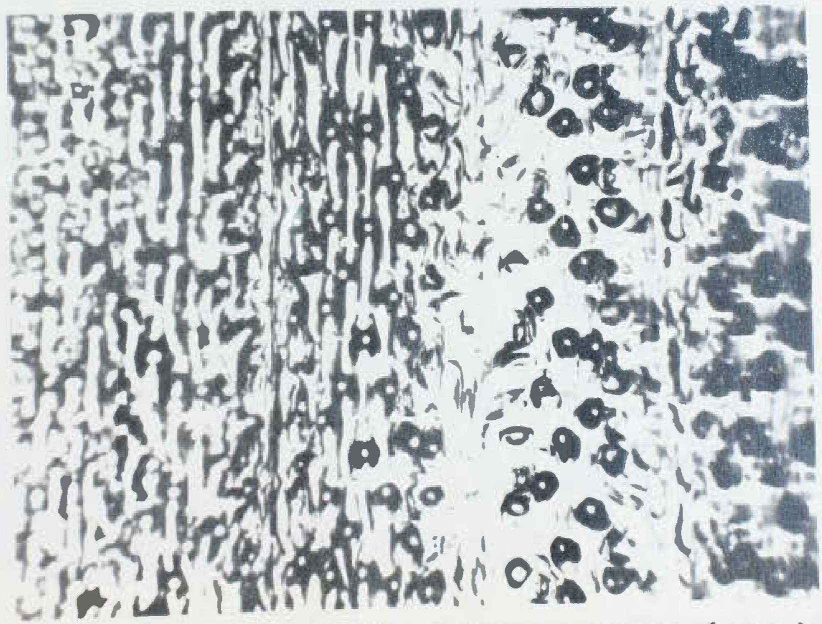
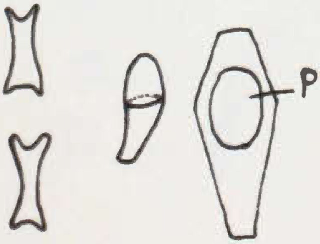
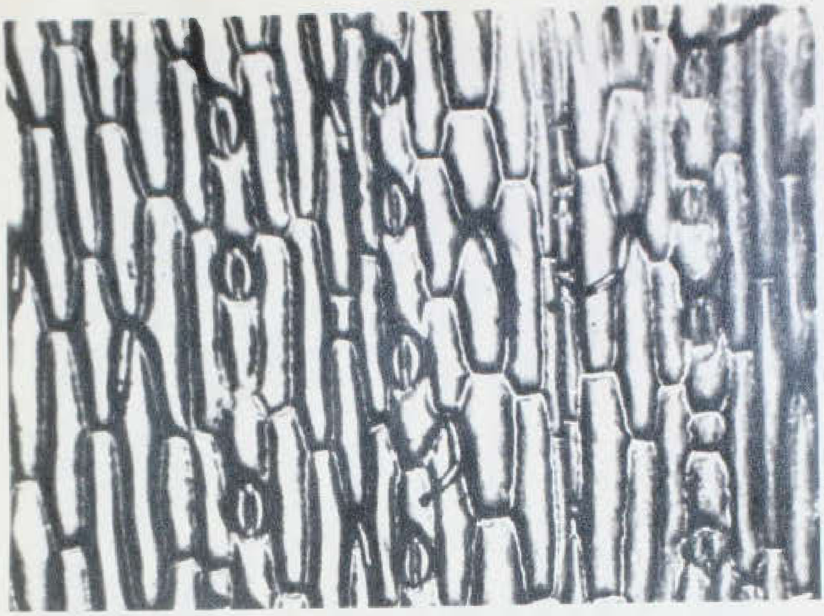
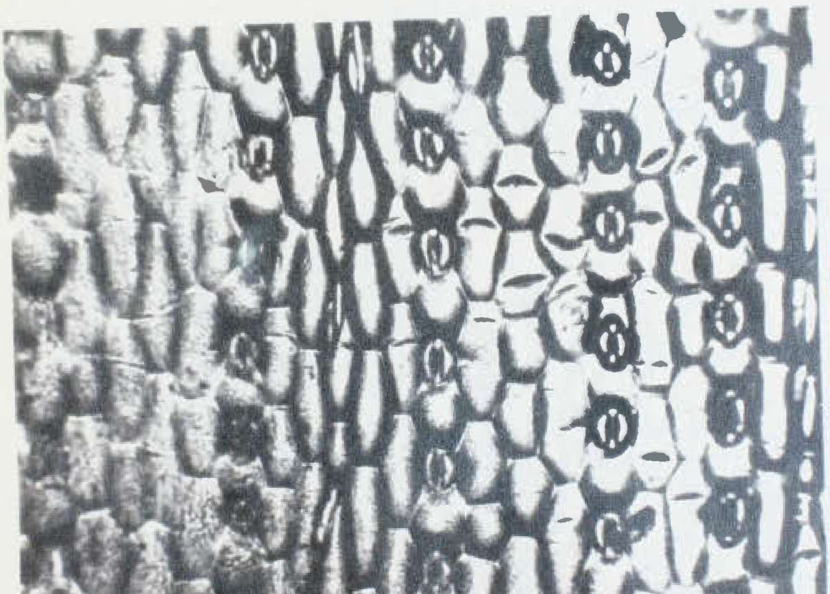


Figure 22. Schedonnardus paniculatus (Nutt.) Trel.



Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies, Micro-hair, and
Long cell with Papilla





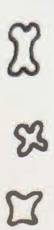
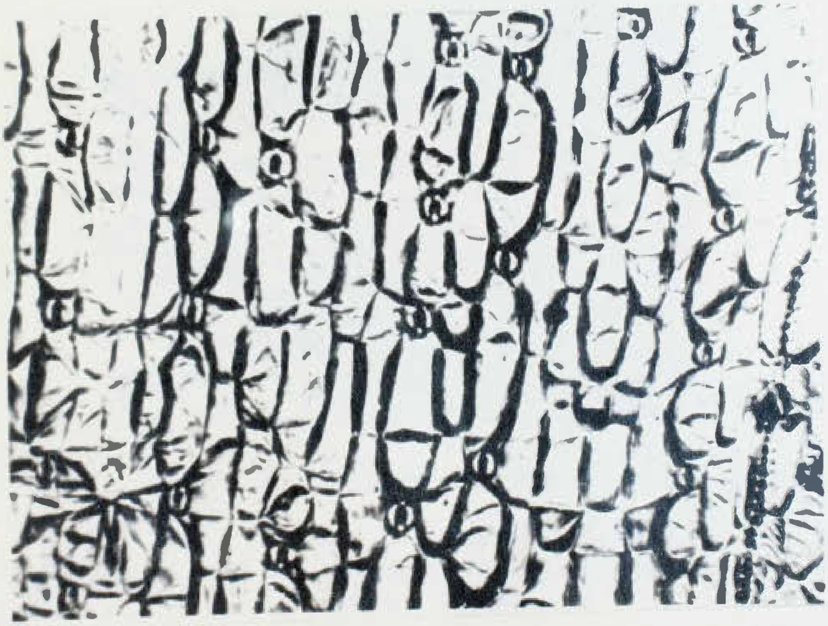


Figure 23. Setaria lutescens (Weigel) Hubb.

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies and
Micro-hair



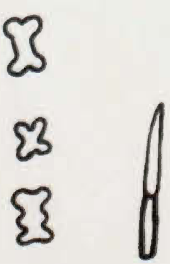
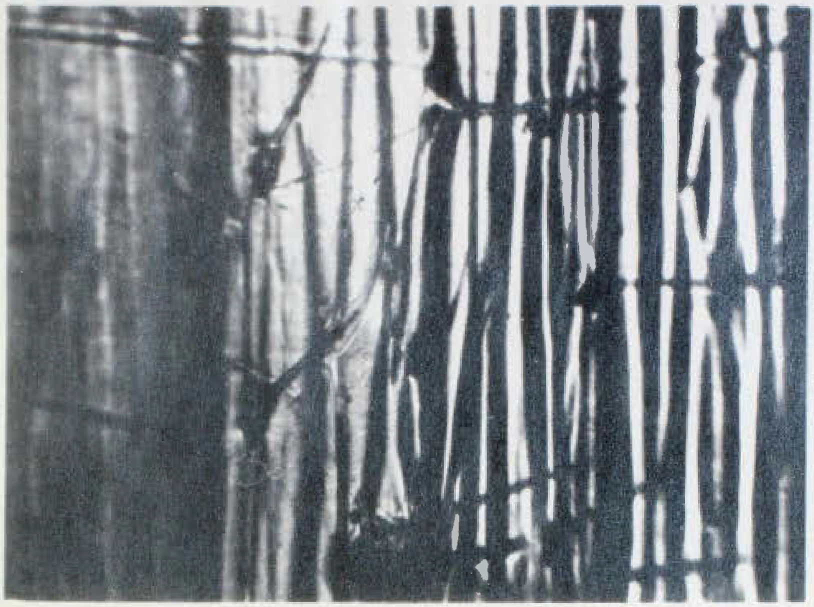


Figure 24. Setaria viridis (L.) Beauv.

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies and Micro-hair



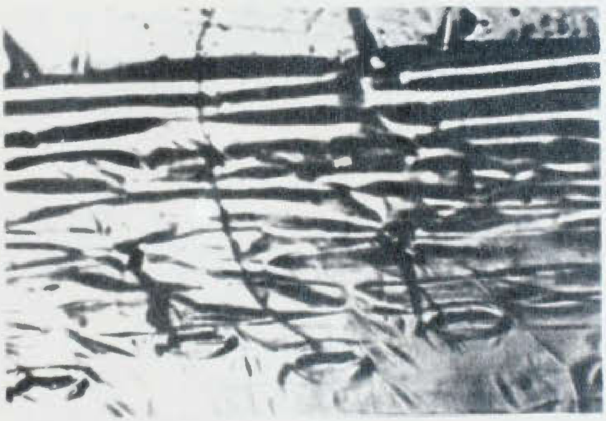
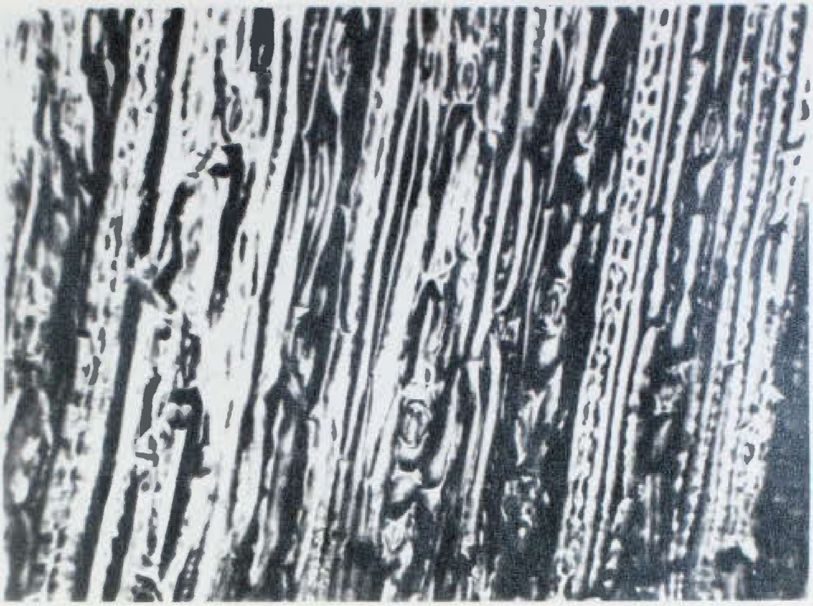


Figure 25. Sitanion hystrix (Nutt.) J.G. Smith

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Macro-hair



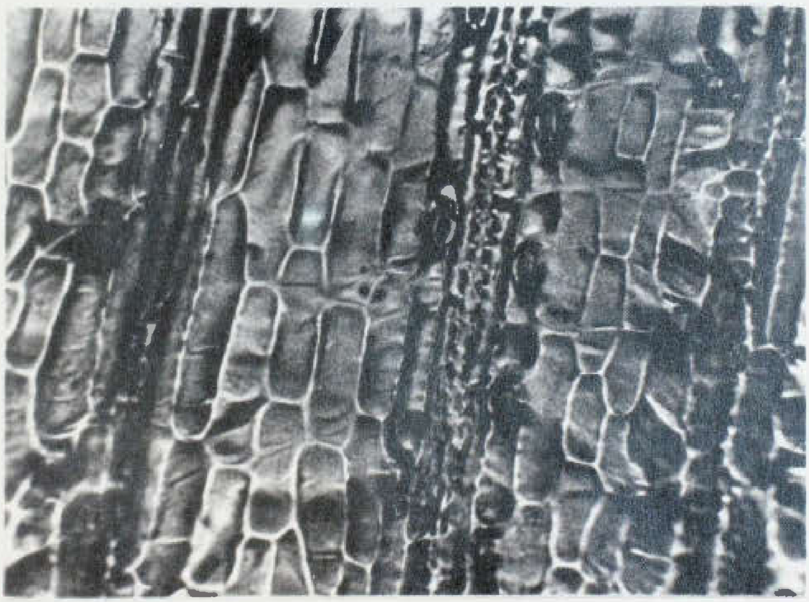
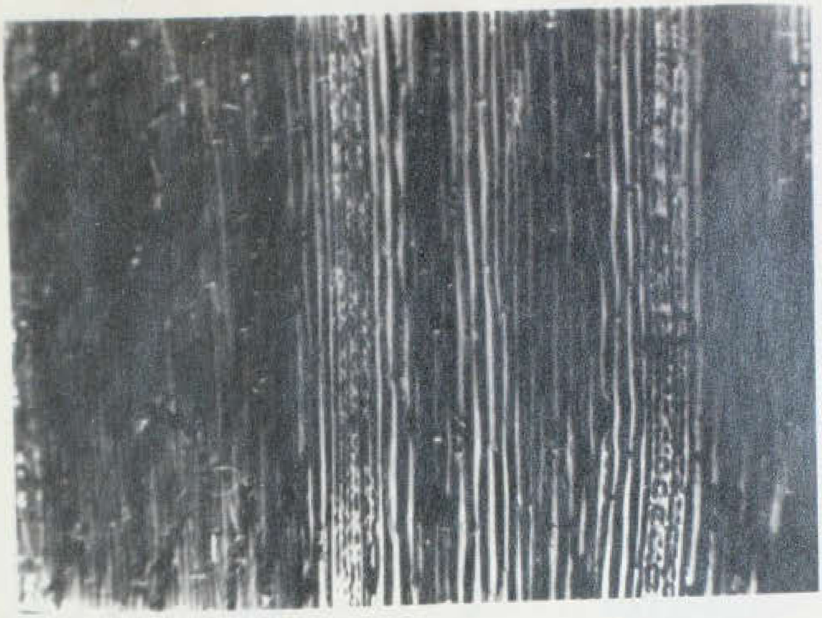
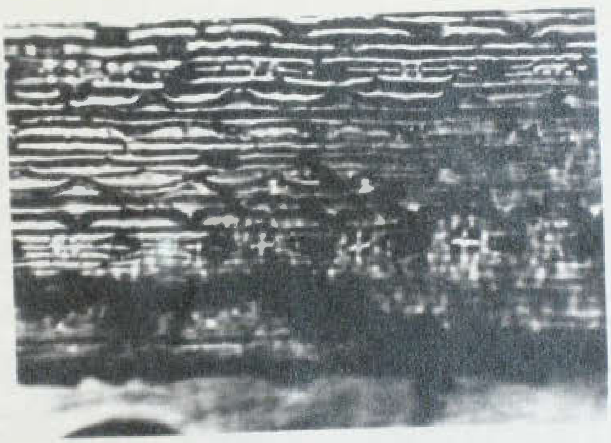


Figure 26. Sorghastrum nutans (L.) Nash

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies and Micro-hairs





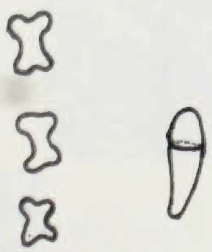
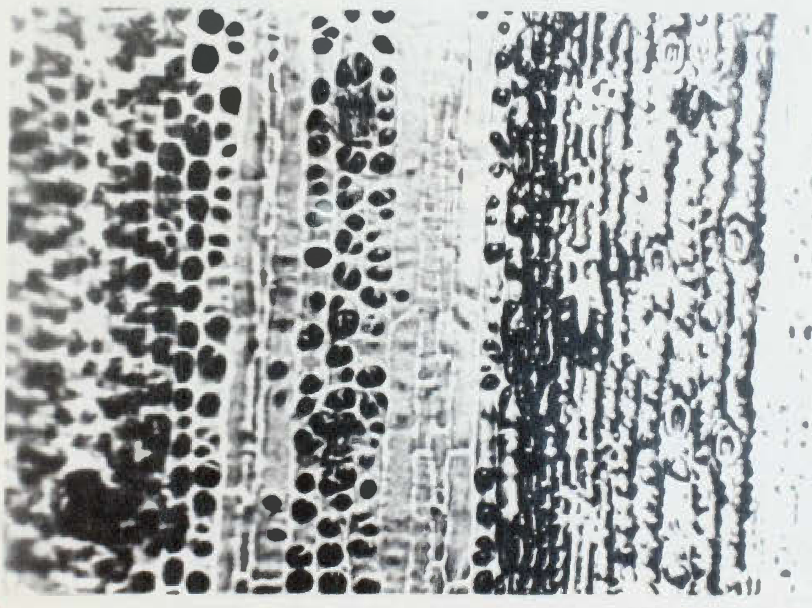


Figure 27. Sporobolus airoides (Torr.) Torr.

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies and
Micro-hair



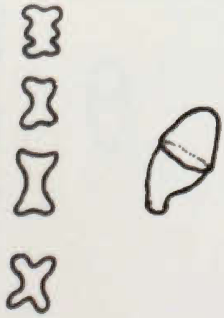
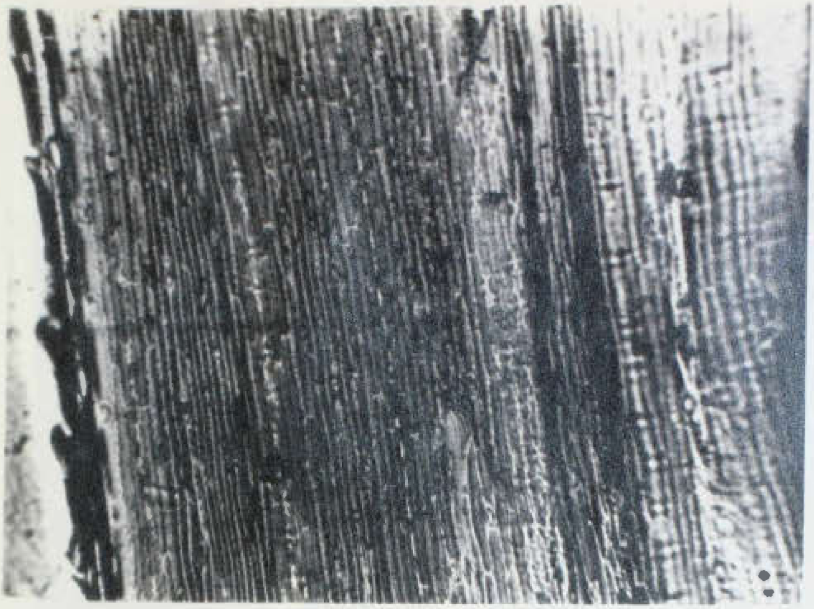


Figure 28. Sporobolus asper (Michx.) Kunth.

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies and
Micro-hair



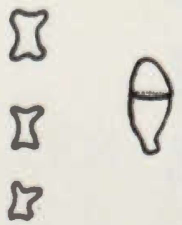
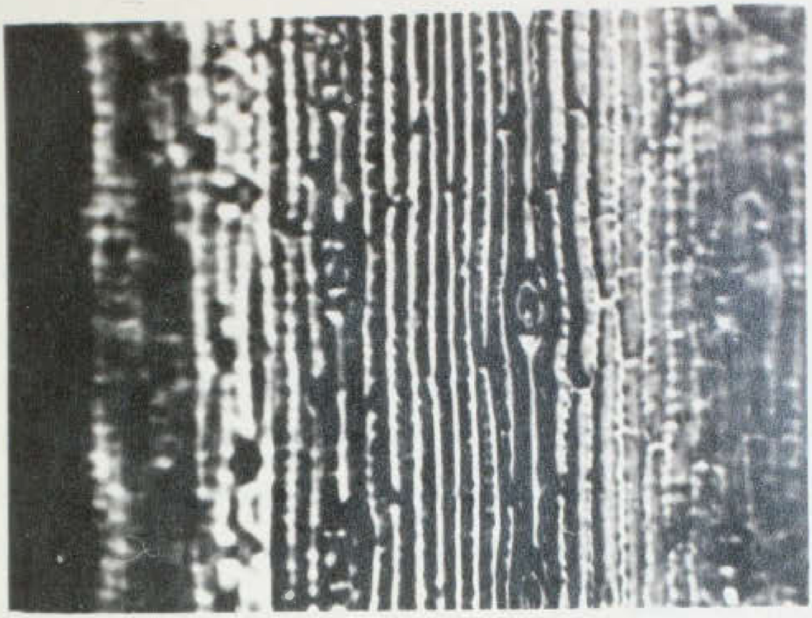
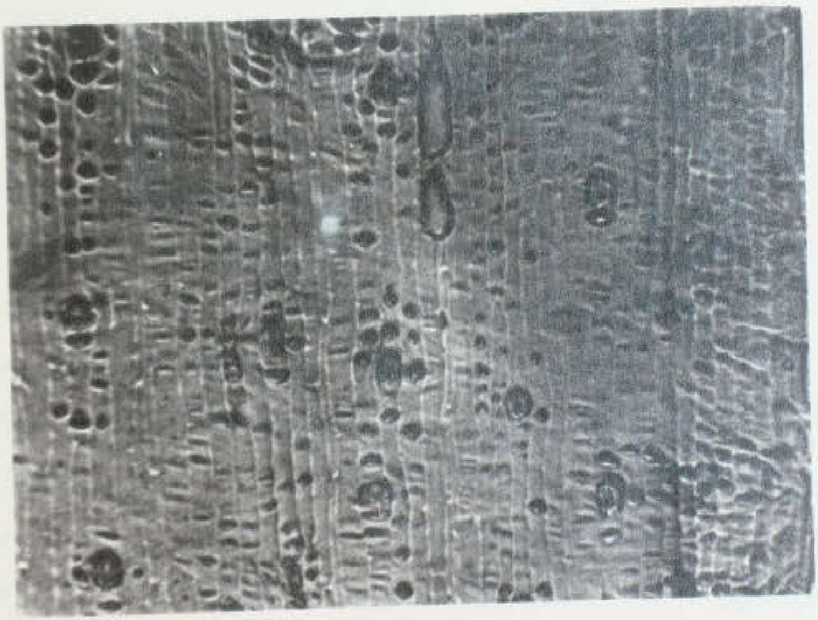


Figure 29. Sporobolus cryptandrus (Torr.) A. Gray

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies and
Micro-hair





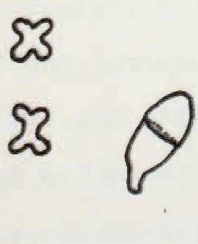


Figure 30. Sporobolus neglectus Nash

Upper : Abaxial surface
Middle: Adaxial surface
Lower : Silica bodies and
Micro-hair

IV. SUMMARY AND DISCUSSION

Thirty species of grass seedlings representative of seventeen genera and six tribes were studied. The microscopical surface characteristics of the first seedling leaves of these selected species were determined from slides of the abaxial and adaxial epidermis. The slides were made by the peel method which uses acetone and cellulose acetate film, and these compared with stained mounts of the abaxial epidermis. A key to species based on the abaxial surface and detailed descriptions of both leaf surfaces of each species is included as part of the study. Photomicrographs of the peels and line drawings of certain diagnostic characters accompany the descriptions of species.

It is not the purpose of this limited study to attempt to solve any of the taxonomic problems concerning the phylogenetic status of the genera and tribes included, but rather to characterize the taxa by their epidermal characters. The data presented here concerning the epidermal characteristics of grass leaves may aid in the clarification of certain problems, however, when correlated with other data. It is the author's aim to first present a detailed description of the microscopical surface morphology of the first seedling leaves of the species included, and second, to recognize similarities and differences between these species.

The epidermal elements examined includes silica bodies, cork cells, macro-hairs, bicellular micro-hairs, prickle-hairs, papillae, stomata and certain other relatively undifferentiated cells. In general, the abaxial leaf surface was found to offer a more varied assortment of epidermal characters and often more numerous characters. It was found that the shape and relative distribution of the silica bodies and the type of bicellular micro-hairs, when present, seem characteristic of certain groups. These two elements especially furnish diagnostic characters in a survey of grasses from several genera and tribes.

The silica bodies of the first seedling leaves were found to occur most often over the veins. They occur both over and between the veins in certain species. The silica bodies were noted to occur most frequently in long rows, usually alternating with a cork cell. The silica bodies also occur solitary in certain species or paired with cork cells. Of the thirty species included in the study, fourteen exhibited predominantly dumbbell-shaped silica bodies or variations of the dumbbell-shape. Five species had horizontally elongated silica bodies and four species cruciate silica bodies. Saddle-shaped silica bodies were predominant in three species although they were noted to occur in certain other species. Cubical, acutely-angled, nodular, tall and narrow, and certain intermediate forms were noted to occur.

The bicellular micro-hairs of the first seedling leaves usually occur between the veins. Only six species of the thirty studied had no micro-hairs. Twenty-one species were found to have bicellular micro-hairs on both leaf surfaces and three species had bicellular micro-hairs only on the abaxial leaf surface. No unicellular micro-hairs were seen. Two general types of micro-hairs were recognized: (1.) the basal and distal cells are of approximated, uniform width and the distal cells taper gradually to sharp-pointed apices; (2.) the basal cells taper markedly toward their proximal ends and the distal cells are hemispherical and broad, giving the micro-hairs a "swollen" appearance.

The new trend in grass systematics has enabled agrostologists to recognize that many grasses of the subfamily Festucoideae also have Panicoid characteristics. In an attempt to formulate more natural taxa, the subfamilies Panicoideae and Festucoideae have been subdivided. Prat (1936) divides the Panicoideae into two groups. Eupanicoid (true panicoid) and Chloridoid. The Eupanicoid group is composed of the tribes Paniceae, Andropogoneae, and Maydeae. The Chloridoid group is made up of the Chlorideae, Eragrosteae, and Sporoboleae. The tribes Festuceae, Hordeae, Aveneae, and Agrostideae are of the subfamily Festucoideae. Other groups are not considered in this study since members of only six of the traditional tribes are included.

In a summary of the data recorded here, certain characteristics may be seen to characterize taxa. The shape of the silica bodies and the type or occurence of bicellular micro-hairs are especially useful as diagnostic characters. The eleven species of the subfamily Panicoideae included in the study represent the Paniceae and Andropogoneae of the Eupanicoid group. All four members of the tribe Andropogoneae have bicellular micro-hairs and dumbbell-shaped silica bodies. The basal and distal cells of the micro-hairs are approximately equal in length. The distal cells of the three species of Andropogon taper to sharp-pointed apices while the distal cells of Sorghastrum nutans are rather blunt. The seven species of the tribe Paniceae have bicellular micro-hairs and predominently cruciate silica bodies, although dumbbell-shaped silica bodies are common in certain species. The distal cells of the micro-hairs taper to sharp-pointed apices and are usually longer than the heavier-walled basal cells. Most of the species of both Andropogoneae and Paniceae have stomata with triangular subsidiary cells. All of the eleven species seem to reflect "true" Panicoid characteristics.

The nineteen species of the subfamily Festucoideae are representative of the traditional tribes Festuceae, Hordeae, Agrostideae, and Chlorideae. Of the three members of the tribe Hordeae, two species had horizontally elongated silica bodies while no silica bodies were seen in Sitanion hystrix. Micro-hairs were absent in all three species and short, stiff macro-hairs were abundant. Of five species of the tribe Festuceae, three species of Bromus had horizontally elongated silica bodies. All three Bromus species were devoid of micro-hairs. Slender macro-hairs were abundant in *Bromus japonicus* and *Bromus tectorum*, but absent in *Bromus inermis*. All members of the tribes Hordeae and Festuceae have stomata with parallel-sided subsidiary cells except two species of *Eragrostis*. The species of *Eragrostis* reflect both Festucoid and Panicoid characteristics and are usually considered distinct from the subfamily Festucoideae. The representative of the Hordeae and Festuceae, except the *Eragrostis* species seem to reflect "true" Festucoid characteristics.

The remaining species included in the study are representative of several genera of the tribes Agrostideae and Chlorideae. The form and relative distribution of the silica bodies of these species is rather varied. Bicellular micro-hairs were present in all species. The micro-hairs were found to have broad, hemispherical distal cells. The basal cells of these micro-hairs varied in length but were tapered toward their proximal ends in all species.

The species of the tribes Agrostideae and Chlorideae are representative of several genera. Most of these genera have both panicoid and festucoid characteristics. Due to the limited number of species involved in this study, general tendencies or trends concerning the shape and distribution of silica bodies and micro-hairs is not clearly evident. It is the author's viewpoint that a broader survey is needed before members of these two traditional tribes can be characterized by their epidermal characteristics.

Examination of the epidermal characteristics of the thirty species revealed that certain elements are found only at the margins or apex of the leaf. In certain species, prickle-hairs or hooks were present only at the margins or were more numerous near the margins. The cell walls of the long cells were most frequently sinuous near the margins or principle veins. Bicellular micro-hairs were usually found to be most numerous near the margins of the leaf. The adaxial surfaces of the first seedling leaves were found to possess fewer specialized epidermal elements, in general, than the abaxial surface. These features of the epidermis may have some role in the ecological anatomy of the individual species. No investigations were made regarding this possibility.

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