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KEY TO SELECTED PLANT SPECIES OF TEXAS USING PLANT FRAGMENTS

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Accurate evaluation of the seasonal diet of grazing animals greatly facilitates application of range and wildlife management principles. Deciding which season(s) of the year is most appropriate to use the range, what the proper kind(s) of grazing animals should be, or when the animal's diet is most likely to need a nutrient supplement obviously requires knowledge of food habits. Accurate identification of plant fragments in animal feces would reflect which plant species were being eaten. Obvious advantages of assessing diet composition via these means are: wild and domesticated herbivores need not be sacrificed to examine stomach contents, diet information can be gathered from animals occupying rough terrain where ocular observations or fistula techniques are not possible, animals can graze or browse naturally without observer distraction, and one to several days' diets is integrated into one sample (that is, observations are not limited to one or two hours per day).

Although unequal digestion of consumed plant species can bias quantitative diet values, the microhistological evaluation of feces has proven to be of real value in diet analyses. A good approximation of the diets of grazing animals now is considered feasible (Dearden *et al.*, 1974).

The diagnostic key presented herein was prepared as an aid for those interested in applying the microhistological technique in Texas or in areas where similar vegetation is found. Measurements in text are given in millimeters, volumes in mililiters, and

weights in grams. For convenience, photomicrographs of reference and fecal material are grouped into plates.

Diagnostic Characteristics

Grasses

Grasses have a linear cell arrangement that can be divided into costal and intercostal zones (Metcalf, 1960). The costal zone, occurring over the veins, is the most useful for species identification because the veins and adjacent cells are not digested as easily as cells of the intercostal zone (areas between veins). Diagnostically useful structures of the costal zone are silica cells, cork cells (collectively called short cells), and bristles. In the intercostal zone lie long cells, stomata and their accompanying guard and subsidiary cells, and protrusions such as microhairs, bristles, and trichomes. Cork cells, bristles, and silica cells also are present in the intercostal zone of some species.

Silica cells are especially important in diet analysis for they assume a variety of distinctive shapes as shown in Fig. 1. These cells, filled with silicon dioxide, are not digested by the animal and are sometimes the only remnant of the grass visible in the feces. If a grass has silica cells in the intercostal zone, they may not be the same shape as those in the costal zone. The frequency and pattern of occurrence of silica cells are important for identifying grasses.

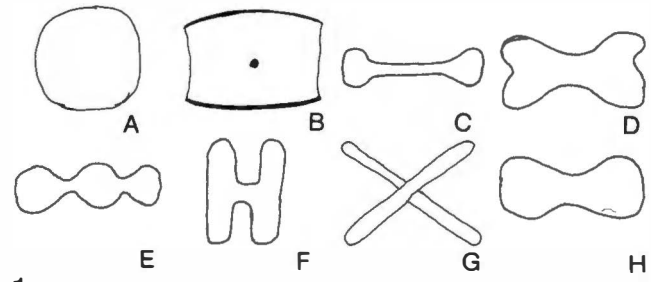
Cork cells are visible in the costal and intercostal zones of most grasses. They occur individually, usually at the end of a long cell, or in pairs with silica cells. Cork cells also assume a variety of shapes as shown in Fig. 2A-D.

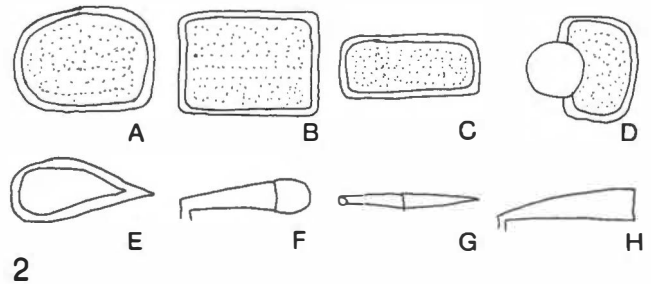
Bristles can be present in the costal or intercostal zones and at leaf margins. They appear as flat, hairlike protrusions that are rounded at one end and pointed at the other as in Fig. 2E.

Microhairs are two-celled microscopic epidermal protrusions with or without a stem (Fig. 2F-H). They can be found in both the costal and intercostal zone. The distal segment can vary in shape from short and round to long and narrow. Often the segment is missing.

Trichomes, or macrohairs, are large unicellular hairs visible with the naked eye or a hand lens (Fig. 3A). Trichomes of grasses often are not seen in fecal slides as they occur only at the leaf margins.

Long cells of the intercostal zone of grasses vary in shape and size as shown in Fig. 3B-E. The ends of these long cells are often





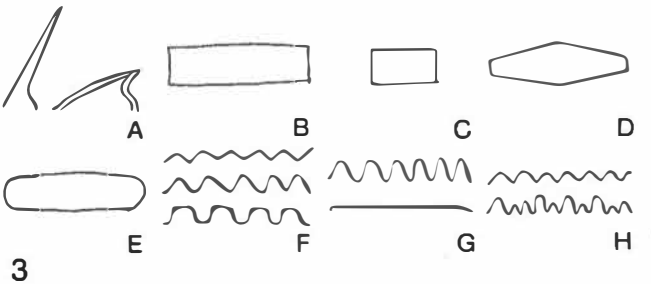
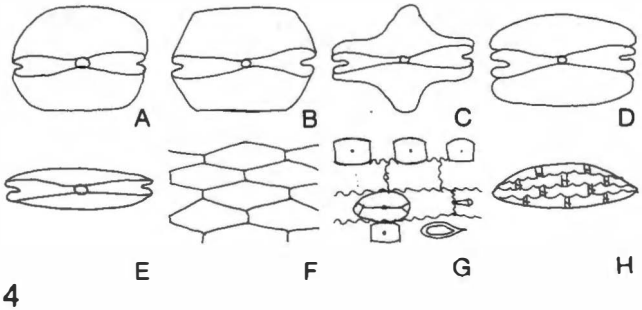


FIG. 1.—Various forms of silica cells: A, round; B, square; C, barbell; D, wrench; E, nodular; F, H-shaped; G, X-shaped; H, saddle-shaped.

FIG. 2.—Various forms of cork cells: A, round; B, square; C, oblong; D, paired with a silica cell to appear crescent-shaped; E, bristle—a flat, hairlike protrusion. Various forms of microhairs; F, with stem and rounded distal cell; G, without stem and with long distal cell; H, with distal cell missing.

FIG. 3.—Various forms of macrohairs in grasses: A, long and thin (left) and short and thick (right). Various forms of long cells of the intercostal zone: B, rectangular; C, square; D, hexagonal; E, oval. Various forms of long cell walls: F, pointed (top), rounded (middle), or square (bottom); G, deep (top) and shallow (bottom); H, even (top) and uneven (bottom) undulations.



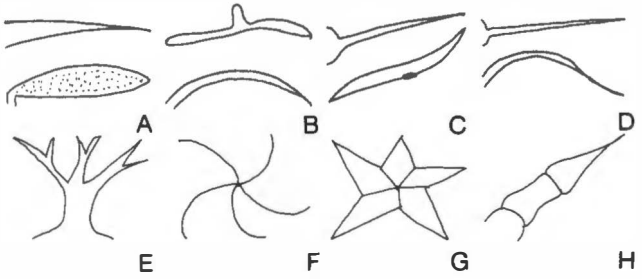


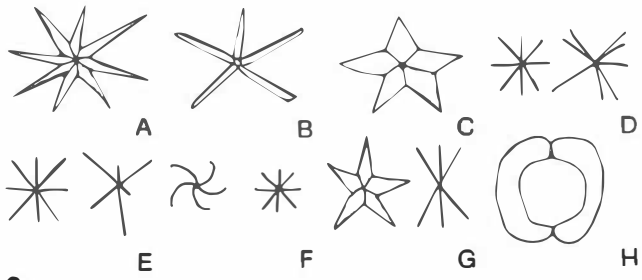
FIG. 4.—Various forms of subsidiary cells of grass stomata: A, round; B, square; C, triangular; D, oval; E, flat. Leaf sheath epidermis, F. Costal and intercostal arrangement of grass leaf, G. Grass seed, H.

FIG. 5.—Various forms of unicellular trichomes of forbs: A, smooth (top) and pubescent (bottom); B, branched (top) and unbranched (bottom); C, attached at an end (top) and attached in the center (bottom); D, straight (top) and curved (bottom). Various forms of multicellular trichomes of forbs: E, dendroid; F, peltate; G, stellate; H, single row of cells.

useful in identifying plant fragments in the feces. The cells may be joined by silica cells, cork cells, or a pair containing both. Microhairs also can serve as part of the cell end.

Shape of the cell wall is distinctive and hence a good diagnostic character in grasses (Fig. 3F-H).

Stomata in Graminea and Cyperacea are similar, but there are noted differences in the shape of the subsidiary cells. Subsidiary cells of grass stomata can assume any of the various shapes outlined in Fig. 4A-E; these are diagnostic but they can be distorted during digestion or preparation of the microscope slide. Therefore, species identification solely on the appearance of the subsidiary cell could be misleading. All grass stomata have two such cells parallel to the stoma's long axis. Guard cells appear barbell-



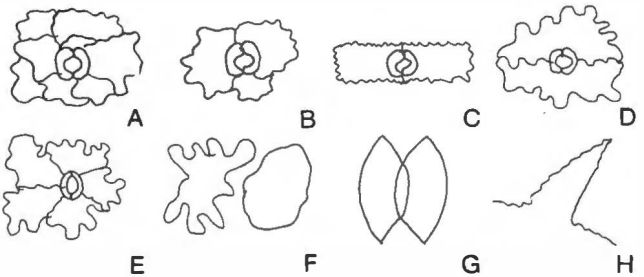


FIG. 6.—Various forms of stellate trichomes of forbs: A, many long thin arms with special center attachment; B, arms of medium length and width, center point of attachment; C, few short thick arms with no special form of attachment; D, arms evenly (left) or unevenly (right) spaced; E, arms uniform length (left) and variable in length (right); F, arms bent (left) and straight (right); G, arms tapering from wide at base to thin at distal end (left) and arms uniform in width (right). Components of forb stomata are two half-moon shaped guard cells surrounding the pore or opening itself, H.

FIG. 7.—Various arrangements of subsidiary cells around the stomata of forbs: A, anomocytic with no special cell arrangement; B, anisocytic with three subsidiary cells present one smaller than the other two; C, paracytic with one or more subsidiary cells occurring on either side of the stomata parallel with its long axis; D, diacytic with two subsidiary cells enclosing the stomata, their common wall at right angles to the long axis of the stomata; E, actinocytic with subsidiary cells arranged in a circular pattern. Shapes of cell walls of forbs are dentate (left) or smooth (right), F. Components of brush stomata are two kidney-shaped guard cells surrounding the pore or opening itself, G. Basic shape of trichomes of woody species, unicellular and short, H.

shaped, due to the center pore or opening itself. Stomata frequency may differ according to site and environmental condition within any one species. Thus, this feature is not often useful in identifying species.

Different parts of grass plants have different epidermal characters, for example, the leaf sheath (Fig. 4F) is composed only of long cells, and the leaf itself consists of costal and intercostal zones (Fig. 4G) and all their components. Consequently, leaves are the best tissue for identification of grasses. Grass seeds are poor diagnostic tissues for they all are fairly similar and usually too dense for light from the microscope to penetrate, as shown in Fig. 4H.

Forbs

Forbs do not have a linear cell arrangement, nor can they be divided into costal or intercostal zones. Furthermore, cork and silica cells are absent.

Trichomes are the outstanding character by which forbs may be identified under the microscope because they exhibit distinctive shapes and are not easily digested. They may be either unicellular or multicellular (Fig. 5A-H). Stellate trichomes vary in the length, width, and number of arms they support and also in the manner in which the arms are attached (Fig. 6A-G).

Stomata consist of the pore, two half-moon shaped guard cells (Fig. 6H), and occasionally subsidiary cells. Subsidiary cells form special arrangements around the stomata as shown in Fig. 7A-E. Cell walls can be dentate or smooth (Fig. 7F). The size, shape, and arrangement of the cells are useful in diet analysis if they are visible in the fecal slide. Shape and depth of the cell wall undulations are also helpful in identifying plant fragments.

Woody Plants

Shrub or woody species have cell arrangements and configurations similar to forbs. The cells usually have smooth walls, and stomata are small with kidney-shaped guard cells (Fig. 7G). (The guard cells of some woody species are similar to the half-moon shaped guard cells common in forb species). Trichomes are generally unicellular (Fig. 7H), the one exception being the *Quercus* species, which have peltate trichomes.

The cell structure of woody species is usually visible in the fecal slide. However, pigments are not always removed during digestion and this can mask characters needed for identification. Cell walls may be smooth or dentate. Epidermal cells of woody species are most often smaller than those of forbs. Nuts, berries, and seeds from woody plants are useful aids in determining the species of a plant fragment.

Methods and Materials

Reference Slides

There must be a complete plant collection from the area to be studied in order to prepare reference slides. Two separate slides of each plant part (leaf, stem, flower, seed, berry, and so forth) should be prepared. The pigments in grass tissue must be removed with hot water and 95 per cent ethanol so that epidermal characters can be seen. Fresh material, which loses its pigments readily, is easier to work with than dried material; however, either is acceptable. It is advisable to cut fresh grass into small pieces and soak them for at least 24 hours in 95 per cent ethanol. Fragments are next blended until pigment is removed, and slides prepared according to instructions in the following section. Check slides under the microscope to be sure epidermal characteristics are visible. If still obscured by pigment, take the remaining plant material from the 200 mesh screen and reblend it with hot water and alcohol. Repeat until all epidermal characters are clearly visible.

Forbs require only the use of hot water for preparation of reference slides. Slides should also be prepared of any flowers, seeds, or berries.

It is difficult to remove pigments from many woody species. Soaking plant parts in 95 per cent ethanol for at least 24 hours will usually aid in removing the pigments. Following soaking, leaves are blended with hot water and alcohol. This method will not extract all color from nuts and seeds, but it will closely simulate the action of an animal's digestive system. Before discarding plant material collected for the preparation of reference slides, check reference slides to be sure epidermal characters needed for identification are visible.

Slide Preparation

Microscope slides are prepared using the method described by Cavender and Hansen, 1970, and Hansen *et al.*, 1971. This technique is described below.

Materials needed are: binocular microscope, 100×; glass microscope slides, standard size and laboratory grade; glass cover slips, 22×40 mm.; slide labels; dropping bottles, 30 ml. (2); teasing needle; spatula with narrow flexible blade; paper towels; 200 mesh screen; drying oven and racks; Waring blender (1 quart).

Two chemical solutions are also used in making slides. Hertwig's solution is a clearing agent that consists of 270 g. cloral

hydrate crystals (a restricted drug requiring a BNDD number to purchase), 10 ml. of 1N HCl, and 60 ml. glycerin. The glycerin and HCl are combined and then the chloral hydrate crystals added. The mixture is next warmed over an alcohol lamp and stirred until all crystals dissolve. Hoyer's solution is a mounting medium containing 200 g. chloral hydrate crystals, 50 ml. water, 20 ml. glycerin, and 30 g. photo purified gum arabic. After the glycerin and water are combined, the chloral hydrate crystals are added and the mixture warmed until the crystals dissolve. The gum arabic is added to the solution, which is then placed in a dark place until the gum completely dissolves. This could take as long as a week.

Fecal samples should be blended at high speed for one minute, and two slides ought to be prepared from each sample. Plant fragments should be spread evenly over the slide and should not overlap. Best results are obtained when, at 100 power magnification, there are about three large fragments per field.

Place approximately 10 ml. of ground or blended sample in a 0.1 mm. (200 mesh) screen and wash under running water for one minute. Remove a small amount of the washed material from the screen with a spatula and spread it near one end of a microscope slide. Add three or four drops of Hertwig's solution to the wet material on the slide, then carefully evaporate most of it by holding the slide above a small alcohol burner, while stirring with teasing needle. It is important not to completely evaporate the Hertwig's solution, as it will make slides difficult to read.

When most of the solution has evaporated, add enough Hoyer's solution to cover an area about two-thirds as large as a cover slip. With a teasing needle, mix the plant material with the Hoyer's and spread evenly over an area as large as a cover slip. Place a cover slip on the preparation and heat the slide over the burner until the Hoyer's solution starts to boil. Immediately wipe the bottom surface of the slide with a cold, damp paper towel to draw air bubbles out of the solution. Using the handle of the teasing needle, gently press on top of the cover slip to squeeze out excess mounting medium and remove any remaining air bubbles. (Very tiny bubbles usually disappear during the drying process and are not detrimental.) Apply a thin ring of Hoyer's solution around the edges of the cover slip, if needed, to form a seal as the slide dries.

Slides are placed flat on racks at 55°C, for two or three days, or until the Hoyer's solution has hardened, and are then stored in a dry place. Hoyer's solution forms a permanent mounting medium

when hardened, but is soluble in water allowing easy cleaning for reuse of slides.

Collection and Preparation of Fecal Material

To preserve fecal material until slides are to be made, store in 95 per cent ethanol, 10 per cent formalin, or oven dry. Freezing fecal material can cause the cell walls of the plant fragments to burst. This makes identification extremely difficult, if not impossible.

Feces from animals that eat many hard seeds or nuts should be air dried (or oven dried below 70°C) and then ground in a Wiley Laboratory Mill using the delivery tube with the 20 mesh (1 mm.) screen. Ground samples may be stored in coin envelopes or in jars until slides are to be prepared. To prepare slides from ground fecal material, place the sample in a 200 mesh (0.1 mm.) U.S. Standard Sieve and wash under running hot water for one minute, then prepare slides.

Feces from animals that eat mainly grasses and forbs may be stored in 95 per cent ethanol. To prepare slides, put sample (and alcohol in which it was stored) into the blender, add hot water (at least enough to cover blender blades), and blend for one to three minutes depending on coarseness of plant material in sample. Pour blended sample into the 200 mesh screen and rinse with hot water, let drain, and prepare slides.

Key to Selected Plant Species

Selected Major Groups

1. Cell arrangement linear 2
   Cell arrangement other than linear 4
2. Distinct costal and intercostal zones; long cells rectangular or square; cell walls sinuous, hairs unicellular; stomata with subsidiary cells paracytic; short cells present (silica and cork cells) ..... Gramineae
   No distinct zones or true short cells 3
3. Plants with smooth cell walls; stomata anomocyctic ..... Liliaceae
   some ..... Juncaceae
   Plants with cell walls sinuous (Cyperaceae has bright spots resembling silica cells, but do not appear to be true ones) ..... Cyperaceae
   some ..... Juncaceae
4. Tissue fragments without visible stomata, without trichomes, druse present ..... Cactaceae
   Trichomes uni or multicellular; druse absent; cells not rectangular; no distinct zones or short cells; subsidiary cells, if present, vary in type 5

5. Cells colorless; tissue fragments usually absent in feces; trichomes common; normal stomata shape ..... Forbs
Cells of tissue fragments appear thick, usually some pigment remains (yellow, brown, tan); trichomes usually unicellular (multicellular and peltate in *Quercus* species); stomata usually kidney-shaped ..... shrubs or trees

Gramineae

1. Silica cells of the costal zone never H-shaped 8
Silica cells of the costal zone H-shaped or similar 2

2. Silica cells of the costal zone not distinctly H-shaped, varying from near H-shaped, to barbell-shaped, to X-shaped 5
Silica cells of the costal zone distinctly H-shaped or nodular 3

3. H-shaped silica cells over the veins greater than 0.0347 mm. in height; rounded cork cells at the ends of long cells in the intercostal zone ..... *Paspalum dilatatum*
H-shaped silica cells over the veins greater than 0.0347 mm. in height; without rounded cork cells at the ends of long cells in the intercostal zone 4

4. Plants with H-shaped silica cells at the end of the long cells in the intercostal zone; the H-shaped silica cells are paired with crescent-shaped cork cells; subsidiary cells of the stomata triangular ..... *Bothriochloa saccharoides*
Plants without H-shaped silica cells at the ends of long cells in the intercostal zone; cork cells in the intercostal zone round; subsidiary cells of the stomata oval ..... *Schizachyrium scoparium*

5. Long cells of the intercostal region not distinctly rectangular, more hexagonal or oval 7
Long cells of the intercostal region distinctly rectangular 6

6. Silica cells of the costal zone not bone-shaped but saddle-shaped or nodular; silica cells of the intercostal zone rounded and paired with crescent-shaped cork cells ..... *Panicum obtusum*
Silica cells of the costal zone bone-shaped to H-shaped; silica cells of the intercostal zone similar and paired with square cork cells ..... *Panicum obtusum*
Silica cells of the costal zone bone-shaped to H-shaped; silica cells of the intercostal zone similar and paired with square cork cells ..... *Panicum coloratum*

7. Silica cells of the costal zone predominantly H-shaped; large oval cork cells at cell ends in the intercostal zone; long cells more rectangular, but with rounded ends ..... *Setaria leucopila*
Silica cells of the costal zone predominantly bone-shaped; sone H-shaped; occasional large oval cork cells ..... *Setaria geniculata*

8. Silica cells of the costal zone not round 11
Silica cells of the costal zone rounded 9

9. Silica cells of the costal zone irregularly rounded to oblong; infrequent long cell walls smooth; long trichomes or evidence of attachment of trichomes ..... *Bromus unioloides*
Rounded silica cells of the costal zone smooth 10

10. Silica cells of the costal zone rounded and paired with crescent-shaped cork cells; microhairs in the intercostal zone ..... *Sporobolus cryptandrus*
Silica cells of the costal zone rounded but without cork cells; intercostal zone has round silica cells paired with crescent-shaped cork cells; long cell walls only slightly dentate; subsidiary cells of the stomata almost square ..... *Hordeum pusillum*

11. Silica cells of the costal zone not bone-shaped 12
Silica cells of the costal zone bone-shaped; hairs common, distinctive, shaped like rose thorns ..... *Aristida purpurea*

12. Silica cells of the costal zone not wrench-shaped 13
Silica cells of the costal zone wrench-shaped, usually in rows of three ..... *Hilaria belangeri*

13. Silica cells of the costal zone square, not saddle-shaped 16
Silica cells of the costal zone saddle-shaped 14

14. Plants without distinct X-shaped silica cells in the intercostal zone 15
Plants with distinct X-shaped silica cells in the intercostal zone, sometimes paired with accompanying cork cells; long cell ends rounded ..... *Cenchrus incertus*

15. Plants with silica cells of the costal zone paired with crescent-shaped cork cells, long cells large (0.2316 mm. long by 0.0347 mm. high); short hairs at ends of the long cells ..... *Elyonurus tripsacoides*
Plants with long cells of the intercostal zone rectangular; cell walls bulge distinctly for stomata; numerous large, round, cork cells in intercostal zone; large hairs in costal zone or evidence of the attachment of such hairs ..... *Stipa leucotricha*

16. Plants with square silica cells in the costal zone, but without bristles 18
Plants with square silica cells; bristles in the costal zone 17

17. Cell wall between silica cells relatively smooth; silica cells small (0.01158 mm. wide); bristles short (0.04632 mm. long) ..... *Bouteloua curtipendula*
Cell wall between silica cells irregularly undulating ..... *Chloris verticillata*

18. Plants with square silica cells in the costal zone only 20
Plants with square silica cells in both the costal and intercostal zones 19

19. Cell walls of the costal zone are relatively smooth or straight-sided, large oval stomata; silica cells paired with cork cells; some silica cells in the intercostal zone paired with cork cells ..... *Tridens congestus*
Silica cells that occur in the intercostal zone each accompanied by a cork cell; silica cells 0.0347 mm. high, cell walls of the costal zone dentate and pointed ..... *Bouteloua hirsuta*

20. Cell walls of the costal zone slightly dentate ..... *Buchloe dactyloides*
Cell walls of the costal zone dentate and rounded; long cells of the intercostal zone much elongated ..... *Eragrostis silveana*

Forbs

1. Plants with trichomes 6
Plants without visible trichomes 2

2. Cell arrangement linear 3
   Cell arrangement not linear, stomata paracytic ..... *Xanthocephalum texanum*
3. Cell walls dentate ..... *Cyperus* species
   Cell walls smooth 4
4. Linear rectangular cells having stomata without special subsidiary cells (anomocytic) 5
   Linear cells, semi-rectangular, with widest portion of cell at middle; stomata with paracytic subsidiary cells ..... *Salsola kali*
5. Plants with exceptionally long cells and with sunken stomata ..... *Allium drummondii*
   Plants with rectangular cells, stomata not sunken ..... *Nothoscordum bivalve*
6. Trichomes multicellular (having both multi and unicellular trichomes in *Sida* species) 11
   Trichomes unicellular 7
7. Unicellular trichomes not branched 8
   Unicellular trichomes branched ..... *Lesquerella lindheimeri*
8. Trichomes without center attachment 9
   Trichomes with center attachment ..... *Phyla incisa*
9. Trichomes without minute spines 10
   Trichomes with minute spines ..... *Oxalis dillenii*
10. Trichomes curved ..... *Oenothera speciosa*
    Trichomes not curved ..... *Verbena plicata*
11. Plants with stellate trichomes 19
    Plants without stellate trichomes 12
12. Plants with trichomes consisting of a single row of cells 13
    Plants with dendroid trichomes ..... *Chamaesarcha sordida*
13. Top segment or cell of trichome elongated into a long tapering point 15
    Top segment of cell of trichome having a very short, acute point 14
14. Trichomes with numerous minute spines having one long middle segment in addition to the basal attachment and the short top segment ... *Zexmenia hispida*
    Trichomes without spines, having three middle segments in addition to the basal attachment and the short top segment ..... *Simsia calva*
15. Trichomes not having top segment hook-shaped 16
    Trichomes having top segment hook-shaped, stomata sunken ..... *Commelina erecta*
16. Trichomes more than two segments 17
    Trichomes with two segments bearing minute pubescences .... *Kochia scoparia*
17. Trichomes with predominantly three segments 18
    Trichomes with 2, 3, or 4 segments; trichomes unusually long, shortest 0.926 mm. average 1.3896 mm. ..... *Rudbeckia serotina*

18. Distal segment of trichome less than 0.2316 mm. long; basal segment much thicker than other segments ..... *Ambrosia psilostachya*
    Distal segment of trichome more than 0.2799 mm. long; top segment much longer than other segments ..... *Ratibida columnaris*
19. Stellate trichomes with more than four arms 20
    Trichomes with four arms in parallel pairs, resembling a large H ..... *Malvastrum coromandelianum*
20. Trichomes with 10 arms or less 23
    Trichomes with more than 10 arms 21
21. Trichomes with arms wider at base and tapering to a point, not stringlike 22
    Trichomes very slim, appearing stringlike, not wider at base of arms ..... *Sphaeralcaea lindheimeri*
22. Trichome arms less than 0.405 mm. in length ..... *Solanum elaeagnifolium*
    Trichome arms more than 0.405 mm. in length; two trichomes commonly connected by a section of tissue ..... *Croton capitatus*
23. Trichome arms over 0.174 mm. in length 25
    Trichome arms 0.174 mm. or less in length 24
24. Trichome arms unequal with at least two arms conspicuously longer than the others; when visible, there is a basal attachment for the trichome ..... *Sida filicaulis*
    Trichome arms relatively equal in length; basal attachment for trichome constricted just above attachment ..... *Abutilon incanum*
25. Trichome arms relatively symmetrically arranged and of equal length ..... *Malvastrum aurantiacum*
    Trichome arms not symmetrical, with at least two arms conspicuously longer than the others ..... *Sida ciliaris*

Shrubs

1. Plants without glandular trichomes 2
   Plants with glandular trichomes ..... *Rhus aromatica*
2. Trichomes unicellular 3
   Trichomes multicellular, peltate ..... *Quercus virginiana*
3. Trichomes with basal attachment 4
   Trichomes with center attachment ..... *Bumelia lanuginosa*
4. Trichomes relatively short and thick, under 0.19686 mm. 6
   Trichomes long and thin, over 0.19686 mm. 5
5. Trichomes over 0.19686 mm. but under 0.3474 mm. ..... *Ziziphus obtusifolia*
   Trichomes over 0.3474 mm., thicker at base ..... *Celtis reticulata*
6. Cell walls wavy and stomata anomocytic ..... *Diospyros texana*
   Cell walls smooth and stomata paracytic ..... *Prosopis glandulosa*

Grasses

Aristida purpurea.—Silica cells in the costal zone barbell-shaped; occasionally, oval to square-shaped cork cells at the ends of the long cells in the intercostal zone. Long cell walls dentate; cells rectangular. Cork cells best seen at 400×. *A. purpurea* has bristles paired with silica cells over the veins. Trichomes resemble rose bush thorns. Reference slide 1A; fecal slide 1B.

Bothriochlea saccharoides.—Silica cells H-shaped, occurring in the costal and intercostal zones. Cork cells round, coupled with silica cells or at ends of long cells. Long cell walls thick and sinuous. Stomata have triangular-shaped subsidiary cells. Reference slide 2A; fecal slide 2B.

Bouteloua curtipendula.—Even, smooth rows of square silica cells in the costal zone, as well as microhairs present in this region. Frequent bristles occur in the costal zone. In the intercostal zone, long cells rectangular in shape with ends either cork cells or cork cells paired with square silica cells or sometimes bristles. In fecal slides, the costal zone, with its smooth cell walls, will be apparent. Reference slide 3A; fecal slide 3B.

Bouteloua hirsuta.—Silica cells of the costal region square; those of the intercostal zone each accompanied by a cork cell. Cell walls of the costal zone dentate and pointed. Bristles infrequent or absent. Reference slide 4A; fecal slide 4B.

Bromus unioloides.—Silica cells of the costal zone circular to oblong with sinuous walls, whereas silica cells of the intercostal zone oval, paired with crescent-shaped cork cells. Cell walls of the long cells have shallow undulations. Trichomes long and thin when visible with large base—usually appears to have no silica cells and smooth long cell walls. Stomata without visible subsidiary cells. Reference slides 5A, 5B; fecal slides 5C, 5D.

Buchloe dactyloides.—Silica cells of the costal zone square. Rows of long cells containing stomata wider than other rows of long cells. Cell walls of the costal zone wavy or moderately sinuous. Very long microhairs in the intercostal zone, when visible. Cell ends are silica cells paired with cork cells. Reference slide 6A; fecal slide 6B.

Cenchrus incertus.—Silica cells in the costal zone saddle-shaped, bristles also apparent in the zones. Silica cells in the intercostal zone X-shaped. Long cells rectangular and sinuous. Subsidiary cells of stomata indistinct. Cork cells of intercostal zone round, occurring at the ends of long cells. Reference slide 7A; fecal slide 7B.

Chloris verticillata.—Silica cells in costal zone square, with very dentate cell walls between them. Bristles in costal zone. Stomata frequent, evenly spaced, and round. Long cells rectangular with dentate cell walls. Cork cells present at ends of long cells. Reference slide 8A; fecal slide 8B.

Elyonurus tripacoides.—Silica cells in costal zone saddle-shaped, sometimes paired with crescent-shaped cork cells. Long cells of intercostal zone rectangular to diamond-shaped, with cork cells at their ends. Cell walls thick and sinuous. Stomata have oval to triangular subsidiary cells. Bristles at the ends of some long cells. Reference slide 9A; fecal slide 9B.

Eragrostis silveana.—Silica cells of costal zone square, sometimes paired with cork cells; silica cells of intercostal zone not paired with cork cells. Uniform cell structure. Stomata round. Reference slide 10A; fecal slide 10B.

Hilaria belangeri.—Silica cells of costal zone wrench-shaped, usually in rows of three; bristles noted in costal zone. Intercostal zone occasionally appears covered with black dots. Reference slide 11A; fecal slide 11B.

Hordeum pusillum.—Silica cells in costal zone round; those in intercostal zone paired with crescent-shaped cork cells. Long cells of intercostal zone with shallow, sinuous cell walls. Stomata appear square. Reference slide 12A; fecal slide 12B.

Panicum coloratum.—Silica cells in costal zone bone-shaped. Long cells of intercostal zone rectangular to diamond-shaped; cell walls not deeply sinuous. Bristles frequent in intercostal zone, sometimes paired with cork cells. Silica cells of intercostal zone bone to X-shaped, occasionally paired with a square cork cell. Subsidiary cells of stomata sometimes indistinct. Reference slide 13A; fecal slide 13B.

Panicum obtusum.—Silica cells of costal zone saddle-shaped to nodular. Silica cells of intercostal zone, when present, rounded and paired with crescent-shaped cork cells at ends of long cells. Long cell walls of intercostal zone dentate, uneven, rounded; microhairs visible at ends of long cells. Stomata appear triangular. Reference slide 14A; fecal slide 14B.

Paspalum dilatatum.—Silica cells of costal zone predominantly H-shaped to nodular. Cell walls of intercostal zone unevenly dentate. H-shaped silica cells paired with cork cells at ends of long cells. Stomata large. Reference slide 15A; fecal slide 15B.

Schizachyrium scoparium.—Silica cells in costal zone H-shaped to barbell-shaped. Cork cells oval, occurring at cell ends in inter-

costal zone. Bristles at some cell ends. Cell wall thick and sinuous. Cell ends are bristles, round cork cells, cork cells paired with silica cell, or a microhair. Long cells rectangular. No H-shaped silica cells in intercostal zone. Reference slide 16A; fecal slide 16B.

Setaria geniculata.—Silica cells in costal zone bone-shaped, usually in rows of three. Long cells of intercostal zone rectangular to diamond-shaped, with cell ends rounded. Round cork cells present at ends of long cell; sometimes paired with oval silica cells. Reference slide 17A; fecal slide 17B.

Setaria leucopila.—Silica cells of costal zone either saddle-shaped to H-shaped or nodular. Long cells of intercostal zone rectangular, some hexagonal. Microhairs present. Round cork cells present at some cell ends. Reference slide 18A; fecal slide 18B.

Sporobolus cryptandrus.—Silica cells round, paired with crescent-shaped cork cells, in costal and intercostal zones. No apparent unpaired short cells. Long cells of intercostal zone bulge at stomata. Long cells rectangular and paired short cells at cell ends. Reference slide 19A; fecal slide 19B.

Stipa leucotricha.—Silica cells of costal zone saddle-shaped, sometimes paired with square cork cells. Long cells of intercostal zone rectangular and bulge at stomata; their ends have cork cells, sometimes paired with silica cells. Reference slides 20A, 20B; fecal slide 20C.

Tridens congestus.—Silica cells of costal zone square and not paired with cork cells. Cell walls of costal zone smooth and straight sided. Long cells of intercostal zone rectangular, with cork cells at cell ends. Reference slide 21A; fecal slide 21B.

Forbs

Abutilon incanum.—Stellate trichomes, usually five to 12 short arms; basal attachment is constricted just above the point of attachment. Arms relatively uniform in length. Reference slide 22A; fecal slide 22B.

Allium drummondii.—Cells arranged in parallel rows, walls smooth, ends indistinct. Cells wider in middle than at either end; cells exceptionally long and without visible trichomes. Stomata sunken, anomocytic. Reference slide 23A; no photo of fecal slide available as digestion is complete.

Ambrosia psilostachya.—Cell walls smooth. Trichomes predominately three segmented, basal segment being much thicker than others. Stomata anomocytic. Reference slide 24A; fecal slide 24B.

Chamaesarcha sordida.—Cell walls dentate and angular. Trichomes dendroid, usually branched into two arms. Stomata anomocytic. Reference slide 25A; fecal slide 25B.

Commelina erecta.—Cell walls smooth, angular. Trichomes three-segmented; distal segment bent and resembling a hook. Stomata large, sunken, and paracytic. Reference slide 26A, sunken stomata; 26B, trichomes; fecal slide 26C, trichome.

Croton capitatus.—Stellate trichomes, 10 to 15 arms. Arms uniform in length and evenly spaced. Usually two trichomes are connected. Reference slides 27A, 27B; fecal slide 27C.

Cyperus stringosus.—Costal and intercostal zones both appear present. Silica cells visible as bright bumps. Long cells cuboidal. Stomata diacytic. Reference slide 28A; fecal slide 28B.

Juncus brachycarpus.—Cell walls smooth. Stomata anomocytic. Reference slide 29A (leaf), 29B (seed). No fecal slide photo available as digestion is complete.

Kochia scoparia.—Trichomes with two long, thin, pubescent segments. Reference slide 30A; fecal slide 30B.

Lesquerella gordonii.—Trichomes branched, usually with four main arms, each of which branches into two arms. Trichomes also show a circular protrusion at the center. Cells puzzle-shaped. Stomata small and anisocytic. Reference slide 31A; fecal slide 31B.

Malvastrum aurantiacum.—Trichomes stellate with approximately eight, thick, yellow-colored, arms. Arms uniform in length and evenly spaced. Reference slide 32A; fecal slide 32B.

Malvastrum coromandelianum.—Trichomes large and H-shaped. Arms thick and yellow. Pollen round and spikey. Reference slide 33A (pollen), 33B (trichome); fecal slide 33C.

Nothoscordum bivalve.—Cells in a linear arrangement in parallel rows. Cells also rectangular with smooth walls. Stomata anomocytic, not sunken. Reference slide 34A; no fecal slide available as digestion is complete.

Oenothera speciosa.—Cell walls wavy. Trichomes unicellular and sometimes pubescent. Stomata anomocytic. Pollen dark gold, having three winglike parts marked with parallel lines. Reference slide 35A (pollen), 35B (trichome), 35C (flower); fecal slide 35D.

Oxalis dillenii.—Trichomes unicellular, pubescent, and occasionally appearing pink or purple in color. Trichomes also slightly curved; a small stem attaches it to epidermal tissue. Reference slide 36A; fecal slide 36B.

Phyla incisa.—Trichomes unicellular, tapered at both ends, and attached at center. Reference slide 37A; fecal slide 37B.

Ratibida columnaris.—Trichomes three-segmented; distal segment at least twice as long as others. Reference slide 38A; fecal slide 38B.

Rudbeckia serotina.—Trichomes extremely large, usually containing four segments. Reference slide 39A; fecal slide 39B.

Salsoa kali.—Cells in a linear arrangement in parallel rows. Cell walls smooth, narrower at ends than in middle. Stomata paracytic. Reference slide 40A (leaf), 40B (trichome). No fecal slide photo available as digestion is complete.

Sida ciliaris.—Trichomes stellate with at least two arms longer than others; some trichomes extremely long and unicellular. Arms thick and unevenly spaced. Reference slide 41A; fecal slide 41B.

Sida filicaulis.—Trichomes essentially stellate with basal attachment; stellate arms, short and thin, numbering approximately seven; at least two arms longer than others. Some short unicellar trichomes. Reference slide 42A; fecal slide 42B.

Simsia calva.—Trichomes smooth and four-segmented; distal segment very short and pointed, caplike. Reference slide 43A; fecal slide 43B.

Solanum elaeagnifolium.—Trichomes stellate. Arms usually eight to 14 in number, uniform in length and spacing, but wider at base than tip. Reference slide 44A; fecal slide 44B.

Sphaeralcea lindheimeri.—Trichomes stellate. Arms generally 14 to 16 in number, long, and very thin, curved, and evenly spaced. Reference slide 45A; fecal slide 45B.

Verbena plicata.—Trichomes unicellular, not curved, and with basal segment much larger than distal segment. Cell walls angular. Stomata anomocytic. Reference slide 46A; fecal slide 46B.

Xanthocephalum texanum.—Cell walls smooth; cells square or rectangular. No visible trichomes. Stomata paracytic. Reference slide 47A; fecal slide 47B.

Zexmenia hispida.—Trichomes with a basal cell, a long middle segment, and a caplike distal segment. Trichomes covered with minute spines, except for the caplike distal segment. Reference slide 48A; fecal slide 48B.

Shrubs

Bumelia lanuginosa.—Trichomes unicellular and attached to the epidermis by a branched arm at the center. Reference slide 49A; fecal slide 49B.

Celtis reticulata.—Trichomes unicellular, long, and thin; basal portion much thicker than distal portion. Reference slide 50A; fecal slide 50B.

Diospyros texana.—Trichomes short, thick, and unicellular. Cell walls wavy. Triangular attachment. Stomata anomocytic. Reference slide 51A; fecal slide 51B.

Opuntia polycantha.—Cells, octangular in shape, oftentimes dense and yellow in color. Other parts of epidermis with indistinct cell walls and large round druse or circular indentations where druse had been. Stomata paracytic. Pollen is large and round, golden brown in color. Lighter gold areas surrounded by darker colored cells; appear lacy. Seed coat a series of stacked circular cells. Reference slides 52A (octangular cells), 52B (druse), 52C (pollen), 52D (seedcoat); fecal slide 52E (druse).

Prosopis glandulosa.—Trichomes unicellular, short, pubescent. Leaf cells smooth walled, square or rectangular in shape. Stomata paracytic. Sprouts with very small, unicellular, pubescent trichomes. Thorns show small, paracytic stomata and very short, smooth trichomes. Bean pod has indistinct cell walls but enlarged stomata. Reference slides 53A (leaf), 53B (bean), 53C (sprout), 53D (thorn); fecal slides 53E (leaf), 53F (bean), 53G (thorn).

Quercus virginiana.—Trichomes peltate; center attachment unique, much different from forbs. Arms uniform in length and all curved in same direction; arms lacking special means of attachment, just come together. Reference slide 54A; fecal 54B.

Rhus aromatica.—Trichomes multicellular, glandular, with a single base cell; several cells attached to base cell give trichome a mushroomlike appearance. Trichomes also large, unicellular. Cell walls smooth. Stomata frequent, anomocytic.

The berry of this plant is important in diet work. Stomata large, cells cuboidal and cream colored. Centers of cells are either paler or darker than rest of cell. Reference slides 55A (glandular trichome), 55B (berry), 55C (trichome), 55D (bark); fecal slides 55E (trichome), 55F (berry).

Ziziphus obtusifolia.—Trichomes infrequent, unicellular. Cell wall smooth; cells square to rectangular. Stomata paracytic. Reference slides 56A (trichome), 56B (bark); fecal slide 56C.

Insect Part

No cell walls, pigmented, usually appears transparent. Fecal slide 57A.

Glossary

Costal zone.—longitudinal zone of grass leaf that follows the veins.
Dentate.—indentations in cell wall.

Druse.—a group of crystals formed by deposits of inorganic materials, usually calcium oxalate. Group of crystals united into a compound structure.

Intercostal zone.—longitudinal zone of the grass leaf between the veins.

Long cell.—found in the intercostal zone of grasses; usually of a somewhat rectangular shape, being longer than wide.

Microhair.—two-celled hair, although the distal cell is commonly missing, that appears in the costal and intercostal zones.

Short cells.—occur in the costal and intercostal zones of grasses, but predominantly in the costal zone. There are two kinds: cork cells, which are usually paired with silica cells or occur at the end of a long cell; silica cells, which appear in the costal and intercostal zones—those occurring in the costal zone are most useful as diagnostic characteristics of grasses.

Sinuous.—with a strongly wavy margin.

Stellate trichome.—refers to star-shape; many arms extend from a central point of attachment.

Stomata.—in grasses, they occur only in the intercostal zone. In shrubs and forbs, the stomata are dispersed throughout the leaf. Stomata consist of three parts: pore, the opening itself; guard cells, two cells that surround the pore and control the size of the pore opening; subsidiary cells, which always number two in grasses and occur next to the guard cells. In shrubs and forbs there are two or more subsidiary cells, or none at all, also next to guard cells.

Trichome.—epidermal hair, sometimes called macrohair in grasses.

Bristle.—also known as prickle hair. Robust, sharply but shortly pointed structure with swollen base. In grasses only. Observed in the costal and intercostal zones.

Peltate hairs.—shield-shaped hair attached by its lower surface.

Undulations.—indentations in the cell wall.

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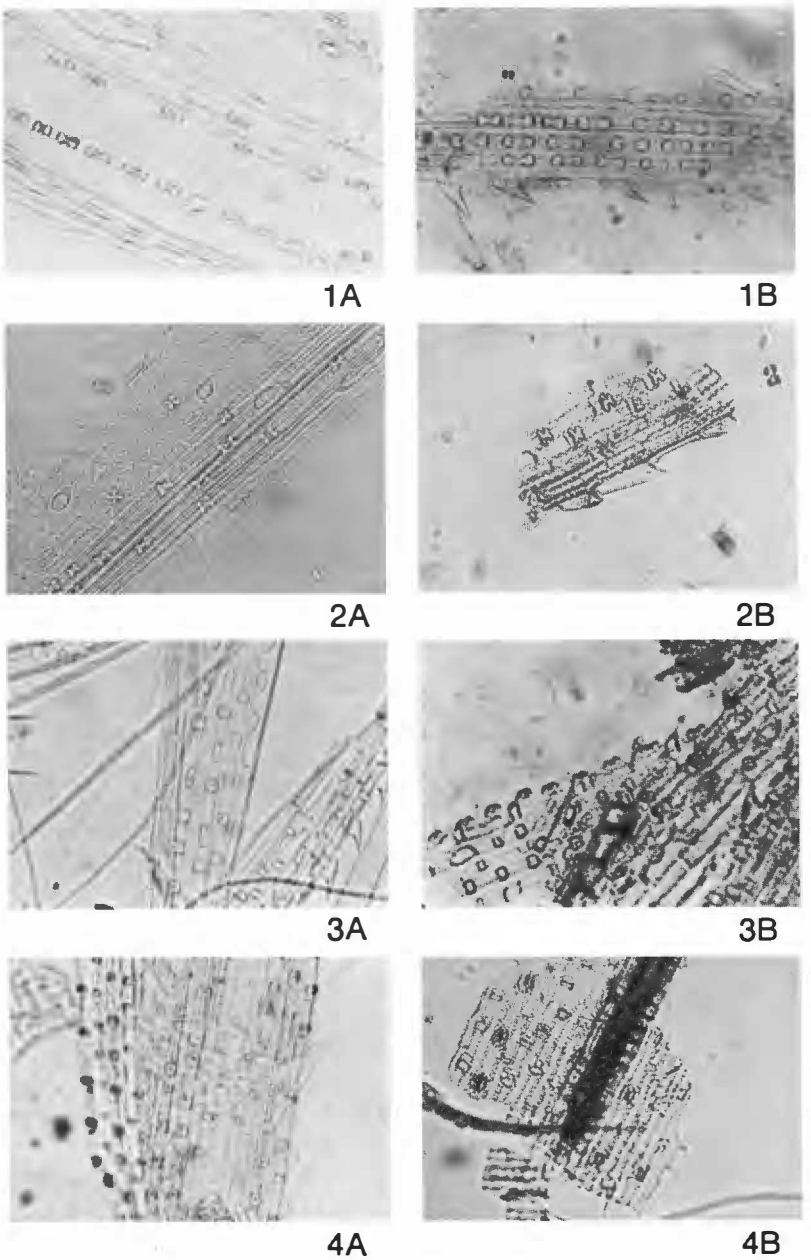
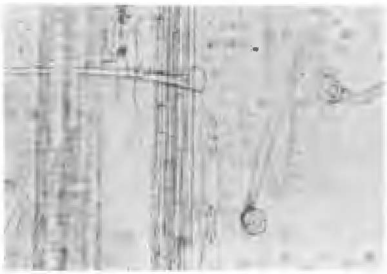
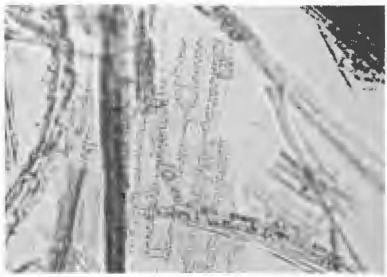


PLATE 1.—Photomicrographs of reference and fecal slides for *Aristida purpurea*, 1A-B; *Bothriochlea saccharoides*, 2A-B; *Bouteloua curtipendula*, 3A-B; *Bouteloua hirsuta*, 4A-B.

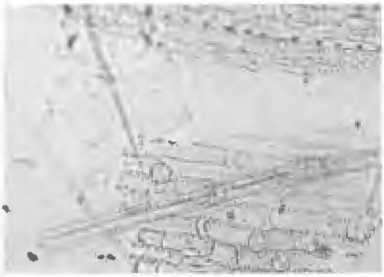


5A

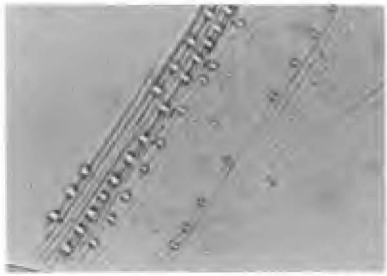
5B



5C



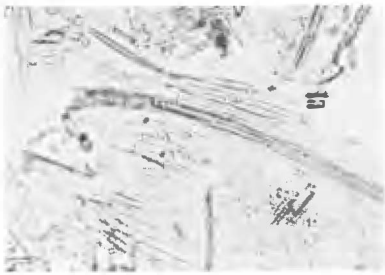
5D



6A

6B

7A



7B

PLATE 2.—Photomicrographs of reference and fecal slides for *Bromus unioloides*, 5A-D; *Buchloe dactyloides*, 6A-B; *Cenchrus incertus*, 7A-B.

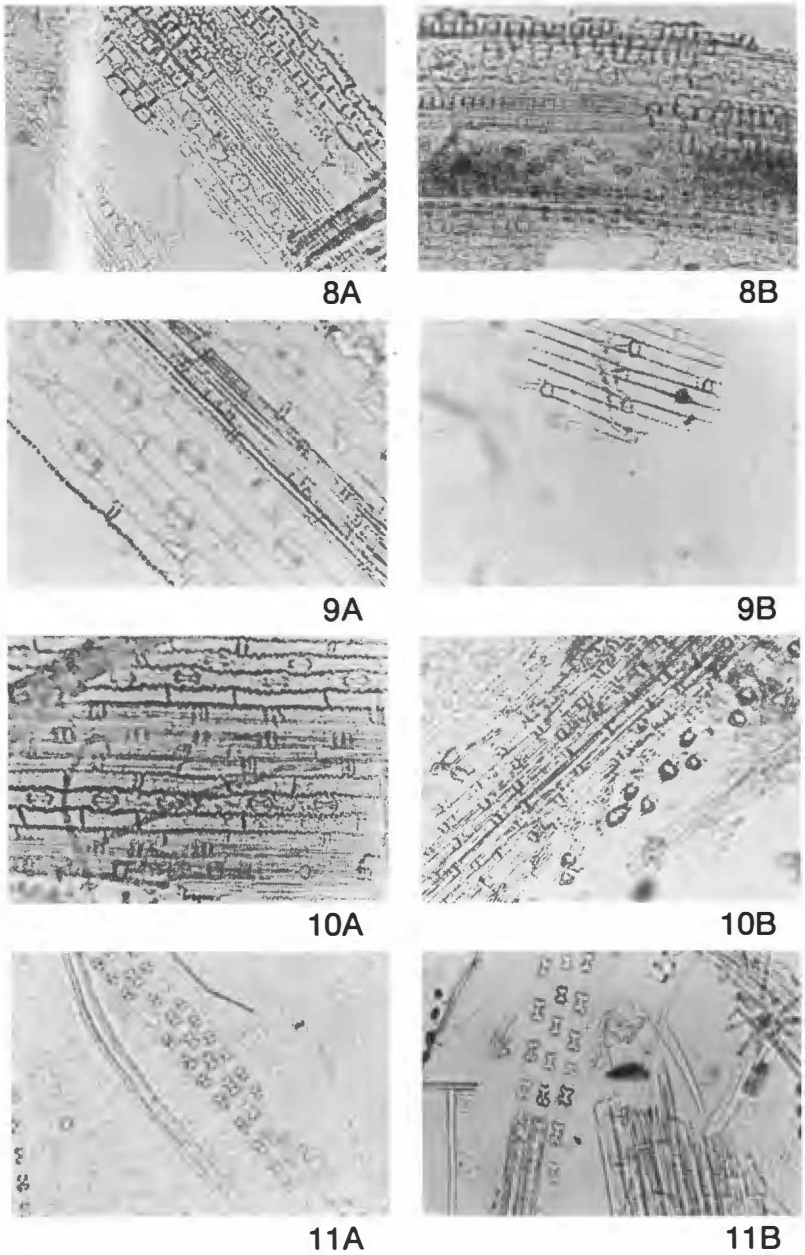


PLATE 3.—Photomicrographs of reference and fecal slides for *Chloris verticillata*, 8A-B; *Elyonurus tripsacoides*, 9A-B; *Eragrostis silveana*, 10A-B; *Hilaria belangeri*, 11A-B.

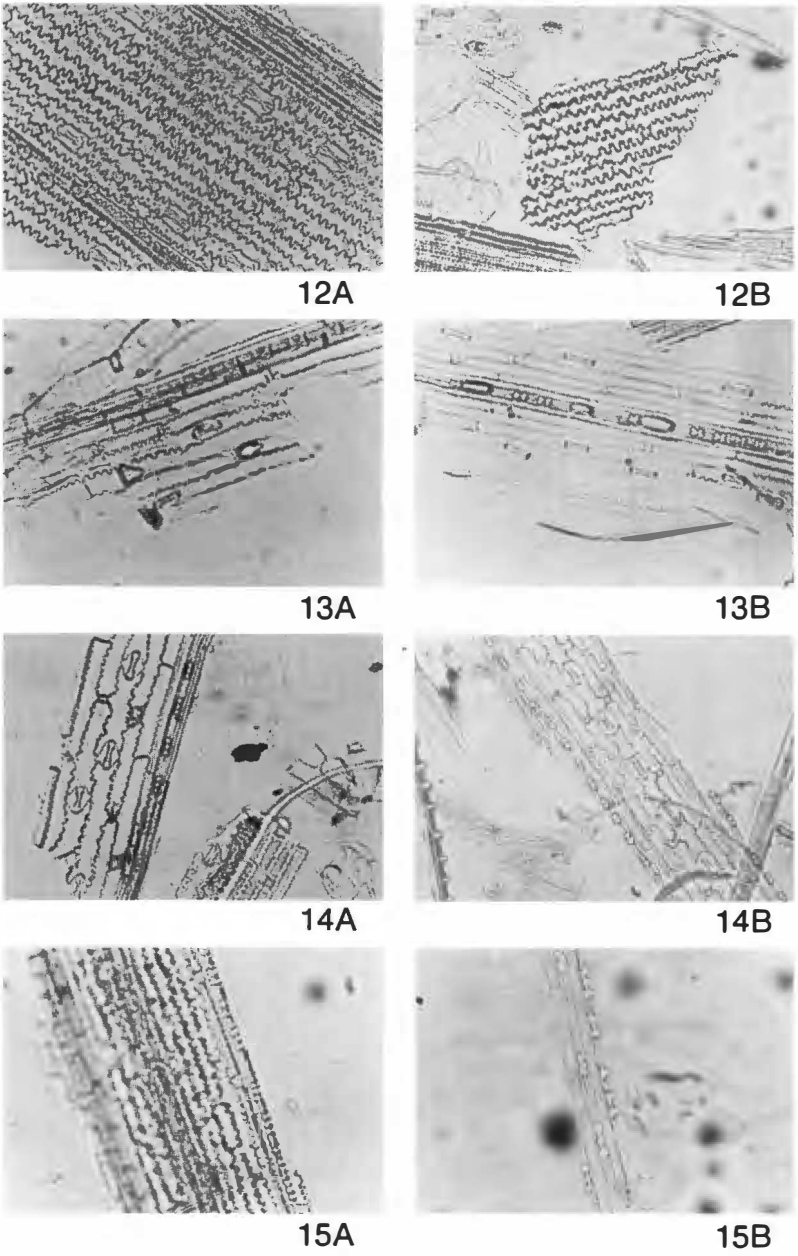
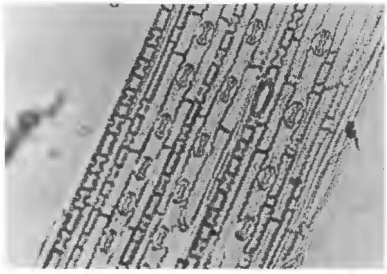
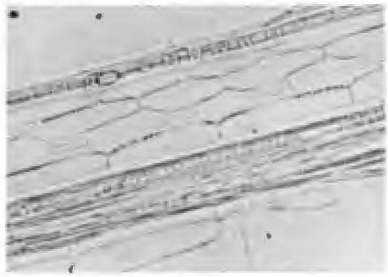


PLATE 4.—Photomicrographs of reference and fecal slides for *Hordeum pusillum*, 12A-B; *Panicum coloratum*, 13A-B; *Panicum obtusum*, 14A-B; *Paspalum dilatatum*, 15A-B.

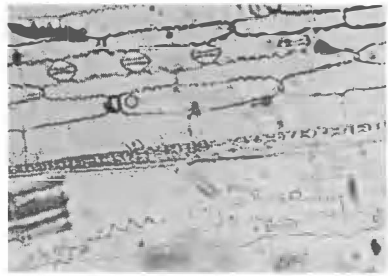


16A

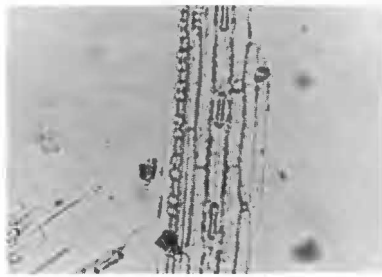
16B



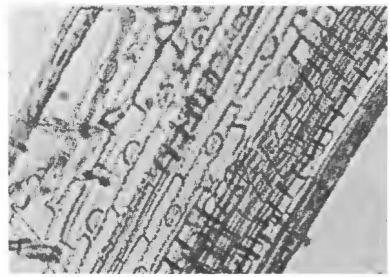
17A



17B

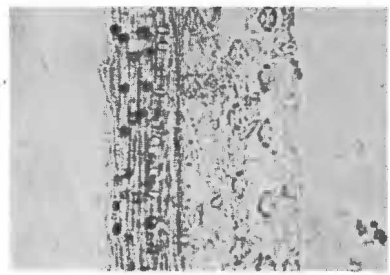


18A



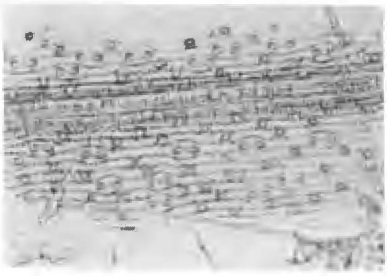
18B

19A

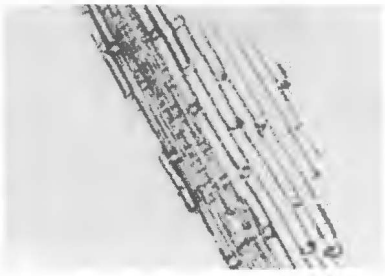


19B

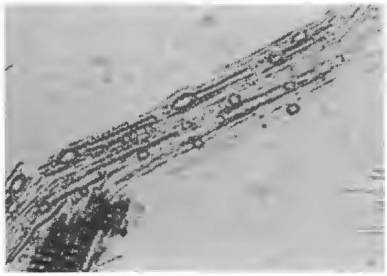
PLATE 5.—Photomicrographs of reference and fecal slides for *Schizachyrium scoparium*, 16A-B; *Setaria geniculata*, 17A-B; *Setaria leucopila*, 18A-B; *Sporobolus cryptandrus*, 19A-B.



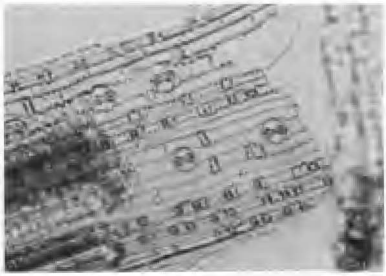
20A



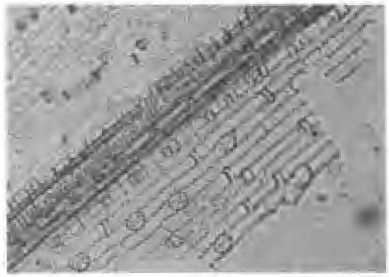
20B



20C



21A



21B

22A

22B

23A

PLATE 6.—Photomicrographs of reference and fecal slides for *Stipa leucotricha*, 20A-C; *Tridens congestus*, 21A-B; *Abutilon incanum*, 22A-B; *Allium drummondii*, 23A.

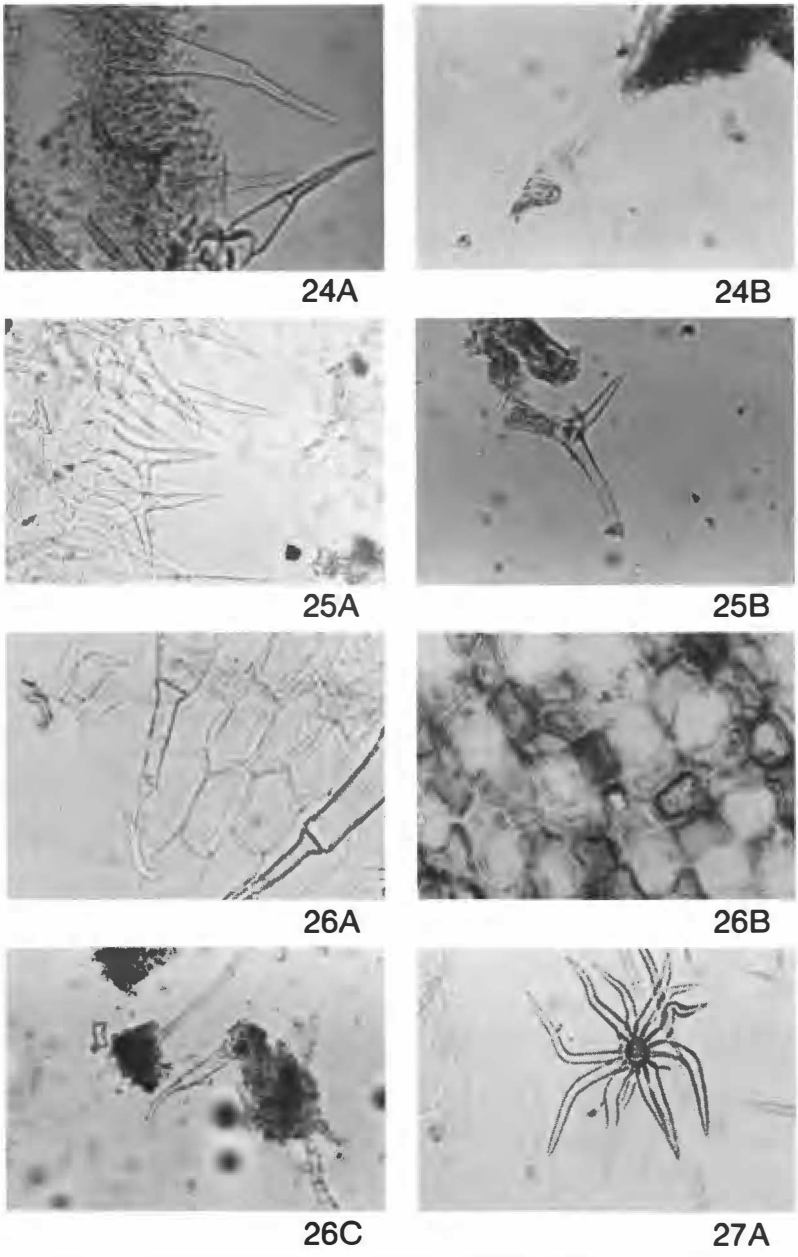
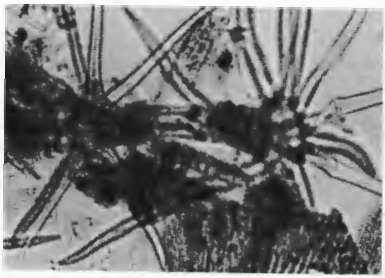
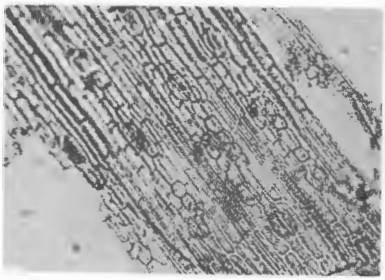
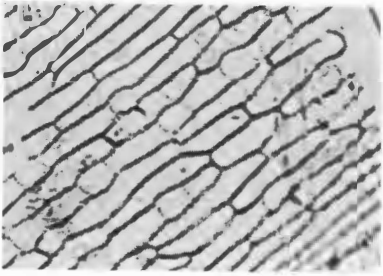
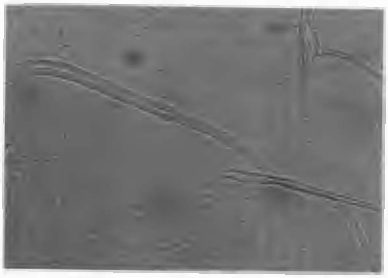


PLATE 7.—Photomicrographs of reference and fecal slides for *Ambrosia psilostachya*, 24A-B; *Chamaesarcha sordida*, 25A-B; *Commelina erecta*, 26A-C; *Croton capitatus*, 27A.









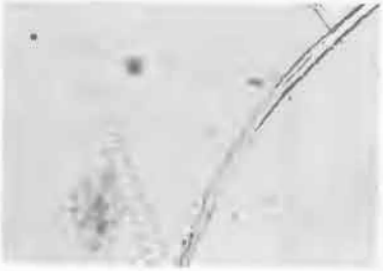


PLATE 8.—Photomicrographs of reference and fecal slides for *Croton capitatus*, 27B-C; *Cyperus stringosus*, 28A-B; *Juncus brachycarpus*, 29A-B; *Kochia scoparia*, 30A-B.

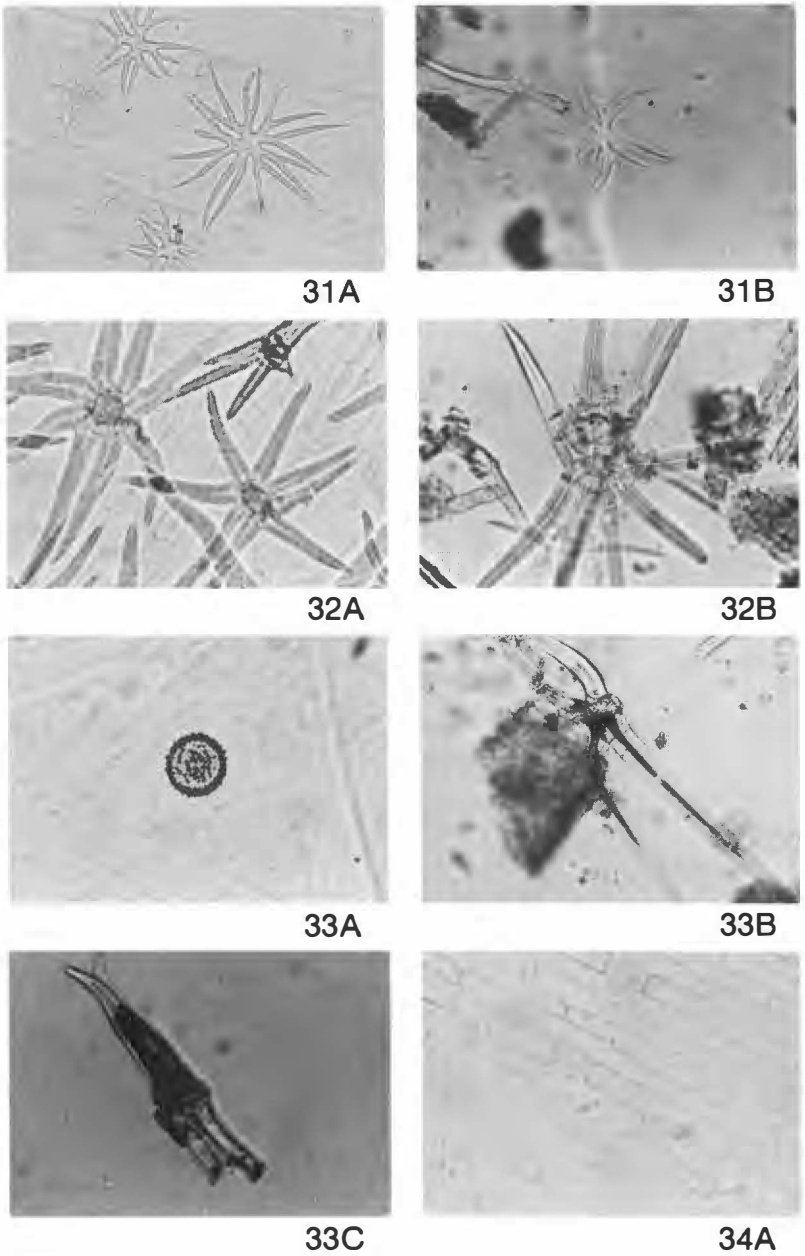
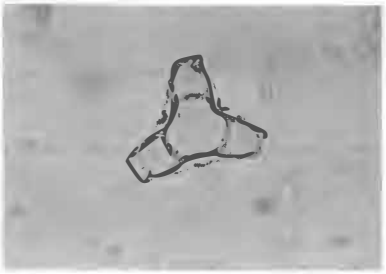
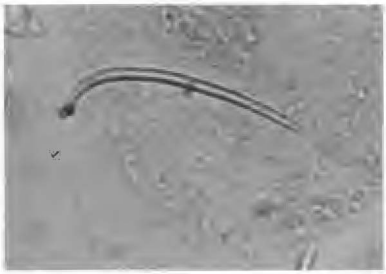


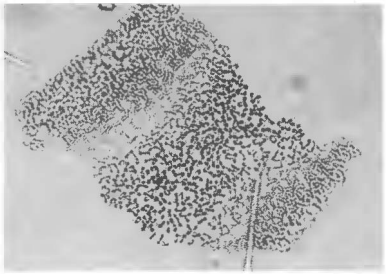
PLATE 9.—Photomicrographs of reference and fecal slides for *Lesquerella gordoni*, 31A-B; *Malvastrum aurantiacum*, 32A-B; *Malvastrum coromandelianum*, 33A-C; *Nothoscordum bivalve*, 34A.



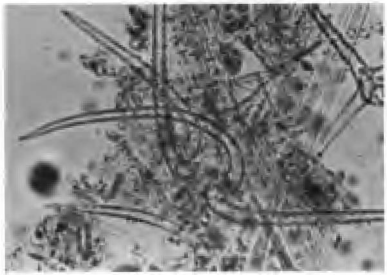
35A



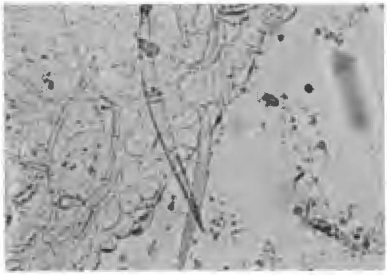
35B



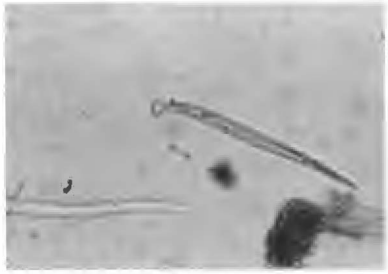
35C



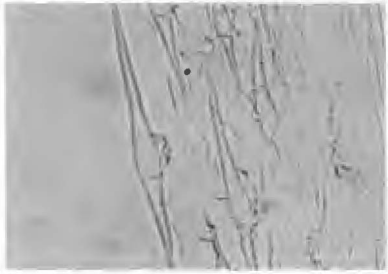
35D



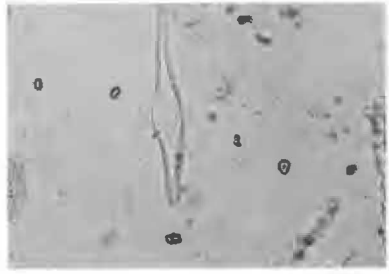
36A



36B

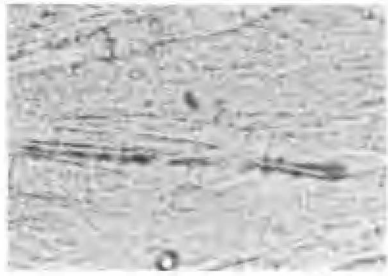


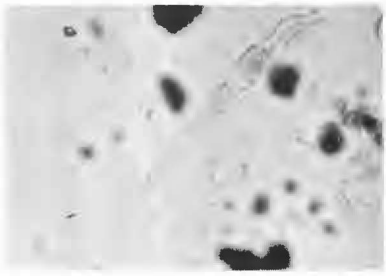
37A

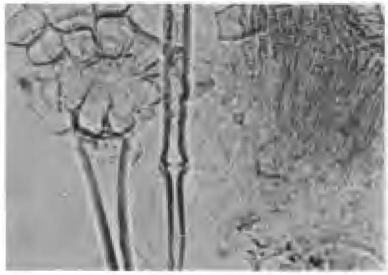


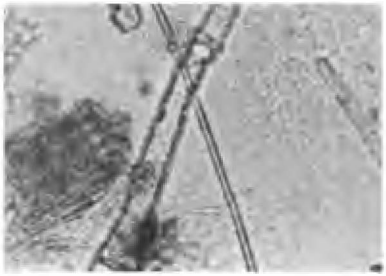
37B

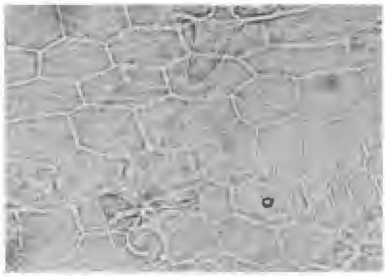
PLATE 10.—Photomicrographs of reference and fecal slides for *Oenothera speciosa*, 35A-D; *Oxalis dillenii*, 36A-B; *Phyla incisa*, 37A-B.











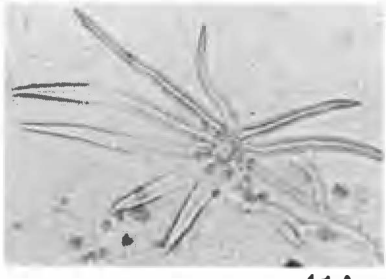
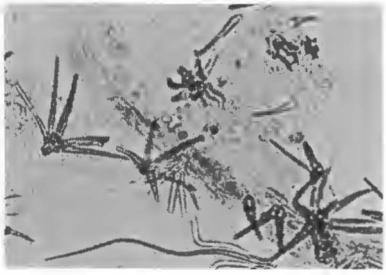
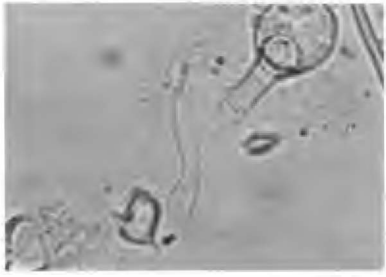


PLATE 11.—Photomicrographs of reference and fecal slides for *Ratibida columnaris*, 38A-B; *Rudbeckia serotina*, 39A-B; *Salsoa kali*, 40A-B; *Sida ciliaris*, 41A-B.

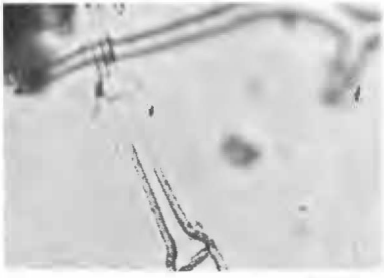


42A

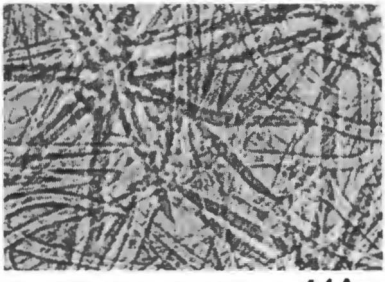
42B



43A



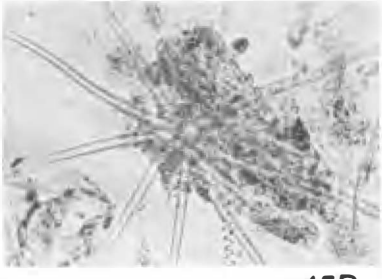
43B



44A

44B

45A



45B

PLATE 12.—Photomicrographs of reference and fecal slides for *Sida filicaulis*, 42A-B; *Simsia calva*, 43A-B; *Solanum elaeagnifolium*, 44A-B; *Sphaeralcea lindheimeri*, 45A-B.

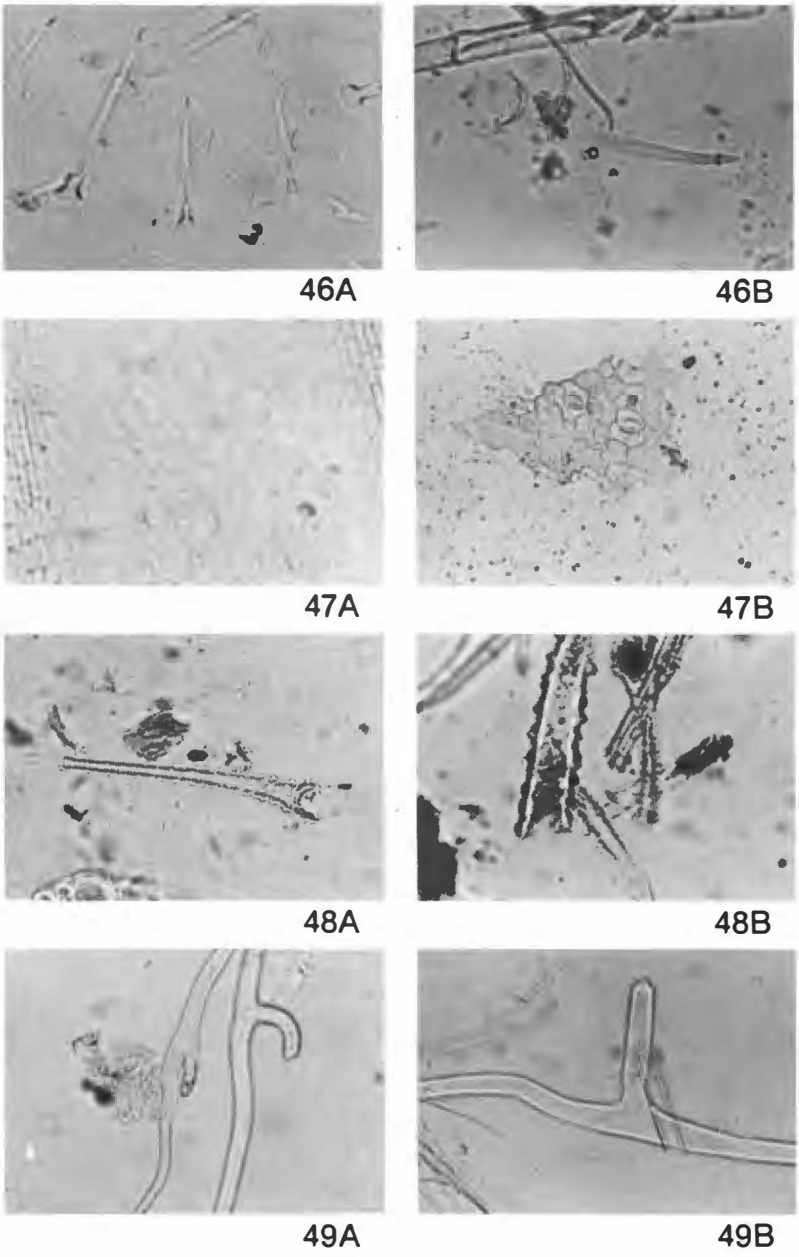


PLATE 13.—Photomicrographs of reference and fecal slides for *Verbena plicata*, 46A-B; *Xanthocephalum texanum*, 47A-B; *Zexmenia hispida*, 48A-B; *Bumelia lanuginosa*, 49A-B.

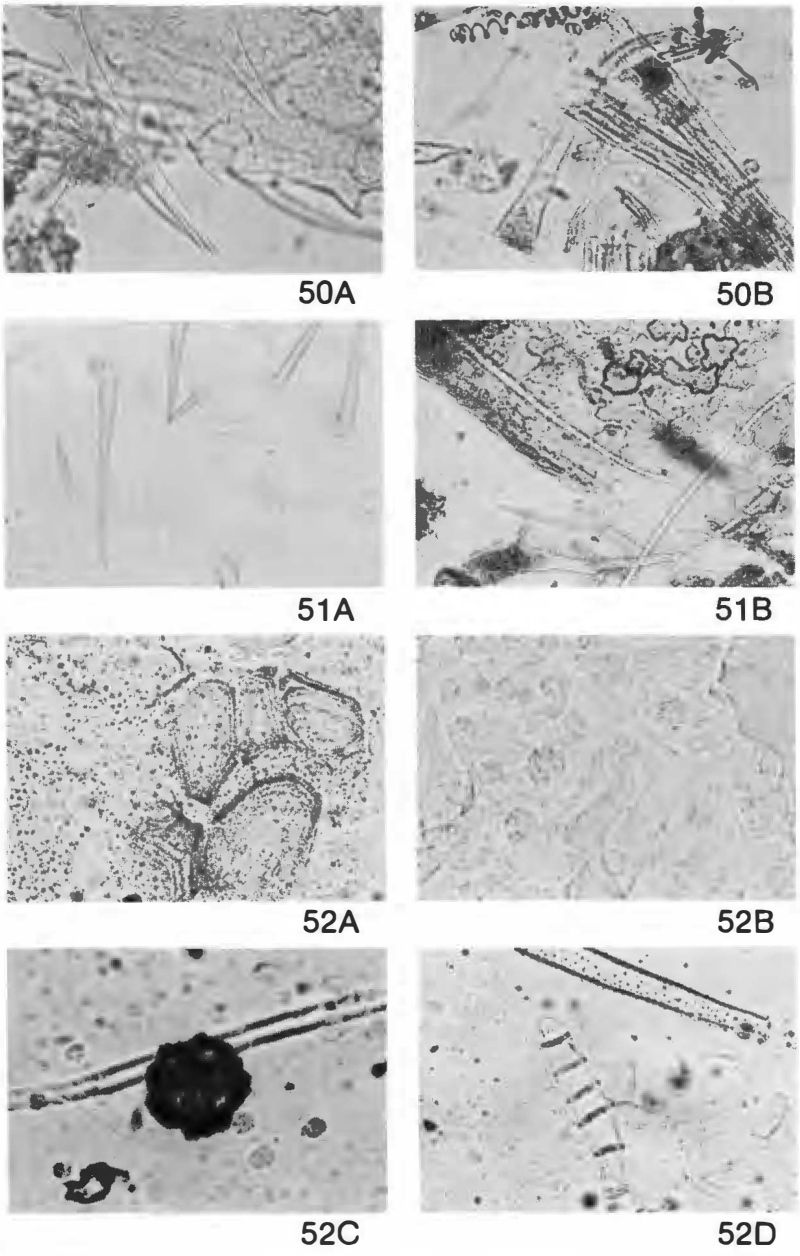
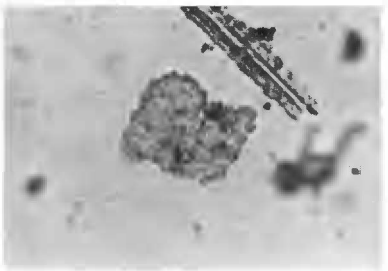
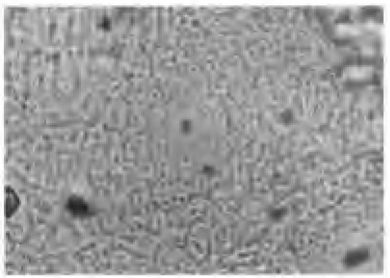
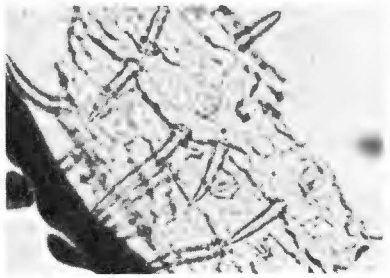
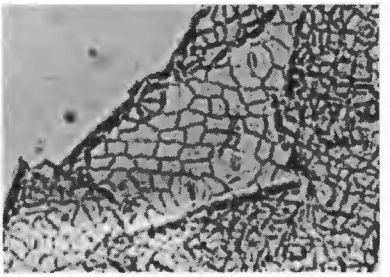


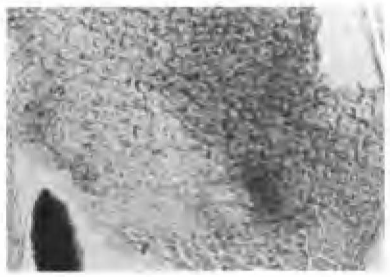
PLATE 14.—Photomicrographs of reference and fecal slides for *Celtis reticulata*, 50A-B; *Diospyros texana*, 51A-B; *Opuntia polycantha*, 52A-D.











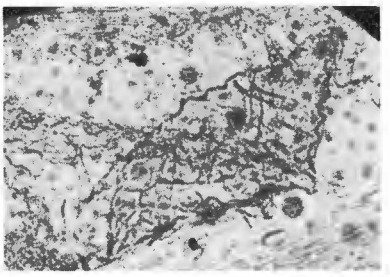


PLATE 15.—Photomicrographs of reference and fecal slides for *Opuntia polycantha*, 52E; *Prosopis glandulosa*, 53A-G.

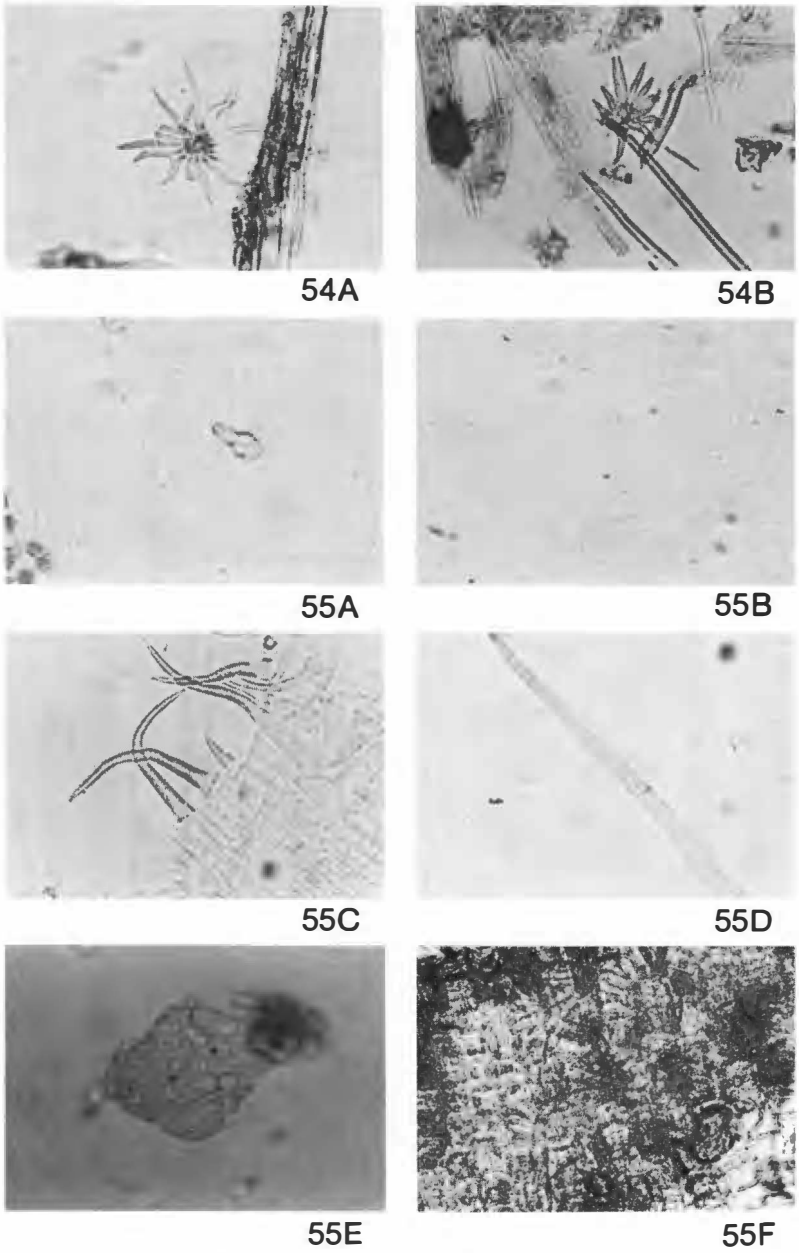


PLATE 16.—Photomicrographs of reference and fecal slides for *Quercus virginiana*, 54A-B; *Rhus aromatica*, 55A-F.

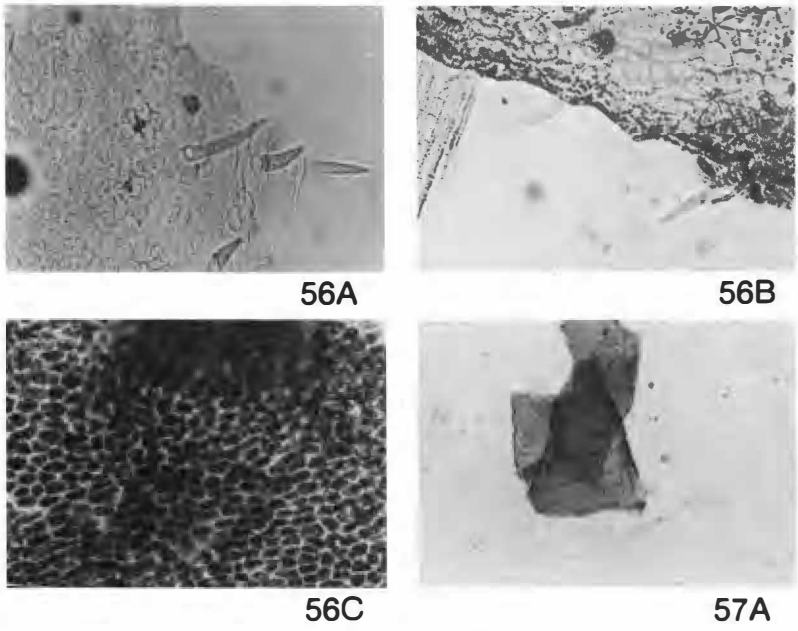


PLATE 17.—Photomicrographs of reference and fecal slides for *Ziziphus obtusifolia*, 56A-C; insect exoskeleton, 57A.

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