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IOWA AGRICULTURAL COLLEGE

EXPERIMENT STATION,

AMES, IOWA.

THE ASPARAGUS RUST IN IOWA.

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The Asparagus Rust in Iowa.

L. H. PAMMEL. E. R. HODSON.

During the summer our attention was called to the appearance of Asparagus Rust on Muscatine Island by Mrs. Alice Walton Beatty. Early in September the rust was found in considerable quantities in one of the asparagus beds on the college farm; since then it has been observed at many points by ourselves and Mr. M. Cumming, in and about Ames. It was also reported to us from McBride, Iowa, by Mr. H. A. Mueller, in September, 1900, as being abundant at that place and at Mt. Pleasant by Mr. E. E. Hodson.

Miss Mary C. Rolfs, of Hampton, Iowa, wrote October 28th, in response to an inquiry concerning the rust: "I have looked at two beds of asparagus, one a small bed where the tops of the bushes have not been cut, the other bed had been trimmed or cut some time ago. In the uncut bed I found one large plant much covered with the disease. I send you the plant in separate package. In the same bed I found about five or six other plants affected near the base of the stalk. This stalk which I send you was bent and seemed to be covered by the other bushes. I notice that those affected seemed to be near the center of the bed where the sun and air do not reach the stalk. In the other bed, that was cut, I found but few plants that were slightly diseased. Mr. Ferris, the nursery man, says he always cuts the tops in the early or middle fall."

In several instances the writers have observed that this fungus is much more abundant in one edge of the asparagus bed than in the center. In one bed the south end of the rows were affected. The plants alongside of houses or near trees seem to be less affected than in the open. In one case, but a few rods distant, the plants on the south side of a house showed no rust whatever while the plants in the open field were covered with the fungus.

It has been so destructive in many of the eastern states and in Europe that a short account and the methods of prevention will not be amiss at this time. The occurrence of the fungus in Iowa this season is interesting as showing how the fungus spreads from year to year. The first general account of its occurrence in this country and its destructiveness was made by Dr. Halsted.[1] Drs. Harkness and Moore mention it in a catalogue of the Pacific Coast Fungi, but no specimen was preserved. Early in September of 1896 the asparagus growers complained about the premature maturing of their asparagus fields. In a letter to L. F. Kinney,[2] Dr. Halsted stated that in that year it was limited to New England, Long Island, New Jersey, Delaware and Maryland. In 1897 it had extended to South Carolina,[3] and accounts of its continued destructiveness appeared in reports of the Rhode Island,[2] Massachusetts,[4] Vermont[5] and Maryland[6] experiment stations. The fungus has been known to mycologists for some time. DeCandolle[8] described the fungus in his work on French plants in 1805. The cluster cup stage[8] was described by Lasch. The Uredo[9] was described by the same author in 1848.

It has been referred to by European mycologists like Schroeter,[10] Frank,[11] Sorauer,[12] Comes,[13] Sajo,[14] Tubeuf,[15] Winter[16] and Saccardo.[17] It is plain from the references here given that this fungus has spread quite rapidily in this country during the last four years. In 1899 it had made its appearance in Illinois according to trustworthy accounts. In a letter to us from a trustworthy correspondent in central Illinois the statement was made that it was common and destructive last year in Illinois. Its sudden and abundant appearance in central Iowa would lead us to suppose it must have existed in Iowa during the previous year but not reported. The present season has been so favorable for the spread of the fungus in central Iowa that a few infected plants early in the season, no doubt, has done much to cause the general infection in this state. There has been an unusual amount of rain all through the growing season and this abundance of moisture coupled with high temperature has furnished ideal conditions for rust.

Exsiccatti: Fuckel, Fung. rhen. 378. Rabenhorst, Herb. Mycol. 680. Rabenherst, Fung. Europ. 594. Thumen, Mycoth Univ. 432. 834.

In order to bring the matter before the people of the state, press notices were sent to the Iowa State Register,[18] Wallace's Farmer,[19] and the Homestead.[20] In response to these notices Mr. H. A. Mueller of McBride, Iowa, wrote as follows: "At your request through Wallace's Farmer,[21] I send you some asparagus branches. The most of it is dead with the exception of some young growth."

General Appearance. The general tendency of rusted plants is to become prematurely yellow, instead of the usual healthy green color. Thus early in September the plants were yellow and the leaves were beginning to fall; a somewhat closer inspection indicated that the stem was blistered, due to the rupturing of the epidermis where the sori or spots of the fungus occurred.

Character of the Fungus. The small spots or sori contain the summer spores or uredo spores, which are brown. These spores are one-celled and smooth. European mycologists describe an earlier stage, the æcidium or cluster cup fungus, in which the spores are borne in chains in a cup. This stage has not been found in this state but it has been found and described by Dr. Halsted as occurring in New Jersey. It is common in Europe. The third stage or winter form technically known as the teleuto stage occurs later; it was abundant during the latter part of September. The spores are two-celled and attached to a permanent stalk. These spores come from the same mycelium that produced the summer spores. The mycelium or vegetative part of the fungus developes in the interior of its host, taking its nourishment from the asparagus, hence the turning yellow and the premature falling of the leaves.

Dr. Halsted finds that the uredo form is frequently associated with the æcidia. In this case the uredo sori are near to, but outside, the oval orange area filled with cups and spermagonia. It is of great importance to notice that the æcidium stage was found only upon early plants which were not molested, and produced brush before the regular plants had appeared. The conclusion seems to be that the cluster cup stage must form early or not at all. If the cluster cup is necessary, a means of prevention of the rust is suggested here

According to the observations of Dr. Halsted[1] the three stages occur upon the same host in this country. He found the æcidium stage as early as June 3rd. Close examination

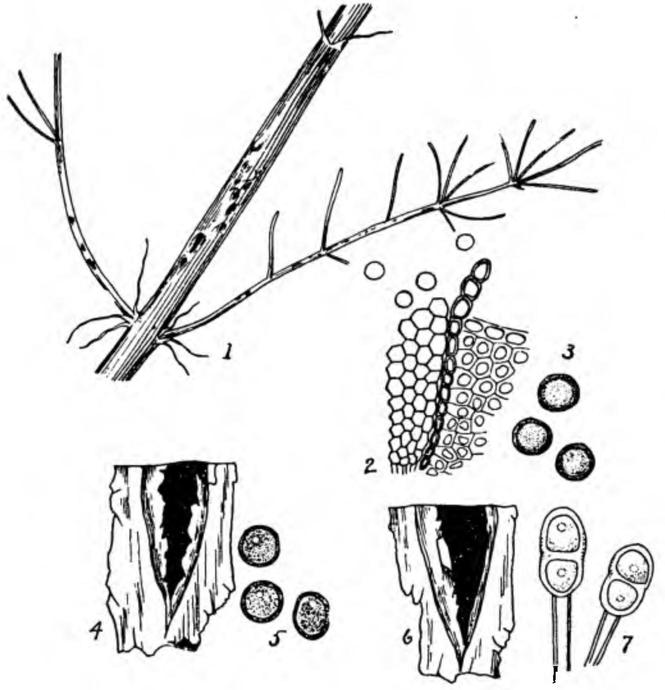

FIGURE I—General appearance of Asparagus rust 1. Aecidium or cluster cup stage 2. Spores shown at 3. Uredo sorus and uredo spores at 4 and 5. Teleuto sorus at 6. Teleuto spores at 7. (1, King, the other figures after Halsted.)

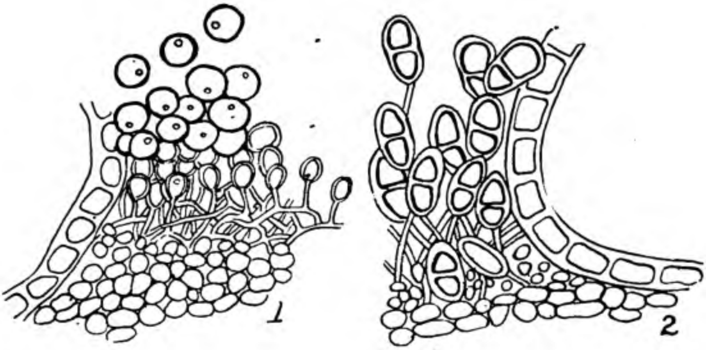

FIGURE II—1. Uredo sorus with spores and mycelium. 2. Teleuto sorus and teleuto spores and mycelium. (After Halsted.)

shows that the æcidium cups are in oval clusters. In many of the sori of this stage the cups formed the border while the center was made up of spermagonia. The spermagonia may be distinguished by their small size and the watery appearance they give to the sori.

HOSTS. *Puccinia Asparagi* has been found upon four species of asparagus, *A. officinalis*, *A maritimus*, and *A. verticillatus*. Dr. Halsted has examined many specimens of the ornamental species, *A. scandens* and *A. plumosus*, but has failed to find the rust. Another rust, *Puccinia phyllocladia*, Cke., is recorded upon *Asparagus falcatus*; this however seems to occur only in Africa.

FUNGUS ENEMIES OF THIS RUST. There is a parasitic fungus, (*Darluca filum*), which preys on the rust. This fungus has much smaller colorless and more delicate spores than the rust and is more susceptible to the spray of the fungicide. So that spraying may defeat its own end. The spores of the Darluca occur in black pycnidia which by their great number give to the sori of the rust a black appearance. *Darluca filum* is a fungus affecting a large number of the Uredineae and does much to prevent the ravages of rusts. It is common this year on corn rust (*Puccinia Maydis*) in this vicinity.

Besides the *Darluca filum* another fungus *Tubercularia persicina* is found to live upon the cluster cup stage, and if this stage is essential for the development of the rust, this parasite may do much to check it. This fungus would not be injured by spraying as the cluster cup grows upon old stalks in out of the way places. This fungus is easily recognized by its purple color.

PREVENTATIVE MEASURES. As the mycelium of the fungus works in the interior of the plant, nothing will destroy the fungus when once the mycelium has entered its host, so that all measures for treatment must be preventative.

According to Dr. Halsted[1] there is a slight decrease of rust in spraying with Bordeaux mixture. He experimented with eight plots,—four sprayed and four not sprayed, as checks. The sprayed plots averaged 55.10 per cent, while those of the checks averaged 74.8 per cent, the gain being 19.7 per cent. Figuring the unsprayed plot as 100 per cent, the decrease by spraying is more than one-quarter.

There is no variety free from the rust, although European growers claim that the Yellow Burgundy is practically rust-

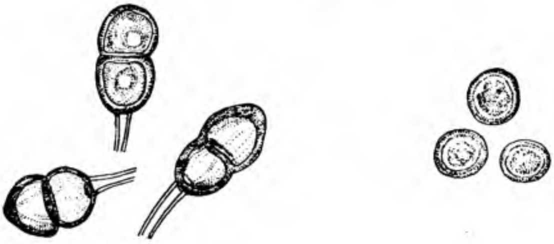

FIGURE III—Uredo spores at the right; teleuto spores at the left. (King.)

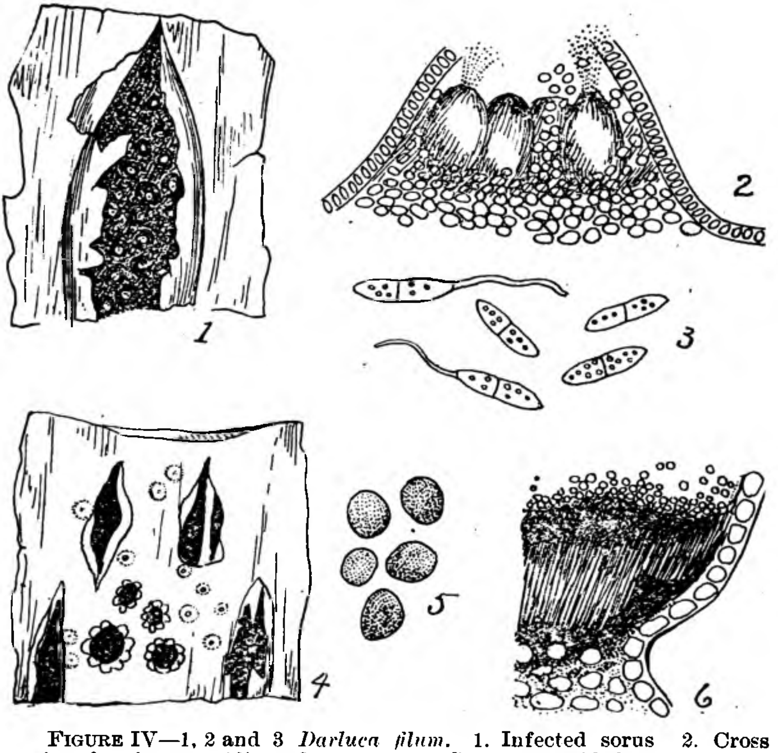

FIGURE IV—1, 2 and 3 *Darluca filum*. 1. Infected sorus 2. Cross section showing pycnidia and spores. 3. Spores magnified two showing germ tubes. 4, 5 and 6. *Tubercularia persicina* 4. Parasite in sorus of rust. 5. Spores of parasite magnified. 6. Section through sorus, showing parasite with spores. (After Halsted.)

proof. The Palmetto is markedly lower than the rest of the American varieties.

The best method of prevention undoubtedly is to clean up all rubbish in the fall and burn it. This will destroy many of the teleuto spores, which carry the rust through the winter. And also keep down all volunteer plants in the corners, as the æcidia develop on these. This stage has not been proven absolutely essential to carrying the rust over from one season to another but probably it has something to do with keeping up its energy and it is therefore a good plan to keep this stage down.

C. Sajo[15] in writing on the asparagus, notes the remarkable freedom from the rust of the wild asparagus and thinks that this is perhaps not due to the greater resistance but to the fact that it is more scattering and is not so easily infected as the asparagus in beds. Miss Rolf's observation plainly indicates that it spreads from a center of infection. Neither fertilizers nor methods of cultivation seem to have any effect upon the occurrence of the rust.

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GRASSES OF IOWA.

PART I.

INTRODUCTION.

No apology is needed for a work describing the grasses of Iowa. The importance of Iowa as an agricultural state depends largely on the value of products derived from members of the grass family, such as corn, oats, blue grass, wheat, etc. Iowa's wealth depends largely on the produce derived from the grasses and cereals.

The work on grasses may be divided into two parts: First, economic considerations on cereals and grasses, especially with reference to general structure, the seed and its germination and vitality, the cereal production of the state as compared with other parts of the world, climatology of some of our most important cereals, grasses in medicines, pastures and meadows of Iowa, their chemical composition, the fungus diseases of our cereals and grasses, and means of prevention. It is only in a few instances that we are provided with precise knowledge of the changes that occur in grasses during their development. This is an important subject and can only be solved through a series of continued investigations.

So far as possible the grasses have all been figured. One-third have been drawn expressly for this work by Miss Charlotte M. King. Some have been photographed by Dr. S. W. Beyer. F. D. Coburn and Mr. Charles N. Page also supplied a few cuts, and we are especially indebted to the United States Department of Agriculture. The descriptive part is supplied mostly by F. Lamson-Scribner. He has also kindly examined all the grasses in the collection and those of the State University of Iowa. The economic, ecological notes and accounts of diseases, as well as the original chemical matter, should be attributed to the senior authors. Thanks are due to the following persons who have contributed specimens: Mr. E. W. D. Holway, Decorah, Iowa; Prof. P. H. Rolfs, Clemson College, S. C.; Prof. H. W. Norris, Grinnell, Iowa; Prof. B. Fink, Fayette; Prof. A. S. Hitchcock, Manhattan, Kan.; Dr. M. Reynolds, Minneapolis, Minn.; F. C. Stewart, Geneva, N. Y.; F.

A. Sirrine, Jamaica, N. Y.; Prof. E. E. Kaufman, Fargo, N. D.; Prof. G. W. Carver, Tuskeegee, Ala.; F. Reppert, Muscatine; Prof. C. E. Bessey, Lincoln, Neb.; Bandusia Wakefield, Sioux City; A. A. Miller, Davenport; W. D. Barnes, Blue Grass; C. A. Wilson, J. I. Schulte, C. R. Ball, W. E. Gossard, C. O. Pool, W. Newell, Charles Le Buhn, A. F. Sample, J. H. Rolfs, Emma Sirrine, C. B. Weaver, B. H. Hibbard, H. C. Taylor, A. P. Whitmore, W. H. Warden, C. E. Eckles, Miss A. Estella Paddock, H. H. Hume, C. A. Battles, H. A. Crawford, W. D. Fitzwater, H. O. Sampson, Geo. F. Sokol, E. R. Hodson, L. R. Walker and other students of the Agricultural College.

Specimens sent from F. Reppert of Muscatine, W. D. Barnes of Blue Grass, A. A. Miller of Davenport, J. H. Mills of Mount Pleasant, R. I. Cratty of Armstrong, and B. Fink of Fayette, are especially worthy of mention. Several local species are found in the vicinity of Muscatine and Davenport which do not occur elsewhere in the state. We wish also to express our special thanks to Prof. T. H. Macbride and B. Shimek of the State University of Iowa. The latter has not only favored us with specimens, but has gone through the entire collection of the State University and listed such as were determined by Professor Lamson-Scribner. We wish also to express thanks for uniform courtesy shown us by the Division of Agrostology of the United States Department of Agriculture. We are also indebted to Dr. William Trelease of the Missouri Botanical Garden for the use of books, to Dr. Robinson of Gray Herbarium of Harvard University for having kindly looked up the specimens referred to in Gray's Manual, sixth edition; to Dr. Harshberger of the University of Pennsylvania for the specimens of *Zea canina* and its hybrids with *Euchlaena;* Prof. G. W. Carver for help on fungus diseases of grasses, and Dr. H. Foster Bain and Dr. Calvin, who encouraged the work in every way. We wish also to express our thanks to the agricultural press of this state, which has kindly assisted us in every way possible in making a complete collection of our grasses. Special mention should be made of the volunteer observers of the Iowa State Weather Service, who have in every way assisted us. Their notes and specimens have been of much value to us. Special thanks are also due to Miss Emma Sirrine, Dr. H. Foster Bain, Dr. S. Calvin; to C. R. Ball, and R. Combs, who assisted in preparing the bibliography; to Dr. S. W. Beyer, who made most of the photographs; C. B. Weaver and several students,

who made some of the drawings representing anatomy of leaves, and Miss Charlotte M. King, for faithful drawings. Thanks are due also to Mrs. M. S. Schoonover, Miss Nellie Newman and Miss Loughran for clerical help.

The names of collectors and of localities will be found in their appropriate connection. We trust that this volume, a preliminary one of the botanical series, will meet with the approval of botanists as well as the people of the state.

The chemical analyses of the grasses, presented in this work, were made by the chemical section of the Experiment Station, and the faithful service of Messrs. Mead and Grettenburg have added largely to the completeness of the work.

L. H. PAMMEL,
J. B. WEEMS.

Ames, Iowa, November 1, 1899.

GRASSES—GRAMINEÆ.

General Description.

Characters of the Order.—Fibrous-rooted, annual or perennial, herbaceous plants (among our species Arundinaria alone is woody), with usually hollow, cylindrical (rarely flattened) and jointed stems (culms) whose internodes for more or less of their length are completely enveloped by the sheath-like basal portion of the two-ranked and usually linear, parallel-veined leaves.

Flowers without any distinct perianth, hermaphrodite or rarely unisexual, solitary or several together, in spikelets, these disposed in panicles, racemes or spikes, and consisting of a shortened axis (the rachilla) and two or more chaff-like, distichous bracts (glumes), of which the first two, rarely one or none or more than two, are empty (empty glumes); in the axil of each of the succeeding bracts (except sometimes the uppermost) is borne a flower (hence these are named flowering glumes). Opposed to each flowering glume, with its back turned toward the rachilla, is (usually) a two-nerved, two-keeled bract or prophyllum (the palea), which frequently envelops the flower by its enfolded edges. This bract is the prophyllum of the extremely short axis or branch which supports the flower; its absence indicates that the flower is strictly sessile or inserted directly on the rachilla; the rachilla or axis of the spikelet may or may not be produced beyond the palea. At the base of the flower, between it and its glume, are usually two very small hyaline scales (lodicules); rarely there is a third lodicule between the flower and the palea. Stamens, usually three (rarely two or one, or more than three), with very slender filaments and two-celled, usually versatile anthers. Pistil with a one-celled, one-ovuled ovary, and one to three, usually two, styles, with variously-branched, most frequently plumose, stigmas. Fruit, a true caryopsis, rich in albumen. (In Sporobolus and Eleusine the fruit is a utricle, the seed being loose within the thin pericarp.) Embryo small, lying at the front and base of the seed, covered only by the thin pericarp.

The organs or parts of grasses, as in other plants, are those of vegetation and those of reproduction; to the first belong the root, stem or culm, and leaves; to the second the stamens and pistils.

Roots.

Gross characters.—Grass roots are always fibrous. The more or less strong underground rhizomes are often called roots; they are not true roots, but are specially modified stems.

Minute anatomy.—The purpose or function of the roots is to obtain nutrient material from the soil and conduct these matters through certain channels. It is important, therefore, to consider the structure of the roots from an anatomical standpoint. One

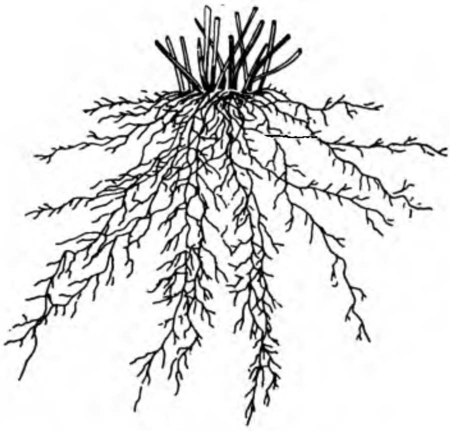


Fig. 2. Blue grass and its system of roots. (King.)

illustration will serve to show the structure, and for that purpose the corn plant may be taken as a type.*

The first root is early formed by the plant; it exists in the seed. When appropriate material, moisture, warmth and oxygen is

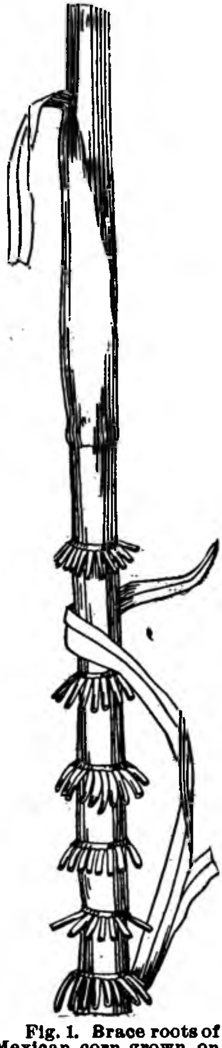


Fig. 1. Brace roots of Mexican corn grown on college farm. (King.)

*For literature see: J. W. Harshberger. Maize; A Botanical and Economic Study. Contr. Bot. Lab. Uni. Penn. 1: 75-202. 1893. Strasburger, Noll, Schenck and Schimper Lehrbuch der Botanik. 558, 1894. J. Sach's Lecture on the Physiology of Plants; English translation by H. Marshall Ward. A Text-book of Botany. 858: 461 f. G. Haberlandt. Physiologische Pflanzenanatomie. 550: *235 f.* De Bary, Comparative Anatomy of the Vegetative Organs of the Phanerogams and Ferns; English translation by F. O. Bower and D. H. Scott. 659: *241 f.*

furnished to the seed the root pushes through the covering of the seed and enters the soil. At this early stage it is easy to make out a conical tip known as the root-cap. This consists of loosely arranged parenchyma cells. These cells are not alike, but differ in size and shape. It is easy to observe that the cells at a point back of the tip converge; they are destined for a different purpose from the cells above and below.

Fig. 3. Roots of Foxtail (*Setaria viridis*) (King.)

This point is known as the growing point or punctum vegetationis. All other cells are derived from the growing point. Below, the cells of the root-cap are formed. These are continually being removed as the roots push through the soil. The root-cap is purely protective in its function. In the center occurs what is known as the central cylinder (plerome). On either side occurs the cortex (periblem). The outer layer is the epidermis (dermatogen). These cell walls are more or less mucilaginous. All of these young cells contain an abundance of protoplasm and a distinct nucleus. At a little distance back of the tip, the epidermal cells form root hairs. These are at first straight and have delicate walls, but as they increase in length they become tortuous and insinuate themselves among soil particles, the grains of sand adhering owing to the mucilaginous character of the cell walls. Owing to their intimate contact with the same, it is difficult to remove the soil. The older root hairs are continually being replaced as the root increases in length. A cross section through an older root shows that it is made up of three parts: the outer epidermis; the central axis or cylinder, containing the fibro-vascular elements; and between the two, the parenchymatous tissue.

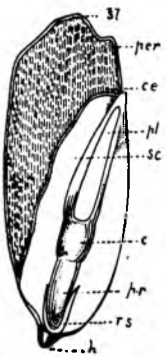


Fig. 4. Section of Maize seed. *ce*, endosperm; *pl*, plumule; *sc*, scutellum; *c*, caulicle; *pr*, primary root; *h*; hilum; *rs*, root sheath. (King.)

The central cylinder is bounded by the endodermis and a peripheral layer. The cells of the endodermis are without intercellular spaces, and are more or less plicate. In secondary roots the rear walls are thickened somewhat like a crescent. The bundles are arranged in a radial manner, the woody elements (xylem) occupy the center and alternate with the soft tissue (phlœm). The woody elements consist of scalariform ducts; spiral tracheids and an annular duct.

The primary or seminal root is of short duration, and is soon replaced by the secondary, or as they are commonly called, "brace roots." These roots show conspicuous large bundles

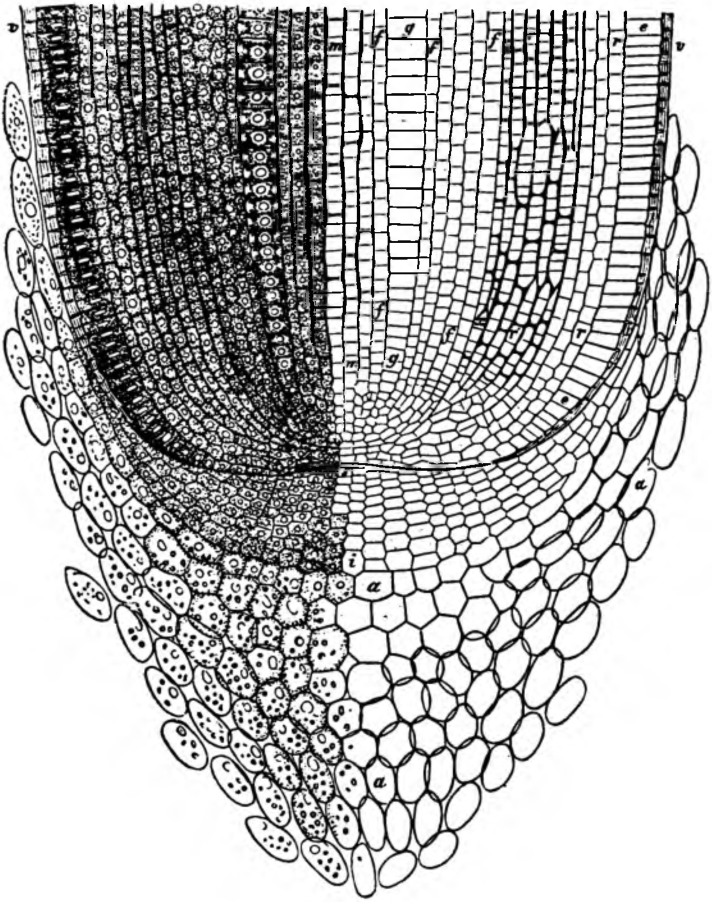


Fig. 5. Root of Maize. *a*, root-cap of loose cells; *s*, growing point; *e*, epidermis; *v*, thick walls; m, g, f, plerome, central cylinder; *g*, a vessel; *f*, wood; *m*, pith; *x*, *r*, cortex (Sachs)

in which occur spiral tracheids, annular and scalariform ducts. The secondary roots arise from the nodes, and ordinarily are aerial, though some are formed soon after the seed germinates. These appear as swellings, the continued growth within causing the stem to become ruptured, and allowing the

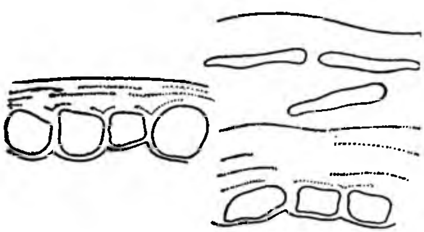


Fig. 5a. Cross-section through tip of brace root, showing epidermal cells; to the left before the addition of water; to the right after the addition of water, the outer part having expanded.

tip to emerge. It points downward and hence is positively geotropic.

Harshberger* notes that before entering the soil, gum is formed on the tip. We have often noticed this, but botanical authors have not generally noted this interesting phenomena. This thick gum is brought about by the swelling and later breaking down of the epidermal cell walls. This substance in water takes the form of mucilage, undoubtedly for the purpose of assisting the root to hold itself to the soil. The method of formation of roots has been studied by Harshberger. The developing secondary root shows before the point breaks the epidermis and hypodermis. "Three superimposed hollow cones are found immediately beneath the two outer protective layers, the outer and middle cones being separated by a cushion of parenchyma. The outer cone is composed of actively growing cells with the nucleus and nucleolus plainly visible. It corresponds evidently to the calyptrogen layer of Janczewski. The inner cones correspond to the periblem and plerome cylinders with the outer layer of the periblem as the dermatogen or proto-epidermis. The cells of the plerome, destined to form the central vascular system, are much longer than broad, the long axis anticlinal."†

Distribution of roots.—It is well known that roots have an important relation to the development of corn, especially in the manner of occurrence. The habit of the roots largely influences the amount of growth the plant can make provided other factors, sunshine and warmth are favorable.

The development of roots is largely governed by external factors, especially amount of rainfall and moisture in the soil.

In a paper read before the biological section of the American Association for the Advancement of Science, the following summary was made by the writer:

"It has been stated that not more than 10 per cent of the roots of corn enter the subsoil. Sturtevant‡ estimates as a

* Maize, l. c. 81.

† l. c. 81.

‡ Conn. Board of Agriculture. 1882: 70.

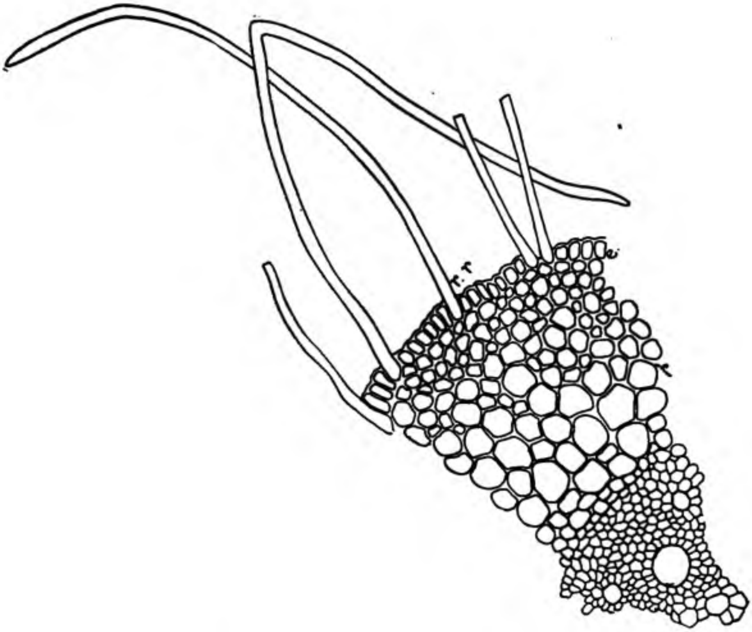


Fig. 6. Cross-section of root of corn germinated in moist chamber, showing ro hairs.

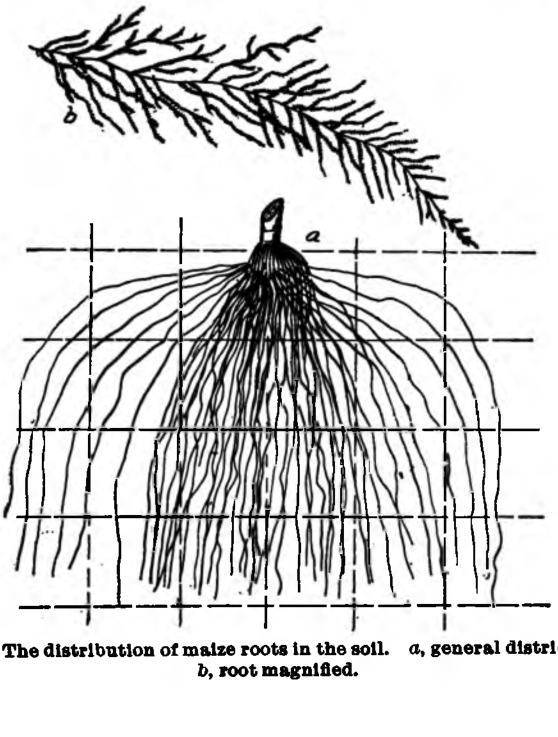


Fig. 7. The distribution of maize roots in the soil. *a*, general distriоution; *b*, root magnified.

result of some work carried on with Gilbert that only one one-thousandth of the roots of corn enter the subsoil. Armsby also observes that in a stiff clay soil few of the roots of corn enter the subsoil. Thiel also observes that in our cultivated plants most of the fine roots which supply the plant with mineral matter occur in the upper strata. Hunt,* in commenting on some experiments made in Illinois, says: 'Two-thirds of the roots would have been broken by root pruning four inches deep; more than two-fifths would have been broken at three inches deep; and one-seventh at two inches deep.' Newman† observes that most of the roots are within four inches of the surface; these roots severed from the plant will deprive it of three-fourths of its nourishment."

Hays‡ says: "Returning to the direction or spread of the roots in the soil, those of the first whorls, say the five lower ones, start out nearly horizontally. This is in accordance with certain facts, viz: at this season of the year surface soil is warm, while the subsoil is yet cold; the upper soil is also richer in plant food and usually contains at this season an abundance of moisture. We see at 1, 2 and 3, plate I, that all the roots go nearly horizontally, and a cultivator running four to six inches deep, and the same distance from the hill, would sever most of these roots. After about the fourth week we find these primary roots changing their course, however, for having heretofore pushed outward they now grow downward, soon taking a nearly vertical direction. Not alone the roots which first grew outward, but all those now starting from the nodes above as well, take this downward course from the very beginning."

Armsby§ states as the result of some work carried on under his direction by Hickman: "Concerning the direction of the growth, a few words may be written, although the plan of the experiment did not include accurate observations and measurements upon this point. It was observed that the nodal roots, and especially those later formed, branched out horizontally from the stem for a considerable distance, and then turned downward quite rapidly. In the stiff soil in which the plants were grown, few of the roots appeared to enter far into the subsoil, which is a very stiff clay, so that in this situation

*Bull. University of Ill. Agrl. Exp. Station. 13: 427, 1891.

†Bull. Alabama Agrl. Exp. Station. 4: 1887.

‡Prairie Farmer 1887: 373. 631; Bull. Minn. Agrl. Exp. Sta., 5:

§Ann. Rep. Penn. State Coll. 1886: 97.

the corn seems to be a shallow-rooted plant, as much by reason of the obstacles which the roots encountered in growing downward, as by any habit characteristic of the plant. Other observations, to which attention will be called later, indicate that in looser soils corn roots grow to a much greater depth than was observed in this locality."

Since this above was written, King* has made a careful study of the root development of corn, from which it appears that forty-two days after planting the roots had penetrated a depth of eighteen inches. The surface roots sloped gently downward toward the center of the row, where those nearest the surface were some inches deep. When corn was three feet high the roots occupied the entire soil down to a depth of two feet.

"Here the roots are seen to occupy the entire soil down to a depth of two feet, which is the height of the cage. At this stage the surface leaders descend in a gentle curve toward the center of the row where they pass each other and lie only six inches deep.

"Just as the corn is coming into full tassel a third sample was taken which is represented in figure 10, and here it will be seen the roots have fully occupied the upper three feet of soil in the entire field. In the center of the row, too, the surface leaders have risen still higher, and a few of them are now scarcely five inches deep, though the great bulk of them are still six inches or more below the surface at the center."

Concerning the distribution of the roots of our forage grasses very little definite is known, since few experiments have been made. The roots of blue grass during the spring and early summer are more or less horizontal and these spread obliquely downward in the soil. The grass makes little growth during dry weather for the reason that the majority of the roots occur in the surface soil. The well developed rhizomes maintain its vitality. The roots of annual grasses like Setaria, *Panicum capillare*, and *P. sanguinale* are developed in a manner similar to corn.

The Stem.

Gross character.—Grass stems are always branched at the base, and occasionally in their upper portions. If the branches are all apparently at the root, the culms are said to be simple,

* Annual Rep. Wis. Agrl. Exp. Sta. 9: 113.

the visible portion above ground being unbranched. Sometimes the stems or branches stand vertically upright, when they are termed erect; they may spread a little at first, and then assume an erect position, the lowermost joints being bent or kneed; such culms are said to be geniculate at the base. The

Fig. 8. Mexican corn. Showing method of growth on grounds Iowa Agricultural college.

basal branches may lie flat upon the ground and spread more or less extensively, taking root at the usually numerous joints, and at definite points sending up erect flowering branches, or branches bearing leaves only; such grasses are said to have a creeping habit, or are stoloniferous. Again one or more of the lowermost branches may not come to the surface at all, or only after it has extended through the soil for a greater or less distance. These form the "creeping roots" (rhizomes) of grasses, but they are true stems or branches, for they are always distinctly jointed, and at the joints there are scale-like leaves—characters never found in true roots. The joints of these

Fig. 9. Japan millet (*Panicum crus-galli*), showing method of forming stools.

underground stems may be very short, and from each node may spring a flowering branch. So condensed may this growth be that the rhizome is entirely concealed, but in perennial grasses it is always present, and in the best turf or sward-forming grasses it is sufficiently manifest. In couch-grass, and especially in Johnson grass and cord grass, these rhizomes are greatly developed, penetrating the soil in all directions, forming a sward that is exceedingly difficult to break.

Grass stems are usually round or cylindrical, rarely flattened, and generally hollow between the joints or nodes (solid or with pith in the Andropogons, Indian corn, sorghum and a few other grasses). The nodes, familiarly termed the joints, are the points on the culm or its branches from which the

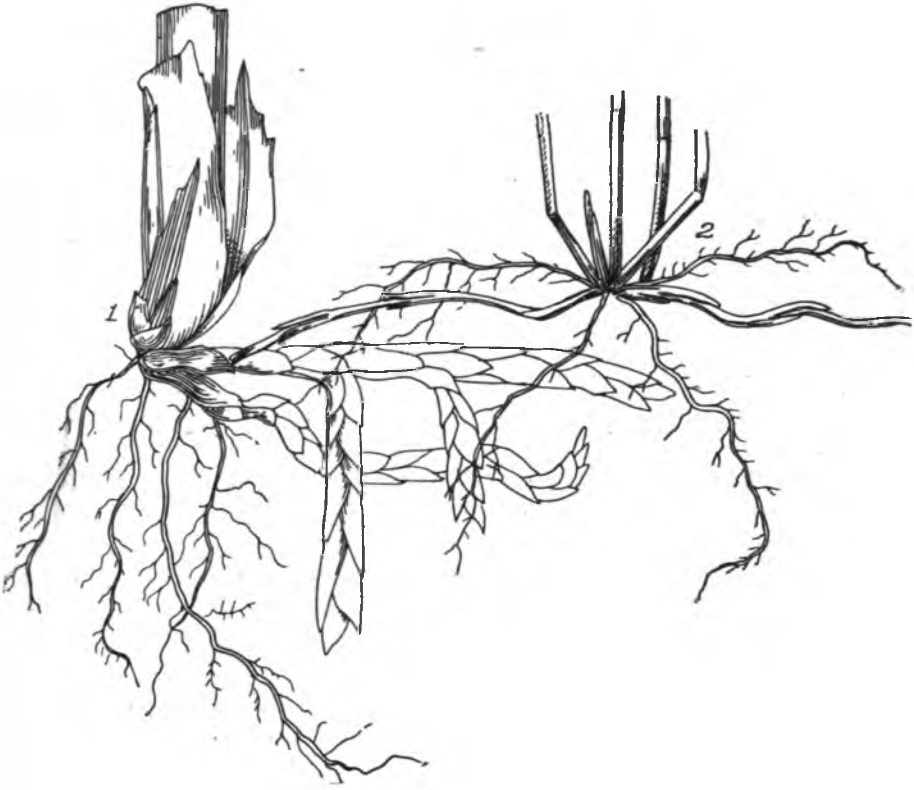


Fig. 11 Rhizomes. 1. Rootstock of slough-grass (*Spartina cynosuroides*). 2. Quack-grass (*Agropyon repens*). (King.)

leaves originate; they are usually somewhat swollen, the enlargement being either in the culm or, as is very often the case, in the basal part of the leaf-sheath. The space between two nodes is the internode. All branches, excepting those of the general inflorescence, originate in the leaf-axils, that is, within and at the base of the leaf-sheaths, and between the branch and the main axis or stem there always is a longer or shorter two-keeled prophyllm with its back tnruned towards the main axis. The presence of this prophyllum always indicates the presence of a branch, although the branch may be very much shortened, as in the case of the true floral axis where this prophyllum is the palea.

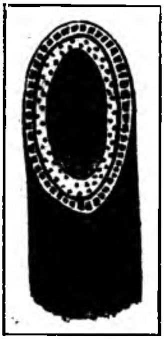


Fig 12. Section of culm of Wild Rice (*Zizania aquatica* L.) showing fibro-vascular bundles and chambered pith. (King.)

Minute anatomy of stem.—A cross section of a culm from which the leaf sheath has been removed will show first an epidermal layer composed of thick walled cells, isodiametric in *Zizania aquatica*, but longer than wide in *Bromus mollis*. Variations occur in other genera. In a longitudinal section the epidermal cells are longer than broad. The epidermis is unbroken except for the stomata, which are not as frequent as in the leaf and sheath. The stomata connect with the loose spongy parenchyma. In Zizania and Bromus, Zea and other grasses the epidermis is followed by sclerenchyma sheath. This sheath varies in thickness in different grasses, being particularly well developed in Zizania and Zea. In some grasses like *Zizania aquatica* there are two sclerenchyma sheaths, one immediately under the epidermis, a second layer below the spongy parenchyma. Sclerenchyma is also found in connection with the bundles.

The fibro-vascular bundle is especially prominent. In pithless culms the fibro-vascular bundles are arranged, usually, in two circles; one occurs on the inside of the sclerenchyma ring, the other on the outside of it.

In species with pith, like Zizania, a first row of bundles occurs on the outer edge of the second sclerenchyma sheath. A second row of bundles occurs just underneath or a little below the sclerenchyma sheath. The remaining bundles are arranged in indistinct circles. Hackel says: "The fibro-vascular bundles run parallel in the internodes; the superficial ones join those of the lower internodes directly, the others take the form of a shallow arch bending towards the center (in culms with pith), where they pass through several internodes, and finally bend outwards to join the superficial ones. In the nodes the bundles cross and interlace and by means of small and short cross-bundles, which pass from the axillary shoots or buds towards the center. In this way arise the diaphragms or plates of tissue which separate the pith cavities of the internodes."

The function of the sclerenchyma is to give the plant firmness and support. It is evident that strength is obtained best

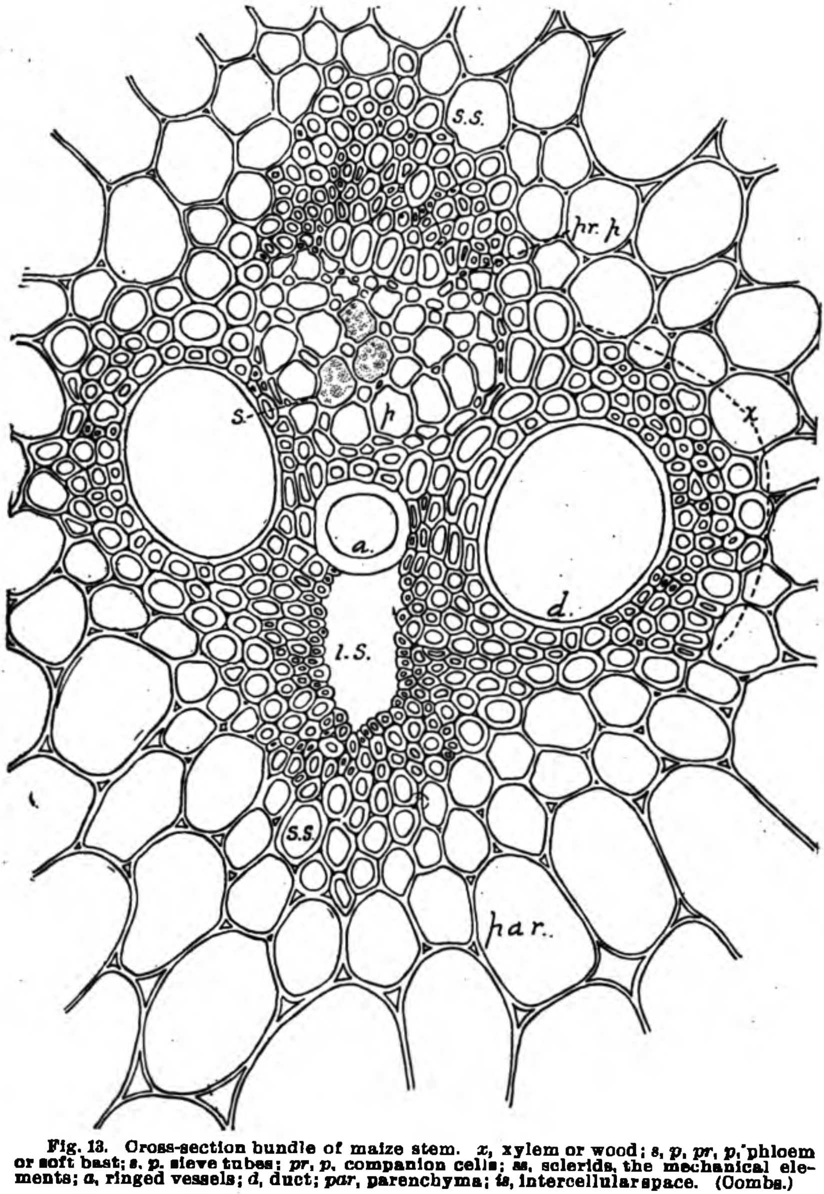


Fig. 13. Cross-section bundle of maize stem. *x*, xylem or wood; *s*, *p*, *pr*, *p*, phloem or soft bast; *s*. *p*. sieve tubes; *pr*, *p*, companion cells; *ss*, sclerids, the mechanical elements; *a*, ringed vessels; *d*, duct; *par*, parenchyma; *is*, intercellular space. (Combs.)

by having the sclerenchyma in close proximity to the epidermis. The peripheral bundles, including the sheath, constitute a system of compound pillars indispensable to maintain a plant in an erect position.

The fibro-vascular bundles, in addition to the thickened lignified elements may be divided into two parts: the soft bast or

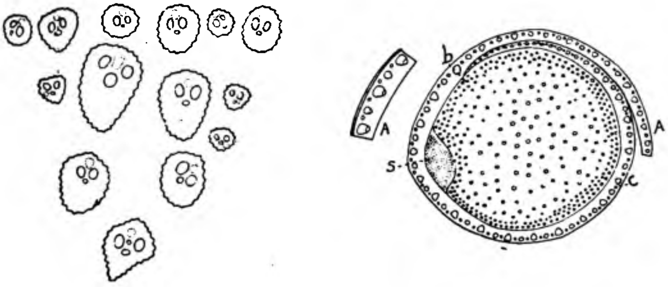


Fig. 13 A. Cross section of corn. To the right general arrangement of bundles. *a*, leaf sheath; *s*, where leaf originates. To the left bundles more magnified.

phloem which consists of the sieve tubes and the companion cells; second, the xylem which consists of several pitted vessels and a spiral duct towards the center and below an intercellular passage; this has resulted from the breaking down of an old ringed vessel.

Theodore Holm, in an interesting review of an extended paper on structure of rhizomes states that, "Although the function of the stolons in the Gramineæ is nearly the same, being at once reservoirs of nutritive matters and for the service of the vegetable propagation, some differences have also been observed in the interior structure."

It has been shown from the numerous intergradations between the underground stolons and the shoots above ground, that the organizations of the stolon depend upon a modification of the above-ground shoot. The structure of the shoot above ground is well marked by the position of the mechanical tissue, which is either truly sub-epidermal or more or less distinctly sub-cortical, the bark being as a rule not very strongly developed. But there is a large series of modifications between the form and those derived from such shoots as show a tendency to replace the stolons.

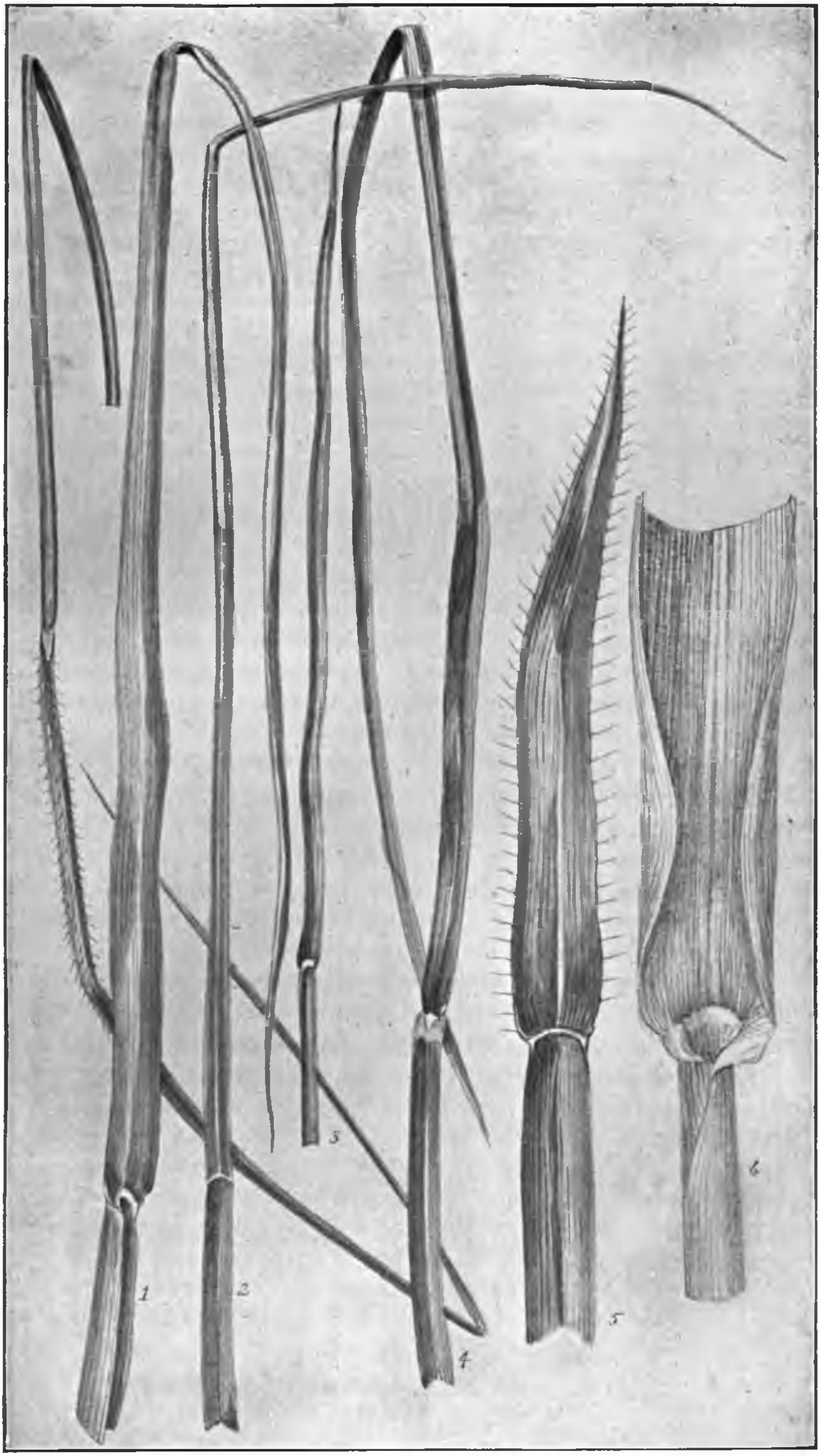


Fig. 14. Leaves of grasses. *1*, Blue stem (*Andropogon provincialis*, Lam.); 2, *Poa pratensis* L.; 3, *Hordeum jubatum* L.; *4*, *Andropogon scoparius* Michx; 5, *Paspalum ciliatifolium* Michx; *6*, *Zea mays*

The Leaves.

Grosscharacter.—The leaves of grasses have two distinct parts: the sheath and the blade. The sheath, or basal portion, usually closely surrounds the stem, and is split or open upon the side opposite the blade, or is entire, then forming a closed cylindrical sheath (vagina) about the stem. When split, the free edges usually overlap each other. At the top of the leaf-sheath, at the point where the blade originates, there is upon the inside usually a thin and delicate prolongation, often very short, called the ligule. Sometimes the ligule takes the form of a fringe of hairs. The leaf-blade is generally narrow, usually many times longer than broad, with nearly parallel edges. Such leaves are called linear. From this form the leaves may vary to lanceolate or ovate in outline. Sometimes the narrow leaves have their edges rolled inward, when they are said to be involute. Occasionally the leaf-blade is very short, and sometimes it is wanting altogether, the sheath alone remaining. As to the surfaces of the leaves and sheaths, they may be smooth or rough, or more or less hairy. The terms used here are those of general application.

The position of the leaves on the stem is to be noted as affording a ready character for distinguishing grasses from the nearly allied grass-like sedges. Starting with any leaf on the stem of a grass, the next leaf above will be exactly on the opposite side of the stem; while the next or second leaf above will stand directly over the starting point. Such an arrangement is called distichous or two-ranked; *i. e.*, in counting two leaves from the first we pass completely around the stem. In sedges the leaf arrangement is three-ranked; it is the third leaf from the first which stands directly above the first.

The mature blades often show torsion, being either twisted to the left, right, or in both directions; being twisted in one direction above and the other below. Certain grasses are turned 180 degrees at the base so that the upper and lower sides are reversed. In this case the stomata occur on the original upper side. This is true of grasses growing in the woods and is brought about through the influence of light.

Minute anatomy.—The fibro-vascular bundles are separate or they unite to form a strong mid-rib as in corn. The fibro-vascular bundles of the leaf consist of the soft bast phlœm and woody elements, the xylem. The bundle is protected on each side by sclerenchyma, true at least of the primary veins; this gives the leaf additional strength. The number and character of the bundles varies in different species of grasses. In *Sporobolus heterolepis*, Miss Emma Sirrine and Mrs. Hansen found that the mid-rib consists of a single mestome bundle.*

This bundle is surrounded on the upper side by chlorophyll bearing parenchyma, while the lower side contains stereome. The mestome bundles to the right and left of the mid-nerve are entirely closed, that is entirely surrounded by chlorophyll bearing parenchyma. There are three types of mestome bundles in this species as follows, the mid-nerve with stereome on the lower side which is in contact with leptome or the second with stereome on lower and upper sides in contact with leptome, and third, entirely closed. These alternate with those having stereome on upper and lower surfaces. The leaves terminate with one closed mestome bundle. The uncolored parenchyma of the leaf is in immediate contact with the stereome. This is most conspicuous near the mid-nerve. The chlorophyll parenchyma may be divided into two parts, first, large parenchyma cells, which surround the bundles, and, second, to the outside of these, elongated cells in one or more rows. This species represents a type intermediate between plants adapted to very dry climates and one adapted to somewhat moister conditions. Mrs. Hansen has described the structure of a typical xerophytic plant, *Festucu tenella.*† In this species the mestome bundles number twelve and are of three types. First, primary, open both on inferior and superior surfaces of leaf, *i. e.*, those which have hadrome and leptome respectively in contact with stereome, either in direct contact or are separated from it by several rows of thin-walled parenchyma cells. Second, the secondary type. These are entirely surrounded by chlorophyll-bearing parenchyma. Third, intermediate type. These open inferiorly. Only one bundle of primary type occurs and this is in the mid-nerve. The leptome and hadrome are in direct contact with each other. The leptome is separated from the stereome by thin-walled parenchyma cells. A considerable development of thin-walled parenchyma cells occurs above the mestome

*Some anatomical studies of leaves of Sporobolus and Panicum. Proc. Ia. Acad. Sci., Des Moines. 3: 151. *pl. 6. f. 1-3.* 1896. Contr. Bot. Dept. Ia. St. Coll. Agrl. Mechanic Arts. 1.

†A comparative study of the leaves of Lolium, Festuca, and Bromus. Proc. Ia. Acad. Sci., Des Moines. 4: 127. 1897. Contr. Bot. Dept. Ia. St. Coll. Agrl. and Mechanic Arts. 4.

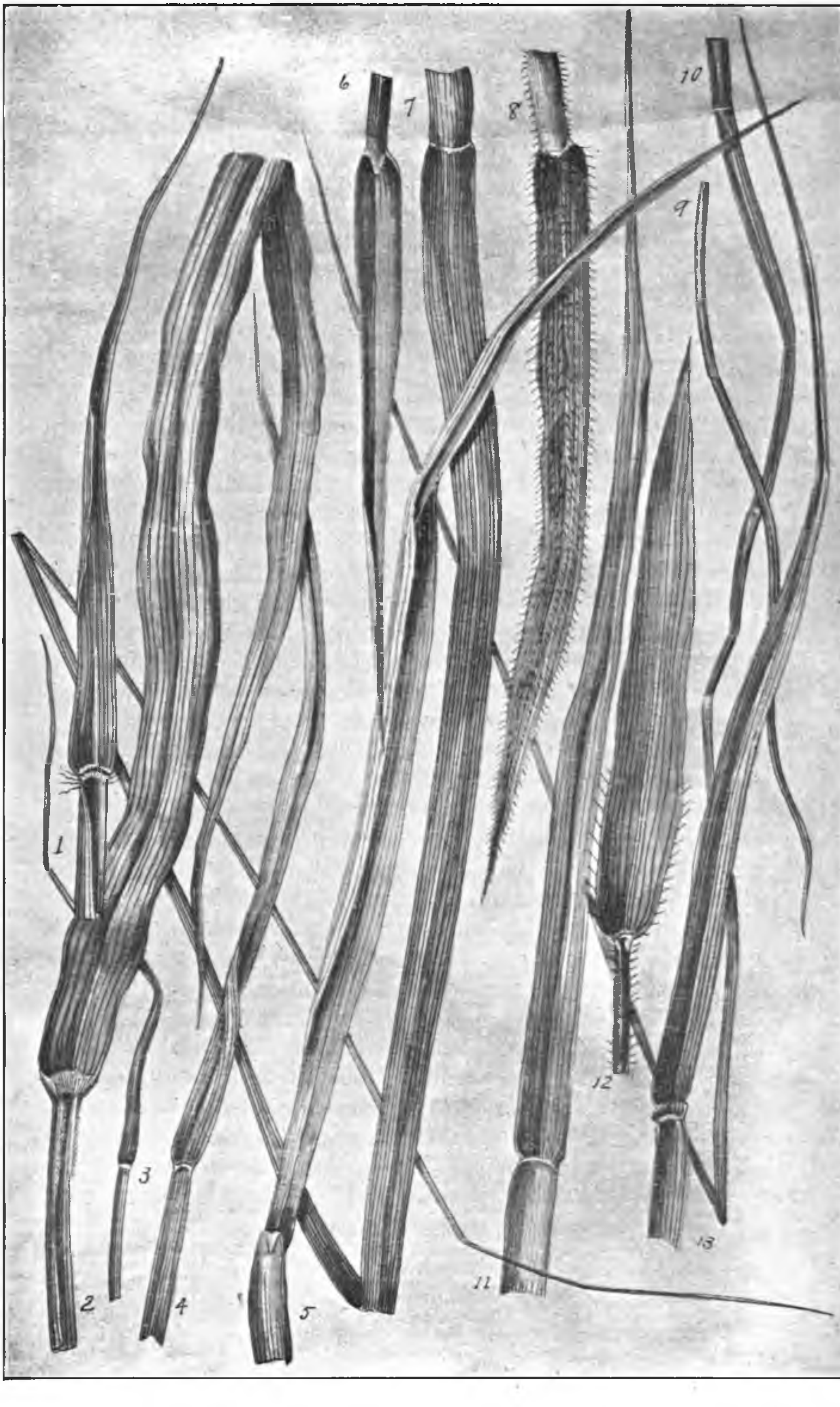


Fig 15. Leaves of grasses. *1*, Stink grass *Eragrostis major* Host; *2*, *Setaria italica*, Kunth; *3*, *Sporobolus vaginæflorus*; *4*, *Muhlenbergia Mexicana*; *5*. *Andropogon nutans*; *6*, *Phleum pratense*, L.; *7*, *Spartina cynosuroides* Willd; *8*, *Panicum capillare*, L.; *9*, *Aristida basiramea*; *10*, *Sporobolus heterolepis* Gray; *11*, *Elym*

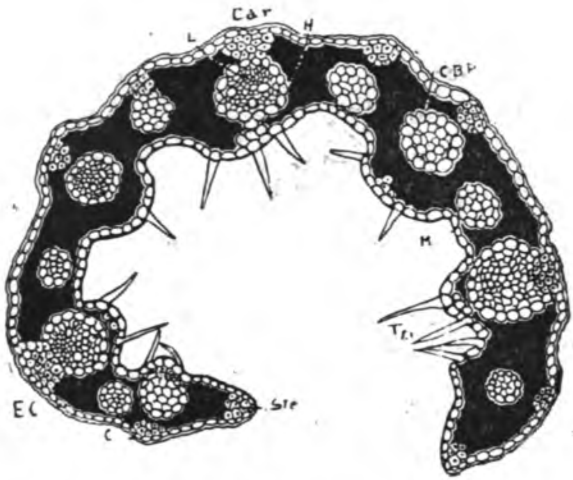


Fig. 16. Section of leaf of *Festuca tenella* Willd. *Car*, mid-nerve; *CBP*, chlorophyll bearing parenchyma; *M*, mestome bundle; *EC*, epidermal cells; *Ste*, stereome; *Tri*, trichome; *L*, leptome; *H*, hadrome. (Hansen and King.)

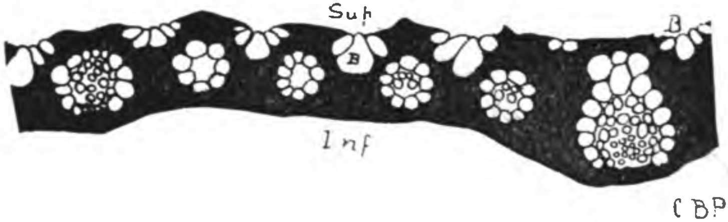
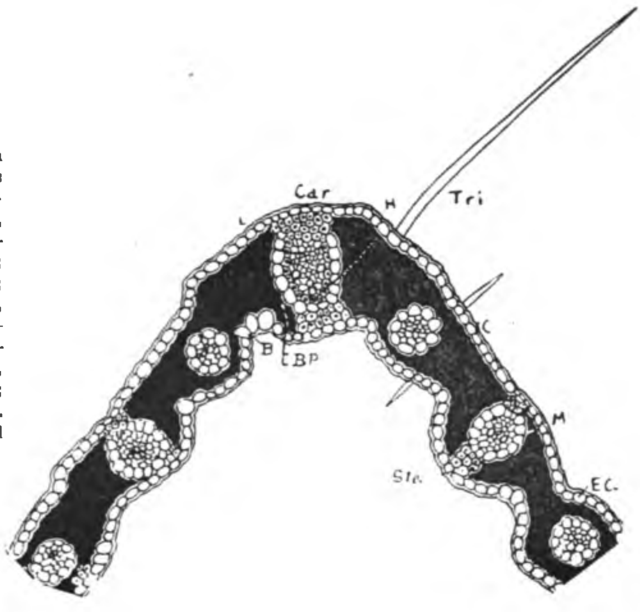


Fig. 17. Section of leaf of *Eragrostis major* Host. *Sup*, superior surface; *Inf*, inferior surface; *B*, bulliform cells; *CBP*, chlorophyll bearing parenchyma (Ball.)

Fig. 18. Section of leaf of *Bromus mollis*. *B*, bulliform cells; *CBP*, chlorophyll bearing parenchyma; *Car*, mid-nerve; *Tri*, trichome; *L*, leptome; *H*, hadrome; *EC*, epidermal cells; *M*, mestome bundle; *Ste*, stereome. (Sirrine and King.)



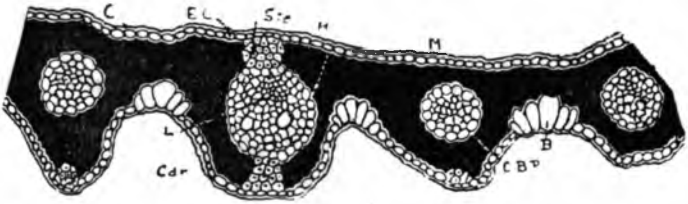
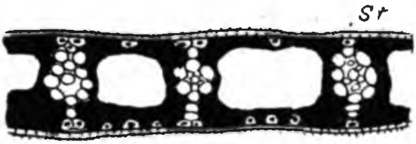
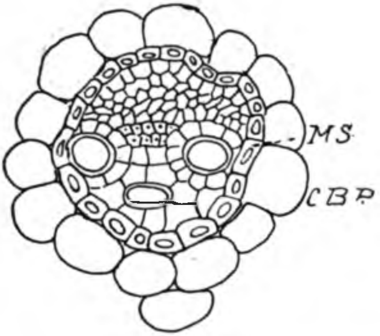


Fig. 19. a. Section of leaf of *Festuca elatior* var. *pratensis* Hackel· *Car*, mid-nerve; *CBP*, chlorophyll-bearing parenchyma; *B*, bulliform cells; *M*, mestome bundle; *L*, leptome; *H*, hadrome;. *Ste*, stereome; *EC*, epidermal cells. (Pammel and King.)



c. Cross section. From leaf of *Pleuropogon californicum*. *MS*, mestome sheath; *CBP*, chlorophyll bearing parenchyma. (From Holm.)



b. Section of leaf of *Pleuropogon californicum* Nees. *St*, stereome. (From Holm.)

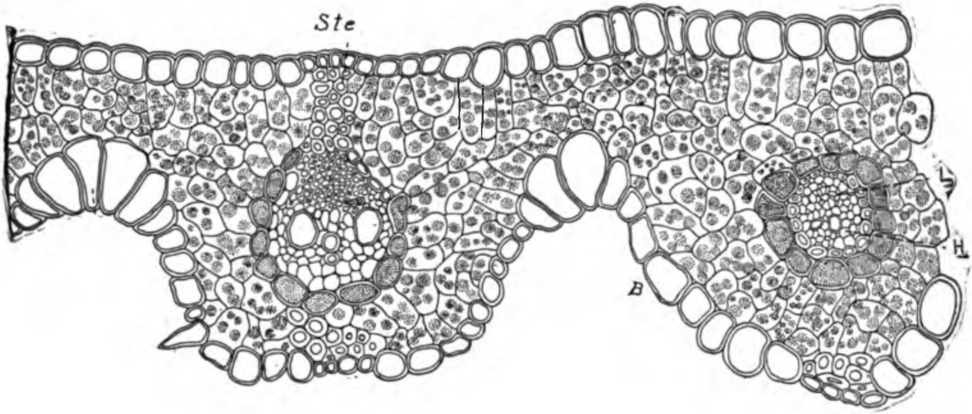


Fig. 20. Section of leaf of *Festuca elatior* var. *pratensis* Hackel. *L*, leptome; *H*, hadrome; *Ste*, stereome. (Pammel and King.)

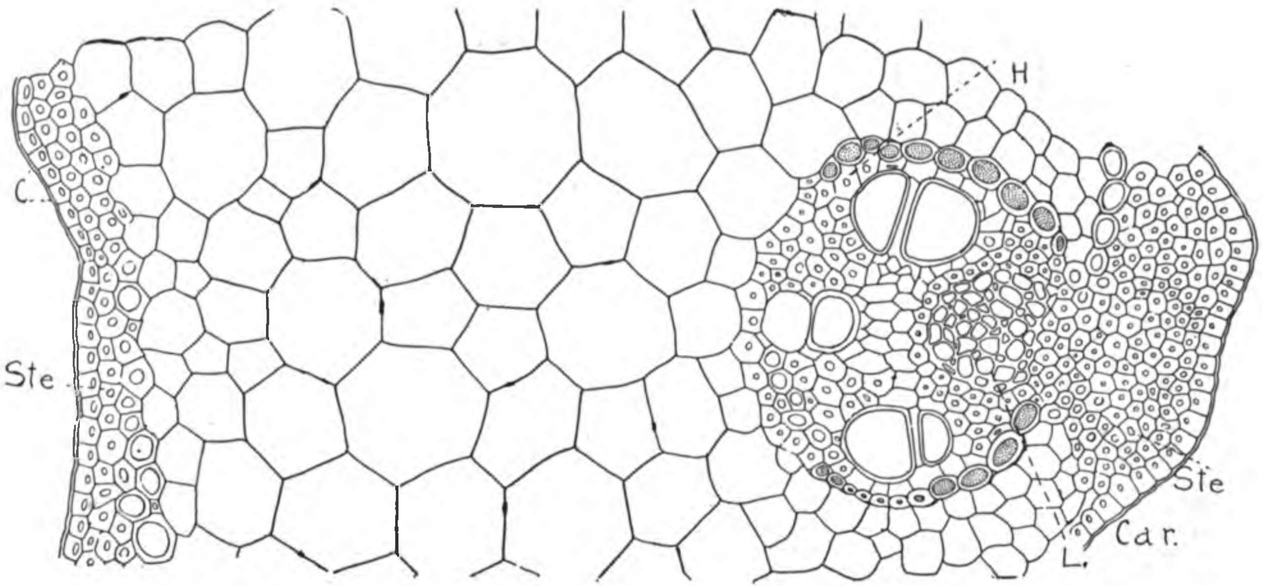


Fig. 21. Section of leaf of *Andropogon nutans* L. *Car*, mid-nerve; *L*, leptome; *H*, hadrome; *Ste*, stereome; *C*, cuticle. (Weaver and King.)

bundles of the mid-nerve. Two bundles of the third type occur near the margin of the leaf. The cells separating the leptome from the stereome are in this case somewhat thicker-walled than those in the mid-nerve.

The mestome bundles of second type are of two sizes, the largest ones having leptome and hadrome poorly developed, and the smallest having no thick-walled cells.

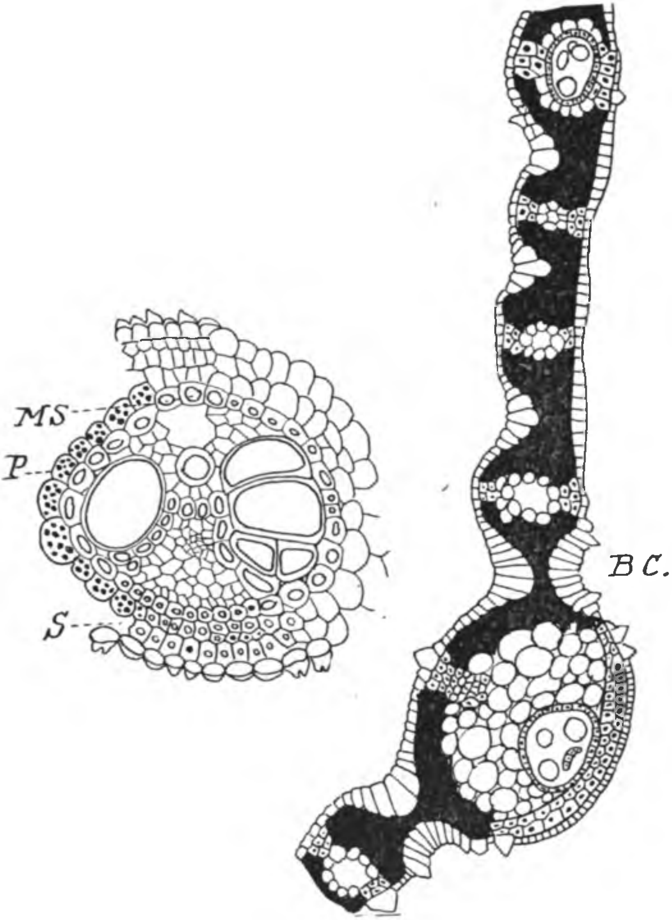


Fig. 22. Section of leaf of *Leersia oryzoides* Schwartz. *BC*, bulliform cells; portion of mid-rib in section; *MS*, mestome sheath; *P*, parenchyma; *S*, sclerotic cells. (Holm.)

The thin-walled parenchyma, with its inner closed sheath does not differ from that of *Festuca pratensis* and *Lolium perenne*. Stereome seems to be more strongly developed in this species than in *Festuca elatior*, var. *pratensis* and *Lolium perenne*. It occurs on the margin of the leaf, and also on inferior surfaces of all bundles of the first and third types, and on inferior surfaces of all large bundles of the secondary type. Mesophyll occupies a small area in this species since the mestome bundles are close together.

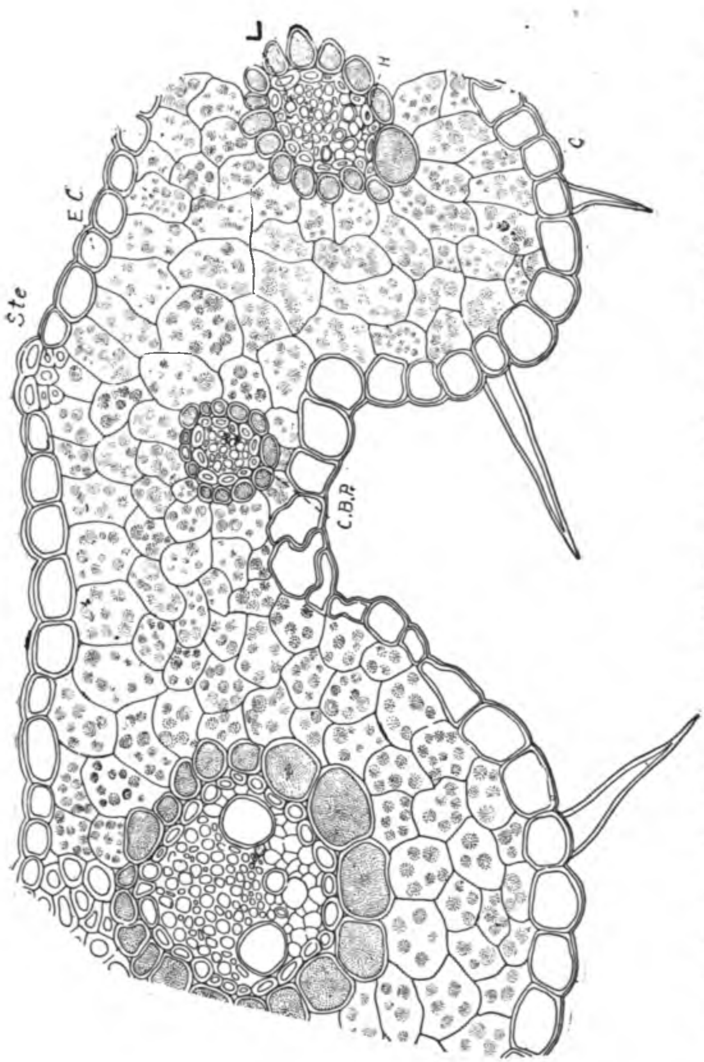


Fig. 23. Section of leaf of *Festuca tenella* Willd. *L*, leptome; *H*, hadrome; *CB.P.*, chlorophyll bearing parenchyma; *Ste*, stereome; *EC*, epidermal cells; *C*, cuticle. (Sirrine and King.)

Mr. Theo. Holm has described the anatomical characters of *Distichlis spicata*† a grass adapted to halophytic conditions,

† A study of some Anatomical Characters of North American Gramineæ III. Bot. Gazette. 16: 275. *pl. 23. f. 1-3.* 1891. Miss E. L. Ogden has likewise studied the leaf structure of Jouvea and of *Eragrostis obtusiflora.* Bull Div, Agros. U. S. Dept. Agrl. 8: 12-20. *pl. 9.*

and in many respects similar to the species described above. The stereome of the superior face is widely separated from the mestome bundles by the parenchyma. In *Pleuropogon californicum* there is a distinct mestome sheath surrounding the bundles and the walls are thick. The leptome and hadrome are separated from each other by two layers of thick-walled

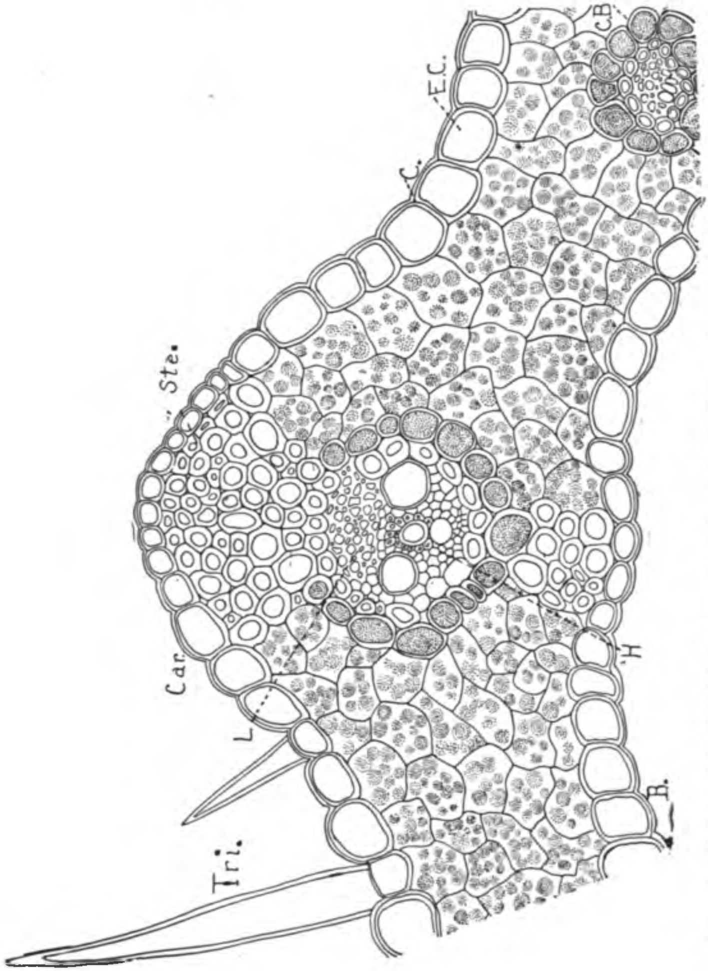


Fig. 24. Section of leaf of *Bromus mollis*. *Car*, mid-nerve; *L*, leptome; *H*, hadrome; *B*, bulliform cells; *Ste*, stereome; *GB*, chlorophyll bearing parenchyma; *EC*, epidermal cells; *Tri*, trichone. (Sirrine and King.)

parenchyma cells. In the large bundles stereome occurs above and below. They are separated from the parenchyma sheath by a few colorless cells. It may be interesting to compare the leaf structure of xerophytic and mesophytic

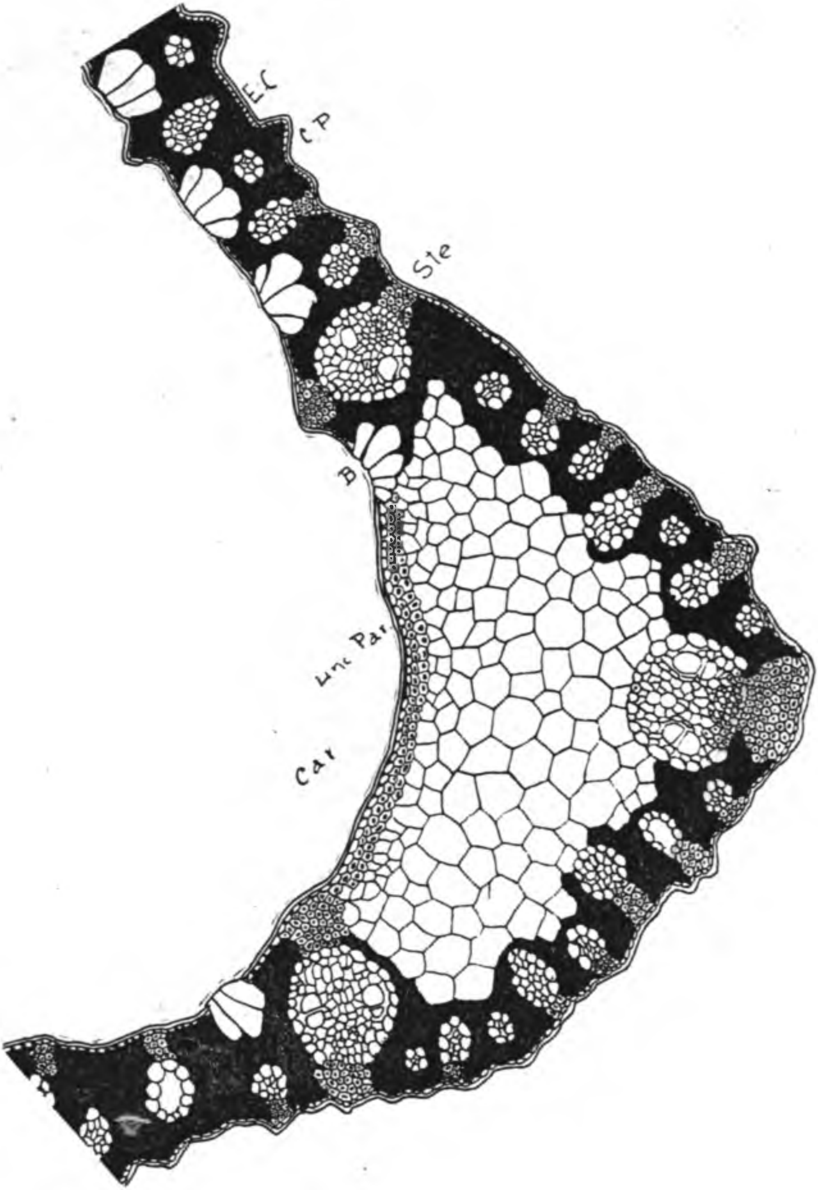


Fig. 25. Section of leaf of *Andropogon nutans*. *Car*. mid-nerve; *Unc. Par*, uncolored parenchyma; *B*, bulliform cells; *Ste*, stereome; *EC*, epidermal cells; *CP*, conical point. (Weaver and King)

plants, belonging to the same genus. Miss Ogden‡ describes the anatomical character of the *Eragrostis obtusiflora* thus:

‡ l. c. 17.

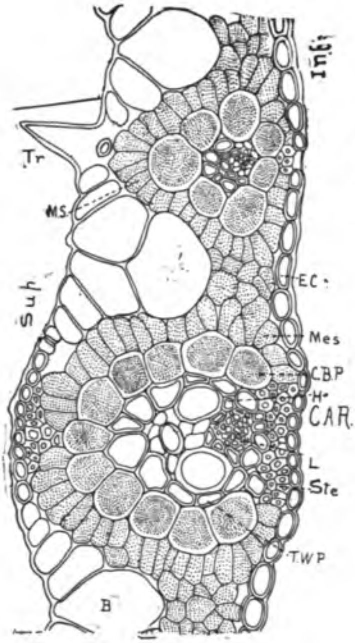


Fig. 26. Section of leaf of *Eragrostis purshii* Schrad. *Sup*, superior surface; *Inf.* inferior surface; *Car*, mid-nerve; *L*, leptome; *H*, hadrome; *St.* sterome; *MS*, mestome sheath; *Tr*, trichome; *B*, bulliform cells; *Mes.* mesophyll; *EC*, epidermal cells; *C. B. P*, chlorophyll bearing parenchyma. (Ball.)

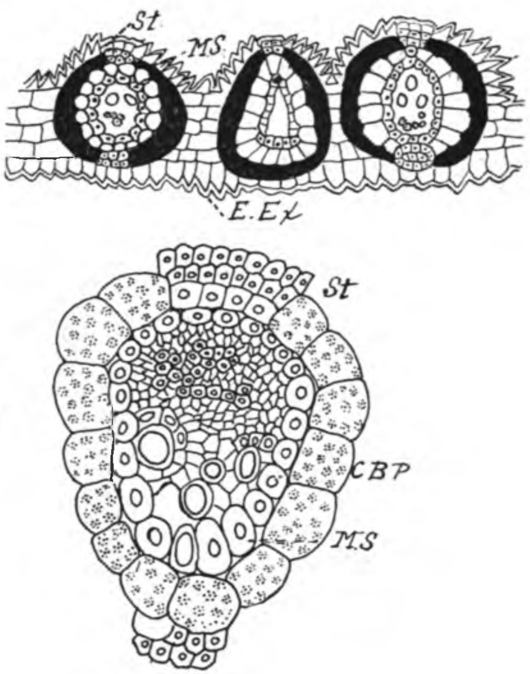


Fig. 27. *Distichlis maritima* Raf; *M S*, mestome sheath; *St*, stereome; *E. Ex* epidermal expansions. (Holm.) Section of bundle shown below. *MS*, mestome sheath; *St.* stereome; *C. B. P.*, chlorophyll bearing parenchyma. (Holm.)

"The secondary bundles differ in the marked line between xylem and phloem and also in the nature of the sheath. This consist of a single row of cells. Below and above the bundles these have relatively smaller cavities and thicker walls than the corresponding cells of *Jouvea pilosa*, but frequently on either side of the bundle there occurs one cell much larger than the others, of more angular shape, and in almost any section taken at random a transverse pitted wall is conspicuous. The two uppermost cells of the inner chlorophyll-bearing ring are at least twice as large as the other cells of the ring, and are usually wedge-shaped with the narrow end turned towards the bundle."

Mr. C. R. Ball,‖ in an interesting study of the leaves of several species of Eragrostis, well describes the mestome bundles of *Eragrostis purshii*, which number twenty-one. Sixteen belong

‖An anatomical study of the leaves of Eragrostis. Proc. Ia. Acad. Sci., 4: 140-141, 1897. *pl.* 7. *f.* 2, 3 *and* 4; *pl.* 9. *f.* 12. Contr. Bot. Dept. Ia. St. Coll. Agrl. and Mechanic Arts, 4.

to the secondary and five are intermediate. "In the secondary bundles (veins 3) the chlorophyll-bearing parenchyma sheath is nearly round in outline and composed of seven or eight sub-circular cells. Hadrome, leptome and thick-walled parenchyma are not so well developed as in the preceding species. The intermediate bundles (mid-nerve and veins 2), five in number, are open below. Hadrome, leptome, and thick-walled parenchyma are well developed, the latter especially so. The chlorophyll-bearing parenchyma sheath is composed of from ten to fifteen cells. The mestome sheath is continuous above and sometimes below the secondary bundles, but is interrupted by sterome above the intermediate type. The mid-nerve is but little enlarged and not easily distinguished from vein 2 except by its position. Stereome is present in quantities both above and below the intermediate bundles and occurs in small groups of three or four cells in the secondary bundles. The mesophyll passes beneath some of the secondary bundles as a single layer of cells."

In Mr. Ball's study of *Eragrostis pectinacea*, which is *xerophytic* in its nature, a very striking chlorophyll parenchyma sheath occurs near the secondary bundles. "It is distinctly triangular in outline, with the apex directed towards the superior surface. The lateral cells are elongated transversely to the section, and the inferior or basal cells are small and nearly round. Hadrome and leptome and thick-walled parenchyma are well developed."

We find a well marked type of bundle structure of leaf in some of the mesophytic grasses represented by *Festuca elatior* which has been described by Mrs. Hansen.* "The number of mestome bundles in a single cross-section in middle of leaf is twenty-four, and are not so close as in Lolium. There are three types: First, primary type, open on inferior and superior sides. Second, secondary type, those that are entirely closed, and these are most numerous. Third, the intermediate type, which are open only on superior side. The bundles of secondary type are most numerous. Three of the closed bundles occur near the margin of leaf. One bundle of the primary type is found next to the closed bundles. The third type is found to the left of mestome bundle of mid-nerve, and to the right of mid-nerve is found a mestome bundle of second type. One primary mestome bundle occurs in mid-nerve. In the

*l. c. 128: *pl. 9, f. 1. pl. 11, f. 9.*

mid-nerve, leptome and hadrome are well developed. The pitted vessels are large. Stereome is well developed on inferior and superior surfaces of the bundles. In the mid-nerve, leptome and hadrome are separated from each other by thick-walled cells. The cells in leptome are somewhat more thick-walled than in hadrome."

Mr. C. B. Weaver's study* of *Andropogon provincialis* shows the presence of four types of bundles, viz.: first, mid-nerve; second, entirely closed; third, open, and fourth, larger secondary bundles with stereome both above and below.

"The mid-nerve consists of three large bundles open above and below. The central bundle is but little larger than the secondary bundles. In the hadrome occur the conspicuous pitted and spiral ducts. The chlorophyll-bearing parenchyma cells surrounding the larger bundles are not as conspicuous as those of the smaller mestome bundles. The stereome above the mid-nerve is well developed and is wider than the middle larger bundle; while opposite on the lower side of the leaf occur but few stereome cells, and these latter are in direct contact with the epidermal cells. The cells composing the leptome portion of the mid-nerve bundle are uniform in size. The uncolored parenchyma cells which occur below and to the side of the mid-nerve bundle, are large. These cells are in contact with the three large bundles of mid-nerve. The smaller mestome bundles on either side of the mid-nerve occur close together. The chlorophyll-bearing parenchyma cells surrounding these are conspicuous. These bundles are not uniform in number on both sides the mid-rib, which goes to show that the development of the leaf is unequal. On each side of the mid-nerve occur four of the larger secondary bundles. The edges of the leaf are provided with stereome. The stereome about the cells varies in the number of cells. The cells of the mesophyll occur as dense masses with numerous intercellular spaces. They vary in shape from elongated to spherical. An occasional small trichome may be seen."

It may be interesting to compare the above structure with that of a typical woodland grass, and for that purpose we may take *Bromus breviaristatus*. According to the researches of Miss Emma Sirrine,† the mestome bundles number forty-one.

*An anatomical study of the leaves of some species of the genus Andropogon. Proc. Ia. Acad. Sci, Des Moines. 4: 132, 1897. Contr. Bot. Dept. Ia. St. Coll. Agrl. and Mechanic Arts. 4.

†A study of the leaf anatomy of some species of the genus Bromus. Proc. Ia. Acad. Sci., Des Moines. 4: 125. *pl. 4, f. 1; pl. 7, f. 7*, 1897. Contr. Bot. Dept., Ia. St. Coll. Agrl. and Mechanic Arts, 4

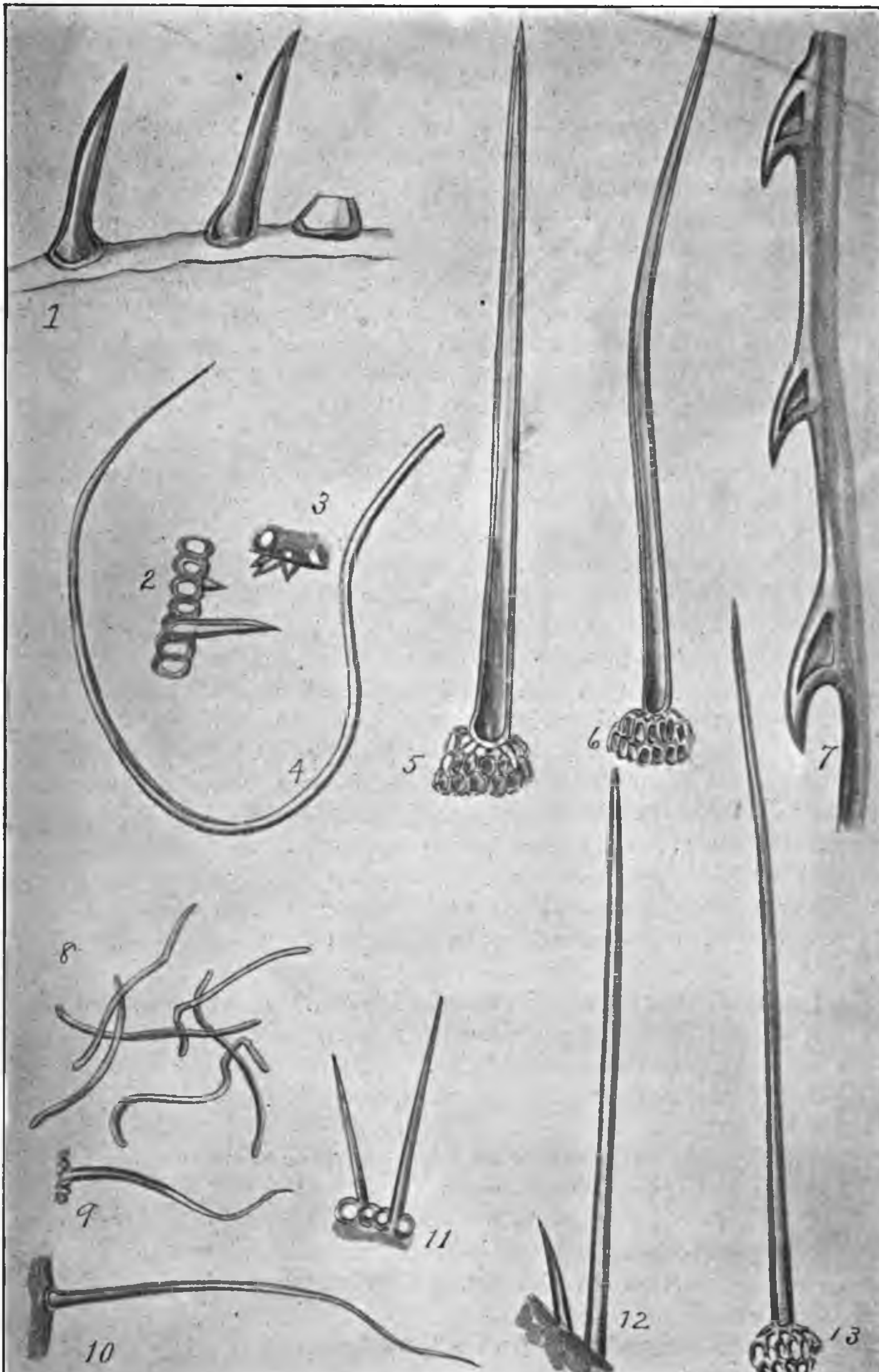


Fig. 28. Trichomes of grasses. *1*, *Leersia lenticularis*, from palet; *2*, *3*, *Andropogon scoparius*, from under surface of leaf; *4*, *Eragrostis major*, f om ligule; *5*, *Panicum capillare* L., from sheath; *6*, *Panicum sanguinale*, from sheath; *7*, *Spartina cynosuroides*, from edge of leaf; *8*, *Poa pratensis*, from flower; *9*, *Bromus asper*, from under surface of leaf; *10*, *Bromus ciliatus*, from sheath; *11*, *B. mollis*, from under surface of leaf; *12*, *Andropogon provincialis*, from rachis; *13*, *Bouteloua racemosa* Lag, from leaf-blade. (King.)

The primary bundles open on both inferior and superior surfaces. Leptome is in direct contact with stereome. The hadrome is separated from it by corlorless parenchyma. Mid-nerve consists of only one bundle, and with the exception of size, the large amount of stereome and colorless parenchyma is the same as that of species adapted to open ground.

The colorless parenchyma occurs beneath all primary bundles, while a sheath encloses all the bundles. Stereome is abundant on both inferior and superior surfaces of the intermediate bundles. Mesophyll surrounds all the secondary bundles and occurs between the other two types, and on the inferior portion of the intermediate type.* In maize, according to Combs, the sheath in cross section shows, beginning at the upper surface, the epidermis of large, thin-walled cells, immediately inside of which is stereome in patches, which are located opposite the large bundles on the outer side. Then comes the inner area of the sheath, made up of large, polygonal, colorless, thin-walled parenchyma cells.

The outer or lower surface of the sheath presents an entirly different aspect and varies greatly with the variety of corn. Generally speaking, it is more or less ribbed, caused by the large fibro-vascular bundles. The creases have colorless unicellular hairs which are usually not developed on the epidermis over the bundles. The epidermal cells are small and thick-walled, and protect the plant against drouth and other injuries. Beneath the outer epidermis occur the bundles referred to above, usually with intervening smaller ones, but this varies with different corns. For example, a Mexican corn, number 1, shows two sizes of bundles not connected with each other, forming no external ridges, and the epidermis shows only a few very short spur-like hairs, while a form from South America shows heavy ridges, many hairs, and only one kind of bundle.

In all cases there exists an area of stereome between the bundles and the outer epidermis.

The only chlorophyll in the sheath is located in the chlorophyll parenchyma sheath which surrounds the bundles, except a portion on the outer side which is occupied by stereome.

The anatomy of the species thus far considered here, are

*Proc. Ia. Acad. Sci., 5: 201. Contr. Bot. Dept. Ia. State College of Agr. and Mech. Arts. 10: 6.

such as belong to the types of plants known as halophytic, xerophytic, and mesophytic. Of the fourth type, hydrophytic, the genus *Leersia* is good representative, especially *Leersia oryzoides* which has been well described by Mr. Holm.* In this species the mestome bundles are of three types. A thick-walled mestome sheath, in connection with a layer of thick-walled parenchyma, separate the leptome from the hadrome. Leptome and hadrome are well developed. The largest bundles are not so numerous as the smaller ones of the second degree; in the latter a distinct mestome sheath occurs inside of the colorless parenchyma. The thick-walled parenchyma between leptome and hadrome is absent. The smaller type of bundles contain only leptome with a distinct mestome sheath. Mr. Holm further remarks that in addition to these forms of bundles, which lie in the same plain, there are from one to three very small ones which belong to the upper face of the mid-nerve and this is peculiar to the genus Leersia.

Epidermis.—The epidermal cells are quite irregular, varying greatly in size. For the purpose of this description it will be convenient to take up the epidermal cells under two headings. First, the general character of cell. Secondly, the bulliform. We may obtain an idea of the diversity of the structure by a consideration of some of the different species. One type is very well represented in *Bromus inermis.*†

Here the epidermal cells are large, regular and well-developed, with a thick cuticle. The cuticle is thicker below and above the mestome bundles than elsewhere. Trichomes are absent. Stomata occur on both surfaces of the leaf, but especially between the bulliform cells.

In *Festuca tenella*, according to Mrs. Hansen,‡ the epidermal cells covering the stereome are thick-walled and not as large as the other epidermal cells. In *Andropogon nutans*§ the epidermal cells are very large, and nearly equal in diameter. The cuticle is strongly developed with hair-like projections, more abundant on the lower than on the upper surface.

Mr. C. R. Ball has described the epidermal cells of *Eragrostis pectinacea*, as having thicker-walled cells than in *Eragrostis purshii*‖ the latter being a species adapted to a dry and

* A study of some anatomical characters of North American Gramineæ. IV. Bot. Gazette. 17: 358. *pl. 21.*

† Emma Sirrine, l. c. 122.

‡ Emma Pammel, l. c. 129. *pl. 9. f. 2. pl. 10, f. 5 and 6.*

§ C. B. Weaver, l. c. 133. *pl. 12. f. 1 and 5. pl. 15 f. 14.*

‖ l. c. 141. *pl. 16. f. 2. pl 18. f. 15-16.*

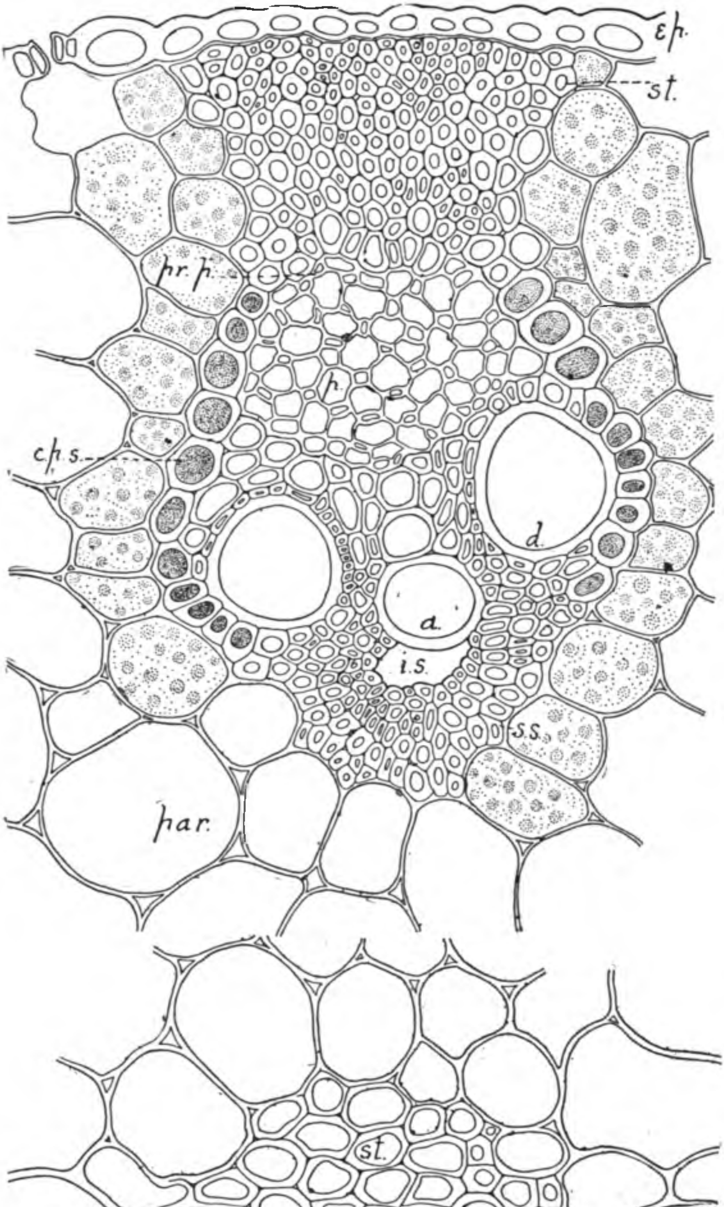


Fig. 29. Cross-section leaf of maize. *ep*, outer epidermis, cross-section of stoma to the left; *p*, soft bast or phloem and companion cells; *cps*, chlorophyll-bearing parenchyma; *d*, duct; *a*, ringed vessel; *is*, intercellular space; *ss*, *st*, stereome; *iep*, inner epidermis. (Combs.)

sandy soil. The cells of *Eragrostis purshii* vary considerably in size, being smaller above or below the bundles than those adjacent to the mesophyll.

In *Sporobolus cryptandrus** the cells have a particularly well developed cuticle. Miss Ogden describes a most peculiar kind of epidermal cells in *Eragrostis obtusiflora* with curved, beak-like expansions that project from the stomata; the cells are very unevenly thickened.

Scent glands.—Another most interesting feature to be added to the epidermal layer is the peculiar glands which grow on certain grasses. One of the best known illustrations of glandular trichomes in grasses occurs in the common stink grass (*Eragrostis major*). These glands were first studied by Professor Trelease.†

The somewhat similar glands of *Sporobolus heterolepeis* had previously been studied by C. E. Bessey.‡

Recently Mr. C. R. Ball has studied the glands of *Fragrostis major*. The following is condensed from papers by Mr. Ball and Professor Trelease. The small projections, or scent glands as they are known, are epidermal structures consisting of the single layer of cells. Those at the center are considerably elongated and the parenchyma cells are provided with thick-pitted walls. Those in the center are much thinner-walled. As compared with the unmodified epidermal cells, these elongated glandular cells are also thin-walled at top, where, in common with the other elements of the epidermis, they are invested with a rather heavy cuticle. In some cases this membrane is seen to be free from the crater of the gland in the form of a blister, while in others it has been ruptured, so that only fragments are present. Miss Ogden describes glandular bodies as occurring in *Eragrostis obtusiflora*. In her description it is stated that these glands are provided with a narrow neck and a capitate exodermal portion.

Fig. 30. Scent glands of stink grass (*Eragrostis major*). Figure to right, surface view; left view in section. (Ball.)

*Emma Sirrine and Emma Pammel, l. c. 153.

†The glands of Eragrostis major Host. Proc. Soc. Proc. Agrl. Sci., 10: 70. 1889.

‡Glands on a grass. Am. Nat., 18: 420, *f. 1.* 1884.

Bulliform cells.—Between the nerves occur peculiar epidermal cells which are wedge-shaped; these are known as bulliform cells. Hackel* says these are arranged in the form of a fan whose growth and expansion causes the blades to open out; in those leaves which are rolled in the bud these cells are only found on each side of the mid-rib. Excellent bulliform cells occur in orchard grass, Spartina, etc. In some species of Sporobolus, the leaves are rolled up much of the time. Where the leaves open the bulliform cells are large and penetrate deeply. In *Festuca tenella* and some other species of the genus the leaves do not open and hence bulliform cells are absent, or, but slightly developed. This is also true of Stipa and Nardus. It is owing to this peculiar cell development that the leaves of Sporobolus roll up so easily when they become dry. It requires excessive moisture to open them. Excessive transpiration during dry weather causes the leaf blades to roll up because they have lost their turgescence, but when the atmosphere is moist they flatten out. The bulliform cells afford protection to our wild prairie grasses, and thus they pass the hot, dry winds unharmed while many cultivated grasses are injured. The lower side of the leaf is protected by the strongly developed cuticle which prevents transpiration.

Professor Beal, who has made a study of the bulliform cells of many leaves, says as follows: "The leaves of *Poa* have two bands, one on each side of the middle. *Andropogon squarrosus* has one band on each side of the middle and a small one at each edge. The leaf of the *Phleum pratense* has one band of several shallow cells on each side of the middle and others between the veins. The leaves of *Zea mays* have a band between each two primary bundles and above each third class bundle. The leaves of the *Leersia oryzoides* have numerous bands on the upper surface on each side of the middle, and on each side of the keel on the lower side. The leaf *Amphicarpum purshii* has opposite bands of bulliform cells on both surfaces. Those above are most prominent. In case of the leaves of *Panicum plicatum* the bands of bulliform cells are first on the upper side then on the lower, and are found in grooves. The leaves of *Andropogon prinoides* have large epidermal cells of nearly uniform size, distributed along the surface, excepting over the veins."

*True grasses, English translation, Lamson, Scribner, and Southworth. 9.

From studies made in the botanical laboratory of the Iowa Agricultural College, the bulliform cells of different species of grass are sufficiently diagnostic in grasses occurring under different climatic and soil conditions, to warrant a study of them. These differences may best be considered by taking some of the different species. Mr. Ball* found that the bulliform cells of Eragrostis are two or three in number, and in some cases not easily distinguishable from the epidermal cells.

Mr. Theo. Holm† says of *Leersia oryzoides:* "The bulliform cells form grooves between all of the mestome bundles and are of unequal lengths, the middle cells being the largest, with a narrowing towards the surface, thus being nearly triangular in cross sections, the cells on the sides gradually becoming smaller." Both of these species are adapted to hydrophytic conditions and hence the bulliform cells need not be nearly so well developed as in species adapted to dry weather conditions. This is also true to some extent of *Panicum proliferum*, in which the bulliform cells vary from two to five, usually consisting of one large or two large central cells. In *Sporobolus cryptandrus* and *S. heterolepis* the bulliform cells are very nicely developed. According to Miss Emma Sirrine and Mrs. Hansen,‡ the bulliform cells of *S. hetrolepis* occur in four or five rows, a large central cell and three or four smaller cells on each side. In *S. cryptandrus* they are somewhat larger than those in *S. heterolepis*. In the latter there are usually two or three quite large cells and two smaller on each side. One or two groups of bulliform cells occur between a large mestome bundle, and, as in *S. heterolepis*, these do not occur between the last two bundles. In *Andropogon scoparius* the bulliform cells occur as a continuous row, excepting over the secondary bundles. In Johnson grass the bulliform cells gradually merge into the epidermal cells. The bulliform cells of sugar cane§, which is adapted to the hydrophytic conditions, consist of three or sometimes more rows quite strongly marked. In fact these cells are very much larger than the remaining epidermal cells.

It may be interesting here to briefly give the structure of the bulliform cells of the various varieties of corn. These have been studied by Mr. Combs.

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* l. c.

† *IV* Bot. Gazette, 17: 359.

‡ l. c. 151.

§ Wm. C. Stubbs. Sugar Cane, *1. 20. f. 6. 8.*

The bulliform areas are composed of from three to seven rows of polygonal cells with thin walls. They are arranged longitudinally with the leaf and are occasionally interrupted by or grade into the exserted cells about the base of the large hairs. These areas usually consist of about fourteen rows of epidermal cells. They are located alternately with the veins. The epidermis of the lower or outer face is much the same as above, except that the bulliform cells, hairs, and spur-like hairs or tubercles are wanting, and the walls are thicker.

Stomata.—The stomata occur in longitudinal rows; the two narrow guardian cells containing chlorophyll are surrounded by two large secondary cells. A thin cross-section of leaf of *Sporobolus heterolepis* shows a nearly continuous row of rectangular epidermal cells, broken only by the stomata.

The ecological parts of the grass leaf are rather instructive. The cuticle and cell walls are strongly developed in the corn. The same is true of many other dry climate grasses. In grasses like barnyard grass, the epidermal cells are larger and the cell walls and cuticle less developed, as they grow in places where moisture is obtained easier and transpiration is not so excessive. The chlorophyll-bearing parenchyma surrounds the bundles and differs somewhat in different genera. In *Sporobolus heterolepis* large parenchyma cells surround the bundles. These are joined by one or more rows of smaller cells to the outside. In this arrangement there is economy, since the plant can carry away the elaborated food materials. The blades as well as sheath are frequently provided with trichomes, abundantly produced in *Bromus mollis*, *Leersia oryzoides*, Zea (Mexican corn). Those interested in a further study of the anatomy of leaves should consult specially the works of Hackel, Holm, Miss Emma Sirrine, Miss Emma Pammel, Duval Jouve, Ball, Combs and others. These studies are of value from a systematic standpoint, as has been abundantly shown by Holm, Jouve, Ball and others. The character of bundles, sclerenchyma, bulliform cells vary in different genera and species, and often may be used to determine the species and help to separate them, but we should not lose sight of the fact that allied species present somewhat similar characters and usually have a similar structure.

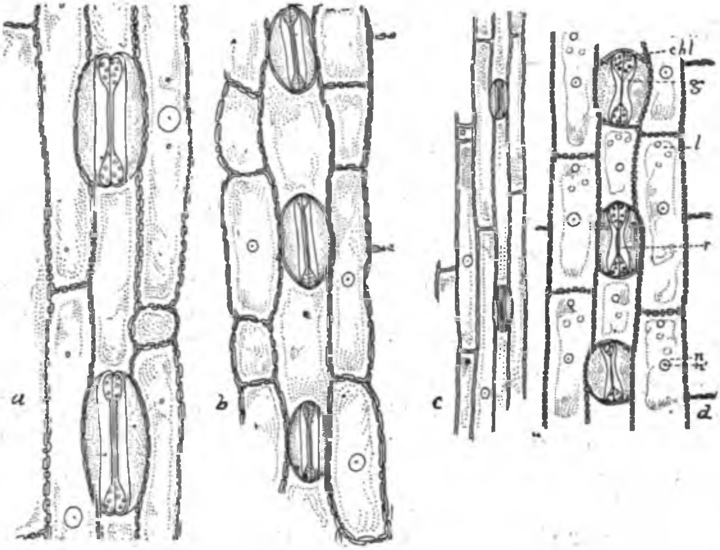

Fig. 32. Stomata of grasses. *a*, wheat; *b*, *Panicum crus-galli*; *c*, *Bromus inermis*; *d*, *Poa pratensis*; *chl*, chlorophyll grains; *g*, guardian cells; *l*, leucoplastids; *r*, rift; *n*, nucleus; *n'*, nucleolus. (King.)

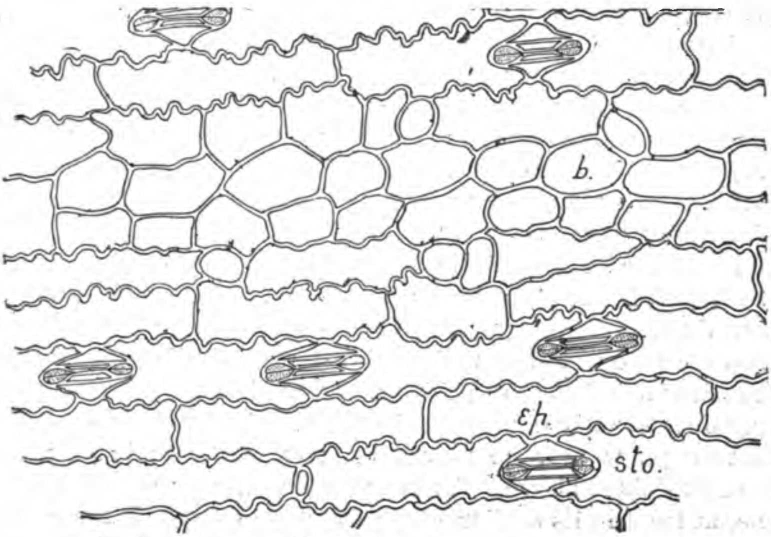

Fig. 33. Stomata of maize leaf. *b*, bulliform cells, upper surface; *ep*, epidermal cells with irregular walls; *sto*, stoma. (Combs.)

The Flower.

Parts of the flower.—The flowers of grasses possess only the essential organs—the stamens and pistils. The bracts enclosing these are modified leaves or leaf sheaths and prophylla. Sometimes the stamens and pistils are separated, when the flowers are either male or staminate (containing stamens only), or female or pistillate (containing pistils only). These staminate and pistillate flowers may occupy different parts of the same plant or (more rarely) entirely distinct plants. Flowers having both stamens and pistils are termed hermaphrodite.

In each flower there are usually three stamens. These have slender filaments, and usually versatile, sometimes basifixed, two-celled anthers, which are pale yellow, sometimes nearly white, or purple, or some shade of red. The pistil consists of the ovary and usually two feathery or plumose stigmas, which may be sessile or raised on short or long and more or less divided styles.

The fruit or ripened ovary constitutes the "grain." This is a true caryopis, *i. e.*, a dry one-seeded fruit in which the outer covering or pericarp is closely adherent to the seed. The "grass seed" of commerce consists of the grain enveloped usually in more or less "chaff" (glumes and paleas).

Arrangement of the flowers.—The arrangement of the flowers in grasses is peculiar. They are situated in what are termed spikelets, either solitary (one flowered spikelets) or two or more together (two to several or many-flowered spikelets). Each flower is located in the axil of a chaff-like bract or glume called the flowering glume (really a leaf-sheath). At the base of the spikelet there are usually two bracts or glumes having no flowers in their axils; these are the outer or empty glumes.

Hackel, in his work on grasses, says: "The palea, which, with its enclosed flower, stands opposite the flowering glume, does not belong to the main axis of the spikelet, but to the branch which bears the flower. That this relation of parts may be gradually obliterated in the one-flowered grasses, and that the palea may be moved back upon the main axis, has been explained above. As long as an axis or a rudiment of one, at least in its earlier stage, is visible beyond the palea, this latter possesses (like the prophylla of the culm branches) two keels, or at least two lateral nerves, without a mid-rib;

Fig. 35. Inflorescence of *Koeleria cristata* Pers. *Eatonia obtusata* Gray. *Eatonia pennsylvanica* Gray.

Fig. 34. Spike of *Setaria glauca*. (King.)

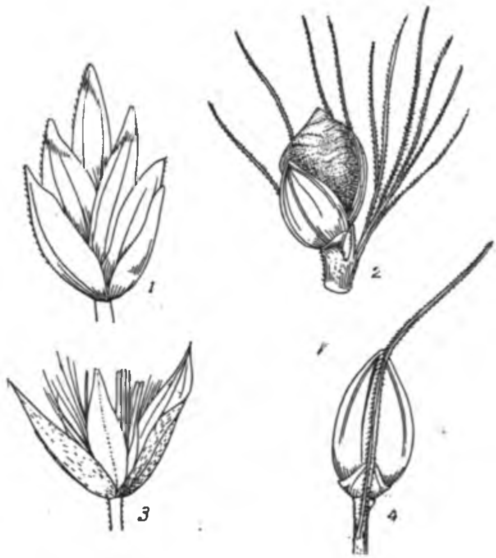

Fig. 36. Spikelets of grasses. *1, Poa pratensis*, spikelet four-flowered, the two lower scales the sterile glumes; the flowering glume of others only show; *2, Setaria glauca; 3*, Spikelet of *Calamagrostis canadensis*, the two sterile glumes, flowering glumes and palet; *4, Setaria verticillata.*

Fig. 37. Pollination of Maize. *A*, young ear with stigmas; *B*, to the right, pistillate flower with scales and chaff; B, above staminate flower; *J*, pistil; *J*, *G*, ovule. (Details after Nees, Hackel.)

only when all trace of the axis is absent does the palea become from one to many nerved (with a mid-rib) or nerveless. It is almost always of a more delicate texture than the flowering glume, its edges are usually turned in, and it has a furrow instead of a mid-rib. The prophyllum of the culm branches has no blade, and the palea resembles it in being almost always (excepting Amphipogon) awnless; and as the former is sometimes split in two parts (Cynodon), so the palea is often split at the time the fruit is mature (many Sporoboli and Triticum monococcum L.). This state has been understood by some authors as originally bifoliate, and false genera have been established upon it by some (Diachyrium Griseb, etc.). The palea is completely aborted in many Andropogoneæ and species of Agrostis."

The axis to which these glumes are attached is termed the rachilla, and between each flower and this rachilla there is usually a two-nerved bract, the palea the prophyllum to the floral branch. In one-flowered spikelets where there is no extension or prolongation of the rachilla, this palea is apparently opposite the flowering glume. The lower pair of glumes—the empty ones—often differ from each other in size or length, and sometimes, though rarely, one or both are absent. In others they occur as rudiments, as in Leersia. In a few cases it consists of but a few scales,

Fig. 38 *Eragrostis trichodes.* Loose paniculate inflorescence.

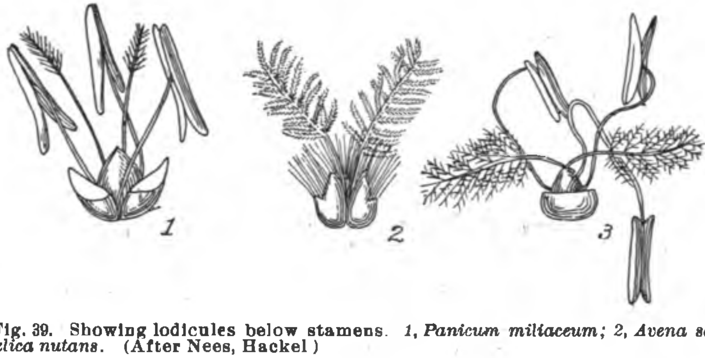

Fig. 39. Showing lodicules below stamens. 1, *Panicum miliaceum;* 2, *Avena sativa;* 3, *Melica nutans.* (After Nees, Hackel.)

generally two, rarely more than two. In this case they are generally described as sterile flowers as in such genera, Panicum and Andropogon. This question is discussed more at length by Hackel and Scribner.*

The glumes may be awned or "bearded," or awnless; they may be sharp-pointed, obtuse or toothed at the apex; they may be nerveless or one to many-nerved. As to

Fig. 39 B. *Zea mays* a single spikelet with staemens.

other variations it is necessary to refer the reader to the larger descriptive works on botany.

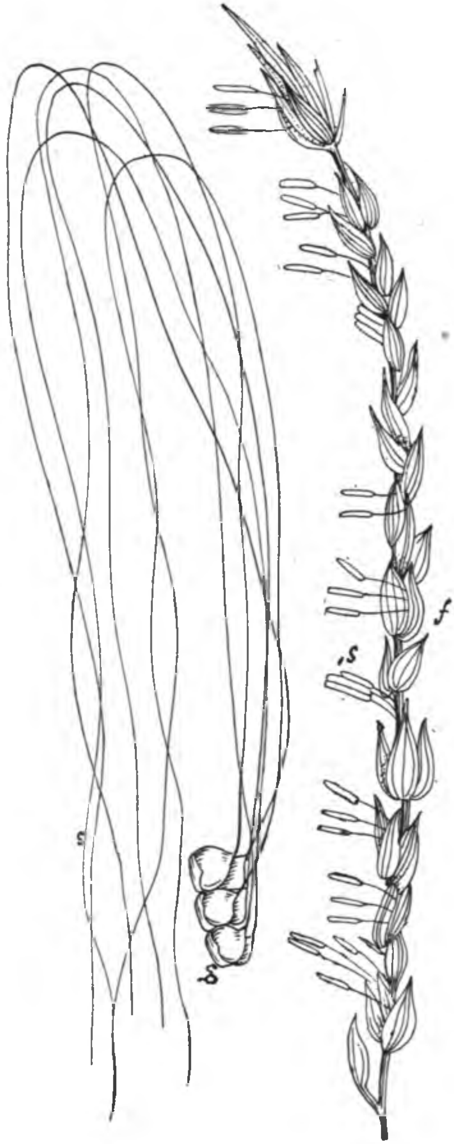

Fig. 39 A. *Zea mays*. To the left, pistil; g, ovary; s, stigma; to the right, f, flowers; s, staemens.

Opposite the palea and above the flowering glume occurs two small delicate scales known as the lodicules. Sometimes there are more than two, sometimes they are wanting. These lodicules stand close together. In the front they are

*English translation True Grasses, from Die Natuerlichen Pflanzenfamilien. See also Bentham, Notes on Gramineae. Linnean Soc. Jour. Bot., 19: 22.

close together. Various views have been held in regard to these lodicules. The question has been discussed by Bentham, who states: "It might therefore be suggested that the palea and lodicules of Gramineæ represent perianth-segments of an outer and inner series, although I by no means pretend to assert it as a proved fact." Hackel* in an early paper discussed the original homology of these organs. In his own words in a later paper, "The author has endeavored to prove that the anterior scales represent the halves of a leaf which sometimes (Melica, Fig. 81, f.) remains undivided, and can be regarded as a second, and the posterior scale as a third, palea. The anomalous condition of these paleas (in respect to the ordinary palea) is explained by their biological properties. The rapid swelling of the bases at least, causes the separation of the flowering glume and palea, and consequently the opening of the flower. In grasses where they swell only a little the spikelets open but slightly, and where the lodicules are membranous or entirely lacking, the spikelet remains entirely closed at the sides, and the reproductive organ protrudes only at the apex (compare Anthoxanthum, Alopecurus, etc.). The absence of the lodicules is not necessarily a case of abortion; for if they are bractlets, a decrease in their number (as in the Juncaceæ) is not very remarkable. Their large number (eight or more) and apparent spiral arrangement is striking in Ochlandra; here their relations have, however, still to be studied in living material."

The subject of lodicules again finds discussion in a recent paper by W. W. Rowlee.†

Arrangement of the flowers.—The arrangement of the spikelets upon the stem constitutes what is termed the inflorescence, or what we often hear erroneously called the "head." If that portion of the main axis or stem which bears the spikelets is unbranched so that these are sessile (*i. e.*, without pedicels), the inflorescence is a spike, as in wheat or rye grass; when the main axis is branched, each branch forming a pedicel to a single spikelet, the inflorescence is a raceme. This form is not common. Usually the primary branches branch again and again, resulting in the formation of a panicle. The panicle may be open or widely spreading, as in oats or in Kentucky blue-grass; or, if the branches are very short, it may be narrow

* Engler's bot. Jahrbuecher. 1: 33.

† The morphological significance of grasses. Bot. Gaz 25: 199.

and spike-like, as in timothy or in meadow foxtail. All gradations of form between these two extremes occur.

Pollination and fertilization.—Grasses are mostly anaemophilous, that is, pollinated by the wind. Flowers, as stated above, are mostly hermaphrodite; some are monoecious and a few dioecious. In monoecious grasses like Zea the staminate flowers form the so-called tassel. Each staminate flower contains three stamens; when mature they hang loosely from the flower. The pollen consists of small round grains easily shaken out of the versatile anthers. The slightest breeze suffices to set the anthers in motion, causing them to shed "loads of pollen." Since the pollen is light it may be easily carried by the wind. The pistillate flowers occur in the axils of the leaves and constitute the so-called cob. Each ovule has coming from it a long, slender filiform thread, the stigma, provided with plumose hairs. These plumose hairs are readily made out with the naked eye and are for the purpose of holding the pollen grains. The moist surface of the stigma causes the pollen grain to germinate. It sends a slender tube down the style to the ovule where the generative nucleus unites with the egg cell of the ovule, and as a result of this fertilization the kernel develops into a seed. Corn produces an enormous amount of pollen. Much of this is of course wasted. The staminate flowers are visited by honey bees and other insects chiefly for the pollen. Corn, when in flower, has a decided odor.

Bulbilis dactyloides is said to be dioecious. Mr. Plank* made some observations which led him to believe that the grass was not dioecious but monoecious, and Professor Hitchcock,† in order to verify this statement, conducted the following experiments. A few seeds of the species were germinated. A single stolon was transferred to an out-door plat. This produced numerous stolons, gradually spreading over the ground. The second season witnessed no flowers, but the third season both staminate and pistillate flowers were produced, the staminate preponderating. The flowers made their appearance mostly at the nodes, so that in reality they started as independent plants.

In *Distichlis spicata* and occasionally *Poa arachnifera* the plants are dioecious. In these cases the pollen must come from other plants.

**Buchloe dactyloides* Englm. not a dioecious grass. Bul. Torr. 19: 303. 1892.

†Note on buffalo grass. Bot. Gazette. 20: 464.

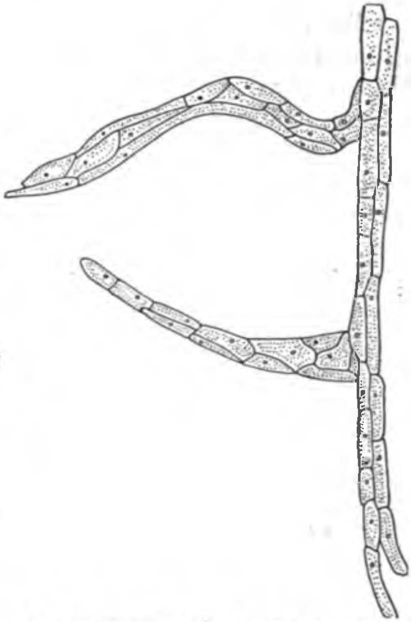

Fig. 40. Plumose stigmas of maize. (Pammel and King.)

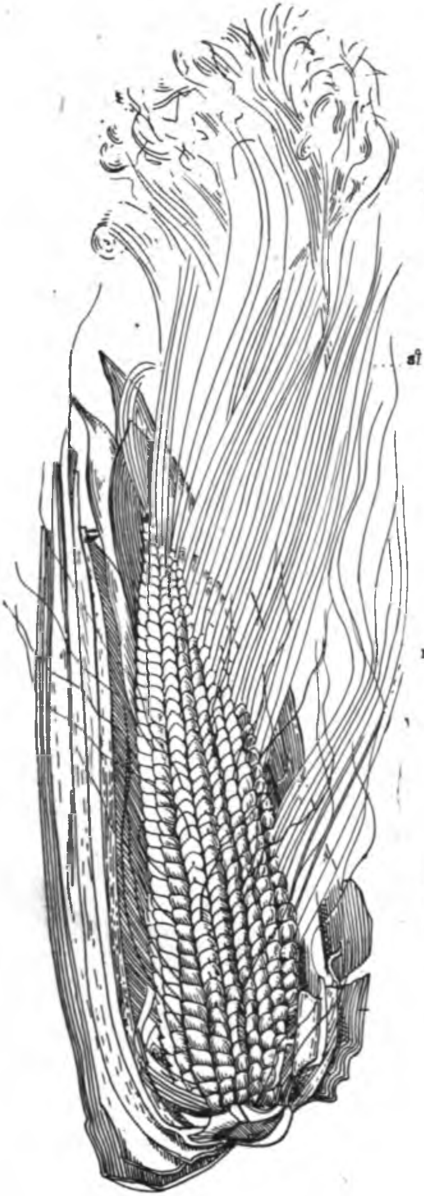

Fig. 42. Pistillate flower, ovules developing. *st*, styles. (King)

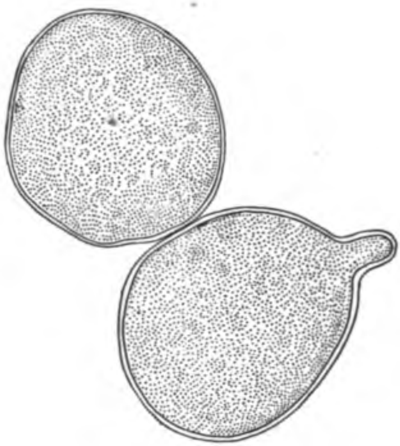

Fig. 41. Pollen grains of maize mounted in water. (Pammel and King.)

Arrhenatherum avenaceum has hermaphrodite flowers as well as staminate. The anthers are long and pendulous. The least jar or the slightest breeze will cause a shower of pollen to issue from the anthers; the very plumose stigmas ar e exposed and readily receive the pollen. Self-pollination can occur in many grasses as stamens and pistils mature at the same time, but this is prevented in tall meadow oat grass and others by the difference in time in which stamens and pistils mature. In this grass the pistil matures first and is therefore proterogynous. When the pollen is mature and is shed, the stigmas have wilted and are no longer in a receptive cnditi on. In most grasses stamens mature first and the flowers are proterandous.

The flowers of our *Andropogon provincialis* with digitate spikes are gently blown by the wind. When they come in contact with a neighboring plant they are sure to leave some of the pollen on the receptive stigma. The long, purple plumose stigma is proterogynous, and therefore not ready to receive the pollen when the stamens dehisce. The flowers open during the early morning (5 A. M.), when there is considerable dew on the ground.

Professor Hitchcock* has described quite interestingly the

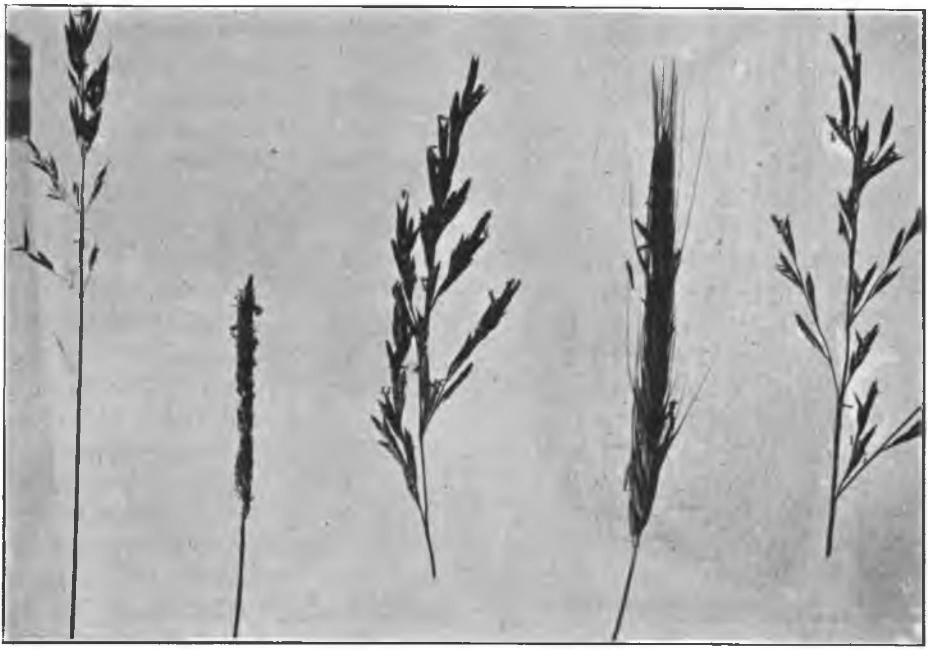

Fig. 43. The opening of grass-flowers. Beginning to the left: Tall Meadow Oat grass, *Arrhenatherum avenaceum;* Meadow Fox-tail, *Alopecurus pratensis;* Hungarian Brome, *Bromus inermis;* Rye, *Secale cereale;* Meadow Fescue, *Festuca pratensis.*

*Report on a collection of plants made by C. H. Thompson in southwestern Kansas in 1893. Contr. U. S. Nat. Herb., 3: 537.

manner in which grama grass, *Bouteloua oligostachya* is pollinated.

The plants grow closely intermingled, forming a dense, soft mat a few inches in height. The flowers are arranged in one-sided spikes, of which there are usually two or three. The two stigmas protrude from the base of the partially opened glumes and recurve towards the main rachis. The anthers, as is usual in grasses, hang on slender filaments, easily shaken by the slightest breeze. The spikes are so arranged that when acted upon by the wind they turn like vanes. This brings all the spikes in a direction nearly parallel to the wind, the stigmas being to the windward and the anthers to the leeward; thus the stigmas necessarily receive pollen from a different plant. The same adaptation is seen in other species of Bouteloua and in some other grasses.

Many of the flowers of grasses have a pair of small scales, physiologically of great importance, as they assist in the pollination of grasses. The bases of these lodicules are grown together. The rapid swelling of the bases at least causes the separation of the flowering glume and palet, and hence the opening of the flower. These turgid scales may be seen at the time of flowering in many grasses. They are very evident in *Poa arachnifera, Panicum miliaceum, Avena sativa, Bromus mollis* and *Festuca elatior.* In grasses where these scales swell but little, the flowers do not open very far. Where they are absent the spikelets are closed at the sides and the stamens and pistil only protrude at the apex. The time of opening of grasses in different genera varies greatly. It is well known that temperature and moisture greatly influence the opening of flowers. Rain and low temperature may retard the opening, not only hours but days. Dry air and a high temperature also retard opening. The flowers of grasses open, as a rule, early in the morning, usually when there is some dew. *Festuca pratensis* opens before 7 A. M. Mr. F. A. Sirrine found that about Ames the flowers of grasses usually open between 5 and 9 A. M. Some, however, open between 5 and 7 P. M. Kerner von Marilaun* states 4 to 5 A. M. for Poa and Koeleria; 5 to 6 A. M. for *Brazia media, Aira cæspitosa,* wheat and barley. Rye, 9 A. M. This is, however, not always the case in cereals, as they may open at any time of the day.

* Pflanzenleben. 2: 139.

Hays and Boss* state that the flowers of wheat open at 40 minutes past 4 and closed at 18 minutes past 5 A. M., in Minnesota. Flowers of oats and timothy open between 7 an A. M.

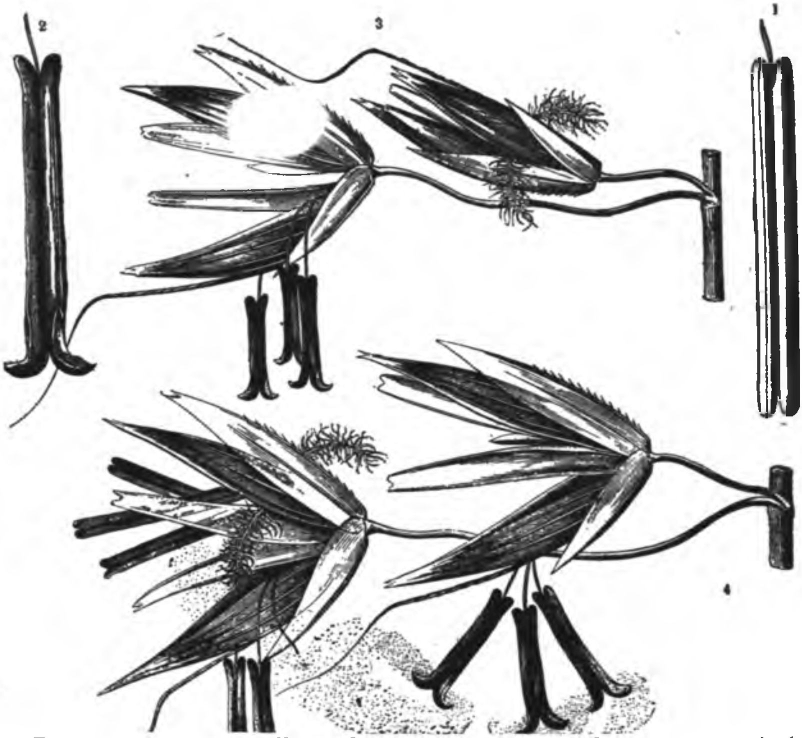

Fig. 44. Pollination of tall meadow oat grass (*Arrhenatherum avenaceum.*) *1*, Stamens before pollen is discharged; *2*, Pollen discharged from anther; *3*, Pollen discharged; *4*, Pollen in the act of discharging. (After Kerner von Marilaun.)

Fig. 44 B. Flower of wheat with stamens and pistil. (After Sauders.)

Agrostis, 11 A. M.; Elymus, between 12 and 1 P. M. Agropyron at 4; Holcus opens its flowers twice during the day, at 8 A. M. and at 7 P. M., provided atmospheric conditions are favorable; when the temperature is not below 57° Fahrenheit.

Beal says, in regard to the length of time a grass remains in flower: "As a rule, a certain specified flower of a grass remains open only for a short time, but different flowers of a plant may appear at successive periods extending over eight days,

*Wheat varieties. breeding, cultivation. Bull. Univ. of Minn. Agrl. Exp. Sta. 62: 415.

more or less, in Indian corn; seven days, more or less, in timothy, several days in oats and wheat, and for a much longer period in branching grasses like Eragostis and Muhlenbergia." Several grasses produce what are known as cleistogamous flowers. *Amphicarpum purshii*, indigenous to New Jersey and southward, produces two kinds of flowers. Those with open flowers sterile, while those borne on the small runners at the base of the culms are abundantly fertile. *Leersia oryzoides* produces cleitsogamous flowers.

Fig. 44 A. Spikelet of wheat showing glumes, palet, stamens and pistil. (After Saunders.)

Cross-fertilization.—Hackel has shown that cross-fertilization is much more rare and difficult in barley, and in certain races like the six-ranked, the short spiked two-ranked and the peacock barley, the flower of the grasses, especially in some climates, never open and consequently cross-fertilization is impossible. Wheat is also pollinated in the bud during cloudy and rainy weather. In rye, on the other hand, the rule is to have the flowers cross-pollinated. They have in fact lost the power of self pollination. Cross-fertilization takes place readily in nature as shown in numerous forms of corn, such as sweet, pop, dent and flint. Corn is remarkable in showing the immediate effect of cross-fertilization or xenia the first season, though it is also evident* in succeeding generations.

*Just as I am reading proof there has come to hand a valuable paper on Xenia, by Webber. Bull. U. S. Dept. of Agr. Div. of Veg. Path. and Veg. Phys. 22: 1900.

In wheat, according to Hays and Boss,* unusual variation may occur. They state that the fife and blue stem parents only had very short awns, while in the progeny there are several types with awns of various lengths. Several of the plants had dark-brown chaff, others chaff with a light metallic tinge. Some of these varieties may be due to previous crosses, and the tendency of the plants to vary. The two varieties crossed are not closely related, one parent having hairy chaff and the other smooth.

Fig. 45. Flowers of *Glyceria fluitans*, stamens and pistils. (King.)

Hybrids.

Hybrids have been produced in grasses but they are rather difficult to work with, owing to the delicacy of the flower. The remarkable wheat and rye hybrids of Bliss Carman in which fertile offspring took place in two distinct genera, Triticum and Secale, are worthy of notice.

Focke† in his work on plant hybrids notes a number of hybrid grasses. Thus he records a hybrid between the *Avena sativa* and *A. orientalis*. There are also several hybrids between species of the genera Poa and Calamagrostis and Alopecurus and Bromus. He also records a hybrid between Aegilops and Triticum. According to this it is stated that after several years of culture a variety with constant characters is produced which was called Aegilops blé by Fabre. It seems extremely doubtful whether Fabre had a genuine hybrid in this instance.

Wilson‡ seems to have produced a fertile hybrid between Triticum and Secale, and they have even reported bigeneric hybrids between Agropyron and Elymus.

Immediate and secondary influence.—It is well known that in some cases pollen has an immediate influence on the fruit or seed. This has long been known to be the case in corn. As long ago as 1758§ it was observed that when differently colored varieties grew near each other they affected each other's seed. Later experiments were made by Dr. Savi and Professor Hil-

* Wheat: varieties, breeding, cultivation. Bull. Minn. Agr. Exp Sta. 62: 460. This valuable bulletin gives a great deal of valuable information on the subject.

† Die Pflanzen mischlinge ein Beitrag zur Biologie der Gewächse. 407.

‡ Trans. Bot. Soc. Edinb 12: 286.

§ Darwin: Animals and plants under domestication, 1: 430.

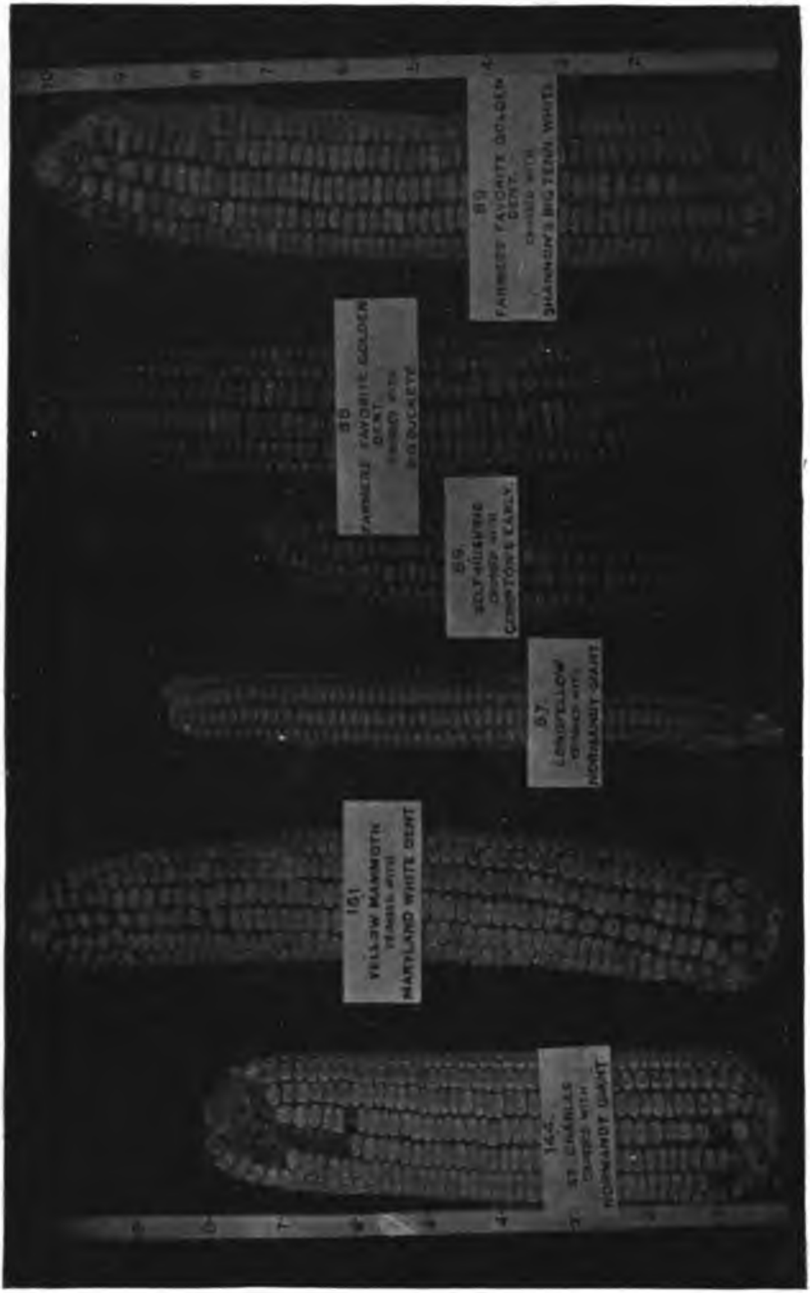

Fig. 45. A. No. 50, Pride of the North crossed with Champion White Pearl. No. 60, Self-husking crossed with Early Hathaway. No. 61, Self-husking crossed with Woodworth's Yellow No 66, King Philip crossed with Leaming. No. 151, Yellow Mammoth crossed with Maryland White Dent. No. 164, Mason's Flour corn crossed with Conscience. After Kellerman Swingle.

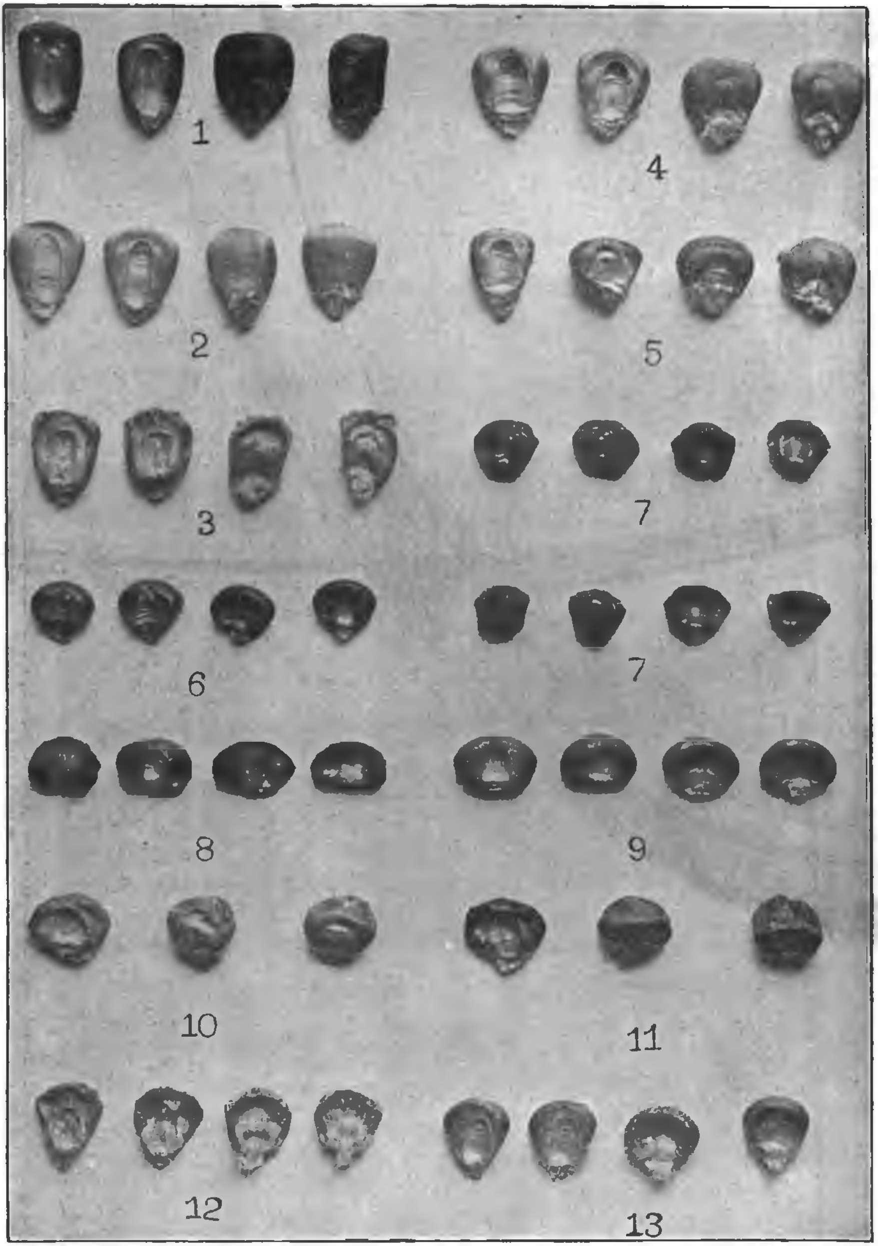

Fig. 45 A. Changes in form and color of kernels of corn produced by xenia. 1. Leaming Yellow, anterior and posterior views of kernels. 2. Champion White Pearl; two views. 3 Stowell's Evergreen, two views. 4. Stowell's Evergreen, showing xenia from crossing with pollen of Champion White Pearl 5. Stowell,s Evergreen, showing xenia from crossing with pollen of Leaming Yellow. 6. Gilman Flint, showing xenia from crossing with pollen of Stowell's Evergreen. 8. Black Mexican. 9. Black Mexican, showing xenia from crossing with pollen of Gilman Flint. 10 Stowell's Evergreen, female, x Black Mexican male; kernels are white and transparent resembling the mother parent. 11. Stowell's Evergreen female, x Black Mexican male, showing xenia in blue-black color imparted to the aleurone layer of the endosperm. 12-13 Kernels from an ear of a pure race of white sweet corn, some of which show xenia from crossing with pollen of a yellow Dent race Those of figure 12 are normal, evidently having been self-fertilized, while those shown in figure 13 show xenia. After Webber, U. S. Dept. of Agr.

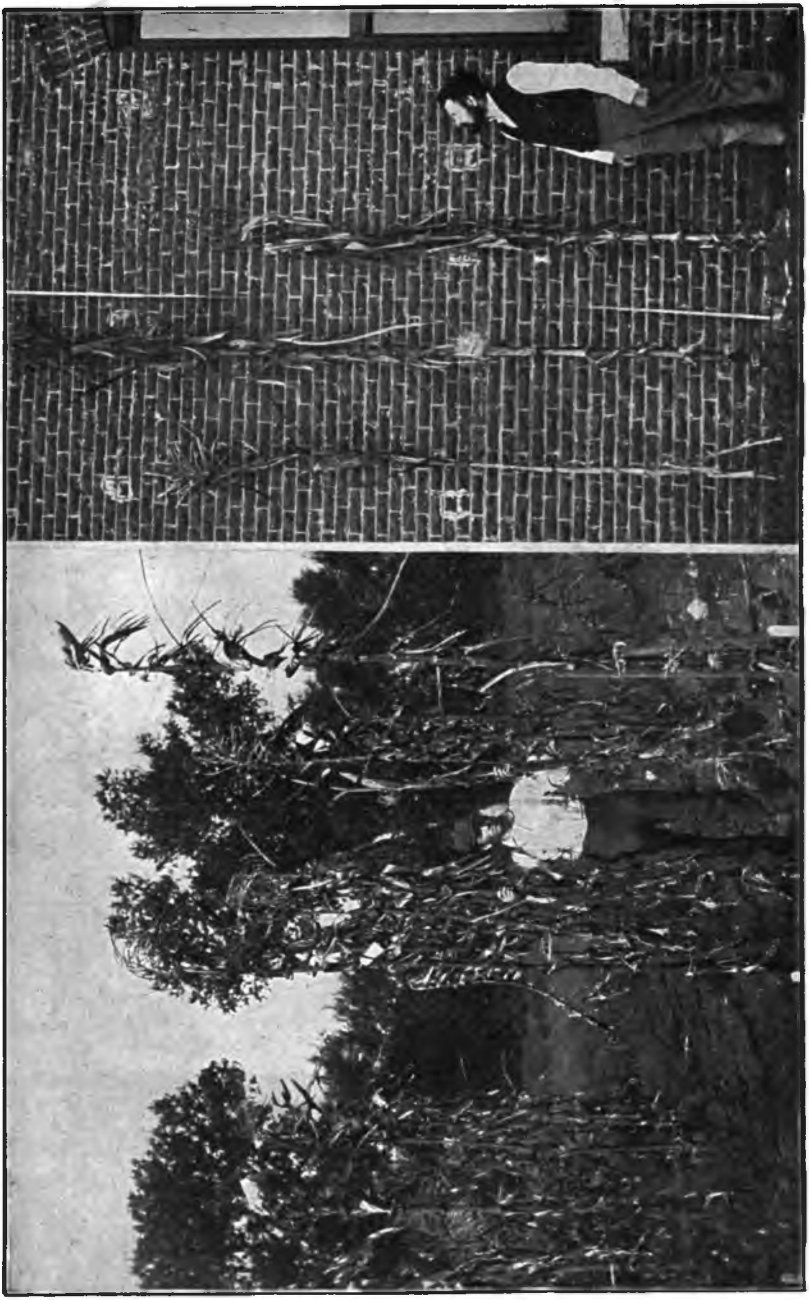

Fig. 45 B. 1-2. First generation Hybrids of Hickory King corn, female, x Cuzco corn, male, and types of parent stalks for comparison.

1. Hybrids of Hickory King female, x Cuzco 759, male, (first generation hybrid) showing increased vigor. In order to show the size as compared with the parents, the attendant held a stalk of Hickory King in his left hand and one of Cuzco in his right hand.

2. Central stalk a hybrid of Hickory King female x Cuzco 759 male; stalk on left, Hickory King, the mother parent; stalk on right Cuzco, the father parent. (Stalks in each case of maximum size).—After Webber, U. S. Dept. of Agrl.

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Fig. 45 C. Comparison of hybrid of Gilman Flint corn female X Hickory King corn male with parents, and ears showing change caused by xenia in composition of kernels

1. Hybrid and parents: Hill in center, a first generation hybrid of Gilman Flint female X Hickory King male, grown from one kernel; hill on right, Gilman Flint, the mother parent; hill on left, Hickory King, the father parent.

2. Ear of sweet corn, the smooth kernels of which show xenia from crossing with the pollen of a yellow Dent race. Natural size.

3. Ears of Gilman Flint, the wrinkled kernels of which show xenia from crossing with

debrand. Both have come to the same conclusion. P. Dudley* writes as follows: "Indian corn is of several colors, as blue, white, red and yellow. If these sorts are planted by themselves, so that no other be near them, they will produce their own color; but if you plant the blue corn in one row of hills, as we term them, and the white or yellow in the next row, they will mix and interchange color." Dr. Sturtevant† says: "Corn, the maize plant, shows in its kernels the influence of cross-fertilization of the same year. Some varieties seem to possess the power of resisting either cross-fertilization or the changes induced thereby." Professor Crozier‡ writes (Cross between Stowell's Evergreen and Yellow Hathaway): "These observations show that foreign pollen affects the appearance of the crossed kernels the first season, but also that an unusual appearance may be due to a cross of the previous year." Professor Beal§ says: "During the past year I planted near each other three hills of the following kinds of corn, well mixed together, viz: Waukashum, White Flint, Black Pop Corn, Early Minnesota Sweet, King Philip and Black Sugar. Every ear showed a mixture produced by pollen from one or more of the varieties except those of the King Philip variety." But Flint corn did not show the effect of pollen from Dent corn in the first year. Kellerman and Swingle,‖ who crossed a large number of varieties, have come to the same conclusions that other observers have, namely: that the so-called varieties of maize cross more or less freely, and the effects may or may not be visible the first year. As a result of some work done on the college grounds Professors Crozier and Rolfs¶ write concerning the immediate influence of cross-fertilization upon the fruit: "In all cases some, and in some cases all of the ears changed in appearance in the direction of the variety furnishing the pollen." A practical gardener, Mr. F. S. White,[1] writes as follows: "The past season I had sixteen varieties of white sweet corn and also a small lot of Black Mexican. When I came to save my seed corn I found grains of this black corn stuck in every variety."

*Philosophical Transactions Abridgment, vol. 6²: 204-205. Kellerman and Swingle. Annual Rep. Kansas Agrl. Exp. Sta. 2: 346, 1889.

†Ann. Rep. New York Agrl. Exp. Sta. 2: 37-56.

‡Proc. Soc. Prom. Agrl. Sci. 1887: 1.

§Rep. State Board of Agrl. Mich. 1878: 450.

‖Ann. Rep. Kan. Agrl. Coll. Exp. Sta. 2: 288, 1889.

¶Agrl. Sci., 4: 23.

[1]Iowa State Register, Dec. 11. 1891.

Walter T. Swingle and Herbert J. Webber, in a paper on Hybrids and their utilization in Plant Breeding, say as follows*:

The most convincing series of experiments was carried out by the famous French plant breeder, Henry L. de Vilmorin, in 1866. In the spring of that year he planted a dozen varieties of maize from 1,000 to 1,300 feet apart, which distance was found sufficient to prevent spontaneous inter-crossing by wind-blown pollen. The ears to be crossed were enveloped in thin flannel, which excluded pollen perfectly, for such ears, if not artificially pollinated, never gave a single kernel. To have a standard for comparison, an inclosed ear of each sort was artificially pollinated from the same sort. The ears thus obtained were imperfectly filled, but the kernels reproduced all the characters of the seed planted. On the other hand, when inclosed ears were artificially crossed 'with pollen from another sort, * * * the ears often, but not always, contained kernels showing the characteristics of their male parent. The proportion of such grains, when they existed, was very inconstant, being liable to vary from 1 to 60 per cent.' The effect was limited to changes in the color of the kernels. In most cases the pollen of a black corn was used in crossing, and this color exists in the substance of the kernel. No conclusions were drawn except from plats of maize, the ears of which, when left exposed or fertilized with their own pollen, reproduced without change the sort planted.

"In 1867 Hildebrand reported an experiment in crossing corn, using a yellow sort for the female and a dark brown sort for the male. Realizing that the older experiments had been faulty, since no proof was given that the sort used as the female parent was pure and might not be showing the effects of a previous cross, he pollinated some of the plants of the yellow sort with their own pollen and obtained ears, all the kernels of which were exactly like the mother grains. On the other hand, two ears obtained by fertilizing the yellow sort with pollen of the dark brown sort had about half of the kernels like those of the mother sort, or a little lighter, while the other half, scattered about among them, were a dirty violet color. On these latter, therefore, the pollen of the brown-kerneled sort had exercised a direct transforming influence."

Numerous other experiments have been made in this country on the subject of the immediate influence of foreign pollen

*Year book U. S. Dept. of Agr. 1897: 404-405.

on the kernels. The literature is given quite fully by Kellerman and Swingle.*

Webber† says: "In the writer's experiments it was found that the plumbeous or blueish black color of the aleurone layer of the endosperm in the cuzco and Black Mexican races was apparently shown in almost all cases as xenia when these races were used as the pollen parents in crossing with white or yellow races of Dent, Flint or sweet corn. In all of the cases observed by the writer no exception has been found to the rule first asserted by Koernicke, that xenia is shown only in the endosperm, the portions of the kernel outside of the endosperm remaining unaffected."

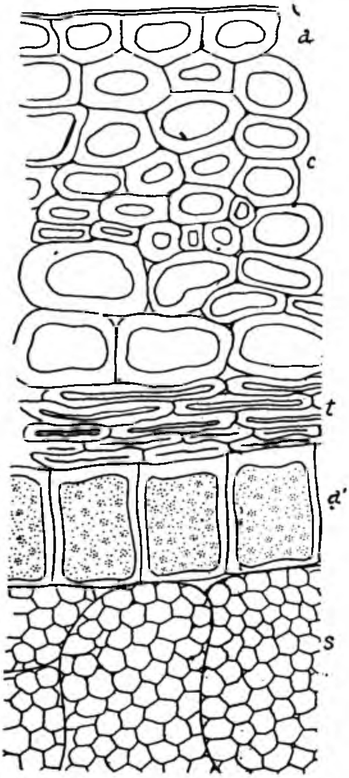

Fig 47. Caryopsis of Mexican corn, popcorn type; *a*, epidermal cells of capsule; *c*, capsule; *t*, testa: *d*, aleurone cells; *s*, starch layer. (Pammel and King.)

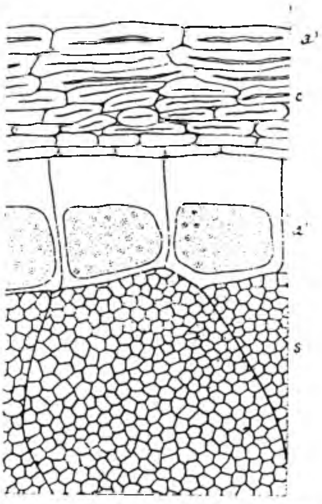

Fig. 46. Maize caryopsis; *a*, epidermal cell of caryopsis; *c*, caryopsis below testa; *a*, aleurone layer; *s*, starch layer. (Pammel and King.)

*Experiments in Crossing Varieties of Corn. Bull. Kan. State Coll. Agr. Exp. Sta., 17: 151-174. *pl. 3*, and Ann. Rep. Kan. Agrl. Coll. Exp. Sta. 2:

†For literature, see valuable paper by Webber. Bull. U. S. Dept. Agrl. Div. Veg Path. and Phys. 22: 1900.

Caryopsis or fruit.—The fruit in grasses is called a caryopsis. The thin pericarp or capsule is closely connected with the seed. Physiologically the pericarp takes the place of the testa, being well and strongly developed, while the testa is only feebly so. In general the structure is as follows: The epidermal layers, thinner walled parenchyma and a delicate fibro-vascular bundles. Bran consists of the testa and capsule with the adjacent layer, the nucellus when present and the endosperm. It should also be observed that the pericarp often unites with the bracts, especially palet, but seldom to the flowering glume as in barley.

Dr. Rodney True* summarizes his work on development of cereals as follows:

I. In corn, wheat and oats, at the time of fertilization the single ovule is furnished with two integuments which are more or less complete. As development proceeds (1) the outer integument soon disappears; (2) the inner cells of the wall of the ovary are absorbed, in varying proportions; (3) the tissue of the nucellus is absorbed, with local exceptions.

II. At maturity these remain as seed covering: (1) The external portion of the wall of the ovary in varying proportions, forming the pericarp; (2) the inner integument persisting in a state of compression. The epidermis of the nucellus also persists, though much compressed.

III. Late in the development of the fruit, the remaining (inner) integument becomes soldered to the adjacent inner cells of the pericarp, forming the fruit correctly described by Mirbel under the name of "cerium" and rechristened by Richard the "caryopsis."

Zea mays L. In another connection one of us has discussed the structure of Zea.† The pericarp consists of thick-walled epidermal cells followed by a layer of variable thicknesses, the walls of which are greatly thickened, with radiating pore canals. The testa is insignificant, the walls are thinner than in pericarp. Remmants of the nucellus may be distinguished in some parts of the seed. This is followed by the endosperm. The aleurone cells are smaller, very different from those underlying it. The starch cells following the aleurone are closely packed and filled with angular starch grains.

Avena sativa L. In common oats the caryopsis is slightly

*Bot. Gazette, 18: 214 *pl.* 24-26.

†Proc. Ia. Acad. of Sci. 5: 199.

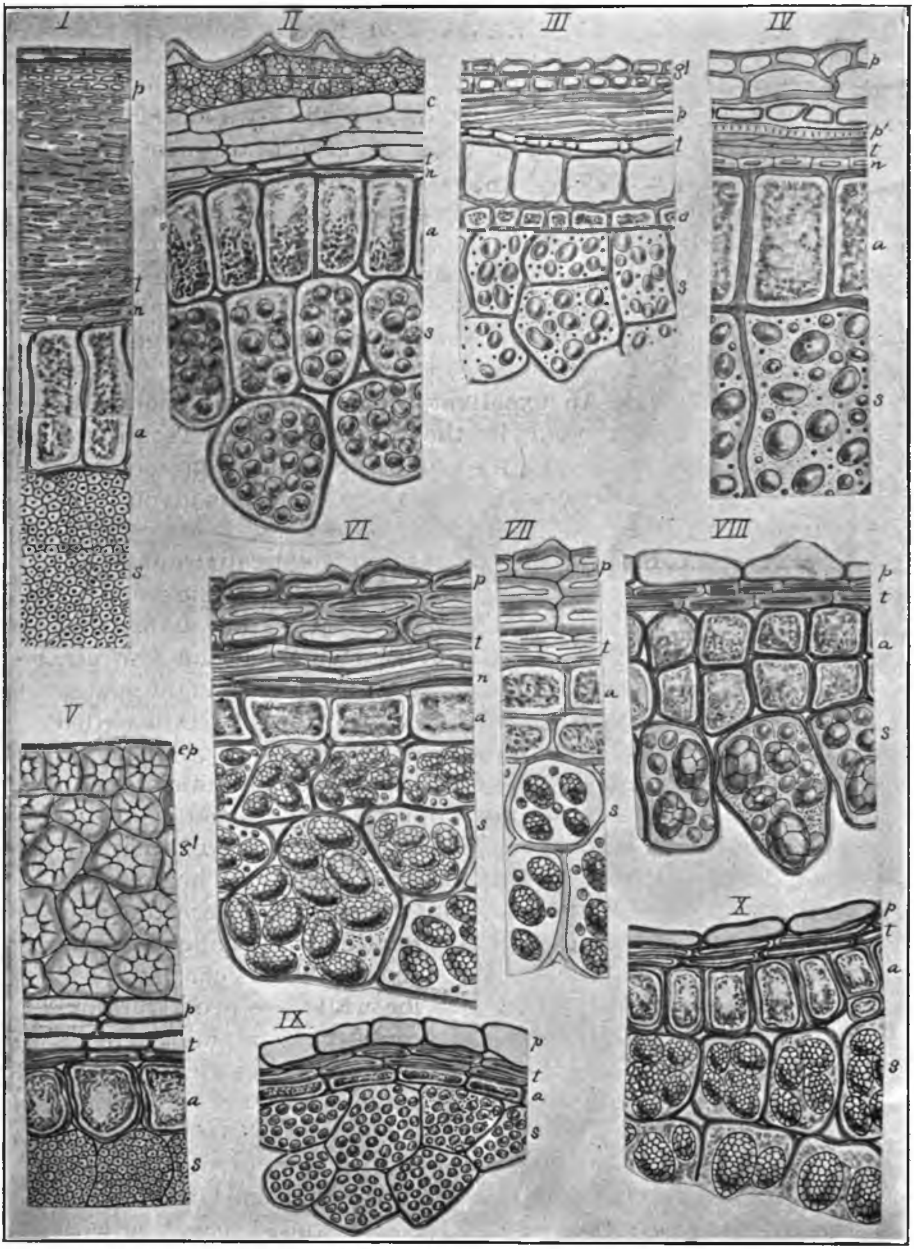

Fig 48 I. *Zea Mays:* nucellus a single row of cells, pericarp much more developed than the testa. II. *Hordum jubatum:* thick-walled sclerotic cells of glume with short trichomes above the caryopsis; c remnant of nucellus. III. *Sorghum vulgare* var. *communis* (*Andropogon. Sorghum* var.): small aleurone cells; simple spherical or elliptical starch grains. IV. *Secale cereale:* large spherical or somewhat elliptical starch grains; nucellus a single row of cells; p porous thickened walls of pericarp. V. *Euchlæna mexicana:* starch grains solidly packed together. VI. *Avena sativa:* pericarp with irregular cells on surface; the minute "down" of seed; a single row of cells to aleurone layer; in VII same, showing more than one row; starch grains compound. VIII. *Arrhenatherum avenaceum:* aleurone layer of two rows of cells; starch grains compound. IX. *Phleum pratense:* lower figure, general view cross section of seed with embryo in position. X. *Poa pratensis:* large compound starch grains in endosperm.

hairy. The large epidermal cells are thick-walled, slightly irregular on the surface, followed by several rows of thick-walled cells in a general way much like the epidermal cells. The testa consists of a much compressed layer mostly of two rows of thick-walled cells; remnants of the nucellus evident. The aleurone layer of the endosperm consists of one or two rows of cells; the outer portion of the starch cells contains less starch than the inner. The starch consists of large compound grains, the component parts five to six-sided.

Secale cereale L. An excellent account of the structure of this fruit will be found in the works of Harz, Tschirch & Oesterle, Tietschert, Gregory and other writers on economic food products. Literature of the whole subject is given fully in a paper by Pammel.*

The pericarp consists of tangentially elongated epidermal cells with large cavities. The outer wall is thickened as well as the inner, the lateral walls thinner. Harz states that there is an important distinction between *Secale* and *Triticum;* a somewhat analogous structure, however, occurs in the spelts The epidermal layer is followed by smaller thin-walled parenchyma cells. The layer next to these parenchyma cells is frequently composed of thick-walled porous cells with pore canals. These cells not evident except in mature fruits. The testa is but slightly developed and consists of comparatively small cells frequently colored brown. The nucellus occurs as a remnant especially in the groove, where the cells are thick-walled and somewhat gelatinous. The endosperm resembles that of wheat. The aleurone layer consists of a single layer of cells. The exterior walls are greatly thickened. The cells of the starch layer large, containing a large number of round or elliptical starch grains, extremely variable in size. The starch grains on the whole are larger than those of the genus *Triticum.*

The adhering palet consists of several rows of thick-walled cells. The epidermal cells are longer and somewhat thicker-walled. The cells below are also thick-walled, provided with pore canals. In places the epidermal cells develop into a short trichome. Underneath the thick-walled cells occur several rows of thin-walled irregular parenchyma cells. The

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* Pammel. Histology of the Caryopsis and Endosperm of some grasses. Trans. Acad. Sci. of St. Louis, 8: 199. *pl. 17—19.* Proc. Ia. Acad Sci., 5: 199, 1897. Contr. Bot. Dept. Ia. St. Coll. Agr. and Mech. Arts, 10. 1, 1898. Hays and Boss, Minn. Agr. Exp. Sta. Bull. 62: 418. Bolley, Bull. N. D. Agr. Exp. Sta. 9: 1.

pericarp follows. It consists of several rows of thick-walled translucent cells, the cavity being very much reduced. The testa is colored brown. The cells are tangentially elongated and the cell-walls are thinner. The nucellus is very much reduced excepting in the groove, where it occurs as thick-walled cells. The endosperm differs in a very marked degree from either that of Triticum or Secale, especially the aleurone, which consists of three to four or exceptionally more rows of cells. The starch cells are much larger and contain large spherical or elliptical starch grains, accompanied by numerous smaller ones. Small protein grains are abundant.

Structurally there are wide differences between the tribes of the order, very marked in some closely allied genera. The pericarp is well developed in such genera as Zea, Arundinaria, and fairly well in Triticum, Secale, Hordeum and Avena. The testa is but slightly developed in most cases, notably so in Festuca, *Panicum glabrum*, Aristida and *Oryza sativa*, the protective features being provided for by the glumes surrounding the fruit, or the wall of the ovary. The nucellus is never entirely absent, especially in the groove. It is usually much compressed. In the genera Festuca and Bromus, the cells are large, thick-walled and mucilaginous, and no doubt act as reserve food. The aleurone layer is variable. It is never absent. Of one row of cells in Triticum, Zea, Zizania. The cells are very small in *Panicum crus-galli*, Aristida, *Setaria italica*. Of more than one row of cells in Avena, Arrhenatherum, Festuca, and *Hordeum vulgare*. The starch cells differ in size and contain small spherical or elliptical grains in *Sorghum vulgare* and *Cenchrus tribuloides*. Large spherical or somewhat elliptical grains occur in Triticum and Hordeum, accompanied by numerous smaller ones. Small five or six sided grains in *Panicum crus-galli*, *Zea mays*, *Euchlaena mexicana*. This applies in general to the tribe Maydeae and Paniceae. Cenchrus is, however, an exception to the rule. Compound starch grains occur in Zizania, Oryza, Avena, Arrhenatherum, Glyceria, Poa, Phalaris and Arundinaria; most grasses appear to have compound grains. The endosperm always contains protein, though much reduced in the starch cells, except in the aleurone layer, where no starch occurs. The starch cells next to the endosperm contain more protein than the interior of the endosperm. Fat is also present in small amounts. The compound starch grains of Nardus in the tribe Hordeae are somewhat anomalous.

Specific gravity.—Little work has been done in this country on the specific weights of our seeds. Such studies have been made of European wheat by Harz, Nobbe, Koernicke and Werner and others. Several years ago Pammel and Stewart made some determinations indicating the difference in wheat in this respect and that a study of the specific gravity and number of seed per pound and bushel of considerable interest and commercial importance.

Wolfenstein gives the following figures with reference to wheat:

Summer wheat, Halle, Germany	1.3884
English wheat, England	1.4134
Purple straw wheat, Australia	1.4011
Tuscan wheat, Australia	1.4156
Siberian wheat, Siberia	1.4149
Michigan Amber, Michigan	1.4292

Climate and soil both greatly modify the weight and character of the seed. This variation is also great in different varieties. To compare the results obtained from these studies a few figures are taken from Harz. One hundred seeds of the following varieties weighed as follows: Prince Albert, 5.102 grams; Archer's Prolific, 4.298 grams; Hunters wheat, 3.714 grams; Mediterranean wheat, 4.532; White Genesee wheat, 4.403 grams.

Some tests made by Pammel and Stewart* with wheat from various localities in the United States gave the following results: World's Fair, Seneca Falls, N. Y., 1.146296; Winter Fife, La Crosse, Wis., 1.44578; Martin Amber, La Crosse, Wis., 1.35054; Golden Cross No. 2, 1.47524; Bissell, Manhattan, Kan., 1.4765; Turkey Red, Manhattan, Kan., 1.441; Missogen, Berkley, Cal., 1.480; Carter's Hundredfold, Berkley, Cal,, 1.518; Fultz, Raleigh, N. C., 1.489; Red May, Raleigh, N. C., 1.454; Turkey Red, Iowa, 1.43727. According to Wolfenstein, as quoted by Nobbe, the lowest specific gravity out of the thirty samples, occurs in white wheat (Saxony), 1.3766. An average sample of Bohemian wheat from the market, consisting of three varieties had a specific gravity of 1.4208. The highest specific gravity recorded is 1.4396, Ohio Red.

* **Bull. Ia. Agrl. Exp. Sta. 25: 26.**

It is interesting to compare the specific gravity of wheat with that of a few other seeds obtained in Europe. An average sample of corn has a specific gravity of 1.147; Castor Oil bean, .908; Buckwheat, 1.104; Field pea, 1.355; White clover, 1.41; Kale, 1.35; Rutabaga, 1.38.

Schulte and Wright in the botanical laboratory, Iowa State College of Agriculture and Mechanic Arts, determined as follows concerning the weights and specific gravity of several cereals. Corn: Giant White Dent, 1.2547; Hickory King, 1.2932; King of Earliest Dent, 1.3284; South Dakota Flint, 1.3367; Mastodon, 1.2712; Jumbo, 1.2352; Chester County Yellow, 1.2753; Common Yellow Field, Iowa grown. 1.2826; Common White Field, Iowa grown, 1.3627; Golden Cable, Missouri, 1.2821; Pride of the North, 1.2766; Iowa Gold Mine, 1.2836; Longfellow Flint, 1.3044; Iowa Beauty, 1.2816; White's Mammoth Red, 1.2511; Monarch Rice popcorn, Iowa, 1 3550; Red Beauty popcorn, 1.3738; Hickory King, Alabama, 1.3088; Pride of the Farm, 1.3306; Alabama Yellow, 1.2022; Hickory King, Kansas, 1.2555; Improved Leaming, Kansas, 1.2945. Wheat: Turkey Red, Iowa, 1894, 1.3290; 1895, 1.3065; Fife, 1894, 1.4177; Red Clawson. Missouri, 1894, 1.3594; O'Kangan Valley Velvet Chaff, 1.5197; Wisconsin Triumph, 1.4077; Turkey Red, Kansas, 1894, 1.3659; Turkey Red, Iowa, 1.4137. Oats: Nameless Beauty, Wisconsin, 1.3432; Giant Yellow, Wisconsin, 1.3178; White Bonanza, Wisconsin, 1.3290; Red Rust Proof, Kansas, 1.2550; Full Moon, Iowa, 1.2302; New Salt Lake, Iowa, 1. Clover: Iowa, 1.2121; White Superior Scotch, 1 2334; Black Mammoth Cluster, Wisconsin, 1.1257; Wide Awake, Wisconsin, 1.1892.

Mr. J. U. Loyd,* who has made an exhaustive study of the grain weight, records the following densities: Duluth Hard Springs, 1.394; India, No. 1 Club Bombay, 1.385; Manitoba Spring Hard, 1.388; Ohio White Winter, 1.387; Black Sea, Azima, Russia, 1.383; Patagonia, South America, 1.380; Wisconsin Spring, 1.377; Australia, 1.377; Ghirka, Fine Russia, 1.364; California No. 1, 1.358; River Platte, South America, 1.357; England White, 1 346; New Zealand White, 1 346; Odessa, Russia, 1.343; Chili, 1,332; England Red, 1,337; Washington State, 1.327.

According to the same investigator 100 grains of wheat of the following varieties weigh as follows: New Zealand White,

*The Grain Weight: A study of wheat. Cincinnati. 16.

77.9; England Red, 77.4; No. 1 Club Bombay, 84.2; Baltic, Rus sia, 56.6; Ghirka, Fine Russia, 49.3; Chili, South America, 77.9; Ohio White Winter, 51.4; Wisconsin Spring, 47.4; Duluth Hard Spring, 46.7; River Platte, South America, 46.1; California Choice, 74.4; Manitoba Hard Spring, 43.9.

Messrs. Schulte and Wright determined as follows concerning the number of grains in a gramme: Corn: Giant White Dent, 3.4; Hickory King, Wisconsin, 2.0; Common White field, Iowa, 3.5; Eclipse, Wisconsin, 3.2; Iowa Gold Mine, 2.9; Hickory King, Iowa, 2.1; Improved Leaming, Iowa, 2.9; White's Mammoth Red, 2.9; Red Beauty popcorn, 8.3; Monarch Rice, 11.6; Hickory King, Alabama, 1.9; Alabama Yellow, 1.8; Stowell's Evergreen, Iowa, 4.1. Wheat: Turkey Red, Iowa, 40; Red Clawson, Missouri, 23; Fultz, Missouri, 29; Wisconsin Triumph, 39; Turkey Red, Kansas, 32; Currell, Kansas, 35. Oats: Giant Yellow, Wisconsin. 27; Red Rust Proof, Kansas, 35; New Salt Lake, Iowa, 45; Black Mammoth Cluster, Missouri, 39; White's Superior Scotch, Iowa, 33; Lincoln, Iowa, 40.

In 1893 wheat, obtained from various sources, gave the following results: New York, La Crosse, Wis., Jones' Winter Fife, 37.3; Wisconsin Triumph, 33.5; Iowa Turkey Red, 35.92; New York, Red Clawson, 22.77; World's Fair, 26.92; Golden Cross No. 2, 24.077; Bissell, Kansas, 28.77; McPherson, 33; Turkey Red, Kansas, 33.77; Missogen, California, 18; Carter's Hundredfold, 23.233; Fultz, North Carolina, 34.933; Early Red Clawson, 31.28; Amber, 28.6.

One hundred seeds of Michigan Amber weighed 3 5134 grammes. Purple straw, 6.864; English wheat, 3.7798; Summer wheat, Halle, 2.8654.

Schertlen gives the following specific gravity of some grass seeds: *Muhlenbergia mexicana*, 1.100; *Arrhenantherum elatius*, with chaff; 0.600; *Avena sativa*, 1.345; *A. orientalis*, 1.021; *Bromus inermis*, 0.746; *Holcus lanatus*, with chaff removed, 0.301; *Hordeum vulgare*, with chaff, 1.351; *Panicum miliaceum*, 1.179; *Zea mays*, 1.147.

Dissemination.—An important step in the life of every plant is the dissemination of its seed, since without this the species has little chance to perpetuate itself.

Grasses are disseminated by wind, animals, hygroscopic movements, water and man.

Speaking of dissemination Hackel says: "In all wild grasses certain parts of the spikelet or of the entire inflorescence fall off with the fruit. If the spikelet is many-flowered and every flower ripens its fruit, then its axis breaks into as many pieces as there are fruits, and every piece carries a floral glume and palea. If the spikelet is one-flowered, the axis of the spikelet may separate above the empty glume, so that the floral glume and the palea fall off with the fruit (Agrosteæ); or it may divide below the empty glume, and the spikelet fall off as a whole (Paniceæ, Andropogoneæ, etc.). If the spikelets form a spike or a raceme, it frequently happens that the latter divides so that one spikelet falls off with each joint (many Andropogoneæ and Hordeæ); short spkes (*Triticum ovatum* Godr.) fall from the culm as a whole. All these arrangements are necessary for the distribution of the seed; they are lacking (with two exceptions) in all cultivated cereals, but are present, on the contrary, in all native races of the same species, so far as these are known. Since these arrangements are very disadvantageous for the complete gathering of the fruit, varieties whose axes are less or not at all articulated will be preferred in culture, and will be finally fixed by natural selection."

Seeds to be disseminated by the wind must be sufficiently light. Surrounding the fruit are bracts, which diminishes the specific gravity. *Hordeum jubatum*, and Agrostis are carried by wind because of their lightness. In many grasses copious hairs are developed either as parts of the sterile glume or parts of the axis. In Andropogon the rachis or both rachis and the sterile flowers are provided with long hairs. In Phragmites the base of the flowers are silky villous and with a conspicuous silky-bearded rachis.

In Calamagrostis the callus of the flowering glume is provided with short or long hairs. In Poa the principal veins of the flowering glume are cobwebby (figure 36). The seeds readily adhere to woolly objects, or they may be carried by the wind.

The beautiful European *Stipa pennata*, and our variety, *neomexicana*, are well adapted for wind dissemination. Its long plume makes it easy for the wind to carry.

The wind, however, acts in other ways. The Australian Rolling Spinifex forms a large round head. This breaks away and rolls over the dry sands of Australia until it is carried to a dry place, when it expands and soon takes root. In tickle grass (*Panicum capillare*) the whole inflorescence breaks away

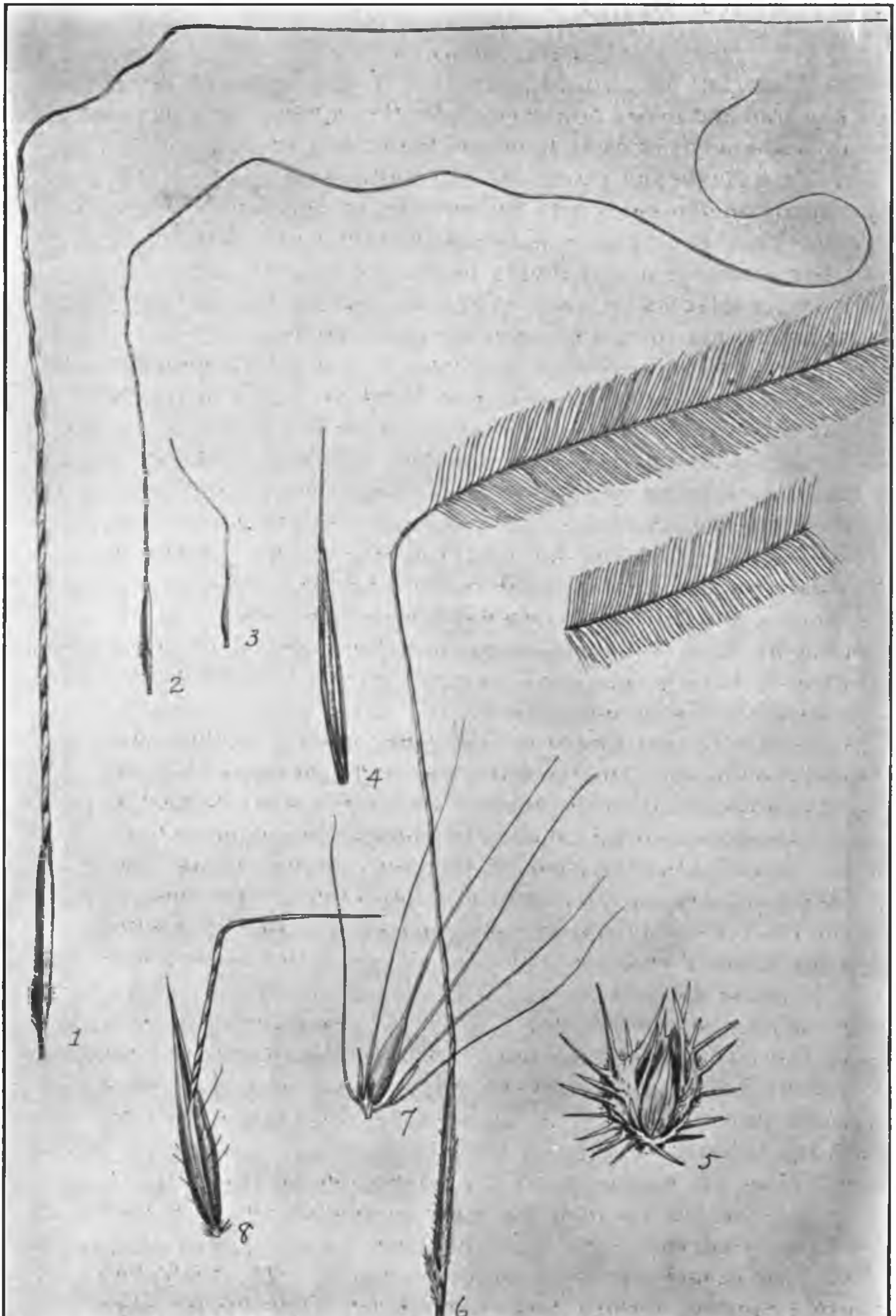

Fig. 49. Dissemination of grasses. *1, Stipa spartea*, twisted awn and hairs, self-burying "seed;" *2, S. comata; 3, S. viridula; 4, Zizania aquatica*, a floating "seed;" *Cenchrus tribuloides*, with a bur for attaching itself; *6, S. pennata; 7, Hordeum jubatum*, animal dissemination; *8, Avena fatua*, a "seed" with hygroscopic characters. (King)

and is either bodily carried up in the air or rolls along the ground. Many of our native grasses like Eragrostis are carried in a similar way. To be sure, many of the seeds fall long before they separate from the plant. And yet dozens of fruits may be counted on a single panicle. The wind may also carry the seed over the snow during winter.

Animals and hygroscopic movements.—Animals are most efficient in conveying the seed of many grasses. The stiff, sharp spines of the involucre in Sand Bur (*Cenchrus tribuloides*) are most efficient in piercing the skins of animals. Indeed it sometimes causes considerable annoyance to animals and man. In Streptochaeta, says Hackel, "The ripe fruit hangs from delicate spiral threads (the awns) which are fastened together at the end of the spike; they are free below, and their soft-pointed bracts, bent outward, act like fish-hooks by catching into the fur of any animal that touches them in passing."

Our common Squirrel-tail grass (*Hordeum jubatum*) is most efficiently carried by animals. The spikes, when mature, break up into joints, and although the joints are not sharp-pointed they readily cling to the fleeces of animals. So, too, do the broken points of Sitanion cling to animals.

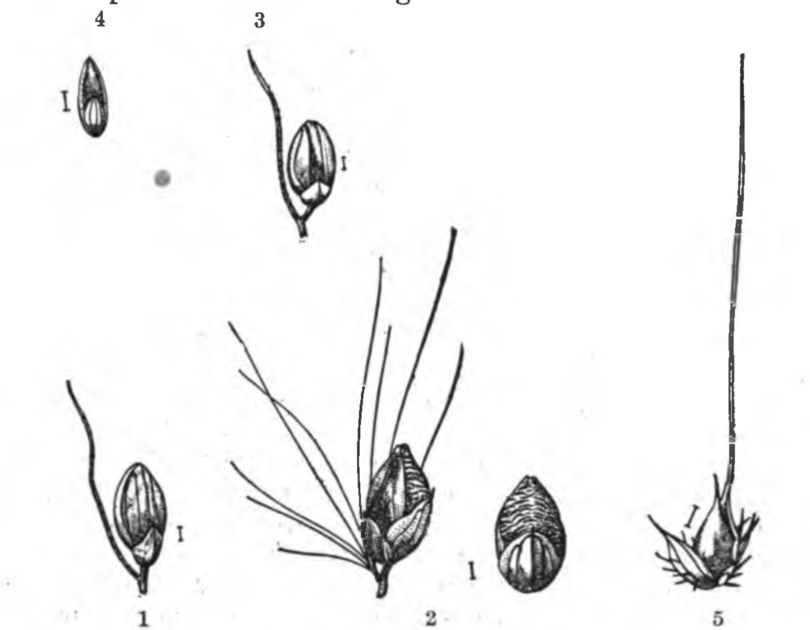

Fig. 50. *1*, Foxtail (*Setaria viridis*); *2*, *Setaria glauca*; *3*, *Setaria verticillata*. The seeds of all three species carried by animals, especially sheep and cattle. *4*, *Panicum sanguinale*; *5*, *P. crus-galli*. The seeds of these are carried by birds, used as food.

A most interesting case of animal dissemination is afforded by a native species of *Stipa spartea*. The cylindrical grain is provided with a sharp-pointed cullus which makes it easy to penetrate clothing, the skins of animals and soil. The grain is enclosed by the hard, persistent, flowering glume which surrounds the palet. The lower portion of the coriaceous flowering glume, as well as the pedicel, are covered with stiff hairs that point upwardly in an oblique direction. The flowering glume bears a strong awn twisted like a rope. This awn is very sensitive. The coils unroll or unwind when damp, and

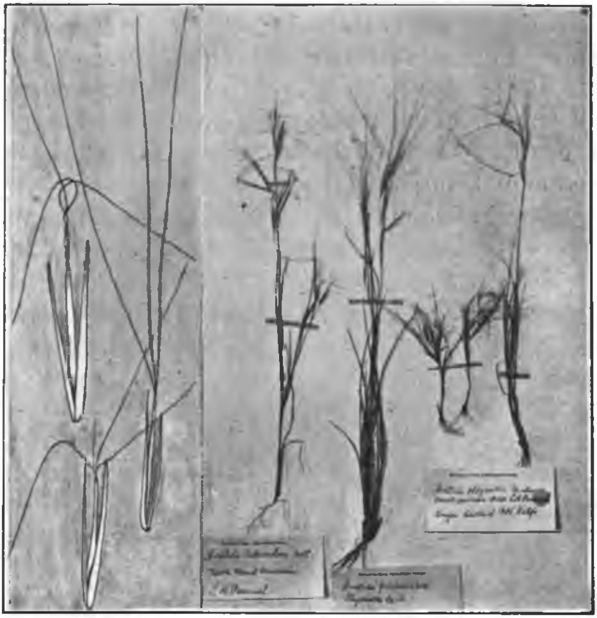

Fig. 51. Dissemination of Aristida. *Aristida tuberculosa*, awned flower, lower detail; *Aristida purpurea*, awned flower, detail at the right; *Aristida oligantha*, awned flower, detail at top.

when dry they return to their former condition. Whenever this drying-out takes place the points of the flowering glume are rotated with lateral variations. The upper half of the awn remains straight and soon becomes bent at nearly a right angle to the twisted part. This portion of the awn is of very material assistance when it comes in contact with surrounding objects. The bristles at the lower end prevent the seed from being pulled out. "This rotation and nutation, together with the action of the bristles, soon causes the bract surrounding the fruit to bore deeply into the ground." This boring into the soil takes place in a short time. Beal says, in speaking of the Feather grass (*Stipa pennata*): "Francis Darwin found that the rate increases up to the fifth revolution, and then diminished quickly. In three wettings and three dryings, a little over an inch was buried in dry sand. A rise of temperature affects the awns in the same way as increased moisture; a fall of temperature acts like dryness. Mr. Darwin found that minute strips of the awn, consisting even of two long cells, twisted just as well as the entire awn. He thinks that the torsion is produced by the striation or stratification of the cell walls. These are a series of parallel lines, alternately light and dark, traversing the surface of the cell. Very frequently the two systems wind spirally round the axis in opposite directions. When the tissue expands during the absorption of water, it is due mainly to the swelling of the less dense striæ. This is thought to be the cause of torsion in cotton wool. Soon after being buried, where the soil is moist, the awn breaks off at a joint from the apex of the grain."

Mr. R. M. Christy states that a large number of the seeds are often found beneath the skin of sheep, especially about the shoulders. Dr. M. Stalker states that in many of the northwestern counties of Iowa they occasion much annoyance to sheep, and, in some instances, cause the death of animals. They penetrate and bury themselves in the flesh. Dogs, and even persons, are also affected. F. H. King says that he was much annoyed by the fruit of this grass. *Stipa capillata* of southern Russia, *Aristida hygrometrica* of Queensland and *Heteropogon contortus* of New Caledonia inflict similar injuries.

The beautiful south European grass (*Stipa pennata*) also buries itself in the soil. The long, feathery awn enables the wind to carry it away. The "seed" is small, the flowering glume has a pointed callus and above it obliquely pointed stiff hairs. As in the other species it is provided with strong, twisted awns that end in a long, beautiful feather. As the seeds are carried by the wind they eventually fall, with the "seed" end to the ground, as it is heavier at the lower end. The "seeds" remain in this position as long as dry, but when moist the spirally twisted awn unwinds the plume and helps to hold it in the soil; thus, finally, the "seed" is buried in the ground.

Several species of Avena, *A. barbatum* and *A. fatua*, our wild oats, are similarly provided with twisted awns that help to bury the seed. Several species of Aristida also bury themselves, as do members of the genus Danthonia. In *Triticum ovatum* the entire spike falls off. It possesses a very pointed base, and the numerous rough awns pointed outward, thereby movements of the wind exert a pressure upon the point which drives it into the ground.

The peculiar use of the awns of *Avena sterilis* are described by Hackel as follows: "Two strongly awned fruit-bracts fall off, fastened together; in moist surroundings the twisted awns begin to rotate their diverging upper halves, consequently they cross and press against each other until the bracts are forcibly separated, thus giving the fruit an impetus which throws it off for some distance.

In many cases seeds of grasses are distributed by birds and animals which feed upon them but do not digest them. Birds of various kinds freely feed upon *Setaria glauca, S. viridis, Panicum miliaceum*, often carrying them great distances. Many herbivorous animals also help to carry seeds in this way, as is evidenced by seeds of many grasses that come up from excreta. This manner of distribution for most seeds is a most precarious one, as the "seeds" pass through the digestive canal, germination is hastened, and thus they may be destroyed. But the fleshy berries of many Bambuseæ are especially adapted to animals which do not destroy or digest the seeds. Many animals, especially wading birds and others, carry seed of grasses in the mud that clings to their feet.

The light specific gravity of many grass fruits make them especially susceptible to dissemination by water. The chaff, in many cases, remains persistent, and so constructed that the whole floats readily. Thus rice and wild rice will float for a time until they are soaked with water. Water, however, adds mostly in a mechanical way, currents of water carrying away large quantities of earth with which are mixed seeds of grasses. Neighboring farms have frequently been sown with seeds of wild oats in this way, as has been witnessed in many cases along the bluffs of the Mississippi in Wisconsin and Minnesota.

Certain fruits of grasses are thrown out by expulsion. Professor Beal says of Sporobolus: "The ovary of Sporobolus is very thin and tender. Free seeds may often be seen still adhering to various portions of the glumes and branches of the panicle. One of my special students, at my suggestion, has made a few experiments to determine the mode in which the seed escapes. Inside the ovary and about the seed there is a gummy secretion. When about ready to escape or at a certain stage of maturity, if water be applied to the panicle, in a short time the seeds come forth. A part of the panicle was wet and in thirty minutes twenty-seven seeds escaped. In another case the seed began to escape in ten minutes after the water was applied. After drying six days in a room seeds started out in twenty minutes after wetting. In other cases seeds have been seen to escape in six minutes and in one case in four and one-half minutes. If the ovary is carefully removed from the floral glume and palea and water is applied, the seeds usually escape a little quicker than when left in the floret."

"On applying water the ovary may be seen to slowly enlarge, till it bursts and the seed pops out in a hurry. If a little water is applied, it moves more slowly, and if the glumes are still near the ovary the seed moves upward and usually adheres to some part of the panicle. A slight sprinkling or a heavy dew would bring the seeds out, but a heavy rain would wash them down at a time when the condition would be favorable for germination. Several other species, as I judge from herbarium specimens, expel and hold their seed in a similar manner. The action of the water on the ovary seems to be purely mechanical and is explained in well known works on physics. The water enters the ovary faster than the gum can escape. The ovary is flattened and splits on the side next the palea." The gum spoken of by Beal is a mucilage and resides in the outer walls of the cells of the capsules that swell on the addition of water.

Man, too, is an agent in the scattering of the seeds of grasses and the introduction of new seeds. Certain grasses most commonly follow the culture of certain grains, as chess and its occurrence in wheat fields.

It is a well known fact that chess is more abundant where wheat is extensively cultivated, and there is no question that this weed was introduced by the wheat seed brought from Europe Darlington* observes, "This foreigner is a well known pest among our fields of wheat and rye and occasionally appears in the same field for a year or two after the grain crop. Years ago it was observed that this weed was common

*American Weeds and Useful Plants. Revised by George Thurber. New York. 386.

along the roadside, the seed of this weed having been scattered from the farmers' grain wagons." *Lolium temulentum* is another well known illustration where man has acted as a disseminator. This weed was well known to the ancients as a serious pest in grain fields. This weed seldom occurs in this state now. Formerly it was much more common, when Iowa was a wheat-growing state.

The sand-bur affords another excellent illustration of man as an agent in scattering seeds. During the early days, sand-bur was common along the sandy embankments of streams; now it has become common throughout the state of Iowa, and largely because the sand used for building purposes is obtained from the river bottoms. Then, too, it has been scattered far and wide by the railroads who use the gravel as ballast. *Setaria verticillata* has followed and occupied the waste places in many parts of this state, especially in the southern tiers of counties. It was largely introduced with foreign seed, or as a ballast weed in seaport towns. The common finger-grass (*Panicum sanguinale*) and pigeon-grass or fox-tail are largely disseminated through the use of clover and other agricultural seeds. Mr F. C. Stewart, some years ago, determined that it was the principal impurity in fifteen samples of red clover grown in various parts of this country. He says of it as follows: "The weed seed most commonly found in clover seed is *Setaria viridis.* This species appeared in fifty samples, *Setaria glauca* appearing but thirty-one times, *Panicum glabrum* twenty-four, and *Panicum sanguinale* three times." O. Burchard* reports that orchard grass in North America contains *Panicum capillare, Phleum pratense, Poa pratensis, Arrhenatherum elatius, Bromus erectus, Festuca pratensis, Holcus lanatus, Lolium perenne* and *Poa trivialis.* Burchard† further states that "almost every lot of red clover seed from the United States is found to contain, even when thoroughly purified, varying quantities of the following seeds: *Panicum crus-galli, Panicum filiforme, P. sanguinale, Panicum capillare, Phleum pratense, Setaria glauca,* and *S viridis.*" We should observe, however, that some of the plants mentioned by this writer do not occur in clover seed, as, for instance, *Panicum filiforme. Bromus mollis,* a worthless forage plant, has been widely distributed as a weed, not only

*Contributions from botanical laboratory and seed-control station of Hamburg. 3: 1893. Abst. Exp. Sta. Rec. U. S. Dept. of Agrl. 5: 333.

†The objects and methods of seed investigation and the establishment of seed-control stations. Exp. Sta. Rec. U. S. Dept. Agrl. 4: 891.

because of its admixture in other more valuable forage plants, but its direct introduction as a forage plant. Johnson grass (*Andropogon sorghum* var. *halapensis*), has been widely distributed in the southern states since its introduction as a forage plant in South Carolina, about 1830, by Governor Means. Ten years later it was introduced into Alabama by Captain William Johnson. Since then it has been widely distributed throughout the south, where in some places it has become an execrable weed. It has advanced as far north as central Missouri, where it was introduced with seeds in part grown as a forage plant.

Another grass that has been distributed largely by human agencies is the Bermuda grass, introduced in this country first as ballast, from southern Europe. It has now spread over the entire southern states, and although a most valuable grass, is a dangerous weed when grown where not wanted. A few years ago we found, on the college grounds, the *Bromus tectorum*, the seed of which came with some packing material. Instances of this kind might be given much more extended notice in this connection. One other case is worthy of mention; Wild oats (*Avena fatua*), which has become widely distributed in Iowa, Wisconsin and Minnesota, occurring commonly as a weed in oat and wheat fields, but generally in oat fields. It is impossible to remove the seed of this species from oats. In the Rocky Mountain districts, wild oats is extremely common and this species was introduced in the same way. In California there are several pernicious species of Avena that were introduced with grain seed.

GERMINATION.

Structure of the embryo.—After the seed has been distributed, the next important step is germination. The small embryo is usually straight, rarely slightly bent with the radicle turned downwards. The following is taken from Hackel's excellent account: "Its most striking portion is the scutellum, which is regarded as the cotyledon. It is a flat but somewhat thick body, roundish to elongated oval in circumference, lying close on its inner side to the albumen, with the plumule and radicle surrounded by the coleorhiza situated in its somewhat shallow exterior. The plumule lies free upon the scutellum, but below the plumule the axis of the embryo is united with it. This is the point of insertion of the scutellum beyond which it projects downward and outward as far as the point of the coleorhiza. This descending point of the scutellum is grown for a longer or shorter distance to the posterior part of the co'eorhiza, so that they entirely unite in front or leave only a small cleft. If this is the case it is only in germination that the side portions are pushed back and the entire embryo becomes visible."

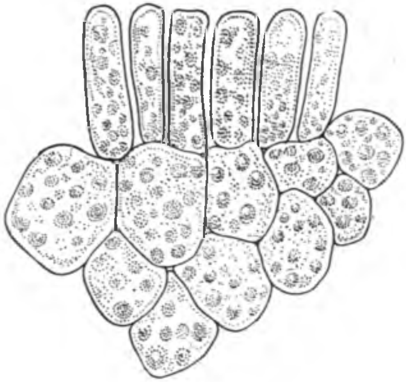

Fig. 51 A. Cross-section embryo of corn The cylinder epithelium above and large parenchyma cells below. (Pammel.)

The scutellum has a most interesting epidermal layer, the so called cylinder epithelium. These palisade-like cylindrical cells are thin walled and physiologically of great importance to the germinating plant. It is the function of these cells to absorb the dissolved, starchy substance of the endosperm. This cylinder epithelium is nicely shown in the germinating wheat. During germination the scutellum remains within the pericarp.

"In many grasses there is in front of the embryo and opposite the scutellum a small, scale-like appendage, the epiblast. It is especially clear in Stipa, and yet better developed in Zizania (where it is as long as the plumule), but it is entirely lacking in many grasses (rye, maize and barley); generally it is

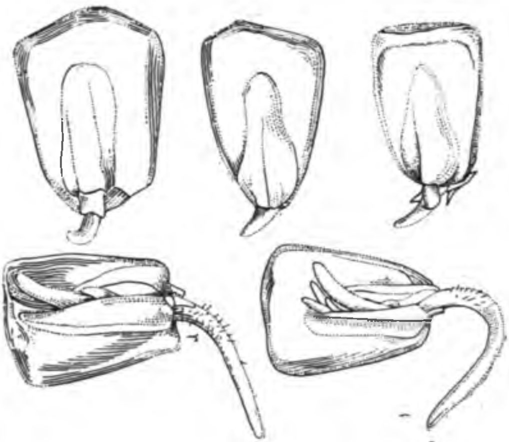

Fig. 52. Maize germinating. Scutellum in front; *r*, primary root. In lower left hand corner, the plumule showing also second seminal roots from first node. (King.)

Fig. 53. Squirrel-tail grass germinating, sterile spikelets, young plant and roots. (King.)

a delicate formation consisting of parenchyma without fibro-vascular bundles, and its morphological nature is still doubtful. Yet the view that it is the rudimentary second cotyledon is the most reasonable, for among other things this makes comprehensible the surprising position of the first leaf of the plumule of the embryo, consisting of a very short, often indistinct internode of the axis (epicotyl), and of two to four leaves, and according to the development of the former the plumule is sessile or petioled. The first leaf, the germ-sheath, surrounds the others like a closed tube, which breaks through the ground with its hard point at the time of germination, and opens at its apex after a time to allow the exit of the second leaf. It is colorless or pale green or frequently reddish. Many authors consider it a part of the cotyledon, a view which is certainly incorrect, for in many grasses it is separated from the scutellum at the time of germination by a distinct internode, which is often much elongated. In others this epicotyl is very short or entirely lacking, so that the back of the sheath may even be grown to the scutellum.

"The majority of grasses have only one radicle, and grow therefore with a primary root; in addition to which, especially from the epicotyl, new roots soon arise which finally exceed the main root in growth. In several grasses, especially in the cereals, and also in *Coix lachryma* and others, the foundation of these secondary roots is already laid before germination, usually in the hypocotyl (the axis below the insertion of the scutellum); seldom and only to a rudimentary degree, in the epicotyl. The planes of these secondary roots are parallel to that of the scutellum; they can therefore be seen only in tangential and not in radial section of the seed. In germination, each rootlet independently breaks through the coleorhiza, which surrounds each with a small sheath. Before the roots break through, the elongating coleorhiza ruptures the pericarp and sends numerous hairs from its epidermis, thus fastening the somewhat superficially placed seed to the ground.

Physiology of germination.—It may be interesting now to discuss the physiological process of the germination of grass seeds. The food material made by the leaves is deposited in the seeds in the form of reserve material, consisting of two classes of substances, the albuminoids and carbohydrates. The amounts of these vary in different species. The manner in which the albuminoids are deposited varies, but they occur largely in the form of proteids, deposited in the form of aleurone grains.

The carbohydrates occur largely in the form of starch, though in some few cases reserve cellulose occurs, as in the perisperm of the seed of Bromus and allied grasses. An examination of the endosperm of grass seeds indicate that the outer layer of the endosperm consists of cells that differ in a marked way from the remaining cells. The researches of Haberlandt and several other writers have shown beyond a doubt, that this layer is a secreting organ in which ferments are produced which are transferred to the remainder of the endosperm, where the starch is converted to a sugar where it is taken up by the cylinder absorption epithelium, the outer row of cells of the scutellum.

The wide and universal distribution of the aleurone layer would appear to indicate some physiological purpose. Its function has been nicely demonstrated by Haberlandt and other writers.

Brown and Morris,* who have studied the germination of barley and a few other grasses, differ in regard to the digestive action of the aleurone cells. Haberlandt's work was carried out with rye, and as stated above indicate that the aleurone layer is a diastatic secreting tissue and that the aleurone layer does not entirely belong to the reserve food system. Haberlandt found the corrosion of starch grains first took place between the scutellum and the aleurone layer on the ventral side and this corrosion rapidly extended to the starch grains

*Jour. Chem. Soc. London. 57: 458.

on the dorsal side of the scutellum. It was also found that this corrosion of starch took place last of all in the groove. Haberlandt therefore concludes that the scutellum as well as the aleurone layer are secreting organs. To test this work, Haberlandt removed portions of the testa, including the aleurone layer, which had germinated to a certain degree. The second was washed with a brush containing one to two per cent sugar solution, placed upon moist filter paper with the aleurone layer upward. Upon the aleurone layer was placed a small quantity of moistened rye meal. The whole was then kept moist at a temperature of 18 to 20 C. In a couple of hours a corrosion of the starch grains had taken place. These sections were compared with others not so treated. In order to demonstrate this, Haberlandt cut around the edge of the scutellum and found that notwithstanding the break in the continuity of the aleurone layer and its complete separation from the embryo, it did not prevent the spread of the diastatic action, when these were later germinated. The inactive aleurone cell, according to the same investigator, contains no appreciable amount of diastase.

Brown and Morris, who investigated this question, state that they were at first inclined to believe as Haberlandt does, that the progressive action of the corroded starch grains were due to the special action of the aleurone cells. They further stated that the true explanation is due to the solution of the cell walls of the starch containing endosperm, but that this is a necessary preliminary to the dissolving action of the starch.

J. Gruss,* from a series of experiments on corn and several other plants, concludes that there exists in the germinated seed a soluble diastase which is capable of diffusion through the cell wall in the same way that sugar does. The removal of the cotyledons diminishes the amount of diastase in the stem. Brown and Morris state they found that the mother substance of the diastase secretion is probably derived from the endosperm. The form in which reserve starch enters the growing embryo has been found to be mostly invert-sugar, but there is also a considerable amount of cane sugar, as Kuhnemann† has shown. Later Kjeldahl‡ found that cane-sugar is

*Pringsheim Jahrb. f. wiss. Bot. 26: 379-437. *pl. 2*. 1894; Ber. Deutsch. Bot. Gesell. 13: 2-13. *pl. 1*. 1895.

†Ber. Chem. Gesell. 8: 202-387.

‡Rèsumè du Compt rend des travaux du Laboratoire de Carlsberg. 1881: 189.

present in barley and malt. The amount of cane-sugar in barley is given by O'Sullivan as follows:

Cane-sugar	2.8 per cent	to 6.0 per cent
Maltose	1.3 " "	" 5.0 " "
Dextrose	1.5 " "	" 3.0 " "
Levulose	0.7 " "	" 1.5 " "

O'Sullivan concluded that the maltose was derived from the starch.

It may be interesting here to compare the percentage found by Brown and Morris.

	BARLEY AFTER STEEPING IN WATER FOR 48 HOURS.		BARLEY AFTER GERMINATION FOR 10 DAYS.	
	Embryos, grams.	Endosperms, grams.	Embryos, grams.	Endosperms, grams.
Cane-sugar..	0.0204	0.0338	0.3430	0.1787
Invert-sugar	0.0070	0.0227	0.0174	0.1790
Maltose......	....	....	....	0.3640
Total...	0.0274	0.0565	0.3604	0.7217

	BARLEY AFTER STEEPING IN WATER FOR 48 HOURS.		BARLEY AFTER GERMINATION FOR 10 DAYS.	
	Embryos, per cent.	Endosperms, per cent	Embryos, per cent.	Endosperms, per cent.
Cane-sugar .	5.4	0.3	24.2	2.2
Invert-sugar	1.8	0.2	1.2	2.2
Maltose......	....	....	....	4.5
Total...	7.2	0.5	25.4	8.9

These writers also conclude that the transformed starch is absolved from the endosperm by the columnar epithelium of the embryo in the form of maltose, and then is rapidly converted into cane-sugar. The main point of difference between the conclusions arrived at by Haberlandt and Brown and Morris are that the former believes that aleurone layer is largely a secreting organ. Brown and Morris say that the absorptive epithelium columnar cells is a secretory tissue, and that there is no doubt that one of the special functions of these cells is the secretion of enzymes.

It was Sachs who first stated that the columnar epithelium was an absorptive layer, and most writers agree that this is one of its many functions, but Brown and Morris say that the absorptive function is secondary in its importance. According to these writers, when they had removed the columnar epithelium, the embryo developed when it was placed upon a culture medium containing a readily assimilable carbohydrate, such as cane-sugar or dextrose, just as it would have done in its unmutilated state, and when such a mutilated embryo is placed upon a starch gelatin mixture it entirely lost its power of corroding and dissolving starch granules. The secretion of diastase appears to be increased by the presence of the small quantity of acid, and its secretion is stimulated by the presence of digestible material, "that the flow of amylohydrolytic enzyme from the glandular cells of the scutellar epithelium might be influenced by the presence of starch, either in the granular form or as soluble starch." Starch does not stimulate the epithelium cells to increased secretion. It has been known for some time that the cell-walls of the endosperm end of a date seed become dissolved and is used for the nourishing of growing plantlets. This was shown very nicely by Sachs.*

This has also been abundantly proven for other seeds in which the reserve material is cellulose. Mr. J. R. Greene, who made a glycerine extract of the cotyledons of the date seed, concluded that the glycerine extract contained a trace of enzyme capable of converting cellulose into sugar. Brown and Morris have shown that during the early stages of germination the cell walls of the endosperm are disintegrated, and that the disappearance of the cell walls always precedes the attack upon the starch granules. That malt of barley contains an enzyme, to which they have given the name of cytohydrolytic as well as amylo-hydrolytic enzyme. The former when slightly assimilated and allowed to act upon wheat or barley, causes disintegration. As no other malt extract was used it is evident that this ferment has a decided soluble action upon the endosperm-cellulose of *Bromus mollis,* where the cell walls are considerably thickened, and also on the cell walls of other grass seeds. It is also interesting to note here that heating the

*Bot. Zeit. 20: 242, 249. *pl. 9.* 1862.

enzymes totally destroys the activity as a cellulose dissolving agent, and that it does not pre-exist in the resting seeds, but it is a product of germination.*

The reserve foods, as indicated, consist of two general classes, the carbo-hydrates occuring under three forms: sugar, starch and cellulose, and the albuminoids occurring in the form of albumoses and the vegetable globulins. Of course these are very concentrated. In the aleurone cells the albuminoids have received special names in different seeds.

The outer row of cells of the embryo make up what is known as the cylinder epithelium, or referred to as the epithelium. (Fig. 51 A.) The embryo contains very little starch or none. Now the dissolved material of endosperm is transferred through the absorptive epithelium by diffusion and transferred to the growing embryo within a few hours after the moistened corn is put under favorable conditions for germination. The protoplasm of the epithelial cells becomes coarser in structure, and the granules increase in size. The contents of the cells and nucleus are less distinct; they reach their maximum change in from 24 to 36 hours. At this stage the epithelium ceases to produce its secretory enzymes. The protoplasm loses its large granules and contains small refractive granules. The cell contents become hyaline. The contents of the endosperm become gradually absorbed, the cells having become greatly elongated. The first action of the endosperm is a dissolution of the cellulose and the appearance of transitory starch in the scutellum or cellulose, and therefore acts first in supplying the growing embryo with food. "In the first place the cellwall swells up slightly, and its stratification becomes much more apparent, owing to a partial separation of its constituent lamellae. These are gradually disintegrated, but the middle lamella appears to offer a somewhat greater amount of resistance than the other. Ultimately the whole of the cellwall is broken down into very minute spindle-shaped fragments, with their long dimensions arranged tangential to the original cell-wall. Owing to this arrangement, these minute fragments, when viewed with low powers, gives the appearance of ghost-like cellwalls for some time after the wall has really ceased to be continuous. Ultimately, as the action continues, the residual fragments also disappear, and there is no visible sign of sepa-

*These writers, Research of the germination, etc. Jour. Chem. Soc. 57: 465., give an account of obtaining these enzymes.

ration between the contents of contiguous cells. In the case of starch grains, minute pitted furrows occur. These increase in number until the grains become very irregular, showing large radial clefts. It may be stated in this connection that the embryo acts like a parasite. It is well known that the embryo can very readily be removed from the endosperm. Sachs* points out that the embryos of normal plants are of a parasitic nature, and it has been shown by several investigators that it is possible to excise the embryo of various seeds and germinate plants. Thus Van Tieghem†, who discussed the dependence of various parts of the embryo and the amount of dependence of the embryo upon its endosperm. In this work the writer experimented with both albuminous and ex-albuminous seeds. Among the former corn was used. Van Tieghem reached the important conclusion that the young plant can develop without the aid of endosperm, up to a certain stage. That the nutritive matter of the endosperm can be replaced, up to a certain point, by a paste formed of its own substance, or by the paste containing the predominating substance of albumen. Further experiments were made by Blociszweski,‡ who demonstrated that the embryo seeds separated, wholly or in part, from their endosperm or cotyledons, could grow without the aid of the stored-up material of the endosperm or cotyledons, and that assimilation begins, providing that the plumule has the necessary amount of light.

Now, Brown and Morris succeeded in growing the embryo of barley seeds, when grafted upon the endosperm of other barley seeds; that these embryos grew as well as others dependent on its own endosperm. The foreign endosperm underwent all the usual changes. They succeeded likewise in obtaining a growth of barley germs upon wheat. They concluded that the starch-containing portion of the endosperm is simply a storehouse of dead reserve material, and that it is not vital in any sense of the word.

Time required for germination.—We may next inquire what time is required for germination. Nobbe,§ in his admirable work on seeds, states that seeds of cereals and clovers in general require 10 days. *Melilotus alba*, Avena, beets, Cucurbitaceæ, grasses (excepting Phleum, which germinates in ten

*Physiology of Plants. 373.
†Ann. des Sci. Nat. V. 17: 205.
‡Landw. Jahrb. 5: 14. Abst. Jahr. d. Agr. Chem. 1876: 232.
§Handbuch der Samenkunde. 511.

days), need fourteen days, and Abietineæ, twenty-one days. Gilbert H. Hicks* gives the germinative energy for cereals, clovers, peas, vetches, flat peas, flax, dodder, poppy, Brassica, Lepidium, radish, spurry and chicory at three days. For ordinary field conditions this is somewhat too short a period. In laboratory and greenhouse our tests show that corn requires five or six days as an average.

The time required for germination varies greatly. This depends largely upon external conditions. Sachs has given us the following temperature required for germination:

	OPTIMUM.	MAXIMUM.	MINIMUM.
Zea mays (corn)............	33c	46c	9.5
Triticum vulgare (wheat)...	29	42	5
Hordeum vulgare (barley)..	29	38	5

Haberlandt gives as the maximum temperature of germination of cereals the following: Wheat, 31-37 C; rye, 31-37 C; barley, 31-33 C; oats, 31-37 C; corn, 44-50 C; millet, 44-50 C.

He has determined the minimum temperature and rapidity of germination as follows: Time of counting when caulicle appeared:

	4.75 C.	10.5 C.	15.6 C.	18.5 C.
Winter wheat..............	6	3	2	1.75
Winter rye....	4	2.5	1	1
Barley..................	6	3	2	1.75
Corn.....................	....	11.25	3.25	3
English rye grass	10	5.5	3.75	3
Timothy..................	....	6.5	3.25	3

O. Burchard has made the following determination of grass seed and temperature:

	CONSTANT TEMPERATURE, 68° F.				CONSTANT TEMPERATURE, 86° F.				
Germination after days	5	7	14	28	5	7	14	21	28
Poa pratensis, per cent.	5.06	12.89	24.39	25.72	6.45	10.11	12 28	12.61	12.61
Poa trivialis, per cent.....	16.17	39 67	69.33	71.33	19.83	31.83	33.25	39.17	40.0
Poa nemoralis, per cent. ...	8.75	18.58	26.33	27 12	7.0	13.5	17.42	17.59	17.59
Poa annua, per ct..	54 9	76.33	74.83	75.17	56.83	68.0	72.83	73.67	73.67
Poa compressa, per cent	0.0	0 17	0.5	0.67	0.0	1 67	3.33	3.33	3.33
Agrostis stolonifera, per cent.	59.5	63.92	64.59	64.75	78.17	83.33	84.59	85.0	85.0
Alopecurus pratensis, per cent ...	9.75	30.67	64.5	71 92	8.08	30.84	59 75	64.34	65.15

*Year Book. U. S. Dept. of Agrl. 1894: 399.

	CHANGEABLE TEMPERATURE.			
Poa trivialis, per cent	35.33	62.0	73.67	75.33
Poa nemoralis, per cent	18.0	43 5	56 17	57.67
Poa annua, per cent	72 17	82.33	84 67	84.67
Poa compressa, per cent.	0.0	18.17	52.17	54.5
Poa pratensis, per cent.	11 72	21.11	45.28	49 84
Agrostis stolonifera, per cent.	90.34	96.0	96 42	96.42
Alopecurus pratensis, per cent	14 5	46 67	72.34	74 42

Vitality.—When the necessary conditions are present—a favorable temperature and moisture—the process begins. The first step is absorption of moisture. When this has proceeded far enough, and with the required amount of heat, the radicle breaks through the coleorhiza or root sheath. The first leaf surrounds the other leaves in the form of a tube, and pushes through the ground; later it opens out. In some cases a single strong primary root appears, but in others a number may even break through the root sheath. The scutellum remains within the pericarp The young plant is nourished by the material stored away in the endosperm. It is transferred to the embryo by a row of palisade cells that occur on the outside of the scutellum. The walls are delicate, and during their activity are made up of granular cytoplasm. During the process of germination, the protoplasm does not only become active, but is changed in its structure, as will presently be shown. Now, as a further evidence of germination, it is well known that during the process, evolution of heat takes place. This is due to oxidation. This process has also been called respiration. The carbohydrates are consumed and CO_2 is given off. This may easily be shown by germinating corn or rye or oats in a close atmosphere in a vessel which does not permit the produced gas to escape. This gas may afterwards be collected in the well known respiration apparatus of Sachs'. The activity of respiration, that is, the carbon dioxide, given off by a given plant, will vary according to the state of development of the seed. At first little will be given off, and as the process of germination increases, more will be given off; as the material is consumed more and more, the process diminishes and the activity of respiration ceases.

Fig. 56 A. Germination of wheat. (King)

It has also been shown that plants, during germination, do not lose any nitrogenous substances, nor do they form nitrogen gas. T. H. Schloesing, Jr.,* who experimented with lupines, concludes that the seeds of plants do not lose any of their nitrogenous substance in the form of gas during germination. Soon after germination is under way the primary root produces lateral rootlets; these as well as the main root form root hairs that serve to bring nourishing material from the soil as well as to anchor the plant. The following table by Nobbe is interesting as showing the germination of grasses compared with other plants.

	Maximum.	Minimum.	Mean.
Agrostis stolonifera	55	1	28
Pinus strobus	15	10	13
Allium cepa	93	47	63
Alopecurus pratensis	28	1	9
Arrhenatherum avenaceum	84	26	55
Avena sativa	98	97	98
Phleum pratense	99	62	86
Zea mays	98	18	87
Brassica oleracea	97	1	47
Daucus carota	87	10	58
Linum usitatissimum	99	82	89
Medicago sativa	95	42	86
Trifolium pratense	98	39	87
Lactuca sativa	63	14	37
Meadow grasses	49.8	6.4	27.4
Cereals	95	45	81.5
Crucifers	98	52.5	87
Cucurbits	91	39	74

Temperature and germination.—It is a well known fact that temperature is an important factor in the germination of seeds. Nobbe †has given us an instructive table, from which the following is taken:

SEED.	16° C. 60 5° F.		25° C. 77° F.		31° C. 88° F.		37.5° C. 100° F.		44° C. 111° F.	
	Seeds ger.	Hours.	Seeds ger.	Hours.	Seeds ger.	Hours.	Seeds ger.	Hours.	Seeds ger.	Hours.
Barley	100	92	92	72	24	144	.....	.....	.....	.....
Cabbage. early small	100	56	100	32	100	48	.....	.....	.....	.....
Red clover	100	32	100	24	100	24	100	24	.....	.....
Corn	80	44	68	56	100	48	100	48	12	80
Flax	100	32	100	23	100	47	.....	.....	.....	.....
Oats	100	80	100	48	100	80	100	48	36	96
Timothy	76	168	100	44	88	148	.....	.....	.....	.....
Wheat	100	56	100	32	100	48	.....	.....		.....

*Comt. rend. 120: 1278. Abst. Cent. Agrikulturch. 25: 737.

†Handbuch der Samenkunde. 226. Landw. Versuchs. Stat. 117: 74. 1874.

The minimum degree of temperature for corn is 49.9 F., maximum 134.8 F., optimum 91.4 F. To this table may be appended the results obtained for a few cereals in our laboratory, greenhouse (were germinated in sand) and field. The temperature of the laboratory was not kept. The seeds of the laboratory were germinated in porous clay trays.*

LABORATORY AND GREENHOUSE TEST.

VARIETY.	GREENHOUSE.						LABORATORY.
	Temperature, 7 A. M.	Temperature, 1 P. M.	Temperature, 7 P. M.	Humidity, Minimum.	Humidity, Maximum.	Per ct. of germ.	Per ct. of germ.
Yellow dent	89 29	67.13	86.21	37.86	82.36	16	33⅓
Dent	88.89	60	82 33	35	83.56	72	73⅓
White dent	87 5	75.38	90 28	38.88	80.25	100	85
Dent	88.7	73	68.9	39.1	81.1	12	66⅔
Dent	85.77	62.92	77.15	42.77	86.92	76	80
Mills Co. white dent	82	62.8	83	38.3	81.1	100	100
Striped corn	85.83	74 5	89.83	43	75.17	96	100
Early Minnesota Sweet	82	62.8	83	38.3	81.1	96	76
Pop corn	82.59	62.29	81.86	38	82.29	100	100
Feeder's Favorite	80.89	60	82.33	35	83.56	66	76
No. 5	78	66⅔	69 2	52 2	92	100	90
No. 6	70.8	66⅔	69.2	52.2	92	100	100
University No. 13	70.8	66⅔	69.2	52 2	92	100	100
Bloody Butcher	70.8	66⅔	69.2	52.2	92	98	88⅓
Iowa Silver Mine	70.8	66⅔	69 2	52 2	92	100	100

According to Sempolowski, the percentage of germination in grasses is as follows:

	Max.	Min.	Ave.
Agrostis stolonifera	59	8	28
Agrostis alba	21	18	19
Aira caespitosa	9	2	6
Aira flexuosa	50	19	5
Alopecurus pratensis	9	1	5
Anthoxanthum odoratum	42	10	23
Arrhenatherum avenaceum	55	25	44
Arrhenatherum flavescens	28	......	14
Bromus mollis	96	45	72
Cynosurus cristatus	55	4	23
Dactylus glomerata	84	10	58
Festuca ovina	68	14	48
Festuca pratensis	75	35	54
Festuca rubra	70	21	39
Holcus lanatus	39	16	27
Lolium italicum	87	25	62
Lolium perenne	92	57	75
Phalaris arundinacea	12	8	10
Phleum pratense	96	82	90
Poa pratensis	25	1	9
Poa memoralis	6	1	3
Poa trivialis	7	2	7

*A fuller account of these studies is given by Pammel. Proc. Soc. Prom. Agrl. Sci. 1898: 194. Contr. Bot. Dept. Iowa St. Coll. Agrl. and Mechanic Arts. 12.

On the general subject of climate and its influence on the germination of seeds, little that is positive can be said. In some of our own experiments the California seeds germinated better, and the plants were more vigorous than those of Iowa, but it should be taken into considera ion that the California wheats are soft and that it is not improbable that the reserve food substances were brought into a state of solution sooner than in the hard wheats. The very striking differences reported by Professor Bailey in corn do not occur in wheat. The cross-bred wheats and other varieties grown in the state of New York and the East, seems to have germinated slower than those from the Mississippi Valley states, especially so when compared with the wheats of Kansas, Iowa and Wisconsin. As stated in a previous paragraph, the California wheats were especially characterized by the high per cent of germination and the vigor of the young plants. It may be stated that the test made with these plants occurred several months la er than those made with the other wheats. Yet a second trial gave us nearly the same results.

In the second trial the plants were all grown at the same time. The Early May of Kansas was comparable with the Patati, only somewhat stouter. The Bissell and Andrews were smaller than the Early May. The Turkey Red, Kansas, was smaller than the Bissell. The cross-bred wheats lacked vigor, and were extremely slow in coming up. The Canada Hybrid, in this experiment, came up rather slowly, although finally it grew quite vigorously.

The following table shows the influence that latitude has on the germination of a single variety of wheat tested at Ames.

VARIETY AND SOURCES.	GERMINATION AFTER DAYS, PLANTED 1 INCH DEEP.						
	4	5	6	7	8	9	10
Turkey Red, Atlantic, Iowa (Franklin)	13	38	42	....	43	....	44
Turkey Red, Manhattan, Kans	6	20	31	33	40	42	43
Turkey Red, Iowa Experiment Station.	....	2	4	12	15	22	36
Turkey Red, Des Moines, Ia. (Ia Seed Co.)	5	21	31	36	44	43	44

It may be of interest to briefly compare the germination of the different varieties of wheat from different states grown under the same conditions. This work was carried out several years ago by Pammel and Stewart.

Early May, from Kansas, total percentage of germination, 88. All of the seed practically germinated in eight days; one-half in four days. Martin Amber, La Crosse, Wis., only seven seeds germinated in four days; 78 per cent in thirty-nine days. Red Clawson, N. Y., two seeds germinated in six days; six seeds in eight days; after the twelve days seventeen had germinated or 38 per cent. Missogen, Cal., none had germinated in the four days; on the fifth day forty-five seeds had germinated; on the sixth day seventy-seven seeds; on the seventh day ninety-six seeds.

The lowest temperature at which maize will germinate according to Sturtevant is 43.7 F., for all the varieties. It is probable that further trial will place the lowest temperature at 42 or below, but the difficulty of keeping an unquestioned record between close limits for a long period is very great. In Experiment 4, Sturtevant succeeded for twenty-nine and one-half days, when repairs to the water service necessitated its conclusion.

An extended series of tests made at the college the past season from seed collected about Ames, and quite a number of seed sent from other sources, show the following instructive results.

GERMINATION OF CORN WHEN KEPT UNDER DIFFERENT CONDITIONS.

VARIETY.	WHERE KEPT.	AGE.		Per cent. Germinated.
		'95	'96	
Yellow dent	Open crib college barn	2	....	33⅓
Calico dent	Seed of 1895, closed crib	2	....	93⅓
Legal tender	Dry room	2	....	100
Yellow dent	Shock	....	1	66⅔
Calico	Open crib	2	....	60
Calico corn	Loft above a chicken coop	....	1	100
Sweet corn	Seed of 1896, shock	....	1	100
White rice pop	In paper packages	....	1	100
Iowa silver mine	College seed room	....	1	100
Stowell's evergreen	College seed room	....	1	88

This table certainly shows that when the corn is kept properly there is little danger from deterioration. It is impossible to judge the quality of corn by germinating early in the season when the atmosphere is humid and cold. Seeds kept in damp places when brought into the laboratory frequently germinate well. On drying, however, these seeds soon lose their vitality in a few months. In our experiments the seeds were kept in a dry room and kept under the same conditions.

A number of experiment stations have tested the vitality of corn seed and from the results the following is gleaned. Saunders* states that out of eleven tests the highest percentage was 100, the average 76 down to 63. Corn tested, two varieties, maximum 77, minimum 70, average vitality 73.5. A. J. Pieters† states that in Egyptian sweet corn the germination was 76 whereas it should have been 92.5.

A. Burgerstein‡ who conducted some experiments testing the 10 years old seed of cereal arrives at the following conclusions. Barley retains its vitality better than other seeds. Seeds of this cereal 8 to 10 years old are not especially different than that of from 2 to 7 years old. Oats are nearly as good. In the case of wheat 90 to 100 per cent germinated in from 1 to 4 years; in 5 to 7 years, 85 to 87 per cent; 8 to 10 years, 70 to 80 per cent. The number of wheat seeds capable of germinating diminished 20 to 30 per cent in a single decade. In the case of rye the percentage of germination in 5 years dropped to 65 per cent; 7 years, 36 per cent; 9 years, 13 per cent; 10 years, 1 to 2 per cent. Rye had practically lost its germination in ten years.

The results of some experiments made with wheat at the Iowa experiment station§ indicate that some of the cross-bred wheats s on lose their vitality.

Regermination.—It has been a common belief among many farmers, as well as others, that certain seeds were capable of germinating more than once. Mr. C. H. Andric‖ states that he observed the regermination of wheat. This fact has been likewise observed for corn, oats and rye. The question is therefore of general interest; we have in this connection summarized the work of several experimenters as well as some original work done at this station several years ago. Professor Goff¶ has done some rather interesting work in connection with corn. He sprouted the seeds in apparatus and then removed to a warm dry place where they were allowed to

*Canada Experimental Farms. Appendix to the Report of the Minister of Agrl. 1892: 40-42.

†Year Book U. S. Depart. Agrl. 1895: 176.

‡Naturw. Rundschau. 1896: 23. Verhandl. geo. bot. Gesells. Wien. 45: 414. Abst. Biedermann's Cent. Bl. Agrikulturch. 25: 637.

§Pammel. Proc. Soc. Prom. Agrl. Sci. 1898: 194.

‖Wallace's Farmer and Dairyman. 1897: 150.

¶Ann. Rep. of the Board of Control, N. Y. Exp. Sta. 2: 65. 1883.

remain seven days and then germinated. The following table shows the result of his work:

WAUSHAKUM FLINT CORN.

1st Test.	2d Test.	3d Test.	4th Test.	5th Test.	6th Test.
100.	97.	97.	65.	20.	0.

Total number of days dried, 47.

WHITE RICE POPCORN

1st Germ.	2d Germ.	3d Germ.	4th Germ.
100.	96.	29.	44.

Total number of days drying, 28.

BLOUNT'S PROLIFIC DENT.

1st Germ.	2d Germ.	3d Germ.	4th Germ.	5th Germ.	6th Germ.
96.	83.	14.	0.	12.	0.

Total number of days dried, 28.

Beal, of the Michigan Agricultural college,* did some work along the same line with wheat. Later Ten Eyck,† made some experiments at Madison, Wis., from which it appears that corn, "Pride of the North," first germinated 100 per cent., 500 seeds being used in this test. Second, 285 seeds tested 97.54 per cent. Third test 213, 23 per cent. Fourth test 43 seeds used, 11.68 per cent. Fifth test, 5 seeds, no germination. Total number of days dried, 21. In the second trial the same variety of corn was used. First germination, 500 seeds used, per cent of germination, 99.82; second germination, 276 seeds used, per cent of germination, 77.90; third test, 196 seeds used, per cent of germination, 66 33; fourth germination, 77 seeds used, per cent of germination, 64.94; fifth test, 23 seeds used, per cent of germination, 52.17; sixth germination, 12 seeds used, per cent of germination, 16.67; seventh test, 2 seeds used, per cent of germination, 0. Total number of days dried, 42.

One of us and Mr. F. C. Stewart, some years ago, made regermination tests, but the work was not entirely completed, owing

*Rep. Mich. St. Board Agrl. 1881-1882: 123.
†Agrl. Sci. 6: 454. 1892.

to an interruption in the plan of the experiments, but the results made were interesting and instructive. The results of the work indicated that seeds which were soaked for a considerable period of time and then allowed to dry, failed to show as good germinating plants as those not soaked. The per cent of germination being in some cases lower and on the whole the germination proceeding more rapidly when the seeds had been moistened. The germinated plants from seeds moistened for a considerable period were easily subject to the attacks of saprophytic fungi, and hence made a very feeble growth.

Rambousek* states that experiments with rye, wheat and barley have shown that such seeds in which the radicle only is injured may continue to germinate, and that in this respect wheat and rye are much more resistant than barley.

THE PURITY AND VITALITY OF GRASS SEED.

CARLETON R. BALL.

In the following pages have been brought together most of the available facts pertaining to this subject which seem important in determining the status of our grass seeds with reference to their purity and vitality. Reference has been made to only such works as gave the results of a considerable number of tests and the subject is further confined to our own country. For four of our common species the results obtained from miscellaneous sources have been summarized by the author under the heading "various other tests," and all the data are presented in tabular form for better comparison.

A study of the tables will show beyond doubt that the quality of commercial grass seed has improved considerably in the last fifteen years. It will also show as conclusively that further improvement is not only necessary in the interest of good pastures and clean farms, but is also easily possible. Tables Nos. V, VI and VII give both purity and vitality of a large number of species of grasses.

PURITY.

Since the '60's, when Nobbe made his classic disclosures of the deplorable state of affairs which then existed in Europe,

*Prager. landw. Wochenblatt. 1895: 393. Centr. Agrikulturch. 24: 393.

the fact that the commercial seed of grasses and forage plants contain relatively large amounts of impurities has been quite generally appreciated. It is true that the quality has improved considerably since that time. This is due largely to the establishment and operation of numerous seed-control stations and the prosecution of similar work by many of our American experiment stations. Good descriptions and illustrations of grasses have become more available for popular use and thus a discriminative knowledge of them more widely diffused.

A discussion of the impurities of grass seeds may be taken up under two heads as follows:

a. Intentional adulteration.

b. Na ural or accidental impurities.

Intentional adulteration.—The substances principally used to adulterate the seeds of grasses are fine sand and the seeds of cheaper and often very inferior grasses. Neither of these can be detected except by a careful examination. In fact it is almost impossible for the average consumer to detect the presence of a foreign grass seed in his package because the seeds of some species resemble each other so closely as to render it difficult for the specialist to distinguish them. Rolfs reports* finding sand in some quantity in the seeds of fiorin or bent grass (*Agrostis alba*) and sweet vernal grass (*Anthoxanthum odoratum*). McCarthy† states that sand and crushed quartz rock have been detected in samples of timothy.

The seed of English or perennial rye or ray grass (*Lolium perenne*) is commonly used to adulterate the seeds of other grasses, partly because it is very cheap and partly because it resembles them closely. It is frequently found in the seeds of such grasses as tall fescue and meadow fescue (*Festuca elatior* and *F. elatior pratensis*), Italian ray grass (*Lolium italicum*) a dearer and better grass, and in orchard grass. Rolfs found 41 per cent of it in a pound of the Italian ray grass and 11 per cent in water fescue. The amount in orchard grass is discussed under that species. Sheep's fescue is sometimes used in seeds of crested dog's tail and is sometimes sold as red fescue. Seeds of several species of worthless Poas are used with the seeds of rough-stalked meadow grass (*Poa trivialis*) an imported grass. Several other grasses are less frequently used.

*Preliminary report on the examination of some seeds. Bull. Iowa Agr. Exp. Station. 18: 75-86.

†Seed testing: Its uses and methods. Bull. N. C. Agr. Exp. Station. 108: 349-415. 1894. See 382-391. (Also Bull. 73: 73-78: 1889).

Natural or accidental impurities.—Under this head must be placed the varying amounts of dirt, sand, sticks, dead seed and chaff resulting from improper cleaning, and also the seeds of weeds and weedy grasses which grow naturally, or through introduction, with the valuable grasses. Of the first series there will always be a small amount in the best cleaned seed. The amount of weed seeds can, however, be easily reduced to practically nothing by pulling up the weeds before the grass seed is harvested. The desirability of any sample of seed is not always fairly indicated by the percentage of weed seed it contains, for it is readily seen that a small per cent of a very bad weed would be more dangerous than a much larger per cent of a comparatively harmless weed.

One of the most common weeds whose seeds are found in grass seed is plantain (*Plantago major*). The lance-leaved plantain or rib grass (*P. lanceolata*) is being rapidly scattered over this country by means of imported grass seed. Other common weeds are sheep sorrel (*Rumex acetosella*), dock (*Rumex crispus* et al), shepherd's purse (*Capsella bursa-pastoris*), May weed (*Anthemis cotula*), pigweed (*Amarantus* sp.), lamb's quarter (*Chenopodium album*), mallow (*Malva sylvestris*), buttercup (*Ranunculus* sp.), and occasionally Canada thistle (*Cnicus arvensis*), and ox-eye daisy (*Chrysanthemum leucanthemum*).

Among the weedy grasses whose seeds are troublesome may be mentioned the pigeon grasses or foxtails (*Chaetochloa viridis* and *C. glauca*). These are especially common in clover seed, hence are apt to get into grass fields. Some European seeds contain the seeds of blue pearl grass (*Molinia caerulea*) and darnel (*Lolium temulentum*), two dangerous grasses. Chess or cheat (*Bromus secalinus*), wild oats (*Avena fatua*), and sand bur (*Cenchrus tribuloides*) are also met with. Seeds of many other less harmful or of valuable species are found mixed with what should be pure seed of one species. Gilbert H. Hicks* says: "Very few kinds of grass are raised for seed purposes alone; hence most grass seed is obtained from meadows or places where different species are found growing together."

The following tables set forth some comparative facts concerning the purity of the seeds of four of our common grasses. The first column shows the number of samples of which tests were made. The last three columns show the minimum, average and maximum percentages of pure seed in each series of

*Pure seed investigations. Yearb. U. S. Depart. Agril. 1894: 389-408.

samples. I have quoted from a very good table of purities compiled by C. L. Parsons,* and have also given the tabulated results of various tests collated by myself. The standards of purity established by the U. S. Department of Agriculture in 1896 and those of McCarthy† in 1894 are also given.

Poa pratensis. Blue grass.—The seed of blue grass is not often purposely adulterated and is usually quite pure seed. It contains relatively little of weed seeds, and the impurities consist of small amounts of sand, dirt and sticks, with often a large per cent of chaff.

TABLE NO. I.

PURITY OF BLUE GRASS SEED.	Number.	Minimum.	Average.	Maximum.
Various tests	8	94.	97.7	100.
Parsons, summary of American tests	5	92.	96.7	99.
U. S Department of Agriculture, standard	....	....	90.	......
McCarthy, standard	....	....	84.8	......

Agrostis vulgaris. Red top.—There is little adulteration of red top seed. Rolfs reports one sample containing much quartz sand. When it is allowed to ripen until the seed shells out a large amount of empty chaff will be found in the packets. It usually contains dirt and the seeds of such low-ground plants as dock, plantain, buttercup, sedges and timothy.

TABLE NO. II.

PURITY OF RED TOP SEED.	Number.	Minimum.	Average.	Maximum.
Parsons, summary of American tests	6	14.	48.3	100.
Various tests	7	16.	63.1	100.
McCarthy, standard	....	....	97.4	......

Dactylis glomerata. Orchard grass.—The condition of orchard grass seed was thoroughly investigated at the Connecticut Experiment Station in 1892.‡ Their results were summarized as follows:

*A summary of American seed tests. Agri. Sci. 7: 541-545.

†Yearb. U. S. Dept. Agri. 1896: 623-624.

‡Conn. Agr. Exp. Station. Ann. Report 1892: 152-154.

"*First.*—Of the seventeen samples of orchard grass purchased in New York, Boston, and at various places in Connecticut, one sample contained as much as 98.8 per cent of pure seed, the remainder being chaff. Another contained no orchard grass seed whatever, and consis ed mainly of *Lolium perenne*, or perennial rye-grass. Excluding this sample the other sixteen samples contained on the average 77.4 per cent of pure seed.

"*Second.*—Seven out of sixteen samples contained notable quantities, from 8.3 to 35.5 per cent, of seed of perennial rye-grass, *Lolium perenne*, which is less valuable and sells at a lower price. 'Tested' orchard grass seed is quoted at 11 cents per pound and 'tested' perennial rye grass at 4.5 cents. A single sample contained 14.1 per cent of a species of *Bromus*, probably *B. secalinus*, or chess." McCarthy says uncleaned seed often contains one-fifth of its weight in chaff, dirt, and various weed seeds. The most common weeds are dog fennel or May weed, ox-eye daisy, sheep sorrel, and species of knotweed or heartsease (*Polygonum*).

TABLE NO. III.

PURITY OF ORCHARD GRASS SEED.	Number.	Minimum.	Average.	Maximum.
Connecticut Experiment Station, 1892	17	....	72.85	98.8
Parsons, summary of American tests	10	39.	87.2	100.
Various other tests	7	84.75	95.25	100.
McCarthy, standard, 1894	...	....	73.9	......

Phleum pratense. Timothy.—Timothy seed is usually quite clean. It is sometimes adulterated with sand and quartz and generally contains small quantities of dirt, sticks, and chaff, and the seeds of various weeds, clover, and some grasses. Among the common weed seeds are those of plantain, dock, buttercup, May weed, shepherd's purse, pigweed, and mallow. Of the grass seeds, red top, fowl meadow (*Poa serotina*), and the pigeon grasses or foxtails, are most commonly found. Professor Chester* found seed of Canada thistle in one sample.

*Ann. Rep. Delaware Exp. Station. 1889: 37-63. (Also Bull. 5).

TABLE NO. IV.

PURITY OF TIMOTHY SEED.	Number.	Minimum.	Average.	Maximum.
Parsons, summary	16	67.	92.75	100.
Various tests	20	95.15	98.5	100.
McCarthy, standard for choice	....	....	97.6	......
U. S. Department of Agriculture, standard	....	....	98.	......

Cereals.—An article on this subject would hardly be complete without something in regard to the purity of the seed grain of this country. As a rule they have a very high standard of purity; 99 per cent pure is the government standard, and that established by McCarthy was over 97.5 per cent. The seeds of a few weeds are usually to be found in wheat seed and to a lesser extent in oats. The most frequent of these are chess or cheat (*Bromus secalinus*), corn cockle (*Lychnis githago*), sheep sorrel (*Rumex acetosella*), pigeon grass, foxtail (*Chaetochloa*), rib grass (*Plantago lanceolata*) and garlic (*Allium vineale*). W. S. Devol,* who examined several samples of wheat seed, states that the seed of chess may be present in wheat at the rate of 9,000 per bushel and still amount to only about one-tenth of 1 per cent, and that the seed of corn cockle at the rate of 1,888 seeds per bushel would make only six-hundredths of 1 per cent of the total. Let us have a pure seed league with the motto, "An ounce of prevention is worth a pound of cure."

VITALITY.

It is a well known fact that the seeds of grasses have a comparatively low vitality. It is also a fact, though perhaps not so generally known, that the vitality of the average sample of commercial grass seed, as determined in germination tests, is much below what may be taken as an average standard. In fact, the average vitality of commercial grass seed is considerably lower in proportion to this reasonable standard for grass seeds than are the average vitalities of most other commercial seeds in proportion to the reasonable standards determined for them.

There are several reasons which, taken together, will largely account for this state of affairs. In the first place, the seeds

*Fourth Ann. Report Ohio Agri. Exp. Station. 1885: 185-186.

of grasses have been a commercial article for a much shorter period of time than have the seeds of most of our field and garden crops. Grasses were long regarded as one of nature's gifts, like air and water, and as little effort was made to improve their quantity or quality; little attention was paid to their seeds until recent years when various causes have combined to place hay and pasturage among the most important of our farm products. At the present time only imperfect devices exist for gathering and cleaning the seed, and little is known as to the best methods for increasing and retaining the vitality. In order to secure the greatest quantity at the least expense the seeds of many species are gathered while still green, and in this way the vitality is doubtless impaired. The drying of such green seeds is often imperfectly done and many of the seeds become mouldy.

The demand for the seeds of any but the most common kinds is so very limited and irregular that they may be held over from year to year in the unsold stock of the seedsman until their vitality is almost or completely exhausted.

In many of the grasses, as the blue grasses (Poa species), fescues (Festuca species), ray grasses (Lolium species), orchard grass (*Dactylis glomerata*), and others, the seed as gathered consists of not only the grain or caryopsis itself but also of the flowering glume or chaff which surrounds the seed more or less closely. This fact often makes it very difficult to say whether what appears to be a seed actually contains a seed or whether it is only an empty chaff. This can be determined only by a careful examination. Where this empty chaff made up a large per cent of the total it is evident that the vitality of the supposed seed would be very low.

Table No. V gives the average percentages of purity and vitality possessed by choice grass seeds. The figures were obtained from an extensive series of microscopic examinations and germination tests and were compiled by Prof. Gerald McCarthy from his own work* at the North Carolina Experiment Station, from the reports of many other American stations and four of the leading European seed stations, and from data furnished by many American and foreign seedsmen. The last three columns give the maximum, minimum, and optimum temperatures for germinating these seeds.

*Bull. N. C. Agr. Exp. Station. 108: 383-384. 1894.

TABLE No. V SHOWING VIABILITY AND PURITY OF GOOD COMMERCIAL SEEDS, AND TEMPERATURE AT WHICH THEY GERMINATE.

KIND OF SEED.	Viabilty per cent.	Purity per cent.	TEMPERATURE. Maximum ° F.	Minimum ° F.	Optimum ° F.
Grasses and Cereals:					
Agrostis stolonifera (fiorin)	82.	71.1	95	60	75
Agrostis vulgaris (red top)	72.	97.4	95	60	75
Alopecurus pratensis (meadow foxtail)	42.	83.5	95	60	75
Anthoxanthum odoratum (sweet vernal)	30.	85.7	95	60	75
Anthoxanthum puelli (annual sweet vernal)	26.	83.7	95	60	75
Arrhenatherum avenaceum (tall oat grass)	69.	68.1	95	60	75
Avena sativa (common oats)	95.	97.5	90	55	70
Avena flavescens (yellow oat grass)	37.	42.5	95	60	75
Bromus mollis (soft chess)	46.	64 4	90	55	70
Bromus inermis (Hungarian brome)	81.	76.3	90	55	70
Bromus pratensis (meadow brome)	61.	77.4	90	55	70
Bromus schraderi (rescue grass)	70.	95.	90	55	70
Cynodon dactylon (Bermuda grass)	52.	98.5	95	65	80
Cynosurus cristatus (crested dog's tail)	62.	89.1	95	60	75
Dactylis glomerata (orchard grass)	81.	73.9	95	60	75
Festuca duriuscula (hard fescue)	67.	86.7	95	60	75
Festuca elatior (Randall grass)	83.	85.4	95	60	75
Festuca tenuifolia	60.	71.4	95	60	75
Festuca ovina (sheep's fescue)	71.	80.3	95	60	75
Festuca pratense (meadow fescue)	81.	86.9	95	60	75
Festuca rubra (red fescue)	48.	73.1	95	60	75
Holcus lanatus (velvet grass)	39.	68.2	95	60	75
Hordeum vulgare (cultivated barley)	82.	97.9	95	50	65
Lolium italicum (Italian rye grass)	73.	93.	95	50	75
Lolium perenne (English rye grass)	76.	94.3	95	50	75
Oryza sativa (cultivated rice)	85.	97.1	95	65	80
Panicum germanicum (golden millet)	88.	97.5	95	65	80
Panicum milaceum (millet)	82.	98.	95	65	80
Panicum sanguinale (crab grass)	85.	97.5	95	65	80
Panicum spicata (pearl millet)	82.	98.	95	65	80
Phleum pratense (timothy)	89.	97.6	95	60	75
Poa arachnifera (Texas blue grass)	60.	88.5	95	60	75
Poa compressa (June grass)	70.	80.8	95	60	75
Poa nemoralis (wood grass)	60.	78.9	95	60	75
Poa pratensis (Kentuck blue grass)	60.	84.8	95	60	75
Poa serotina (fowl meadow grass)	75.	83.5	95	60	75
Poa trivialis (rough-stalked meadow grass)	55.	85.	95	60	75
Secale cereale (cultivated rye)	91.	99.	90	55	75
Chaetochloa Italica (Italian millet)	87.	97.5	95	60	75
Sorghum halapense (Johnson grass)	75.	95.	99	65	80
Sorghum nigrum (sugar cane)	75.	97 5	99	65	80
Sorghum saccharatum (broom corn)	75.	97.5	95	60	75
Triticum vulgare (cultivated wheat)	95.	98.2	95	55	75
Zea mays (Indian corn)	95.	98.5	100	65	85

Table No. VI shows the minimum, average and maximum percentages of vitality and impurity for a large number of grasses. The column headed "Days required" shows the number of days required for all vital seed to germinate. "No." indicates the number of tests from which the figures given were obtained. These figures were compiled by Charles Lathrop Parsons* and include most of the tests made up to January, 1891. By comparing this table with table No. V, some interesting facts are brought out. It will be noted that the vitalities are much lower than the standard of table No. V. For example, timothy is about 9 per cent lower, orchard grass 21 per cent, red top 28 per cent, and Kentucky blue grass over 50 per cent lower. These results are based on a large number of tests in each case, as may be seen by referring to the first column.

Table No. VII was condensed from the results of tests published by Prof. F. L. Harvey.† The seeds were germinated in cloth pockets in a galvanized tray containing water in the bottom. In noting these vitalities the reader must bear in mind that the tests were continued for only fourteen days, and that most grasses require a longer period for complete germination. This accounts for the large number of sound seeds remaining at the end of the test. Of course, not all of them would have germinated if the test had been continued, but it is probable that part of them would have done so.

*A Summary of American Seed Tests. Agrl Science. 7: 541-545.

†Germination Experiments. Maine Agrl. Exp. Station, Ann. Report. 1888: 136-137. (See pp. 143-147.)

TABLE NO. VI.

GRASSES.	VITALITY.				IMPURITIES.				DAYS REQUIRED.			
	No.	Min.	Aver.	Max.	No.	Min.	Aver.	Max.	No.	Min.	Aver.	Max.
Aira flexuosa (wood hair grass)	1	1	1	1	...	...	...	...	1	6	6	6
Agrostis canina (Rhode Island bent grass)	3	47	60	81	2	3	40	77	3	10	11	12
Agrostis stolonifera (creeping bent grass)	2	52	59.5	67	1	17.7	17.7	17.7	1	12	12	12
Agrostis vulgaris (red top or bent grass)	30	4	34.2	92	6	0	51.7	86	5	9	12	15
Ammophila arundinacea (beach grass)	1	2	2	2	...	...	...	...	1	14	14	14
Alopecurus agrostis (slender foxtail)	1	53	53	53	1	2	2	2	1	9	9	9
Alopecurus pratensis (meadow foxtail)	5	2	15	23	1	6.2	6.2	1.2	...	19	19	19
Anthoxanthum odoratum (sweet vernal)	8	5	23.9	80	2	.55	1.62	2.7	3	11	12	13
Anthoxanthum puelli (annual sweet vernal)	1	26	26	26	1	6.7	6.7	6.7	...	...	...	...
Arrhenatherum avenaceum (tall meadow oat grass)	7	2	42.7	92	2	3.65	7.38	11.1	4	8	14	23
Avena flavescens (yellow oat grass)	5	2	24	50	1	6.6	6.6	6.6	...	...	...	...
Bromus mollis (soft chess grass)	2	2	21	40	...	...	...	...	1	6	6	6
Bromus pratensis (meadow brome grass)	1	0	0	0	...	...	...	...	...	...	...	...
Bromus unioloides (brome grass)	2	0	9	18	1	4.77	4.77	4.77	...	...	...	...
Cynodon dactylon (Bermuda grass)	1	66	66	66	1	19	19	19	...	...	...	...
Cynosurus cristatus (crested dog's tail)	5	9	42.2	100	2	.25	1.32	2.4	2	12	14	16
Dactylis glomerata (orchard grass)	18	10	55.9	96	10	0	12.8	61	4	12	13	14
Euchlaena luxurians (teosinte)	5	8	56	82	1	.97	.97	.97	3	6	12	20
Festuca elatior (tall fescue)	5	22	47.4	85	...	...	...		..	11	12.5	14
Festuca duriuscula (hard fescue)	7	3	31.1	48	2	1	10.2	19.4	2	11	14	17
Festuca heterophylla (various-leaved fescue)	1	3	3	3	...	...	...	...	1	14	14	14
Festuca ovina (sheep's fescue)	7	0	20.7	54	2	.55	3.07	5.6	3	6	12	18
Festuca pratensis (meadow fescue)	11	6	66.3	96	2	2.4	3.07	8.75	5	10	14	19
Festuca rubra (red fescue)	3	8	48	100	2	1.3	1.65	2	1	19	19	19
Festuca tenuifolia (slender fescue)	3	3	13.3	30	1	3.7	3.7	3.7	1	14	14	14
Glyceria arundinacea (tall meadow grass)	1	14	14	14	1	63.7	63.7	63.7	...	...	...	...
Holcus lanatus (meadow soft grass)	4	0	29	60	3	5	18.7	44.5	2	11	14	17
Lolium italicum (Italian rye grass)	10	4	50.8	96	3	4	6.1	16.7	4	10	12	17
Lolium perenne (English rye grass)	14	12	63.2	100	4	0	6.8	19.4	4	10	16	21
Panicum miliaceum (millet)	5	64	84	92		...	...	...	4	3	4	5
Phleum pratense (timothy or Herd's grass)	51	0	80.1	100	16	0	7.25	33	23	1	7	16
Phalaris arundinacea (reed canary grass)	2	6	33	60		...	...	...	1	7	7	7
Poa aquatica (water meadow grass)	3	0	.66	2	2	.35	5.92	11	1	19	19	19
Poa compressa (Canada blue grass)	1	11	11	11	...	...	...	...	1	13	13	13
Poa nemoralis (wood meadow grass)	6	6	10.6	15	1	.10	.10	.10	3	12	15	18
Poa pratensis (Kentucky blue grass)	42	0	6.3	40	5	1	3.3	8	5	11	14	18
Poa serotina (fowl meadow grass)	5	3	20	50	5	7.55	61.5	90	4	9	12	14
Poa trivialis (rough-stalked meadow grass)	4	2	5.7	13	2	10	12.7	15.4	1	13	13	13
Chaetochloa italica (Hungarian or German millet)	11	5	59.3	89	3	0	.32	62	7	4	9	16
Sorghum halapense (Johnson grass)	5	0	6.8	22	2	3.5	12.2	21	1	4	4	4

TABLE No. VII.

TESTS OF FOURTEEN DAYS DURATION.

KIND OF SEED.	Per cent of impurities by weight.	Sound seeds left.	Percent sprouted.	No. of days required for one-half to sprout.
Agrostis vulgaris, (red top, fancy)	....	20	80	4
Agrostis vulgaris, (red top, fancy)	....	19	64	8
Agrostis vulgaris, (red top, fancy)	84	80	20	....
Agrostis vulgaris, (red top, fancy)	....	75	25	....
Aira flexuosa, (wood hair grass)	....	99	1	....
Alopecurus agrestis, (slender foxtail)	2	43	53	7
Ammophila arenaria, (beach grass)	...	2	97	3
Anthoxanthum odoratum, (sweet vernal)	....	80	14	....
Anthoxanthum odoratum, (sweet vernal)	....	80	19	....
Anthoxanthum odoratum, (sweet vernal)	....	85	15	....
Arrhenatherum avenaceum, (tall meadow oat grass)	....	50	48	....
Arrhenatherum avenaceum, (tall meadow oat grass)	....	98	2	....
Arrhenatherum avenaceum, (tall meadow oat grass)	...	40	60	5
Agrostis canina, (Rhode Island bent)	....	19	81	4
Agrostis canina, (Rhode Island bent)	77	48	52	9
Agrostis canina, (Rhode Island bent)	3	50	47	....
Agrostis stolonifera, (creeping bent)	....	48	52	9
Bromus schraderi, (rescue grass)	....	100	....	....
Bromus pratensis, (meadow brome)	....	100	....	....
Bromus mollis, (soft chess)	....	57	2	....
Cynosurus cristatus, (crested dog's tail)	....	89	11	....
Dactylis glomerata, (orchard grass)	....	60	38	....
Dactylis glomerata, (orchard grass)	....	40	57	9
Dactylis glomerata, (orchard grass)	....	50	50	14
Euchlaena luxurians, (Teosinte)	....	92	8	....
Festuca pratensis, (meadow fescue)	....	87	13	....
Festuca pratensis, (meadow fescue)	....	90	6	....
Festuca pratensis, (meadow fescue)	1	20	73	5
Festuca elatior, (tall fescue)	....	75	25	....
Festuca elatior, (tall fescue)	....	75	25	....
Festuca heterophylla, (various-leaved fescue)	....	97	3	....
Festuca ovina, (sheep's fescue)	....	97	3	....
Festuca tenuifolia, (slender fescue)	....	70	30	....
Festuca duriuscula, (hard fescue)	....	90	3	....
Holcus lanatus, (meadow soft grass)	5	74	22	....
Kaffir corn	....	....	98	2
Lolium italicum, (Italian rye)	....	2	96	3
Lolium italicum, (Italian rye)	...	65	35	....
Lolium perenne, (perennial rye grass)	....	55	45	....
Lolium perenne, (perennial rye grass)	....	57	36	....
Lolium perenne, (perennial rye grass)	....	10	83	4
Panicum miliaceum, (golden millet)	....	2	87	....
Panicum miliaceum, (golden millet)	....	8	91	3
Panicum (Setaria) Germanicum, (Hungarian millet)	....	5	82	2

TABLE No. VII.—Continued.

KIND OF SEED.	Per cent of impurities by weight.	Sound seeds left.	Per cent sprouted.	No. of days required for one-half to sprout.
Panicum (Setaria) Germanicum, (Hungarian millet)	....	50	27	3
Panicum (Setaria) Germanicum, (Hungarian millet)	....	22	68	2
Panicum (Setaria) Germanicum, (Hungarian millet)	....	13	68	2
Phalaris arundinacea, (reed canary grass)	....	94	6	....
Phleum pratense, (timothy)	....	10	88	4
Phleum pratense, (timothy)	....	5	95	5
Phleum pratense, (timothy)	....	10	91	4
Phleum pratense, (timothy)	....	2	96	6
Poa serotina, (fowl meadow grass)	70	88	12	....
Poa serotina, (fowl meadow grass)	50	97	3	....
Poa serotina, (fowl meadow grass)	90	50	50	14
Poa serotina, (fowl meadow grass)	90	68	32	....
Poa pratensis, (Kentucky blue grass)	....	95	5	....
Poa pratensis, (Kentucky blue grass)	....	88	12	....
Poa pratensis, (Kentucky blue grass)	1	83	17	....
Poa nemoralis, (wood meadow grass)	....	85	15	....
Poa nemoralis, (wood meadow grass)	....	86	14	....
Poa aquatica, (water meadow grass)	...	100	..	....
Poa trivialis, (rough-stalked meadow)	10	87	13	....
Poa compressa, (Canada blue grass)	....	89	11	....
Sorghum halapense, (Johnson grass)	....	98	2	....
Sorghum halapense, (Johnson grass)	....	100	....	....

TABLE No. VIII

NAME OF SEED.	Duration of test in days.	Per cent germinated.	Per cent sound unsprouted.	½ germinated in — days.
Red top	15	92	8	3
Kentucky blue grass	18	11	89	3
Red fescue	19	8	92	....
Italian rye grass	17	75	25	5
Meadow soft grass	17	34	66	....
Hard fescue	17	46	54	....
Crested dog's tail	17	9	91	....
Hungarian grass	16	89	6	6
Bermuda grass	23	00	100	....
Meadow fescue	19	84	16	6
Meadow foxtail	19	19	81	....
Water meadow grass	22	00	100	....
English rye grass	21	74	26	11
Sheep's fescue	18	11	89	....
Tall meadow oat grass	23	36	64	....
Wood meadow grass	18	11	89	....

Table No. VIII was condensed from data tabulated by Prof. F. D. Chester. The figures given are the results of duplicate tests in each case. The vitalities average quite high.

In 1877 Professor Beal of Michigan tested the vitality of twenty-two species of forage grasses. These seeds were purchased direct from a seedsman in New York. The seeds, or what appeared to be seeds, were counted out in lots of fifty seeds each, and two lots of each species were germinated between folds of bibulous paper in the greenhouse, at a temperature ranging from 56°–70° F. Two lots more of each species were tested again later and the results of the tests are given below in condensed form:

TABLE No. IX.

FIRST TEST.	Minimum.	Average.	Maximum.
Schrader's bromus	56	62	68
Hungarian grass	62	67	72
Timothy	94	96	98
Nineteen other species	0	8.4	39
SECOND TEST.			
Schroeder's bromus	56	59	62
Hungarian grass	42	45	48
Timothy	30	41	52
Nineteen other species	0	8.1	23

Professor Beal then made tests of some grass seeds which he had gathered on the college farm two and three years before. Besides their age, part of them had been stored in a damp basement. He did not consider them good seed. While testing them he also tested some more from the same lot described above. Both lots were shelled out of the chaff by hand so that there were exactly fifty seeds of each species. The striking results are given below:

*Seed testing. Delaware Agrl. Exp. Station. Ann. Report. 2: 46-57. Also Bull. 5.

†Michigan Board of Agriculture. Ann. Report. 1877: 377-392. See 387-389. Also Beal; Grasses of No. Am. 1: 209-210. (Ed. 2.)

TABLE No. X.

KIND OF SEED.	Eastern seeds.	Old college seeds.
Schrader's bromus	64	96
Sheep's fescue	0	72
Kentucky blue grass	6	28
Rye grass	18	74
Meadow fescue	6	92
Orchard grass	66	82

Blue grass. Poa pratensis.—For convenience of comparison some facts concerning the vitality of four of our common pasture and forage grasses have been set forth separately. The seeds of this very valuable lawn and forage grass possesses the lowest vitality of any of our commonly cultivated grasses. Just why this should be is not so evident. Some facts obtained by G. E. Morrow and T. F. Hunt* are of value in solving this problem. They made vitality tests of eighteen samples of blue grass seed from seventeen different prominent seedsmen and also of one sample of seed gathered on the station grounds. The seed were first tested in the Geneva apparatus for thirty-eight days, and later the tests were repeated in soil in the open air and in the green house, where they continued from March 14th to July 27th.

There is such a striking difference in the results obtained from the tests made in the Geneva apparatus and those made in soil that I have tabulated the figures to show this difference, and have added to the column headed "In Geneva apparatus" the results obtained by McCarthy as a standard, those gotten by Parsons, and also those given by fifteen other tests from different sources. The first and fifth columns give the number of samples on which the results are based.

*Ill. Agri. Exp. Station Bull. 15: pp. 478-482. 1891.

TABLE NO. XI.

VITALITY OF BLUE GRASS SEED.	IN GENEVA APPARATUS. Number.	Minimum.	Average.	Maximum.	IN SOIL. Number.	Minimum.	Average.	Maximum.
Seventeen different seedsmen(Morrow & Hunt)	18	0	2	7.	....	.....	....	.....
Seventeen different seedsmen (in open air and shade)....	....	....	....	....	18	7.	21.95	35.2
Seventeen different seedsmen (in greenhouse)...........	....	....	....	....	18	2.5	12.51	22.9
Experiment Station seed....	1	0	0	0	....	.....	....	.....
Experiment Station seed (in open air).................	....	....	....	....	1	......	48.3	.....
Experiment Station seed (in greenhouse)..............	....	....	....	....	1	.....	57.2	.....
Parsons	42	0	6.3	40.	....	.....	....	.....
Various other tests	15	0	7.23	19.	....	.....	....	.....
McCarthy (standard)........	....	...	60.	....	....	.....	....	.....
Morrow & Hunt (seed gathered green)	....	....	....	....	3	71.6	72.5	72.8
Morrow & Hunt (seed gathered ripe)................	....	....	....	....	1	......	80.1	.....
U. S. Department of Agriculture (standard)	....	....	45.50	.....	...	......	.....	.....

Some seedsmen having claimed that the low vitality of blue grass seed was due to the grass being cut too green and the consequent heating of the seed, tests were made to determine this fact. Three lots of grass were gathered green and dried in as many different ways: one in a cellar, one on the floor in a dry room, and one in a grain sack. After a germinating test lasting about sixty-eight days, they gave vitality percentages of 71.6, 72.5 and 72.8 respectively, while a sample gathered ripe and dried on the floor in a dry room gave 80.1 per cent of viable seed. These figures are given at the bottom of the preceding table. From such results it would seem apparent that for some reason the apparatus for testing seeds does not show the true vitality of blue grass seed as determined by soil tests, and also that careful harvesting and drying of the seed would greatly improve its quality.

Red top. Agrostis alba.—The following table will show the comparative vitality of red top seed in this country, based on a large number of tests.

TABLE NO. XII.

VITALITY OF RED TOP SEED.	Number.	Minimum.	Average.	Maximum.
Morrow & Hunt, from seventeen different seedsmen.	19	4	25	63
Parsons, summary of American tests...............	30	4	34.2	92
Various other tests	10	4	45	92
McCarthy, standard for choice seed.............	.....	.....	72	.....

It is quite probable that the same conditions that affect blue grass seed affect the seed of red top also, and that if tests were made in soil the general average of vitality might be found to be considerably higher. Better methods of gathering and drying would doubtless work toward the same end.

Orchard grass. Dactylis glomerata.—The most extensive tests of this seed of which I have any knowledge were made at the Connecticut experiment station in 1892. Seventeen samples from different eastern markets were obtained and tested. One was found to contain no seed of orchard grass at all. The results from the remaining sixteen are given in the following table:

TABLE No. XIII.

VITALITY OF ORCHARD GRASS SEED.	Number.	Minimum.	Average.	Maximum.
Connecticut experiment station....................	16	4.5	50	88
Various tests of other stations......................	16	12	53.3	82
Parsons, summary of American tests	18	10	55.9	96
McCarthy, standard for choice seed.......	.....	.....	81	.....

Timothy. Phleum pratense.—Timothy has been tested for vitality a great many times and approaches more closely to the standard than any other grass. The comparative results are given below:

*Conn. Agr. Exp. Station. Ann. Report. 1892: 152-154.

TABLE No. XIV.

VITALITY OF TIMOTHY SEED.	Number.	Minimum.	Average.	Maximum.
Morrow and Hunt, from sixteen seedsmen.........	16	42	76	96
Parsons, summary of American tests..............	51	0	80.1	100
Tests at various stations..........................	48	30	91.48	100
McCarthy, standard for choice seed................	..	......	89	.....
U. S. Department of Agriculture, standard	....	......	85-90	.....

These figures show that the timothy seed is improving in vitality and that the average sample now exceeds the standard once set for choice seed. It is much to be hoped that the next ten years may bring about a similar improvement in the seeds of other species.

Diseases of Germinating Cereals.

Moulds.—The most serious difficulties which corn and other grasses have to contend against in germinating are moulds and bacteria. The following moulds are commonly found: The common blue mould (*Penicillium glaucum*), green mould (*Eurotium* (*Aspergillus*) *glaucus*) and black mould (*Rhizopus nigricans*). Cladosporium, Macrosporium and Sterigmatocystis may occur occasionally, but they are not generally common.

Haberlandt, who made a study of the mouldy rye and its germination, found a gradual decline in its germination as the seed became older.

Logewall, who had observed that rye seed rapidly loses in its power of germination, especially in damp and warm weather, attributes this to micro-organisms. In the case of wheat, however, this did not appear to make any difference. As a result of his rye experiments he determined as follows:

One hundred rye kernels without infection, germination 100 per cent; 100 rye kernels with infection, germination 98 per cent; 100 rye kernels injured without infection, germination 97 per cent; 100 rye kernels injured with infection, germination 91 per cent.

C. Rambousek,† states that moulds of damp seeds destroy the germinative energy to a considerable degree and its distructive influence is most severe on barley.

*Wissenschaftlich praktische Unters auf dem Gebiete des Pflanzenbaues. 1: 66-68, 1875. Harz. Landw. Samen Knude. 1: 294.

†Prager. Landw. Wochenblatt. 1895: 393. Biedermann's Centr. Agrikulturch. 24: 393.

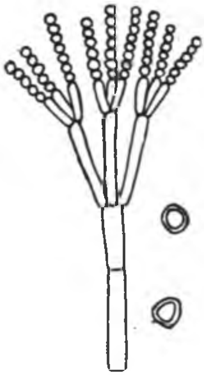

Fig. 61. Common blue mould (*Penicillium glaucum*). Spores at end of branches; spores borne in chains. (Pammel and King.)

Penicillium glaucum.—This is one of the most common of all our moulds and is easily recognized by the glaucus green color it produces on the surface. At first a white mycelium spreads over the surface of the seed. It starts usually in the hilar regions. The mycelium, through an enzyme action, undoubtedly, dissolves the starch. Raised masses are formed on the surface. These consist of masses of fungus thread strands. The strands send out lateral branches, from the end of which a whorl of short branches appears, as shown in figure 35. These give rise to one or more whorls. From the ultimate branches a chain of small spores is produced, the last one in the chain being the oldest.

The ascospores have not been found in corn, but occur in poorly lighted places and are produced in the absence of oxygen. The spores produced in chains germinate when the required amount of moisture and heat is present, so that unlimited numbers of generations may proceed from a single spore. These spores also preserve their vitality for a considerable length of time. Brefeld† has shown that they will germinate though kept in a dry place for several years.

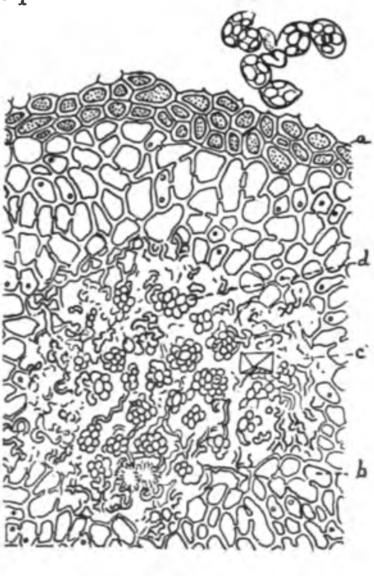

Fig. 62. The sclerotium or resting stage of Penicillium glaucum consisting of a hard compact mass. The asci and ascospores shown above. (Brefeld.)

Eurotium (Aspergillus) glaucus DeBary.—This species is common in stored corn, and will be referred to in connection with a disease of cattle. The mycelium of this fungus spreads over the surface of the corn, in the hilar regions. The bracts surrounding the grain are the special points of attack. From this point the hilar region is attacked. The

†Untersuchang. u. Schimmelpilze. II and IV.

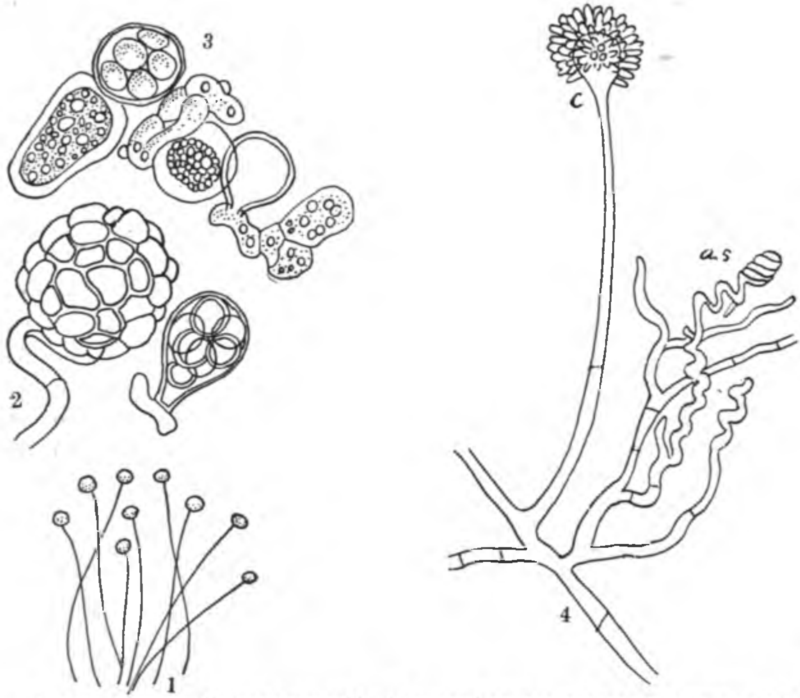

Fig. 63. Common Herbarium mould. (1) general appearance, showing long conidiophore and sterigmata on end; (2) perithecium with one of its asci and ascospores; (3) contents from an unripe perithecium; (4) a small part of a mycelium with conidiophore *c*, and spore bearing sterigmata, young ascogonium *a. s.* (DeBary except 1.)

mycelium enters the kernel because of the dissolving action of an enzyme produced by the mycelium. From this mycelium erect threads (conidiophores) arise. These are enlarged at the end. From the enlarged portion of the conidiophores numerous small and radiating stalks (sterigmata) are produced, each bearing a chain of spores, the end spore of the chain being the older. These spores germinate under favorable conditions of moisture and heat, and again give rise to the same stage. In addition to this, the condidial stage, a second kind of reproductive body occurs. This is produced by the coiling of a branch of the mycelium having several turns. Two or three slender branchlets grow from the base. One of these grows more rapidly and connects with the top of the spiral coil formed first. The contents of those last formed unite with the spiral known as the ascogonium. After fertilization a perithecium is produced.

This contains the asci. Each ascus is surrounded by a delicate wall and contains eight biconvex ascospores.

Rhizopus nigricans. Ehrh.—The third mould commonly found is the black mould. The mycelium spreads over the tissue, and on the surface small black bodies, the sporangia, are produced. The conidiophore arises from the felted mycelium. The conidiophore bears an enlarged spherical head, the sporangium, within which occur the spores. On adding water to the specimen, the wall of the sporangium collapses and the end of the stalk, known as the columella, turns back, giving it something

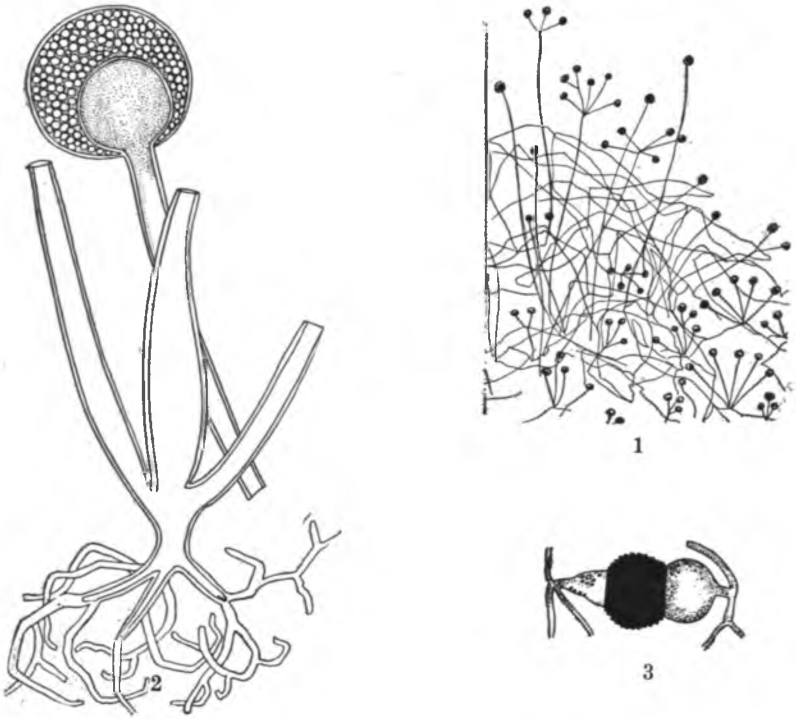

Fig. 64. (1) Common black mould (*Rhizopus nigricans*) showing sporangia and method of spreading by stolons. (2) *R. nigricans* showing rhizoids, conidiophore, columella, sporangium and spore. (3) Zygospores of one of the mucoraceae showing method of conjugation.

of the appearance of an umbrella. The columella before it collapses projects into the sporangium. The spores germinate readily when placed in a moist atmosphere. In addition to the production of a sporangium a stalk may bend over and cause the further extension of the fungus by producing what is known as a stolon. The old name for the fungus, *Mucor stolonifer*, was given to it because of the production of these stolons. In addition to the formation of spores in the sporangium, zygospores are produced in certain races. Two threads of the mycelium lying in proximity and nearly parallel, each produces a tube. These meet, the walls are absorbed, and just back from the meeting point a cell is cut off. The contents from the old cells pass into the newly formed cell. We also observe that the cell of one arm is somewhat smaller than the other. This spore is a resting spore or zygospore. It lies dormant for a period, then germinates by forming directly a conidiophore with its sporangium containing the spores.

Bacteria.—In an examination of mouldy corn, bacteria have been found in large quantities, but none of these have been studied sufficiently to speak of the power they have in causing rot. Prillieux* states that wheat is often covered with a bacterial organism that produces a red coloration. Not enough, however, is known of this organism to say whether it is the cause of the disease mentioned by him or not.

The first step in the germination of corn, as said before, is the absorption of water. If the embryo is vigorous, and conditions are favorable, the young embryo will push through the testa and pericarp.

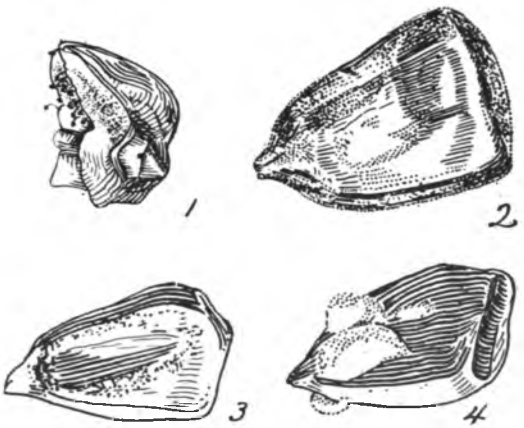

Fig. 65. Mouldy maize kernels. These failed to germinate. *1*, Sterigmatocystis; *2*, Apergillus; *3*, Rhizopus; *4*, Penicillium.

On the other hand, if it is weak it is unable to do so. A cold, damp soil and frequent rains are not favorable for the embryo to push through, and hence the invasion of saprophytic

*Prillieux. Annal de Sci. Nat. Bot. VI. 7: 248.

fungi, for none of these organisms are truly parasitic. Much of the corn during the season of 1897 showed a fairly good percentage of germination, and yet the stand was very poor; the seed in fact rotted in the ground. This was due to the conditions above stated. Good germination requires warm weather, with sufficient rain so as not to dry out the seed.

CHEMICAL AND PHYSICAL INFLUENCES ON THE GERMINATION OF GRASS SEEDS.

Chemical.—It has been customary for a long time to treat wheat and other cereals with certain chemical substances for the purpose of preventing fungus diseases. They have also

Fig. 66. Copper compounds and the germination maize. U. S. Dept. of Agrl. formula, *12, 13*; *5*, Bordeaux mixture full strength; *6*, Bordeaux mixture one-half strength.

been treated for other purposes. These purposes may be classified as follows; *First*, to hasten germination; *second*, to protect the seed from insect and other animal pests; *third*, to prevent the attacks of fungi; *fourth*, to furnish the young plants nourishment. It is very doubtful indeed if any kind of treatment with chemicals actually hastens the germination of seeds. Formerly a large class of substances were given which would support and hasten germination. The literature on this subject as given by Nobbe* states that the seeds of certain crucifers when in contact with chlorine germinated in from six to seven hours, while seeds placed in water germinated in thirty-six to

Fig. 67. Copper compounds and the germination of maize. U. S. Dept. of Agrl. formula. 3, 4, treated with ammoniacal carbonate of copper normal; 1, 2, double normal.

*Samenkunde. 255.

thirty-eight hours, but Otto* makes the statement that with oxalic acid he succeeds in causing seeds to germinate which were between 20 and 40 years old. Bailey,† who treated a large number of chemicals with substances as permanganate of potash, chlorate of potash, etc., demonstrated that these retarded rather than hastened germination. In a paper by Pammel and Stewart‡ on the subject of corn and different fungicides it was shown quite conclusively that the treatment in every case was injurious.

Pammel§ had previously shown that corn roots, when treated with a mixture containing copper salt, were injuriously affected, the total amount of germination being retarded. These experi-

Fig. 68. Copper compounds and the germination of maize. Strong ammoniacal carbonate of copper.

ments were conducted in the greenhouse. Dr. Walter H. Evans,‖ in a compilation of the treatment of seeds with copper sulphate, to prevent the attack of fungi, comments on this experiment as well as others. Evans seems to question the

*Balfour; Class book of botany. 3: 628.

†Ann. Rep. Mich. Agrl. Exp. Sta. 1: 110. 1888.

‡The influence of fungicides upon the germination of seeds. Agrl. Sci. 8: No. 5. 1894.

§Are copper salts injurious? Bull. Iowa Agrl. Exp. Sta. 16: 321.

‖Copper Sulphate and germination. Bull. Div. Veg. Phy. and Path. U. S. Dept. Agrl. 10: 14.

result of the experiment. In order to show that there is no question in regard to these results, the accompanying figures show a marked difference between treated and not treated plants, kept under the same conditions. Quite a large number of experiments have been made in testing the effects of chemical solutions on the germination of corn, and it has been shown that quite a large number of salts act injuriously, and even a weak solution sometimes checks the germination of corn. The conclusions reached by several investigators are here given. It was very evident in some work conducted by Pammel and Stewart* with the copper compounds that even the very weak solution retarded and in some cases prevented germination.

Thus, for instance, when corn was soaked for two hours in ordinary copper sulphate solution, more than three-fourths would not germinate. Ammoniacal carbonate of copper was also used. When the corn was soaked in it for two hours only twenty-seven kernels out of 100 grew, but when the treatment was continued for only one hour fifty-seven kernels grew.

In an exhaustive paper on the subject by Hitchcock† and Carleton,† they state in regard to ferrous sulphate that corn soaked for twenty-four, forty-eight and seventy-two hours, respectively, gives the following percentages of germination:

Time of immersion	24	48	72
Per cent	24	20	17

The germination was from 80 to 100 per cent of that obtained with water, but retarded. Prof. L. R. Jones‡ concluded that soaking corn in Bordeaux mixture for one hour and less, had no perceptible effect, and soaking six hours was slightly beneficial. Soaking in copper sulphate solutions, of either strength, for lengths of time up to fifteen minutes, did no apparent injury. Soaking one hour was slightly injurious. But, after all, the substances which have been experimented on, among them ferrous sulphate, have been widely used to better the soil. Mayer§ shows that 200 grams of iron sulphate acted injuriously on rye, barley and oats, and that 100 grams on wheat. This quantity of iron sulphate was added to sixteen kg. of soil.

*Agrl. Sci. 8: 215.

†Bull. Kansas Agrl. Exp. Sta. 41.

‡Ann. Report Vermont Agrl. Exp. Sta. 1891: 139-141.

§Nederlandsch Landb., Weekblad. 31: 2. 1892. Biedermann's Centr. Agrikulturch. 22: 158.

In regard to several other grasses Mr. Thompson* states of oats, clover, ray grass, corn, *Avena orientalis*, *Arrhenatherum, avenaceum* and *Medicago sativa* that sulphate of iron acts injuriously upon the development of the roots. Most of the earlier references are fully given in the review in the paper quoted by Pammel and Stewart as well as Evans.

Physical.—Maldiney and Thouvenin† have made some experiments to determine the influence of X-rays upon germination. In the case of *Panicum miliaceum* the writers found that when under the influence of X-rays for two hours germination was hastened. The amount of moisture and physical condition of the soil are most important factors during the process of germination.

SEED SELECTION AND THE CROP PRODUCED.

There can be no question that the careful and intillegent selection of seed influences the crop. This has been amply demonstrated in a great many crops. It is a well-known fact that the European sugar beet growers carefully select "the mother beet" by making tests of the amount of sugar present. It has also been shown by Wiley‡ that by a careful selection of sorghum canes, with a high percentage of sugar, the standard has been raised. Mr. Oma Carr§ shows that in certain varieties the per cent of sugar content was increased as follows:

VARIETY.	1888.		1889.		1890.		1891.		1892.		1893.	
	Sucrose.	Purity.	Sucrose.	Purity.	Sucrose.	Purity.	Sucrose.	Purity.	Sucrose.	Purity.	Sucrose.	Purity.
Amber...........	9 5	63	11.7	74	12.8	71	12.9	72	14.5	76	14.3	63.4
Colman...........			14 6	76	14.9	76	15.6	76	17 2	75	15.5	75
Orange	10.4	63	12.1	71	13.5	72	13.6	68	17.7	80	16.2	80

Wiley records several pedigrees of the improved canes and the amount of sugar they contain and gives a discussion of the results. Hicks and Dabney‖ have shown that there is a marked increase in the weight of seedlings of radish, early Amber cane, Kafir corn, winter vetch, sweet pea, rye, oats and barley from the heavier seed, that there is an increase in the root development when seeds are planted. In case of heavier peas early flowering is noticed. Webber says: "Mr. Henslow¶ found

*Ueber die Wirkung von Schwefelsaurem Eisenoxydul auf die Pflanze. Dorpater Naturforscher-Gesellschaft. 18: 96-101.

†De l'influence des rayons X sur la germination. Revue generale de bot. 10: 81.

‡Experiments with sorghum. Bull. U. S. Dept. Agrl. Div. Chem. 29: 52. 39: 25. 40: 27.

§Experiments with sorghum. Bull. U. S. Dept. Agrl. Div. Chem. 40: 28.

‖Year book. U. S. Dept of Agrl. 1896: 305.

¶Year book. U. S. Dept. of Agrl. 1896: 89.

that seedlings of large seeds, owing to their greater vigor, crowd out the seedlings of small seed. A continual selection of the small seeds for several generations, he says, will cause the plants to die out altogether by failing to produce seed, or else a tiny race of beings will, for a time, be maintained. These vegetable runts, the result of insufficient nutrition and insufficient light, are of common occurrence in nature." B. T. Galloway, by growing selected lots of large and small radish seed, found that "the largest seeds germinated more quickly and with more certainty, and produced marketable plants sooner and more uniformly than the small seeds." The latter, however, "gave porportionally larger plants." In this case, which at first thought seems confusing, we see, as Mr. Galloway suggests, the effect of long continued, natural methodical selection. The radish is cultivated for the root, and selection has been continually directed to increase the size of this part without attention to the seeds. If more nutrition is utilized in root development with plants of equal vigor, less would probably remain for seed development, resulting naturally in small seed. Thus, long continued selection, aiming only to increase the size of the root, which is done with some detriment to the seed, might be expected to ultimately lead to an inherited tendency of the small seeds to develop large plants, and vice versa." The subject of corn from this standpoint, has been quite fully treated by Arthur and Golden.*

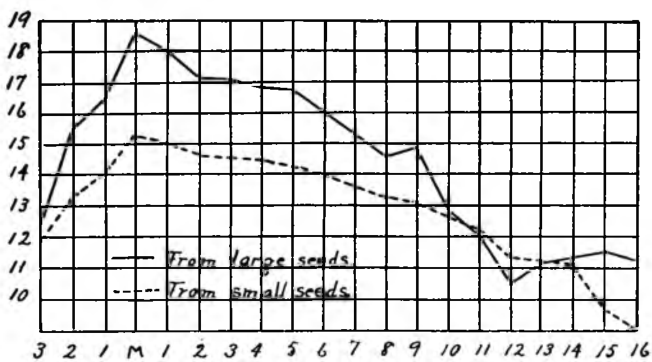

Fig. 68. Product from large and small seeds. (Arthur and Golden.)

*Agrl. Sci. 5: 117.

They have given numerous references to the work of European and American investigators. Among the latter we desire especially to mention the works of Goff* and Latta.†

The work of Arthur and Golden is in the line of our own work. We quote from their results as follows: "Thirty kernels from a single ear of white dent corn were separately weighed, of which six grew that were over 400 milligrams each, and nine that were under 300 milligrams each. The product of these gave a greater average weight of ears for the large than for the small seed, which was also true of the cobs and kernels taken separately."

	Product of large seed.	Product of small seed.
Average weight of seed in milligrams	312	268
Average weight of cobs in grams	55	47

The accompanying graphic illustration of the results brings out the difference in the weight of the kernels even more strikingly. The solid line indicates the product from the large seed and the interrupted lines from the small seeds. The diagram as a whole shows the variation at different parts of the ear, the butt being to the left and the tip to the right.

"The kernels from each ear of the product were removed and weighed by fifties, beginning at the end of the ear and proceeding in order to the other. The average of all of the heaviest fifties, one from each ear, gave the maximum weight, marked M in the diagram. The average of the fifties ranging first, second, third, etc., right and left of the maximum was then found. Thus the diagram represents the difference of the weight of the kernels of the ear in the order they occupied on the cob, the butt of the ear lying to the left and the tip to the right of the diagram.

The figures below the diagram indicate the position of each fifty seeds on the ear; the figure at the left gives the average weight in grams of fifty seed. Webber‡ states that "Roujon,

*Ann. Rep. N. Y. Agrl Exp. Sta. 3: 199. Ann. Rep. N. Y. Agrl. Exp. Sta. 4: 181. 128, 120.

†Bull. Indiana Agrl. Exp. Sta. 27: 32: 14.

‡Influence of environment in the origination of plant varieties. Year book U. S. Dept. Agrl. 1896: 92.

by selecting and planting only the smallest seeds from the least developed specimens of sunflower, corn and other plants, obtained in two years very small plants. The corn was reduced in size to about eight inches high. As the height diminished the number of seed decreased, and the final result was absolute sterility."

In the case of corn, farmers have done a great deal towards selection by saving the best for seed. There has been much discussion as to whether the kernels found at the base are better than those at the tip. Tests made at the Kansas Agricultural Experiment Station* show: "Considering all the facts shown in this experiment and in the experiment with corn planted at different distances, the inference seems plain that we must plant corn with the sole object of raising grain, or with the sole object of raising feed." The average of three years' trials are slightly in favor of the butt kernels, according to Georgeson, Burtis and Otis.†

Cereals.

The importance of cereals as a crop in Iowa merits a separate consideration. This is especially necessary in the case of the more important. The term cereal is applied to all members of the grass family in which the grains are used for food. Some of the more important works which consider cereals and cereal culture are as follows:

Koernicke‡, Metzger§, Seringe‖, Hackel¶, Darwin**, DeCandolle††, Beal‡‡, Wallace§§, Brewer‖‖, Emmons¶¶, Klippart***,

*Bull. Kansas Agrl. Exp. Station. 30: 1891.

†Bull. Kansas Agrl. Exp. Station. 45: 143. 1893.

‡Koernicke-Werner. Handbuch des Getreidebaues. Koernicke Die Arten u Varietaten d. Getreides 1: 470. *pl. 10.* 1885. Werner, Die Sorten u. d. Anbau d. Getreides 2: 1010. 1885.

§Europaische Cerealien. In botanischer und landwirthschaftlicher Hinsicht bearbeitet 74. *20 pl.* Mannheim. 1824. Heidelberg.

‖Seringe. Cereales Europennes. 1841. Monographie des Cereales de la suisse. 1819. Berne and Leipzig.

¶Hackel. True grasses. English Translation Lamson-Scribner and Southworth, 228. 110 1890.. Hackel. Gramineae in Naturlichen Pflanzenfamilien II. Theil. 2 Abth.

**Darwin. Charles. Animals and Plants under domestication. 1: 329-341.

††DeCandolle, A. Origin of cultivated plants. English translation 468. 1892.

‡‡Beal, W. J. Grasses of North America. 1: 457 f. 175. 1887. (Ed. 1.) 457. 175. 1896. (Ed. 2.)

§§Wallace. India in 1887. 363. *71 pl. 5. f. 1 map.* 1888.

‖‖Brewer. Report on the cereal production of the U. S. 10th Census of the U. S. 3: 173. *16 maps.*

¶¶[10]Emmons. Agriculture of New York in Nat. Hist. N. Y. 2: 90-274. *pl 26-28.*

***Klippart. Essay on the origin, growth, diseases, variety, etc., of the wheat plant. Ann. Rep. Ohio St. Board of Agrl. 12: 562-816. 11 pl. 1857.

Simmonds*, Harz†, Tschirch and Oesterle‡, Snyder and Voorhees§, Neftel‖, Plumb¶, Hehn, **Williams††, Lamson-Scribner‡‡, Buschan§§.
paper on maize, thinks, from evidence of archaeology, history,

Maize. (*Zea Mays*, L.)—Harshberger published an extended ethnology and philology that central and southern Mexico is the original home of maize. This is supported by the facts of botany and meteorology. Several closely related genera are of Mexican origin, as *Euchlaena* and *Tripsacum*. The latter genus occurs as far north as southern Iowa. Naturalists generally agree that closely related species and genera had their origin from some common progenitor.

The Indians probably first found the plant in the region above 4,500 feet altitude and south of 22° north latitude and north of the river Coatzacoalcos and the isthmus of Tehuantepec. It probably reached the Rio Grande about 700 A. D., and by the year 1000 had reached the coast of Maine. It was introduced into Europe soon after the discovery of America.

Rye (*Secale cereale* L.)—Rye has not been long in cultivation, according to DeCandolle‖‖, unless perhaps in Russia and Thrace. It has not been found in the Egyptian monuments and there is no name for it in the Semitic languages, nor Sanskrit, nor the languages derived from Sanskrit.

It appears to have originated in Europe, where it was anciently cultivated, and it is probable that it originated in the regions between the Austrian Alps and north of the Caspian sea. The other known species of the genus Secale inhabit western central Asia or the southeast of Europe. In central Asia rye is spontaneous and grows as thickly as though sown.

Barley. (*Hordeum sativum, Jessen.*)—This cereal is without doubt one of the most ancient of cultivated plants, and is supposed to have originated from *H. spontaneum*, Koch, which

*Simmonds, P. L. Tropical Agriculture. 515. 1877.

†Harz. Landw. Samenkunde. 1: 552. 2: 552-1362.

‡Tschirch & Osterle Anatomischer Atlas der Pharmakognosie und Nahrungsmittelkunde. 41, 42, 43, 44, 45, 52, 53.

§Snyder & Voorhees. Studies on bread and bread-making. Bull. of U. S. Dept. of Agri. 67: 56.

‖Neftel, Flour milling process. 10th Census Rep. 3: 22. 6 pl.

¶Plumb. The Geographic Distribution of Cereals in North America, Bull. Div. of Biological Survey. U. S. Dept. of Agri. 11:24. *pl. 1.*

**Hehn. Kulturpflanzen und Haustiere. in ihrem Uebergang aus Asien nach Griechenland und Italien sowie in das ubrige Europa. 522. 1887.

††Williams. Millets. O. Exp. Sta. Farmer's Bull. U. S. Dept. of Agr. 101: 28. 6.

‡‡Lamson-Scribner. Grasses of Tennessee. Bull. Agr. Exp. Sta. Tenn. 5: 2.

§§Buschan. Vorgeschichtliche Botanik d. Cultur. u. Nutzpflanzen d. alten Welt auf grund prahistorischer Funde. 268. 1895.

‖‖DeCandolle Origin of Cult. Pl. 370.

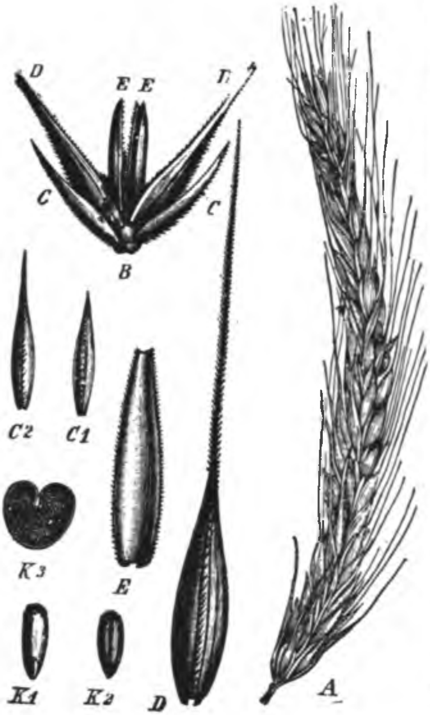

Fig. 68 A. Rye with details of flower and spike. (Nees from Hackel.)

Fig. 68 AA. *Zea canina*, Watson, grown at Knoxville, Tenn. Original of cultivated maize. (Photograh, F. Lamson-Scribner.)

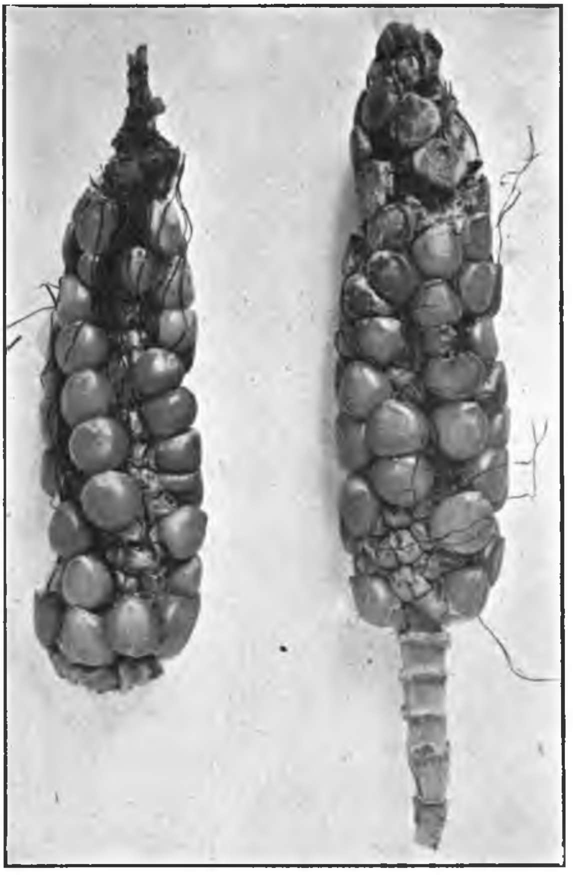

Fig. 68 B. *Zea canina* grown at Knoxville, Tenn. showing cob and kernels. (Photograph, F. Lamson-Scribner.)

Fig. 68 BB. Different varieties of maize. *Zea mays.* (1) Mexican; (2) Mexican; (3) Dent legal tender; (4) Dent; (5) Sweet; (6) Pop; (7) Husk maize with bracts removed; (8) Dent, mortgage lifter; (9) White dent; (10) Dent; (11) Flint; (12) Black Mexican sweet. (King.)

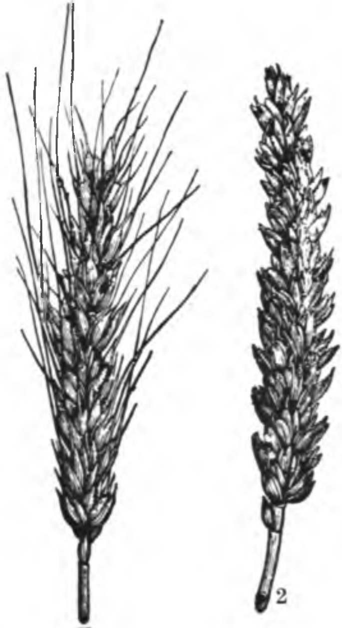

Fig. 69. Wheat, *Triticum sativum.* Common bearded winter wheat, Triticum sativum vulgare 2. Triticum sativum vulgare muticum. (Hackel.)

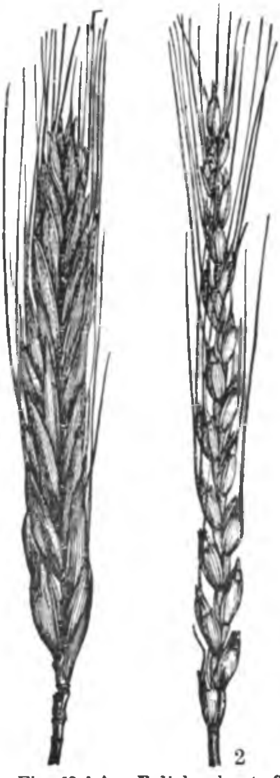

Fig. 69 AA. Polish wheat, *Triticum Polonicum.* 2. Bearded spelt. *Triticum sativum spelta.* (Hackel.)

Fig. 69 A. "German wheat," *Triticum sativum dicoccum.* 2. One-grained wheat, *Triticum monococcum,* L. (After Hackel.)

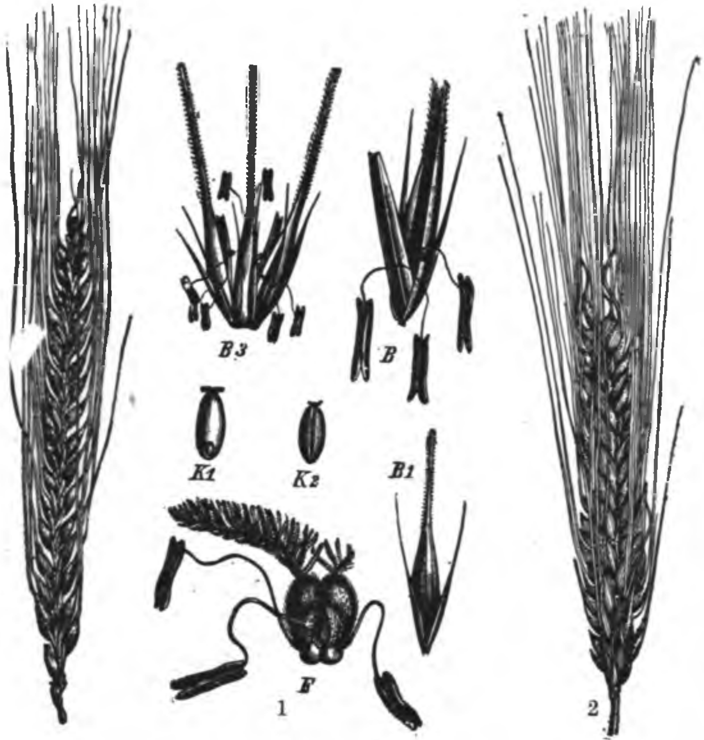

Fig. 69 B. Two-ranked barley, *Hordeum sativum distichon*. (After Hackel.)
1, *Hordeum sativum hexastichon*. (B 3) group of three spikelets; (B) spikelet from behind; (B 1) from in front; (K 1) fruit from in front; (K 2) from behind. (After Nees.)
2. Common four-rowed barley, *Hordeum sativum vulgare*. (After Hackel.)

Fig. 69 BB. 1. English wheat, *Triticum sativum turgidum*. 2. Flint wheat, *Triticum sativum durum*. (After Hackel.)

grows wild in Asia Minor and Caucasian countries to Persia and Beloochistan as well as Syria and Palestine.

Wheat. Triticum sativum, Lam.—The only form known in a wild condition is the *T. monococcum, L.* Cultivated wheat is prehistoric. Several of the forms are of great antiquity. The ancient Egyptian monuments contain abundant specimens of wheat. The Chinese grew wheat 2,700 years before Christ. The Hebrew scriptures contain records of prehistoric wheat. Wheat was frequently used by the Lake Dwellers of west Switzerland.*

The Polish wheat, *Triticum polonicum*, a form obtained by cultivation, probably originated in modern times. The Spelts, *Triticum spelta*, probably was cultivated to some extent by the ancient Romans and Greeks, but there is some question in regard to it. *T. monococcum* was probably anciently cultvated, siince it is mentioned by some of the ancient writers. The seeds were found among the Swiss Lake Dwellers. The Romans did not cultivate it. It is probable tha it was introduced from Asia Minor to Spain, and from there to France and Germany.

Oats. Avena sativa, L.—This is a comparatively modern plant. It certainly was not cultivated by the Egyptians or Hebrews, nor was it cultivated very anciently in India, as there is no Sanskrit name for the plant. Its cultivation in India is carried on chiefly by the English. The ancient Greeks knew it by the name of Bromus and the Romans, Avena. Pliny's remark that the Germans lived on oatmeal seems to show that its cultivation was carried on north of Italy and Greece. Apparently it later became diffused to the south in

*De Candolle. Origin of Cult. Pl. 435.

the Roman empire. That its culture is very ancient with the Kelts is shown by the fact that the inhabitants of the Orkney and Shetland islands have long used it.

Fig. 69 C. Oats, (From Iowa Seed Co.)

Sorghum and Kafir corn. (*Andropogon sorghum*) Brot.—The original home of *Andropogon sorghum* is tropical Africa where durra is cultivated. It is frequently cultivated in Asia, but Linnaeus supposed it to be of Indian origin. It certainly was not cultivated anciently there, since there are no ancient names

Fig. 70. *Andropogon sorghum* and some of its varieties. *1*, Kafir corn; *2*, Jerusalem corn; *3*, Amber sorghum. (Kansas State Board of Agrl.)

for it, nor could it have been anciently cultivated in Europe, since the Lake Dwellers did not use it, nor did the writers of ancient Greece or Italy speak of it. The durra in its allied forms is wild in tropical Africa, and there is every reason to believe that its culture spread from South Africa to Europe and Asia.

Foxtail millets.—These millets belong to the genus Setaria or Chaetochloa. Some writers consider the Hungarian millet (*Setaria Germanica*) distinct from the German millet, *S. Italica.* The millets are of very ancient culture in temperate parts of the world and have been grown since prehistoric times. The grain seems to have existed in a wild form in China and Japan and in the Indian Archipelago, and early spread to India, where ancient Sanskrit names occur. In China this is one of five plants which the emperor* sows each year in a public ceremony, according to a command given by Chin–nong 2700 B. C.

De Candolle thinks that the Lake Dwellers of the stone age seem to have known the Setarias. It was also anciently cultivated in China, and the *S. germanica* seems to have escaped from cultivation in Japan. By some writers it is supposed to have originated from *S. viridis*, Beauv., our common foxtail or pigeon grass.

*De Candolle. Origin of Cult. Pl. 380.

Common or broom corn millet. *Panicum miliaceum*, L.—This plant is likewise of prehistoric culture, especially in Europe, Egypt and Asia. The Greeks and Romans were familiar

Fig. 70 A. Corean Foxtail millet. (Div. of Agrostology U. S. Dept. of Agrl.)

with it. The Lake Dwellers during the stone age used this millet to a considerable extent. Its culture is thought to be very ancient in eastern Europe.

Fig. 71 A. Ankee millet (*Panicum crus galli*), *a*, *b*, two views of the spikelet;*c*, *d*, twoviews of the seed. (After Div of Agrostology U. S. Dept. of Agrl.)

Fig. 71 B. Shama millet (*Panicum colonum*), *a*, *b*, *c*, *d*, different views of the spikelet and glumes; *e*, *f*, two views of the "seed." (Div. of Agrostology U. S Dept. of Agrl.)

Fig. 71 BB. Broom corn millet. (Div. of Agrostology U. S. Dept. of Agrl.)

Although there is some doubt in regard to its cultivation in China, some writers think it is one of the grains planted at the annual ceremonies, instituted by the emperor Chin-nong. It was early introduced into India and was at one time one of the most important cereals grown in France. It probably originated in the Egypto-Arabian countries.

Barnyard grass, Panicum crusgalli L.—This species is indigenous to Europe and extending to Asia, and now well-known as a cosmopolitan weed. It is extensively used as a forage plant in Japan. Of the other barnyard millets the Ankee is used quite extensively in the north and northwest. The Mohave Indians are said to use this seed very extensively for food. In warmer parts of Asia several other species of Panicum are used, especially *Panicum indicum* L. The Sanwa millet (*P. frumentaceum* Roxb.) and *P. colonum*, the Shama millet or Jungle rice, native to the tropics and sub-tropical countries of the old world. It has become naturalized in the warmer parts of the United States. It is a native to Asia and is extensively grown in India. Crab grass (*Panicum sanguinale*) was anciently cultivated as a cereal but its culture in modern times has almost entirely ceased. It was apparently never used very extensively. It is said to have been extensively cultivated in Bohemia and used for soups, and still finds use in that country.

The term Millets. This is applied to a number of grasses. The term barnyard millet was first applied by Brooks* and later adopted by Williams.† Williams has extended the use to not only those millets which originated from common barnyard grass but to varieties and species closely allied to it.

*Ann. Rep. Mass. Hatch Agrl. Exp. Sta. 8: 31.
†Year book of the U. S. Dept. of Agr. 1898: 276.

Elsewhere the statement has been made that the millets are important cereal crops. The more important of these are the *Setaria italica* and the *S. germanica.* The common foxtail millets grown in the United States are grouped under the following standard varieties:

Fig. 71 C. German millet (*Setaria italica*), *a* and *b* two views of the spikelet with three bristles; *c* seed. (Div. of Agrostology U. S. Dept. of Agrl.)

(1) Common millet. (2) German millet. (3) Golden wonder millet. All belong to *Setaria italica.* (4) Hungarian millet belongs to *Setaria Germanica.*

Sorghum millets are extensively grown in south Africa, Kansas, and Asia. Broom corn millet, *Panicum miliaceum,* is grown quite extensively as a cereal plant in India and China. The other millets here mentioned are grown chiefly in older Asiatic countries.

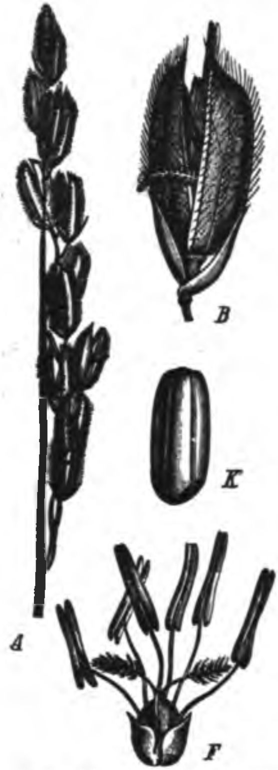

Fig. 71.D. Rice (From Hackel True Grasses.

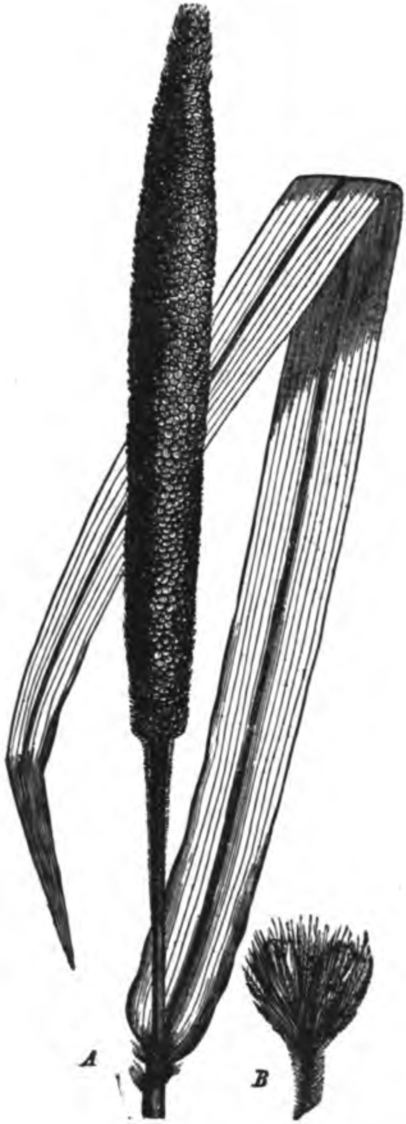

Fig. 71 E. Pearl Millet (From Hackel True Grasses.)

Rice (*Oryza sativa*, L.)—In China it was one of the cereals used by the emperor Chin-nong, 2800 B. C., in fact it was the principal cereal and by the Chinese it is supposed to be indigenous. Its cultivation in India was later, but DeCandolle is inclined to think that it may have been indigenous to that country as well as China.

Pearl millet. Pennicetum typhoideum, Rich.—This is an important agricultural grass in central Africa although its original home is not known. It is believed, however, that it originated in Africa and it is possible that the wild form can still be found there.

Coracana or ragi. Eleusine Coracana, Gaert.—The ragi of the inhabitants of Hindoostan is scarcely grown as a cereal outside of India, though in addition to its growth in India it is also found in Malay, Egypt and Abyssinia. The plant is of tropical origin and without doubt originated in India from the *E. indica.* A nearly allied species, if not identical, the *E. tocussa*, Fres., originated in Abyssinia. The ragi grows well under unfavorable conditions and therefore is used extensively in India.

Manna-grass. Glyceria fluitans, R. Br.—Manna-grass is a cosmopolitan aquatic grass and in parts of Europe, Prussia,

Fig. 71 F. Manna Grass (Division of Agrostology U. S. Dept. of Agrl.)

Silesia and Poland is cultivated. The fruit is used for the purpose of making mush.

Wild rice. Zizania aquatica, L.—This plant is indigenous to the Mississippi valley, extending as far south as Louisiana. It also occurs along the eastern coast of North America between

Fig. 71 G. Canary Grass (King)

New York and Massachusetts. It is most common, however, in the northern Mississippi valley. It is also found in eastern

Asia. While the plant is not cultivated, it is carefully protected by the Indians, and is found much in favor by the Aborigines as a cereal product.

Canary-grass. Phalaris canariensis, L.—The home of this grass is usually attributed to the Canary islands but it is probable that this assumption arises from the fact that the plant has received the common name of Canary-grass. It is more than probable that its culture originated in Spain. It grows wild in southern Europe, especially Sicily and Catalonia. It is used as a cereal only in some of the southern countries of Europe.

Upright sea lime grass. Elymus arenarius.—This large grass is common along the coast of northern Europe and the British islands and along our western coast as far south as Oregon.* Aside from its great value as a sand binder the seeds are used for food by the Digger Indians of the northwest. By the inhabitants it is called "Rancheria grass."

Bamboos. Bambusa, Schreb.—The seeds of several species of bamboos are used in East India like rice. It is said by

Fig. 72. Tef (*Eragrostis abyssinica*) grown on college grounds. I. S. C.

*Lamson-Scribner. Year book. U. S. Dept. Agrl. 1894: 429.

Hackel that in Brazil and India misfortune follows the sudden production of such vast quantities of mealy seeds. Mice and rats increase at an extraordinary rate and after having eaten the bamboo fruits turn to the neighboring fields and devour the cultivated crops.

Tef. (*Eragrostis abyssinica*, Link).—Tef originated in Abyssinia. It is believed to have sprung from *Eragrostis pilosa*. It is now a cosmopolitan weed in temperate and tropical regions. It probably originated north of the equator in Africa. As a cultivated plant Tef is only used by the Abyssinians. The colored seeds have the appearance of grits, and the flour made from these is boiled into bread.

CEREAL PRODUCTION.

The chief cereal growing countries of the world is shown in the following table, taken from Broomhall,* of the Liverpool Trade *News*.

1896. IN MILLIONS OF BUSHELS.

	Wheat.	Corn.	Rye.	Barley.	Oats.
France	340	......	80	48	301
Russia, proper	300	†13	‡671	162	640
Poland	20	......	......	.....	....
Caucasia	45	......	......	.....	....
Hungary	140	140	118	.....	....
Austria	42	......	......	106	186
Croatia and Slavonia	6	......	......	.....	....
Herzegovina and Bosnia	2	......	......	.....	....
Italy	134	74	4	8	26
Germany	110	......	244	116	370
Spain	70	......	......	.....	....
Portugal	6	......	......	.....	....
Roumania	80	64	12	30	17
Bulgaria	40	6	5	20	7
East Roumelia	8	......	......	.....	....
Servia	14	......	......	.....	....
Turkey in Europe	22	......	......	.....	....
Greece	5	......	......	.....	....
United Kingdom	59	......	......	77	194
Belgium	19	......	29	3	27
Holland	6	......	11	5	19
Switzerland	4	......	......	.....	....
Sweden	5	......	23	14	65
Denmark	5	......	18	24	46
Norway	1	......	......	.....	....
Cyprus, Malta, etc.	2	......	......	.....	....
Europe, total	1,119				

*Herbert Myrick. Am. Agrl. Year Book and Almanac. 557.
†Fifty governments according to agricultural ministry.
‡Sixty governments according to agricultural ministry.

1896. IN MILLIONS OF BUSHELS—Continued.

	Wheat.	Corn.	Rye.	Barley.	Oats.
United States of America	590	2,270	24	70	717
Canada	60	18	....	16	114
Mexico	15	....	....	.....	....
Argentina	60	80	....	.....	....
Chili	16	....	....	.....	....
Uruguay	6	6	....	.....	....
Total America	747	....	....	.....	....
India	205	....	....	.....	....
Turkey-in-Asia	50	....	....	.....	....
Persia	20	....	....	.....	....
Japan	14	....	....	.....	....
Total Asia	289				
Algeria	18	....	....	30	8
Tunis	6	....	....	4	....
Egypt	7	34	....	.....	....
The Cape	2	....	....	.....	....
Total Africa	33				
Victoria	7	....	....	.....	....
South Australia	3	....	....	.....	....
New Zealand	7	....	....	.....	....
New South Wales	7	....	....	.....	....
Tasmania	1	....	....	.....	....
Other Australia	1	....	....	.....	....
Total Australia	26				
World's total	2.388	2,705	1,239	733	2737

Cereal production in the United States.—It may be interesting in this connection to compare the production of the cereals of the United States, and finally comparing that with the state of Iowa. In this way will be shown the relation of Iowa to its sister states in the matter of cereal production. It will be most convenient to place these in the form of a table, and the table representing the crop production most easily accessible for 1897 is that prepared by Mr. Snow of the crop reporting bureau of the American Agriculturalist:

	IN THOUSANDS OF BUSHELS.												POUNDS.
	WHEAT.		CORN.		RYE.		BARLEY.		OATS.		SORGHUM.		RICE.
	1897.	1889.	1897.	1889.	1897.	1889.	1897.	1889.	1897.	1889.	1897.	1889	1889.
New York	8,600	8,304	15,480	15,109		3,065		8,220	44,256	38,896			
Pennsylvania	22,151	21,593	38,889	42,318		3,742		493	37,169	36,197			
Texas	7,174	4,283	68,628	69,112		62		48	24.045	12,581			
Arkansas	2,863	955	38,437	33,982		15			7,608	4,180			
Tennessee	11,453	8,300	60,904	63,335		165		63	11,800	7,355			
West Virginia	5,816	3,634	14,348	592		117		5	3,204	2,946			
Kentucky	14,449	10,707	62,660	78,434		423		165	12,572	8,775			
Ohio	38,280	35,559	104,160	113,892		1,007		1,069	29,079	40,136			
Michigan	23,570 S 441	24,771	36,300	28,785		2,101		2,522	27,564	36.961			
Indiana	33,356	37,318	114,750	18,843		877		250	33,620	13,491			
Illinois	9,968 S 936	37,389	234,900	289,697		2,628		1,197	109,011	137,624			
Wisconsin	2,580 S 7,548	11,698	40,170	34,024		4,250		15,225	67.933	60,739			
Iowa	2,870 S 14,784	8,249	31,665	313,130		1,445		18,406	132,447	146,679			
Minnesota	1.118 S 53,951	52,300	222,750	24,696		1,252		9,100	58,244	49,958			
Missouri	15,900	30,113	145,190	196,999		308		34	24,102	39,820			
Kansas	62,547 S 2,610	30,399	160,010	259,574		2,917		165	25,542	44,629			
Nebraska	2 498 27,484	10,571	190,521	215,895		1,085		1,822	50,366	43,843			
Califorina	34,775 S 869	40,869	1,998	2,381		243		17,548	1,950	1,463			
Oregon	7,014 S 11,565	9,296	495	238		63		874	8,029	5,948			
Washington	8,747 S 11,752	6,345	276	156		19		1,269	3,800	2,273			
Oklahoma	17,415	30		234		1				76			
New England	380												
North Dakota	45,455	26,403	393	178		12		1,570	16,553	5,773			
South Dakota	30,395	16,541	25,326	13,152		65		902	15,750	7,469			
New Jersey		1,828		8,637		875		1		2,837			
Maine		79,826		380		6				3,668			
New Hampshire		35,192		988		11				892			
Vermont		161,720		1,700		43				3,316			
Massachussetts		1,813		1,830		117				388			
Rhode Island		98		253		9				100			
Connecticut		7,482		1,471		214				593			

	IN THOUSANDS OF BUSHELS												POUNDS.
	WHEAT.		CORN.		RYE.		BARLEY.		OATS.		SORGHUM.		RICE.
	1897.	1889.	1897.	1889.	1897.	1889.	1897.	1889.	1897.	1889.	1897.	1889.	1889.
Delaware		1,501		3,097		6				382			
Maryland		8,348		4,928		352				2,019			
District of Columbia				10		1				1			
Virginia		7,904		27.172		397				5.695			
North Carolina		4,292		25,783		276				4,512			5,846,404
South Carolina		658		13.770		17				3 019			30,338,951
Georgia		1,098		29 261		87				4,767			14,556,432
Florida				3,701		13				391			1,011,805
Alabama		208		30,072		14				3,230			860
Mississippi		16		26.148		3				1,382			399,270
Louisiana				13,081						297			676,746
Montana		457		14						1,535			75,645,433
Wyoming		74		25		2				388			108,423
Colorado		2,845		1,511		54				2,514			7,110
New Mexico		343		583						193			
Arizona		100		82						33			
Utah		1,515		84		33				597			
Nevada		81		6						99			
Idaho		1,176		24		10				587			

Cereal production of Iowa.—The cereal produciton of the state of Iowa, as collected by Mr. J. R. Sage,* for the years 1894 and 1895 is as follows:

	WHEAT.		CORN.		RYE.		BARLEY.		OATS.		SORGHUM.		RICE.	
	1894.	1895.	1894.	1895.	1894.	1895.	1894.	1895.	1894.	1895.	1894.	1895.	1894.	1895.
Winter	2,672,601	3,351,550	128,989,047	313,692,210	1,624,078	1,946,720	8,035,634	15,881,618	107,691,460	73,450,000				
Spring	6,797,695	7,047,235												

*Monthly Review Iowa Weather and Crop Service. 5: N. 1894. Ann. Rep. 1895:

According to Mr. Hyde in the Year Book of the Department of Agriculture for 1899, the crop production for the principal cereals of the United States for 1899 was as follows:

	Corn, Bushels.	Wheat, Bushels	Oats, Bushels.	Barley, Bushels.	Rye, Bushels.
Maine	427,428	43,942	4,956,665	347,652	14,745
New Hampshire	975.546	8,789	1,047.445	115,500	13,860
Vermont	1,710,936	78,320	3,959,333	538,904	53,941
Massachusetts	1,449,504	....	489.027	50,850	133,296
Rhode Island	251,596	....	95.368	9,135	....
Connecticut	1,799,811	5,490	525,056	....	256,464
New York	15,605,059	7,005.765	45,401.608	4,052.472	3,633,600
New Jersey	9,937,824	1,788,865	2,284,632	....	1,000,785
Pennsylvania	40,255,872	20,472,923	39,148,032	179,844	3,936,090
Delaware	4,547,312	932,557	320,080	....	....
Maryland	18,562,432	10,710,966	1,675,596	....	353,276
Virginia	34,880,900	6,330,450	5,145,518	....	330,471
North Carolina	31,953,168	3,495,598	4,787,208	....	320,278
South Carolina	16,713,189	963,762	3.023,976	....	19,125
Georgia	32,494,790	2,021,225	4,291.857	....	94,830
Florida	5,092,370	.....	320,454	....	....
Alabama	33,015,120	431,186	3,012,070	....	14,576
Mississippi	39,043,712	25,010	1,365,740	....	....
Louisiana	25,896,726	....	553,284	....	....
Texas	81,151,398	9,044.635	17,067,975	35,460	37,660
Arkansas	48.087,140	1,953,361	5,964,442	....	19,052
Tennessee	59.997,760	8,292,727	5,326,244	19,569	107,028
West Virginia	18.043,584	3,880,751	3,158,452	....	132,290
Kentucky	55,392,687	8,201,575	8,194,806	25,001	244.430
Ohio	99,048,816	39,998,006	32,945.976	603.400	625,920
Michigan	26,476.350	13,335,193	30,599,048	927,144	1,097,012
Indiana	141,852,594	25,361,175	34,301,248	153,300	464,633
Illinois	247,150.332	12,665.410	127,278,948	395,502	1,154,325
Wisconsin	41,686.365	11,773,382	67,687,380	7,670,550	3,073,125
Minnesota	31,171,272	68,223,581	52,688.416	8,144,125	1,112,472
Iowa	242.249,841	18,195,489	126.985,749	12,011,896	2,029,860
Missouri	162,915,064	11,398,702	20.299,350	12,960	127,439
Kansas	237,612,222	36,468,044	39,129,410	3,183,165	1,545,852
Nebraska	224,373,268	20,791,776	51,474,120	943,176	997,104
South Dakota	30,017,416	37,128,339	15,332,278	2 410,354	36,765
North Dakota	553,495	51,758,630	17,987,670	5,909.352	244,725
Montana	36,386	1,792,935	2,317,468	216,405	....
Wyoming	53,944	395,345	442,290	....	....
Nevada	....	687.006	....	....	....
Colorado	2,911,488	7,337,781	2,448.846	337,932	33,236
New Mexico	480,300	2,579,855	178,032	35,488	....
Utah	162,680	3,736,454	872,236	194.865	58,684
Washington	128,478	21,710.394	3,031 965	1,410.360	35,936
Oregon	297.418	21,949,536	5,118,640	797,916	61,776
California	1,536 975	33,743,909	1,843.787	22,239,776	547,080
Oklahoma	10,133,365	16,202,765	....	....	....
Arizona	....	343,139	....	....	....
Idaho	....	3,440,103	4,099,968	405,510	....
United States	2,078,143.933	547,303,846	796,177.713	73.381,563	23.961,741

Climatology.

Climate has such an important bearing, not only on the production of our cereals, but on the production of grasses, that a few tables should be introduced, showing the amount of precipitation for the growing months, as well as the annual rainfall. It is equally important to know the temperature for the same period. Dr. Geo. M. Chappel, of the U. S. Weather Bureau, and J. R. Sage, of the Iowa Weather and Crop Service, have kindly furnished me with the following data:

SIOUX CITY.

Precipitation—inches.

	April.	May.	June.	July.	August.	September.	Annual.
1893	3.56	3.17	1.63	2.29	5.85	1.11	23.83
1894	2.79	1.91	2.74	1.81	1.68	0.73	18.79
1895	3.20	2.15	4.95	2.63	1.54	3.91	20.29
1896	6.16	6.39	2.94	5.54	0.86	2.09	30.77
1897	4.03	1.24	2.13	2.26	2.51	0.51	20.38
1898	1.37	4.69	6.61	2.78	3.10	0.95	22.91
Averages	3.52	3.26	3.50	2.88	2.59	1.55	22.83

Mean total for the six crop months—17.30.

Temperature—degrees.

	April.	May.	June.	July.	August.	September.	Annual.
1893	44.6	57.0	72.0	75.0	70.7	66.0	45.0
1894	51.6	62.4	72.0	76.0	75.2	65.7	49.2
1895	57.0	62.0	68.0	72.4	72.6	67.7	47.8
1896	52.0	64.4	70.0	72.4	71.8	58.4	41.2
1897	47.6	59.1	68.4	76.2	68.2	71.7	46.8
1898	49.6	59.5	70.9	73.3	72.5	65.2	47.8
Average	50.4	60.7	70.2	74.2	71.8	65.8	46.4

Average for the six crop months—65.5.

CRESCO.

Precipitation—Inches.

	April.	May.	June.	July.	August.	September.	Annual.
1893	5.95	2.79	4.14	3.85	1.20	2.08	......
1894	3.21	2.63	3.00	0.09	1.03	3.16	22.76
1895	1.69	3.39	3.83	4.37	2.52	1.69	24.38
1896	5.09	6.74	4.27	3.26	2.62	4.83	24.07
1897	2.23	0.69	6.95	2.12	4.36	3.26	25.04
1898	2.80	2.84	2.53	2.91	1.35	1.03	23.91
Averages	3.50	3.18	4.12	2.77	2.18	2.68	24.03

Mean total for the six crop months—18.43.

Temperature—Degrees.

	April.	May.	June.	July.	August.	September.	Annual.
1893	40.2	52.9	68.2	71.1	67.4	60.5	....
1894	48.7	58.1	69.4	74.2	72.0	62.4	46.2
1895	51.0	58.8	66.6	69.2	70.2	65.0	43.1
1896	50.2	62.9	66.3	69.4	69.1	55.4	44.3
1897	44.8	55.8	64.8	72.1	65.0	67.2	43.5
1898	44.8	57.9	67.6	71.2	69.4	63.6	44.5
Averages	46.6	57.7	67.2	71.2	68.8	62.4	44.3

Average for the six crop months—62.3.

KEOKUK.

Precipitation.—Inches.

	April.	May.	June.	July.	August.	September.	Annual.
1893	5.41	4.36	2.37	2.60	1.16	3.18	27.94
1894	2.75	3.06	2.95	0.37	0.51	4.86	25.20
1895	3.38	3.45	2.61	5.46	2.28	2.67	29.42
1896	2.35	4.40	2.18	8.01	3.90	9.44	36.77
1897	3.34	1.86	5.43	6.75	0.65	0.64	33.14
1898	4.80	6.70	4.77	3.06	6.92	8.07	52 48
Averages	3.67	3.97	3.38	4.38	2.57	4.81	34.16

Mean total for the six crop months—22.78.

Temperature—Degrees.

	April.	May.	June.	July.	August.	September.	Annual.
1893	49.9	59.8	73.0	78.0	72.0	69.0	49.9
1894	54.0	63 0	76.0	78.0	77.0	68.0	53.7
1895	55.1	63.6	73.0	73.8	76.7	70.7	50.8
1896	60.0	70.0	71.8	76.0	74.9	62.5	53.0
1897	51.3	61.2	72.9	78.3	72.4	74.4	52.6
1898	51.8	64.0	75 6	77.1	75.7	70.8	52.9
Averages	54.4	63.6	73.7	76.9	74.8	69 2	52.2

Average for the six crop months—68.8.

SIBLEY.

Precipitation.—Inches.

	April	May.	June.	July.	August.	September.	Annual.
1893	......	1.65	2.41	3.37	2.26	0.88	.....
1894	4.13	3.59	3.34	1.01	0.97	2.57	22.47
1895	2.81	5.20	4.85	1.13	0.67	......	......
1896	5.33	5.42	3.92	3.67	4.38	6.67	38.65
1897	2.48	0.73	4.20	4.32	0.95	1.15	24.98
1898	1.44	5.42	4.99	2.69	3.06	0.67	21.63
Averages	3.24	3.67	3.95	2.70	2.05	2.39	26.93

Mean total for the six crop months—18.00.

Temperature—Degrees.

	April.	May.	June.	July.	August.	September.	Annual.
1893	......	55.2	69.1	69.3	66.4	60.9	......
1894	48.1	58.6	69.8	72.6	71.4	62.6	45.8
1895	54.0	58.2	65.0	......	......	......	......
1896	48.8	61.8	66.6	69.2	68.6	56.0	......
1897	44.7	56.0	64.8	72.2	64.0	68.6	......
1898	46.0	56.5	68.1	70.5	67.6	62.9	44.6
Averages	48.3	57.7	67.2	70.8	67.6	62.2	45.2

Average for the six crop months—62.3.

DES MOINES.

Precipitation—Inches.

	April.	May.	June.	July.	August.	September.	Annual.
1893	5.61	2.84	4.69	3.55	1.60	1.33	25.64
1894	1.70	1.41	1.67	0.29	1.89	4.46	20.06
1895	3.41	2.86	5.26	3.10	3.57	3.20	26.80
1896	3.47	6.50	2.69	8.15	5.49	3.61	37.09
1897	7.37	2.31	3.15	2.88	1.77	1.56	27.07
1898	2.64	4.22	6.85	1.86	1.09	1.91	28.33
Averages	4.03	3.36	4.05	3.30	2.57	2.68	27.50

Mean total for the six crop months—19.99.

Temperature—Degrees.

	April.	May.	June.	July.	August.	September.	Annual.
1893	46.0	56.9	71.4	75.5	70.0	66.2	46.7
1894	53.0	62.0	74.4	77.7	76.0	66.7	51.2
1895	55.4	62.7	70.5	72.7	73.8	69.4	49.0
1896	56.0	66.5	70.1	73.2	72.7	59.6	50.1
1897	49.4	59.7	70.0	76.4	70.4	73.7	49 6
1898	50.0	60.7	72.2	74.2	73.8	67.4	49.5
Averages	51.6	61.4	71.4	75.0	72.8	67.2	49.4

Average for the six crop months—66.6.

CEDAR RAPIDS.

Precipitation.—Inches.

	April	May.	June.	July.	August.	September.	Annual.
1893	3.89	2.79	4.89	1.98	2.47	2.85	30.67
1894	1.65	3.08	2.43	0.18	2.51	3.96	26.27
1895	2.30	2.84	2.23	3.22	1.50	3.64	23.39
1896	5.23	3.99	1.91	6.59	2.40	3.18	29.77
1897	5.97	2.10	3.96	4.35	2.62	3.78	29.34
1898	2.47	3.41	3.60	1.90	4.38	3.11	29.58
Averages	3.58	3.04	3.17	3.04	2.65	3.60	28.17

Mean total for the six crop months—19.08.

Temperature—Degrees.

	April.	May.	June.	July.	August.	September.	Annual.
1893	45.9	57.2	72.2	73.3	70.2	64.8	46.4
1894	53.2	61.8	74.4	76.1	74.7	65.3	50.8
1895	54.2	63.0	72.6	74.0	74.6	69.9	48.8
1896	59.2	69.8	73.2	74.2	73.8	59.1	50.2
1897	47.4	58.0	68.6	76.4	58.7	70.9	47.9
1898	48.8	60.8	73.2	75.4	73.3	67.3	48.7
Averages	51.4	61.8	72.4	74.9	72.6	66.2	48.8

Average for the six crop months—66.6.

CLARINDA.

Precipitation.—Inches.

	April.	May.	June.	July.	August.	September.	Annual.
1893	3.11	3.17	4.12	8.84	6.22	2.38	33.27
1894	2.06	1.37	4.02	0.41	0.23	2.53	17.96
1895	2.82	2.99	8.33	6.44	4.64	0.95	30.79
1896	3.72	7.48	2.12	6.63	2.86	2.56	33.73
1897	6.00	2.01	4.04	2.63	2.53	1.55	26.32
1898	3.70	5.15	2.99	4.49	1.16	5.74	33.49
Averages	3.57	3.70	4.27	4.91	2.94	2.62	29.26

Mean total for the six crop months—22.01.

Temperature—Degrees.

	April.	May.	June.	July.	August.	September.	Annual
1893	47.4	57.9	70.5	75 3	69.6	65.9	47.1
1894	53.3	62.1	73.5	76.3	77.6	66.4	51.0
1895	53.9	62.2	68.6	70.2	73.2	68.4	47.8
1896	54 3	63 8	68.4	73.7	73.8	61.5	49.8
1897	50.8	61 6	72.9	78.8	71.6	73.2	51.3
1898	51.8	62 2	75.0	80.2	80.6	72.6	52.4
Averages	51 9	61.6	71.5	75.8	74.4	68.0	49.9

Average for the six crop months—67.2.

Fig. 72 A. Mean Temperature 1898 (Dr. Chappel.)

Dr. C. Hart Merriam, who has been considerably interested in the geographical distribution of animals and plants, has divided the United States with reference to cereal production and the geographical distribution of plants into boreal, transition, upper austral, lower austral, gulf strip of lower austral and tropical. The tropical, of course, is confined to the southern portion of Florida, reaching Texas on its southwestern boundary for only a short distance, on the western coast of America, up the gulf of lower California to Arizona. The boreal does not strike the state of Iowa but lies chiefly to the north of the United States and extends down through the mountain regions of the western coast and the Rocky mountains. It is of some extent also along the Atlantic coast. The transition zone occupies an area chiefly through northern Wisconsin, Minnesota, Michigan, New York, Massachusetts, Maine and scattered areas in the Rocky mountains and in the Pacific coast region. This zone extends into northern Iowa. The greater part of the state of Iowa lies in what is known as the upper austral. This includes most of the prairie states, including some area in the Rocky mountain states and some of the Pacific coast. It embraces a portion of Ohio, West Virginia and a small area from Virginia to Alabama, thence northwest through Tennessee and Kentucky, northern Arkansas and a portion of Oklahoma. The lower austral occurs along the Atlantic coast from Virginia southwest to Mexico, extending as far north as southern Kansas, western Kentucky and Tennessee and only a very limited area in southern Missouri. The gulf strip of the lower austral is chiefly confined to a small strip along the gulf coast including the greater part of Florida.

Prof. C. S. Plumb, under the direction of Dr. C. Hart Merriam, has gathered together some facts on the distribution of the cereals. It may be of interest to state what he has found with reference to some of our chief cereals. The flint corns, such as Longfellow and King Phillip occur in the transition and upper edge of the upper austral. The dent corns like Hickory king, Bloody butcher, St. Charles white, occur in the upper austral; Hickory king in the upper austral and upper part of lower austral; Mosbey's prolific, lower austral; pride of the north, transition; Stowell's evergreen, upper austral; pop, all varieties, upper austral; winter wheat, Clawson, transition and upper austral; Fullcaster, Turkey red, upper austral; spring wheat, Ladoga, Saskatchewan, fife, transition;

Sonora, upper and lower austral; oats, of the open panicle type, American banner, transition; Welcome and Lincoln, transition and upper Austral; red rust proof, upper and lower Austral; oats with closed panicle, white Russian, transition zone; black Tartarian, transition.

Fig. 73. South American corn (*Zea mays*). Climate and the growth of maize. This failed to mature in Iowa. Had a large number of nodal roots.

Maize.—Harshberger*, who has studied the various phases of maize, presents an interesting meteorological table of various points in Mexico for the months of April, May, June, July, August, September and October, 1889. He introduced evidence determining that it originated in Mexico, probable near Guadal-jara, Leon and Pueblo. Leon is 5,400 feet above the level of

*Maize: l. c. Contr. Bot. Lab. U. of Penn. 1: 75-202. *pl. 14-17.* 1893.

the sea, it is therefore a highland plant. Its original home was south of the 22° north latitude.

In regard to the climate Brewer* states: "That the bulk of corn is grown not as is generally supposed, in the warmer parts of the United States, but in the states Illinois, Iowa, Missouri and Indiana 40.8 per cent of the entire crop grows where the mean annual temperature is between 45° and 60° F. Below an annual temperature of 45° F. the product falls off very rapidly, while above 50° F. it falls off very slowly. The distribution of the crop depends on certain climatic conditions. The mean annual temperature is of less importance, and it is very important that the rain fall should be evenly distributed. "The table of the distribution of the crop according to elevation shows that over 50 per cent is grown at an elevation of between 500 and 1,500 feet, only 4.4 per cent above that, and only about an eighth of the crop is grown nearer the sea level than 500 feet."

Corn needs hot weather, plenty of sunshine and a sufficient amount of rainfall. In 1894 the average yield for Iowa was twelve bushels per acre, a little over one-third of an average crop. Acreage planted 6,738,970; total yield 80,867,640 bushels. About 60 per cent was cut for fodder. It is interesting to note the fluctuation in the crop reports for that year. The figures were in June, 101 per cent; July, 107 per cent; August, 40 per cent, and September, 36 per cent.

Mr. C. F. Spring, under the writer's direction, has made an estimate of the number of bushels per acre in the north half of the state, and the south half. The average for the north half of the state for the year was thirty-six bushels per acre; for the south half, thirty-eight.

Every portion of the state of Iowa is adapted to the growing of corn, and from a climatic standpoint corn is one of the most interesting of cultivated plants. It is wonderfully flexible in its nature, and this flexibility makes it possible to cultivate it over a wide range of latitude. Simmonds† says: "Its flexibility of organization makes it very easy of adaptation to climate and soil." It is now cultivated on the western continent from Patagonia to Canada, an extent of territory north and south of over 7,000 miles. The many varieties that have been produced under these very different conditions show great vari-

*Cereal production. U. S. Tenth Census Rep. 3:100.

†Tropical Agrl. 295.

ations, not only in the texture of the grain but in the fruit, leaf, stalk and ear. All of the varieties are marked by certain peculiarities.

Wheat.—This important cereal assumes important changes under different climatic conditions, but less so than corn. Major Hallet* has shown that some varieties are quite constant. Metzger† states that a variety of wheat which was quite constant in Spain, assumed its proper characters only during hot summers. Another variety, when cultivated in Germany, became more constant only after twenty-five years of cultivation.

The most northern extension of wheat is obtained in Norway, according to Schuebler‡, at 64° north latitude. Schuebler further states that under favorable conditions summer wheat may ripen as far north as 68° 28′. At Skibotten this cereal was sown May 9, 1870, germinated on the 23d, and ripened on the 30th of August, therefore requiring 113 days. The mean temperature for May was 41.2° F.; June, 55.6° F.; July, 55.6° F.; August, 55.1° F.

Winter wheat does not mature because of the long period that the ground is covered with snow. The lowest southern latitude at which wheat is grown is at Chili in the Chilian colony, Punta Arenas Magellanes. The chief zone in which wheat occurs is in the north and south temperate zones. In tropical regions the temperature is too high to allow the proper development of wheat. This is shown very nicely in the tables presented on a preceding page. In regard to the United States the success of the culture of wheat is very materially affected by the long warm and hot months. Thus the southern United States is not a wheat growing country because of the rankness and vigor of the vegetation. This causes an undue amount of rust. Where the culture of wheat is successful in the warm regions, especially the southern parts of the tropical regions, its culture must be carried on during the winter months. According to Royle§, it succeeds best from October to March, and in the sub-tropical zone from November to May. Wallace‖ in his work on India states that it flourishes best where the supply of sunlight is abundant, yet it is in regions of moderate

*Gardners' Chronicle. Darwin. Animals and plants. 1: 332.
†Getreidearten 66. 91. 92. 116. 117.
‡Die Pflanzenwelt Norwegens. 75.
§Royle. Illustr. Bot. of the Himalaya. 418.
‖India in 1887. 247.

temperature and moderate rainfall, but we find it grown to the greatest advantage in that part of India where, at least during the winter months, the climatic conditions of the summer of Europe are most nearly approached. Definite limitation of area cannot be made since the region is not itself sharply defined.

A study of the tables prepared by Professor Brewer shows that the greatest production of wheat occurs where the mean annual temperature is 50° and 55° F. The ideal climate for wheat is one of mild winters, and some of the most noted wheat regions of the world are where snow and frozen ground are unknown or very rare although most of the wheat of the world grows in regions of cold winters. Rainfall, also, has a marked influence on the amount of wheat production. Twenty-eight per cent of the crop of the United States grows with an annual rainfall of between 40 and 45 inches, 62.7 per cent where it is between 35 and 50 inches and 92.4 per cent where the annual rainfall is above 25 inches, although there are some exceptions, as in California where the mean annual rainfall is less than 25 inches.

Wheat ripens successfully at the following altitudes: Norway, 300 m ; on the southern exposure of the Alps, 1,264 m., and Thibet, 4,549 m.

The quality of the grain produced in any locality is dependent upon several conditions; namely, climate, soil and cultivation. It is said by Frank T. Shutt that certain Russian wheats, like Ladoga,* cultivated in the northwest territory has been greatly improved since its growth in the Canadian provinces. There is a well-marked increase in the amount of albuminoids. The main difference between the hard and soft wheat is that the hard wheats contain a greater amount of albuminoids while the soft wheats contain a greater amount of starch.

Koernicke and Werner† state that the colder regions of the temperate zone are more favorable for the soft wheats. These are especially characterized by the low contents of albuminoids. These varieties where grown in dry and warmer countries are characterized by an increase in albuminoids. Only certain portions of Iowa are adapted to the growing of spring wheat. The average number of bushels per acre in northern Iowa is seventeen; in the south half of the state Mr. Spring estimates

*Saunders Bull. Canada Cent. Exp. Farm 18: 1893.

†Handbuch 2: 483.

the yield per acre at only fourteen bushels. Winter wheat shows just the opposite, the yield in the north half of the state was only seventeen bushels per acre, the south half, nineteen.

Rye.—Rye in a general way covers the same territory that wheat does. According to Koernicke and Werner* the southern extension is at Punta Arenas Magellanes, 50° south latitude. In Switzerland it matures between 1,700 m. and 1,900 m. In the United States the successful cultivation of rye extends further southward than that of wheat and oats. In regard to its culture in the United States it may be said that the chief region of its cultivation is north of the Ohio river and west to central Nebraska, although it is successful further south than wheat, especially in the states of Texas, Louisiana and Mississippi. Professor Brewer† says concerning its culture: "During the whole colonial period, and, indeed, far into the present century, it was the common ingredient of bread for a great many families in this country. Wheat never flourished well in portions of New England, and the same may be said in a lesser degree of parts of the middle states and of a belt of land extending southward along the Appalachian mountains, while over the whole of this region rye flourished reasonably well." In this state the same conditions hold as to wheat, sixteen bushels per acre in the south half and nineteen for the north half.

"Before the days of railroad transportation, and especially before the opening of the Erie canal, rye bread was the common bread among a large portion of the population of the whole region indicated, in many places, particularly in New England, rye being usually mixed with corn for bread, and 'Rye and Indian' was a familiar term in most households east of the Catskills and north of the Delaware. A similar bread of maize and rye is still common bread of Portugal, the relative proportions of each varying with the year, a good year for rye being usually a poor one for corn, and the composition of the bread varying accordingly."

The distribution and importance of rye in Europe is much greater than in the United States, but in a very general way it covers the same area as wheat does. The vegetative period is about 125 days for summer rye, with a mean temperature of 54°.

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*Handbuch 2: 579.

†Cereal Production. Tenth Census Rep. 3.

Barley.—Of the cereals, with the exception of corn and sorghum, barley is of a wider distribution than any of the others. The white four-rowed barley (*Hordeum tetrastichum pallidum*) extends further northward than any other form, 70°. Its period of vegetation has been much shortened and it is less sensitive to the unfavorable weather and night frosts in this high northern latitude. According to Dr. Unger this barley is sown in Umea on the 30th of May, and is harvested on the 25th of August, the vegetative period being eighty-five to ninety days. The average yield per acre in Iowa for the north half of the state is thirty-one; for the south half, twenty-eight.

Oats.—The distribution of oats is not so extensive as that of barley or rye. In the humid temperate regions it does not succeed. Oat culture is not extensive in the warm, dry climates, especially with an intense heat. Its vegetative period is long and for that reason it is not grown so far north as barley. The vegetative period varies between eighty-eight and 150 days. The units of heat required to develop different varieties is between 1,404.37, for certain varieties in Germany and 2,060 for certain varieties in Paris. These figures are according to Dr. Wittmack.*

The place of the greatest production of oats is in the Mississippi valley, which grows 63.1 of the whole crop. The reasons for this are not so much the climate as the peculiar topographic features. Ninety-one per cent of the crop is grown between an altitude of 100 and 105 feet. Mr. Spring's studies show that in Iowa the average yield per acre for the north half of the state was thirty-nine bushels; for the south half, thirty-one.

Sorghum.—This is the chief cereal crop in tropical and subtropical Africa, and has also spread over parts of Arabia, Asia Minor, India, China and Japan and is found also to some extent in southern Europe where it succeeds admirably. The dry climate of our own country, especially in Kansas and Nebraska, is admirably suited to sorghum cultivation. In Europe, on the steppes of Russia, it scarcely reaches beyond 48° north latitude, according to Koernicke. Prof. Thos. A. Williams says concerning its growth in the United States†: "The sweet sorghums are successfully grown in nearly every state and territory in the union, the only exception being some of the colder New England states and those in the northwest which include

*Koernicke-Werner.o Handbuch 2: 751.

†Sorghum as a forage crop. Farmers Bull. Of. Exp. Stat. U. S. Dept. of Agrl. 50.

the higher altitudes of the Rocky mountains and other ranges. In most localities south of Pennsylvania, Minnesota and Oregon, two or more crops may be harvested in a single season."

Rice.—The early varieties of rice mature in from 100 to 120 days the late varietes from 150 to 200 days. They require a mean temperature of 55° F., summer varieties of 71° to 89° F., being an average mean of 68° F. Rice culture is most successful in tropical and sub-tropical regions, although it has succeeded as far north as 38° north latitude in Illinois, but its culture is nearly abandoned in that state. Its general successful commercial culture in the United States does not extend much beyond 34° along the Atlantic coast, and then again extensively along the Gulf coast. Koernicke states that its latitude in Europe is 45°. Its general culture in Asia occurs in Corea, Japan and China. Simmonds says: "One of the most extensively diffused and useful of grain crops, and supporting the greatest number of the human race, is rice. It occupies, in fact, the same place in most tropical regions that wheat does in the warmer parts of Europe, and oats and rye in those more to the north. It is raised in immense quantities in India, China, Java and most eastern countries, in parts of the West Indies, Central America and the United States, and in some of the southern countries of Europe. The chief food of perhaps one-third of the human race, it affords the advantages attending wheat, maize and other grains, while it is susceptible of cultivation on land too low and moist for the production of other useful plants."

Grasses in Medicine.

Quack grass.—But few of the grasses are used in medicine. One of the best known of the grasses used in medicine is quack grass (*Agropyron repens*). The root is taken in the form of a decoction and is a useful remedy in suppression of urine and vesical calculus. The drug is still much used in France, where it is used for the discharge of mucus from the bladder.

Lemon grass.—The lemon grass oil or citronella oil is derived from several species of the genus Andropogon. The *A. Nardus* is a native of Ceylon and Hindoostan. The *A. citratus* or lemon grass oil of verbena is likewise cultivated in Ceylon and Singapore and is native to the same general region. Another species, *A. schoenanthus*, is native to northern and central

India, and by distillation yields the Rusa oil. These aromatic oils have been known since early in the eighteenth century, and have become commercial products since the early part of this century. It is used principally for rheumatism, and Rusa is said to stimulate the growth of hair. The lemon grass oils are used most extensively in America by soap makers and perfumers. In India cattle are said to be very fond of the fragrant Andropogon and the flesh and milk become strongly flavored with its strong aroma.

Andropogon.—A related species of Andropogon, *A. laniger*, is used in India for cholera. The roots have a very strong odor analagous to myrrh. The roots of *A. muricatus*, native to southern India and Bengal, were anciently much used by the Brahmins, where it is known as cuscus grass. The roots are much used for making screens known as tatties, and when wetted give off an agreeable odor.

Cumarin.—Several of our grasses are known to give off an odorous product, e. g. cumarin, and this is identical with that found in the tonka bean (*Dipterix odorata*). Two grasses producing cumarin are found in this state, namely, sweet vernal grass (*Anthoxanthum Puelli*) and our northern vanilla grass (*Hierochloe borealis*).

Phragmites and Arundo—An infusion of the roots of *Phragmites vulgaris* is used as a diuretic. The rhizomes of *Arundo Donax* are also used for the same purpose.

Paspalum and Coix.—The *Paspalum notatum* Flugge is used for gonorrhœa. The *Coix lachryma* is used as a diuretic and to combat inflammatory affections of the respiratory organ. In China it is extensively cultivated for a similar purpose. It is also used as a diuretic according to Gomez de la Maza.* The capsules are used by followers of the Roman Catholic faith for rosaries.

Hordeum.—Mention should be made also of the use of barley (*Hordeum sativum*) in medicine. This anciently cultivated plant has been used in medicine for a long time. The so-called pot or hulled barley is only partially deprived of its husks. In pearl barley all the integuments are removed, and this is the barley that finds a place in the Pharmacopoeia. Barley is used especially for the making of drinks for sick in febrile, in pulmonary and urinary disorders.

Sugar cane.—*Saccharum officinarum* also largely enters into medicines. It is known by the pharmaceutical name of Sac-

*Essayo farmacofitologia Cubana 8.

charum. Cane sugar has a chemical composition of $C_{12}H_{22}O_{11}$. Its medical use when in solution is almost exclusively lenitive, but in powder it is a stimulant, and is employed to diminish dryness of the mouth and fauces, to stop irritation and mitigate cough. It is said also to have a diuretic effect. Used in a moderate quantity it promotes digestion and stops nervous excitment. It is said also to be a very efficient remedy for apathæ of the mouth, and in granular eyelids. It is also said

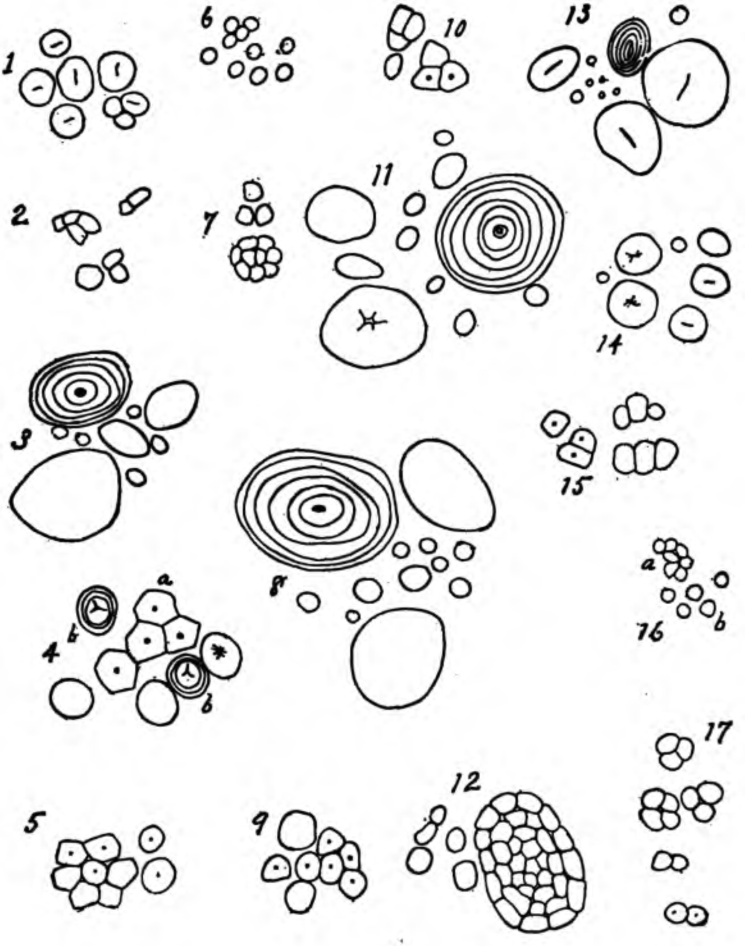

Fig. 74. Amylum. Various forms of starches from grass endosperm: *1*, sorghum; *2*, rice; *3*, wheat; *4*, maize; *5*, Italian millet; *6*, *Panicum miliaceum*; *7*, *Eragrostis abyssinica*; *8*, wh at more magnified than 3; *9*, barnyard grass; *10*, *Panicum sanguinale*; *11*, rye; *12*, oats; *13*, barley; *14*, Jerusalem corn; *15*, buckwheat; *16*, manna grass; *17*, *Eleusine coracanna*.

to be valuable in chronic laryngit's when inhaled by a sudden aspiration.

Refined sugar is extensively employed in making lectuaries and lozenges. Not only does it prevent the unpleasant taste but acts as a preservative.

Amylum.—Amylum or the starches are of universal distribution in the endosperm of grasses but the only starches used in a medicinal way are those of wheat, corn, rice, rye and oats. These starches differ in their structural peculiarities, but all have the same chemical composition. The drug known as Catchu is frequently sold in India, and contains the flour of Rage (*Eleusine coracana*). In India it is made into tablets and lozenges. Its principal medicinal qualities do not reside in the starch of the grass s but is due to the stringent qualities of the cutch.

Most alcoholic stimulants are derived by a process of fermentation of the starches contained in rye, barley, wheat, corn, and rice. For ordinary malt liquors barley is largely used and also starches of corn and rice. The products of wheat, corn and rye are largely used for the various brands of whiskies.

Glucose.—Glucose, having the chemical composition of $C_6 H_{12} O_6$ though existing naturally in grapes and a large number of fruits is usually prepared by the action of hydrochloric or sulphuric acid upon starch, the term glucose being applied to the syrupy product made by this process and the term grape sugar to the solid product from the same source.

Maize.—The stigmas of corn silk are used in medicine under the name of Mayd s stigmata. They are diuretic and lithontriptic. An infusion of corn leaves is sometimes used as an anti febrile, but its action is said to be unreliable.*

*Harshberger (Contr. Bot. Lab. Uni. Penn. 1: 185) quotes from an article in the Am. Jour. of Phar 5: 315.

Sugar Producing Grasses.

ROBERT COMBS.

The grasses containing sugar or sucrose (C, H, O_{11}) are few, there being but three species that are known to contain it to any great extent. These species are corn or maize (*Zea mays*, L.), sorghum (*Andrmedian sorghum*, Brot.) and sugar cane (*Saccharum officinarum*, L.). These plants all have stored up in the pith cells of the internodes of the culms a greater or less quantity of sucrose, which quantity varies greatly according to the age of the culm and the part used.

Corn.—Experiments and analysis made by Prof. Peter Collier* and others show that, though at its maximum stage, about August 20th, corn contains a goodly per cent (about 12 to 14 per cent) of sucrose, its period is of such short duration (about ten days or less) and the quantity before and after the maximum is so small that it cannot be economically used as a commercial source of sugar. The kernel, however, is used to a great extent as a source of glucose, the latter being obtained by the action of sulphuric acid on the starch.

Sorghum.—Certain varieties of this grass have been clearly shown to contain sucrose, varying from 13 to 18 per cent, and holding this content from four to six weeks, or even longer. The United States Department of Agriculture† has made almost continuous experiments and investigations along the line of selecting and improving varieties, and in the matter of processes of manufacturing sugar from sorghum from 1879 to 1893.

Experiment stations were established in various parts of the United States‡, and especially in different parts of Kansas, where at one time (1889) there were nine.

The plant was much improved in sugar content and much improvement was made in the process of manufacture, but since the removal of the sugar bounty (1893) the industry has entirely collapsed.

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*Report U. S. Dept. of Agrl. 1881-82: 452. *pl. 14-16.*

†Reps. U. S. Dept. Agrl. 1880-87:

‡Bull. U. S. Dept. Agrl. Div. Chem 2: 6: 8: 14: 17: 18: 20: 26: 29: 34: 37: 40.

Sorghum cane has been used for many years for the manufacture of a kind of syrup known in commerce as "sorghum molasses." It is made by exp essing the juice from the trimmed stalks by means of a mill or roller pressure, straining and clarifying, sometimes by the addition of a small quantity of freshly slacked quicklime, and heating to boiling, skimming and settling, but usually without the addition of lime, although in this way it produces an inferior product.

It would seem that the process of manufacture must be at fault at some point and that point is in the clarification of the juice. The gums or "solids not sugar," impurities of the juice are of such a character that they cannot be removed by any known process of clarification without sufficient facility and economy to enable the sucrose content to be easily crystallized; therefore the financial failure of the industry when put upon its own feet and unassisted by government bounties.

Sugar cane.—Commercial sugar was obtained only from sugar cane until the early part of the present century, when sugar beets were discovered to be an available source. The Chinese* claim to have manufactured sugar from cane for over 3,000 years. They most probably obtained it either in Cochin-China or Bengal, where all evidence points to the plant having been native. Many Greek and Roman writers speak of either sugar or cane, or both.

The best of the more recent accounts on the production of sugar may be obtained from Stubbs†. Simmonds‡ in his work on Tropical Agriculture treats the subject very fully.

Other Uses of Grasses.

Grasses are widely used for other purposes. It is impossible for us in this connection to give all the different uses to which grasses are put. The *Panicum junceum* is used in Argentine Republic as a substitute for soap. Straw paper is made out of straw of several cereals. A great deal of other straw is also manufactured into paper of various kinds, and this is a subject of considerable commercial importance. Paper is made not only from rye and wheat but also from maize, and the time will come when the manufacture of paper from maize will assume much greater importance than it does at present. Dr. Harshberger says of the maize: "Maize seems to be the best adapted

*Wray. The practical sugar plants. 1848. Stubbs Sugar cane. 1.
†Stubbs Sugar cane. 1.
‡Tropical Agriculture. 128.

to the purpose. In the last century two maize-straw paper manufactories were in existence in Italy. The paper produced was not of a satisfactory quality, the cost was too great, and the manufacture forthwith stopped. The chief expense was found in the transportation of the crude material to the seat of operations. All the fibre and gluten wastes can be used in the manufacture of paper. The catalogues of the Austrian exhibition at London in 1862 in German, French and English, consists of such paper." At the present time the manufacture of paper from maize in Vienna is an extensive operation. The paper has a yellowish tint and is, therefore, very restful to the eyes. Paper of Indian corn requires very little sizing; it bleaches well and is of greater strength than rag paper, and no machinery is necessary for tearing up the leaves.

Crookes and Fischer state that "among the straw species appears the maize (Indian corn) from the fibre of which a paper is made that for purity and whiteness cannot be equalled. The inner bark of the bamboo affords a very fine paper, yielding the most delicate impressions from copper-plate, and this paper was originally called India-proof. Paper is also made from *Andropogon sorghum.* A very fine fibre is also made from Esparto grass (*Stipa tenacissima*).*

Many other grasses are adapted for fibre paper purposes and several grasses produce fibre of fine quality.

In Labrador the *Elymus arenarius* is employed for the manufacture of table mats and baskets. Bamboo (*Bambusa arundinacea*) is used for the purpose of making paper stock and the canes are also split and shredded and afterwards wrought into various forms. The Marram grass, *Ammophilia arenaria*, is used in northern England for the making of table mats and baskets and also for agricultural tie bands. For a valuable paper on the subject of fibre producing plants, the one prepared by Charles Richards Dodge, "A Descriptive Catalogue of Useful Fibre Plants of the World,"† is recommended.

The Hopi Indians use *Hilaria jamesii.* They make from the stout fibre of this plant coiled trays. The strong fibre of *Hierochloe borealis* according to Dr. Havard‡ is used by the Penobscot Indians for the making of baskets and pretty fancy work. Its long radical leaves become strongly involute in

*For an account of the making of paper see Man. of Chem. Tech. by Rudolph Von Wagner. English translation. Crookes and Fischer. 853: 1892.

†U. S. Dept. Agrl. Fiber Inves. 9.

‡Garden and Forest. 3: 619.

drying, forming flexible threads which are braided into fine strips and these are woven into baskets and other pretty fancy work. He has also found braids of this grass in the camp of the Crow Indians on the Yellowstone. The delicate and lasting fragrance of the dried leaves gives this grass additional value.

Maize husks are used extensively in the United States for upholstering purposes and for the manufacture of matresses and for similar uses. Horse collars are made of the husks or "shucks" in the south; door mats are also made in some of the northern states, these being very serviceable. Mr. Dodge says the husks are also employed in the manufacture of chip hats in Florida. These, when properly trimmed are both stylish and pretty.

The corn pith cellulose is employed as a packing material in the cofferdams in connection with the armour plating of United States war vessels. The corn pith is suitably cleaned and pressed into blocks when it is ready for use.

An excellent account of the use of corn pith cellulose and other productions of corn may be found in a recent nnmber of the Orange Judd Farmer.* This journal summarizes the various uses to which the products made from corn stalks may be put:

"1. Cellulose for packing cofferdams of battleships, this preventing them from sinking when pierced by balls or shells.

"2. Pyroxylin varnish, a liquid form of cellulose, the uses of which are practically unlimited.

"3. Cellulose used for nitrating purposes for making smokeless powder and other high explosives, for both small and great arms, as well as purposes for which dynamite or all other explosives are required in various forms and degrees of strength.

"4. Cellulose for packing, it being the most non-conductor known against heat or electricity, jars or blows.

"5. Paper pulp and various forms of paper made therefrom, both alone and mixed with other grades of paper stock.

"6. Stock food made from fine ground outer shells or shives of corn stalks, and also from the nodes or joints. The leaves and tassels also furnish a shredded or baled fodder.

"7. Mixed feed for stock, containing fine ground shells of shives as a base, and in addition thereto various nitrogenous

*27: 363.

meals and concentrated food substances, or blood, molasses, distillery and glucose refuse, sugar beet pulp, apple pomace and other by-products.

"8. Poultry foods of two types, namely—type 1, containing a dominant nitrogenous factor for laying hens, and No. 2, containing a dominant carbohydrate factor for fattening purposes."

This manufacture is carried on extensively by the Marsden Co., of Philadelphia, in Owensboro, Ky.

The straw of several varieties of wheat is used for the manufacture of braids or straw plait. The finest of these come from Italy, thus the celebrated Tuscan plait comes from Florence and is produced from a variety of wheat cultivated especially for the straw and without regard to the grain. The industry is carried on extensively also in parts of China. The straw of rye (*Secale cereale*) is likewise used for the making of hats. An interesting account of its use in this connection will be found in Mr. Dodge's paper on "The Useful Fibre Plants of the World."

Brooms.

Another important use of grasses is for the manufacture of brooms. The plant usually used for this purpose is broom corn, *Andropogon sorghum*. The cultivation of broom corn for the manufacture of brooms is an extensive industry in Ohio, Indiana, Illinois, Iowa and Kansas. Good crops may be obtained with proper attention and care on any clean, fertile soil. The seed is planted about the same time that corn is. The soil should be well tilled and in excellent condition; the weeds must be kept down to get the most remunerative crop. The brush must be cut before the seed is fully formed.

Soil Binders.

Grasses are extensively used as sand and soil binders. These grasses are especially important along the sea shores where the tides and waves are a constant menace to the land and dwellings situated in proximity to the sea. "The digging out and undermining by swift currents, the beating of the waves on lake and ocean shores and the perpetual shifting about of loose sands by the waves and winds, cost our country many millions of dollars annually," says F. Lamson-Scribner in his paper on grasses as sand and soil binders.* The sand

*Year book U. S. Dept. Agrl. 1894: 421.

or soil binding grasses have strong root stocks or rhizomes. There are two kinds of these soil binders. *First.*—The coarser kinds which are exposed to the most severe action of the winds and waves. These have their rhizomes deeply buried in the sand. *Second* —Grasses with prostrate stems that creep over the surface of the sand and produce at frequent intervals long fibrous roots. Some of the more important of the sand binders are Marram grass, *Ammophia arenaria*, the *Elymus arenarius*. Of the many other grasses which aid in holding the soil, mention may be made of the rolling spinifex (*Spinifex hirsutus*), Louisiana grass (*Paspalum compressum*), and sand grass (*Calamovilfa longifola*). The latter species is especially valuable in many sections of this state where it retains the loose sandy soil along some our streams. The *Spartina cynosuroides* is a valuable grass in holding the alluvial soil of the Missouri river bottom in position.

Oil.

Maize oil is obtained from the embryos of corn. Dr. Harshberger* says: "The oil is not obtained by direct expression, but the grain is malted, and the germ is separated by careful crushing and winnowing. The germs are then submitted to hydraulic pressure, and yield 15 per cent oil, and a press cake rich in albumen, containing 4 to 5 per cent oil. Maize oil is of a pale golden-yellow color, and has a peculiarly agreeable taste and odor. It is a thick liquid, and has a specific gravity of .9215 at 59° F. It consists of olein, stearin, palmitin, and contains some volatile oil. It solidifies to quite a solid mass at 10° C. (14° F.)."

It is one of the common by-products in the manufacture of glucose from the embryo of corn. It is an excellent oil for salad purposes and is also a possible adulterant of olive oil and used in the manufacture of soap.

Fuel.

In many of the western states the cobs of corn are used for fuel purposes, and Dr. Harshberger states that three tons of corn cobs equal one ton of hard coal for fuel purposes. It is hard to estimate the value of corn cobs as a fuel. F. N. Fowler who has charge of the Lockwood elevator, one of the largest elevators along the C. & N. W. railroad in central Iowa, states that it is impossible to make an estimate of the total value of

*lc. 187.

the corn cob for fuel purposes in this state. Mr. Fowler states that while corn cobs at 50 cents a load are good for combustible purposes, they are not so cheap as slack at $1.10 a ton. Fifteen loads are equal to a ton of hard coal. Burning cobs are extremely hard on the fire brick. It should be stated that in addition to its value for fuel purposes, a fine quality of potash may be obtained from the ash of burnt cobs.

The Poisonous Effects of Grasses.

Darnel.—It is a well known fact that a number of grasses are poisonous. It was well recognized by the ancients that darnel (*Lolium temulentum*) is poisonous, for it is written: "But while men slept, his enemies came and sowed tares among the wheat."*

Darnel, when ground up with wheat and made into flour, is said to produce poisonous effects on the system, such as headache and drowsiness. This poisonous property is said to reside in a narcotic principle, Loliim, and according to Hackel "causes eruptions, trembling and confusion of sight in man and flesh-eating animals, and very strongly in rabbits, but it does not effect swine, horned cattle or ducks." Lindley† states that the grain is of evil report for intoxication in man, beast, birds, and bringing on fatal convulsions. Haller speaks of them as communicating these properties to beer. It acts as a narcotic acid poison. Darnel meal was formerly recommended as a sedative poultice. In Taylor's‡ work on poisons, the statement is made that the seeds, whether taken in powder or in decoctions, have a local action on the alimentary canal and a remote action on the brain and nervous system. He states further that no instance is reported of its causing fatal injuries to man, and as much as three ounces of a paste of the seeds have been given to a dog without causing death. Then he goes on to cite the experience of Dr. Kingsley, in which several families, including about thirty persons, suffered severely from the effects of bread containing the flour of darnel seed. These persons had staggered about as though intoxicated. It is claimed by some investigators that this plant is not poisonous. One writer claims to have made bread with

*Matthew 13: 25-30. John Smith, Bible Plants, in commenting on the above passage, states that it is not the tares or a plant commonly called tares (*Vicia sativa*), but the above grass.

†Flora Medica. London. 609.

‡On poisons in relation to medical jurisprudence and medicine. 653. *f.* 65. 1875. (3d 3) Philadelphia.

flour said to contain considerable quantity of the darnel, which was eaten without any injurious effects. There are other grasses which have a similar narcotic effect. Quite recently it has been claimed by several European investigators, notably Guerin* and Hanausek,† that the fruit of *Lolium temulentum* contains a poisonous fungus. Guerin states that the hyphae of a fungus constantly occurs in the nucellus of the seed and the layer of the caryopsis lying between the aleurone layer and the hypha portion of the wall. He also thinks that the toxic action of the Loliums is due to this particular fungus hypha. These fungus threads have not been found in *L. italicum* and but once in *L. perenne.* The fungus is allied to *Endoconidium temulentum.* The fungus lives symbiotically in the maturing grain and is therefore not a parasite. Nestler,‡ who made an examination of *L. perenne*, *L. multiflorum*, *L. remotum* and *L. festucaceum*, found nothing comparable to the fungus mycelium which occurred in *L. temulentum.* He also succeeded in demonstrating the presence of the mycelium of the fungus as indicated by Guerin. According to Nestler the *Fusarium roseum* is identical with the fungus occurring in *L. temulentum* found by Guerin.

Sleepy grass.—In the west a species of grass has received the common appellation of sleepy grass. It has long been regarded by range people as poisonous. Dr. Palmer, who found this grass in Coahuila, New Mexico, observed that it was poisonous to cattle, horses and sheep, causing them temporary sleepiness. Later Dr. Havard§ states that in 1888 he received from Dr. M. E. Taylor, of Stanton, N. M., a grass with the following statement: Hereabouts grows a grass—the eating of which by horses will, within a few hours, produce profound sleepiness or stupor, lasting twenty-four or forty-eight hours, when the animals rally and give no evidence of bad effects. It is known among cowboys as "sleepy grass" and dreaded by them on their "round ups" as their horses are liable to eat it and cannot then be kept up with the herds. The tradition is that horses that have once eaten of it will not touch it again. To quote from Dr. Havard, "From the same gentleman I received a letter in 1890, in which he says: 'Since I corresponded with Dr. Taylor it has been brought to my notice that

*Jour. d. Bot. **12**: 230. 5 *f.* **12**: 380. 1898. Bot. Gazette **28**: 136. 1899.

†Ber. d. Deutsch. Bot. Gesell. **16**: 203-207. 1898.

‡Ber. d. Deutsch. Bot. Gesell. **16**: 207-214. *pl. 13.* 1898.

§The sleepy grass. Garden and Forest. **4**: 111.

cattle are affected in a similar way to horses, and that the curious properties which so effect animals are contained in the blades. Quite a number of our horses have been ill this spring after having eaten it. It usually takes them about a week to recover, during which time they are unfit for work, and especially so during the first three days.'

Fig. 74 A. One of the grasses referred to as sleepy grass *Stipa viridula*. (After F. Lamson-Scribner Div. of Agrost. U. S. Dept. of Agri.)

"Captain Kingsbury, of the Sixth United States cavalry, under date of March, 1890, wrote me from Fort Stanton that the sleepy grass affected nearly all his horses at two camping places. It was hard work to make them walk.

"The similarity of symptoms, whether observed in Coahuila or in New Mexico, is certainly remarkable, and furnishes strong evidence of the substantial accuracy of the observations as reported. It would seem, then, reasonably established that this plant possesses narcotic or sedative properties, affecting principally horses, but also cattle and probably other animals; that animals are not fond of it, but eat of it inadvertently or when under stress of hunger; that cases of poisoning occur especially in the spring, when the radicle and lower blades first come up, and that the active principle resides in these blades, and perhaps only during that season."

The old world species *Stipa inebrians* is said to affect animals like *S. robusta* referred to by Dr. Havard.

Millets.—Several millets, and especially Koda millet (*Paspalum scrobiculatum*), are known to be poisonous and injurious. According to Grant, several well-known cases of poisoning resulted from the consumption of this grass largely used because of the scarcity of food grains. He suggests that it is due to a poisonous volatile alkaloid. There have been numerous complaints, from time to time, from the injurious effects of millet *Setaria italica* when fed to horses and cattle.

Dr. Hinebauch* states in regard to this trouble that in the winter of 1891 and 1892 a disease commonly called millet disease was prevalent to a considerable extent in North Dakota. That this disease was attended by a death rate of 7 to 10 per cent. It received the name of millet disease from the fact that from 95 to 98 per cent of the animals that were affected had been fed on millet. He says: "When millet is fed in considerable quantities it stimulates the kidneys to increased action. The urine is light colored and the bladder evacuated every two or three hours, large quantities of water being passed at each time. At the time the first symptoms of lameness were noticed, the kidneys had almost ceased to act." And then he goes on to say: "When the cause was kept up a sufficient length of time for the reaction to set in, the material which would under normal conditions be secreted by the kidneys is allowed to remain in the system and produce deleterious effects." Apparently the condition of the millet had little to do with this action. In a later bulletin† on the same subject Dr. Hinebauch reports a more extended investigation, giving considerable experimental data as well as urinary analyses. The post mortem examinations revealed some interesting facts. The cartilages on the ends of the long bones show deep furrows run-

*Rheumatism in horses. Bull. Gov. Agrl. Exp. Sta.. N. Dak. 7: 1892.

†Feeding of millet to horses. Bull. Gov. Agrl. Exp. Sta. N. Dakota. 26: 1896.

Fig. 74 AA. Shama millet (*Panicum colonum*), *a, b, c, d*, different views of the spikelet and glumes *e, f*, two views of the "seed" (Div. of Agrostology U. S. Dept. of Agrl.)

ning in a direction parallel with the motion during flexion and extension.

"Both grooves of the astragalus were partially denuded of cartilage, so that the corresponding elevations of the tibia which articulate in the grooves did not have cartilage interposed between them. The whole general appearance, instead of being of a white, glistening color, was of a dark, dull color bordering on brown. The fluid which escaped from the joint when opened, instead of being a yellow, amber color, was brown and contained red blood corpuscles, indicating that inflammation was present. The joint fluid was brownish black in color and contained red blood corpuscles.

"In conclusion we would say that our experiments here have thoroughly demonstrated that millet, when used entirely as a coarse food, is injurious to horses. First. In producing an increased action of the kidneys. Second. In causing lameness and swelling of the joints. Third. In producing infusion of the blood into the joints. Fourth. In destroying the texture of the bone, rendering it softer and less tenacious, so that traction causes the ligaments and muscles to be torn loose. The experience of many farmers with whom I have talked confirms the above conclusion, and we could multiply case after case showing that the above conditions are the results of feeding millet."

Very recently the North Dakota Station has published the results of further experiments on the subject of feeding millet. Two tests were made. In the first trial two geldings in good health were fed hay and grain for about two weeks. Millet was then substituted for hay for about ten days.

Recently Ladd* has isolated a glucoside from the aqueous extract of millet hay, which, when fed in small quantities, gave the characteristic symptoms.

From the experiments made by Dr. Hinebauch and others, it would appear that feeding millets alone as coarse fodder is injurious to horses. It produces an increased action of the kidneys, and causes lameness and swelling of the joints. It causes an infusion of blood into the joints, and destroys the texture of the bone, rendering it soft and less tenacious, so that the ligaments and muscles are easily torn loose.

In a paper on millet by A. A. Crozier,† the experience of several farmers is given as to whether millet is injurious or not. The testimony given differs greatly. Some claim it is injurious while others claim it is not. The condition of maturity seems to make a difference as to its injurious qualities.

Mechanical Injuries and Obstructions.

Awned grasses.—Under the subject of dissemination, reference was made to the subject of the fruits of stipa burying themselves in the flesh of sheep and other animals. It has long been known that the *Stipa capillata, L.*, indigenous to Russia, and the *Stipa spartea*, native to North America, as well as *Aristida hygrometrica Br.*, native of Queensland, and *Heteropogon contortus*, native of New

*Am. Chem. Jour. 20: 862.

†Millet, Bull. Mich. Agrl. Coll. Exp. Sta. 117: 14. 1894.

Caledonia frequently bore in to the skin and intestines where they cause fatal inflammation. The following very full account is from Dr. M. Stalker:* "You ask whether the fruits of the porcupine grass (*Stipa spartea*) are ever a source of inconvenience or injury to living animals? This may be very emphatically answered in the affirmative. In many of the northwestern

Fig. 74 B. Needle grass (*Stipa comata*) *a*, spikelet showing awned fruit; *b*, lower glumes removed. (After Lamson-Scribner. Div. of Agrost. U. S. Dept. of Agrl.)

counties of Iowa this grass grows in the greatest profusion, and during the latter part of June, the season for maturing and consequent falling of these spines, they are the occasion of much annoyance and in some instances the death of domestic animals. Only such animals as are covered with wool or a thick growth of long hair are seriously inconvenienced. Sheep suffer most. The spines readily find a lodgment in the wool,

*Bessey, Injuriousness of Porcupine grass. Am. Nat. 18: 929. 1884.

and after burrowing through it frequently penetrate the skin and bury themselves in the flesh. A large number of these barbs thus entering the tissues of the body produce an amount of irritation that is sometimes followed by death. I have seen large numbers of these imbedded in the skin and muscular tissues of shepherd dogs that were covered with a thick growth of soft hair. These sagacious animals frequently exihit the greatest dread at being sent into the grass during the season of danger.''

Professor Bessey in his account of the structure of this plant received several responses, and one of these was from Professor King, now of the University of Wisconsin. "In connection with the two notes relating to the fruit of the porcupine grass, it may not be without interest to say that while engaged in geological work in Dakota, north of the Northern Pacific railroad, we were much annoyed by the fruit of this grass. Indeed, I found the only way to walk with comfort through this grass was to roll my pants above my knees and my socks down over my shoes. I also observed, on several occasions, these seeds planted two inches deep in the soil with the awns protruding from the ground. It is plain that with the point of one of these fruits once entered below the soil, the swelling and shrinking, due to varying amounts of moisture, would work the seeds directly into the ground."

The *Stipa comata*, or needle grass of the west, which is common throughout the Dakotas, and throughout west Dakota, Nebraska, Wyoming and Colorado, is common in prairie hay, and Prof. Thomas A. Williams* mentions that, though a forage plant, and not cut until the needles have fallen so that the stock may not be injured, the fruit of this plant often injures stock to a considerable extent.

Corn stalks.—For a long time farmers in the west and other parts of the United States have been troubled with the so-called corn stalk disease. This has been attributed to various causes, as impaction of the stomach and a bacterial disease. Dr. Mayo, of the Kansas Agricultural Experiment Station, attributed it to an excess of potassium nitrate in the stalks.

Injuries from barley.—It has long been known that the barbed awns of barley, wild barley and other plants act injuriously in a mechanical way. In the west this is especially true of wild

*Grasses and forage plants of the Dakotas. Bull. U. S. Dept. Agrl. Div. Agrostology. 6: 20.

Fig. 75 A. Squirrel-tail or wild barley; b, spikelets; c, d, flower. (King.)

barley, *Hordeum jubatum.* Dr. S. H. Johnson,* of Carroll, states in the Carroll Herald, that this grass, when found in hay and allowed to ripen, if in any quantity, is very injurious to horses' mouths. He says: "The small awns seem to work in and cause deep ulcerating sores, which form under the tongue and lips. The writer has seen a large number affected and made a careful examination, and found them deep in the flesh, where they had remained for three months or more. I have seen lips eaten completely through and tongues eaten almost off by the grass. As to cattle, I have seen some affected, but not to any extent, because the mucous membranes are much thicker. The sooner the grass is eradicated the better."

Professor Nelson,† who has carefully studied this question, says on the injury to stock: "The awned heads, when taken into the mouth, break up into numerous sections, scatter about within the mouth and everywhere adhere to the mucus membrane, which soon becomes pierced with the long, stiff awns. As the animal continues to feed more awns are added, and those already present are pushed deeper into the flesh. Inflammation soon results and leaves the gums of the animal in a condition to be more easily penetrated. The awns are particularly liable to be pushed down and alongside and between the teeth. As the swelling and festering progresses the awns are packed in tighter and pushed deeper and cause suppuration of the gums as well as ulceration of the jaw bones and the teeth. Through the absorption of the ulcerated sockets and roots the teeth

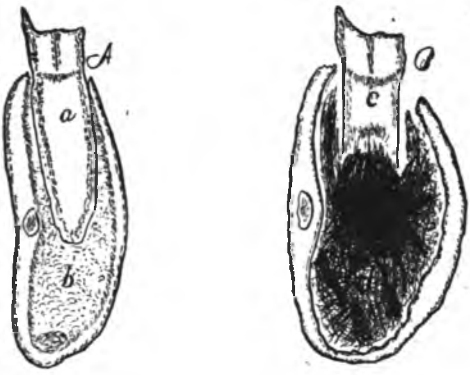


Fig. 75 *B*. Cross-section of normal jawbone; *a*, fang of tooth; *b*, marrow. B—Cross-section ulcerated and enlarged jawbone; *c*, decayed fang of loosened tooth; *d*, cavity in enlarged jaw, the embedded awns removed.

*Carroll Herald. 1895: 28 j.

†Squirrel-tail Grass. Bull. Wyoming Agrl. Exp. Sta. 19.

become loosened and even drop out, but the animal, impelled by hunger, still endeavors to eat such hay as may be offered."

There are also cases on record where these awns produce hair balls. An interesting account of hair-balls may be found in a paper by Dr. Trelease.* "Barbed trichomes and barbed

Fig. 75 C. Little barley (*Hordeum pusillum*) probably also causes mechanical injuries. (F. Lamson-Scribner Div. of Agrost. U. S. Dept. of Agrl.)

stiff bristles have been known to cause serious injury to stock Professor Coville has recently called attention to some of these coming from a plant that has had considerable advertising as a forage plant, Crimson Clover (*Trifolium incarnatum*). Professor Coville† says: "The crimson clover hair-balls, measur-

*An unusual Phyto-Bezoar. Trans. Acad. Sci. St. Louis. 7; 493. *pl. 40.*
†Bot. Gazette. 20: 414.

ing two or three inches in diameter, were taken from the stomach of horses, whose death they had caused. They were compact and much resembled the hair-balls often found in the stomachs of ruminants, but were entirely composed of the small barbed trichomes from the mature calyx of crimson clover." Millets are said also to produce "masses" probably hair-balls according to a writer* in the American Agriculturist.

Harz† has given an account of the injurious effects of oats bran. This feed favors the development of large bezoars. In the paper cited he has extensively discussed this question as well as giving references to literature.

Corn Moulds and Disease.

It is not uncommon some years to find that many ears of corn are affected with various moulds. These moulds frequently appear as the results of the attack of *Heliothis armigera*; however, this is not always the case. Sometimes only the top is affected, or only a part of the ear both at lower and upper end, or several rows may be attacked. These moulds are mostly saprophytes, and so far as known do not attack living tissues. One of the most frequent of the moulds is the green mould *Eurotium (Aspergillus) glaucus* which is described elsewhere in this paper.

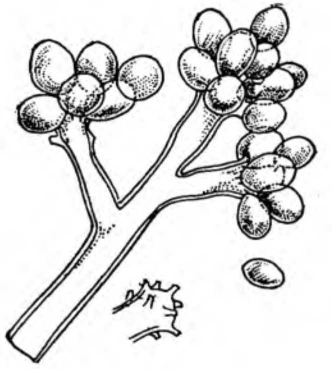


Fig. 76. Mould from mouldy corn (*Botrytes vulgaris*), showing conidiophore and spores. (Pammel and King.)

N. S. Mayo,‡ as the result of some work done in Kansas, concludes that a disease known as "staggers," "mad staggers," or as he has termed it *enzootic cerebritis* is caused by feeding corn which is attacked by *Aspergillus glaucus*. Mayo states that the spores of the fungus gain entrance to the circulation, and find lodgment in the kidneys and liver. He supports his conclusions by experiments made by him on a guinea pig and a young colt. He also quotes Kaufmann, who was successful in producing a disease with *Penicillum glaucum* and *Aspergillus glaucus*.

*1882: 127.
†Harz. Land. Samenk. 2: 1315.
‡Bull. Kansas Agrl. Exp. Station 24: 1891.

There is considerable loss in many states from cerebro-spinal meningitis. In many parts of the country this is attributed, as I have said before, to mouldy corn. Dr. Bitting,* of the Indiana Agricultural Experiment Station, made an investigation of this question and concludes that mouldy corn is not responsible for this disease. Upon an examination of mouldy corn he found several moulds and a bacterium. To test the poisonous properties, two horses were injected under the skin with five cubic centimeters of the active growth in boullion of the bacterium found in mouldy corn, and later followed by an injection of ten centimeters. Later larger amounts were given, and each animal was induced to eat as much as five pounds of the infected meal per day. One of the moulds as well as the bacterium gave negative results; the Fusarium produced a redness of the gums and some salivation. In no case did cerebro-spinal meningitis result.

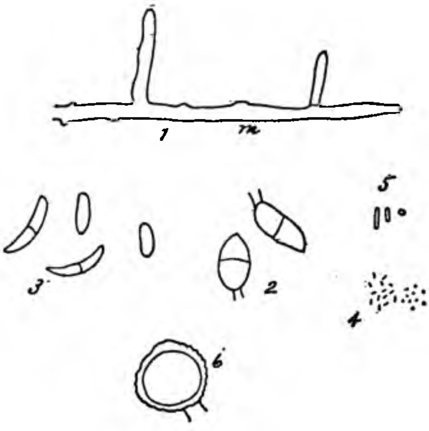


Fig. 77. Moulds and bacteria from mouldy corn. 1 and 3, Fusarium; 1, mycelium; 2 and 6, other moulds; 4 and 5, bacteria. (Pammel and King.)

The results of the experiment show that inoculations with culture of the bacteria and moulds were ineffective. Eating of the mushes containing pure culture showed that only in the case of a growth of a species of Fusarium did any intestinal disturbance follow, and that in one case the feeding of the rotted grain produced considerable intestinal disturbance and some nervous symptoms, but that the disturbance was light in the other.

Grawitz succeeded in producing infection by adapting the digestive tract of the animals to an alkaline medium. It is a

*Farmers' Bulletin U. S. Dept. Agrl. Exp. Sta. Work. XVI. 122: 26.

well-known fact that several of the moulds related to Asperillus are the cause of what is called mycosis in many of the lower animals. *Aspergillus glaucus* or, more properly speaking, the *Eurotium* (*Aspergillus*) *glaucus* is extremely common not only in hay but in many other objects, and yet this disease is very rare. This question should be further investigated.

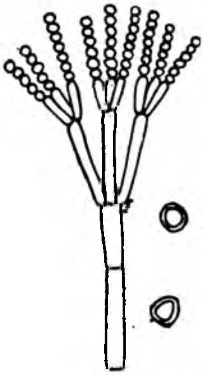


Fig. 78. Common blue mould (*Penicillium glaucum*). Spores at end of branches; spores borne in chains. (Pammel and King)

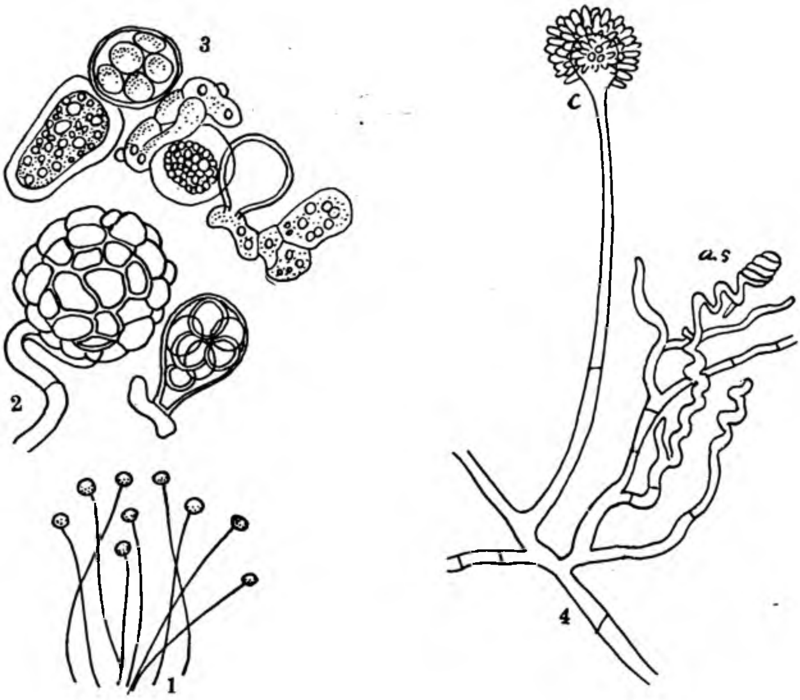


Fig. 79. Common Herbarium mould. (1) general appearance, showing long conidiophore and sterigmata on end; (2) perithecium with one of its asci and ascospores; (3) contents from an unripe perithecium; (4) a small part of a mycelium with conidiophore *c*, and spore bearing sterigmata, young ascogonium *a. s.* (DeBary except 1.)

Fungus Diseases of Grasses.

A large number of our forage plants are subject to serious fungus diseases, which materially lessen the crop. While these diseases are most severe to the cereals, where they annually entail a loss of millions of dollars, many of our best forage grasses are subject to most destructive rusts and smuts. One way to overcome these dangerous pests is in a study of their life history to see if methods of culture cannot improve the

Fig. 80. Downy mildew of millet (*Sclerospora graminicola.*) The leaves partially disintegrated; *a*, leaf magnified; *b*, conidia; *c*, conidiophore bearing conidia (spores) (Pammel and King.)

Fig. 81. *Sclerospora graminicola.* Leaves torn up into shreds, filled with oospores. (King.)

quality of the product or render the plant less susceptible to the disease. Much in the following pages has been gleaned from various sources, as well as work of our own based on experiments extending over a period of years.

DOWNY MILDEW.

This disease is caused by *Sclerospora graminicola* (*Sacc.*) *Schroet.* Though a large number of plants belonging to many different

Fig. 82. To the left leaf of *Setaria viridis* containing the oospores of *Sclerospora graminicola*, a single spore at (*a*). (After Trelease.) To the right spike affected by the same fungus; (*b*) single spikelet enlarged. (After Halsted.)

orders of flowering plants are affected by downy mildews, few of these pests are found on grasses. This fungus, though well-known for some years in Germany and Italy, has not been long known in this country. It was first reported in Wisconsin, as occurring on Hungarian grass (*Setaria italica*) and foxtail and pigeon grass (*Setaria viridis*). Dr. Halsted* reported it from Iowa on the last named host in 1886, and the next year on Hungarian grass.

It is now common throughout the state of Iowa. The fungus has been found by the writer quite as common in Nebraska as in Iowa. Webber† gives its distribution in that state, Ashland, Weeping Water (Williams), Lincoln (Bessey), where he found it on green and yellow foxtail (*Setaria viridis*, *S. glauca*). have also received it from North Dakota, where it was collected by Prof. Bolley. Like many other pests, it comes from Europe, and in all probability was brought to this country with the seed of either Hungarian or foxtail, as both grasses are native to that continent.

Little mention is made of this fungus by Tubeuf,‡ and it is not mentioned by Loverdo.§ The account by Sorauer is short. A good account was given by Trelease;‖ it was also described by Farlow.¶

Halsted,** who found it common here at Ames, reported on it in several publications.

The fungus produces a mycelium in the interior of the leaves and soon sends short branches conidiophores through the stomata. These bear the conidia, the summer reproductive bodies. Last spring I had an opportunity of observing an unusually large number of young diseased plants. A white frosty-like substance (the conidia and conidiophores) appeared on the leaf in patches extending along the veins. The opposite side of the leaf was invariably of a yellowish color. In July and August the summer spores are not so commonly seen, especially in the older leaves. Last spring the weather was quite favorable for the development of this fungus. Young plants affected soon

*Trelease. Parasitic fungi of Wis. 7.

*Bot. Gaz. 11: 272.

†App. to Cat. Fl. Nebr. Contr. Shaw School Bot. 9: 11. Trans. Acad. Sci. St. Louis. 6.

‡Pflanzenkrankheiten. 152.

§Les maladies des cereales.

‖In Beal. Grasses of No. Am. 1: 429.

¶Bot. Gaz. 9: 39.

**Bot. Gaz. 11: 272. 13: 56. Bull. Iowa Agrl. Coll. Dept. Bot. 1886: 53. Bull. Dept. Bot. Iowa Agrl. Coll. 1888: 99.

succumbed to the disease, the leaves wilted and soon rotted. Later in the season the leaves of older plants being more rigid, did not show this rotting, but many of the leaves of the affected plants are brown and torn up into fine shreds. A little shaking will bring out a large number of small round bodies, the oospores; these are enclosed in a thick cell-wall. The spikes are also frequently attacked, producing large distortions. The pistil and stamens do not develop, while the bracts surrounding the essential organs are greatly lengthened. Thus in some affected spikes of Golden Wonder millet and Hungarian grass the distortions were so large that they were not recognizable. The oospores are so numerous as to fill up the tissue between the epidermal cells. The oospores serve to carry the fungus over winter. It is not a difficult matter, if the seed is purchased from an infected district, to carry the disease to remote distances, as it is a comparatively easy matter for some of the bracts containing spores to get in with the seed, or for some of the spores to become attached to the seeds.

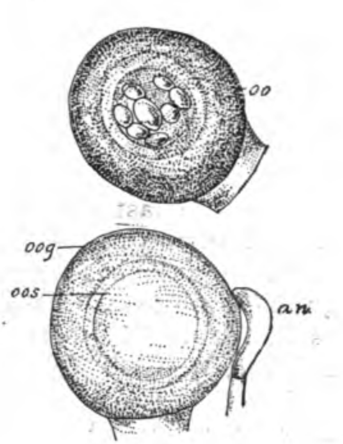


Fig. 83. Downy mildew of Hungarian grass *Sclerospora graminicola; oog*, oogonium; *oos*, oosphere; *an*, antheridium; *oo*, oospore. (Pammel and King.)

Mildew of Indian corn.—In a recent German scientific periodical, M. Raciborski describes a very destructive downy mildew of corn which he has named *Peronospora maydis.* Many of the fungi of this group cause great loss, as for example the potato rot fungus, downy mildew of the grape, and others which might be mentioned. This fungus of the corn is no exception to the rule. It has been found but in one place in Java. No doubt, however, it will spread and may yet become a source of danger to us. The fact of its occurrence in Java is of interest, because corn is not native there. The author looked for it on native grasses, but failed to find any indications of its occurrence.

Where did the fungus originate? Most probably on some other grass and from that spread to the corn. The descriptions and figures suggest the similar European fungus on millet, *Sclerospora graminicola* described above. In Java the fungus is known as "lijer" which means sleepy or tired. It makes its appearance on young plants. The second and third leaves are usually green. On the fourth and subsequent leaves the disease is easily recognized from a distance, as the plants are white or yellowish white. Either the entire leaves are affected or it forms bands. The young plants fall over. In the tissues of such plants an abundance of an undivided mycelium occurs It has numerous haustoria or suckers which enable the mycelium to take up its nourishment. On the surface of the leaf may be seen a thick white mold, the fruiting threads of the fungus. These make their way through the stomata and bear summer reproductive bodies which germinate in a few hours. Young infected plants show these fruiting bodies in eight to twelve days.

In addition to these reproductive bodies resting spores known as oospores also occur abundantly, especially in the stems and leaf sheaths. Natural infection results by the wind which carries the spores, also from the oospores which may retain their vitality for some time. The writer suggests that the young diseased plants be pulled up with the root and burned. It is not likely that this fungus has been found on corn in this country. It may be expected, however, somewhere on this side of the Atlantic and may prove injurious.*

ERGOT (CLAVICEPS PURPUREA (FR.) TUL).

The subject of ergot is one of considerable importance to the Iowa stockman. Scarcely a year passes but complaints are received about the injurious effects to cattle from the use of fodder that contains ergot.

History.—It may not be out of place to briefly refer to the history of ergotism. Epidemics of ergotism have, without doubt, been correctly referred, even before the tenth century. Wood states that epidemics of ergotism or chronic ergotic poisoning have been recorded from time to time since the days of Galen (130–200 A. D.) and of Caesar (B. C. 190–44). From the ninth to the thirteenth century epidemics were frequent in France, and in the twelfth in Spain. They were first called plagues but later received special names. In 1596 Hesse and adjoining provinces were visited by this plague which was attributed to the presence of ergot in grain. In the epidemic in Silesia in 1722, the king of Prussia ordered an exchange of

*L. H. Pammel. Mildew of Indian Corn. American Agriculturist 61: 708.

*Raciborski Lijer, eine gefahrliche Maiskrankheit. Ber. der Deutsh. Bot. Gesell. 15: 475-478. 1897.

Fig. 84 Ergot on blue grass; to the right leaf of blue grass with uredo pustules of ***Puccinia poarum.***

Fig. 85. **Ergot (*Claviceps purpurea*) on Agropyron. (King.)**
Fig. 86. **Ergot on blue grass 1. Ergot on wild rye 2. (After Salmon.)**

sound rye for the affected grain. Freiburg was visited in 1702, Switzerland in 1715–16, Saxony in 1716, and other districts of Germany in 1717, 1736, 1741–42. France was visited in 1650, 1670 and 1674. From 1765 to 1769 it was abundant in Sweden in rye and barley. Linnaeus attributed it to the grain of *Raphanus raphanistrum*, which was incorrect. The last great epidemic in Europe occurred in France in 1816, in Lorraine and Burgundy; it was especially fatal to the poorer inhabitants.

It has been observed that these epidemics follow a rainy season. Fleming states that in 1041, when the weather was so unpropitious, tempests, rains, and inundations occurring, many cattle perished from the disease. "In 1098, after inundations and heavy fogs, there was a general epizooty among cattle in Germany. In the same year ergotism appeared in the human species."

History in America.—Dr. Randall, in 1849, called attention to a disease in New York, in which the involved parts were finally invariably affected with dry gangrene. He states that in the severe climate of New York farmers allow their cattle to winter in the fields on blue grass (*Poa pratensis*) which is rich in ergot. A disease known as "hoof-ail" was correctly ascribed to ergot by James Mease, of Philadelphia, prior to 1838. The disease was quite severe in Orange county, New York, in 1820. It was minutely described by Arnell. In 1857 the disease was quite severe in Portage county, Ohio. A committee appointed by the Farmers' Association of Edinburg reported that the disease was due to ergot in hay. In recent years* epizootics of ergotism have been reported by Law in New York, Stalker in Iowa, and Faville in Colorado. The most serious outbreak in recent years occurred in Kansas in 1884. This caused considerable excitement since at first it was diagnosed as "foot-and-mouth disease." Salmon, who examined some of the hay from several localities in Kansas, found a large proportion of wild rye (*Elymus virginicus*, var. *submuticus*) to contain a large quantity of ergot. In one case 12 per cent, and in another 10 per cent was found. From this he estimated that from 5 to 6 per cent of the entire weight of the plant must have been ergot and that a twenty-pound ration of hay would contain four ounces of ergot.

*See Salmon on Contagious Diseases of Domestic Animals. 1883-1884: Where an extended history is given, and Fleming Animal Plagues, their history, nature and prevention. 1: 1871. 2: 1882.

Nature of ergot.—Ergot is a stage of a minute parasitic fungus. Although its true nature was not known by early writers, it is mentioned by many of the earlier botanical writers. Lonicer*, about the middle of the sixteenth century, mentions

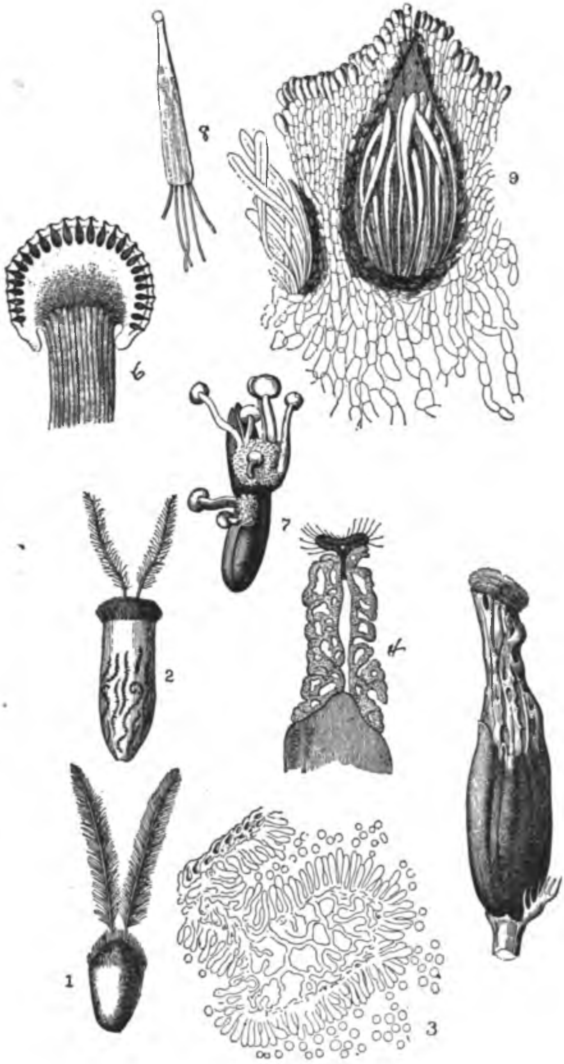


Fig 87. Ergot (*Claviceps purpurea*). *1*, normal ovary of rye; *2*, young ovary of rye infested with ergot; *3*, cross section of ovary showing mycelium and spores on surface, the sphacelial stage; *4* upper part of ergotized grain with spongy sphacelial mass; to the right of *4* mature ergot; *7*, ergot germinating; *6*, section through club-shaped mass and flask-shaped perithecia; *9*, perithecia enlarged with asci; *8*, ascus with ascospores. (After Tulasne from Salmon.)

*Kreuterbuch. 285. 1582.

its specific use. Thalius* (1588) applied the name of "ad sistendum sanguineum."

Bauhin† used the name of *Secale luxurians.* De Candolle‡ applied to it the name of *Sclerotium clavus.* Although other names have been applied to it, the credit of working out the life history belongs to Tulasne, one of the most eminent of French mycologists.

Characters of the fungus and development.—There are still many persons who believe that ergot is a degenerate kernel of rye or wheat, but the researches of Tulasne and other mycologists have laid at rest many of the vague theories concerning it. The black, purple, or dark gray spurs found in the flowers of rye, wheat, and other grasses are simply one stage of a parasitic fungus, known as *Claviceps purpurea,* Tul. These spurs consist of a compact mass of threads known as the sclerotium stage; it was formerly called *Sclerotium clavus.*

No changes occur in ergot while it remains in the head, but the following spring, when laid on damp earth, it produces at different points small, roundish patches which are somewhat elevated. Soon a small white head appears which elongates, becoming stalked, and bearing a globular head at the tip. These heads change from a grayish yellow to a pinkish color. A cross section shows that the central portion is made up of closely woven hyphae or fungus threads, while the edge contains a number of flask-shaped bodies, the perithecia, in which are found elongated bodies known as asci; each ascus contains eight filiform spores, the ascospores. The ascospores germinate and when coming in contact with a very young ovary the mycelium penetrates the delicate walls of the ovary and gradually displaces it. It is quite easy to trace out its life history by placing the ergot in damp sand and allowing it to remain over winter.

The first indication of ergot in the summer is the formation of the so-called honey-dew, a sweetish and rather disagreeable fluid, which is eagerly sought by flies and other insects which feed upon it. This fluid contains a large number of small spores, so that insects can readily carry the fungus from a diseased ovary to one not diseased. These spores germinate immediately. This stage is called the sphacelia, and formerly was held to be

*Silva Hercynia. 1588. 47. Francfourt.

†Pinax. Theatri Botanica. 23. 1623.

‡Mem. du Mus. 2: 401. *pl. 14. f. 8.*

a distinct fungus. In this stage the mass which has replaced the ovary is soft, but as it becomes older it hardens; ultimately a hard and compact mass, the ergot, is formed.

Chemical composition of ergot.—The grain contains about 30 per cent of a yellowish oil, consisting of fats, principally olein and palmitin. It contains, according to Wenzell, two alkaloids, ecboline and ergotine, which are said to be the active principles of the drug Another alkaloid, ergotinine, has also been isolated, but according to Kobert,* ergot contains three poisonous substances. These are cornutin, an alkaloid having a specific action on the uterus, causing it to contract; sphacelic acid, a non-crystalizable and non-nitrogenous substance which causes the poisoning and gangrene; ergotinic acid, a nitrogenous glucoside without action on the uterus and narcotic in its effect. Besides these substances it contains others, prominent among them being a sugar called mycose, which is also present in other fungi.

Medical use.—Ergot has long been used in medicine on account of its specific action on the uterus. Its effects are (1) gastroenteritic, causing salivation, inflammation and diarrhoea; (2) a dry gangrene of the extremities, hoofs, ears, tail, etc.; (3) contraction of the uterus and, as a consequence, abortion; (4) want of feeling, lameness.

Cereals affected.—Rye is more subject to it than any of the other cultivated cereals. The largest specimens are usually produced on isolated specimens of rye coming up in fields. It seldom happens that all of the ovaries are affected. Wheat, especially winter wheat, is subject to the disease. The officinal ergot is usually obtained from rye.

Wild grasses.—Of our native grasses, wild ryes (*Elymus robustus*, *E. virginicus*, *E. striatus*, *E. canadensis*, *Asprella hystrix*) are most subject to the disease. Most cases of ergotism in this state undoubtedly result from the ergot of *Elymus robustus*, which is a common everywhere. *Agropryon spicatum*, a grass not uncommon in northwestern Iowa, and Quack grass (*Agropyron repens*), are also much subject to its attacks. Scarcely a head of the two species cultivated on the college farm could be found which did not have some ergot. This may be for the same reason that it occurs most abundantly on rye, namely, that the grasses occurred in isolated places. In some pastures, timothy (*Phleum pratense*), is much subject to the attack of *Claviceps*

*Froebner: Lehrb. d. Toxologie f. Thierarzte. 1890.

purpurea. Thus in Wisconsin I observed a large percentage of timothy in an old pasture which contained many heads which were ergotized. Blue grass (*Poa pratensis*), *Poa annua*, *Calamagrostis canadensis*, *Agrostis vulgaris*, *Glyceria fluitans*, and many others, in some seasons and localities, are diseased.

Other forms of ergot.—It may be possible that some of the forms of ergot on grass may be referred to other species. Halsted states, however, that the ergot on *Elymus robustus* is *Claviceps purpurea*. The *Hordeum jubatum* contained apparently the same species, with some minor differences but these are due to the nature of the host.* The *Claviceps microcephala* (Wallr) Tul. occurs on *Phragmites*, *C. setulosa* (Quel) Sacc with a yellow stroma on Poa, and *C. pusilla Ces* on *Andropogon Ischaemum*.

Preventative measures.—With modern methods of cleaning cereals there need be little fear of the presence of ergot in flour but it still continues to be a decided menace to cattle, especially where it develops in our grasses, as timothy, blue grass, red top, and wild rye. It is imperative to cut all of these grasses before the ergot is mature. The presence of ergot in these wild grasses no doubt causes its spread to wheat and rye fields. Von Thumen thinks that the *Lolium perenne*, so commonly cultivated in Europe, is largely responsible for its abundance in Austria.† He emphasizes the importance of cutting the grass in waste places several times during the year to prevent the formation of ergot.

CAT-TAIL FUNGUS.

Cat-tail fungus, *Epichloe typhina* (Pers.) Tul. This fungus was described by Persoon‡ as *Sphaeria typhina* in 1801 and by him recognized as parasitic. Tulasne§ transferred it from the genus Sphaeria to that of Epichloe. It has been described from an economic standpoint by several mycologists—Sorauer‖, De Bary¶, Trelease**, Frank†† and Tubeuf‡‡.

This fungus is occasionally very abundant and destructive to timothy, and occurs occasionally on other grasses, notably

*Bull. Dept. of Bot. Iowa Agrl. Col. Ames. 1886: 19.
*Bull. Dept. of Bot. Iowa Agrl. Col. Ames. 1888: 8.
†Die Bekampfung der Pilzkrankheiten unserer Culturgewaechse. 36.
‡Syn. method. fungorum. 29.
§Selecta fungorum. 3: 24.
‖Pflanzenkrankheiten. 410.
¶Flora 1863: 401 Bot. Zeit. 1865: 100. (According to Sorauer, 411).
**In Beal. Grasses of No. Am. 1: 423 (Ed. 1.)
††Krankheiten d. Pflanzen 458. *f. 81* (Ed. 2.)
‡‡Pflanzenkrankheiten. 207.


Fig. 87A. Cat-tail fungus (*Epichloe typhina*) on timothy. (King)

Poa, Elymus and Dactylis. The fungus produces a whitish stroma, which surrounds the grass culm near the upper leaf sheaths This velvety ring consists of a loosely arranged mycelium which takes the nourishment from the grass plant, causing the parts above the ring to die, since it prevents the conductingof food to the leaves above. This stroma produces small, one-celled conidia borne on conidiophores. As the stroma becomes yellow, deep-seated perithecia occur. These contain the asci in which eight hyaline ascospores are found. The fungus spreads from a center of infection to neighboring stalks, especially by means of the conidia. To prevent the fungus from spreading it is advisable to cut the grass at the time the fungus appears on the young plants.

HYPOCRELLA (HYPOXYLON (PK. SACC.)

This fungus is closely related to the preceding. It produces a thin grayish stroma which usually becomes black and extends along the upper surface of the leaf or surrounds the culm. The perithecia are small and crowded; the asci narrow and linear; the ascospores linear, colorless, with numerous nuclei.*

The fungus attacks living grass, stems and leaves.

POWDERY MILDEW OF GRASSES.

The powdery mildew (*Erysiphe graminis* D. C.) is a serious fungus disease at times. It was described by DeCandolle† and has been noted by several writers.‡

Every one who has had occasion to walk through a blue grass meadow after a rain, especially in damp and shaded places close to the ground, must have noticed a white mealy covering on the blades of many of the leaves. The Germans have called this mehlthau (literally translated meal dew) which

*Saccardo Syll. Fung. 2: 581.
Ellis and Everhart. N. Am. Pyrenenycetes. 91.
Peck. Rep. Mus. State Nat. Hist. 27: 108.

†Fl. Franc. 6: 106. For synonymy see Loverdo Les Maladies Crypt. 212.

‡Sorauer. Pflanzenkrankheiten. 331.
Frank. Krankheiten d. Pflanzen. 554. (Ed. 1.) 264. *f. 51.* (Ed. 2.)
Tubeuf. Pflanzenkrankheiten. 194.
Trelease in. Beal. Grasses of N. Am. 1: 423.
Pammel. Fungus diseases of Iowa Forage Plants. 14-15.

is certainly very expressive of its appearance. An examination with a microscope will show that this white substance is composed of spores and a mycelium. The mycelium is cobwebby and spreads over the surface, but does not penetrate the leaf. In numerous places erect branches are produced, these bear numerous spores. This stage was formerly called *Oidium monilioides.* Called Oidium because the spores resemble an egg. In all cases of Oidium this is not true; the species was called monilioides because necklace like, referring to the manner in which the spores are borne. Worthington G. Smith states the spores are so numerous that it would take about a million spores to cover a square inch.

These conidia or summer spores germinate, under favorable conditions, in from ten to sixteen hours. The temperature most favorable for germination is from 17–26 C. In a powdery mildew occurring on the squirrel-tail grass, and supposed to be the same fungus, these spores are also capable of immediate germination. On blue grass the fungus frequently does not produce perithecia but ends its existence with the formation of conidia.

Under favorable conditions, especially moisture and damp weather, the fungus spreads rapidly. The leaf of grass affected by this fungus soon dries up. When the leaves have become dry and the affected plants are disturbed a little, clouds of dust arise, especially in shady places. The perfect stage of the fungus is not of common occurrence, though if careful search is made in the fall, small black specks may be seen; these are the perithecia and contain the asci and ascospores. It is the resting stage or winter condition of the fungus. The writer found the perfect fungus abundant on *Poa wolfii* in Colorado, and Carver found it abundant on blue grass near Ames one season. The Oidium stage does not retain its power of germination very long, but the ascospores contained in the perithecium germinate the following spring, and when the tube comes in contact with the proper host the mycelium spreads over the surface of the leaf and causes the mealy appearance.

Plants affected.—It affects especially blue grass with us and is much worse some seasons than others. English investigators report that this fungus is most abundant when slight frosts occur, also with heavy rains and wet soils. Texas blue grass (*Poa arachnifera*), fowl meadow grass (*Poa serotina*), *Eatonia obtusata*, and red top (*Agrostis alba vulgaris*) and many

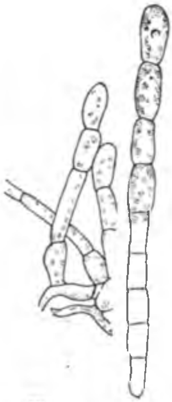


Fig. 88. Oidium of *Erysiphe graminis* on wild rye (*Elymus robustus*).

Fig. 89. Powdery mildew of blue grass (*Erysiphe graminis*), leaf of blue grass curled; to the right the leaf more magnified, the black spots perithecia, to the right perithecia more magnified. (King.)

Fig. 90. Powdery mildew of bluegrass, *Erysiphe graminis*, Oidium stage. The leaf to the right hand magnified, the one to the left more magnified, showing the powdery substance.

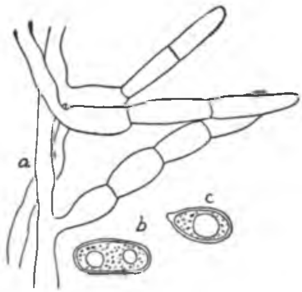


Fig. 90A—*a*, mycelium and erect conidiophores; *b*, *c*, conidia.

of the grasses when grown in moist, shady places, and becoming rank, suffer from this disease From this it would seem that proper drainage would alleviate the trouble. In England wheat is commonly affected and greatly injured. In moist and shady places in this country it is affected. Eriksson reports the fungus severe on wheat at Stockholm, Sweden. Barley and oats are also affected. Von Thumen* states that the fungus is abundant on *Lolium perenne* and *Dactylis glomerata*. The writer has observed it abundantly on several species of Poa, especially *Poa wolfii*, near Golden, Colorado.

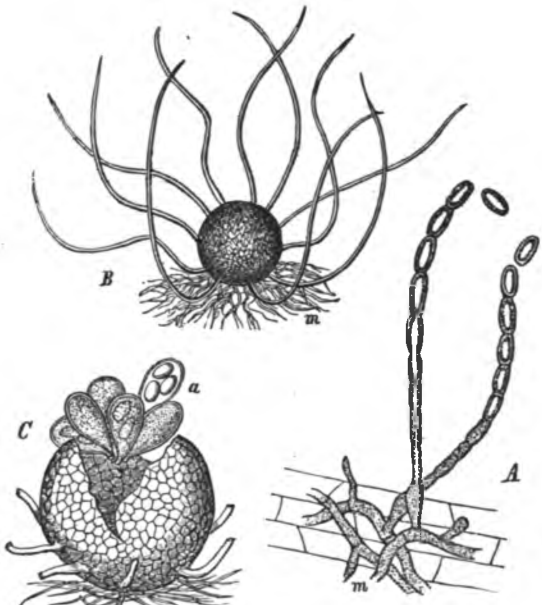


Fig. 91. Powdery mildew of grass (*Erysiphe graminis*). *A*, Oidium stage and mycelium *m*; *B*, perithecium with appendages and mycelium *m*; *C*, perithecium with asci and ascospores. (Frank.)

*Bekampfung d. Pilzkrankheiten. 39.

GIBBELLINA CEREALIS, PASS.

Passerini,* who described this fungus in 1886, states that it was very destructive. Later Cavara† published an extended account of the fungus and has given us the details of its life history. Loverdo‡ likewise describes it. The culm of affected plants is very weak and does not produce fruit. The culm above the first node above the ground shows a grayish-brown circular spot. Later these spots lengthen and become confluent. The spots are covered with a mouldy mycelium which

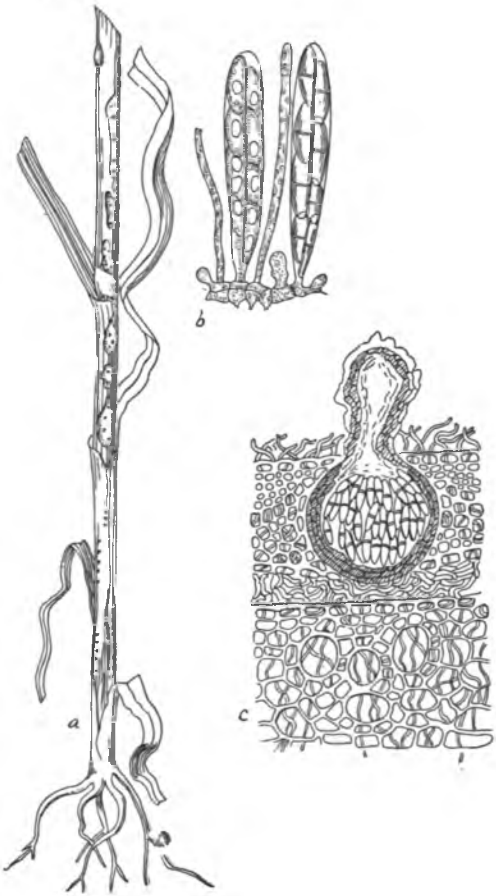


Fig. 92. Stem blight, *Gibbellina cerealis*; *a*, general appearance; *b*, asci with ascospores and paraphyses; *c*, stroma, mycelium and perithecium. (Cavara.)

*Bol. de Comiz. Agr. Parm. 1886:
†Ueber einige parasitische Pilze. Zeit. f. Pflanzenk. 3. 16.
‡Les Maladies. Crypt. 225.

sometimes nearly encircles the stem. The lower leaves are dead. The mycelium consists of thick, branched, hyaline septate threads, which spread over the surface of the host, sending haustoria into the cells. The erect threads bear oval or ellipsoidal spores after the fashion of an Oidium. These spores propagate the fungus during the summer. Later immersed perithecia are formed, arising from a deep, white stroma. The perithecia consists of somewhat flattened cells. In the interior occur numerous paraphyses and asci. The club-shaped asci contain eight two-celled yellowish-brown ascospores arranged in two rows. The fungus apparently enters the plant through the delicate tissues of the germinating seedling.

BLACK SPOT DISEASE OF GRASSES.

The *Phyllachora graminis* (Pers.) Fuckel occurs on many cultivated and wild grasses; other species occur on clover and other leguminous plants. This parasitic fungus disease cause blackish spots on the lower or both surfaces of the leaf. The fungus causing these black spots on grasses has been called the black spot disease of grass. This was first described by Persoon* as *Sphaeria graminis.* Fuckel† made the correct combination. It is generally so called by mycologists.

During August, and especially later, the coal black spots along the veins are especially prominent; they are considerably

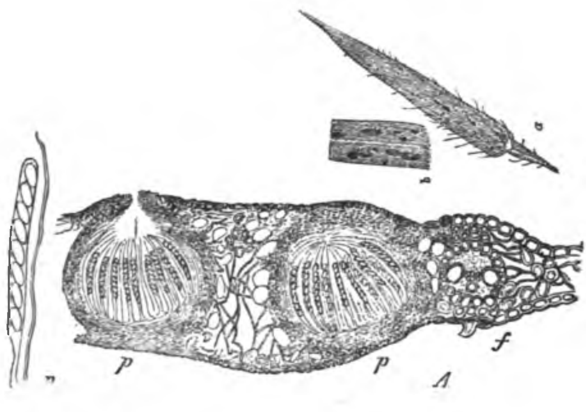


Fig. 93. Black spot disease of grass (*Phyllachora graminis.*) *A*, showing cross-section of leaf through a black mass; *B*, an ascus with spores enlarged. (*A* and *B*, Frank; a after Trelease.)

*Syn. 30. Dothidea graminis. (Pers.) Fr. Sys. V. 387.

†Symb. Myc. 216. Saccardo Syll. Fung. 2: 602. Ellis and Everhart. N. Am. Pyreno. 599 *pl. 40. f. 1-4.*

less than one-eighth of an inch in length and width. They occur on both surfaces of the leaf, but are more abundant on the upper. These black spots are composed of a dense mycelium, which in the green leaves bears numerous small spores which serve to propagate the fungus in the summer. In dead leaves small perithecia are found, which contain numerous elongated bodies, the asci within which are found eight small, colorless spores, known as ascospores; these latter carry the fungus over the winter. In Iowa the grasses most commonly affected by this fungus are quack grass (*Agropyron repens*), wild rye (*Elymus robustus*), *Asprella hystrix*, and *Panicum Scribnerianum.* Occasionally this fungus is quite destructive. Frank,* Tubeuf,† Trelease‡ and Pammel have given accounts of this fungus.

BROWN SPOT OF WHEAT HEADS.

The *Phoma hennebrgii*, Kuehn on wheat was first detected by Kuehn.§ Frank‖ has noted it in Germany and Eriksson¶ for Sweden. This fungus causes brown spots on the sterile and flowering glumes In these spots small perithecia occur. These contain small, one-celled conidia. The kernels become spotted and shriveled. Whole fields may be affected. Related to this is the *Phoma lophistomoides*, Sacc., which is a saprophyte, according to Cavara.** The perithecia are small, 60–80^u in diameter, with an oblong ostiolum, and are immersed in the tissue. The spores are small and thread-like, rounded at the ends, 8-10^u long, .5–.75^u wide.

BROWN SPOT DISEASE OF GRASSES.

The *Septoria graminum*, Desm has received the name of "Take-all" in Australia on account of the nature of its destructive work. N. A. Cobb says: "Taking the occurrence in spots, as a starting point, I determined to see whether some other characteristic symptom could not be made out, and in this I was partially rewarded, for I found in the great majority of cases that the plants dried up when young, mysteriously as some farmers said, and left the ground bare or covered with weeds. This will seem old news to farmers and hardly worth as much

*Krankheiten der Pflanzen. 2: 455. *f. 80.* (Ed. 2.)
*Pflanzenkrankheiten. 243.
†In Beal. Grass of N. Am. 1: 424.
‡Fungus Diseases of Iowa Forage Plants. 24.
§Rabenhorst Fung. Europ. 2261.
‖Zeit. f. Pflanzenk. 3: 28.
¶Mitth. d. K. Akad. Stockholm. 1890.
**Ueber eine parasitische Pilze. Zeit, f- Pflanzenk. 3: 23.

attention as I have given it, yet it is not without a reason that I have made so much of it, as will soon be seen. Moreover, I found the wheat in nearly all well attested cases of 'Take-all' to be infested with two fungi, namely, *Cladosporium herbarum* and *Septoria graminum.* Both these fungi have long been known

Fig. 94. (*a*) *Septoria bromi* on *Bromus secalinus*, small black spots on leaf the perithecia.

Fig. 95. Spores of *Septoria bromi.*

to botanists, but it is only within recent years, when vegetable pathologists have begun to enquire carefully into the causes of the various diseases of useful plants, that both the Cladosporium and the Septoria have been found to be serious pests in the grainfield.''

This fungus disease is common to many grasses and is quite destructive at times. It was described by Desmasier*. It is common, not only in this country but in Europe as well. Eriksson† reports it as common in Sweden and Cavara‡ says it is on the increase in Italy. Cobb§ remarks on its common occurrence in Australia. Trelease‖ discussed it in his work on fungi injurious to grasses and clovers. It is most injurious to wheat and here it causes the young plant to turn a yellowish-green, then becomes yellow. The leaf finally dries and withers. It appears on the sheaths and culms. The interior of the plant contains an abundance of the mycelium. In the dead spots of the leaf may be seen small black specks—the perithecia, which are either aggregated or scattered. These perithecia contain hundreds of small, several-celled spores, 40–50^{u} x 1–15^{u}. They are said by Cavara not to be divided. The spores are, however, occasionally two celled.

In a somewhat extended account of this disease Cobb states that the entire plant is not always involved. It is a variable fungus, its character depending upon the host which it attacks. On *Poa annuus* the leaf is mainly involved and in many cases is totally destroyed. Cavara¶ states that the spots on the leaves are small, elliptical, red or yellow, or the latter may be entirely absent. The injury it does to the young plant is very great; in some cases their total destruction has been observed.

Janczewski** who has studied the life history of *Septoria graminum* states that this represents the pycnidial stage of *Leptosphaeria tritici* and that the conidial form is the *Cladosporium herbarum*.

*Ann. Sci. Nat. Bot. II. 19: 339. 1843.

†Eriksson. On nagra sjukdomar a odlof vaxter samt om atgarder till motarbetande af vaxtsjukdomar. 20.

Tubeuf. Pflanzenkrankheiten. 491. Mangin also states that it is parasitic. See Jour. Roy. Mic. Soc. 1898: 568.

Loverdo. Les maladies crypt. 283.

‡Zeit. f. Pflanzenk. 3: 19. Also Briozi. Zeit. f. Pflanzenk. 3: 216.

§Plant diseases and their treatment. Agrl. Gaz. New So. Wales. 3: 991.

‖In Beal Grasses of No. Am. 1: 428.

¶l. c. Zeitsch. f. Pflanzenk. 3: 19.

**Bull. Acad. d. Sc. Cracovie 1892: See Frank Krankheiten. d. Pflanzen. 302. 419. *f. 63.*

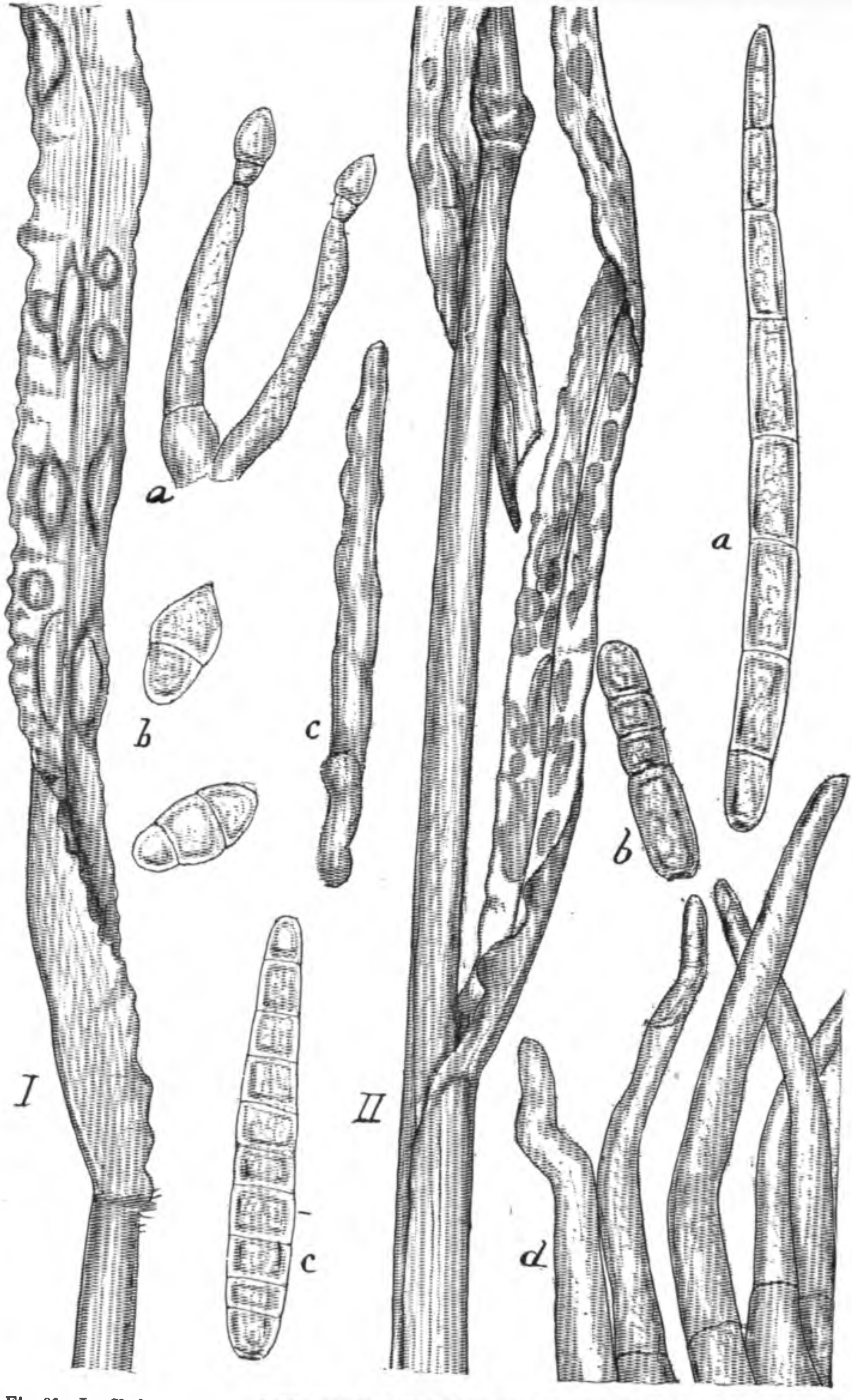


Fig. 96. I. *Cladosporium herbarum* on oats; (*a*) conidiophores and conidia; (*b*) conidia; (*c*) conidiophore. II. Cercospora on barnyard grass; (*a*, *b*, *c*) conidia; (*d*) conidiophores. (Pammel and King.)

The *Septoria tritici* Desm. is closely related to the above and should perhaps be regarded as nothing more than a variable form of *S. graminum.* The spots it produces are at first yellow, then reddish-brown, and finally whitish. The spores are 50–60^{u} long by 1.5^{u} to 2^{u} wide and usually divided. A Septoria has been reported on the glumes of wheat in Ohio by Selby.*

Several other species of Septoria are allied to the above species, one, the *Septoria bromi* Sacc. is common in this state on *Bromus secalinus.*

CLADOSPORIUM HERBARUM (PERS.) LINK.

This fungus is destructive in parts of Australia, and has been reported on the increase in Europe by Frank‡, it also occurs in this country as reported by Peck. The writer has likewise observed it on wheat and oats in Iowa. Harvey reported it on oats in Maine. On wheat it is commonly referred to as blight. It attacks all parts of the plant but is especially common in the heads. The mycelium of the fungus grows not only on the surface of the plant but also in the interior. The conidiophores and spores are olive green. The conidiophores pass through the stomata or break through the epidermis. The spores are one to two-celled and are borne on the end or on short lateral branches. The spores are extremely variable in shape and size.

The general effect of the disease is to cause the kernels to shrivel. The disease occurs rather destructively on oats as recorded by Cobb.§ Professor Peck‖ records the occurrence of a Cladosporium on oats, which he describes as a new species, the *Fusicladium destruens.* He says in regard to oats. "The foliage of the plants presented a singular admixture of green, dead-brown and reddish hues, strongly suggestive of that of a 'rust-struck' field." Peck thinks this fungus inhabits the leaves of some of our northern grasses and has escaped from them to oat fields. Mr. F. C. Stewart made a study of Cladosporium while at Ames, finding it on many wild grasses, especially blue grass. Giltay¶ reports that plants are infected in the same way as in some of the grain smuts, the spores being carried

*Bull. Ohio Agrl. Exp. Sta. 97: 42.

†Cobb. 3: 991.

‡Ueber die Befallung durch Cladosporium und Phoma. Zeit. f. Pflanzenk. 3: 28. Rep. Maine State Coll. 1894; 96. *f. 3.*

§Cobb. 3: 1000.

‖Rep. N. Y. State Mus. of Nat. Hist. 43: 9. *pl. 3. f. 19. 22.* 1890.

¶Ueber die Schwarze des Getreides. Zeit. f. Pflanzenk. 3: 200.

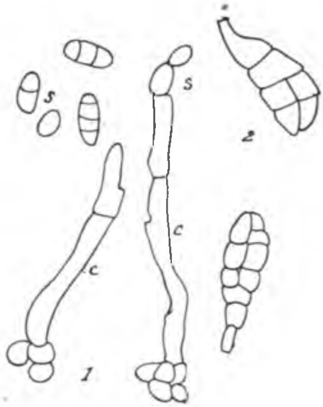
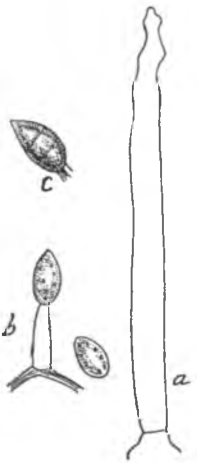


Fig. 97. Cladosporium and other fungi on kernels of corn. Kernels of corn injured on top.

Fig. 97A. Cladosporium-like fungus. S, spores; *c.* conidiophores; 2, Macrosporium.



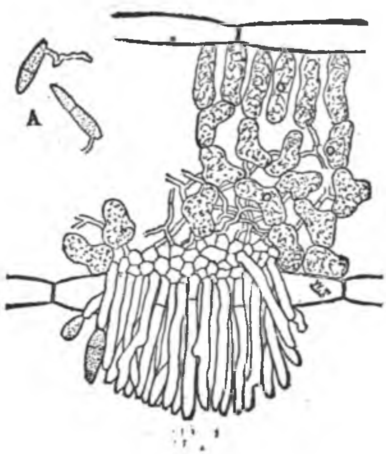


Fig. 97B. Cladosporium Zeae from corn kernels; *a*, conidiophores; *b*, *c*, spores.

Fig. 98. Spot Disease of Orchard Grass (*Scolecotrichum graminum*) Cross-section of leaf, general fruiting layer of fungus with conidiophores and conidia; *A*, spores germinating (Trelease).

over by the fruits, and that the disease can be prevented by treatment with hot water. A species of Cladosporium commonly affects the kernels of maize, at times quite troublesome. According to Peck the *C. Zeae* Pk. is parasitic and attacks the unripened grasses.

SPOT DISEASE OF ORCHARD GRASS.

Of the many imperfect fungi which attack grasses, one of the most serious is the spot disease (*Scolecotrichum graminis*), described by Fuckel.* The only extended economic account was made by Trelease,† in 1886. There are also shorter accounts by the writer.‡ This fungus is especially common on orchard grass. It is reported as destructive on timothy and oats by Eriksson.§ It also occurs on timothy and at times is quite destructive. It produces what is sometimes called rust. The writer has also found it on barley. Tubeuf‖ reports it on oats. It has, however, never been noticed on this host in Iowa. Trelease,† describing the occurrence of the fungus about Madison, Wis., says: "When the basal leaves of orchard grass had reached their full length, my attention was attracted by a very abundant discoloration of this species, sometimes confined to the extremity of the leaves, sometimes extending nearly to their base. So far as my observations went, nearly every stool of orchard grass was affected."

The first indication of the fungus is an elongated brown or purplish-brown spot. In older specimens the centers of these spots are gray or whitish and contain minute black dots. These small dark spots contain the tufts of brown fungus threads, which make their way out through the stomata. These fruiting hyphae bear small, smoky-brown, two-celled spores. The fungus causes the cells of the leaf to become much altered, because the colorless threads of the fungus permeate them. The hyphae are sometimes septate and the spores are usually borne at the end or occasioally in a lateral position. On barley the disease is marked by brown or purplish-brown spots which appear on the leaf transversely. Trelease notes that the season of 1886 was a very dry one, very little rain having fallen for several months.

YELLOW LEAF DISEASE OF BARLEY.

The yellow leaf disease (*Helminthosporium graminum*, Rabh) is one of the most destructive of the parasitic diseases affecting barley in Iowa. The fungus has been known for a considerable length of time in Europe, where it was first described by

*Symb. 107. Saccordo. Syll. Fung. 4: 348.
†Beal. Grasses of North Am. 1:428.
†U. S. Dept. Agrl. Rep. 1886: 129.
‡Pammel: Fungus Diseases of Iowa Forage Plants.
‡Pammel: New Fungus Diseases in Iowa. Jour. Myc. 7: 96.
§Bidrag till kannedomen om vara odlade vaxters sjukdomar. 185. *pl.* 9.
§Sorauer. Just. Bot. Jahresb. 1885: 502.
‖I. c. Pflanzenkrankheiten. 526.

Rabenhorst and found by Caspary.* The writer has published several notes on this fungus.† It is closely allied to several species of Helminthosporium. Mr. Ellis, to whom specimens were submitted, writes that the fungus is, without doubt, Rabenhorst's *Helminthosporium graminum* and this is the same as *H. inconspicuum*,‡ C. & E. and Passerini's *H. turcicum.*§ The specimens in Ellis North American fungi were found on dead leaves of *Zea mays*. Passerini's specimens were also found on the species and he attributed it to the fungus he has described. Briosi and Cavara‖ have described, figured, and distributed the same fungus in their collection of parasitic fungi. The spores of these species seem to agree well enough with Rabenhorst's *H. graminum*,¶ which was found by Caspary on barley. Frank**, in his earlier work on the parasitic diseases of plants, considered it to be only a well developed Cladosporium, but later refers it to Helminthosporium. In 1885, Eriksson†† found a disease on barley, near Upsala and Stockholm, which he considered identical with that found by Caspary on barley in Germany. Kirchner‡‡ reports it as common in Germany and gives a good account. Later Aderhold§§ reported on its common and destructive occurrence in Silesia.

The Iowa barley disease agrees with Eriksson's, but differs from the corn disease found by Passerini. According to the latter observer the leaves of corn affected by the fungus are at first yellow, then become more or less discolored and finally wilt.

The spots in the specimens distributed by Briosi and Cavara on corn are sharply limited and extend across the veins. This disease manifests itself long before the barley has headed out. In the barley disease the spots extend from the base to the very tip of the leaf in parallel rows. The diseased leaves form quite a contrast to those of adjoining healthy plants, as they are variegated pale yellow and green. All the stalks of a stool

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*Herbarium mycologicum. 332.

†Pammel. Fungus diseases of Iowa forage plants. Pammel. Jour. Myc. 7: 96. See also Sorauer. Pflanzenkrankheiten. 348. Tubeuf. Pflanzenkrankheiten. 531.

‡Ellis N. Am. fungi. No. 45. Grevillea. 6: 88.

§La nebbia del granturco. 3. Schroeter. Just Bot. Jahresb. 1878: 184. Comes. Crittogamia agraria. 1: 409.

‖Fungi Parassiti delle piante cultivate od utili essicati deliniati e descritti. Fasc. III and IV, No. 81.

¶Herbarium mycologicum. 332.

**Krankheiten der Pflanzen. 582. (Ed. 1.) 316. (Ed. 2.)

††Ueber eine Blattfleckenkrankheit der Gerste. Bot. Centralbl. 29: 89. Sorauer Just Bot. Jahresb. 1885: 515. Distributed in Fungi Scand. 187.

‡‡Braunfleckigkeit der Gerstenblatter. Zeitsch. fur. Pflanzenk. 1: 24.

§§Zeitsch. fur. Pflanzenk. 5: 10.

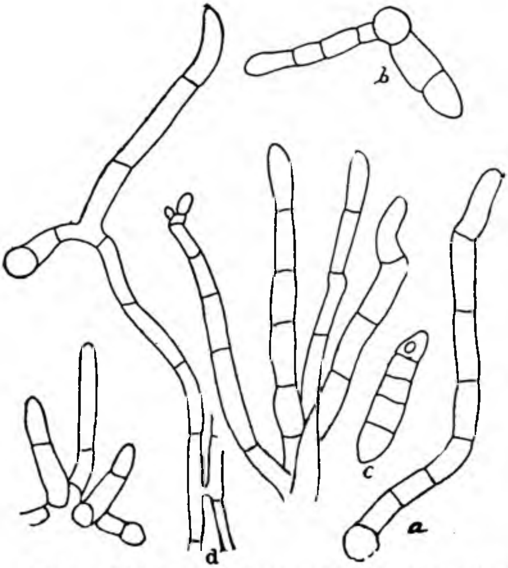
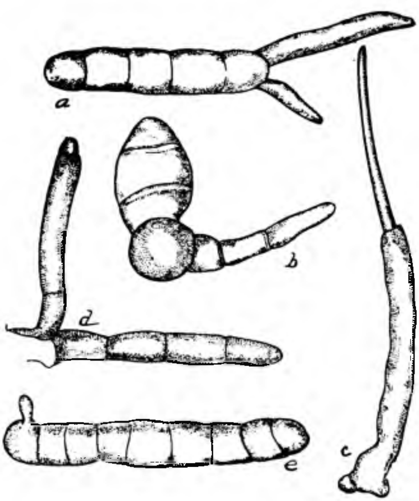


Fig. 99. Yellow leaf diseae of barley (*Helminthosporium graminum*, Rabb.) *a*, hypha; *b*, hypha arising from short cells; *c*, conidium, cluster of conidiophores to the left; *d*, mycelium. (Pammel and King.)



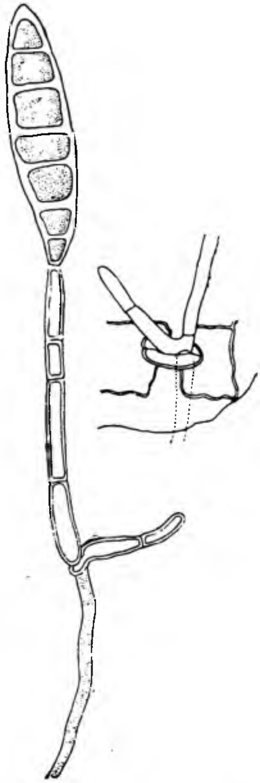


Fig. 100. *Helminthosporium graminum*; *a*, spore germinating; *d*, conidiophore; *b*, conidiophore; *e*, conidium or spore.

Fig. 101. Leaf browning of corn (*Helminthosporium turcicum*) to the right. Mycelium below and a seven-celled spore above. Condiophore pushing through the stoma in right-hand figure. (Pammel and King.)

are affected. The plants die prematurely, and soon after death the leaves become torn into shreds. An examination of the affected parts when the variegated linear stripes appear shows a colorless mycelium permeating the tissues of the leaf. In older parts of the leaf blackish masses are clearly made out with the naked eye. These masses consist of the spores and fruiting fungus threads. The erect septate hyphae make their way through the opening of the stoma or break through the epidermis, bearing large three to six-celled spores at the end. Occasionlly one finds these hyphae branched. The mass of brown hyphae and spores along the veins can be seen easily with the naked eye. The spores germinate readily, often a number of germinating tubes coming from a single spore. The *Helminthosporium teres*, Sacc., on oats, described by Briosi and Cavara, is closely allied to the above species. The mycelium is intercellular and causes elongated dead spots, finally death of the leaf.

LEAF BROWNING OF CORN (HELMINTHOSPORIUM TURCICUM, PASS.)

Spot diseases are abundant and destructive on many of our cultivated plants. Corn, so far, has been unusually free from these troublesome diseases. In 1876, Passerini,* an Italian mycologist, described a fungus, *Helminthosporium turcicum*, as occurring on living leaves of corn. It was distributed by Rabenhorst.†

Earlier, Cooke and Ellis‡ described a somewhat similar Helminthosporium, the *H. inconspicuum*, on dead leaves of corn. The Cooke and Ellis species is sometimes parasitic. Comes§ holds that this fungus is distinct, although closely related to the European. Peck‖ states that it occurs on living or languishing leaves of Indian corn, and Harvey reports the var. *britanicum*, Grove on oats. Professor Peck gives the following account of the disease: "If the lower leaves of corn stalks be examined toward the end of summer, some of them will be found to be dead and discolored at and near the pointed end. This discoloration is sometimes continuous, involving the whole

*La Nebbia del gran turco. Parma. 1876. Abst. J. Schroeter. Just. Bot. Jahr. Just. 1876: 184.

†Fung. Europ. 23.

‡Saccardo. Syll. Fung. 4: 411. Grevillea. 6. 88. Ellis. N. Am. Fung. No. 45.

§Crittogamia Agraria. 409.

Ann. Rep. State Mus. Nat. Hist N. Y. 34: 51. 456. *pl. 3. b.*

‖Ann. Rep. Maine State Coll. 1894: 21. 95.

outer half of the leaf, and sometimes is interrupted and forms spots of various sizes and shapes. The spots, by increasing in size, become confluent, and thus a leaf, at first spotted, may soon become uniformly discolored. The discoloration results from the death of the leaf tissues and the destruction of the green coloring matter of the leaf cells, the affected parts appearing to the observer like so much dead leaf."

Stewart* states that the *H. inconspicuum* on Long Island must be regarded as an enemy of considerable importance. Both sweet and field corn suffered in some cases so severely as to materially lessen their value for fodder. The farmers attributed the cause of the disease to a period of unusually hot weather which prevailed during the month of August. Thaxter† states that it is also injurious at times in Connecticut where it is known as "white blast of Indian corn." It is common at times in Iowa and does much injury.

Later Briosi and Cavara distributed a fungus on corn with a description of Passerini's *H. turcicum.* In 1891 one of us gave an account of *Helminthosporium graminum*, Rabh., on barley in which reference was made to the fungus on corn. J. B. Ellis, to whom the fungus was submitted states that it is identical with the corn fungus. After a careful examination of the material at hand we are of the opinion that these fungi are different. The Italian fungus has not been observed here, but an account is given to complete the list of diseases occurring on corn. In the Italian disease the spots are sharply limited across the veins, one to three inches long, one-sixteenth to one-eighth of an inch wide. The dead tissues have the appearance of dead corn leaves when ripe or affected by frost and produce premature wilting. The surrounding green is in strong contrast. Over the dead areas may be seen small brown clusters, the hyphae and spores.

One or more of the fruiting hyphae make their way through the opening of the stoma. These come from a colorless mycelium. The conidiophores as well as the spores are brown. The latter are large, 8–100^{u} in length, 20–24^{u} in width. This fungus is often associated with *Cladosporium fasciculatum* Corda

*Rep. Geneva N. Y. Agrl. Exp. Sta. 15: 452. *pl. 32. f. 2.* 1896.

†Rep. Conn. Agrl. Exp. Sta. 1889: 171. 1890.

and *Alternaria tenuis* Nees. The disease is not limited to corn but also occurs on sorghum (*Andropogon sorghum*).

GRAY SPOT DISEASE (PIRICULARIA GRISEA (COOKE) SACC.)

Crab grass (*Panicum sanguinale*) is seriously affected at times with the above fungus. It is sometimes difficult to find a healthy plant. The affected leaves at first are pale green in color, then become brown. The mycelium occurs in the interior of the leaf; the hyphae protrude through the openings of the stomata, bearing small pear-shaped spores slightly smoky in color. The spores measure 9 x 18^u. The affected parts have an ashy gray color.*

WHEAT SCAB (FUSARIUM ROSEUM, LINK).

This fungus as an enemy of wheat was first described by Worthington G. Smith† as *Fusarium culmorum.* It is probably not common on the continent of Europe, as it is not reported by Loverdo, nor is much said of it by Sorauer. That it is a serious trouble here will be seen from the following estimate in Velvet chaff wheat: Out of a total of 125 heads, 73 were perfect, 24 blighted one-third, 7 entirely blighted, and 24 blighted less than one-third. In the variety John, Mr. Stewart estimated the loss at about one-fifth. In hybrid Dattel, out of 120 heads counted, 57 were perfect, while 8 were entirely, 8 one-half, 15 one-third and 32 partially destroyed. Weed‡ has made this fungus the subject of several papers. He says: "In 1890 I saw a field of 100 acres in Madison county, Ohio, considered the finest wheat field in the county, and which was expected, shortly before harvest, to yield 35 to 40 bushels per acre, so severely attacked by the disease that the yield was reduced to 8 bushels per acre. Two other fields, one of 25, the other of 50 acres, were shrunken in yield at least one-third from the same cause. The fungus apparently gains access to the tender, undeveloped kernel, sapping its life and sending down feeders into the main axis of the head on which the kernel and enclosed chaff are borne."

*Saccardo. Syll. Fung. 4: 217. *Trichothecium griseum* Cooke Rav. Amer. Fung. *580.*

†Diseases of Field and Garden Crops. 208. This fungus is placed with Endoconidium by Prillieux and Delacroix.

‡Soc. Prom. Agrl. Science. 11: 47. *f. 1,* Fungi and fungicides. 199. See also Pammel. Jour. Mycology. 7: 97.

The disease appears about the time when the grain begins to turn. Either the entire head or some part of it ripens suddenly and prematurely. If the head is partially destroyed the lower part will be green. Affected heads or parts of the same have a whitish appearance instead of a golden yellow. The

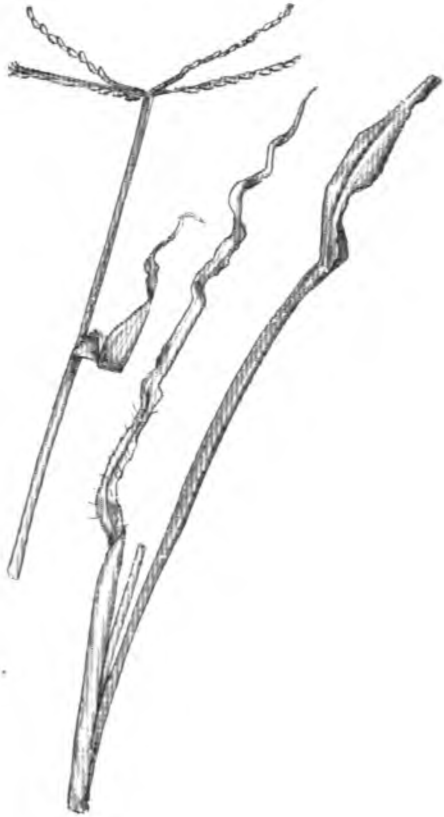


Fig. 102. Gray spot disease of crab grass (*Piricularia grisea*). (King.)

disease usually starts at the upper end, although it may begin at the lower end. The mycelium is whitish or varies from yellow to orange, divided, torulose. The spores are borne on erect threads arising from the mycelium, terminal or lateral, crescent-shaped, at first one-celled, finally divided into two or more cells. The color of the spores is whitish or, in masses, orange or pink. In germination each cell produces a germ tube. The several-celled spores may break up into conidia.

The *Fusarium heterosporum* Nees, is common in parts of Germany, and Tubeuf quotes Frank as stating that the destruction of rye is total in some places, the fungus investing the whole kernel. Rostrup* mentions it as destructive to germinating barley. It also occurs upon ergotized rye and is regarded by some mycologists as distinct from *Fusarium culmorum.* It is probable that the various species of Fusarium

Fig. 103. Wheat scab (Fusarium roseum or, *Gibberella saubinettii* (Mont.) Sacc.). *1*, wheat head affected with wheat scab, upper portion destroyed; *2*, spores of Fusarium; *3*, glumes covered with perithecia; *4*, perithecia; *5*, asci from perithecia, with ascospores, one of these enlarged at *6*; *7*, conidiophore and conidia grown in agar. (After Selby, Ohio Agrl. Exp. Sta.).

infesting cereals should be referred to *F. roseum*, Link,† and according to Saccardo‡, the ascigerous stage is *Gibberella saubinettii* (Mont.) Sacc. Selby§ agrees with Saccardo in regard to its genetic connection with Gibberella.

*I. 538.
†Frank. Krankheiten der Pflanzen 358. (Ed. 2.) 1896.
‡Syll. Fung. 2: 554.
§Bull. Ohio Agrl. Exp. Sta. 97: 40.

SMUTS—USTILAGINEÆ.

The Ustilagineæ are popularly known as smuts and are well known to all farmers, at least those affecting our cereal grasses. Among the several hundred species those of cereals are most destructive, entailing a loss to the farmer every year of millions of dollars.

A large number of the economic grasses are likewise affected, but these are not so often observed, though the loss in many cases is quite serious. I have not attempted to discuss all of the smuts of our economic grasses, though I have given short accounts of the more important, and especially the smuts of cereals. Many important studies have been made in this country especially of our economic species. Kellerman and Swingle, Arthur and other mycologists have made important contributions to our knowledge of Ustilagineæ. I have freely

Fig. 104. Maize smut, *Ustilago maydis*. Ear affected, *e*, smut boils; *r*, kernels; *c*, bracts.

Fig. 105. Smut boil making its appearance at the node. (King.)

used their material with such work as has been done from time to time during my connection with this experiment station.

CORN SMUT (USTILAGO MAYDIS). D C.

For more than a century this troublesome fungus disease has been known. The first reference to it was made by Aymen* in 1760, who records the disease on the tassel of corn. In 1806 it was described by De Candolle† as *Uredo segetum.* Var. *mays-zeae.* D. C. Burger,‡ in his work on corn, gives a short account of the fungus. Bonafous,§ in his treatise on corn, gives the most complete of the early accounts of this disease. Kuehn,‖ Tulasne,¶ Meyen, **Brefeld, ††Fischer de Waldheim,‡‡ and a host of other writers have contributed to an account of corn. For a good bibliography as well as abstracts and conclusions of these writers we must refer to a paper by Hitchcock and Norton.§§ These writers have followed Magnus in adopting the name of *Ustilago mays zeae* (D. C.) Magnus, but the name in common use, that of *Ustilago Maydis*, seems preferable and is adopted in this paper.

General characters.—Corn smut makes its appearance when the plant is three or four feet high, a little before the time of flowering, although in some cases it is not observed till the ears form. Careful search will show that many leaves, as well as the nodes, are infested before the ear forms. In the leaf, small wrinkled patches appear. These are frequently reddish in color; later assume a glossy white color, and as it becomes older changes to a black sooty mass. The lower nodes are especially infested; also where the leaf joins the sheath. The

*Rec. sur. les progres et les causes de la Nielle. 77.

†Fl. Fr. 2: 596.

‡Abhandling uber Mais. 242-43. 1809.

§Historie Naturelle. Agricole et economique du Mais. 94. 1836.

‖Die Krankheiten der Kulturgewachse. 70. 1859.

¶Memoire Sur les Ustilaginees comparees aux Uredinees. Ann. Sci. Nat. III. 7: 83. 1847.

**Pflanzen Pathologie. 102. 1841.

††Untersuchungen aus dem Gesammtgebiete der Mykologie. Also Neue Untersuchungen uber die Brandpilze und Brandkrankheiten. II Nachrichten aus dem Klub der Landwirthe zu Berlin. 1888.

‡‡Contr. to the biology and history of the development of the Ustilagineae. Rep. N. Y. Agrl. Soc. 1870: 280. Translated from Pringsh. Jahrb. Wiss. Bot. 7: 61.

§§Bull. Kans. Agrl. Exp. Sta. 62. 190-197. 1896. See, also, Corda. For contributions to the knowledge of the different kinds of brands in the cereals and blight in grains, by Corda, translated by Smith, 19. *pl. 3 f. 1-2.* Emmons' Agrl. of N. Y. 2: 265.

sheaths, leaves and stems are more frequently attacked than the ears, as is shown elsewhere in this paper. The staminate flowers or tassels are especially affected, either a few of the spikelets or a large number, or a very distinct boil makes its appearance below the staminate flowers on the stem.

The most characteristic appearance of the smut occurs in the ear, forming the so-called boils. This may include the whole ear or only a small part. The smaller ears further down are affected later, in part by auto-infection or from spores contained in the field.

Fig. 106. Maize smut on leaf. S—Smut boil, leaf very much wrinkled. The black smut boils contain the spores. (King.)

Fig. 107. Tassel showing corn smut boils and spores. (King.)

Microscopic characters.—The sooty mass consists of a large number of small bodies known as spores, that serve for the reproduction of the fungus. These spores are usually round, spherical, somewhat spiny and measure about $\frac{1}{3300}$ (8–13 x 8–11^{u}) inch in diameter. Hitchcock* has given the measurement of a large number of spores. Under proper conditions of moisture these spores germinate. This proceeds best in sterilized rain-water and if kept under proper conditions of warmth, a tube emerges through a pore. The spore consists of an outer wall, which is spiny, and an inner more delicate, the endospore. The tube or promycelium, as it is called, normally bears lateral

*Hitchcock. Variation in spores of corn smut. Science 22: 353.

bodies, the conidia, but under more favorable conditions of food these may branch and bear secondary conidia. If the nutrient material is not exhausted this process of budding may be continued for a long time. These spores may propagate in a decoction of manure. It will then be seen that these budding conidia may be a center of infection.

The conidia as well as the secondary conidia are blown about by the wind and under proper conditions cause the infection of the corn plant. Several years ago Mr. F. C. Stewart* made some extended studies of the germination of corn smut in which it was shown that the thermal death point of smut spores is 15 min., 105°–106° C. in dry oven, and 52° C. when immersed in water; and that corn is unable to come through an inch of soil after 15 minutes treatment with water at 70.5° C., and in dry oven at 78° C. Brefeld† found that smut spores produced an abundance of secondary conidia when they were germinated in sugar solution, but with us this has never been a very satisfactory method of propogating them as the cultures soon became infected with bacteria which materially checked the progress of the germination of spores. These bacteria came from the smut.

Age has something to do with the germination of the spores. In our own work fresh spores never germinated as well as those perfectly dry. Those of a previous season always germinated well. They may preserve their vitality for a considerable length of time. Brefeld has shown that spores 2 years old germinated readily, and that spores 7 years old germinated in nutrient solution in from five to eight days.

Norton and Hitchcock, however, found that the young spores just formed germinate best, and grow more vigorously after germination. Brefeld, however, found that old spores when germinated will grow as vigorously as the newer.

Manner of infection.—Until the exhaustive researches of Brefeld, the statement of Kuehn,‡ an excellent observer and investigator were accepted. Kuehn stated that the mycelium from the germinating spores enters at the root node, the most tender part of the corn plant, as in the case of wheat bunt. He supposed this to be true of other smuts as well. It has been

*Effects of heat on the germination of corn and smut. Iowa Acad. Sci 2: 74-78. 1894.

†Untersuchungen aus dem Gesammtgebiete der Mykologie. Ueber Hefenpilze, V Heft. 67-76. 1883.

‡Bot. Zeit. 33: 122.

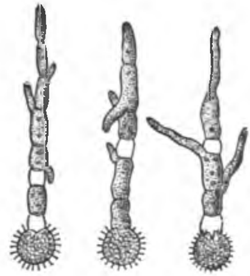


Fig. 108. Maize smut spores germinating in sugar solution. (Brefeld U. S. Dept. Agr.)

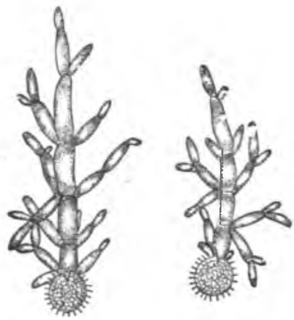


Fig. 110. Maize smut germinating in water. (Brefeld U. S. Dept. Agr.)

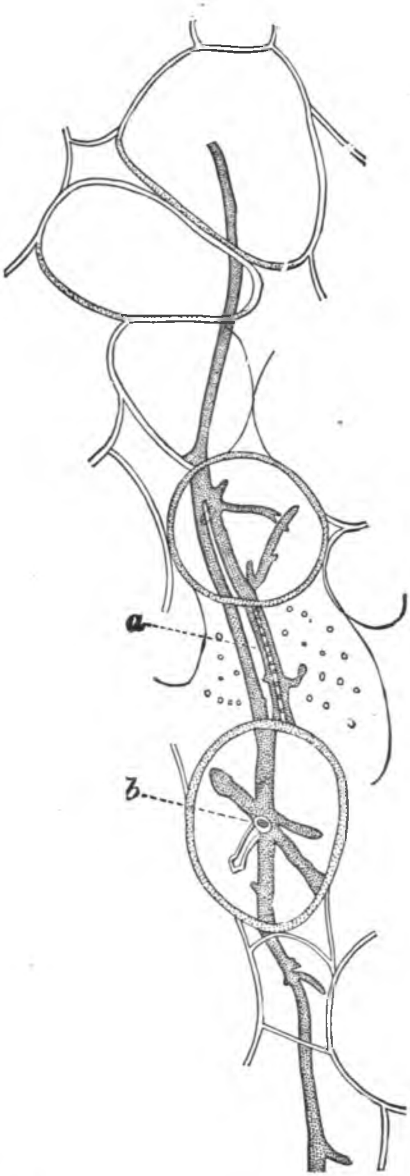


Fig. 109. Maize smut (*Ustilago maydis*); *a*, mycelium of fungus and cells of the host. (U. S. Dept. of Agrl.)

shown that Kuehn was in error, at least for some of our smuts. Because, however, of Kuehn's work, it was recommended to treat seed corn as wheat seed was treated for bunt. In 1892 experiments were made at the Iowa Agricultural College* with corn, in which seed was treated with hot water heated up to 53–55° C.; also ammoniacal carbonate of copper, and copper sulphate. The hot water treatment, as the work of Stewart indicated, could not have been effectual, since the smut spores can be heated higher than corn. The other treatment should have been effectual, since the smut spores are sensitive to copper solutions. In all cases there was no appreciable difference between treated and check. Independently of this work, the botanists of the Kansas Experiment Station† made some experiments from which the following conclusions were drawn:

"Further investigation is necessary in order to determine the mode of infection—a point that must be settled before we can hope to employ rational methods for the prevention of this annoying and destructive pest."

More complete experiments made by Hitchcock and Norton‡ indicate that:

1. "Infection may take place at any time of the season when the corn is growing, and does not depend so much on the time of the season as on the stage of development of the plant.

2. "Infection may take place in any part of the plant where growing tissue is present, and at any time in its life, but scarcely ever before the plant has attained the height of three feet.

3. "After the tissues are hardened, the smut cannot penetrate them, and consequently infection does not take place in older parts of the corn, but only in the growing tissues. This growing condition is found in the young leaves when the first smut appears in the field; later it occurs mostly at the junction of the leaf and sheath, where cells are present for a long time in a state of growth, and are consequently exposed longer to penetration by the germ tubes from the conidia; still later this is found in the flowers and young parts of the ear and tassel; while finally the only parts open to infection are the rudimentary ears, which develop after the larger ears, at each joint on the lower part of the stalk.

*Bull. Iowa Agrl. Exp. Sta. 25. 315. See also Bull. 20. 721.
†Bull. Kansas Agrl. Exp. Sta. 23: 315.
‡Bull. Kansas Agrl. Exp. Sta. 62: 183-187.

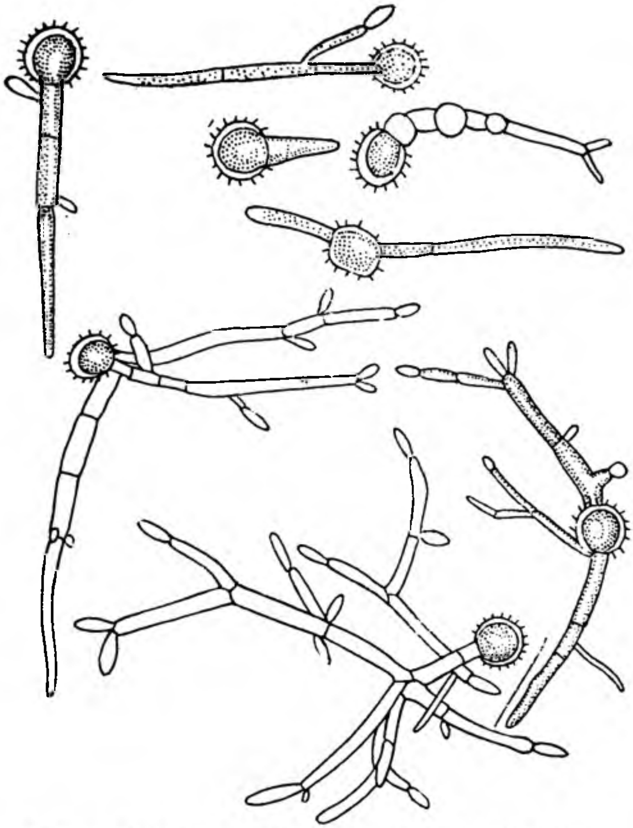


Fig. 109.—Corn smut (*Ustilago maydis*) germination of spores in water.

4. "The infection is probably through the conidia and not directly from the spores. Brefeld's investigations, mentioned elsewhere, seem to demonstrate this.

5. "The period of incubation, or time between infection and the appearing of smut boils, is about ten days.

6. "It is probable that the early infections come from the spores of last year, which germinate on the ground at the first favorable weather in the spring, while the later and more abundant infections are from the new spores developed early in the season."

Professor Morini* seems to have established the fact that the passage of spores through the intestinal tract favors the germination and penetration of the sporidia in its host plant.

*Morini. Il. Carbone delle piante Chimica Veterinaria 7: See Loverdo Les Maladies Crypt. 76.

We add here also Brefeld's* conclusion. His experiments are divided into four series from which the following conclusions were drawn. *First.*—Very young seedlings could be infected to a slight extent; older ones not at all. *Second.*—Successful infection in rolled up young leaves, when plants were a foot high. *Third.*—Successful in young inflorescence. *Fourth.*—When brace roots were in right condition they took the disease.

"According to this, the final result of all the infections with corn smut on maize is entirely different from the previously described results with smut fungi living exclusively in the grains. The smut germs come to full development and produce smut pustules and spore beds on every spot of the still undeveloped parts of the plant into which they have penetrated. The action of the germ is narrowly localized—only those parts of the young plant become smutty which have been attacked directly by the fungus germs; all the rest remain normal and sound. The formation of the smut pustules begins quickly, at longest three weeks after the infection."

"The complete result of all the here-cited infection experiments with dusty smut, millet, and corn smut affords, in the first place, indisputable proof that the germs of smut fungi which live saprophytically outside of the host plants can produce smut diseases."

"When the smut was nourished saprophytically longer than a year in continnal reproduction outside of the host plant, then only did the outgrowth of the conidia into germ tubes cease. Along with this the power of infection was extinguished, *i. e.*, with the disappearance of a comprehensible morphological character, for the germs can only penetrate into the host plants by means of their germ tubes."

"The earlier view that only the young seedlings of the host plants are receptive to the fungus germ has not been sustained. On the contrary, the fungous germs can penetrate into all sufficiently young parts of the host plant."

Mycelium.—The fungus vegetates in the interior of the plant by what is termed the mycelium; a single thread being known as a hypha. In its early stages these fine threads penetrate chiefly between the cells of its host, sending short branches into the cells; these are known as haustoria. These are frequently branched, and may extend as far as the nucleus and

*Untersuchungen aus dem Gesammtgebiete der Mykologie. Heft XI. Smith. Jour. of Myc. No. 4. 6: 162. 1890.

beyond. Seymour* observes that the thicker the cell-walls which the mycelium penetrates, the more abundant are the haustoria. In later stages of the fungus the mycelium extends through and into the cells of its host, becoming densely packed, but not much beyond the point of infection. The mycelium has a peculiar glistening opalescent appearance. In course of time spores are formed from the branching mycelium by abstriction; in this way a chain of spores is formed. In appearance and color these parts do not differ essentially from the mycelium. The protoplasm is highly granular, the cell-walls become gelatinous; these walls later are absorbed, so that little else than a mass of black spores remain. As a result of the infection, the host develops an increasing number of thin-walled parenchyma cells. This is due to the action of the fungus.

Hosts.—Corn smut occurs on but two host plants so far as known. Corn is, of course, the common host plant, but Trelease has also collected the fungus on Teosinte (*Euchlaena Mexicana*), and it may be expected on related genera.

Distribution and damage.—The fungus is found wherever corn is grown. Botanical writers refer to it in Iowa, Wisconsin, the Carolinas, New Jersey, Indiana, Kansas and Texas.† I have examined specimens from Illinois, New York and Massachusetts. European mycologists report it from Italy, Ger-

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*Smut of Indian corn (*Ustilago Zea Mays*). Rept. U. S. Dept. of Agrl. 1887: 380-382.
†Tuckerman and Frost. Cat. Pl. Amherst Coll. 83.
Day. Cat. of Nat. and Native Plants of Buffalo. 143.
Ellis in Briton. Pl. of New Jersey. 506.
Trelease. Parasitic Fung of Wis. 34.
Schwienitz. Syn. Fungi. Car. 71.
Bessey. Bull. Bot. Dept. Iowa Agrl. College. 1884: 127.
Ravenel. Fung. Car. Ex. IV. 100.
Kellerman. Bull. Kan. Agrl. Coll. Exp. Sta. 23.
Bull. Neb. Agrl. Coll. Exp. Sta. 11: 67.
Norton. Trans. Acad. Sci. St. Louis. 7: 234.
H. S. Jennings. Bull. Texas Agrl. Coll. Exp. Sta. 9: 29.
Hitchcock and Norton. Bull. Kan. Agrl. Exp. Sta. 62.
Kellerman & Werner. Cat. of Ohio Plants. 347.
Seymour. Rep. U. S. Dept. of Agrl. 1887: 380.
Peck. Rep. State Mus. Nat. Hist. 34: 26.
Webber. Cat. of Flora of Neb. 73.
Bessey. Bull. Neb. Exp. Sta. 11: 24.
F. Lamson-Scribner. U. S. Dept. of Agrl. Rep. 1887: 385.

many, France, England, Astria, Hungary, Belgium and Chili.*

Damage Done.—In warmer countries it is said to be much more severe than in colder countries. It appears that climate greatly influences the amount of smut present. I have† reported on the abundance of this disease in Philippine island corn grown on the college grounds. It occurred on every plant, not only affecting ears, but a large number of nodes had smut boils. The same thing was again observed in 1897 on some corn from South America and Mexico, cultivated on the college grounds.

Henry states that in the vicinity of Madison, Wis., in 1881, there was a loss of 5 to 25 per cent. This could not have been general but was most probably an unusual condition, occurring only in some fields. In 1882 personal observations showed very little smut in many parts of Wisconsin. The loss is often 25 per cent in sweet corns grown in gardens, and in fields where rotation has not been practiced.

Halsted‡ states that in 1886, the college corn field had sixty-two hundredths of 1 per cent. Bessey§ states that one year in one field 66 per cent of loss occurred. In this case the field had been in corn for several years. He further observes that 15 per cent is not uncommon. Brewer‖ observes that in 1879 there were cases in which there was a loss of 16⅔ per cent, but in most cases there was less than 1 per cent.

Maize smut not injurious to cattle.—It has been held by many that corn smut is injurious to cattle. This has been a common belief in some quarters. In some kinds of smut a small amount of ergotine is found. Professor Power of the Welcome Research Laboratory, England, found this true for the smut

*Chili. Saccardo. Syll. Fung. 7: 472.
Fischer De Waldheim. Ustilagineæ. 217.
Germany. De Bary. Die Brandpilze. 4.
Sorauer. Planzenkrankheiten. 201.
Frank. Die Krankheiten der Pflanzen. 110 (Ed. 2.)
Winter. Die Pilze. 97.
Tubeuf. Pflansenkrankheiten. 291.
Austria. Thumen. Bekampfung der Pilzkrankheiten. 29.
Italy Comes, D. O. Crittogamia agraria. 75.
Penzig. Fungi Agrumicoli.
France. Jean Loverdo. Les Maladies cryptogamiques des cereales. 68.
Tulasne. Mem Les Ustilagineæ 84.
England. Smith. Diseases of Field and Garden Crops. 254.

†Pammel. Fungus diseases of Iowa forage plants. 4

‡Bull. Dept. of Botany Iowa Agrl. College. 1886: 16.

§Bull. Dept. of Bot. Iowa Agrl. Coll. 1884; 127. Also Bull. Neb. Agrl. Exp. Sta. 11: 25.

‖Cereal Production of the U. S. Tenth Census Rep. 3: 107.

on *Setaria glauca*, and there are many persons who think that this smut is injurious to cattle that feed in corn fields where there is a great deal of this fungus.

Kedsie reports the following composition: Moisture, 8.30 per cent; albuminoids, 13 06 per cent; carbohydrates, 25.60 per cent; cellulose, 24.69 per cent; sugar, 4 per cent; fat, 1.35 per cent; ash, much sand, 25.5 per cent. Professor Kedsie was unable to find any poisonous alkaloids. In 1868, the United States department of agriculture employed Professor Gamgee* to ascertain the cause of the cornstalk disease.

Prof. W. A. Henry,† in a recent work says, speaking of work done by the Bureau of Animal Industry, Clinton D. Smith and Gamgee: "In experiments by the Bureau of Animal Industry, U. S. Department of Agriculture, Washington, corn smut was fed to heifers without ill effects. With all the trials but one ending without disaster, it seems reasonable to conclude that corn smut is at least not a virulent poison, if, indeed, it is one in any sense of the word. It is probable that in the Wisconsin cases, where one cow died and the other was indisposed, the animals suffered because of eating too much highly nitrogenous material rather than anything poisonous. Worse results might have followed the feeding of the same volume of corn meal or cotton seed meal. It would seem that there is little or no danger from corn smut unless cattle consume a large quantity. This is possible where they are allowed to roam through stock fields and gather what they will. There may be cases where animals seek out the smut and eat inordinately of it."

Recently Smith‡ of the Michigan Agricultural College gave the results of some experiments with corn smut. Varying amounts of smut were fed to three grade Shorthorn cows and one grade Jersey. Two of the cows were started with two ounces a day and increased to eleven pounds. Two others were started with two ounces and increased to a pound. The test lasted forty-nine days. They appeared to relish the smut. It produced no signs of abortion in pregnant cows, and the milk yield was normal. Smith concludes that the smut in corn fields is not likely to prove injurious.

*Report U. S. Dept. Agr. 1869: 73.

†Feeds and Feeding. A hand book for student and stockman. 176. 1898. See also Rep. Board of Regents, University of Wis. 1881.

‡Bull. Mich. Agrl. Exp. Sta. 137.

Beal* states that under certain conditions smut is likely to be injurious to cattle. The experiments made by Moore† also indicate, like those of Smith, that smut is not injurious.

Beginning on the morning of January 17, 1894, and continuing until noon of February 2 (sixteen and one-half days), the heifers were fed morning and evening with from two to three quarts of a mixture of equal parts by weight of cut hay and a mixture of corn meal, middlings and wheat bran, and sixteen quarts of smut. No injurious affects were observed by Moore.

It seems reasonable to conclude from these experiments that under proper conditions corn smut is not injurious. In our experience no cases have ever been reported to us where cattle were supposed to have died from eating corn smut.

Prevention.—In previous paragraphs it has been stated that smut does not necessarilly enter the corn plant when the latter germinates but at a later period. From this it follows that it will be useless to treat the seed. Experiments made at the Agricultural college indicate, that no well-known fungicide or the hot water treatment is effective. The treated kernels in some cases contained as much smut as those not treated. As indicated in a previous paragraph, Bessey found a considerable increase in smut where corn was planted in the same field several years in succession and one of us has also observed the same condition. It has also been shown that when a variety is not acclimated it is much more subject to smut. This fact has again been noticed in a striking manner, in some South American and Mexican corn grown on the college grounds, where there had been no corn for years and no corn fields near it this year, nor for some years. These particular varieties produce so much foliage and the vegetative organs are so vigorous that they are unable to properly resist the attacks of the fungus.

It has also been recommended that the smut boils should be carefully collected at husking time and burned. It would not be a troublesome operation to throw all smutted corn in a separate small box. This would remove the smut from the kernels, but it would be impossible to collect and destroy the smut boils on cornstalks where it is more abundant than in the ears and in smut occurring on leaves. Financially we believe that this operation would not pay. The best and most feasible

*Rep. State Board of Agrl. Mich. 1880: 288.

†Corn stalk disease. Bull. Bureau of Animal Industry. U. S. Dept. of Agrl. 10: 47. 1895.

methods would be to plant corn which is thoroughly acclimated and such varieties as are least subject to smut. Crop rotation is to be strongly urged. Corn should never follow corn. A year rotation will destroy a large number of the smut spores.

HEAD SMUT OF SORGHUM (USTILAGO REILIANA, KUEHN).

In 1875, Kuehn* described a fungus occurring upon sorghum, the *Ustilago reiliana.* Since then this fungus has been found widely distributed on sorghum in Africa, India, China, Egypt, Italy, Hungary, and Germany and in the United States it has been reported from New Jersey, Kansas, Nebraska, Iowa and Wisconsin. A related smut, *U. sorghi* Link. has also been found widely scattered in this country, on sorghum.

Ustilago reiliana attacks the upper part of the plant, especially the ear and staminate flowers, almost destroying it. In but few cases does grain mature. Hitchcock and Norton† state that "The smutted stalks are usually not over half as high as the unsmutted, and in weight are very deficient. Eleven stalks were weighed and averaged 539 grams each, while plants affected with *Ustilago maydis* from the same field averaged about 1,300 grams and healthy plants averaged 1,500 grams or more. So if this smut should ever become abundant in this country, it may seriously change the corn crop as it has the sorghum industry in other parts of the United States.

In 1876 an Italian botanist, Passerini,‡ found this fungus upon corn, but until 1895 it had never been reported on sorghum. Mr. J. B. S. Norton called attention to its occurrence in Kansas. This disease is not uncommon in Kansas and across the line near Superior, Neb. So far this fungus has not been

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*Rabenhorst's Fungi Europ. 1988. Kuehn. Die Brandformen der Sorghum Arten. Mitth. d. Ver. f. Erdkunde zu Halle. 1877: 81, Saccardo. Syll. Fung. 7: 456.

Kellerman and Swingle. Notes on sorghum smuts. Bull. Kansas Agrl. Exp. Sta. 23: Sorghum smuts, Proc. Kan. Academy Sciences. 1890: 158.

Trelease. Preliminary List of Parasitic Fungi of Wis. 34.

Webber, H. J. Rusts and Smuts of Nebraska. Bull. Nebr. Agrl. Exp. Sta. 11: 69. Cat. Fl. of Neb. 74. Rep. Nebr. State Board of Argl. 1889:

Saccardo. Syll. Fung, 7: 471.

†Hitchcock and Norton. Bull. Kansas Agrl. Exp. Station. 62: 198.

Norton, J. B. S. A study of the Kansas Ustilagineæ. Trans. Acad. of Sci. St. Louis 7: 233.

Frank. Krankheiten der Pflanzen. 111 (2 ed.)

Tubeuf. Pflanzenkrankheiten. 303.

Sorauer. Pflanzenkrankheiten. 209.

Comes. Crittogamia Agraria. 75, 537.

Saccardo. Syll. Fung. 7: 471.

‡Passerini. La Nebba dei cereali. 1876.

Bot. Gazette. 30: 163. 1895.

Fig. 112. Head smut of sorghum (*Ustilago Reiliana*) on tassel of corn. (From Kansas Agrl. Exp. Sta.)

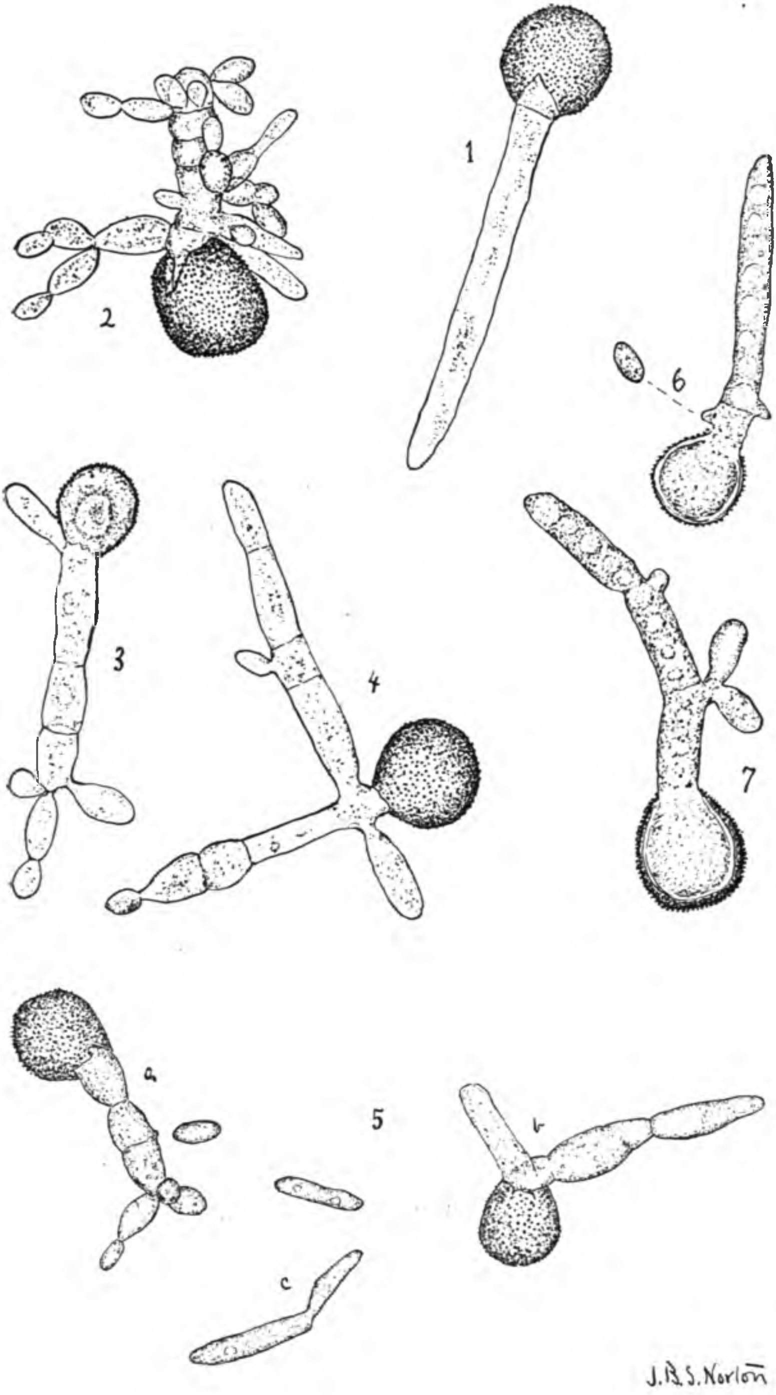

Fig. 113. Head smut of sorghum (*Ustilago Reiliana*). *1, 2, 3, 4,* germination in water after three days; *5*, after forty-eight hours in water. A, with detached conidium, showing point of attachment; C, conidia from another spore; *6, 7,* spores germinating thirty-six hours after. (Norton. Kansas Agrl. Exp. Sta.)

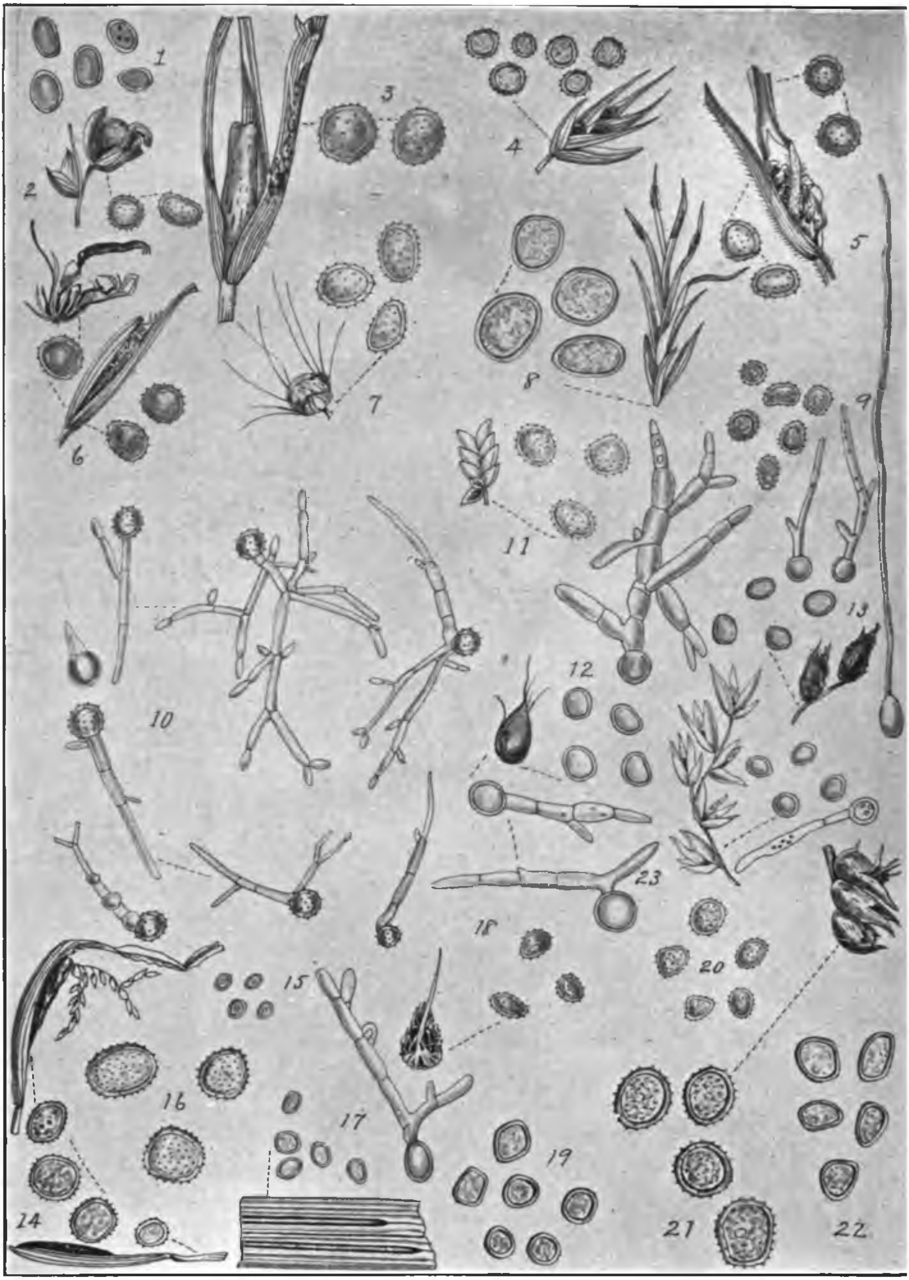

Fig. 114. Smut diseases of grasses. *1, Ustilago panici-miliacei* on *Panicum miliaceum; 2, U pustulata* on *Panicum proliferum; 3, U syntherismæ* on *Panicum proliferum; 4. U. bromivora*, var. *macrospora* on *Bromus breviaristatus; 5, U. syntherismæ* on *Panicum capillare; 6. U syntherismæ* on *Cenchrus tribuloides; 7. U. neglecta* on *Setaria glauca; 8, U. buchloes* on *Buchloe dactyloides; 9, U avenæ*, var. *levis* on oats; *10*, germinating spores of corn smut; *11, U. spermophorus* on *Eragrostis major; 12, U. hordei* on barley; *13, U. avenæ* on oats; *14, U rabenhorstiana* on *Panicum sanguinale; 15. U. hypodytes* on *Stipa spartea; 16, U. montaniensis* on *Muhlenbergia glomerata; 17. U longissima* on *Glyceria arundinacea; 18, U. nuda* on barley; *19, U aristidæ* on *Aristida purpurea; 20, U. tritici* on wheat; *21, U. sorghi* on sorghum; *U. perennans* on *Arrhenatherum avenaceum; 22. U. lorentziana* on *Hordeum jubatum; 23, U segetum.* (Pammel and King.)

reported in this state on corn, and the following account has been taken from Hitchcock and Norton, who have especially studied the disease. "It appears in tassels and ears as a rather hard, compact mass of smut, of a rough granular appearance. It does not have the large soft swellings that *Ustilago maydis* has bu at first the ovate pointed mass of smut is inclosed in a white membrane as is the case with *Ustlago maydis*, but this soon disappears. On older smutted places, the large fibro-vascular bundles of the corn gives the smut mass a coarse, stringy appearance. The smut is usually seen best in the tassel or upper part of the plant, the whole upper portion often being converted into a smutty mass just above the ear. When it attacks the ears, the husk usually conceals it until late in the season. The smut usually attacks all the ears, rudimentary ears or shoots on the stalk, converting them into masses of smut but not enlarging them. Often the tassel may not be smutted but usually is. Sometimes when the smut is not very bad on the stalk the flowers are curiously deformed. The ears are almost always attacked and often a cluster of ears is borne where there is normally but one. Often instead of producing flowers, and not actually smutted, the floral organs grow into long projections."

Microscopic characters.—The characteristic spores are larger than corn smut, being from 7^u to 15^u in diameter and nearly smooth. The outer wall of the spores is provided with very fine spines. Spores germinate readily in water, by producing a rather long, divided and frequently branched promycelium. Secondary sporidia are also produced. Brefeld observed that these spores retained their vitality for eight years at least when placed in nutrient solution they germinated.

In addition to its occurrence on maize, sorghum is a frequent host. It was found on sorghum in Kansas in 1890 by Kellerman.* It has also been found in this state, in Jones county, by Mr. Reed. It presents the same general characters on sorghum as on maize.

KERNEL SMUT OF CORN.

This smut (*Ustilago Fischeri*, Pass.), was described by the same Italian botanist, Passerini.† This affects the kernels,

*Proc. Kas. Acad. Sci. 1890: 153. Bull. Kas. Agrl. Exp. Sta. 23.

†Di una nuova specie di carbone nel granturco. Estratto Boll. del comizio agra Parma. Novembre, 1877. 4. Just. Bot. Jahresb. 1877: 123.

although sometimes the adjacent bracts also. A large number of kernels may be affected. On breaking the kernels open, a powdery mass mixed with starch may be seen. The starch grains are corroded, showing that in the action of the fungus a ferment dissolves the starch. The spores are spiny and measure from 4 to 6$^{\mu}$ in diameter. Very little is known of the fungus. It was distributed by Von Thumen* and Rabenhorst † It is described by Loverdo,‡ Tubeuf§ and other mycologists. It is not referred to by Farlow and Seymour in their valuable host index. So far as known it does not occur in this state, but the writer has received it from Jamaica.

Fig. 115. Kernel smut of maize (*Ustilago Fischeri*) on maize, spores to right, below, a sectional view of an affected kernel. (Pammel and King)

This fungus is probably a tropical or subtropical species, and may occur in southern United States. It certainly occurs in the West Indies. The writer some years ago found it among some ears of corn sent to him by Wm. Fawcett, the director of the botanical garden at Jamaica.

KERNEL SMUT OF SORGHUM.

This parasitic fungus (*Ustilago Sorghi* (Link) Winter), is quite widely distributed in the United States, though not as common as many other economic smuts. Link,‖ in 1825, described it under the name of *Sporosporium sorghi*. Tulanse¶ named it *Tilletia sorghi-vulgaris*. Kuehn** gave it the name of *Ustilago tulasnei* in 1874. In 1897 Mr. G. P. Clinton†† studied the fungus and applied the name of *Cintractia Sorghi-vulgaris* (Tul.), Clinton. This was done in order to avoid confusion with the doubtful *Cintractia* (?) *Sorghi* (Sorok.) De Toni.‡‡ The first reference to the occurrence of this fungus in this country was by Trelease,‡‡ who found it on imported seed of sorghum grown in Wisconsin, further stating that Farlow had received it from the Depart-

*Mycotheca universalis. 1624.

†Rabenhorst. Fungi Europ. 2500.

‡Les maladies Crypt. 80

§Tubeuf. Pflanzenkrankheiten. 296.

‖Linn. Sp. Pl. 62. 96. 1825. (Ed. Willd.)

¶Ann. d. Sc. Nat. III. 7: 116. *pl. 5 f 17-22.* 1847.

**Sitzb. natur. Gesellsch. Halle, 1874: Bot. Zeit. 32: 122. 1874.

The fungus has been distributed by Rabenhorst, Fung. Europ. No. 1997. Thumen, Herb. Myc. Oec. No. *63*. Briozi and Cavara, Fungi Parasit. No. *28*. Ellis, North Am. Fung. No. *1496*. Roumeguere, Fung. Selecti Exiss. No. *5128*.

††Broom corn smut. Bull. Univ. Ill. Agri. Exp. Sta. 47. This paper contains an excellent bibliography.

Syll. Fung. 7: 481.

‡‡Parasitic Fungi of Wis. 34. 1884.

ment of Agriculture, Washington. These specimens, it appears, came from New Jersey. It was also reported from New York to Trelease by Sturtevant. Webber* reported it on Millo maize in Nebraska in 1889. It was reported as common in Kansas by Kellerman.† Hitchcock has kindly furnished me with specimens from Kansas, and in Clinton's paper on Broom Corn Smut the statement is made that it occurs on Early Amber, Rangoon, Red Liberian and many others; also on broom corn and Kafir corn. In 1899 it was found on Kafir corn at Ames by Mr. Evers In Illinois it was first collected by Waite‡ in 1887, at Urbana. Further localities are reported by Clinton.§

Characters of the fungus.—The diseased plants attain their normal height. The panicle is elongated and all of the seeds are destroyed. In the case of broom corn as described by Clinton it is as follows: "An examination of the brush of an infected plant, unfortunately, shows that it is of a very inferior grade, usually almost worthless. Here, then, is a much more important loss, for the brush is the part for which broom corn is raised. Good broom corn has the rays of about uniform thickness and length, and all springing from a series of very contracted nodes so as to give them about the same point of origin. In the case of infected plants these internodes are usually elongated, and the rays are of unequal lengths, so that there are a series of irregular rays arranged on an elongated and thickened central axis—qualities very undesirable."

The covering of the grains is pale. At maturity the grains are grayish in color. Finally the membrane becomes broken, permitting the spores to escape. The whole interior of the ovary is converted into a mass of spores, the anthers being also affected. The spores are spherical, or somewhat angular, rarely elliptical, 5–9.5 x 4–5.5^{u}. The spores germinate readily when placed in water. Clinton states that spores 1 year old germinate. Some writers state that spores 6.5 years old germinate.

Infection takes place by the penetration of sporidia as well as the "infection threads." According to Clinton, entrance to the plant takes place at the growing point. "Thus the germinating seed in its early stages is the only place where the broom-corn is liable to become successfully infected. As a

*Ann. Rep. Neb. State Board of Agrl. 1889. 214. 1890.
†Bull. Kans. Agrl. Exp. Sta. 23.
‡Bull. Univ. Ill. Agrl Exp. Sta. 47: 376.
§l. c.

Fig. 115A. Kernel smut of sorghum (*Ustilago sorghi*). The affected inflorescence to the right and spores to the left.

germinating plant becomes older and its tissues harder of penetration by the threads, infection becomes less possible until, at the time when the plant breaks through the ground and its first leaves show, it is practically exempt from successful infection." Short treatment of the seed with warm water has no injurious effect. Experiments made for three years by Clinton showed favorable results by treating with hot water. The spores were killed at 135° F.

Ustilago cruenta. — Another smut affecting this host has been described by Kuhn*—the *Ustilago cruenta.* This species produces brownish-red spherical or elongated enlargements which contain the smut spores affecting any part of the panicle. The somewhat variable spores are 5–12^{u} long x 5–9^{u} wide, smooth yellowish or brownish, germinate readily in water, and in nutrient solutions produce abundant secondary conidia. Kuehn† surmises that it is the cause of a destructive disease Durra of millet in Africa.

LOOSE SMUT OF WHEAT.

For a long time all of the loose smuts—oats, wheat and barley (*Ustilago tritici* (Persoon) Jensen)—were considered by botanists to be one species, to which the name *Ustilago segetum* (Bull) Dittm.‡ was applied. This smut was known to writers as early as 1552, when Tragus§ applied the name *Ustilago* An early writer, Bauhin, 1595, described it as *Ustilago secalina.*‖ None of the early writers, however, recognized it as a fungus. Persoon, an early mycologist, gave it the name of *Uredo tritici,*¶ considering it a variety of *Uredo segetum.* Other names were subsequently applied, and in 1888, Jensen** reported that wheat

*Hamburger Garten u. Blumen Zeitig. 28: 177.
†Tubeuf. Pflanzenkrankheiten. 305.
‡Sturm Deutsch. Fl. 3: 67 *pl. 33.*
§Die Stirpium Nomencl. Prop. Lib. 3: 666.
‖Phytopinax. 52.
¶Syn. Meth. Fung. 224.
**The Prop. and Prev. of Smut in Oats and Barley. Jour. Roy. Agrl. Soc. 24: 9.

smut would infect only wheat plants. Oat smut would not produce wheat smut, nor barley smut produce smut in wheat. Kellerman and Swingle* give a full bibliography. It is described under *U. segetum* in the works cited below:

Distribution and damage.—This disease occurs wherever wheat grows. We have observed it abundant in many portions of Iowa where wheat is grown; also in Minnesota and Wisconsin. According to Dr. Erwin F. Smith, it is common in Michigan. Kellerman and Swingle also report it as common in Michigan. In a collection of smuts prepared for the World's Fair this was sent to me from many states. It is reported as common in Nebraska (Bessey), Indiana (Arthur), North Dakota (Bolley) and New York (Beach). It is also common in Germany (Sorauer, Frank, Tubeuf, etc), England (Plowright and Marshall Ward). These references suffice to show that this fungus is of wide distribution. The damage caused by this smut is often very considerable. It is the one most familiar to the Iowa farmer. Perhaps the loss to Iowa farmers is not far from .5 per cent. Dr. Erwin F. Smith reports that he observed in a patch of five acres in Michigan a loss of 50 per cent in 1870. Much of this loss can, no doubt, be prevented by judicious culture.

General characters.—The affected plants are lighter green in color. The smut converts the chaff, and frequently all adhering parts except the central stalk, to a powdery mass. The smut is not covered with a membrane. As Professors Kellerman and Swingle say, "The spores are completely free, and in this species is perhaps the dustiest of all loose smuts." The wind removes nearly all of the smut excepting a small portion adhering to the central stalk. Unlike bunt, not all the stalks of a stool are affected. Professor Bessey, some years ago, noted this fact of wheat grown at Ames.

In 1892 the writer made some observations on two varieties of wheat grown on the college farm in which the same results were obtained.

This fact clearly indicates that the manner of infection is very different than in bunt or loose smut of oats.

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*Rep. Kansas Agrl. Exp. Sta. 1889: 261.

Tubeuf Pflanzenkrankheiten. 303; under *U. tritici.*

†Saccardo. Syll. Fung. 7: 461.

Sorauer. Pflanzenkrankheiten. 198.

Frank. Krankheiten. d. Pflanzen. 110. (Ed. 2.)

Marshall Ward. Diseases of Pl. 86. Plowright. British Ured. and Ustilag. 273.

Microscopic characters.—The powdery mass is made up of a large number of very minute brown-colored spores with an olivaceous tinge, especially when in masses. The spores are somewhat variable in size, usually nearly round, or angular, or elliptical.

Germination of the spores.—It is not difficult to obtain germinating spores in sterilized water, but the process is slower than in oats smut. In germination a tube (promycelium) is pushed through the light colored outer wall of the spore (epispore). Sporidia are not produced. In nutrient solution germination begins in fifteen hours, starting in the same way, but more vigorous. Sometimes these become very long. The segments frequently break up.

OATS SMUT.

Oat smut (*Ustilago avenae* (Pers.) Jensen), has long been known to mycologists. Until the elaborate investigations of Jensen* it was regarded as identical with that occurring on wheat and known as *Ustilago segetum.* It was called *Uredo avenae* by Persoon.† The literature is cited quite fully by Kellerman and Swingle.‡

COMMON LOOSE SMUT OF OATS.

The oats (*Ustilago avenae* (Pers.) Jensen), is affected by two smuts; one is the common loose smut of oats (*Ustilago avenae*), a disease long and well known to agriculturists. This smut converts the flowers especially, the grain and adhering parts to a black, powdery substance. It may affect all of the flowers or only a part.

In most cases it completely destroys the tissues of the spikelets, leaving a black mass of spores with threads and tissues of the plant. The smut, during its early stages, is covered with a membrane. The spores are free and form a dusty mass of olive or dusky brown color; they are oval, sub-globose, elliptical or somewhat angular, irregular or deformed, and lighter on one side; contents usually clear or slightly granular. The outer wall or exposure is minutely warty.

Germination.—The spores germinate readily in water; they are said to retain their vitality for a number of years. We have

*Le Charbon des Cereales. 4: 1889.

†Syn. Meth. Fung. 224. 1801.

‡Rep. Kans. Agrl. Exp. Sta. 1889: 215. Bull. Kans. Exp. Sta. 8: 15. See also Bolley. Bull. North Dakota Agrl. Exp. Sta. 1: Arthur. Bull. Indiana Agrl. Exp. Sta. 35: Syll. Fung. 7: 461.

had no difficulty in getting fresh spores to germinate abundantly in twenty-four hours. The promycelium is slender and bears narrow, elliptical bodies called sporidia, which later cause the infection of the plant. The spores also germinate readily in normal nutrient solution, frequently budding. Brefeld observed that the sporidia, when transferred to a nutrient solution, continued to form sporidia. He obtained these yeast-like spores for many generations.

Manner of infection.—Infection in this smut is probably by way of the seed. Wolff, in his classic experiments, found that smuts entered through the first formed leaves. Brefeld's classic experiments also indicate that infection takes place during the early stages of the germination of oats.

Jensen thinks that smut does not enter with barnyard manure, and he supports it by some evidence:

	1885.	1886.
Barnyard manure plot	42 smutted heads	1.2 per cent smutted.
Artificial manure plot	35 smutted heads	1.0 per cent smutted

He furthermore suggests that infection is brought about by spores contained in the husks which lodged there while the oats were in flower, but this is contrary to the usual experience. Kellerman and Swingle state: "In an experiment of ours in June, 1888, a square rod of oats just in blossom were dusted with smut spores in considerable quantity on the 20th, 22d, 25th and 27th of the month. When ripe it was harvested and kept separate In the spring of 1889 it was planted, together with other plots, with seed from other parts of the same field. One of the artificially infected plots (23) was 6.8 per cent smutted, and the other was 5.36 per cent, while the untreated plot had 6.4 per cent of smut, midway between the two artificially smutted ones."

Damage and distribution.—The damage done by this smut is very large. Arthur gives the following percentages in different varieties grown at Geneva, N. Y.: "J. C. Arthur, in 1884, gave the results of counts of oats grown on the farm of the New York Agricultural Experiment Station at Geneva, N. Y., and found American Triumph, of 1,237 heads counted, had 10 per cent smutted."

Arthur* estimates the loss for Indiana at $797,526. Jones† examined 35,177 heads for oats smut; the average smut in 1892

*Loose Smut of Oats. Bull. Purdue Univ. Agrl. Exp. Sta. 35: 83.

†Annual Report of Vermont Agrl. Exp. Sta. 6: 73-82.

was 1.6 per cent. On this basis Swingle* estimates the loss in that state to be $26,454. From these figures Swingle† thinks 8 per cent a low average. This would entail a loss of $18,000,000 annually. Averaging 18,504,140 for the years 1890–1893.

On our own grounds we have found oats smut less common than the figure given by Swingle.‡ Harwood and Holden§ estimated the loss in Michigan in 1892 at $1,000,000.

Is it any wonder that smut should be so abundant since a single head may contain millions of spores?

Dr. Cobb says: "A single head of smutted oats may easily contain 500,000,000 spores; that is to say, a number of spores so great that if they were distributed evenly over an acre of land there would be over 1,000 spores on every square foot. In as much as these spores are instrumental in spreading the smut disease, we shall no longer wonder at finding the disease so common."

KERNEL SMUT OF OATS.

In addition to the above smut (*Ustilago avenæ* (Pers.) var. *levis*, Kellerman and Swingle) another form has been observed by Kellerman and Swingle,‖ which destroys only the grain and does not affect the glumes. On cutting open such a diseased husk the whole interior of the grain will be found converted into a powdery mass consisting of spores. This species was collected by Farlow and distributed by Ellis¶ in his North American fungi. The spores of this smut are dark brownish, oval, elliptical or subglobular, 6–12 x 55–8ᵘ, usually 6–9 x 6–7ᵘ. The exospore is nearly smooth. The spores germinate readily in nutrient solutions, producing short promycelia and narrow germ tubes. The species is probably quite widely distributed though not nearly so common as *Ustilago avenæ*.

BARLEY SMUT.

Barley is affected by two well-known smuts in Iowa. The covered barley smut (*Ustilago hordei* (Persoon) Kellerman and Swingle) and the naked barley smut (*Ustilago nuda* (Jensen) Kellerman and Swingle). Formerly both of these smuts were

*The Grain Smuts. Their Causes and Prevention. Year book U. S. Dept. Agr. 1894: 413

†l. c. 413.

‡Bull. Mich. Agrl. Exp. Sta. 87: 189.

§Rep. Kansas Agrl. Exp. Sta. 6: 259. 1890.

‖Ellis. North Am. Fung. 1091.

¶Swingle. Year Book U. S. Dept. Agr. 1894: 412. Farmers' Bulletin U. S. Dept. Agr. 75.

supposed to be identical with the smut occurring on wheat and oats.

The covered barley smut is said to be less abundant in Denmark than the naked barley smut, but it is quite widely distributed in Europe. It is also widely distributed in the United States: New Hampshire (Farlow), Maine (Harvey), Kansas (Kellerman and Swingle), Michigan (Beal), Indiana (Bolley), New York (Peck), and Iowa (Pammel, Stewart and Weaver). It is more common in Iowa than naked smut. This smut was first named by Persoon* and the correct combination was made by Kellerman and Swingle† who cite the very full literature. This smut differs from all other loose smuts, in that the panicle is not converted into a loose powdery mass, but is more or less covered by a membrane, which breaks and allows the spores to be scattered through the broken membranes.


Fig. 116. Covered Barley Smut (*Ustilago hordei*). (King.)

The spores of *U. hordei* are dark colored, spherical, slightly irregular, 5–8 x 5–7", usually 6–8 x 7", somewhat larger than *U. nuda*. The exospore is smooth. Germination proceeds readily in water with abundant sporidia from which secondary sporidia occur.

In naked barley smut the parts of the flowering panicle attacked are converted into a loose powdery mass, thus allowing the spores to be blown away very readily. The membrane covering the smut is very thin, dark, dull gray in color and easily broken. It consists of the modified epidermal cells of its host; the whole of the inflorescence being converted into a blackish powder. Kellerman and Swingle say: "The reason, notwithstanding the presence of fibers and a thin enveloping membrane, this species spreads its spores very readily and seems wholly different from typical

*Syn. Meth. Fung. 224.
†Rep. Kansas Agrl. Coll. 1889: 268.

Ustilago hordei, is found in the fact that the spores are free, and do not adhere to each other or to the shreds of the host tissue. The infecting threads, unlike those of the *Ustilago hordei*, grow to their normal height, and do not tend to remain enclosed by the uppermost sheath of the barley plant." In *Ustilago hordei* the thin membrane encloses the smutted kernel until harvest time. The spores are free, forming a dark mass of olive color, sometimes elliptical or sub-globose, usually the one side lighter than the rest, as in the other loose smut. The spore wall consists of two parts, the exospore and endospore. The exospore of *U. nuda* is slightly roughened. The spores germinate in sterilized water and nutrient sugar solution under favorable conditions of temperature usually in twenty-four hours or less. The promycelium or germ tube comes out of a large germ pore. It is curved and slender. According to Kellerman and Swingle it attains its full length in thirty hours. Sporidia are not produced, according to Kellerman and Swingle. This smut occurs in Kansas, Iowa, Wisconsin, New York, Michigan, Minnesota and Europe.

Manner of infection.—Little is known of the manner of infection; the seeds of the smut apparently propagate the smut so that infection is carried with seed barley.

WILD BARLEY SMUT.

This smut (*Ustilago lorentziana*), converts the ovary, palet and flowering glume of *Hordeum jubatum* into a black, powdery mass, as in *Ustilago nuda*. The spherical spores are minutely roughened. This species does good service in the northwest in destroying much of this detestable weed.

OTHER SMUTS OF THE GENUS USTILAGO.

Pigeon-grass smut (*Ustilago neglecta*, Niessl.) The most common of our smuts is that occurring on Setaria or pigeon-grass (*S. glauca.*) *Ustilago neglecta* was first described by Niessl* and has been reported by numerous American and European† mycologists. In Europe‡ it is said to effect *S. glauca*, *S. verticillata* and *S. viridis*. I find, however, no record of its occurrence on any other host but *S. glauca* in this country.§ On this host‖ it is extremely common, not only in Iowa, but throughout

*Rabenhorst. Fung. Europ. 1200.
†Winter die Pilze. 1: 97 as U. *Panicici-glauci.*
‡Tubeuf. Pflanzenkrankheiten. 306.
§Saccardo, Syll. Fung. 7: 472.
‖Farlow and Seymour. Host Index.

the neighboring states. This fungus converts the ovaries into a powdery mass, consisting of spherical to ovoid spiny spores, 9–16 x 7–11^u.

Covered smut of switch grass (*Ustilago syntherismæ.* (Schw.) Ell. & Ev.) This is widely distributed in the United States and is indeed common wherever *Panicum capillare, P. proliferum Cenchrus tribuloides* occur. Norton,* who has studied the germination of Kansas smuts, places under this species provisionally several of the smuts which are much alike. It certainly appears that the forms on the above weeds germinate in much the same way, but rather difficult in water. On *Panicum proliferum* and *Cenchrus tribuloides* the ovaries as well as the whole inflorescence become greatly enlarged, and for considerable time the spore mass is surrounded by a white membrane, which, on drying, breaks, allowing the spores to be liberated. The spiny spores are variable in size, 10–12^u in diameter, ovate or somewhat polyhedral, 12 x 14^u, to oblong polyhedral 12–14 x 8–10^u. This smut prevents the production of seed. The plants are much dwarfed. The allied *U. rabenhorstiana,* Kuehn†, also converts the whole in florescence into a powdery mass. The affected plants are dwarfed and more branched; the minutely roughened spores are spherical to oblong elliptical 8–14 x 7–11.5^u. The promycelium is branched; conidia are absent. Another form affects the individual flower, and not the inflorescense, as in the usual form. This smut is extremely common and destroys a large number of plants every year in this state.

Some of our cultivated grasses are affected with other members of the genus Ustilago. In some cases they affect very valuable grasses. One of these, *Ustilago bromivora* var. *macrospora,* was found on one of our native and valuable grasses, *Bromus breviaristatus,* by Mr. F. A. Sirrine on the college farm. This, as well as the smut on tall meadow oat grass, was described by the writer‡ some years ago.

Brome grass smut affects parts of the flowers causing them to develop into a powdery mass. In tall meadow oat grass I also observed that all the stalks of a stool are affected, clearly showing that the fungus enters early in the development of the plant. The *Ustilago bromivora,* Fisch. de Wald. is apparently the variety *macrospora* of Farlow. It occurs abun-

*The Kansas Ustilagineae. Trans. Acad. of Sci. St. Louis. 7: 235.

†Hedwigia. 15: 4. 1876.

Saccardo Syll. Fung. 7: 471.

‡Jour. Myc. 7: 98.

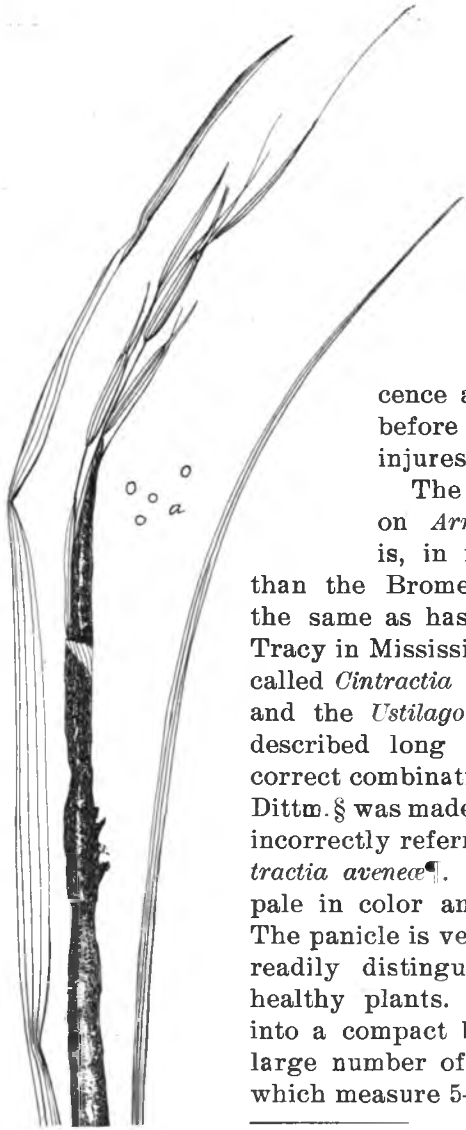

Fig. 117. Porcupine grass smut (*Ustilago hypodytes*) affecting parts of inflorescence and culm; *a*, spores. King.

dantly on one of the best of our native species of Bromus, the *B. breviaristatus* and it has been reported on *B. ciliatus* by Dr. Halsted.* It affects the inflorescence so as to completely destroy it. This smut will probably not occasion much loss, as it attacks the inflorescence and the grass can be cut before it appears, but it greatly injures its vitality.

The *Ustilago perennaus* iu common *Arrhenatherum avenaceum*; it is, in fact, much more common than the Brome smut and seems to be the same as has been found by Professor Tracy in Mississippi on the same host, and called *Cintractia aveneæ*, Ellis and Tracy,† and the *Ustilago segetum* of some writers described long ago by Bulliard.‡ The correct combination *Ustilago segetum* (Bull.) Dittm.§ was made much later. The writer‖ incorrectly referred the Iowa smut to *Cintractia aveneæ*¶. The affected plants are pale in color and somewhat drawn out. The panicle is very light in color and is readily distinguished from surrounding healthy plants. The ovary is converted into a compact brown mass made up of a large number of small sub-globose spores which measure 5–6^{u} in diameter.

*Bull. Iowa Agrl. Coll. 1886: 59. Saccardo. Syll. Fung 7: 461. Winter Die Pilze 1: 77.

†Jour. of Myc. 6: 77.

‡His. Des Champ. Fr. 1: 90 *pl. 474.*

§Dittm. in Sturm, Deutsch Fl. 3: 67. *pl. 33.*

‖Jour. Myc. 7: 98.

¶Rostrup Ustilagineæ daniæ 139 named the fungus *U. perennans*. See Tubeuf Pflanzenkrankheiten. 299.

Fig. 118 Sprouting grass smut (*Ustilago panici-miliacei*) showing large swelling in upper part of plant. (King.)
Fig. 119. Tall meadow oat smut (*Ustilago perennans*). (King.)

Barnyard grass is affected with several smuts which, by some mycologists have been placed in the genus Ustilago. Burrill* described an *Ustilago sphaerogena* occurring in the ovaries of barnyard grass. The pustulate swellings of the spikelet vary greatly. The Burrill specimen is identical with *Sorosporium bullatum* Schr.† or *Tolyposporium bullatum* Schr. The spore masses are spherical or elongated, consisting of many spores. The individual spores are somewhat polygonal, with a few warty projections. This is true of the specimen collected by Seymour in Osborne, Ill., and the Arthur specimen from Ames. The writer has collected a somewhat similar fungus with larger spores which are more minutely echinulate, in

*Ellis and Everhart. N. Am. Fung. No. *1892*.
Saccardo Syll. Fung. 7: 468.
Winter die Pilze. 1: 104.
†Krypt. Fl. Schles. 276. Saccardo Syll. Fung. 7: 502.
Bull. Torr. Bot. Club. 22: 175.

Clinton, Iowa. A second fungus has been described by Tracy and Earle on this grass, namely, *U. crus-galli.* This fungus affects the panicles and upper nodes. The mass of spores is covered by a more or less persistent membrane. The pustules in some cases are quite large, an inch or more long. The round spores are minutely roughened and measures 8–12^{u} in diameter. Magnus* described a smut on barnyard grass, the *Cintractia seymouriana*, and in a later number of the same journal changes the name of the fungus to *C. crus-galli* (Tracy and Earle)†, Magnus. The spores and general character of the fungus makes it closely allied to the Burrill fungus, but the spores examined by the writer are globose or nearly so, and somewhat smaller. The *U. bullata*, Berk., produces pustulate swellings in the individual spikelets of a species of Triticum. These vary somewhat in size, but it is evidently closely allied to *U. sphaegroena.* The *Ustilago bullata* is allied to the *U. pustulata*, Tracy and Earle,‡ which occurs on *Panicum proliferum.* It infests the ovaries, forming rounded bullate swellings. Spores dark brown, oval to sub-globose, slightly echinulate, found at Ames. *U. Panici miliacei* (Pers.) Wint. is widely distributed in Europe on *Panicum miliaceum* and *P. crus-galli.* It produces large distorted swellings in the inflorescence very much like *P. syntherismæ.* The fungus on *Panicum capillare* is sometimes referred to *U. panici miliacei.*

Manna grass smut (*Ustilago longissima*), Sow., Tul.,§ is common on species of Glyceria, producing elongated gray pustules in the leaves. These pustules contain the globular, smooth spores which measure 3–6 x 3–4.5^{u} in diameter. The latter germinate readily in a damp atmosphere or in water. The writer obtained abundant germination by keeping the spores in a vasculum or in a closed vessel for twenty-four hours. The short promycelium is narrow and straight. It produces from its end a one-celled conidium. The writer has found this species on *Glyceria arundinacea.*

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*Ber. d. deut. Bot. Gesellsch. 14: 216.

†l. c. Heft. 9.

Syll. Fung. 7: 468. Berkley and Hooker. Antarct. Voy. 199. pl. 106. f. 12.

‡Bull. Torrey. Bot. Club. 22: 175.

Tubeuf. Pflanzenkrankheiten. 301. Winter Die Pilze. 1: 89. Saccardo Syll. Fung. 7: 54.

Uredo longissima. Sow. in Berk. Engl. Fl. 5: 375. *t. 139.*

§Tulasne. Mem. Sur. les Ustil. Ann. d. Sci. Nat. Bot. *III.* 7: 76.

Saccardo. Syll. Fung. 7: 451.

Plowright. Mon. Brit. Ured. and Ust. 272.

The *Ustilago sacchari*, Rahb., is a destructive smut in Italy, Java and Africa, occurring on the stems of *Erianthus* and *Saccharum.*

Porcupine grass smut (*Ustilago hypodytes*), Schlecht. Fr. This smut is very common on porcupine grass (*Stipa spartea*). Arthur* records its occurrance on *Elymus canadensis.* The writer has never met with it on any member of the genus Elymus, although it is extremely common at times on the porcupine grass. It was described by Schlechtdendahl† as *Caeoma hypodytis.* Fries‡ transferred it to the genus Ustilago. This name is adopted by Saccardo§ and also by Plowright.‖

This fungus is characterized by its occurrence in the culms beneath the leaf sheath. It is most common during the latter part of May and early in June. It frequently destroys large patches of this grass. In addition to the host mentioned above, it occurs upon quack grass, Calamagrostis, Bromus and Phragmites. Its distribution is quite common throughout Europe and northern Africa, but as stated above, it usually occurs in this state upon the Stipa.

Wild timothy (*Mulenbergia glomerata*) is affected with *Ustilago montaiensis*, Ell. & Holw.¶ This smut affects the ovaries, causing them to become greatly enlarged, very much like *Ustilago bullata.* The smutty mass is surrounded by a persistent membrane, which later cracks and breaks. The glumes and bracts are pale in color. The spores are brown and minutely roughened. This fungus appears to occur only in Montana, but ought to be looked for in this state.

The *Ustilago buchloes*, Ell. & Tracy, affects the leaves of buffalo grass, causing enlargements. The smut is covered by a delicate membrane which soon becomes ruptured, and this distributes the spores. The spores are brown and smooth. It occurs in the southwest.

Ustilago andropogonis, Kellerman and Swingle,** occurs upon tall blue stem, *Andropogon provincialis.* This smut causes the host plant to flower several weeks earlier and dwarfs the

*Iowa Ustilagineae. Bull. Iowa Agrl. Col. Dept. of Bot. 1884: 172.
†Flora Berol. 2: 129.
‡Syst. Myc. 3: 518.
§Syll. Fung. 7: 453.
‖Mono. of the British Ured. and Ustilag. 273.
¶Ellis and Everhart. N. Am. Fung. No. 2263.
**Jour. Myc. 5: 12.

affected plants. It affects the ovaries. The spores are dark brown or black, sub-globose or slightly oval.* The fungus appears to be closely allied to if not identical with *Sorosporium ellisii*, Winter,† and this specific name should therefore be used. The Cerebella is allied to the Sorosporium; one species, the *C. spartinæ*, occurs and affects the spikelets of slough grass.

The *Ustilago aristidæ*, Pk., was described by Peck.‡ It occurs upon *Artistida purpurea.* It is common in parts of Nebraska where the writer has found it covering wide areas. It has been reported by Norton f om Kansas. This smut fills the ovaries, and the awns are much shorter than usual. An Ustilago also occurs on *Sporobolus, vaginæflorus*, the *U. vilfæ.*§ The *Ustilago spermophora*, Berkley and Curtiss ‖ is very common at times on *Eragrostis major.* Generally only a few of the ovaries are smutted, but in some cases entire sections of the panicle were affected. The spores are sub-globose and minutely roughened. During the past season, 1899, it was extremely common here in this state.

BUNTS (TILLETIA).

Wheat is attacked by two species of bunt in this country, the *Tilletia foetens* (B. & C.) Schroeter, and *Tilletia tritici* (Bjerk) Winter. Of these the former is far more common. Both are exceedingly destructive to wheat.

Tillitia foetens (B. & C.) Schroeter. This fungus was first described by Berkeley and Curtiss;¶ earlier than this it was recognized by Wallroth.** Kuehn, in 1874, gave it the name of *T. laevis.* It usually passes under this name in European mycological works, so given by Sorauer,†† Frank‡‡ and Tubeuf.§§ This name is also used in Massee's‖‖ monograph on Tilletia. The present combination was made by Schroeter.¶¶

*Norton. Trans. Acad. Sci. St. Louis. 7: 236.

†Hedwigia. 22: 2. 1883. Saccardo Syll. Fung. 7: 513.

‡Bull. Torr. Bot. Club. 12: 35. *pl. 25. 19-23.* See also Norton. Trans. Acad. Sci. St Louis. 7: 232.

§Winter. Bull. Torr. Bot. Club. 10: 7.

‖Curtiss. Cat. N. Carolina. 123. Syll. Fung. 7; 466.

¶Ravenel. Fungi. Car. 100. Berkeley. Notices of No. Am. Fungi. 573. Grevillea. 3: 59.

**Flora Crypt. Germ. 2: 213. *1661*, 1833.
Rabenhorst. Fungi Europ. 1697.
Hedwigia *12*: 152. Winter die. Pilze. 1: 109.

††Pflanzenkrankheiten. 185.

‡‡Krankheiten der Pflanzen. 118. *f. 20-21.*

§§Pflanzenkrankheiten. 325.

‖‖Bull. Miscel. Inf. Kew. **1899**: 141.

¶¶Bemerkungen und Beobachtungen ueber Ustilagineen. Cohn. Beitrage zur Biologie d. Pflanzen. 2: 365, 1888.

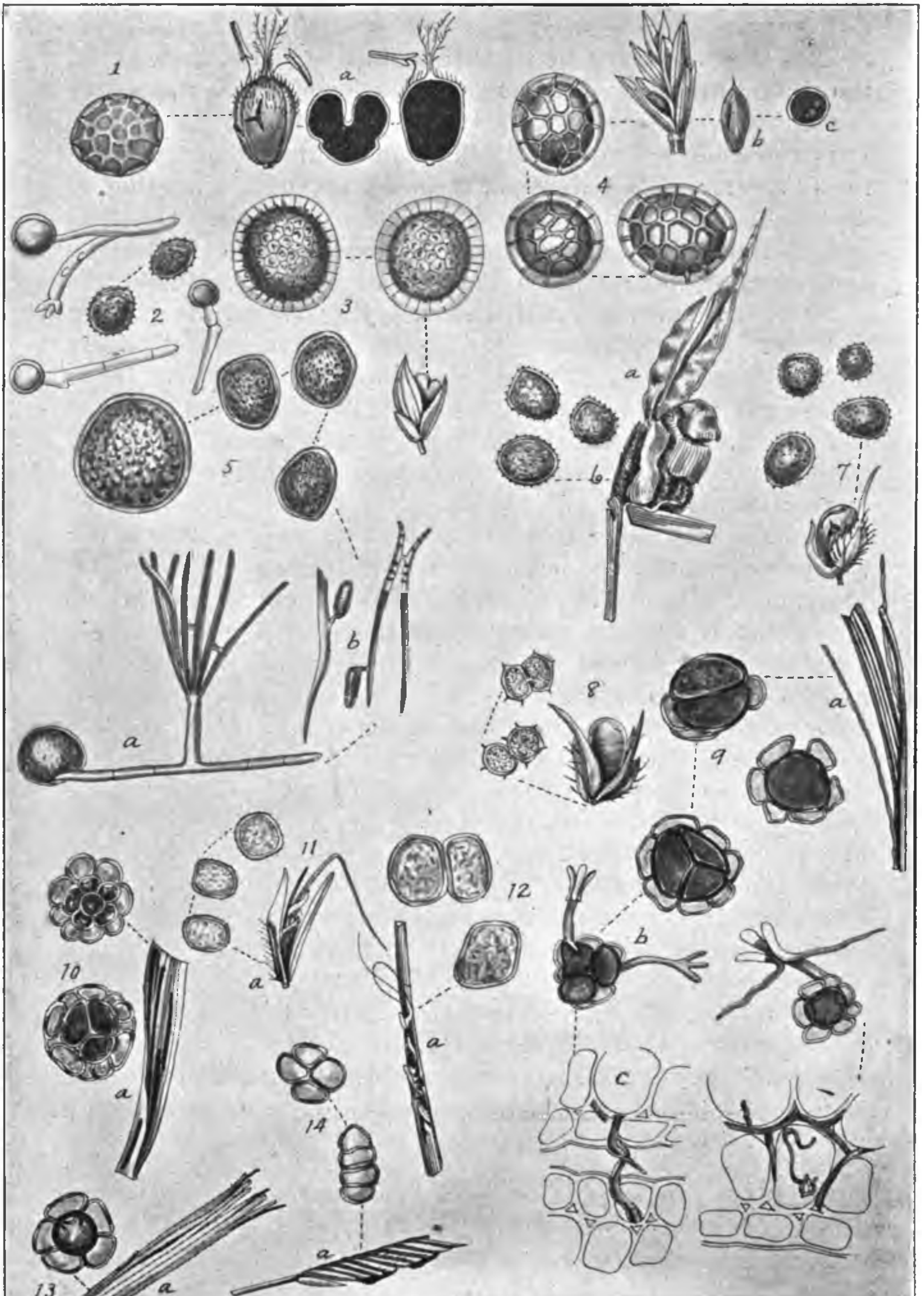

Fig. 120. *1.* **Wheat Bunt** (*Tilletia tritici*); *2,* **Timothy Smut** (*Tilletia striaeformis*); *3, Tilletia rotundata; 4, Tilletia controversa; 5,* **Wheat Bunt** (*Tilletia foetens*); *6,* **Barnyard Smut** (*Ustilago crus-galli or Cintractica*); *7-8, Sorosporium bullatum; 9, Urocystis occulta; 10, Urocystis agropyri; 11-12, Ustilago; 11, Sorosporium ellisii* var. *occidentalis; 12, Sorosporium ellisii* var. *provincialis; 13, Urocystis agropyri* on *Bromus ciliatus; 14, Cerebella spartinae* on *Spartina.* (Pammel and King)

This bunt is widely distributed in Europe and America. In the United States it is common in Wisconsin, where the writer found it in considerable quantity in the vicinity of La Crosse. It is reported by Trelease.* It is common in Indiana, according to Arthur.† It is likewise common in Ohio, according to Hickman,‡ and in Nebraska, according to Webber.§ Halsted‖ reports it as injurious to wheat in New Jersey. Kellerman and Swingle¶ have studied, more than other persons in this country, its nature and distribution in Kansas and the country at large. Swingle has also published several important papers on the subject.

It is not common in Iowa, though it has been found several times by the writer on the college grounds since 1891, and it has been found abundantly in the wheat screenings of some of our local mills.

General characters.—It is not always an easy matter to tell the presence of this smut by the character of the plant, although the heads are darker green, appearing as though stimulated by an extra amount of fertilizer. When the grain is ripening the diseased plants are recognized, the smutted heads having a paler color instead of the characteristic golden color of good wheat. The chaff is more spreading and the kernels are greatly swollen. One cannot be deceived by this disease when the kernels are crushed, for a very disagreeable odor is given off. According to Swingle, a whole bin of wheat may be charged with it. It is said by people who have followed the threshing machine that this odor is very pronounced where the disease is serious. I have myself noticed the bad odor in passing along the side of a field in western Wisconsin where the fungus was abundant.

Microscopic characters.—The spores of this fungus are nearly round or somewhat elliptical, smooth, 15–22 x 15–20^{u} in diameter. Under favorable conditions of heat and moisture the spores germinate in the course of a few days, by producing a promycelium. This tube produces, in the presence of oxygen,

*Parasitic Fungi of Wisconsin. 35

†Bull. Ind. Agrl. Exp. Sta. 28.

‡Bull. Ohio Agrl. Exp. Sta. II. 3: 205.

§Bull. Neb. Agrl. Exp. Sta. 11: 70.

‖Rusts, smuts, ergots and rots. Separate from Rep. New Jersey State Board of Agrl. 1889,

¶Bull. Kansas Agrl. Exp. Sta. 12: 1890.

The grain smuts, their causes and prevention. Yearbook U. S. Dept. Agrl. 1894: 409.

The grain smuts. U.S. Dept. Agrl. Farmers' Bulletin. 75: 6.

Fig. 121. Bunt of wheat, *Tilletia foetens*, after Bessey.

a whorl of slender bodies—the primary sporidia. These sporidia produce short tubes which join them to each other. The infection may result from the slender threads produced by the primary sporidia, or from the secondary sporidia, which also produce slender threads. These germ tubes can enter the plant only by way of the delicate tissues of the seedling.

Damage.—It is difficult to estimate the amount of damage. The percentage in Iowa is usually very small, but in Wisconsin I have seen whole fields destroyed, and Arthur* likewise gives an illustration where one-half of the crop was lost.

*Bull. Ind. Agrl. Exp. Sta. 28.
l. c. Farmers' Bull. 75: 6.

Swingle says: "There are no accurate statistics as to the amount of damage caused by them. In many localities, however, the losses are very great, and without doubt the losses in the entire United States amount to many millions of dollars annually. In some fields 50 and even as high as 75 per cent of the heads are smutted, and in addition the healthy grain is so contaminated with the fetid spores as to be almost worthless for flour and worse than useless for seed."

Tilletia tritici (Bjerk) Winter.—This species is more commonly referred to by European writers than the *T. foetens*. Thus Tubeuf,* Frank,† Loverdo,‡ Sorauer,§ Plowright,‖ Wolf and Massee¶ all mention its common occurrence in Germany, France and England. In the Mississippi valley it does not appear to be as common as the specimens above described. Bessey** reports this species as occurring in Iowa in 1884 and since. Harwood has reported†† it as common in Michigan. Kellerman and Swingle‡‡ report it in Kansas. In a general way this fungus is much the same as the former species. Harwood notes that wheat attacked by this species has shorter stalks than the normal. It affects the kernels and the chaff, spreading as in the last species. The spores are smaller, globose, with net-like ridges, 16–20^u in diameter. This last character easily distinguishes this form from the other smut. Its life history is the same. All of the heads of a stool are affected.

In European mycological works it is usually referred to as *T. caries*, by Sorauer, Frank and others. Tubeuf and Saccardo§§ refer to it as *T. tritici*, while Massee, in his revision, places it under the name of *T. caries*.

Tilletia secalis (Corda) Kuehn.—Bunt of rye was described by Kuehn‖‖ in 1876. Though quite destructive in Europe, Germany and Bohemia, it has not been found in this state. The kernels are filled with a brownish-black powder. Like the

*Pflanzenkrankheiten. 318.

l. c. Krankheiten der Pflanzen. 117. (2 Ed.)

†Les Maladies. Crypt. 86.

‡Pflanzenkrankheiten. 185.

§British Uredineæ and Ustilagineæ. 283.

‖Der Brand des Getreides seine Ursachen und seine Verhutung. 12. Halle.

¶Wolf and Massee. Kew. Bull. of Miscel. Inf. 1899: 142.

**Bull. Iowa Agrl. Coll. Dept. Bot. 1884: 119.

††Bull. Michigan Agrl. Exp. Sta. 87: 5.

‡‡Preliminary experiments with fungicides for stinking smut of wheat. Bull. Kans. Agrl. Exp. Sta. 12.

§§Syll. Fung. 7: 481.

‖‖Bot. Zeit. 1876: 470.

other bunts, it produces a disagreeable odor. The spores are spherical or very rarely elliptical, usually 20ᵘ in diameter.

Tilletia hordei (Koernicke).—Bunt of barley was described by Koernicke* in 1877 from specimens found in Persia on *Hordeum fragile* as well as on *H. murinum.* This smut occurs in the ovaries and is covered by a blackish-brown membrane. The spores are smaller than those of *T. secalis*, measuring 19.5–20.5ᵘ in diameter.† The epispore is but slightly thickened, and reticulated.

Tilletia Lolii, Auersaw.—This bunt occurs in the fruit of *Lolium temulentum*‡ and other species. Spores are spherical or irregularly spherical or rarely elliptical; pale yellow or yellowish-brown, 17.57–20 by 24ᵘ in length, usually 19. Epispore with prominent projections which form a net work, the meshes of which, according to Winter. are 3.5ᵘ in width. The allied *T. controversa*, Kuehn, attacks the ovaries of *Agropyron repens;* the globose spores are pale brown. The mycelium is perennial in the rhizome of its host.

Tilletia rotundata (Arth) Ell. & Ev.—In South Carolina a Tilletia has been found quite abundantly on rice. It affects the ovaries, converting them into a black granular mass According to Anderson§ who has studied the disease, the ovaries are seldom hypertrophied or atrophied, but retain to a great extent the form and size of the normal ovaries. The large, spherical, spiny spores are surrounded by a hyaline envelope. They are from 26–30ᵘ in diameter. According to Tracy and Earle this fungus occurs on various wild grasses like *Panicum virgatum* and Leersia. This is synonymous with *T. corona*, Scribner.‖ Massee evidently overlooked the American studies of the species. A second species, the *T. oryzae*, Pat.,¶ occurs on rice in Japan. The globuse or ovoid spores are olive-brown and warted; united into hard blackish-green mass. This belongs to Brefeld's Ustilaginoidæ.

Tilletia Moliniæ (Thum) Winter.—This species was first described by Von Thumen** as *Vossia Moliniæ.* Koernicke†† changed it to *Neovosia Moliniæ* (Von Thum) Kornicke, but Sac-

*Mycologische Beitrage. Hedwigia. 16: 30.
†Saccardo. Syll. Fung. 7: 484. Frank. Krankheiten der Pflanzen. 427 (2 Ed.)
‡Saccardo Syll. Fung. 7: 483. Winter. Die Pilze 1: 109.
§Bot. Gazette. 27: 467. 1899.
‖Bull. Torr. Bot. Club 23: 210.
¶Bull. Soc. Myc. 3: 124. 1887.
Saccardo Syll. Fung. 9: 286.
**Oest. Bot. Zeitschert29: 18,
††Syll Fung. 7

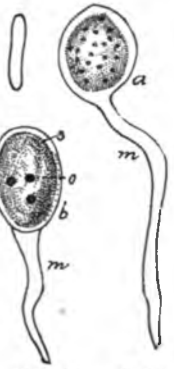

Fig. 122. *Tilletia moliniae* on Phragmitis; *a*, spore; *m*, pedicel; *o*, oil bodies. (King)

cardo* and Winter place it under *Tilletia Moliniæ* (Von Thum) Winter. Dr. Farlow, who identified the fungus for me on Phragmitis, states that it seems to agree with that species. It was found by Mr. E. R. Hodson in considerable quantity on *Phragmites communis* in the vicinity of Colo. The ovaries are enlarged, much longer than broad. The interior is filled with a black powdery mass, the spores. The spores are round or elliptical, seldom spherical, dark brown in color, rough, and surrounded by a persistent thick-walled colorless exospore, with the permanently attached mycelium at one end, resembling a slightly twisted pedicel. Massee,† in his recent monograph of Tilletia, excludes this species from the genus Tilletia. The spores measure 16.6 to 20.8 x 24.9 to 29.1. It may be a good species but cultural experiments will be necessary to determine this point. In Europe it occurs on *Molinia cærulea.*

TIMOTHY SMUT.

This fungus (*Tilletia striaeformis* (Westd.) Magnus) has been known for a considerable length of time. It affects several different species of grasses. It was first described as *Uredo striiformis*, Westd.‡ The proper name for the fungus was given it by Magnus.§ This fungus has been quite abundant for a number of years in Wisconsin, Missouri and Iowa. The first economic account of it was given by Trelease in his paper on the smut of timothy.‖ He reported it as common in Wisconsin on timothy and that it also occurred on *Agropyron repens* and wild rye (*Elymus canadensis* var. *glaucifolious*). The writer gave a short account of the fungus in a series of papers on Fungus Diseases of Iowa Forage Plants,¶ referring to its common occurrence on timothy and *Agropyron repens*, both in this state and in Massachusetts. Since then the writer has frequently found it on blue grass and timothy in this state. In Europe the fungus is quite common on a number of different hosts, namely, perennial rye grass (*Lolium perenne*), tall meadow oat

*Winter die Pilze 1: 109.

†Bull. Miscl. Infor. Kew. 1899: 156.

‡Westend. Bull. Acad. Brux. 1851: 406.

§Winter Die Pilze 1: 108. For other references see Saccardo, Syll. Fung. 7: 484 and Plowright Mon. British Bred. and Ustil. 284.

‖Rep. U. S. Dept. Agr. 1885: 87.

¶9. See also Jour. Myc. 7: 97.

Fig. 122. Timothy smut (*Tilletia striaeformis*) affecting timothy. Leaves torn up into shreds; *a*, spore germinating; *b*, promycelium with sporidia at the end. (King and Pammel.)

grass (*Arrenatherum avenaceum*), *Bromus inermis*, sheep's fescue (*Festuca ovina*), tall meadow fescue (*Festuca elatior*), etc.

The fungus is closely related to stinking smut of wheat. The spores germinate in the same way and probably enter its host when the seed germinates. There is this important difference between the two species, this smut does not affect the "seed" in the same way. Its life-history is also somewhat different. The stinking smut is at most very short-lived, while this species is certainly a perennial. The destructive work of stinking smut comes on at a time when flowers and seed are forming. *Tilletia striaeformis* appears long before, perhaps soon after the first leaves come out early in spring. In Iowa I have noticed it about the middle of May; it continues, however, to develope on the younger leaves till the middle of June, when often the bracts of the flowers become affected. Last spring in one of the meadows on the college farm a large number of young plants were affected; the loss was very considerable. The plants were shorter and marked with longitudinal lead colored stripes, often extending to the very tips of the leaf. When these lead colored patches are torn open a black powdery mass, the spores, are exposed.

As the plants become older the epidermis of these lead colored patches breaks and thus exposes the spores. The constant action of the wind soon causes the leaf to be torn up into shreds. The affected plants never become so tall as the adjoining ones, seldom fruiting well. I think there can be very little doubt that the fungus is a perennial as the following will illustrate. During the spring of 1887 and 1888 I observed a small bunch of timothy in the Missouri Botanical Garden at St. Louis, every leaf and stalk in the bunch was affected. Both seasons it was found on the same plants. Here at Ames, also, I have seen the smut on the same plants for two seasons.

THE GENUS UROCYSTIS.

This genus contains several parasites destructive to our cultivated plants. Our grasses are effected by two of these, the rye smut and the wild rye smut.

RYE SMUT.

This fungus (*Urocystic occulta*, Wallr.), first described by Wallroth* in 1883, has been repeatedly observed in various European

*Fl. Crypt. Germ. 2: 212. Erysibe occulta, Urocystic occulta (Wallr.) Rabenh. Klotzsch Herb. Myc. No. *393*. Fung. Eur. *1790*.

countries by Sorauer,* Frank† and others. It also occurs in Australia where it is said to do much damage. It was first found in this country by Underwood‡ and Cook, who distributed the fungus, and later in Connecticut by Thaxter.§ It is not nearly so common in Europe as other cereal smuts and to my knowledge has never been found in Iowa.

It is stated that between the years of 1850 and 1860 it was so destructive in parts of South Australia that in some localities cultivated rye sustained a loss of 66 per cent. Like timothy smut it attacks the leaves, sheaths, stem, and inflorescence, but generally it is found on the leaves and sheaths. It makes its appearance about the middle of May and continues through June. It is characterized by lead colored patches which are arranged in parallel rows along the veins. The epidermis which covers the sori soon becomes ruptured and exposes the powdery spores, and like timothy smut, the leaf is soon torn up into brown shreds. The spores differ very materially from any we have thus far considered. They are arranged in clusters made up of two kinds of cells. The central ones are darker in color, and are capable of germination; the surrounding cells are lighter in color and do not germinate. The Urocystis spores do not germinate very readily. The promycelium bears the sporidia at the end. The fungus enters its host through the very young leaves close to the seed. Wolff states that the fungus cannot enter later. In eight or nine weeks rye, inoculated with sporidia, produced spores in the seventh or eighth leaf. When the sporidia come in contact with the leaf they attach themselves very closely, penetrate the cuticle of the epidermal cell, growing crosswise through the young seedling and then passes from the inner epidermal cell of one leaf to the outer of another. The mycelium when once in the interior of the plant grows in the intercellular spaces, sending haustoria into the cells.

WILD RYE SMUT.

This smut, *Urocystis agropyri* (Preuss), Schr., occurs on several grasses in Europe and the United States.‖

*Pflanzenkrankheiten. 190.

†Krankheiten d. Pflanzen. 121 (Ed. 2).

‡A Century of Illustrative Fung. No. 57. 1889.

§Rep. Conn. Agri. Exp. Sta. 1899: 143. *pl. 2. f. 9-10.*

‖Saccardo. Syll. Fung. 7: 516.
Farlow and Seymour. Hort. Index. 150.
Tubeuf. Pflanzenkrankheiten. 329.

In Massachusetts the writer found it common on *Agropyron repens*, and it is reported on the same host in Europe by Tubeuf. It is also reported on tall meadow oat grass and *Festuca rubra* and *Bromus inermis*. Thus far it has only been observed by me on the wild rye, *Elymus robustus*. This species is very common about Ames. It makes its appearance early in June and continues through July. Hundreds of culms are affected. In many cases it is difficult to find a sound leaf in some places. The fungus is characterized by linear lead-colored patches, which occur along the veins of the leaves. On drying them the epidermis becomes ruptured, exposing the black powdery spores, which have much the same character as the rye smut, measuring 1–3 x 8–12^u in diameter. The spores do not germinate readily. It is certainly a perennial. The species was first described from European specimens.*

TREATMENT FOR SMUT.

All smuts are not amenable to the same treatment, since the manner of entering the host differs. In many diseases of plants hygienic methods are of much value, and to some extent these are of value also in smuts. Of course, in the case of corn smut, much can be done by removing the smutted portions of the plant, and rotation of crops should always be practiced. Though this will destroy but a small portion of the smut, it is helpful. Use care in seed selection—the seed should be free from smut. In the way of treating the seed, two methods have been in vogue—hot water and the chemical treatment. The latter has been in vogue for a long time, especially the method of treatment with blue stone. For full accounts Swingle's† papers should be consulted.

Formalin.—During recent years much has been said about formalin as an antiseptic as well as a disinfectant. Experiments made by Close‡ and Bolley§ indicate that it is valuable to prevent stinking smuts, as well as loose smut of oats. It is used at the rate of one pound to fifty to sixty gallons of water, and the seed soaked two hours. The 40 per cent solution should be used. The strong solution is poisonous; the dilute solution is not dangerous. A one per cent solution gave good results.

**Uredo Agropyri.* Preuss in Klotzsch Rabh. Herb. Myc. *1696.*
Urocystis Agropyri (Preuss) Schr. Brandu. II. Restp. Schl. 7.
†Yearbook U. S. Dept. Agrl. 1894: 415.
Farmers' Bull. Office of Exp. Station. U. S. Dept. Agrl. 75.
‡Rep. N. Y. Agrl. Exp. Sta. 16. 294. 1897.
§Bull. North. Dak. Agrl. Exp. Sta. 27.

Potassium sulphide.—Potassium sulphide has proved efficacious. The method given by Swingle is as follows: "Dissolve one and a half pounds of potassium sulphide in twenty-five gallons of water in a wooden vessel (a tight barrel serves very well for this purpose). The potassium sulphide should be of the fused form, known as liver sulphur. This can be obtained of any druggist for from 25 to 50 cents per pound, according to the quantity purchased. It should be kept protected from the air in a tight glass vessel until ready for use. The lumps of potassium sulphide dissolve in a few minutes, making the liquid a clear yellowish-brown color. After thoroughly stirring, put into the solution about three bushels of oats and agitate well to insure wetting every grain. The solution must not only cover the grain, but must rise several inches above it, as some of it is soaked up by the grain. Leave the oats in the solution for twenty-four hours, stirring several times during the day to make sure that every kernel is wetted, after which spread out to dry. A number of experimenters have found that soaking the seed two hours in a 2 per cent solution (eight pounds to fifty gallons) was nearly or quite as effective as the longer treament. The grain should be stirred repeatedly to insure thorough wetting. Seed thus treated is much easier to dry than that soaked twenty-four hours. Probably this form of treatment will prove the best.

"In treating large quantities of seed a hogshead or wooden tank might be used. The solution should be kept well covered to keep the air from it, and should not be used more than three times. In no case should metal be allowed to come in contact with it. This treatment is thoroughly effective for loose smut of oats, and is worthy of a trial for stinking smut of wheat."

Ceres powder.—This substance is advertised as a preventive of smuts, is, according to the analyses of Hollerung and other German investigators, only crude potassium suphide sold under another name and at a much higher price.

Sar solution.—This consists chiefly of sodium sulphide and as given by Swingle is prepared as follows: "Place fifteen pounds of flowers of sulphur in a barrel, mix thoroughly with one-half pound of finely-powdered resin, and stir well with three quarts of water, which should make a thick paste. The paste must not be thin and watery, nor so dry as to crumble to powder when stirred. Then add ten pounds of caustic soda and stir well.* After from three to fifteen minutes the mass turns a reddish-brown and boils violently, and must be stirred well, preferably with a broad paddle, to prevent it from running over. After it has ceased boiling, add about two gallons of water (hot if possible, but cold will do) and then carefully pour off into another vessel marked to hold six gallons, and add hot water till the six-gallon mark is reached. This gives a stock solution, which must be kept in tightly closed jugs or in closed barrels or kegs, since it boils if it comes in contact with the air. It is also decomposed if it touches metals. Of this stock solution use one and one-half pints to fifty gallons of water, soaking the seed twenty-four hours, or one gallon to fifty, soaking two hours. In either case treat the seed according to the directions given for the potassium sulphide treatment."

Hot water.—Numerous experiments by Jensen, Arthur, Kellerman and Swingle, Jones, the writer and many others have shown that hot water is efficacious as a preventative for oats smut and bunt.

Provide two large vessels holding at least twenty gallons each (two wash kettles, soap kettles, wash boilers, tubs, or even barrels will do). One of these vessels should contain warm water at say 110° to 120° F. and the other hot water at 132° to 133° F. The first is for the purpose of warming the seed before dipping it into the second, unless this precaution is taken it is difficult to keep the water in the second vessel at the proper temperature. A pail of cold water and a kettle of boiling water should be kept at hand to draw from when necessary to raise or lower the temperature; or, better still, in case a kettle or boiler is used, the temperature of the water may be kept up by placing the vessel over a small fire. Where steam is available, it can be conducted into the second vessel containing the hot water by means of a pipe provided with a stopcock. This answers better than any other method for heating the water and for elevating the temperature from time to time.

Place the seed to be treated, at the rate of half a bushel or more at one time, in a closed vessel which will allow the free entrance of water on all sides. A bushel basket made of heavy wire, with wire netting, say twelve meshes to the inch, to spread inside, may be used for this purpose; or a frame can be

*"Finely-powdered concentrated lye sold in grocery stores in one-pound packages, such as Red Seal granulated lye, serves admirably. If considerable quantities of the solution are to be prepared, it will be cheaper to purchase powdered caustic soda, 98 per cent pure, in ten-pound tins, through some wholesale dealer in drugs or chemicals."

made at a trifling cost and the wire netting stretched over it. This will allow the free passage of the water and at the same time prevent the seed from passing out. A sack made of loosely woven material—for instance a gunny sack—may be used instead of the wire basket. In some respects a perforated tin vessel is preferable to any of the above. It is important not to fill the baskets or sacks completely, as the grain is wetted more easily, drains better, and is more uniformly exposed to the hot water when it can move about freely. It is also important to have a volume of hot water at least six to eight times as great as the capacity of the basket or sack; otherwise the temperature varies too much.

Copper sulphate.—This has long been used for the treatment of oats smut and bunts. It is used in the following proportions: Dissolve one pound of copper sulphate in twenty-four gallons of water; immerse for twelve hours. After this immersion Swingle recommends to place the seed for five minutes in lime water made by slacking one pound of good lime and then diluting to ten gallons with water.

Corrosive sublimate—This well known disinfectant has been recommened by Bolley* for bunt, in the proportion of one pound to fifty gallons of water. The following are the directions given for applying this treatment: "Pile the wheat upon the floor or upon a canvass and thoroughly sprinkle or spray on the solution, while the grain is being constantly shoveled over so that every grain becomes wet over its entire surface. Do not use any more of the solution than necessary to do this, as an excess is injurious to the seed." The writer has found it efficacious to prevent oats smut. It should be constantly stirred, and care used not to use too much of the liquid; too long contact greatly impairs germination. In this method great care should be used, as the solution is very poisonous.

The potassium sulphide treatment, as well as the hot water method, show that there is an increase in the yield. Arthur states that hindered germination is due to the liberation of large quanties of diastase by the action of heat.

RUSTS, OR UREDINEÆ.

The term rust as applied to cereals is usually pretty well understood by most people, though the term is often incorrectly applied to many other fungi. The term is limited to a class of

*Bull. North Dak. Agrl. Exp. Sta. 27.

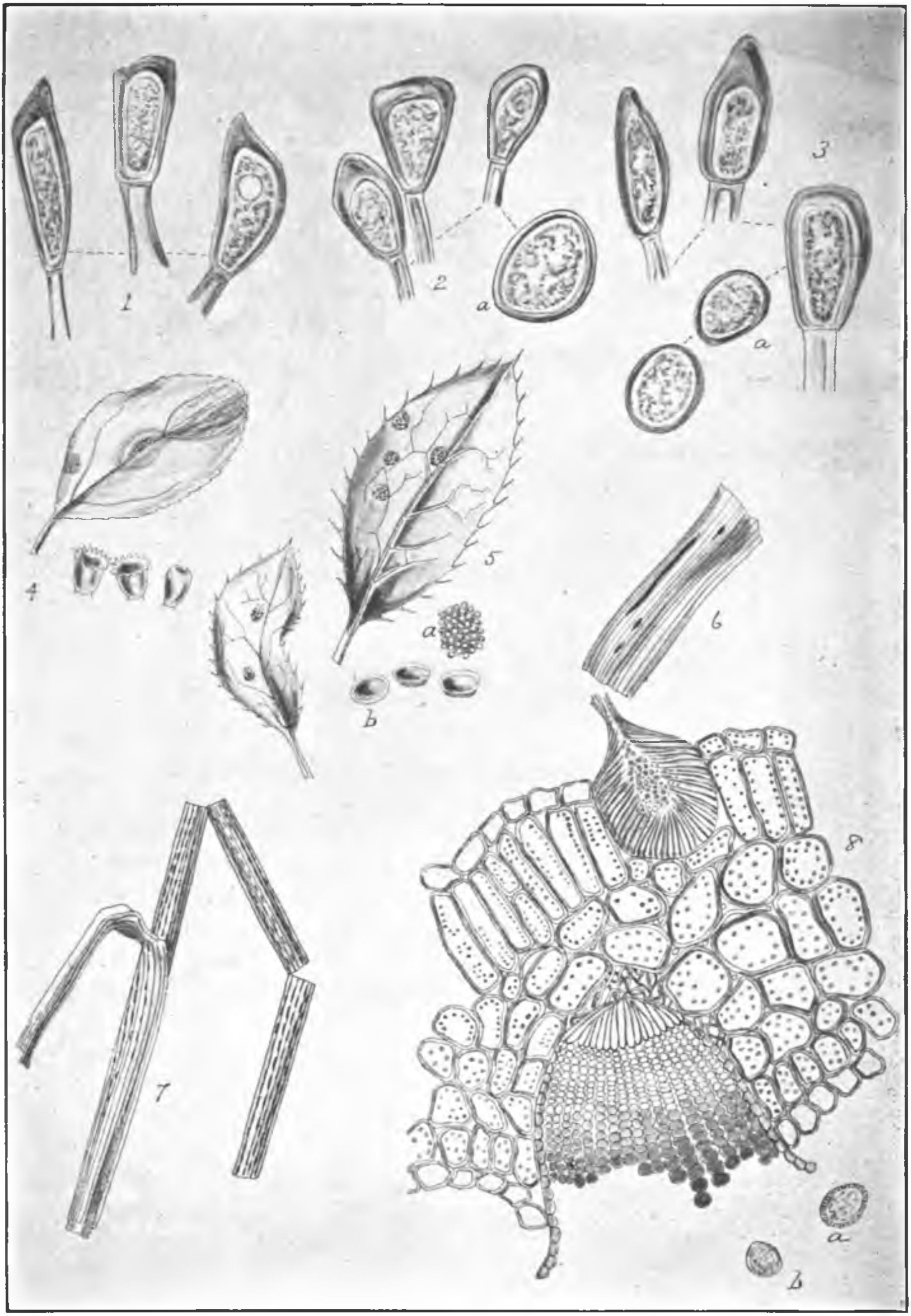

Fig. 124. Rusts of grasses. *1*, Spartina rusts (*Uromyces acuminatus*) on spartina cynosuroides; *2*, teleuto spores of orchard grass rust (*Uromyces dactylidis*) uredo spores at *a*; *3*, teleuto spores of *Uromyes poæ*, uredo spores at *a* on Poa; *4*, *Puccinia coronata* on *Rhamnus cathartica*; *5*, aecidium of *Puccinia graminis* on barberry, *a* and *b*, spores magnified; *6*, *7*, *Puccinia graminis*; *8*, aecidium of *Puccinia graminis*, the cup below spermogonia above *b* spores, *a* peridial cell. (Pammel and King.)

fungi belonging to the Uredineæ as will be made clear in the following pages. The Uredineæ are among the most destructive of the parasite fungi of cultivated and wild plants. Well-known illustrations are, cereal rusts, rust of apple, coffee leaf disease, hollyhock rust and carnation rust. The rusts are common on a large number of grasses. The most important of those affecting Iowa forage plants will be taken up under the head of (1) rusts of cereals, (2) rusts of other grasses.

History.—Rust was well known to the ancients. This affection is mentioned in connection with smut. It is referred to in several places in the Bible.* Aristotle mentions its occurrence and causes. Plinius, Columella, Ovidius and other writers mention the occurrence of rust. But little mention was made of it during the middle ages, though beginning with the seventeenth century reference to it became frequent. Some of the laws looking toward the extermination of the barberry date from 1660 when an act having that object in view was passed in Rouen. In 1755 Massachusetts passed a law looking towards the extermination of the barberry. A complete and full history will be found in the work of Eriksson and Henning.

RUSTS OF CEREALS.

The subject of rusts is one of special interest to us because large losses are usually entailed by our cereal crops. During the last decade several wheat crop failures in parts of our state have been caused by rust. It is, therefore, proper that this subject should receive consideration.

Eriksson and Henning,† in their recent monograph, find that our cereals have several specialized forms of rusts. Carleton,‡ as the result of some careful studies, finds that our cereal rusts are specialized.

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*5 Moses 28: 22. 1 King 8: 37. 2 Chro. 6: 28.

†Die Getreideroste ihre geschichte und natur sowie Massregeln gegen dieselben. Stockholm. 464. *pl. 13. map I. f. 5.* 1896.

‡Cereal Rusts of the United States. Bull. Div. Vegetable Phys. and Path. U. S. Dept. Agrl. 16.

The following outlines show the chief cereal rusts and their host plants:

Maize (*Zea mays*),	*Puccinia sorghi*, Schw.
Wheat (*Triticum vulgare*),	*Puccinia graminis*, Pers. f. *tritici.*
	Puccinia glumarum (Schmidt) Eriks. & Henn. f. *tritici.*
	Puccinia rubigo-vera (D. C.) Wint. f. *tritici.*
	Puccinia dispersa, Eriks. & Henn.
Oats (*Avena sativa*),	*Puccinia coronifera*, Klebahn.
	Puccinia coronata.
	Puccinia graminis. f. *avenæ.*
Barley (*Hordeum vulgare*),	*Puccinia graminis.*
	Puccinia simplex, Koernicke.
	Puccinia glumarum. f. *hordei.*
Rye (*Secale cereale*),	*Puccinia graminis.* f. *secalis.*
	Puccinia glumarum. f. *secalis.*
	Puccinia rubigo-vera. f. *secalis.*

Eriksson and Henning use the name *P. dispersa* for the old *rubigo-vera*, which has been in use among mycologists for a long time. Carleton, after having made a careful morphological study of the rusts of northern Europe and the United States, concludes that the *P. dispersa* and *P. rubigo-vera* are identical, and that the name *P. rubigo-vera* should be used. He concludes that we have six cereal rusts and a possible seventh in the United States.

CORN RUST.

Corn rust (*Puccinia sorghi*, Schw.) Schweinitz,* an early American mycological writer, described this fungus as early as 1834, but earlier than this Carradori † an Italian writer, referred to this fungus. It is widely distributed, occurring where corn is cultivated, and at times is quite troublesome, especially in North America. According to Saccardo,‡ it occurs in Italy, France, Austria, Germany, Lusitania, North and South America. Peck§ and Seymour‖ have given us the only early economic accounts of the fungus. There is also a

*Synop. Fung. 295.
†Giorn Fis. Pavia. 8. 1815.
‡Syll. Fung. 7: 659.
§Rep. St. Mus. of Nat. Hist. N. Y.. 34: 29.
‖U. S. Dept. Agrl. Report. 1887: 389.

short account by one of us,* and one by Weed† in his book, "Fungi and Fungicides."

Characters of the fungus.—The fungus produces two stages. The first or uredo stage is similar to the red rust stage of wheat. It occurs on the bracts covering the cob, leaves and sheath. Small, light-brown pustules or sori appear on both surfaces of the leaf. Close examination will show that these sori break through the epidermis where small white spots occur. The rupturing of the epidermis is caused by the continued growth of the spores underneath. The ruptured epidermis shows the small spores. The uredo spores are one-celled, round or more often elongated and spiny. The stalk is detached. The spores measure 23–38 x 20–26^{u}. The uredo sori are clustered or arranged in parallel rows, closely following the veins of the leaf. The uredo spores are capable of germinating immediately and distribute the fungus during the summer. They preserve their vitality for only a short time; at any rate they do not live through the winter. Carleton‡ states that the time of incubation for the uredo is shorter than any of our cereals, varying from five to eight days.

As the leaves become older the yellowish-brown uredo sori are replaced by black sori. These sori may also appear where uredo sori did not occur. The same mycelium which gave rise to the uredo spores later gives rise to the teleuto spores. The sori containing these spores are black. The spore is broadly elliptical and two-celled. It measures 30–52 x 16–24^{u}. The apex may be thickened and somewhat pointed. These spores preserve their vitality for some time; they are dormant through the winter. In the spring each cell may germinate by producing a tube, known as the promycelium, which bears lateral bodies known as sporidia. It is undoubtedly connected with some æcidium or cluster cup stage, but this stage is not known. Carleton reports the occurrence of this fungus on Teosinte (*Euchlaena mexicana*) which is closely related to maize.

The species is of considerable economic importance in our state, but it is seldom that reference is made to it. Duthie and Fuller§ state that corn is singularly free in India from fungus diseases. Agricultural writers in this country do not usually

*Pammel. Monthly Review of the Iowa Weather and Crop Service. 7: 7. 1896.
†Weed. Fungi and Fungicides. 207, *8*, *86*.
‡Cereal Rusts of the United States. 66.
§Field and Garden Crops of Northwestern Province. Ouah. etc. 1: 21.

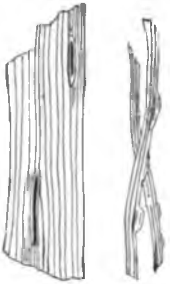

Fig. 125.

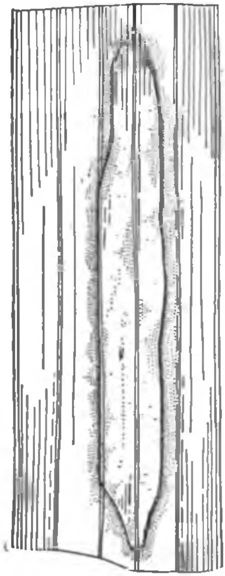

Fig. 127.

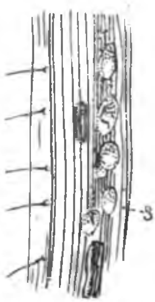

Fig. 128.

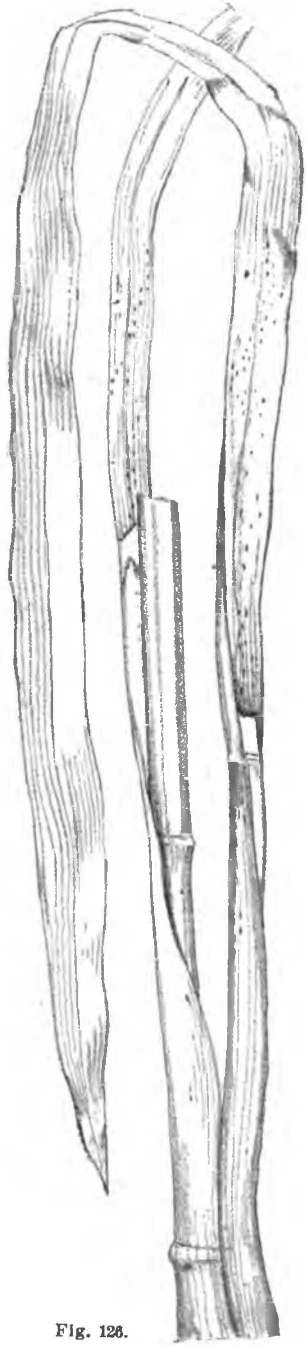

Fig. 126.

Fig. 125. Teleuto sori of *Puccinia graminis*.

Fig. 126. Uredo sori of *Puccinia coronata* leaf of oats, sheath affected with *Puccinia graminis*.

Fig. 127. Maize rust (*Puccinia sorghi*). Teleuto sorus, magnified.

Fig. 128. Maize rust (*Puccinia sorghi*) on *Zea mays*. *s*, sorus.

refer to this disease, but on some varieties of corn it is very severe

We have seen this fungus so abundant as to seriously destroy the leaves and sheaths of corn, in fact so abundant as to materially injure the crop. This was especially true of some varieties of corn grown on the college grounds, the seed of which came from the Philippine is'ands. In this case, no doubt, unfavorable climatic conditions of that variety caused it to rust. It is more severe on sweets than on the dents. At times our field corn is very seriously affected.

Professor Seymour says: "The fungus is always injurious to the corn on which it grows, but the extent of the injury depends largely upon the age and condition of the corn and climatic conditions, and is often so slight as to be of no practical importance. Certain conditions of the weather may retard the growth of the corn and favor that of the rust. Ordinarily the rust is not noticed till the latter part of the summer, when the corn is well grown and not easily injured; but in the first week of July, 1886, the writer observed it repeatedly on the lower leaves of partly-grown corn, whose vigor was plainly impaired by it. The injury consists in loss of food materials elaborated by the plant for its own growth which the mycelium of the fungus uses for its growth and in destroying the power of some of the tissues of the plant to do its work.

COMMON GRASS RUST.

This rust (*Puccinia graminis*, Pers.) in several of its forms is common on many grasses and especially destructive to oats and wheat. The common rust produces three stages. One stage occurs in the barberry and is known as the cluster cup fungus. This stage makes its appearance in the northwest some time during the month of June. In the latitude of Ames, a little before the middle of the month. An examination of an affected leaf will show small black specks on the upper surface, surrounded by a yellow spot; this is known as the spermagonial stage; the flask-shaped bodies are called spermagonia and contain the spermatia. These do not germinate; their function is not known. A sweetish fluid, which attracts insects, is frequently found in connection with these. Directly opposite the flask-shaped bodies are small globular affairs, "cups," (Aecidia), slightly irregular on the margins. Owing to their upward growth they rupture the epidermal cells and finally the lining layer of cells of the cups also break, thus exposing a large number of one-celled spores borne in chains. These spores arise from short stalks contained at the base of these cups; the cluster cup spores are known as aecidiospores. They are transported by the wind and other agencies, and have the power to germinate soon after maturity. When the proper host—a grass like bent grass, oats or wheat—occurs, the germ tube enters by way of the stomata, or the so-called breathing pores. The germ tubes produced by the spore of *Aecidium berberidis* are simple or branched, and in fourteen days usually give rise to the uredo spores, which occur in definite spots called sori. These spots occur in great number along the veins of the leaves. Before breaking open, the tissues of the leaf are somewhat paler at those places. The nourishment afforded by the host causes a vigorous mycelium to form, which soon collects in places, pushes the epidermis out, and an orange-colored pustule is formed; this is known as the uredosorus.

A section through a diseased sorus shows that an abundance of the vegetative mycelium grows between the cells of the plant, and in some cases haustoria penetrates them. This pustule contains a large number of one-celled, round or elliptical, spiny, orange-colored spores, the uredo spores. This spore has two membranes, the outer exospore being provided with wart-like projections. The inner endospore is provided with several pores through which the germ tube appears. These spores germinate in from three to four hours; they can thus start a general infection. These spores, carried by the wind, rain or insects to another part of the same or another plant, germinate. The germ tubes branch and spread over the surface, but the tube cannot enter the host, a grass of some kind, such as wheat, oats or barley, unless it reaches the opening of the stoma, since it cannot bore through the epidermal cells. A single sorus contains hundreds of spores, and as a single plant may contain hundreds of pustules, it can readily be seen that rust must become quite general.

The red rust stage is followed by the black rust stage, known as the teleuto stage. The sori are brownish-black in color, and frequently occupy the same place that the uredo stage did. The spores are dark brown in color, two-celled and smooth, having attached to them a persistent stalk known as the pedicel. The teleuto spores do not germinate till the following spring, when each cell produces a germ tube, the promycelium bearing lateral spores, sporidia. These sporidia, when in contact with the barberry leaf, enter by boring their way through the epidermal cells.

The barberry cluster cup fungus, and its connection with common grass rust.—It is not absolutely necessary for the common grass rust to have its first stage on the barberry, yet experiment has shown beyond doubt that it does occur on that plant. The theory has been advanced that appearing in one of its stages on the barberry gives the parasite new vigor. It is not improbable that in some places the mycelium or vegetative part of the fungus may be perennial in the tissues of grasses, as it is with many other fungi, and I am inclined to think this is true in southern localities. Beyond question this rust produces spores during the entire year in our southern states, and on the approach of early spring gradually moves northward. I may also mention the fact that this rust certainly does not in the west appear before the cluster cup fungus on the barberry appears. It is usually eight or ten days later, and then only to a limited extent. Rust often appears where barberry does not occur within hundreds of miles. This was especially noticeable during the early history of grain culture in the northwest. Rust follows a general infection.

Grasses affected.—In addition to the cereal plants enumerated in the table, this rust has been reported on the following grasses: Bent grass, *Agrostis alba*, *A. capillaris*, *A. canina*, *Aira caespitosa*, *Alopecurus pratensis*, *Agropyron repens*, *A. spicatum*, *A. caninum*, *Avena fatua*, *Briza media*, *Bromus tectorum*, *Briza maxima*, *Bromus mollis*, *Calamagrostis*, *Dactylis glomerata*, *Distichilis maritima*, and Eriksson and Henning report it also on *Elymus canadensis* and several other forms; it has, however, not been seen by me on this host. We have repeatedly seen it on *Holcus lanatus* and *Hordeum jubatum*.*

It should be borne in mind that in many cases these hosts have not been determined by inoculation experiments. The inoculation experiments of Carleton show that the *P. graminis avenæ* are not successful when applied to wheat, but successful when applied to *Avena sativa*, *A. fatua*, *A. pratensis.*, *Dactylis glomerata*, *Arrhenatherum avenaceum*. The following are probable hosts: *Koeleria cristata*, *Ammophila arenaria*, *Bromus ciliatus* and *Loliam perenne*. The *Hordeum jubatum*, according to Carleton, supports two distinct forms of *P. graminis*. The same

*Bull. Iowa Agrl. Exp. Sta. 30: 302. 1895.

author states that the *Puccinia graminis tritici* occurs on cultivated varieties of wheat, *Hordeum jubatum*, and *H. vulgare*. The following spices also act as hosts: *Triticum spelta*, *T. dicoccum*, *Agropyron richardsoni*, *A. tenerum* and *Elymus canadensis*.

Eriksson and Henning and other writers* report this rust on several other species of *Hordeum*, *Koeleria cristata*, *Lolium perenne*, *L. temulentum*, *Agropyron tenerum*.

The cluster cup fungus occurs more commonly on the common barberry (*Berberis vulgaris*) because it is more commonly cultivated. I have also found it on *B cerasisforme* and *B. canadensis* here at Ames. One species of barberry, *B. thunbergi*, is exempt here.

There is no evidence that the rust can survive the winter in the northern states; *i. e.*: that the mycelium is perennial in the tissues of wheat or grass. At least this does not occur in Iowa, and Professors Hitchcock and Carleton failed to find that it is perennial in Kansas. They state that it seems probable that *P. graminis* does not pass the winter in this vicinity in the uredo stage, nor in the mycelial condition. Whether or not it survives the winter further south is a question still to be answered. Eriksson and Henning state that in Stockholm and Sweden the uredo spores do not persist during the winter, and that infection does not result from these occurring in the fall. Cold weather is inimical to their development. The results of the Swedish writers are entirely trustworthy. It is claimed by Von Thumen for Austria, Plowright for England and Kuehn for Germany that this species is perennial. In Austria accord-

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*Arthur, J. C. Notes on Uredineæ. Bot. Gaz. 16: 225. 1891.

Bolley, H. L. Wheat Rust. Bull. Ind. Agrl. Exp. Sta. 26: Wheat rust is the infection local or general. Agrl. Sci. 5: 259.

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Carleton, M. A., & Hitchcock, A. S. Preliminary report on rusts of grain. Bull. Exp. Sta. Kansas Agrl. Coll. Manhattan. 38: 1893. Cereal rusts of the U. S. Div. Veg. Phys. and Veg. Path. U. S. Dept. Agrl. 16.

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Farlow, W. G., & Seymour, A. B. A provisional Host index of the fungi of the United States. 1888-1891. Cambridge.

Lagerheim, G. Contr. a la Flore mycologique de Portugal, Bolet. da Soc. Broteriana. 8: 1890.

Lugger, O. The black rust or summer rust. Bull. Minn. Agrl. Exp. Sta. 64:

Schroeter, J. Die Pilze in F. Cohn's Kryptogamenflora von Schlesien. Lief. 3, 1887-89.

Sorauer, P. Handbuch der Pflanzenkrankheiten. Berlin. (2 ed.) 1886.

Webber, Herbert, J. Catalogue of the flora of Nebraska, Nebr. State Board of Agrl. Lincoln. 1889:

ing to Cobb the species grows during the entire year. Some years ago a systematic investigation was made of the rust affecting cereals in the vicinity of Ames. While *Puccinia graminis* was common in the fall, gradually disappearing on the approach of cold weather, none of the sori were found during the winter or early spring. It was not till the cluster cup fungus appeared that this rust commenced to appear. Some of the infested plants were removed to the green-house and developed rust in abundance during the winter.

COVERED RUST OF WHEAT.

We may now discuss briefly two species of rusts, the *Puccinia glumarum* and *P. rubigo-vera*, which are more or less common on wheat and some other grasses, and have very appropriately received the name of covered rust.

Puccinia glumarum.—Æcidium unknown; the uredo sori occur along the veins. The diseased leaf is frequently of irregular contour, color orange yellow, spores spherical, or short, elliptical, spiny. Teleuto sori, grayish, covered by the epidermis on the stalks and leaves, less frequently on the flowers. Sori divided into chambers, surrounded by paraphyses. Spores with short pedicels, mostly club-shaped, unsymmetrical; apex somewhat truncate, or with one or two projections. This rust does not seem to have been generally recognized as belonging to the description given by Schmidt in 1819. It has been usually referred to as *P. rubigo-vera.* It seems quite certain that most European mycologists who have been working with the economic side of this question have had the *P. glumarum* in mind. Eriksson and Henning say it is difficult to say from the diagnoses of many writers who have discussed this question whether they had *P. glumarum* or *P. dispersa.* In European mycological works the æcidium of this fungus is said to be very common on common speedwell (*Lithospernum arvense*) *Echium vulgare* and *Anchusa officinalis.* Common speedwell is a very common weed in St. Louis and other parts of Missouri and southern Illinois, but I have never found the æcidium on these weeds.

It is very evident from the researches of Eriksson and Henning* that most writers must have been working with a rust very different than *P. rubigo vera.* On the question of the relation of temperature and the appearance of this rust, Eriksson

*l. c. 146.

and Henning state from their extended observations that there are marked differences in the disposition of the rust, depending upon temperature conditions. It appears further from their researches that the amount of precipitation was important in the production of this rust. Concerning the ability of the uredo spores to pass the winter in a living state in northern climates, these writers found no evidence of it in the least, or at any rate the conditions for this are extremely unfavorable. It appears that in some cases where the snow covers the ground during the spring, with a few slight frosts, the mycelium may be carried over, but its occurrence in this way is not very common. On the other hand a long continued snow is likewise detrimental.

Puccinia dispersa.—This species of rust is apparently very common in Europe. There are three different stages The æcidium stage produces circular or elongated, somewhat swollen, spots on the leaves, petioles and stem of several members of the borage family. The spores are between 20 to 30^u or 20 to 30 x 19 to 22^u. The uredo spores are spherical or short elliptical; pale yellow, 19 to 29^u in diameter. The tuleuto spores long remain covered by the epidermis. The sori chambered, surrounded by numerous brown paraphyses; spores are mostly club-shaped, unsymmetrical. Spores 40 to 50^u long. According to Eriksson and Henning the uredo spores can germinate in the fall. In addition to the above named hosts, this rust has been found on several species of *Bromus*, *Trisetum* and *Triticum spelta.* Its distribution cannot be given because in most cases the *P. rubigo-vera* included this as well as the *P. glumarum.* It has been intimated above that the uredo spores make their appearance on young germinating plants in the fall, but it appears that the uredo spores are not common the following spring. The investigations of the authors quoted here indicate that not in a single case was it possible to produce uredo spores in the spring from those of the autumn.

L. H. Bolley, of Fargo, N. D., well remarks in regard to several cluster cup fungi which occur on members of the Borage family: "Several æcidia of unknown life history have been studied with reference to their relations to the red rust of *Puccinia rubigo-vera*, many infectious tests being made upon young wheat and oat plants, all with negative results."

"In this region *Onosomodium carolinanum* bears very profusely an æcidium, which, because of its date of appearance, was worthy of suspicion; but tests enough were made to remove this notion." *P. rubigo-vera* as well as the common grass rust, is very destructive in England and Australia; according to Wolf, not so common in Germany. A few years ago Professor Arthur investigated the subject of wheat rust in Indiana and found that this species was much more destructive to wheat in that state than common grass rust. The same year, 1889, I found that this rust was much more common on our wheat. Carleton* says he is confident that the orange-leaf rust (*P. rubigo-vera*) does very little if any damage to the grain in this country; that in all cases of serious damage to the grain by rust the black-stem rust (*P. graminis*) is the real cause.

In 1891 and 1892 the rust under consideration was hardly as destructive as common grass rust. In 1893 covered rust was more abundant than common rust. Atkinson states that uredo spores develop during any month of the year, during the winter and spring attacking the grains, and during the summer and autumn the grasses, so that we may probably have a perennial infection from uredo spores, Bolley states that there are isolated cases in which the mycelium of this species may live in the tissues of the wheat during the win ers. This, however, can occur only during the mild winters. I have been unable to verify this for the state of Iowa, and Bolley has, likewise, failed in North Dakota. Hitchcock and Carleton find that in the vicinity of Manhattan, Kan., the *Puccinia rubigo-vera* passes the winters in the tissues of the wheat plant in the mycelial condition. During the warm weather of spring a crop of spores is produced which, under favorable conditions, may rapidly spread the disease. The infection of the winter wheat in the fall is materially aided by the volunteer wheat, which carries the rust through the few months following harvest, and these results have been reconfirmed by Carleton† in Kansas and Maryland. According to Sorauer the mycelium is perennial in the parenchyma of the leaves of cereals. We are forced to the conclusion that infection is general and that our wheat suffers much from southern invasion of this parasite. No doubt the perennial character of the mycelium in warm climates plays an important part in spreading the disease. In northern states,

*Improvements in wheat culture. Year book U. S. Dept. of Agrl. 1896: 497.
†Cereal rusts. l. c. 21.

with severe winters, the mycelium, except under favorable conditions, is not perennial.

CROWNED RUST.

Puccinia coronata.—This is a well-known destructive rust of oats and several other grasses and has received considerable attention from early mycologists. Klebahn* has recently described this rust under several distinct forms. The *P. coronata dactylidis* in a narrow sence includes the rust upon *Dactylis glomerata* or orchard grass, *Festuca sylvatica* with æcidia on *Rhamnus frangula* and *P. coronifera.* Ericksson and Henning distribute these forms into *P. coronata* I, and *P. coronata* II. Historically this rust is of considerable importance, since Gmelin† was familiar with this disease in 1791, and described it as *Aecidium rhamni* on Rhamus. Other early mycologists described the fungus, as Persoon, Schumacher, Lamarck and DeCandolle. The *Aecidium rhamni* Gmel. produces round or elongated spots with elongated, conspicuous æcidia. The spores from 18 to 25^u by 14 to 19^u. The uredo sori are long, confluent, mostly on the upper surface of the leaves, seldom on the under surface of the leaf. They are orange-colored, and are soon exposed. Each pustule contains a large number of one-celled, sub-globose, roughened spores. The spores are spherical or short, elliptical. The plant is yellow, 20 to 32^u in diameter by 28 to32^u by 20 to 24^u. The teleuto spores remain covered by the epidermis, and in this respect they resemble the covered rust of wheat (*Puccinia glumarum*). They usually occur on both sides of the leaf. The spores are short stalked, cuneate and more or less truncate above, crowned with several projecting horns. The æcidium stage occurs on a species of buckthorn (Rhamnus) especially (*R. Cathartica* and *R. frangula*). In this state an æcidium is frequently found on a native buckthorn (*R. lanceolata*), but its connection with this host has not been studied. The æcidium attacks not only the leaves, but occurs on mid-vein, petiole, pedicels and flowers. As a result of the attacks, distorted leaves and flowers are produced. A few years ago Hon. C. V. Stout, of Parkersburg, in this state, reported to me some interesting facts with reference to the attack of rust and hedges of buckthorn.

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*Zeitschraft f. Pflanzenk. 4: 120.

†Linn. Sept. Nat. 2: 1462.

Quite a number of farmers of Grundy county in the early days planted hedges of buckthorn around their farms. Mr. Stout had observed for a number of years that oats are very badly rusted in the vicinity of these hedges, so that he had learned not to plant any oats in the immediate neighborhood. Away from these hedges rust was not so severe. For the farmers of the vicinity the buckthorn hedge and rust was an instructive and valuable lesson.

SIMPLE BARLEY RUST.

Puccinia simplex.—In 1865 Koernicke described, under the name of *Puccinia straminis* var. *simplex*, the rust upon barley. This rust appears to be quite common in Scandinavia, Belgium, Hungary and Austria, Æcidium unknown. The uredo spores occur in small sori which are longer than wide. These occur scatteringly upon the upper surface of the leaf. The lemon-colored spores round or short elliptical, spiny, yellow, 19 to 20^u in diameter or $22–27^u$ x $15–19^u$.

RUSTS OF OTHER GRASSES.

It will not be necessary to discuss at any length all of the rusts which are common on grasess and cereals, since they have in part been treated in a former discussion; suffice it to say that a so-called *Puccinia graminis* occurs on blue grass, but it is not common nor destructive in this state. The same species occurs on orchard grass. *Puccinia graminis* is, however, extremely common on bent grass (*Agrostis alba*) and several of the related species. *Puccinia graminis*, or a closely related species, the *Puccinia agropyri*, is very common on the following species of the genus: *Agropyron repens*, *A. spicatum*, *A. caninum* and *A. tenerum.* Until it has been determined whether this form is distinct in America it will be better to treat it with common grass rust, which it resembles in a great many respects, and Carleton has shown by inoculation experiments that *P. graminis* occurs on several species of *Agropyron.*

Pucinnia coronata.—So far as the writer knows, this species is common only upon the orchard grass in the state of Iowa, and this is the form which has been referred to *P. coronata dactylidis.* In Europe, however, this rust is common on other grasses.

Timothy rust (*Puccinia phlei pratensis*).—Timothy, so far as the writer knows, is not affected with any rust in the state of

Iowa. In Europe, Eriksson and Henning* have described the above species.

Puccinia graminis has also been reported on timothy in this country. It is possible, however, that the *Puccinia graminis* recorded may be the *Puccinia phlei pratense.* Æcidium unknown; uredo sori perennial occur on the leaves and sheaths; confluent, brownish yellow, 18–27 x15–19 ^{u}. The elongated confluent, brownish-black or black sori are open or exposed, or with partially removed epidermis; contain the teleuto spores, which are spindle or club-shaped, somewhat constricted in the middle; chestnut brown, round or pointed; the apex strongly thickened, 38–52^{u} x 14–16^{u}. From experiments made by the Swedish workers it appears that this rust is in no way connected with the barberry cluster cup fungus.

Gama grass rust (*Puccinia vexans,* Farlow.)—This rust is extremely common on *Bouteloua racemosa.* First described by Professor Peck† from specimens collected by Brandegee under the name of *Uromyces brandegei* (Peck). But the species was first correctly determined as a *Puccinia* by Farlow.‡ He determined that there were two kinds of thick-walled spores with a permanent pedicel; the two-celled being far more common in the summer, while the one-celled produced during the fall. The æcidium stage of this fungus is unknown. Uredo sori are produced on the upper surface of the leaf and occur in small yellow spots. Spores oblong or elliptical, minutely roughened, 15–25^{u} across sori, with numerous paraphyses. The one-celled mesospores are globose to oblong. The exospore covered with small papillæ; spores 25–30^{u} broad by 30–38^{u} long. Apex of the spores strongly thickened. Pedicels colorless, longer than the spores; two-celled spores smooth.

Blue stem rust.—Blue stem rust is rather common on tall blue stem (*Andropogon provincialis*) as well as the little blue stem (*Andropogon scoparius*); furthermore, it is common on other species of the genus in southern United States. This species was first described by Schweinitz.§ Uredo sori brownish orange on the under surface of the leaf, sometimes confluent. Uredo spores sub-globose, 21–31^{u} in diameter, roughened.

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*Die getreideroste. 153.

†Bot. Gaz. 4: 127.

Saccardo. Syll. Fung. 7: 733.

‡Ellis. North Am. Fungi. *1051.*

§North American Fungi. 295. *2911.*

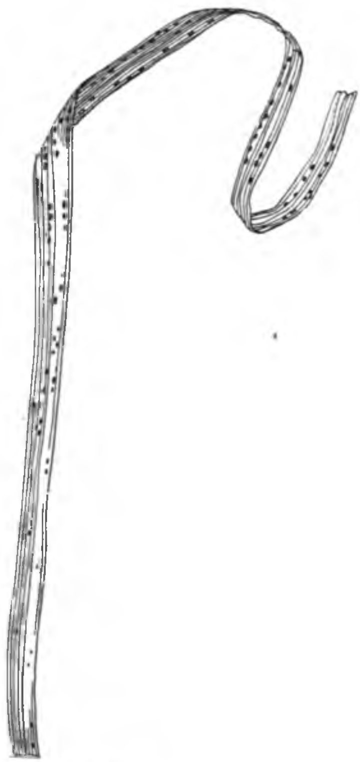

Fig. 129. Uredo Sori of Tickle Grass Rust (*Puccinia emaculata*).
Fig. 130. Teleuto sori of *Puccinia andropogonis* on *A. provincialis*.

Teleuto sori usually on the under surface of the leaves; sometimes on both surfaces, singly or in groups, confluent, the edges of the epidermis of the edges of the sori straight. Teleuto spores two-celled, obovate to elliptical, constricted at the middle. Apex rounded and somewhat obtuse. Spores 30–45 x 15–22^u. Pedicels as long or longer than the spores. This species is most troublesome in this state on *Andropogon scoparius.* In some cases over large areas a large number of leaves have been infested with the fungus. It is especially manifest during the month of September and October, uredo spores being most abundant during the month of August.

Switch grass rust (*Puccinia eamulata* Schweinitz).—This species was described by Schweinitz* and occurs upon several different genera, notably *Tricuspis seslirioides*, *Panicum virgatum*, *P. capillare* and *Eragrostis pectinacea.*

Sori numerous, usually on the upper and lower surfaces of the leaf. They are most abundant on the lower. The uredo sori, brownish, elongated, frequently confluent, irregular. Spores sub-globose, 15–20^u in diameter, echinulate. Teleuto sori irregular, elongated, frequently confluent, black. The epidermis broken, forming a rim around the edge, lacerated. Spores constricted in the middle. Apex obtuse or acute, 30–48^u by 15–21^u. Pedicels long or longer than the spores.

Puccinia poarum, Nielsen,† affects *Poa annua.* The pustules or sori of the uredo stage are orange-colored, round to elliptical, provided with sterile threads known as paraphyses. The uredo spores usually have six germ pores. The spores are round or somewhat elongated and spiny. The teleuto sori are black or dark brown, oblong to linear, without sterile threads, long remain covered by the epidermis, the spores are usually two-celled, brownish-yellow to dark brown, provided with short persistent pedicels.

Puccinia anthoxanthi occurs upon the *Anthoxanthum odoratum.* The spores of this species are extremely variable. Ordinarily they are much longer than broad, and with a rather stout, persistent pedicel. The uredo spores are minutely roughened. The *Puccinia phragmitis* is quite common on *Phragmites communis.* The æcidium of this fungus occurs upon a species of Rumex. A second Puccinia has been recognized upon Phragmitis, *e. g.*, *Puccinia magnusiana* Koern. The æcidium of this occurs upon

*Saccardo. Syll. Fung. 7: 663. Burrill. Parasitic Fungi of Illinois. 201.
†Saccardo Syll. Fung. 7: 625. Nielsen. Bot. Tids. III, 2: 26.

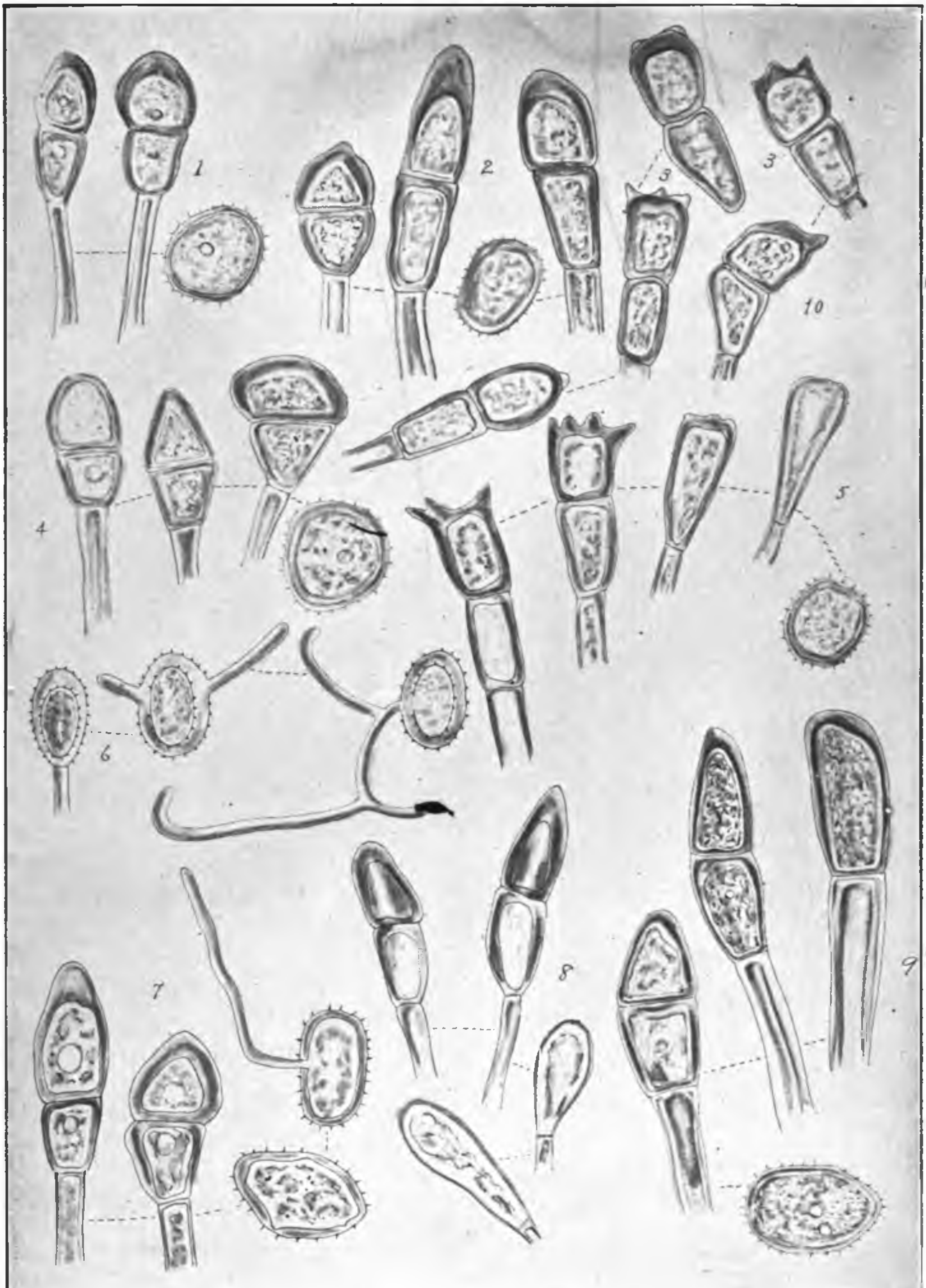

Fig. 131. Rusts of grasses. *1, Puccinia phragmitis* on *Phragmites communis; 2. P. anthoxanthi* Fckl.; *3, P. coronata* on Calamagrostis; *4, P. tricuspis*; *5. P. coronata* on oat leaf; *6*, uredo spores of *P. phlei-pratensis* on Phleum, Ericksson and Henning; 7, *Puccinia graminis* on oats; *8, P. arundinacea* on *Phragmites communis*; *9*, on *Spartina cynosuroides*; *10. P, coronata* on *Cinna arundinacea*. (Pammel and King.)

Ranunculus. Dr. J. C. Arthur, of Lafayette, Ind., has recently determined that the *Æcidium Fraxinii* has its teuleto sporic stage upon Phragmites and that this rust is connected with *Puccinia phragmitis*, and that *Puccinia arundinacea* occurs upon *Phragmites communis* also.

Uromyces dactylidis occurs upon Poa, Dactylis, Avena and Brachypodium. *Uromyces graminicola* occurs upon *Panicum virgatum* and several other grasses. *Uromyces acuminatus*, first described by Arthur, is very common at times on *Spartina cynosuroides*. It received its specific name from the peculiar character of the apex of the spore.

The prevention of rust.—Various opinions have been expressed in regard to the causes of rust and its prevention. By many agriculturists, for instance, it is thought that rust is dependent upon the manner and method of sowing the grain. Some agricultural writers, especially in Germany, have conducted experiments to determine these facts and the statement has been made by some of these writers that where the grain was sown too thick, and soil fertilized, the culms were developed so abundantly that the cereals rust more severely. McAlpine* stated at a conference at Sidney in 1891, that most of the agriculturists of Victoria found that rusts were most severe where the grain had been thickly seeded. Eriksson and Henning† in their treatment of this question states that it appears to have been but a small factor in the determination of rust. Another question discussed along this line by these writers is the question of shallow and deep planting. According to Rostrup wheat sown more than five inches deep is severely affected. The third question discussed is that of sowing by the hand as compared with sowing with a machine. From the results obtained it appears that grain sown by a machine produces a more uniform stand and it was less rusted than the hand sown. The fourth question is that of sowing a mixture of different cereals. This question was early discussed by Sinclair. As a matter of fact it makes very little difference if the cereals are sown separately or conjointly so far as rusts are concerned. The question of climatic influences is an important one as has been shown by numerous investigators. The question, both from an historical and from an experimental standpoint has been dis-

*Rust in wheat. Rep. Proc. of the Conference. Sidney. June 2-8, 1891. Agrl. Gaz. New South Wales. 2: 7. 1891.

†On the diseases of wheat. See Eriksson and Henning. Getreideroste 300.

cussed at considerable length by Eriksson and Henning under the following heads: Heavy rains; sudden temperature changes; wind and dew.

The writers commenting on the subject concluded that the development of black rust is highly favored by the large amount of rain through July and early August. This favors a rapid germination of the uredo spores The most favorable conditions for the rapid development of yellow rust for winter wheat occurs in the month of April when there is a large precipitation.

Eriksson and Henning have also made some experiments on spraying to prevent rust. They tried such substances as sulphate copper, eauceleste, Bordeaux mixture, chloride of iron and sulphate of iron. It appears from these experiments that spraying with Bordeaux mixture and eauceleste, somewhat lessens the attacks of rust.

Experiments made by Galloway* with fungicides, in which seed, soil and plants were treated, showed that certain fungicides, *e. g.*, Bordeaux mixture, potassium bichromate and some others, were effective in checking rust to some degree, yet the expense and method of treatment render it quite impossible to spray the plants to prevent rust. The experiments by Kellerman, Swingle† and the writer‡ also show that it is out of the question to treat rusts.

Eriksson and Henning, in the work quoted before, recommend only to grow such varieties as are most resistant to this disease. They state that this degree of resistance shows itself to best advantage in years when there is considerable rust. They recommend further that winter wheat be sown early in the fall. In regard to oats, they recommend that the soil should not be heavily fertilized; seed should be sown early in the spring, that all barberry bushes and mahonia be removed, and that weeds which harbor rust, like quack grass, should be removed.

Carleton§ states there is as yet no preventive for wheat rust, at least so far as combating it directly.

Bacterial Diseases.

The known diseases produced by bacteria are constantly increasing. Hartig‖ in his well known work on plant diseases

*Rep. U. S. Dept. of Agrl. 1892: 216. Jour. Myc. 7: 95.
†Bull. Kansas Agrl. Exp. Sta. 22.
‡Bull. Iowa Agrl. Exp. Sta. 16: 24.
§Improvements in Wheat Culture. Yearbook U. S. Dept. Agrl. 1896: 497.
‖Lerhbuch. d. Baumkrankheiten. 27. 1882.

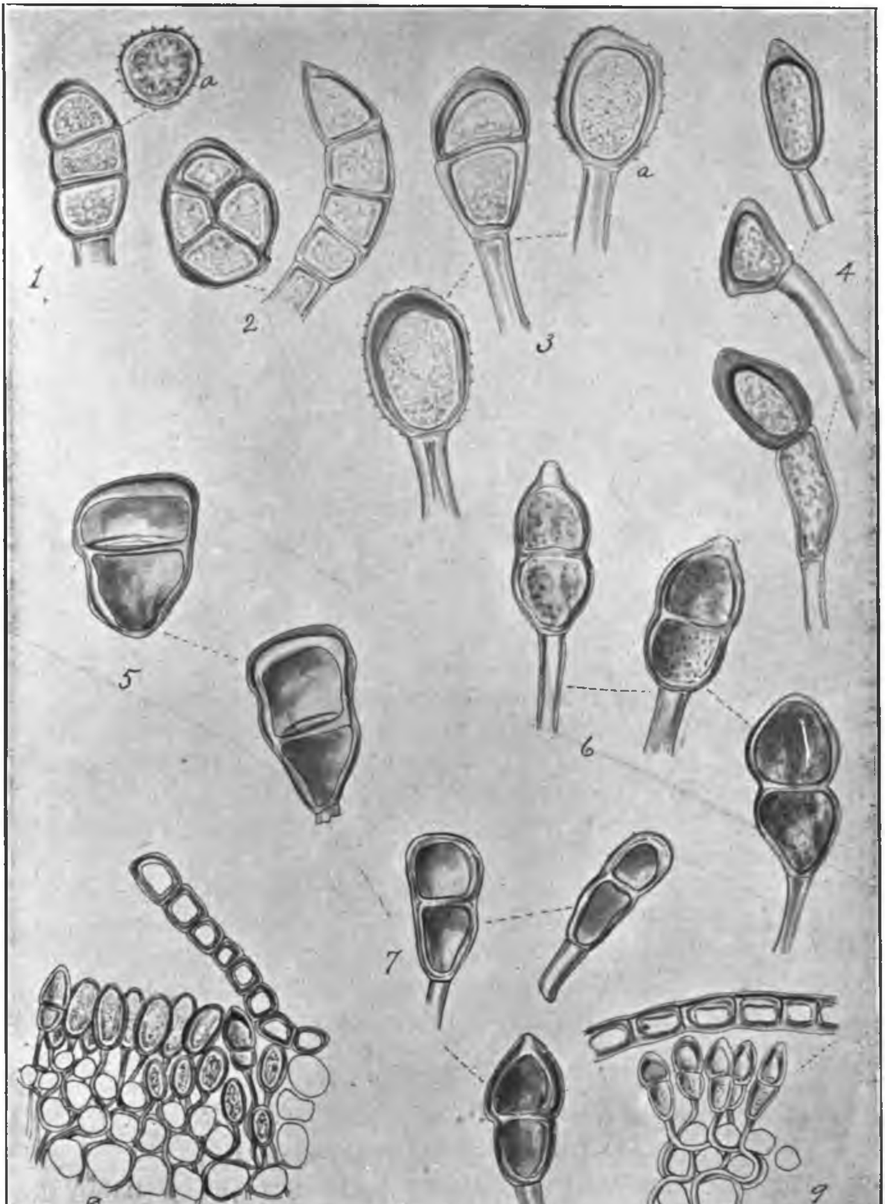

Fig. 132. Rusts of grasses. *1*, a three-celled teleuto spore; *2*, several celled teleuto spore of *Puccinia tomipara;* *4*, *P. veraus*, middle figure a single paraphysis; *9*, *Puccinia graminis*, with mycelium; *8*, *P. rubigo-vera.*

made the positive declaration that bacteria do not produce diseases of plants.

De Bary undoubtedly was one of the most critical and careful of the German botanists. He says:

"Parasitic bacteria do not often appear, according to our present experience, as the contagia of diseases in plants." When De Bary wrote, the following diseases of plants had been demonstrated as due to bacteria: Pear and apple blight,* yellow disease of hyacinth plants;† a disease of wheat, destroying the grain, producing a rose-red color; was supposed, also, by Prillieux‡ to be due to a micro-organism, which destroys the starch grains. Reinke and Berthold‖ also described a wet-rot in potatoes. Later experiments of Van Tiegham§ confirm the results of Reinke and Berthold, that *Clostridium butyricum* (*Bacillus amylobacter*), caused a wet-rot in potatoes.

More recently the list of diseases has been considerably extended. Black rot of cabbage and rutabaga, melon wilt, bacterial disease of rutabaga, tuberculosis of the olive, sorghum blight, bacterial disease of oats, corn wilt, bacteriosis of tomato, egg plant and Irish potatoes, cane disease, gumming of cane and others are caused by bacteria.¶

The literature of the whole subject has been critically reviewed by Dr. Erwin F. Smith.**

In regard to forage plants we are concerned with few of these diseases, namely, bacterial diseases of corn, corn wilt, sorghum blight and bacterial disease of oats.

BACTERIOSIS OF CORN.

In 1889 Burrill†† described a new bacterial disease of corn known as "corn blight," and later published an account in one

*Burrill. Anthrax of fruit trees or the so-called fire-blight of pear trees, and twig-blight of apple trees. Proc. of Am. Ass., Adv. of Sci. 1880: Bacteria as a cause of disease in plants. American Naturalist, July, 1881.

Arthur. Pear blight. Annual Report New York Agricultural Experiment Station 1884: 357. 1885: 241. 1887: 275-288. Bibliography. 300. Am, Nat. 1885: 1181,

History and biology of pear blight. Proc. Phil. Acad. of Nat. Sci. 1886: 322-341. Separate.

†Wakker, J. H. Onderzoek d. Ziekten van Hyacinthen, Harlem. Bot. Centralblatt. 14: 315.

‡Corrosion de grains de ble. etc., par les Bacteriees. Bull. Soc. Bot. de France. 26: 31, 167. 1870.

§Die Zerzetzung d. Kartoffel durch Pilze. Berlin. 1879.

‖Developpement de l' Amylobacter dans les plantes al' Petat de vie normal. Bull. Soc. Bot. de France. 36. 283.

¶Erwin F. Smith. Bull. Div. of Vegetable Pathology. U. S. Dept. Agrl. 12.

**American Naturalist. 1896: 626, 716, 796, 912. 1897: 34, 123.

††A bacterial disease of Indian corn. Proc. Soc. Prom. Agrl. Sci. 10: 19. 1889. Bull. Ill. Agrl. Exp. Sta. Aug, 6: 1889.

Fig. 133. Bacterial Disease of Corn (*Bacillus cloaceæ*). Burrill.

of the bulletins of the Illinois Agricultural Experiment Station. Wide interest was attached to these investgatioɛs, since Billings,* of Nebraska, stated that bacteriosis of corn was identical with the corn stalk disease. His peculiar method of reasoning convinced him that the organism isolated by him was identical with the Burrill organism. This is well stated by Moore.†

"The most interesting part of his investigations was the supposed discovery of the identity of the bacillus which he found in the animal tissues with the one described by Burrill as the cause of a disease in cornstalks. This hypothesis is supported by the fact that by feeding the diseased stalks to a rabbit he produced a fatal disease, and from organs of the dead rabbit he obtained pure cultures of the bacillus. He sent a culture of this bacillus to Burrill, who stated that the organism which he (Billings) had obtained from the organs of dead cattle appeared to be identical with the bacillus which produced the disease on the cornstalks. The correspondence between these two investigators, published by Billings, shows that Burrill was conservative on this question, pointing out obvious resemblances only. The responsibility of the statement that the two bacilli are identical rests with Billings."

Ludwig‡ in his general work on the cryptogams refers to the organism as *Bacillus sècalis*, Burrill. Ludwig apparently first applied this name. Russell used the same name.

Moore§ and Smith, who did some very careful work, identified this organism as *Bacillus cloaceæ*, which Jordan‖ found in sewage, and is widely distributed in surface soil.

Characters of the disease.—The first indication of the disease is the dwarfed condition of the young plants occurring in spots of various sizes; soil upon which it occurs is variable, though it usually occurs in the richest soil. In many cases it occurs upon the lowest ground. In one field Professor Burrill observed the following conditions: "The season (of 1887)

*Original Investigations of Cattle Diseases of Nebraska. 1886-1889. Article II. The corn stalk disease in cattle. 163.

†Corn stalk disease. Bull. U. S. Dept. of Agrl. Bureau of Animal Indistry. 13.

‡Die Neideren Kryptogamen. 95. Abst. Warlich Central Bakt. u Parasiten. 70.

§Moore, A. An inquiry into the alleged relation existing between the Burrill disease of corn and the so-called cornstalk disease of cattle. Agrl. Sci. 7: 368.

‖Jordan, E. O. Experimental investigations by the State Board of Health of Mass. 1890: 2. 8. 36.

was quite dry, and there was at no time subsequent to the planting any superfluous water in the area described. The seed germinated and the young corn grew satisfactorily until after the second plowing, when the plants were more than six inches high; then the newly-tilled spot showed, by the change in the appearance of the corn, in a very definite manner, to the very furrow on the margins, a distinct difference from the rest of the field. The corn ceased growing, became yellow and unusually slender, then for the most part died." After corn has tasseled the disease may be found widely scattered throughout the field, affecting a stalk here and there. The young plants usually show a yellowish cast; the roots are also affected; a stalk split lengthwise shows that the inner middle portion of the stem is of a dark color; on the surface of the leaf and stem brownish, corroded spots may be seen—in some cases these spots are covered with semi-transparent gelatinous material; the ears and husks are affected occasionally.

Moore states that he had no difficulty in obtaining nearly pure cultures of this organism from the first stage of the disease. The dwarfed corn resulting from the attacks of bacteria are quite rare. Moore confirms the results of Burrill that this organism occurs in a large number of cornstalks and is abundant in the gelatinous flakes. Burrill's experiments in showing its pathogenic nature were not successful, but later an application of a pure culture applied to the inside of the leaf sheath, without puncture, gave positive results.

Moore says: "Whether these organisms are of themselves able to gain entrance into the parenchy-matous tissue of the leaf sheaths after being lodged by various agencies against the exterior of the plant, or whether they are inoculated into the tissues by means of insects or injuries to the epidermis otherwise inflicted is not determined."

This organism is therefore parasitic, and should be classed with the faculative parasites. It has been shown that in addition to *Bacillus cloaceae* other saprophytic organisms occur, and that these may produce lesions. This is not inconsistent with the work done by Russell,* who has shown that a large number of bacteria, mostly saprophytes, can live for a certain period and spread as parasites.

*Bacteria in their relation to vegetable tissue. Rep. Johns Hopkins Univ. Hospital 3: 223. 1893.

This organism is described by Moore* as follows:

Morphology.—A motile bacillus varying in length from 1.3 to 2^u, ends rounded. Appears in cultures singly or united in short chains or clumps. From five to fourteen flagella have been demonstrated. It stains readily with aniline dyes.

Cultural characters.—It develops a grayish, somewhat vigorous, glistening, non-viscid growth on the surface of agar. In the depth of agar it is more feeble. Gelatin is softened along the needle track and beneath the quite vigorous grayish growth which appears on the surface at the end of six days. It liquefies very slowly. The liquid gelatin is clear, with a viscid grayish sediment and strongly alkaline in reaction. On potato a dull grayish, non-viscid growth appears within twenty-four hours. In alkaline bouillon the multiplication is quite active, the liquid becoming heavily clouded in twenty-four hours. The casein of milk is coagulated in about eighteen days. It possesses active fermentative properties. In the fermentation tube, when filled with bouillon containing 2 per cent dextrose, the closed bulb is filled with gas in forty-eight hours. The liquid is very acid in reaction. The gas consists of 72 per cent CO_2 and 28 per cent H. In a similar tube containing saccharose the fermentation is quite as active, but the proportion of the gas constituents is different, being 66 per cent CO_2 and 34 per cent H. In bouillon containing lactose the closed bulb of the tube is not filled with gas until the fourth day. The gas is practically the same as that produced in the saccharine bouillon.

Burrill supposed the organism to be widely distributed. Moore also observed the disease in Maryland and Indiana, and some of the organism has been isolated here at Ames. The general characters certainly correspond, and diseased material submitted to Burrill had his verification. Cultures made by one of us and compared with his indicated its presence here. The dwarfed condition mentioned by Burrill was especially pronounced in one field of corn grown in bottom land. This field has since been planted with mangolds, turnips, alfalfa, and beans, besides receiving a heavy coating of various fertilizing material. In year 1897 it had an exceptionally fine crop of corn. It may be that this root trouble is due to an entirely different cause, as has been suggested by Moore.

*l. c. p. 46.

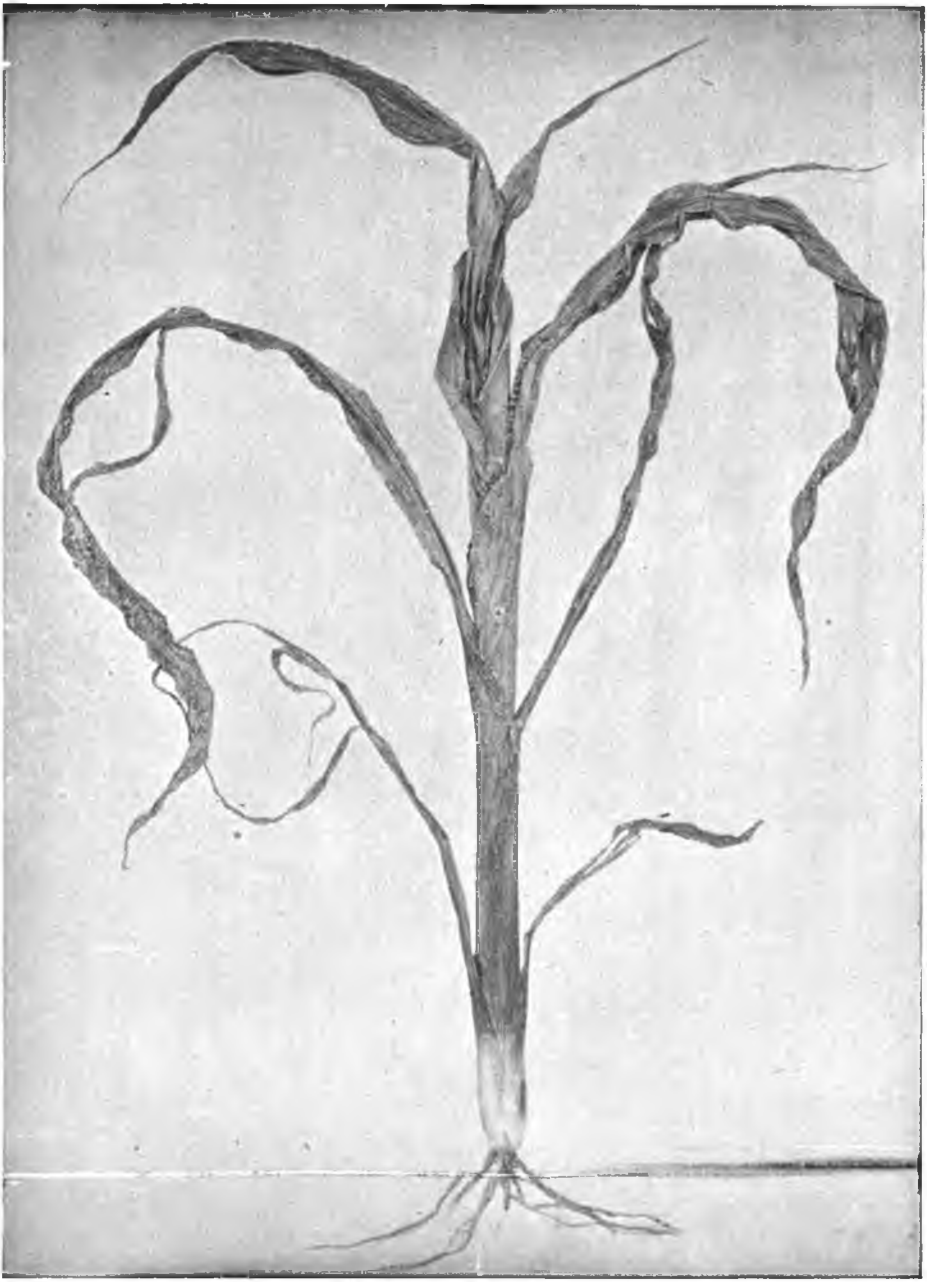

Fig. 134. □ Plant affected with corn wilt. (Stewart. Geneva, N. Y., Agrl. Exp. Sta.)

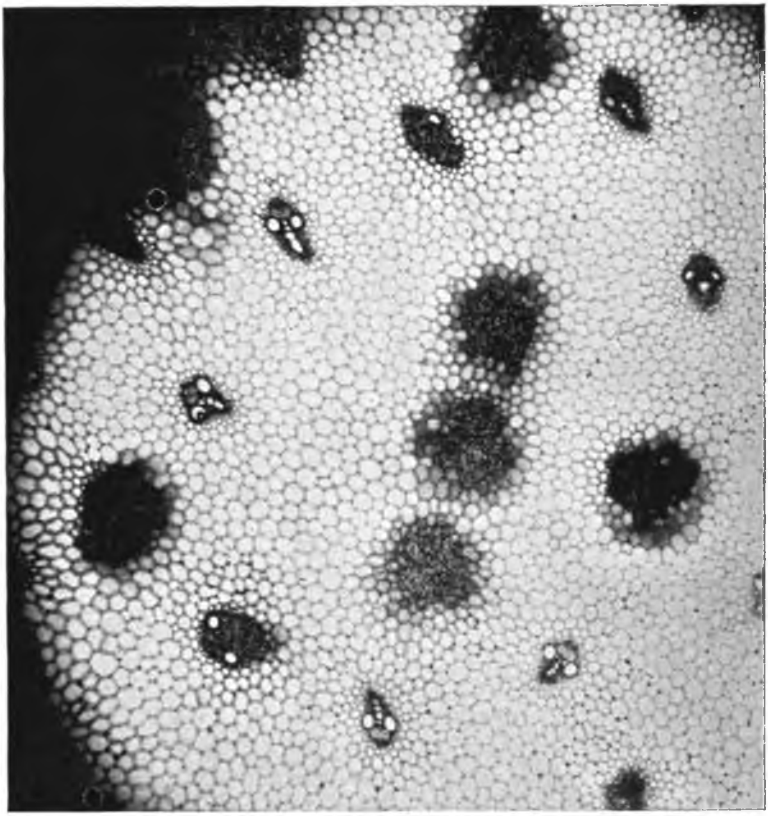

Fig. 135. Corn wilt. Cross-section stem of maize, the black areas, the vessels filled with bacteria. (Stewart, Geneva, N. Y., Agrl. Exp. Sta.)

CORN WILT.

Another bacterial disease of corn has recently been worked over quite carefully by F. C. Stewart* of the Geneva, New York Agricultural Experiment Station, and there is hardly any room to doubt that this disease is different from the Burrill disease and is due to a specific cause.

Stewart briefly called attention to a disease occurring on Long Island which had the following characters: The plants wilt and dry up, although the leaves do not roll as they do when they die from lack of moisture. In young plants death occurs in a few days. In older plants it requires a longer time for the disease to run its course. The disease may attack the

*Garden and Forest. 10: 3. 8.

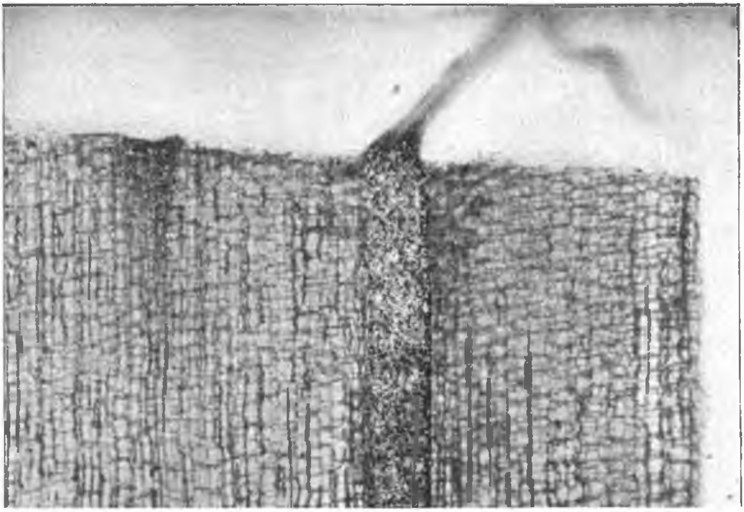

Fig. 136. Corn wilt. Longitudinal section of maize stem showing a mass of bacteria in the large ducts. (Stewart, Geneva, N. Y., Agrl. Exp. Sta.)

plant at any stage of growth, but is most injurious when the ears are forming. The disease is scattered through the field, diseased plants frequently occurring in the same hill with healthy ones. It is also found on various kinds of soil, but it seems to prefer the early dwarf varieties of corn, like the Manhattan. Stewart further states that certain varieties are more severely affected than others. It was first observed at Queens, N. Y., where it has been known for three years. Occasionally an entire crop has been ruined and a loss of from 20 to 40 per cent has been frequent. This disease seems to only affect the sweet corn. Field corn and pop corn are entirely exempt.

Stewart* thinks the organism is not only disseminated by the seed, but may also be spread by manure and implements. To prevent this disease use care in selecting the seed. Plant resistant varieties.

Quite recently Dr. Erwin F. Smith† has investigated this disease and named the organism *Pseudomonas Stewartii.*

SORGHUM BLIGHT.

Related to the diseases above is what is known as sorghum blight (*Bacillus sorghi* Burrill.)

Burrill‡ first described sorghum blight, and the organism which causes the disease. Kellerman and Swingle† have

*Bull. N. Y. Agrl. Exp. Sta. Geneva. 130: 423.

†Proc. Am. Ass. Adv. Sci. 47: 422. 1898.

‡Burrill. A disease of broom-corn and sorghum. Proc. Soc. Promotion of Agrl. Sci, 8: 30. The Microscope, 7: No. 11. 1887.

extended Burrill's work so that we are now pretty familiar with the nature of the disease.

The red blotches on the leaves and sheaths are familiar objects to almost every one who has observed sorghum. On the inside of the sheath the color is somewhat intensified, being of a brilliant carmine color. The red blotches are in the early stages somewhat circumscribed, but later they are large and irregular, often elongated. The roots are often affected, more especially in young plants. The disease makes its appearance quite early. On the college farm many young plants from four to six inches high showed yellow blotches extending across the leaf; sometimes three or four appeared on leaf; a little later a small purple blotch appeared in the center of the colorless portion. Burrill, in describing the disease, says: "Sometimes the appearance of injury is noticeable upon young plants. They grow very slowly, are slender and yellowish in color, and are easily pulled from the ground. The lower leaves die, having previously shown discolored (yellow or red, mostly the latter) patches on various parts of their surface. Not unfrequently these conditions prevail in special areas of the field; perhaps several acres, not apparently different in composition, condition of drainage, etc., will have, throughout their extent, this dwarfed and sickly crop, while the rest of the plantation is healthy and vigorous. More often the evidence of disease appears, to a greater or less extent, over the entire field, all or an exceedingly variable proportion of the plant suffering; not unfrequently stalks four or five feet high can be lifted with ease from the soil."

The *Bacillis sorghi* when growing on potato is said to produce a pearly white growth, although there is sometimes a slight tinge of yellow or pink. In old cultures it is said to be of a dirty white and much wrinkled. On agar the growth is very much the same, the margin is usually crenate. In cultures obtained by the writer the growth was dirty yellow; this kind of growth was not only obtained once but several times. It seems therefore reasonably demonstrated that this organism is the cause of the disease, since a specific micro-organism is constantly associated with the disease and inoculation experiments made with pure cultures derived from the organism found in the discolored patches have shown, beyond a doubt, that the organism produces the disease.

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*Kellerman. Preliminary report on sorghum blight. Bull. Kansas Agrl. Exp. Sta. 5: 281. 1888.

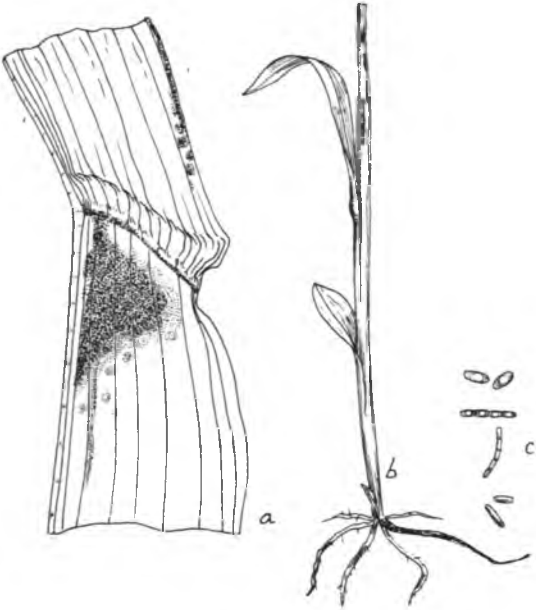

Fig. 137. Sorghum blight (*Bacillus sorghi*); *a*, leaf and sheath affected; *b*, young affected plant; *c*, rod-shaped bacilli. (Kellerman and Swingle.)

Treatment.—Burrill and Kellerman have shown that soil upon which sorghum has been grown contains the organism and that they occur in old stubble. It has also been noted that since sorghum fields are not burned over, the disease is on the increase. It would certainly seem advisable to burn over old fields. But this will not prove sufficient, since the fungus occurs in the soil. Many fungus and insect enemies can be checked very materially by rotation of crops. In either case we cannot expect to remove the disease entirely, since it occurs where sorghum has never been grown. It is probable that the micro-organism is carried through the air and water, as well as the soil.

GUMMING OF SUGAR CANE.

In 1893 N. A. Cobb,* New South Wales, gave a full account of the disease in sugar cane which caused a gumming; this he attributed to *Bacillus vascularum.* The disease seems to have been present in Australia for a considerable length of time, the cane planters having been familiar with a disease characterized

*Ag. Gazette. N. S. Wales. 4: 777.

by the exudation of a yellow substance by the cane. It appears that this disease is quite destructive in portions of the island and that it is not spread to any great extent through the air. The disease starts from the seed. The general characters are as follows: Here and there will be seen stools containing one or more stalks with dead tops; the base of the area in such cases will be found to be rotten, usually having one or more cavities of considerable size occuring near the top of the stalk and filled, or partially filled, with offensive matter. A microscopical examination shows that this is not general, but local. This gum is confined to the vessels, which are plugged with it. The gummy substance contains a substance called *vasculin.* The yellow gummy matter never occurred without bacteria. The organism responsible for this disease is a rather short bacillus united in chains, the rod being surrounded by a gummy exudate. The evidence that this organism is the specific cause of this disease is not demonstrated, since the author did not cultivate this organism, but relied wholly on the general facts and his success in inoculating healthy cane from diseased plants by means of an infection needle.

Quite recently W. R. Dodson* has given an account of red cane, expressing the opinion that one or more bacterial forms accompany red cane, and that the disease in question is due to the breaking down of the protoplasm. No definite results were obtained by Dodson. The red coloration is of common occurrence on the cut ends of cane in the standing stalks, as well as those that are used for sugar purposes, and Dodson states it is very common where injury occurs. I have noted its common occurrence on sorghum in this state, and an examination of the cultures of sorghum cane showed that *Saccharomyces glutinus* was common, but not necessarily the whole cause. In some unexplainable way this red coloring matter is produced where caue is injured. We called attention to this under sorghum blight.

Mr. N. A. Cobb† describes the red rot of cane due to an imperfect fungus, so that it is evident that more than one organism must be considered in the reddening of cane.

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*Bacteriological Notes on Red Cane, in Wm. C. Stubbs' Sugar Cane. 1: 173.

† Agrl. Gazette. N. S. Wales. 4. 806.