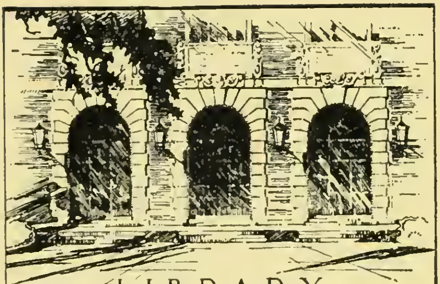

Diseases of
WHEAT, OATS, BARLEY, AND RYE

G. H. BOEWE

ILLINOIS NATURAL HISTORY SURVEY
Circular 48

STATE OF ILLINOIS • William G. Stratton, *Governor*
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Contents

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Stinking smut on wheat. The two heads in the center are infected; those to the right and left of them are normal. Kernels in the lower row are normal; those in the upper row are infected. Harvested grain containing even a small percentage of infected kernels, often called smut balls, is subject to price dockage.

1

Nature of Cereal Diseases

ALL OF THE SMALL GRAINS or cereals, the most important of which in Illinois are wheat, oats, barley, and rye, are susceptible to attack by diseases. The dying of seedlings, the stunting of plants, the spotting of leaves, stems, and heads, the destruction of seeds, the premature dying of plants, and the rotting of roots and crowns are symptoms that indicate disease.

Since 1921 the Illinois Natural History Survey has been engaged in making surveys of the grainfields of the state to ascertain what diseases are present and to determine the prevalence and the intensity of their attacks. As a result of these surveys, the economic importance of the diseases of small grains has been defined more clearly than in the past. Data collected annually over a period of 30 years and averaged show that in Illinois leaf rust alone, which is the most important disease of wheat, attacks 96.0 per cent of the wheat plants, destroys 17.9 per cent of the leaf area, and causes an estimated annual reduction in yield of 7.5 per cent. The loss per year from infectious wheat diseases, indicated by estimates for 20 consecutive years, is 18.5 per cent. With such losses, it is important that farmers be able to recognize and combat the most prevalent and destructive diseases.

The rusts and smuts are well known to most producers of grain, but there are other important diseases, which attack roots or stems or destroy parts of the leaf areas, that are not so generally known. Detailed descriptions of cereal diseases that have been found important in Illinois, and general control measures for these diseases, are presented in the following pages. Diseases are listed under the cereals they attack. A disease that attacks more than one cereal is described most fully in relation to the cereal on which it is most important. Cross references enable the reader to turn readily to the principal descriptions.

KINDS OF PLANT DISEASES

In the process of growth, plants may be subjected to various types of injury that interfere with their normal functioning or development; the abnormal conditions that result are known as diseases. A disease may be localized in part of a plant, such as root, stem, leaf, flower, or seed, or it may affect the entire plant. Many plant diseases are infectious; they are caused by living organisms and are readily spread. Others are not infectious; they are caused by unfavorable environment and do not spread. It is important to recognize the cause of a disease before control measures are applied.

INFECTIOUS DISEASES

Infectious diseases are of three kinds and are classified according to whether the causal agent is a plant, an animal, or a virus. Any organism that depends in any measure upon other living organisms for food may be regarded as in some degree parasitic. Parasitic plants that cause infectious diseases in cereals include fungi and bacteria. Parasitic animals that cause infectious diseases in cereals include nematodes.

Fungi.—Fungi are members of a primitive group of plants. They do not contain green coloring matter, chlorophyll, and so are unable to manufacture their own food. They are dependent upon living or dead organic matter for their sustenance. A fungus that obtains its nourishment from living tissue is a parasite, and the plant it lives on is the host. Some disease-producing fungi can live on either living or dead plant material.

Fungi are comparable in some ways to green plants, fig. 1. The part of the fungus that corresponds to the root, stem, and leaf system of a green plant consists of threads or filaments called hyphae. Hyphae usually are divided into cells by cross walls and they usually branch and rebranch, forming a network of filaments called the mycelium. Growth produced by bread mold is a good example of mycelium. In fungi, as in green plants, a vegetative period concerned with growth and accumulation of food precedes the reproductive phase. In most parasitic fungi the mycelium grows within the host plant's tissue and is not visible on the surface; but in some the mycelium may be superficial, as in the case of powdery mildew, establishing contact with the interior parts of the plant by means of small suckers, which it pushes into the outer cell layers of its host.

The reproductive structures of the fungus, corresponding to the fruit and seed of flowering plants, are the parts most commonly seen by the naked eye. These structures may be produced on the surface of the host, but usually they are formed within

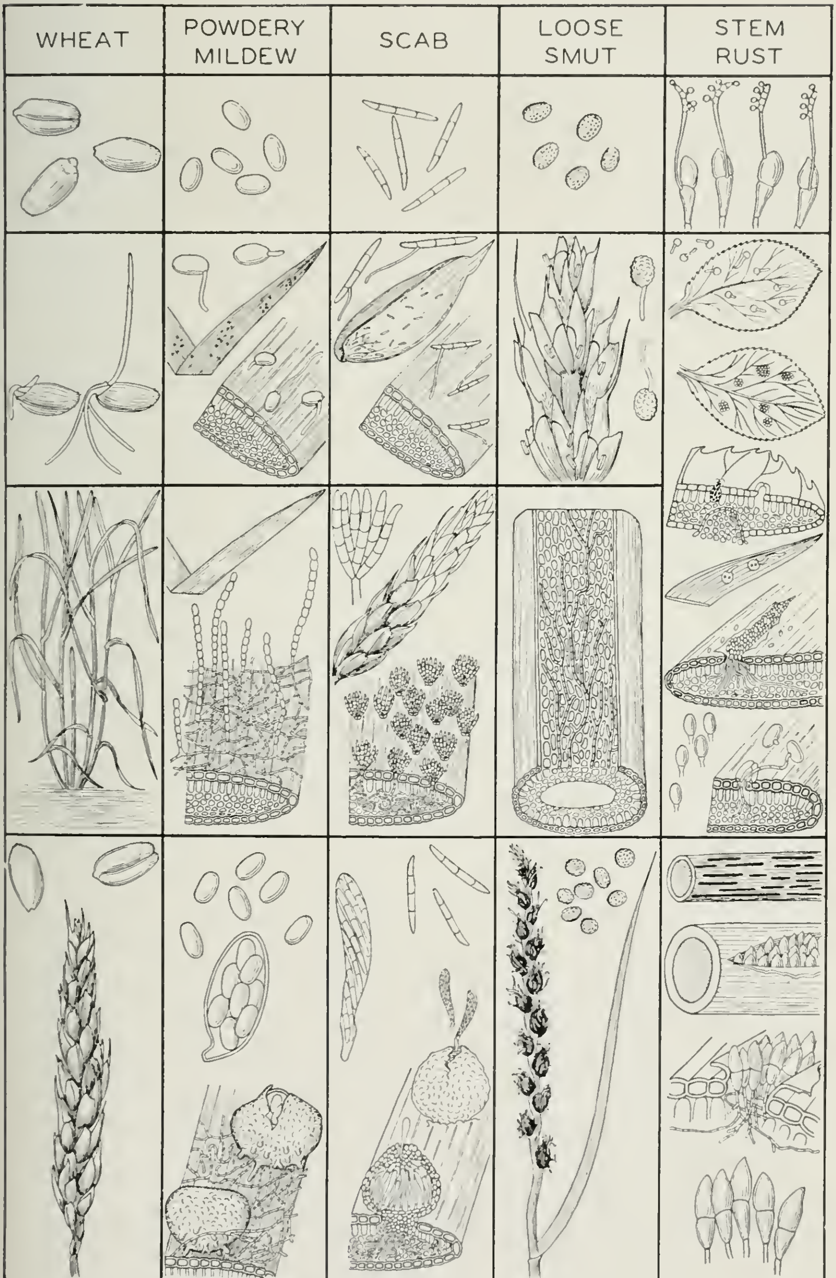

Fig. 1.—Four typical life histories of fungus parasites of cereals shown in relation to the life history of wheat.

the host tissue and break through to the surface by the time the spores they contain are mature and ready to be discharged. A spore, which functions somewhat like a seed, differs from a seed in that it does not contain an embryo or tiny plant. It contains the living material by which a fungus is reproduced. Spores are microscopic, one- or several-celled, seedlike bodies that vary greatly in size, shape, color, and thickness, in the structure of the spore wall, and in other characteristics. It is by means of these spores and the types of fruiting bodies in which they are produced that a fungus is classified.

Different kinds of fungi produce their spores in different ways. Some send up stalks from the mycelium; on these stalks the spores grow singly, in strings like beads, or in clusters. Others produce their spores on small stalks enclosed in flask-shaped or spherical bodies, in more or less flattened cups, or in club-shaped sacs inside spherical bodies. Spores are produced in immense numbers. It has been estimated that there are at least a million, possibly as many as eight million, spores in one small smut ball of the stinking smut of wheat.

Only a very small percentage of the spores that are produced cause infection, because most of them alight in situations that do not furnish the food material and moisture necessary for their development. Some fungi find suitable food material in only one species of host plant, but others, not so specific in their food requirements, thrive on any one of two or more host species. Some fungi require for their complete life cycle two unrelated hosts; for example, stem rust has wheat as its primary host and barberry as its alternate host.

Suitable moisture and temperature conditions are necessary both for spore germination and for enabling the young fungus to enter its host. Usually when a fungus has entered its host species, it will continue to grow. In the host it finds ideal moisture conditions and comes in close contact with the source of its food, which it absorbs directly from the host cells.

Bacteria.—Bacteria are very minute one-celled plants commonly called germs. They have the simplest kind of life cycle. A mature bacterium divides into two nearly equal parts, and each part grows to the size of the original. Under favorable conditions a life cycle is completed in 30 to 40 minutes. The rate of division and growth depends upon environmental factors, such as food and temperature.

Viruses.—Although viruses are not thoroughly understood, they are considered to be complex protein particles that develop and multiply within their hosts and cause them to behave abnormally. They are too small to be seen without the aid of an electron microscope that has a magnification of approximately 20,000. Unlike fungi, viruses do not produce spores, and, unlike bacteria, they do not form cells. They are capable of infecting and producing diseases in plants and animals. Insects are the chief agents or vectors in spreading most viruses, but man is an important agent in distributing certain viruses. Some viruses are seed borne and some are soil borne. Perennial wild host plants are important in carrying some viruses from one year to the next.

Nematodes.—Nematodes (nemas or eelworms) are minute worms that attack various plants. They are closely related to roundworms in man and other animals. They cause swellings and distortions of the plant parts they attack.

Dissemination of Infectious Diseases.—Bacteria, fungi, viruses, and nematodes are carried from place to place by various means. In the case of bacteria or nematodes, entire individuals are transferred, while generally only the spores of fungi are transferred. In what state viruses are carried no one knows.

The most important agents in the dissemination of cereal diseases are wind, water, insects, and mammals, including man. Bacteria and spores of fungi have been known to be carried long distances, in some cases hundreds of miles, without having their viability impaired.

Winds may carry bacteria, viruses, fungus spores, and nematodes on or in fragments of infected plants.

Water may aid in disease dissemination in several ways. Infected plant material may be carried down rivers or along the shores of lakes and other bodies of water. When the infected material comes to rest, the bacteria and other parasites it harbors may become established on crop plants. Water that falls as rain and washes across fields may carry infested soil and plant debris from one field to another and thus spread both soil-borne and air-borne diseases. Rain drops may wash bacteria and fungus spores from one plant to another that is close to it.

Insects play very important parts in spreading the parasites that cause infectious diseases of cereal plants. The hairy bodies and the mouthparts of insects are well adapted to picking up, from diseased plants, disease-producing spores and bacteria which, as the insects travel from plant to plant, may subsequently be transmitted to healthy plants. Many viruses are transmitted by insects; some can be transmitted in no other way.

Wild or domestic animals also may aid in the distribution of cereal diseases. As animals move through the fields of grain, they may rub off on healthy plants the spores that have adhered to their coats from diseased plants.

There are many instances of the introduction and spread of cereal diseases by man. Grain shipped from country to country, state to state, or farm to farm may carry invisible infections to localities previously free of the infections. Infected plant material used as bedding or packing, when shipped from one place to another, may disseminate disease-producing organisms.

NONINFECTIOUS DISEASES

Noninfectious diseases, often called nonparasitic or physiological diseases, are related to the nonliving factors in the environments of plants. Plant development is affected by the physical nature, chemical composition, biological condition, temperature, and water and air content of the soil, and by certain conditions in the air, including those related to temperature, moisture, gases, sunlight, and wind.

In an environment that is suitable for the growth of green plants, the soil contains adequate amounts of water, air, and available mineral elements. It is free of excessive amounts of water, mineral salts, and toxic substances. The temperature of the soil and that of the air are favorable for growth and at no time reach excessively high or low levels. The air about the plant supplies an adequate amount of oxygen and is relatively free of toxic gases. The amount of light is adequate for normal growth. For each kind of plant there is an optimum condition with respect to each of these environmental factors. Lack of the proper amount of any one of these factors or a disturbance in their balance may produce disease. Plants are subject to many noninfectious diseases; rarely if ever is a plant in nature growing under fully optimum conditions.

Mechanical injury to plants may produce noninfectious diseases and also open avenues for infection.

Direct damage by insects is not mentioned in this circular except in a few instances in which the damage closely resembles symptoms of infectious diseases.

COMMON DEFICIENCY DISEASES

For healthy growth, every green plant needs available to it 10 different chemical elements in large amounts and several others in very small quantities. The availability of these nutrient elements is affected by the physical and chemical properties of soil. The *p*H value, or acidity of soil, the colloidal content, and the organic content of soil play important parts in the availability of these elements. Nitrogen, phosphorus, and potassium are the elements most likely to be deficient and the ones in which a deficiency is most likely to limit plant growth or give rise to disease conditions. Other elements may be deficient or in excess in certain areas or in certain soils.

The symptoms of nutrient deficiencies most easily recognized in cereal plants are those related to the color and height of plants, tillering, and the strength of stems. Under field conditions, leaf symptoms for deficiencies of nitrogen, phosphorus, and potassium are difficult to diagnose. A valuable technique for determining the nutrient needs of small grains is to make comparative green tissue tests for nitrates, phosphates, and potash on healthy plants and on plants showing abnormal growth symptoms. Green tissue tests are for soluble nutrients in a plant. They are based upon the assumption that when the supply of a nutrient in the soil is adequate the plant takes in more of that nutrient than it uses in producing new tissues. If the test for a particular nutrient is strongly positive, the conclusion is that the supply of that nutrient is adequate for the needs of the plant at the time the test is made.

Green tissue tests are valuable in determining the relation between lodging of plants and deficient or unbalanced supplies of nutrients and the relation between tillering and available phosphates. They permit the grower to detect nutrient deficiencies before plants show visible signs of these deficiencies. Soil tests also are valuable in determining the amounts of available nutrients in the soil. Deficiency symptoms expressed by plants, green tissue tests, and soil tests should be used together to determine deficiencies in plants and the fertilizer needs of soil.

Nitrogen Deficiency.—All classes of soil, from the most acid to the most alkaline, may be deficient in nitrogen. Most of the nitrogen in soil is a part of the organic matter. Living organisms in soil cause the decomposition of organic matter and change the nitrogen to a form that can be used by plants. The amount of available nitrogen in soil is affected by the temperature, moisture, and air content of the soil. Cereal plants growing in soils high in organic matter sometimes display nitrogen starvation symptoms. These symptoms occur usually when the soils are cold and wet and sometimes when the soils are very dry.

Plants use relatively large amounts of nitrogen in all growth stages. Chlorophyll, the green coloring matter of plants, contains nitrogen. When the available supply of nitrogen is inadequate for the needs of a cereal plant, the first noticeable symptom is the slowing down of the growth rate; retarded growth rate is followed by loss of green color. Nitrogen-starved plants are light green or yellow in color, are stunted and spindly, have sparse foliage, and produce few tillers and small heads.

Symptoms of nitrogen starvation are first visible in the oldest leaves of the cereal plants. These leaves become light green, gradually turn yellow, and die prematurely. Dying of this type is commonly called firing. The color change and dying begin at the tip of a leaf and proceed toward the base. The yellowing of leaves proceeds up the plant from the oldest to the youngest leaves. Usually by the time the third leaf shows yellowing the oldest leaf is dead. The stunting and yellowing symptoms displayed by nitrogen starvation may be caused by other environmental factors, also. While leaf symptoms of nitrogen starvation in young cereal plants are fairly reliable diagnostic characters, they should be verified by green tissue tests.

Phosphorus Deficiency.—Most soils are deficient in phosphorus, which exists in the soils in either organic or inorganic compounds. Soils low in organic matter contain less readily available phosphorus than soils with high organic content. As the movement of phosphorus in the soil is very slight, this element is not so well distributed that it is available to all roots. Phosphorus starvation is usually more pronounced in young cereal plants that have small root systems than in older plants. This starvation is most pronounced if other conditions during early growth of the plants have been unfavorable.

Phosphorus, like nitrogen, is associated with the vital growth processes of cereal plants. It is essential for cell division, tillering, and seed formation. Diagnosing phosphorus starvation symptoms in small grains in the field is difficult because usually no definite leaf symptoms are evident. Cereal plants that grow slowly, that are dark green in color, and that produce few tillers are likely to be deficient in phosphorus. Phosphorus-starved plants mature late and produce low yields of grain. Sometimes a reddening or purpling of leaves, similar to that produced by phosphorus deficiency in corn, is evident in small grains. A general yellowing of the leaves of young plants is evident when the deficiency is severe and the soil is cold and wet during early growth. This yellowing starts in the older leaves and may be confused with nitrogen starvation. Other factors, such as cool weather, diseases, and insect damage to roots may produce symptoms similar to those caused by phosphorus deficiency. Green tissue tests will determine the presence or absence of phosphorus.

Potassium Deficiency.—Most of the potassium in soil is in inorganic form. Heavy soils contain more of this element than light soils. Potassium deficiency in cereal plants is most common in plants growing on sandy soils. Serious shortages of potassium may develop in many soils under a system of intensive cropping. Potassium starvation is so common in most crops that many farmers are familiar with its symptoms.

Potassium is present in all parts of green plants, and adequate amounts of it are essential for growth. As it is readily transferred from maturing parts of a plant to growing tissues, deficiency symptoms show up first on the oldest leaves. Edge scorch of leaves is a symptom common to all small grains. As the amount of available potassium becomes inadequate, the tips and margins of the oldest leaves lose their green color, turn yellow and then brown, and die. The yellowing may appear as longitudinal streaks that alternate with green and progress backward toward the base of a blade. As the deficiency becomes more acute, the yellowing proceeds from the oldest leaves to the younger leaves, and growth is retarded. Cereal plants that reach maturity with insufficient amounts of potassium have straw that is weak and subject to lodging and grain that is shriveled and immature in appearance. Shriveled grain may be caused by severe attacks of rust and by other factors, also. Barley appears to require more potassium than the other small grains. It sometimes develops small purplish-brown blotches on the leaves showing the edge scorch that is a sign of potassium deficiency.

Manganese Deficiency.—Manganese deficiency is most common in alkaline soils. As manganese is necessary for the formation of the green coloring matter in plants, one of the common symptoms of manganese deficiency is the yellowing of leaves.

Oats appear to be more susceptible than other small grains to manganese deficiency. In oats, the disease caused by this deficiency is called gray speck. The symptoms of the disease may appear when the plants are in the third or fourth leaf stage. Gray speck starts as light green or grayish oval or oblong spots or irregular streaks, chiefly in the basal half of the blade of a leaf. Usually the spots are most abundant along the margins of the leaf. They enlarge, become yellow, and finally dry out and become buff or light brown in color. This is the dry spot stage of the disease. As the spots spread across the greater part of the blade, the leaf usually breaks over near the middle. The basal portion of the leaf may soon die, while the tip of the leaf remains green for some time. Manganese deficiency causes stunting and, when severe, death of plants.

The development of the symptoms of manganese deficiency depends upon the susceptibility of the plant variety involved, soil factors, and seasonal conditions. Manganese deficiency symptoms are most pronounced under conditions of high moisture, low temperature, and low light intensity.

In wheat, barley, and rye, manganese deficiency symptoms appear as a general yellowing of much of the leaf area. The yellowing occurs in streaks or irregular spots running lengthwise along each affected leaf. Plants affected by manganese deficiency are dwarfed, and their leaves appear drooped.

Diagnosis of Noninfectious Diseases.—Because abnormal color and growth of plants may result from one or more of many causes, field diagnosis of mineral deficiency diseases in small grains is difficult, especially in old plants. However, a careful observer who considers symptoms in relation to all the factors influencing the growth of plants and who makes green tissue tests and soil tests for available nutrients can arrive at a fairly accurate diagnosis of the deficiency. None of the diagnostic techniques used alone is reliable under all conditions.

Most farm bureau offices in Illinois are equipped to make soil tests for farmers. Information about green tissue tests may be secured from farm advisers or from the Department of Agronomy of the University of Illinois College of Agriculture at Urbana. Two publications that contain information on green tissue tests are Purdue University Agricultural Experiment Station Circular 204 (revised), 1939, and Michigan Agricultural Experiment Station Technical Bulletin 132 (third revision), 1944.

2

Wheat Diseases

BOTH WINTER WHEAT AND SPRING WHEAT are grown in Illinois. Winter wheat is grown throughout the state. Most of the spring wheat, which comprises about 1 per cent of the state wheat acreage, is grown in the northern part of the state.

In Illinois the wheat crop is subject to attack by 36 recognized diseases. Not all of them are widespread or important, but it has been estimated that in 10 recent consecutive years those diseases that are commonly destructive have brought about a reduction in yield of 17.6 per cent, amounting to an average annual loss of over 8,455,000 bushels. Much of this loss could not have been prevented, since no practical means have existed for controlling some of the most destructive diseases. However, a considerable part of this loss could have been avoided had known methods of combating certain diseases been in general use.

The descriptions of wheat diseases in table 1 and on the following pages deal mainly with diseases that are common and widespread; a few diseases now local in occurrence and some that are not yet in Illinois but that are apt to invade the state are described because of the importance they might have in the future.

Table 1.—Infectious diseases of wheat, with brief descriptions of the symptoms produced on leaf, head, stem, entire plant, and seedling. Each page number is a reference to a discussion of the disease mentioned.

Disease	Symptoms	Page
	Leaf	
Leaf rust	Small, round, raised orange-red pustules	14
Stem rust	Elongated, ragged, brick-red pustules	18
Flag smut	Long, lead-colored or black stripes which rupture and liberate black powder	33
Powdery mildew	White or brownish gray powder or mold on leaf surface	40
Downy mildew	Leaves striped with yellow, or leaves almost entirely yellow, fleshy, stiff, erect; some leaves twisted and deformed	42
Soil-borne mosaic	Leaves with yellow stripes of various lengths	59

Yellow dwarf	New leaves bright yellow; tip of each leaf first to yellow; tissue over veins last to yellow	62
Streak mosaic	Leaves with yellowish streaking or mottling; entire leaves becoming yellow as season advances and later turning brown; plants stunted	63
Speckled leaf blotch	Irregular, reddish brown spots, often with ashen white centers studded with tiny, black pimples	24
Glume blotch	Spots light brown, each with brown border, center lighter in color as spot dies, black pimples on both surfaces of each spot	26
Spot blotch	Spots fairly well defined, oval or longitudinal, light brown, each usually with a darker border	44
Yellow leaf spot	Spots oval, short or elongated, yellow or light brown, each with yellow border tapering at ends; yellow border fading into a brownish straw color with age	48
Anthracnose	Tiny, elongated, black elevations developing on dead sheath, blade, stem, and joints on lower portion of plant	50
Basal glume rot	Spots small, dark, water-soaked, enlarging, turning yellow and then brown as tissue dies	57
Black chaff	Streaks elongated, at first olive-green, then yellow, and finally black	55
Nematode disease	Youngest leaves buckled within tightly closed sheath of older leaves	63

Head

Leaf rust	Small, round, orange-red pustules, most of them on chaff	14
Stem rust	Elongated, ragged, brick-red pustules on chaff and spike, some inside of chaff	18
Loose smut	Head a mass of loose, black powder, later a bare spike	30
Stinking smut	Head blue-green, at maturity erect and plump; kernels short, plump, filled with foul-smelling, brownish powder	32
Scab	One or more spikelets light yellow, bleached, dying prematurely; some pink or salmon color at base and along edge of chaff	36
Glume blotch	Grayish to chocolate-brown blotches at tip of chaff, center of old spots grayish white, with few brownish or black, scattered pimples	26
Basal glume rot	Dull brownish to black area at base of chaff; some kernels faint brown or black at germ ends	57
Black chaff	Longitudinal, dark, sunken stripes, mostly on upper half of chaff; blotches if stripes coalesce	55
Spot blotch	Dark brown to black spots or blotches on chaff; spikelet dark to reddish brown, later mottled or bleached; kernel brown or black at germ end	44
Anthracnose	Spikelet or head bleached; small, elongated, black elevations on chaff, base of spikelet, or on spike	50

Powdery mildew	Grayish white powder or mold on spikelet	40
Downy mildew	Head and its parts distorted and with open appearance; chaff fleshy, green; stem at base of head thickened and deformed	42
Ergot	Kernel replaced by a plump, hard, purplish body larger than healthy kernel	52
Nematode disease	Head small, open, remaining green longer than healthy head; grain short, forming a thick, hard gall	63
Insect damage	Entire head and neck white, dead prematurely; stem chewed off above first joint. Damage similar to that caused by scab to entire head.	
	STEM	
Stem rust	Elongated, ragged-edged, brick-red pustules	18
Leaf rust	Small, round, raised, orange-red pustules, mostly on neck	14
Glume blotch	Joints brown, shriveled, rough in appearance, with scattered, black pimples; stems crooked at joints if not completely girdled	26
Anthracnose	Purplish to brownish blotches on or near lower joints; small, elongated, black, elevated fruiting bodies	50
Spot blotch	Brown spots on joints sometimes girdling joints; joints with velvety appearance if fungus fruits abundantly	44
Black chaff	Brownish to black sunken stripes, especially on neck and below upper joint	55
Flag smut	Lead-colored or black stripes running lengthwise in upper part of stem; stripes rupturing and liberating black powder	33
Insect damage	Stem above flag leaf and head white. Damage caused by stem maggot.	
	ENTIRE PLANT	
Anthracnose	Plants ripening prematurely, having bleached appearance; small, black, elongated, elevated fruiting bodies on lower portion of stem	50
Scab	Plants ripening prematurely, having bleached appearance, some with pinkish color near base of plant or at joints	36
Crown rot or spot blotch	Plants dwarfed, reddish brown, lower leaves with dark chocolate-colored spots; roots usually rotted; diseased plants usually occurring in circular areas in fields	44
Take-all	Plants stunted, tillering sparsely, bleached yellow, becoming ashen white; base of stem brown to black, with dark brown to black layer of coarse fungus mycelium between stem and leaf sheath; roots rotted; diseased plants usually occurring in circular areas in fields	52

Downy mildew	Plants severely dwarfed, tillering excessively, dying prematurely; or plants somewhat dwarfed, leaves yellow or striped with yellow, fleshy, stiff, erect, clustered around stem; or plants slightly dwarfed, leaves yellow, fleshy, twisted, erect, and with heads distorted	42
Flag smut	Plants dwarfed, usually not heading; leaves with lead-colored to black stripes, blades splitting along stripes, liberating black powder	33
Soil-borne mosaic	In spring when growth starts, plants light green to yellowish, stunted; diseased plants occurring in patches; new leaves mottled with yellow; irregular yellow stripes or blotches running parallel with long axis of leaf; or Leaves light green, appearing mottled with dark green; tillering excessively, causing rosetting	59
Yellow dwarf	Plants stunted, tillering sparsely, yellowish; newly formed leaves bright yellow; tissue over veins last to turn yellow, no mottling	62
Streak mosaic	Plants stunted; leaves entirely yellow or streaked and mottled; near maturity mottling disappearing, leaves turning brown and dying	63
Nematode disease	Plants stunted, enlarged at base; heads small, open, remaining green longer than normal; leaves crinkled	63
Insect damage	Plants ripening prematurely, bleached in appearance; symptoms similar to those of anthracnose or scab; base of plant appearing healthy. Damage caused by billbug.	

SEEDLING

Scab	Plants stunted, yellowish, some dying; roots rotted, reddish brown	36
Spot blotch	Dark brown rot at or beneath soil line; leaves erect, dark green, with dark brown spots	44
Speckled leaf blotch	Leaves having circular or oval, light green spots with black pimples; in spring many tillers dead and covered with black pimples	24
Nematode disease	Leaves rolled, wrinkled, twisted, or distorted	63

LEAF RUST

Puccinia rubigo-vera tritici

Wheat leaf rust, less commonly called orange leaf rust, mainly affects wheat; it also affects barley and a number of uncultivated grasses that are slightly susceptible. In most years it causes more damage in Illinois than any other wheat disease. Its damage is usually underestimated because it seldom causes severe shriveling of grain. However, it causes a reduction in number of kernels and in the size of kernels. Illinois loss estimates covering a continuous 11-year period, 1946–1956, range from 0.4 per cent in 1953 to 17 per cent in 1946 and 1948 and average 11 per cent; these estimates indicate an average annual reduction in potential yield of over 4,743,000 bushels.

Leaf rust is present in Illinois every year, but variations in weather cause noticeable year-to-year differences in the extent to which rust develops. In most years nearly every stalk of wheat in the state bears leaves with rust pustules. The year-to-year

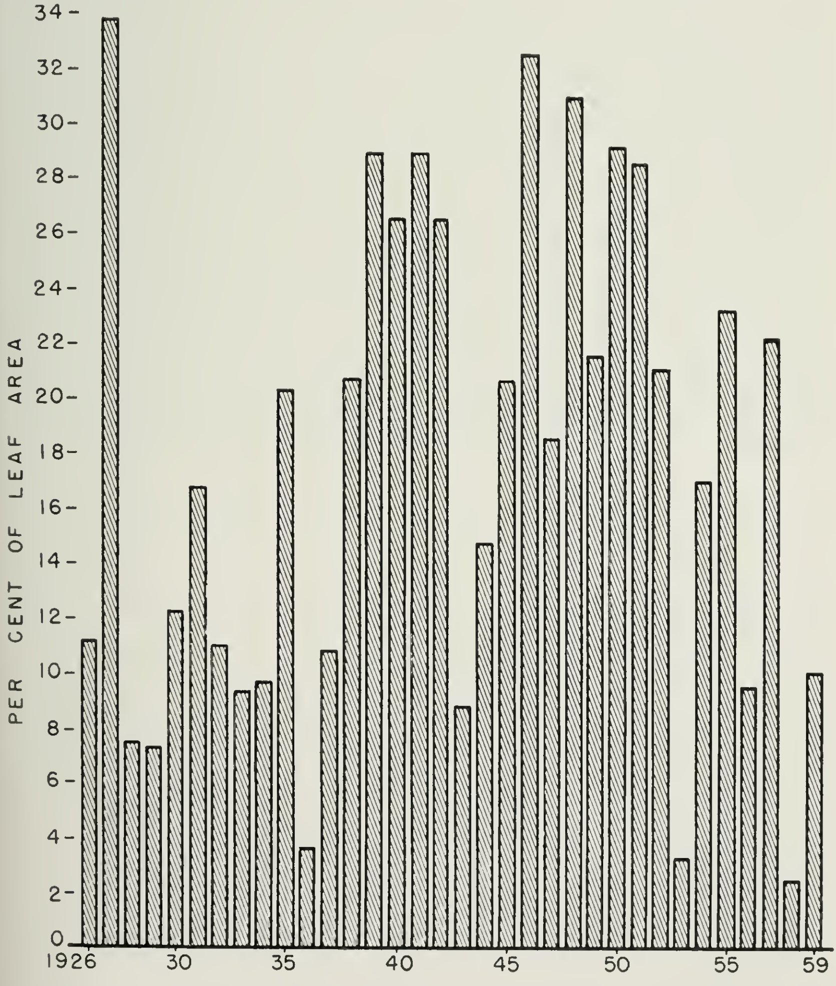

Fig. 2.—Per cent of leaf area occupied by wheat leaf rust in Illinois fields, 1926–1959. The rust varies from year to year in the amount of functional leaf tissue it destroys.

differences in severity of rust lie chiefly in the amounts of rust infection on the leaves. Loss in yield is severe when rust infection occurs early and continues throughout the growing season. Leaf rust causes a reduction in number of kernels per head and

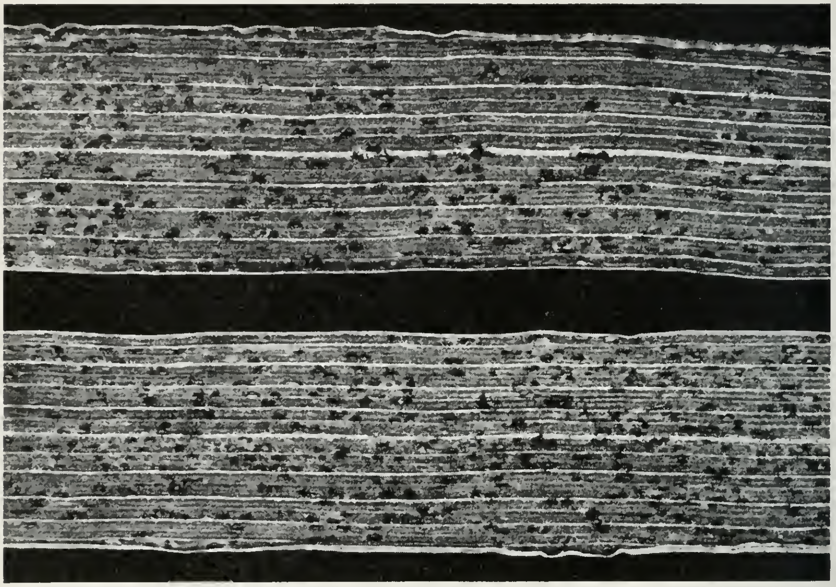

Fig. 3.—Leaf rust on wheat. The dark spots scattered over the leaves, between the veins, are the rust pustules. These are orange-red during the growing season and produce the rust spores by which the disease is spread.

in kernel volume even when shriveling of kernels is not evident. The per cent of leaf area occupied by leaf rust in Illinois over a 34-year period is shown in fig. 2.

Specialized varieties or physiologic races of leaf rust, like those of stem rust, page 18, show considerable selectivity with regard to the wheat varieties they attack; over 140 such races have been found to occur in the world. In 1957, 19 physiologic races were detected in the United States; race 15 was most abundant.

Appearance.—As the name implies, leaf rust of wheat is found mainly on the leaves, but it may occur on the stems, especially that part of a stem between the head and the flag leaf, and occasionally on the chaff. The disease first appears on the older leaves and spreads up the plant to the flag leaf as the season advances. The rust shows as small, round or oblong, raised, orange-red pustules on the surface of a leaf, fig. 3. The pustules are most abundant on the upper surface of the leaf and owe their color to the masses of summer spores they contain. In the early part of the growing season, these pustules are few in number and are scattered irregularly over the leaf surface. Sometimes a circle of smaller pustules occurs around a large pustule. As the season advances, the rust spreads from the older to the younger leaves, and the pustules may become very abundant. In years of heavy rust infection, all the leaves appear plastered with pustules. The small size and orange color of the pustules and the absence of conspicuous leaf tissue around the pustules distinguish leaf rust from stem rust. As the wheat nears maturity, other pustules of about the same size but darker in color appear in great abundance on the sheaths and leaf blades and even on the stems. These pustules, which contain the winter spores, usually do not rupture the tissue. Both types of pustules remain until the wheat has ripened.

Life History.—The wheat leaf rust fungus has an extended and complicated life history, like that described for stem rust, in which five distinct types of spores are produced. Its common alternate host is a meadow rue (*Thalictrum polygamum*), which is an herb in the buttercup family. This species is not found in Illinois and no instance of the natural occurrence of this rust on meadow rue has been found in the United States. Thus, the dark winter spores are functionless in Illinois.

For practical purposes, the life history of wheat leaf rust in Illinois, as throughout North America, may be considered as limited to the summer spore, or orange leaf rust, stage. The summer spores can endure low temperatures and overwinter in the southern states and perhaps some years even in Illinois. The fungus can overwinter as mycelium in wheat leaves and produce the orange pustules in early spring.

Under favorable conditions the leaf rust fungus can produce a new crop of spores every 7 to 14 days during the spring. Summer spores produced in wheat fields in the southern states are carried northward on the wind, settle on wheat plants, and produce new infection as soon as favorable weather occurs. Once established in a wheat field, the rust produces summer spores in such great abundance as to insure its spread through that field.

Control.—At present, the best means of reducing losses by leaf rust of wheat lies in the use of resistant varieties of this cereal. Two or more applications of powdered sulfur have given good control under experimental conditions, but under present field conditions sulfur dusting of wheat is not practical. New chemicals are being tested for the control of leaf rust, and the results are promising. If use of these new materials proves practical, chemical control of rust should become a common practice.

The addition of nitrogen in moderate amounts to soils deficient in this element has resulted in increased yields of wheat, but it has tended to increase the intensity of the rust attack. Adding potassium and phosphorus to soils deficient in these elements has been shown experimentally to increase yields without increasing susceptibility of the wheat plants to leaf rust.

STEM RUST

Puccinia graminis tritici

Stem rust is a disease that attacks many cultivated and wild grasses, including all the small grains, brome grass, squirrel tail, and wheat grasses. It is caused by a fungus, *Puccinia graminis*, which has a complicated life history. The fungus produces five different kinds of spores and requires an alternate host, the common barberry, for the completion of its full life cycle.

Puccinia graminis has become differentiated into a number of specialized varieties that exhibit strict preferences with regard to the cereals and grasses they attack. One variety, *Puccinia graminis tritici*, attacks chiefly wheat but it attacks barley, too; *Puccinia graminis avenae* occurs chiefly on oats; *Puccinia graminis secalis* occurs principally on rye; other varieties occur on redtop, bluegrass, and timothy. The variety that attacks any given crop is usually still more highly specialized in host preference and consists of physiologic races that are rather strictly limited to host varieties; these races have been numbered by plant pathologists to distinguish one from another. At least 189 races of the variety that attacks wheat are known to occur in North America, but, fortunately, only a dozen or so races are important each year. Six races were identified in Illinois in 1958.

Wheat stem rust is present in the state every year. While it is not a limiting factor in wheat production in Illinois, as it is in some other states and some countries, its prevalence and severity of attack vary from year to year with weather conditions and the amount of available inoculum. It has caused an average reduction in wheat yield over a 20-year period of approximately 2 per cent of the potential crop. In about 50 per cent of the years since 1922, the loss has been a trace of the crop, but in 1937 the reduction in yield was estimated at 12 per cent. Stem rust causes low yields and test weight, poor quality, shriveled grains, and lodging of stems if the attack is severe.

Appearance.—The stem rust fungus produces two spore stages, the red and the black, on wheat. The red spore stage is the

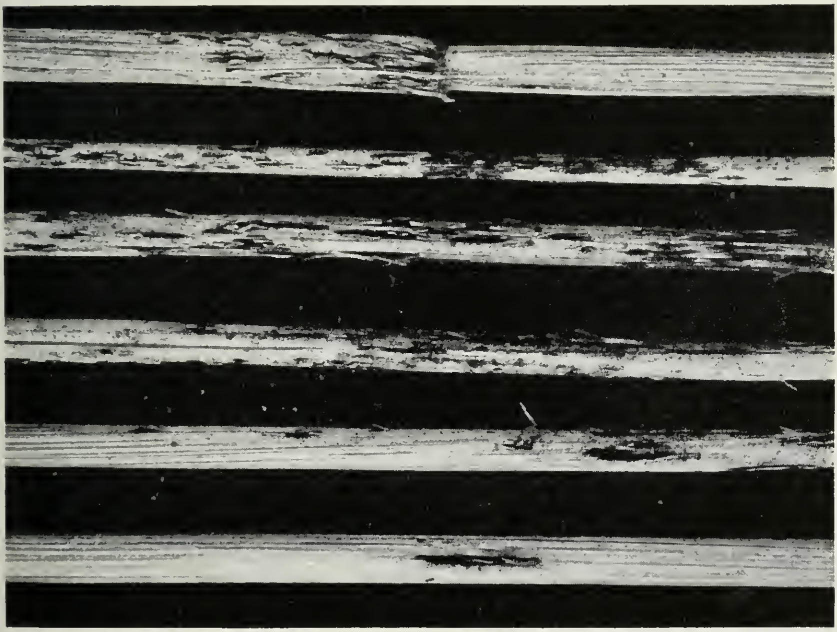

Fig. 4.—Stem rust on wheat. The ragged-edged scars are the red pustules, filled with brick-red spores by which the fungus propagates itself during the summer.

one most commonly encountered during the growing season and may occur on any above-ground parts of the plant.

Stem rust on wheat, fig. 4, is recognized readily by the elongated, ragged pustules it produces on stem, leaf sheath, blade, chaff, beard, and occasionally on the young kernel. Pustules usually begin to appear in late May or early June in southern Illinois and increase in number until the wheat is ripe. Soon after appearing, they rupture the tissue, exposing a powdery, brick-red mass of summer spores. Fragments of the wheat epidermis adhere to the sides and ends of the pustules, giving them a ragged appearance, especially at the ends. This ragged appearance, brick-red color, and length of the pustules are characteristics that distinguish stem rust from leaf rust. Individual pustules may be a quarter inch or more long; in heavy infections two or more pustules may run together and form streaks. As wheat nears maturity the rust fungus forms the black pustules filled with black spores. These spores are most abundant on the leaf sheaths and stems and they may appear in open pustules.

Life History.—The final effort of the stem rust fungus, as the wheat plant nears maturity, is the production of its black spore stage. In this form it overwinters on stubble, straw, and the dead stems of grasses, for these spores are not shed from the pustules in which they are formed. In the spring the black spores germinate, giving rise to a very short tube with four stubby branches, each of which produces a small round spore at its tip. In order to cause infection, the spores must be blown to a leaf of the common barberry plant, *Berberis vulgaris*, which was introduced from Europe as an ornamental shrub. Once a barberry leaf is infected, the fungus grows within it and early in May produces a swollen place on the leaf. Shortly afterward there appear on the upper surfaces of these swellings very tiny pore-like openings from which issue quantities of exceedingly minute spores suspended in drops of nectarlike liquid. Distribution of these spores, by spattering rain or by insects, to swollen areas other than those in which they have been produced accomplishes a process of fertilization similar to pollination, the result of which is the formation on the undersides of the swellings of minute, spore-filled cups—the cluster cup stage of the rust fungus, fig. 5.

The common barberry is susceptible to infection by the many physiologic races of the stem rust. New and even more dangerous physiologic races of stem rust than now exist may result from cross-fertilization on the barberry. Race 15B is a very virulent race that has recently been produced in this manner.

Spores dropping from the cluster cups are caught up by breezes and carried some distance from the shrub on which they have been produced. If they chance to light on a grain or other grass plant susceptible to stem rust, under favorable conditions they germinate and cause infection. If the temperature is 70 degrees F. or higher, the fungus grows within the tissue of the new host and very soon breaks out as brick-red pustules filled with red summer spores. This is the stage in the life cycle of the rust that is commonly known as red rust. The red spores are shed as soon as they are produced and they are carried by the wind, not only to nearby plants but also for considerable distances. Alighting on wheat plants, they germinate and infect them; after a short period new pustules appear, from which a new crop of spores is distributed. The time required for the summer cycle of infection ranges from 8 to 14 days. Its constant repetition

Fig. 5.—The cluster cup form of stem rust as it appears on the common barberry, the principal alternate host of this disease. Spores borne in the tiny cups produce the red rust stage of stem rust on susceptible plants. (Photograph from U. S. Department of Agriculture.)

through the growing season, coupled with the enormous number of spores produced, results in exceedingly destructive stem rust epiphytotics when weather favorable to spore germination and infection prevails. The red summer spores are the only spores produced by the fungus that can reinfect the host species that produced them. As the wheat begins to ripen, the fungus again produces the black pustules characteristic of stem rust.

In most of Illinois, original infection of the wheat crop each year is brought about by summer spores blown northward from fields farther south. Although the summer spore stage does not survive the winter in Illinois, it winters successfully in southern Texas and Mexico, and the spring infection moves northward with the season and the developing wheat crop. In northern Illinois, the common barberry may play a part in initiating local epiphytotics each year.

Control.—Since stem rust infection takes place during the growing season from spores produced either on the common barberry or on wheat plants, prevention of infection is a logical method of control. Toward this end three measures are applicable: the growing of wheat varieties resistant to attack; interruption of the life cycle of the rust so that an important infective spore type cannot be produced; and treatment of the growing wheat so that spores alighting on it do not produce infection.

Wheat varieties entirely immune to stem rust do not exist. However, varieties resistant in various degrees are numerous, and there are types well adapted to any part of Illinois. Farm advisers and experiment station officials can furnish information on resistant varieties adapted to each region. Varieties of wheat that are not resistant to the fungus but that mature early may escape serious rust damage.

Control by interference with the life history of the rust fungus has been carried on in Illinois, as in other central western states, by systematic eradication of the common barberry. Since the black overwintering stage of the rust is able to infect only the barberry, eradication of the barberry should remove the link necessary for carrying infection over from the crop of one year to that of the next in Illinois. Begun in 1918, the eradication campaign has resulted in the finding and destruction of a large number of common barberry bushes in the state. Eradication of barberry, however, does not prevent infection from red or summer spores borne on the wind from the south.

The common barberry is a shrub brought to North America by early colonists. Settlers, moving westward, carried it with them. Nurseries distributed it widely. It propagates readily by seed and has escaped from cultivation in many places. While its eradication may not prove so generally beneficial in Illinois as in states farther north, the individual owner may profit considerably from the destruction of barberries on his farm.

Not all kinds of barberry shrubs harbor the stem rust fungus. The Japanese barberry is immune to attack and can be planted and grown without endangering the wheat crop. The characteristics of the common and Japanese barberries are given below.

Common barberry, *Berberis vulgaris* L., alternate host of the stem rust fungus, is a tall, erect, woody shrub, commonly reaching 12 feet in height. Its bark is dark gray, and its coarse stems are armed with long spines. Its leaves, which are green, fairly large, and bristle-toothed along the edges, grow in clusters at the stem joints, just above the spines, of which there usually are three or more at each joint. Its small, inconspicuous yellow flowers, borne in long, drooping clusters like those of a currant, produce numerous bright red berries that stay on the shrub through the winter.

Japanese barberry, *Berberis thunbergii* DC., immune to stem rust, is a low, spreading, graceful shrub commonly 4 to 5 feet high. Its bark is dark red, and its slender stems are armed with short spines. Its leaves, which are usually green but often red tinted (conspicuously and beautifully so in the fall), small and smooth along the edges, grow in clusters just above the single spine at each joint. Its flowers, which are small and yellow, and its berries, which are bright red and which cling to the bush through the winter, are borne in small bunches of two or three, like those of a gooseberry.

Experimental work, both in the United States and in Canada, has shown that a decided reduction in stem rust attack, accompanied by unexpectedly large increases in yields, can be obtained if growing wheat is dusted with sulfur at intervals before heading time. Successful dusting must be done from airplanes. For many reasons this control measure has not been adopted: fire hazard, small size of fields, barriers around fields, and lack of information on the required number and timing of applications. Several new chemicals are showing promise in controlling rust.

SPECKLED LEAF BLOTCH

Septoria tritici

Speckled leaf blotch gets its name from the appearance of the blotches it causes on leaves. The numerous specks in the blotches are the blackish spore-producing bodies of the causative fungus, which attacks only the leaves and sheaths of plants. Other names frequently used for this disease are leaf spot, nebular leaf spot, and Septoria leaf spot. It is primarily a cool weather disease, doing its greatest damage when plants are not very active. Besides wheat, it attacks spelt and emmer. It has been reported on rye in Washington.

Usually not so conspicuously destructive to maturing wheat as is leaf rust, speckled leaf blotch ranks second in importance among the diseases prevalent in Illinois wheat fields. In most years it does its greatest damage to seedlings in the fall and to tillers in the early spring. However, in some years, as in 1957, it kills the leaves of plants in many fields just before the grain is in the dough stage.

The destructive effect of speckled leaf blotch is greater than usually is realized. In years of severe epiphytotics yields may be reduced 50 per cent or more by the disease. The year 1926 was one of very light infection, when only 11 per cent of the plants examined were infected and 0.4 per cent of the leaf area was destroyed, but, in 1929, 100 per cent of the plants were diseased and by harvest 65 per cent of the leaf area had been destroyed. In an average year, about 90 per cent of the plants are diseased and 14 per cent of the leaf area is destroyed. The destruction of such large amounts of leaf tissue greatly reduces the yield.

Appearance.—Speckled leaf blotch, fig. 6, is most conspicuous early in the spring, when it appears as irregular, longitudinal, reddish-brown, often ashen-centered, spots of various sizes scattered over the leaf surface. It is especially abundant on lower leaves. The spots contain many tiny, black specks not nearly so large as pinheads but plainly visible to the unaided eye.

This disease exhibits symptoms that vary somewhat with the season. In late fall, it may be recognized by the more or less circular to oval, speckled spots on the blades of the seedling leaves. The centers of the spots are at first light green, which shades into the natural green of the leaf; the spots are not very conspicuous until the black fruiting bodies of the fungus are formed. In the spring the spots gradually elongate as the fungus grows in the leaf tissue; they turn reddish brown and, as a rule, become partially surrounded by a yellowish band. The oldest part of each spot usually turns to light brown or ashen white and is studded with tiny, black specks. Many heavily infected leaves have a yellowish cast and they may die prematurely. The lower leaves are usually the most severely diseased. Sometimes a spot extends entirely across a leaf,

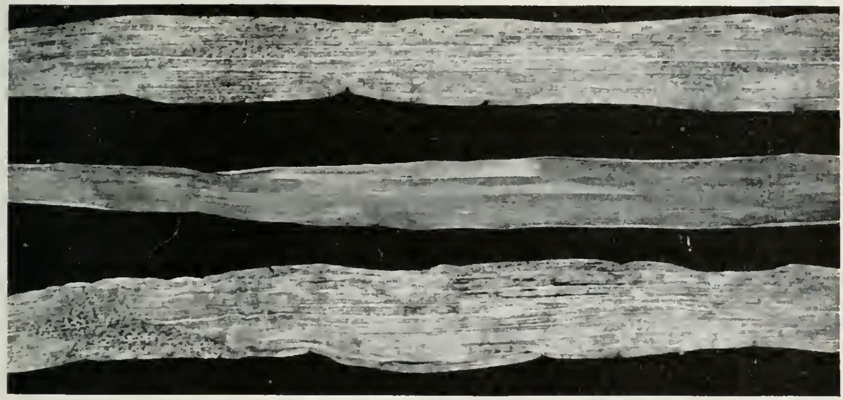

Fig. 6.—Speckled leaf blotch of wheat. The presence of the fungus is indicated by the many black dots in the blotched regions.

usually where the blade is attached to the sheath, killing it at that point and causing the death of all the outward part of the leaf. Very little new infection occurs after flowering time of the grain.

Speckled leaf blotch occasionally attacks the tips of glumes and produces spots similar to those caused by glume blotch, except that the color is darker and the discoloration ends in streaks along the main veins.

In some years speckled leaf blotch kills most of the rosette leaves and as many as 50 per cent of the tillers. This damage is often confused with winter injury. Small, black fruiting bodies over a large part of the area of dead rosette leaves and dead tillers indicate presence of the disease.

Life History.—After the wheat crop is mature and harvested, the speckled leaf blotch fungus lives through the summer on volunteer wheat, emmer, and spelt, as well as in leaf fragments from the wheat crop. Spores shed from infected plants are always ready to infect susceptible grains and other grasses, and the spores themselves are able to remain alive for as long as a year. Mycelium within leaf tissue remains alive for long periods, even under conditions unfavorable to the fungus. When the winter wheat seedlings appear above ground in the fall, speckled leaf blotch infection occurs in them and, since the fungus is adapted to cool weather, the infection grows and spreads until stopped by severe cold. Overwintering in the wheat leaves, the fungus resumes activity again in the spring, and successive crops of spores are produced in the black specks and broadcast until the wheat has matured.

Control.—Little attention has been given to control of speckled leaf blotch. The wheat grower who wishes to prevent loss has at hand several general measures, all of which are described under good farm practices, page 142. The first of these is sanitation: crop residues should be plowed under as soon after combining as possible to hasten the decomposition of infected material, and all volunteer wheat and other infected hosts should be destroyed before seeding time. The second measure is crop rotation: at least 1 year between wheat crops should be allowed. All of the present commercial wheat varieties are susceptible to the disease; some are more susceptible than others. The seed should be thoroughly cleaned, and fall wheat should be sown as early as possible so that it can make good growth before the occurrence of weather cool enough for the disease.

GLUME BLOTCH

Septoria nodorum

Glume blotch, also called glume spot, is one of several diseases in Illinois that attack the chaff or glumes of wheat heads. It attacks stems and leaves also. In addition to wheat, it attacks barley, rye, emmer, spelt, bluegrass, quack grass, wild rye, wild barley, fescue, wood reedgrass, and bottle-brush grass. It is a warm weather disease and does not develop extensively until the crop nears maturity. In most years glume blotch is one of the relatively unimportant wheat diseases in Illinois.

In cases of severe infection, the disease may cause the death of many young tillers. Some of the infected tillers that survive produce small heads with shriveled kernels that, in threshing, may be blown out with the straw and chaff. Some plants of ap-

Fig. 7.—Glume blotch of wheat. The causative fungus attacks the heads most often. On the heads it produces brownish blotches near the tip of the chaff, *A*, on which spore-bearing bodies are relatively rare. Also, it attacks the joints, *A*, discoloring them and producing tiny, black, spore-bearing bodies in the lesions. Severely infected heads, *B*, left, are chocolate-brown and they produce shriveled kernels, *B*, left. Diseased heads and kernels are smaller than healthy heads and kernels, *B*, right.

parently normal growth have heads that are so severely infected that they produce shriveled kernels or no kernels.

As a severe infection of leaves or joints, the disease may cause noticeable reduction in yield. Severity of glume blotch in Illinois varies from year to year. Annual infection of heads ranges from less than 0.1 per cent to 48 per cent and infection of spikelets from a trace to 24 per cent. Estimated annual losses caused by glume blotch ranged from a trace to 5 per cent and averaged 0.7 per cent for a period of 25 recent years.

Appearance.—This disease, fig. 7, when first evident on the chaff, may be seen as small, irregular, grayish or brownish spots or blotches, which later enlarge and become chocolate brown. As the spots age, their centers often turn grayish white, and in these regions tiny, black, pimplelike, spore-bearing bodies usually can be seen. Glume blotch usually occurs near the top third of a glume. The inner surface of infected chaff is not so badly discolored as the outer. Occasionally infection occurs at the base of a glume and cannot be distinguished from basal glume rot unless the fruiting bodies are found. Ordinarily only a few glumes in a head become infected, but in severe cases the entire head is attacked and turns dark brown.

On the stem the attack usually occurs at the joints, which shrivel, turn brown, and later become sparingly dotted with black spore-bearing bodies. The joints of diseased spikes are almost black. Infection at the joints weakens the straw and, if severe, results in lodging. Plants often crook at the joints if infection partially girdles the stems. Spots on the stems are large and light brown but contain no spore-bearing bodies. Glume blotch spots on the sheaths are dark brown and often so large as to include most of each sheath. Spots on the blades of the leaves are light colored. As the central part of a spot dies, it becomes lighter, sometimes almost white in the center; a brown border may surround the spot. In the light area the black spore-bearing bodies appear on both surfaces of an affected leaf. Under conditions favorable to the fungus the spots may be so abundant that they coalesce and involve most of the leaf, which turns brown and dies prematurely. The fruiting bodies are scattered over the diseased area of the leaf and are arranged in rows along the veins. Plants severely infected by glume blotch are stunted in growth, and if the sheath of the flag leaf of a plant is badly diseased the head may be noticeably deformed. Many of the tillers are killed when small, and on those that live the heads are usually only one-third to one-half the normal size and bear but a few small, shrunken kernels.

Glume blotch should not be confused either with black chaff or with basal glume rot. Its spots have no tendency to form streaks and they are neither so sharply defined nor so dark brown as those of black chaff. Glume blotch does not present the water-soaked appearance of basal glume rot, and usually it occurs on the upper third of a glume.

Life History.—The fungus causing this disease is believed to live over winter chiefly in the plant refuse of the previous season's crop, but undoubtedly living infections in volunteer wheat, rye, wild grasses, and young winter wheat play an important role in carrying the fungus over from year to year. It also lives in the seed as mycelium and produces infection in the sheath surrounding the leaves and growing points of a seedling and on seedling leaves. The summer spores produced in black spore-bearing bodies in the diseased spots are known to be able to live for a year. At any time during the growing season, after the leaves unfold, infection may occur. Infection of the wheat head occurs, after blossoming time, from spores deposited by the wind or splashed there by rain. Several crops of summer spores may be produced during one growing season; a special type of winter spore is sometimes produced in old diseased material but it appears not to play a very important part in the life history of the disease.

Control.—Sanitation and crop rotation are essential in controlling glume blotch, since the fungus can live over winter and be disseminated as spores in diseased plant material. The most heavily infected part of the wheat plant remains in the field after harvesting. Since this usually cannot be destroyed, the next year's crop should be situated as far as possible from the crop of the year before it, for both wind and running water are important means of disseminating disease-carrying material. Thorough fanning of seed to remove all infected straw and chaff will reduce the chance of infection from this source. The use of manure containing infected straw, for top dressing the crop, should be avoided. Damage by glume blotch is usually not sufficient to justify seed treatment for this disease alone. Treatment, page 151, to combat other seed-borne diseases will help in controlling this disease. The use of resistant varieties of grain offers the best means of preventing losses from the glume blotch disease.

LOOSE SMUT

Ustilago tritici

Loose smut is the most easily recognized of all wheat diseases because of the characteristic dusty black appearance of diseased heads, an appearance that has given it such common names as smut, black head, and black smut. An important difference between this and other smuts of wheat is that the infection is carried over from season to season within the seed and not as spores on the surface of the seed. Rye is slightly

Fig. 8.—Loose smut on wheat. Smutted heads are conspicuous during heading of wheat. As a rule, glumes and grain are completely transformed to black powder, which shatters off, leaving a bare spike at harvest. The two heads at left are in bloom, the stage at which infection occurs.

susceptible to attack by the fungus that causes loose smut in wheat.

The amount of loose smut in Illinois wheat fields varies from year to year. Although individual fields or limited areas of the state may be at times badly diseased, the damage caused by the disease is never great for the state as a whole. The largest recorded amount of smut infection, 7 per cent of the heads, occurred in 1958, and the smallest amount, 0.3 per cent, in 1930. During 33 growing seasons, 1926 through 1958, the average annual infection for the state was slightly less than 2 per cent of the heads.

Appearance.—The term loose smut is very descriptive, since the fungus spores which make up each black head adhere loosely and are easily shattered off, leaving only the bare stalk, fig. 8. Loose smut is recognizable as soon as the affected head emerges from the boot. Usually the entire head is diseased, although sometimes part of a head remains normal and develops grain. Most of the smut mass, which consists entirely of spores of the fungus, is dislodged during the blooming period, and by harvest only a bare spike remains, which is easily overlooked by a casual observer.

Life History.—The spore masses on smutty heads are broken up and scattered by wind, rain, and other agencies. Any spore that chances to light in a flower of a healthy head germinates immediately, if moisture conditions are favorable. The fungus grows down the flower and establishes itself inside the developing kernel. After establishing itself, it becomes inactive and can live within the seed in a dormant state for a year or more. When an infected wheat seed that has been sown begins to sprout, the fungus becomes active again, grows into the young shoots, up to the growing points, and keeps pace with the development of the plant. As each wheat head forms, the fungus begins its own process of reproduction and replaces the spikelets with a new crop of dusty black spores, which are ready to infect the flowers of healthy plants. A diseased seed or plant cannot be distinguished from a healthy one until the plant begins to head out.

Control.—Since loose smut is not surface borne on the seed, contact treatments are not effective. Any control method, to be effective, must kill the fungus inside the seed without injuring the germ of the seed. Since the thermal death point of the fungus in the seed is a few degrees less than that of the wheat seed germ, the hot-water treatment, page 149, can be used to control the disease.

Certified seed should be relatively free of smut infection. The use of seed from a plot in which care is taken to produce disease-free seed of a variety suited to the locality is a very dependable way of preventing loss from smut, page 147. There are no varieties of wheat that are resistant to all the races of loose smut that occur in Illinois. Some varieties are less resistant than others.

STINKING SMUT

Tilletia foetida

Stinking smut on wheat, sometimes called bunt, gets its name from the characteristic fishy odor given off by infected heads. Often this disease is not recognized in the field, for diseased heads may be mistaken for healthy heads that are unusually plump. Wheat and rye are the only known hosts of stinking smut in the Midwest; the disease has not been reported on rye in Illinois. Two types of losses result from stinking smut infection in wheat: smutted heads are a total loss and reduce yield in proportion to their number; the presence of much smut in threshed wheat gives the grain the foul fishy odor, and such wheat, being unfit for milling, is subject to dockage when sold.

Infections involving as much as 50 per cent of the heads in a wheat field have been observed in Illinois. Data covering 33 consecutive years show for infested fields an average of about 3 per cent of the heads smutted. The prevalence of smut varies from year to year. It depends in part on the existence of soil conditions favorable for infection to occur following planting and in part on the extent to which preventive measures have been used.

Appearance.—A head affected by stinking smut (frontispiece), when it first emerges from the boot, has a distinct blue cast, which it retains until after normal heads are ripe. At blossoming time it is more slender than healthy heads and does not put out pollen sacks, but at maturity it is apt to appear plumper and fuller than normal heads because of its wide-spreading, open chaff. The kernel, during growth, is transformed into a smut ball, which is shorter and plumper but lighter in weight than a normal wheat grain. The smut ball consists of a mass of oily, foul-smelling, dark brown powder—the spores of the stinking smut fungus.

In the field, smutted heads usually stand more nearly erect than healthy heads, because of their lighter weight. The blue tint in diseased heads varies considerably, as does also the spreading of the chaff at maturity. In some varieties of wheat, it is necessary to crush the kernels to determine if heads are diseased. The offensive odor announces the presence of heavy infestations in fields and betrays the presence of quantities of smut balls in grain shipped in cars or stored in sacks or bins.

Life History.—Many of the smut balls are shattered during threshing, and spores thus liberated lodge on healthy kernels, especially at the brush ends and in the grooves. Planted in the soil with the wheat itself, the spores germinate when soil conditions become favorable. By the time a wheat sprout has emerged, the smut fungus has produced spores of another type, and these cause infection of the young wheat plants. After entering a young shoot, the fungus continues to grow as an internal parasite, eventually transforming the wheat kernels into smut balls. A single smut ball, it has been estimated, may contain between 1 million and 8 million spores. Soil can become infested with stinking smut when smut balls shatter off before or during harvest or when the balls are planted along with seed.

Control.—All smut balls should be removed by cleaning and recleaning seed. Spores carried on kernels can be killed by chemical treatment, page 151. The seed should be protected from contamination after it has been treated. Resistant varieties of grain should be used. Even if resistant varieties are used and the seed is thought to be free of smut, the seed should be treated with a chemical.

FLAG SMUT

Urocystis tritici

Flag smut, first discovered in Missouri near St. Louis in 1918, was found in Illinois near East St. Louis in 1919. It is very limited in its distribution in the United States and in Illinois. Most of the flag smut found in Illinois has occurred in four counties bordering the Mississippi River in the East St. Louis area. The loss from flag smut is easily overlooked, because diseased plants are short and usually dead before the crop matures. At present the loss is small, but fields have been found with 30 per cent of the plants affected. Potentially flag smut is a very destructive disease and should be guarded against in disease-free localities. Quarantine restrictions instituted by the state and use of resistant varieties may have eradicated it from Illinois. No flag smut of wheat has been reported in Illinois since 1932.

Appearance.—Flag smut lesions occur on the leaves, the leaf sheaths, and the upper parts of stems as long, lead-colored to black stripes or lines running lengthwise of spirally twisted and deformed plant parts, fig. 9. Affected leaves, many of which are rolled and twisted, split along the stripes and liberate the

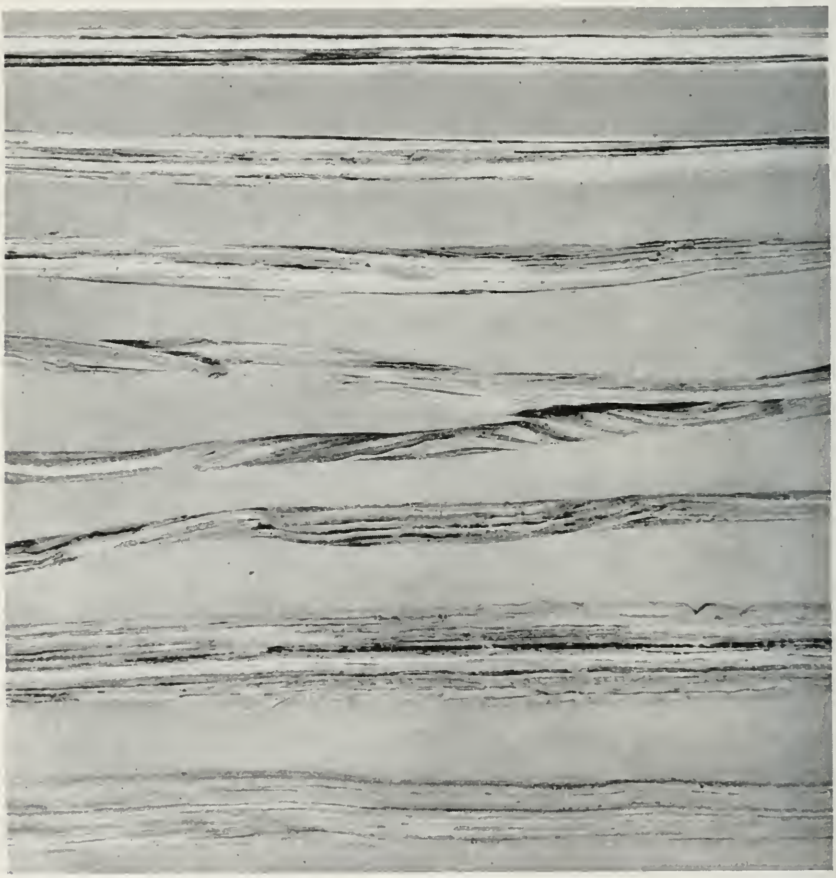

Fig. 9.—Flag smut of wheat. Dark stripes running lengthwise of the leaves and twisted sheaths break open, shedding the smut spores during the growth period in the field as well as during threshing. Because infected plants are dwarfed and seldom head out, they are easily overlooked.

smut spores with which the stripes are filled. In very early stages these stripes are lighter green than the rest of the leaf areas, but soon they develop a leaden and later a black color. They first appear in the upper leaves of diseased plants, before the plants begin to joint, and become very conspicuous by heading time. Infected plants are dwarfed and seldom head out, but if they head out they have the smut stripes on the upper parts of the stems and usually also on the chaff. Flag smut of wheat resembles stem smut of rye but it is caused by a different fungus.

Life History.—The long, leaden stripes characteristic of flag smut are filled with enormous numbers of peculiar smut spores known as spore balls. When the stripes crack open, or are broken open, these spore balls are set free. Falling on the ground, they infect the land so that subsequent wheat crops are in danger of becoming diseased. When diseased wheat is threshed, spores on the straw of smutted plants are spread over the threshed grain as well as throughout the straw and chaff. If contaminated grain is used for seed, it carries with it into the soil the spores of the flag smut fungus.

Whether dropped directly from infected standing wheat plants or carried on the seed planted in the fall, the flag smut spores, once in the ground, germinate as soon as moisture and temperature conditions are favorable to them. The result is the production, within a short time, of a new crop of spores much different in appearance from the parent spores. Spores of this second crop, formed at about the time the sprouts emerge from the wheat kernels, germinate and infect any young sprouts with which they are in contact. Having gained entrance to a wheat plant, the smut organism overwinters there and in the spring resumes growth along with the host, which it dwarfs, distorts, and finally kills. Before the death of its host the fungus produces, in the stripes, the spores which carry it through another year.

Control.—The growing of immune or highly resistant wheat varieties adapted to the infested regions is the best method of preventing damage by flag smut, but where this is not possible seed treatment, supplemented by crop rotation and sanitation, should be used. Seed treatment, page 151, is effective in killing spores carried on the seed.

Flag smut spores are able to remain alive in the soil for more than a year in dry regions. In Illinois, the moisture between harvest and seeding is sufficient to cause most spores to germinate and die before the wheat is sown. However, some spores survive, and if the land is cropped to wheat year after year the disease is certain to increase. Hence, crop rotation is an important step in control.

Infested straw should not be put on land that is to be sown to wheat within 2 years. Because infection does not take place until shortly after the wheat germinates, late sowing of wheat tends to lessen the severity of the disease; the smut spores germinate very poorly or not at all when the soil is cold. It has been found that no flag smut has developed on wheat sown on November 15 or later in Madison County. This planting time, however, is too late to produce a good yield, and the date of seeding should be chosen to give the maximum both of yield and of smut control.

SCAB

Gibberella zeae

The scab fungus attacks wheat, barley, oats, rye, corn, spelt, emmer, and a number of other grasses, including cheat, wild rye, foxtail, quack grass, crabgrass, and bluegrass. This fungus also attacks clover, alfalfa, pokeweed, sweet potato, and some plants in the parsley family. It is most prevalent on wheat, barley, rye, and corn. It is able to live not only as a virulent and destructive parasite on living plants but also as a saprophyte on dead plant material on or in the soil. As a parasite on corn it produces seedling blight, stalk rot, and ear rot. As a parasite on wheat and other small grains it causes seedling blight, root rot, crown rot, stem blight, and scab or head blight. Scab, the best known of these diseases on cereals, is a blighting of the heads and is prevalent in moist, warm seasons from heading time onward. Seedling blight also is a destructive disease; it causes financial loss to grain growers in all parts of the state.

Grain infected with scab is usually light and chaffy. This condition reduces its feeding value and consequently its market value. Scabby kernels contain substances that act as strong emetics in man, hogs, and other animals with similar digestive systems. Grain containing 10 per cent or more scabby kernels fed to hogs may cause vomiting; thus, hogs may refuse to eat the grain.

The severity of scab infection varies greatly from year to year and is closely associated with the weather conditions that prevail following the emergence of the heads. In Illinois field surveys, scab has been found infecting as high as 94 per cent of the heads, destroying an average of 49 per cent of the spikelets. On the other hand, in years that are exceedingly dry, after heading begins only a trace of scab can be found. In 1957, an average of 30 per cent of all wheat heads examined in Illinois had scab, an average of 7 per cent of the spikelets were scabby, and an additional 4 per cent failed to develop because of damage to the rachises by the fungus. In a 33-year period, head blight caused losses ranging from as little as a trace to 11 per cent of the year's crop; the average loss per year was slightly more than 1 per cent.

Appearance.—Scab found on wheat, fig. 10, in its most conspicuous form is head blight, recognized by the premature ripening or bleaching of one or more spikelets of a head any time after flowering. When wheat is in the dough stage, the light yellow color of diseased spikelets of a head show in sharp contrast with the healthy green of the rest of the head. A light pink or salmon color may appear at the bases of infected spikelets and along the edges of the chaff, especially in damp weather. This color is an unfailing diagnostic character. It is due to the presence of quantities of summer spores of the fungus. Kernels of severely affected spikelets have a grayish-white or salmon or reddish color, are badly shrunken and wrinkled, and have a noticeably rough, flaky seed coat. By harvest time, under conditions favorable to the fungus, the heads first attacked may become speckled with superficial, tiny, blue-black particles, which are spore-bearing bodies. Usually scab attacks from one to several of the spikelets on a head but not the entire head. Sometimes the fungus girdles the spike or rachis of a head, killing it at the point of attack and causing the death of the head outward. Attacks of this kind result in no grain or in small, shriveled kernels, which are lost in threshing.

Seedling blight caused by the scab fungus is first noticeable when the infected plants appear stunted. Later these plants turn yellow and die. The roots of diseased seedlings are rotted, reddish brown in color, and may be covered with a mass of grayish or pink mold. If only part of the root system is involved, the

Fig. 10.—Scab on wheat. The four heads in the middle show various degrees of infection, and the head at the right, diseased throughout, shows clusters of the blue-black spore-bearing bodies of the scab fungus. The head at the left is not infected. The nine kernels at the extreme left are normal; those to the right of them show varying degrees of scab injury. Such injury lowers the market value of wheat. Even slightly injured grain, when used as seed, produces poor stands.

plant usually does not stool but sends up a single stem on which a small head is produced.

Poor stands often result from sowing seed affected by this disease. Some diseased seeds are dead before being sown, while others, though they may germinate, are too weak to send their young plants to the surface. If a sprout manages to get through the ground, it may succumb before it can become established. Some diseased plants put out new roots; if a plant succeeds in re-rooting it may live but it is certain to lack vigor.

If foot rot or crown rot occurs as the plants approach maturity, premature ripening or dying of the plants results. If infection occurs earlier, the dead plants have a bleached appearance. Sometimes the fungus attacks the plants at the joints and leaf sheaths. If the stem of a plant is girdled at a joint the portion above the joint dies.

Life History.—The life history of the scab fungus is neither simple nor well understood. The fungus is able to exist either as a parasite of living plants or as a saprophyte on dead plant material. It produces two distinct types of spores, winter spores and summer spores. In the fall it is not uncommon to find its blue-black spore-bearing bodies in abundance on straw or stubble, and in the spring on cornstalks left in the field. When mature these fruiting bodies, whether produced on growing plants or upon dead plant material, contain many small saclike structures, in each of which are eight spores. These winter spores, as they are sometimes called, are discharged during rainy or continued moist spring weather. If they fall upon suitable refuse, they start to grow, soon producing large numbers of summer spores. The summer spores and the winter spores are each capable of producing infection if they fall upon a head of wheat during the blossoming period. In a week or a little longer, pink masses of summer spores may be found at the bases of infected spikelets, and these spores, caught up on the wind and carried to other wheat heads, in turn produce new infections; the process is repeated again and again so long as favorable weather persists and spikelets are susceptible. The fungus may live through the winter as spores on plant refuse and on the seed, and as a mold in plant debris. The mold renews its growth in the spring and produces the summer spores.

Seedling blight is caused by infection carried in the seed, by spores that adhere to healthy seed, or by the actively growing fungus living on decaying crop refuse in the soil. Head infection takes place independently of seedling blight, since the fungus is not able to grow for any distance within the plant.

Control.—The first important step in controlling scab is sanitation. This requires the destruction, by thorough plowing under or burning, of infected stubble, straw, cornstalks, rotten ears, and weed grasses that are apt to perpetuate and spread the fungus. Manure containing infected straw or cornstalks should not be used as top dressing. A rotation system in which wheat, oats, rye, or barley do not follow corn will lessen the degree of infection. Small grains should be planted as far as possible from old cornfields. The seed should be thoroughly fanned to remove all light, shriveled grains and then treated with an organic mercury to kill spores on the surface of the seed, page 151. Delaying sowing until the soil temperature is 60 degrees F. or below lessens the severity of the fungus attack on seedlings.

Resistant or tolerant varieties of wheat sown in a well-prepared soil are a great aid in lessening the possibility of attack. The variety selected should, of course, be adapted to the locality.

POWDERY MILDEW

Erysiphe graminis tritici

The species of fungus that causes powdery mildew attacks wheat, oats, rye, barley, redtop, Canada and Kentucky bluegrasses, wild rye, squirrel tail, wood reedgrass, and other native grasses. Several varieties of the fungus occur. In its parasitism each variety is very closely adapted to its host, and as a result the variety that infects wheat will not cause infection on other plants. The fungus belongs to a group of fungi which live chiefly on the outer surfaces of their hosts, but they make connection with the interior by means of small, suckerlike branches which penetrate the epidermis, enter the surface cells, and draw sustenance from them. Powdery mildew is found scattered in wheat fields throughout Illinois each year. It has become more important in the state in recent years as farmers have increased their applications of nitrogen on wheat in the spring. The fungus does not thrive on plants that are suffering from nitrogen deficiency.

Wheat plants affected by powdery mildew are usually found in parts of fields where growth is dense and the air moist, conditions ideal for infection. The damage the disease does to the wheat plant is due to the fact that the fungus robs the leaves of food manufactured for the plant's own use as well as to the fact that attack by the fungus reduces the amount of

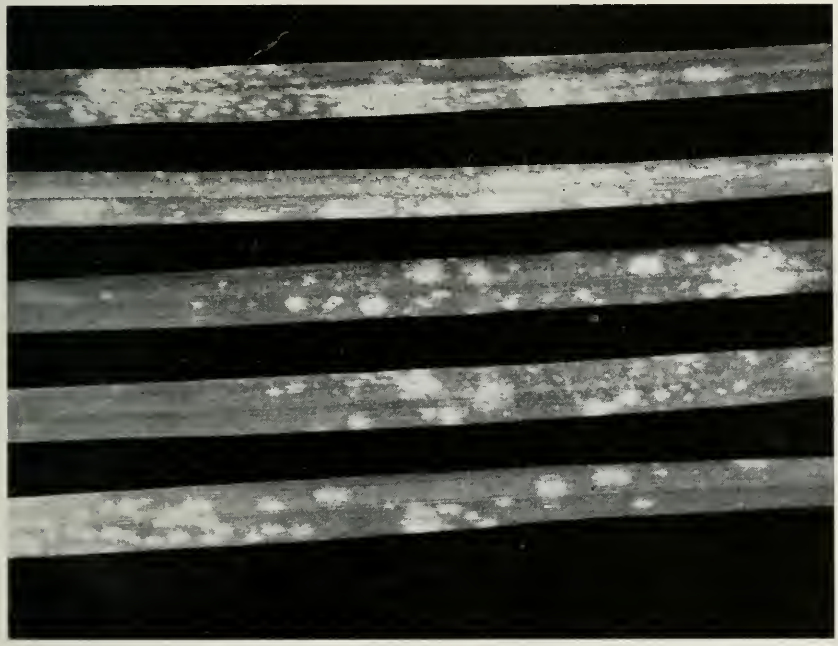

Fig. 11.—Powdery mildew on wheat. The fungus may first be seen on the upper surface of a leaf as small, irregular or circular, grayish-white spots. These spots enlarge and become floury in appearance; they may cover the greater part of the leaf. As the plants near maturity, small, black, spherical fruiting bodies may be formed in the fungus growth. The disease occurs where growth is dense and the air among plants is humid.

leaf area available for food manufacture. In severe cases, plants lodge and kernels shrivel.

Appearance.—Powdery mildew of wheat, fig. 11, usually is found only on the leaves, but it may attack all above-ground parts of the plant. It is noticeable first as small, irregular or circular, light gray spots on the upper surface of a leaf. The spots enlarge as the fungus grows and often may involve large parts of the leaf. As the spots age, the fungus on them takes on a floury appearance, which is due to the production of an enormous number of spores. Often the lower surface of the leaf beneath the diseased spots turns yellow, and older parts of the spots turn brownish. Affected leaves become deformed and crinkled, especially those that have been attacked when young; in severe cases they become brittle or they may die prematurely. As affected wheat approaches maturity, small, spherical, black fruiting bodies, seen as black specks, may be scattered throughout the fungus growth on infected spots. On the glumes the fungus appears as a grayish-white mold.

Life History.—In the floury, grayish spots on the leaves, summer spores are produced in great abundance; they are able to cause new infection immediately and they serve to spread the disease to healthy plants during the growing season. Under favorable conditions of moisture and temperature, new crops of spores are produced every 10 days to 2 weeks until the host tissue dies. A cycle of infection, spore production, distribution, and reinfection is thus established and occurs over and over throughout the growing season. The black, spherical bodies developed in the fungus growth of infected tissue contain winter spores which serve to carry the fungus through the winter and produce initial infections on the new crop the next spring. It is possible that in mild winters in the southern part of Illinois the fungus may overwinter in the vegetative state.

Control.—Because of its superficial habit, this disease could be very easily controlled with chemicals applied to its host plant, since a suitable fungicide sprayed or dusted on the plant would come in direct contact with the fungus and kill it. New chemicals that may be practical for controlling the disease are being developed and tested. This disease has not been destructive enough in Illinois, except in occasional fields in recent years, to justify control measures. Resistant varieties have been developed for use where the disease is destructive. Crop rotation tends to minimize the chances of heavy infection.

DOWNY MILDEW

Sclerospora macrospora

The downy mildew fungus attacks wheat, oats, barley, rye, corn, rice, redtop, quack grass, crabgrass, rye grass, meadow fescue, and a number of other grasses. It is usually found in low, poorly drained areas where seedlings are exposed to excessive moisture. It has not been a major disease in Illinois. However, under conditions favorable to the fungus it might become destructive; growers should watch for it and send samples of plants suspected of harboring the disease to the Illinois Natural History Survey, Urbana, Illinois, for identification.

Appearance.—Plant symptoms produced by downy mildew on wheat, fig. 12, are variable. Some diseased plants tiller ex-

Fig. 12.—Downy mildew on wheat. The diseased plants are variously dwarfed; leaves, especially the flag leaf, are yellowish, fleshy, and erect or twisted; heads are distorted; the chaff is fleshy and green; beards are variously deformed; the stem below the head may be thickened and buckled.

cessively and are severely dwarfed; many tillers grow only a few inches tall. These plants rapidly wither, turn brown, and die; they then appear as clumps of closely crowded dead plants. Other plants are variously dwarfed; the leaves of these plants become striped with yellow, or become almost completely yellow, and fleshy. The thickened leaves are twisted, curled, and stiff and they stand erect. The plants rarely produce heads. Still other plants may be only slightly dwarfed; the leaves are somewhat yellowed, thickened, twisted, and erect. Any heads that are produced are distorted and abnormally large; the chaff may be fleshy and green and have a more open appearance than healthy heads. The stems below the affected heads may be thick and deformed. In bearded varieties the beards are distorted and abnormally long. Diseased heads produce no viable grain.

Life History.—The fungus produces resting spores in infected tissues. These spores remain alive in dead tissues of diseased plants for long periods of time. There is little doubt that these spores can live in the soil of infested fields. Decay of diseased tissues liberates the spores. Under high moisture conditions these spores germinate and produce disease in the plants they infect.

Control.—Good farm practices, such as proper surface drainage, sanitation, crop rotation, and soil preparation, help control the disease. Elimination of susceptible grasses along fencerows, ditchbanks, and waterways will eliminate some sources of inoculum. Infested straw should not be used to top-dress wheat. On land where the disease is severe, susceptible crops should not be grown for several years. Grain to be used for seed should be thoroughly cleaned by fanning to remove all fragments of diseased tissues which carry the resting spores; whenever possible, seed should be selected from fields known to be free of the disease.

SPOT BLOTCH

Helminthosporium sativum

This Helminthosporium disease on wheat and other cereals may affect all parts of the plants. Several names have been applied to describe the various symptoms it produces. It appears as seedling blight, crown rot, root rot, spot blotch (leaf spot), node canker, head blight, and black joint. The causative fungus has many physiologic races. Wheat and barley are most susceptible to attack, rye is slightly susceptible, and oats and corn are almost immune. Many wild grasses are susceptible. Wheat may become diseased at any stage of development; most infection above the crown occurs after the plants head.

Because this disease is obscure in nature and difficult of certain diagnosis, its importance has been greatly underestimated in Illinois, as in most other states. Adequate data on its distribution, prevalence from year to year, and destructiveness are lacking, but it is undoubtedly one of the important forms of crown rot and root rot so frequently and seri-

Fig. 13.—Spot blotch on wheat. This disease attacks wheat plants in all stages of growth. It blights seedlings, rots roots and crowns, kills young tillers, discolors the bases and joints of stems, and makes spots on leaves. Plants infected by it appear dwarfed as they approach maturity and they also assume a reddish-brown tint which serves, with other symptoms, to identify the disease. Apparently resident in the soil, this disease typically attacks the plants in circular patches a few feet to several rods in diameter, doing most damage to plants in the centers of the patches and injuring least the plants near the edges of the patches. (Photograph by A. C. Eldredge.)

ously destructive in Illinois wheat fields. It is most destructive in dry weather.

Appearance.—As seedling blight this Helminthosporium disease on wheat, fig. 13, is typically a dry rot. The fungus first attacks the coleoptile of a plant, on which it produces a dark brown or black lesion that progresses inward and may spread into the roots. Badly diseased seedlings fail to emerge because of complete rotting of roots and shoots. Seedlings attacked at or above the ground line may die because the stems rot off; those that do not die are weakened sufficiently to be stunted and they may tiller excessively. Leaves of infected seedlings that survive are dark green and erect; near the soil line dark brown lesions develop which may extend into the leaf blades. Symptoms of seedling blight are similar in wheat, barley, and some other grasses.

The most striking form of this disease is produced by infection of crowns, roots, and basal portions of stems; the infection produces a distinct rotting of the affected parts. It is characterized usually by the occurrence of more or less circular patches of dwarfed, reddish-brown plants scattered throughout a field. The patches of diseased plants vary in diameter from a few feet to several rods. In size and color the plants in these patches are graduated, those in the centers being very much stunted and reddish-brown in color and those at the outer edges nearly normal in size and color. Sometimes plants are attacked by the disease individually or through several feet of a row. Plants that have been dead for some time become covered with saprophytic fungi and have a sooty appearance. The color of these stands out in contrast to the bright color of healthy plants.

A distinct dwarfing of plants is caused by crown rot and root rot infections. The crown rot phase of the disease develops at or below the soil surface. Leaf sheaths and blades, cortical tissues, and crown roots may be infected. Tiller buds may die. Large chocolate-colored spots develop on the leaf sheath and blade of the first leaf of each infected plant. Occasionally, spots develop on the blade of the second leaf. The base of each stem may have numerous rust-brown spots or streaks. As the infected tissues die they become dark brown in color. The type of root and crown rot in older plants is similar to that in seedlings, except that there seems to be less rotting of the stems in older plants.

In the root rot phase of the disease, the roots of an affected plant may be covered with small, irregular brown spots, or the diseased roots may show a general or local browning. Secondary roots often are infected when quite small; the result is a poor root system and weak and spindly plants. When the entire root system of a plant is decayed, the roots are brittle and they tear off at the crown if the plant is pulled.

Plants with root and crown rot infection may reach various stages of development and maturity, depending upon the degree of infection and upon environmental conditions.

When the fungus attacks the joints of wheat, barley, and other grasses, the disease that results is called node canker or node rot. On the joints are brownish-black spots that may enlarge and involve the entire joints. The joints have a velvety appearance when the fungus fruits profusely. The parts between the joints are seldom much discolored, except near the bases of the plants.

The disease on the leaves is called spot blotch or leaf spot. Spot blotch occurs usually after heading and appears as fairly well-defined oval to more or less longitudinal lesions on the green leaves. These spots range in color from light brown to dark brown and they have definite margins. The oldest spots may develop an olive color that is due to the abundant fruiting structures of the fungus. Several spots may coalesce to form blotches that may cause the death of part or all of an affected leaf. Most infection on leaves occurs after plants have headed.

Head blight is the name given to the disease that results if spikelets are attacked by the fungus. If infection occurs soon after a plant heads, the disease causes death of kernels soon after pollination. Later infections produce small, dark brown spots or dark brown blotches on the chaff and kernels. On the kernels the disease is called black point and is characterized by a conspicuous, black discoloration at the base or embryo end of each infected kernel.

Life History.—The fungus that causes spot blotch lives over winter in the soil, in diseased crop refuse, and in wild grasses, on the seed, beneath the seed coat, and on seedling leaves. Seedling blight and crown rot are brought about by infection carried by the seed or by the fungus present in the soil. As soon as the fungus begins to produce spores in the spots on the leaves and joints of a plant, other plants are in danger of infection from these spores. In the spring, the fungus produces immense numbers of spores on diseased wild grasses, straw, and stubble, and these spores infect wheat and barley. Seed infection, which serves to carry the spot blotch fungus directly from one year's crop to the next, is certain to produce seedling and crown infection.

Control.—Seed treatment with mercury compounds, page 151, should result in good stands of vigorous plants. This treatment, of course, does not prevent air-borne infection, which is very important. Clean seed, sanitation, good cultural methods, good fertility of the soil, rotation of crops, and resistant varieties tend to bring the disease under control. The fungus does not thrive so well at 40 degrees to 60 degrees F. as at higher temperatures, a fact that suggests the advisability of late fall planting of winter wheats and barleys and early planting of spring wheats and barleys. Eradication of susceptible wild grasses such as quack grass, green foxtail, bottle-brush grass, windmill grass, branching foxtail, cheat, wild rye, festuca grass, and wild barley reduces the abundance of infective material.

YELLOW LEAF SPOT

Helminthosporium tritici-vulgaris

Yellow leaf spot is a Helminthosporium disease that affects the blades and sheaths of wheat leaves. No host of this disease other than wheat is known. In most years the disease is not severe in Illinois, but in some years and in some fields many wheat leaves are severely spotted and they die prematurely, causing a heavy loss in yield.

Appearance.—Yellow leaf spot, fig. 14, may appear early in the season. At first the spots are yellow brown, but soon they become light brown, bordered by yellow. The young spots are oval to elongated, usually less than one-sixteenth inch long. They are about the same size, shape, and color on both surfaces of a leaf. When the spots are abundant a large part of the leaf may be yellow. If the spots are close together the leaf tissue between them dies. The spots increase in size as the season advances; the dead, brown area of a spot may be one-fourth inch wide and three-fourths inch long and usually it tapers at the ends. The yellow gradually fades to a brownish-straw color. The leaf dies from the tip toward the base. The spots, particularly when they are small, have broader yel-

Fig. 14.—Yellow leaf spot of wheat. Young spots are at first yellow-brown, but they soon become a light brown surrounded by a yellow border. Older spots, typically lens-shaped, are bordered by yellow. Spots are the same size, shape, and color on both surfaces of a leaf.

low borders and lighter brown centers than spots caused by spot blotch, *Helminthosporium sativum.*

Life History.—The life history of the yellow leaf spot fungus is not known. However, like other species of Helminthosporium, the fungus most likely lives over winter both as spores and as a saprophyte on dead wheat leaves. It produces new spores in the spring. If these spores are carried by the wind to wheat leaves, infection may occur. In time the fungus produces spores in the dead spots of the leaves. Once established in a wheat field, the disease will spread through that field if weather conditions are favorable to the fungus.

Control.—Crop rotation, sanitation, good cultural practices, and resistant varieties should help reduce the severity of the disease.

ANTHRACNOSE

Colletotrichum graminicola

The fungus that causes the disease known as anthracnose attacks roots, stems, leaves, heads, and seeds of wheat in Illinois. Also, it attacks oats, rye, barley, timothy, red top, spelt, emmer, corn, and sorghums, including Johnson grass and sudan grass. It is common on orchard grass, quack grass, cheat, and wild barley. The disease has been reported on species of grasses representing 22 genera.

The loss caused by anthracnose varies greatly from year to year, owing to the fact that the prevalence of the disease is greatly influenced by variations in weather. Illinois records extending back to 1922 show that infection of the wheat crop has ranged from as little as a trace to as high as 50 per cent. Owing to the fact that the disease is obscure and not readily recognized, its importance has been underestimated, and much of the damage done by it has been attributed to rust attack.

Appearance.—Anthracnose of wheat, fig. 15, a rather inconspicuous disease, is manifest oftener on the lower half of the plant than on any other part. Following infection, the tissues at the crown and at the bases of the stems become bleached and later turn brown. Purplish to brownish, water-soaked blotches are formed at or near the diseased joints. Toward maturity of the host plant very tiny, elongated, black elevations, each much smaller than a pinhead, appear in great abundance on the stems, on the leaf sheaths, and sometimes on the leaves;

also, they may be found on the chaff and spikes of diseased heads. These tiny elevations are the spore-bearing bodies of the fungus that causes the disease.

In severe infections the presence of anthracnose is made evident by a general reduction in vigor and plant development and by premature ripening or whitening of the infected plants. The blighting of heads that accompanies this disease is not asso-

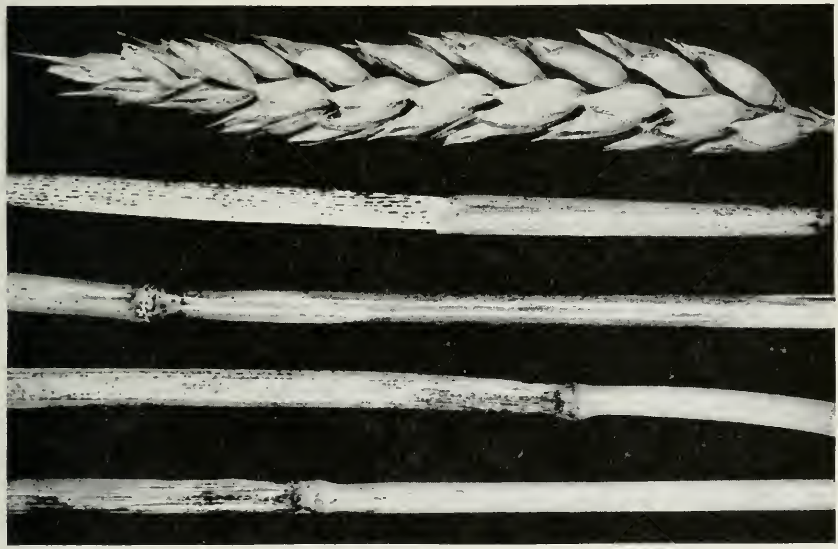

Fig. 15.—Anthracnose on wheat. Discoloration of stem joints is a characteristic of the disease, as is also the presence of black specks on stems, sheaths, and glumes. Severely infected plants ripen prematurely.

ciated with a pink mold, as in the case of scab. Badly affected plants are greatly weakened; the result is shriveled grain, the amount of shriveling depending upon the severity of the attack.

Life History.—The tiny black spots found on various parts of sick plants produce spores which are dispersed by wind and rain to healthy plants. It is thought that infection may occur on any part of a plant. The fungus is able to live as a parasite on living plants and as a saprophyte on dead plant material. It lives through the winter as spores or as mycelium on seed, straw, and stubble of grain, and on wild grasses. Quack grass is very susceptible and is a fruitful source of spores for new infection. Seed-borne infection is thought to be one source of root rot and crown rot.

Control.—While no dependable specific method of control for anthracnose has been worked out, general methods of disease control will do much to reduce losses. These methods include sanitation, crop rotations in which legumes or other nonsusceptible crops are used, improved soil fertility, removal of light kernels by fanning, and seed treatment, page 151. The proper balance of phosphorus and potassium in the soil helps to prevent infection and loss resulting from anthracnose.

ERGOT

Claviceps purpurea

Ergot, a disease that infects the kernels of small grains, is usually found in trace amounts every year on wheat in Illinois. It is much more frequently found attacking rye and is described in detail, pages 136–8, as one of the diseases of that crop. Control measures are seldom necessary for this disease on wheat, but when control is demanded the measures described for the disease when it attacks rye will prove adequate.

TAKE-ALL

Ophiobolus graminis

Take-all, or "white heads," occurs in Illinois, although it is more common in the drier wheat regions of the West. In Australia it is regarded as a very serious disease. Take-all is one of a group of diseases that attack the roots, crowns, and basal stems of cereals and other grasses. Besides infecting wheat, it infects barley, rye, oats, timothy, and redtop and has as wild hosts bluegrass, quack grass, wild barley, cheat, and brome grasses. The loss caused by the disease is hard to evaluate since light to moderate root infection usually is not detected in field surveys. The severity of the crown and basal stem rot phase varies from year to year and in some years is quite high in individual fields.

Appearance.—The symptoms of take-all, fig. 16, vary with weather conditions. Diseased plants usually occur in localized, more or less circular areas up to several feet in diameter or in rows up to several feet long. Under moist conditions the symptoms, as a rule, do not become apparent until about the time wheat is heading. Affected plants are stunted, lose their green color, and rapidly become bleached. Take-all produces a dry rot of roots, crowns, and stem bases. The bases of diseased stems are brown to black; a dark brown to black layer of coarse fungus hyphae can be found on each severely infected stem under the leaf sheath. Severely diseased plants are markedly dwarfed, tiller sparsely, if at all, die prematurely, and are ashen white in color. If a diseased plant reaches maturity, it usually has only one small head, which is barren or which bears shriveled grain. Under dry conditions affected plants are severely dwarfed,

Fig. 16.—Take-all on wheat. This disease causes a dry rot of roots, crowns, and bases of stems. The base of a diseased stem, which is brown to black in color, has a layer of coarse fungus hyphae on the stem beneath the sheath, shown on second stem from left. Plants affected by take-all usually occur in circular areas. Such plants are dwarfed, lose their green color, and rapidly become bleached.

few show the bleached condition, and the layer of fungus hyphae is less prominent.

Brown spots develop on roots during late winter and early summer. These lesions increase in number, and on a badly infected plant the roots, dead and brown by jointing time, break off at the crown if the plant is pulled. Layer roots near the crown branch freely, have a woolly appearance, and appear thicker than healthy roots because they retain soil when pulled. Marked reduction in stooling is characteristic of the disease. At harvest many of the prematurely ripened white heads have a sooty appearance due to growths of saprophytic fungi.

Take-all has some of the symptoms of soil-borne mosaic, such as dwarfing of plants and the patchy appearance of fields in which the disease is present. Mosaic dwarfing, however, shows up very early in the spring. The first indication of take-all is a general yellowing of the plants after they begin rapid growth. A mosaic-infected plant, as it dies, turns brown, droops to the ground, and forms a flat tuft. With take-all, the yellow bleaches out, or a bronze color develops, and dead plants remain erect. In plants infected by soil-borne mosaic no fungus mycelium develops between the leaf sheaths and the stems, no white heads are formed, and maturity occurs a little later than normal.

Life History.—The take-all fungus lives in the soil on diseased, undecomposed straw and roots of its host. Infection occurs when the fungus mycelium grows into the tissues of the roots and crown of a plant. The fungus produces winter spores abundantly in small, black, beaked bodies in the mycelial layer that develops between an infected stem and the leaf sheath surrounding it. These spores live for nearly a year and infect wheat either in the fall or spring. They are rarely found under Illinois conditions. Seeds from diseased plants probably do not carry the fungus, but small pieces of straw, blown by wind, can carry the spore-producing bodies of the fungus considerable distances.

Control.—Straw or stubble is the chief means of carrying the fungus, and sanitation is one of the most important means of control. Eradicating wild grass hosts and volunteer grain decreases the amount of infectious material. Long rotations in which a susceptible crop is used only once in 4 or 5 years serve the same purpose. Varieties of wheat resistant to the disease exist but they are not suitable for Illinois.

Severity of the disease is less if fertility of soil is maintained with a good supply of available phosphorus, potassium, and nitrogen than if the soil is deficient in these plant nutrients. Using clean, vigorous, sound seed will help to prevent severe infestations.

BLACK CHAFF

Xanthomonas translucens undulosum

Black chaff is a bacterial disease that readily attacks both wheat and barley. It also attacks rye, spelt, oats, einkorn, timothy, brome grass, quack grass, and squirrel tail or wild barley. The disease on barley and rye is called bacterial blight. Recently the name, Xanthomonas streak, has been proposed for the disease as it occurs on the cereals and other grasses.

Black chaff was first found in Illinois in 1917, although undoubtedly it was present prior to that time. It occurs in all parts of the state but seldom does an appreciable amount of damage. In most years it is so rare as to pass unnoticed, but during a few recent years it has been abundant enough to cause a slight reduction in yield. Loss caused by the disease in 1946 is estimated to have been equivalent to 2 per cent of the potential wheat crop.

In Illinois field surveys black chaff has been found on as many as 86 per cent of the heads and 30 per cent of the spikelets. The heaviest attack so far recorded occurred in 1951 when an average of 30 per cent of the culms, 11 per cent of the spikelets, and 2 per cent of the joints were infected. This disease probably was imported from Russia.

Appearance.—As the name implies, black chaff, fig. 17, occurs chiefly on the chaff or glumes and can be recognized by longitudinal, dark, more or less sunken stripes or spots, more abundant and noticeable as a rule on the upper than the lower halves of the glumes, where they often coalesce to form larger spots or blotches. The inner parts of the diseased glumes are brown or black spotted, and often the beards of bearded varieties are brownish, especially at the bases. In moist weather tiny, yellow beads of bacteria ooze to the surface of the black lesions and, upon drying, appear as minute, yellow scales.

The leaves, sheaths, stems, and kernels of wheat, as well as the glumes, are sometimes affected by the bacterium that causes black chaff. On the leaves and sheaths, bacteria produce small, water-soaked areas which elongate to produce olive-green streaks. With age the streaks turn yellowish-brown and later

Fig. 17.—Black chaff on wheat. Bacteria invading the tissues of glumes produce dark, sunken streaks on the upper parts of the glumes. Usually similar streaks are found on the stems below the heads and upper joints, and elongated, olive-green streaks occur on the leaves.

become black. Under humid conditions they may be covered with whitish or yellowish scales of dried bacteria. On the stems the bacteria produce brownish to black stripes as the crop reaches maturity. These stripes usually occur on the stems below the heads and the upper joints.

Kernels that are badly diseased are shrunken and, especially at their bases, have a honeycombed appearance due to minute pockets of bacteria. When the disease appears early and is severe, infected heads are dwarfed, spikelets fail to develop, beards are twisted and discolored, and the spikes are badly blackened.

Not all black streaks on the glumes and stems of wheat plants are caused by the black chaff organism.

Life History.—The method of reproduction of a bacterium is described on page 4. The black chaff organism follows this method and in dry storage is able to remain alive on kernels and in diseased tissue for at least 2 years. The bacteria can withstand alternate freezing and thawing for 124 days. They are carried over winter on the seed, chaff, and other infected plant material, including brome grass, a perennial. Also, they may live over winter in the soil. It is not impossible for the bacteria overwintering on perennial grasses to spread to the cereals.

Control.—Since the disease-producing organism may be carried over winter on the seed, use of clean seed or seed treatment is recommended, especially after a year of severe attack. Severely diseased kernels are honeycombed with bacterial pockets. Thorough fanning, by removing light kernels, will discard many of the honeycombed kernels that carry infection. Surface-borne bacteria can be killed if the seed is treated with organic mercury compounds, page 151. Sanitation and crop rotation will help control the disease. Seed treatment for this disease alone is not recommended in Illinois, unless the disease becomes more severe than at present.

BASAL GLUME ROT

Pseudomonas atrofaciens

Basal glume rot is a bacterial disease that attacks chiefly the chaff and grain of wheat. The disease has been found on barley in southern Illinois. On either wheat or barley it is of only minor importance in Illinois. The average loss in wheat, as estimated from observations made in Illinois fields over a long period of years, amounts to about 0.1 per cent of the crop, but in 1938 and 1949 an estimated 0.5 per cent reduction in yield was caused by the disease.

Fig. 18.—Basal glume rot on wheat. Bacterial infection discolors and rots the bases of glumes. Bases of kernels from diseased spikelets, upper row, are discolored and shriveled.

Appearance.—The outstanding symptom of basal glume rot on wheat, fig. 18, is a dull brownish-black, discolored area found at the base of each of the glumes covering a kernel. The discoloration is more pronounced on the inside than on the outside of the diseased glume. Usually less than the lower third of the glume is discolored, but sometimes the entire glume is darkened. Severely infected spikelets are often slightly dwarfed and lighter in color than healthy ones. The only sign of disease on many heads is to be found on the inside of the chaff, as a dark line at the attachment of the glume to the spike. The base of a diseased kernel shows a discoloration varying from faint brown to charcoal black, the color depending upon the severity of the attack. Leaves affected by this disease show small, dark, water-soaked spots. These spots tend to enlarge and elongate and turn first yellow and finally brown as the tissue dies.

Life History.—Since basal glume rot occurs in very close association with the developing grain, it no doubt is carried over from year to year on infected seed. Infected chaff and leaf fragments, blown abroad at threshing time or returned to the field as fertilizer, also serve to perpetuate the disease.

Control.—Proved control measures are wanting, but the recommendations given on page 57 for black chaff should aid in controlling basal glume rot.

SOIL-BORNE MOSAIC

Marmor tritici

Soil-borne mosaic differs from most other diseases attacking cereals in that it is not caused by a fungus or bacterium but by a virus. This disease was discovered in the spring of 1919 in Madison County, Illinois, and later spread to 44 counties of the state. It is known to occur as far north as Putnam and Mercer counties and as far south as Randolph and Wabash counties.

There are at least two strains of the virus and both usually occur together in naturally infested soils; one causes yellow mosaic and the other green mosaic. Mosaic infestations in Illinois have been so serious under some conditions that practically the entire crop of a susceptible variety has been destroyed. However, the over-all loss caused by mosaic is not important.

Soil-borne mosaic occurs on fall-sown rye, barley, emmer, and spelt, as well as on wheat and on a few closely related wild grasses, including a wild annual brome grass.

Appearance.—Soil-borne mosaic, fig. 19, can be detected early in the spring by the presence of light green to yellow patches of plants in the fields. Badly diseased fields are patchy or uneven in appearance; patches vary from small areas occupied by a few plants to areas 50 feet or more in diameter.

The most noticeable signs of yellow mosaic appear when plants begin rapid growth in the spring. However, under certain environmental conditions, symptoms may show on the leaves in the previous fall. When new leaves of diseased plants

Fig. 19.—Soil-borne mosaic on wheat. Infection of wheat plants by this virus results in dwarfing of plants and mottling of leaves. The mottling consists of light green or pale yellowish stripes or blotches which tend to run parallel with the long axis of a leaf.

unfold they appear mottled yellow or light green. The mottling consists of irregular stripes or blotches which vary in size and tend to run parallel with the length of the leaf. The mottling may vary in color from a very light green to a decided pale yellow. Mottling may be found on the sheaths and chaff, also. It is usually less pronounced as the wheat nears maturity. In addition to mottling of leaves the disease causes dwarfing in varying degrees, but rosettes do not develop as in green mosaic.

Plants affected by green mosaic are short and dwarfed and they produce new tillers excessively. The tillers remain short, forming a rosette and giving the plant a bunchy appearance. Leaves of these plants develop a light green, mosaic mottling, which may later be masked by the intense green developed in the leaves. This intense green causes the leaves to have a bluish-green color, which may be retained until maturity. Many plants which are rosetted die prematurely and may be blown away. The amount of mottling, dwarfing, and rosetting caused by green mosaic varies greatly and depends on the susceptibility of the variety of wheat, the amount of virus in the soil, and the seasonal growing conditions.

There are other causes of mottled leaves and patchy, uneven growth of plants in fields. Some of these causes are nutrient deficiencies, uneven distribution of fertilizers, wet spots in the fields, winter injury, and other diseases. In the case of nutrition deficiencies there is usually a gradual increase in the amount of mottling from the flag leaf down, and the light-colored flecks do not tend to follow the long axis of the leaf; the lower leaves may show very little green, in which case the pattern is similar to that of severe mosaic, but the color is usually orange yellow, while in mosaic it is a lemon or faded yellow.

Mottling due to mosaic can usually be distinguished from that caused by other factors if large numbers of plants are examined. If mosaic is present, the young, unfolding leaves should show typical symptoms described above.

Life History.—So little is known concerning mosaic diseases and viruses that no life history can be given. The infective principle is found in the juice of the plant. The virus lives over from year to year in the soil and is able to persist in gumbo soil for 6 years or more. It is not known whether it lives in the organic material or adheres to fine particles of the soil. Sandy soils do not retain the virus as long as silts.

It is known that the occurrence of the disease depends upon the weather of fall and winter, which influences growth and dormancy of the plants. Neither winter nor spring wheat sown in the spring in infected soil shows signs of the disease, but either one sown in the fall may develop the infection. The virus is not seed borne.

Control.—The best method of preventing loss from mosaic is through the use of immune or resistant varieties of grain. Some varieties of soft wheat have been developed that are resistant to mosaic. There are a few varieties of hard wheat adapted to north central Illinois that have satisfactory resistance. Crop rotation will not successfully control the disease.

YELLOW DWARF

Virus (unnamed)

Yellow dwarf is a virus disease. The causative virus attacks wheat, oats, barley, rye, and a number of wild grasses. The disease probably is present every year in Illinois wheat fields. In 1959 it caused characteristic dwarfing, premature dying, and reduction in yield in many wheat fields in the southern half of the state. Wheat plants are susceptible to attack by this virus in all stages of their development. Vectors and hosts of yellow dwarf are discussed on pages 89–91.

Appearance.—New growth of wheat plants infected in the seedling stage is chlorotic or yellowish in color; the outer leaves of these plants are darker green than those of healthy plants and they are smaller. The entire plants gradually become chlorotic as they reach maturity. Diseased plants may be severely dwarfed; they tiller sparsely and produce few heads, these with little or no seed.

Plants that become infected after the tillering stage are not dwarfed or are only slightly dwarfed. The newly formed leaves are bright yellow; the yellowing begins at the tips of leaves. The tissue adjoining veins in the yellow areas retains its green color for some time. In yellow dwarf there is no mottling of leaves, as in the soil-borne mosaic disease.

Life History.—The virus that causes yellow dwarf on wheat has a life history similar to that described on page 91.

Control.—No effective measures are known for the control of yellow dwarf on wheat. Resistant or tolerant varieties of wheat should be grown when they become available.

STREAK MOSAIC

Marmor virgatum

Streak mosaic of wheat has not been found in Illinois. Its vector, the four-legged, cigar-shaped, wheat curl mite, *Aceria tulipae* (Keifer), almost microscopic in size, has been found in a small area of the state. The disease is severe in some of the Great Plains states. In Kansas, it is most abundant in the western half of the state. Symptoms of the disease are apparent in the leaves and the entire plant. Although most infection occurs in the fall, the characteristic yellowish streaking and mottling of leaves usually are first observed after the arrival of warm spring weather. If the weather continues warm, these leaf symptoms become more pronounced, the leaves become yellow, and plants are stunted. As plants approach maturity the mottling disappears; the leaves tend to turn brown and die. Streak mosaic is most severe in warm, dry weather. Growers finding plants suspected of suffering from this disease should send them to the Illinois Natural History Survey at Urbana for diagnosis.

NEMATODE DISEASE

Anguina tritici

Nematode disease is caused not by a parasitic fungus but by a tiny, wormlike animal known technically as a nematode but usually called an eelworm. This small animal often attacks wheat and rye, emmer and spelt less frequently, and oats, barley, and wild grasses seldom.

Only a few reports of the nematode disease are recorded for Illinois, and the disease is not important here. However, it is widely distributed in southern states. Seed imported from infested states should be thoroughly examined for the presence of the galls that are the signs of infestation in the grain.

Appearance.—Plants affected by nematodes can be detected in the seedling stage by their rolled, wrinkled, twisted, or otherwise distorted leaves, fig. 20. Young leaves usually buckle within the tightly closed sheaths of the older leaves. One or more of the stems of a plant may show these symptoms. Diseased plants are stunted and enlarged near the bases, and the heads, which are small, retain their green color longer and have a more open appearance than healthy heads. Openness of the heads, somewhat like that in stinking smut, is caused by galls that extend the chaff. Each of these galls is a kernel that has been invaded by

Fig. 20.—Nematode disease on wheat. Wheat seedling infected with the nematode disease. The wrinkling, rolling, and twisting of the leaves are characteristic of this disease. (Photograph from U. S. Department of Agriculture.)

nematodes. The disease can be detected in threshed grain by the presence of galls, hard and dark brown or black in mature grain. The galls are often mistaken for cockle seed, smut balls, or other impurities. They can be distinguished from smut balls, as they are hard, are not filled with a black powder, and do not have a fishy odor.

Life History.—Thousands of the tiny, eel-like nematodes exist in a dried-out, dormant state in a single mature gall. Many of the galls shatter out in harvesting, but some remain intact and later may be sown with the seed. When a gall is buried in the ground it decays, liberating the multitude of small eelworms within it. These migrate short distances through the soil, in which they may live for several months.

If the eelworms encounter suitable host seedlings, they enter them near the growing points and migrate upward as the plants elongate. When the head of a plant begins to form, the worms enter the young flower. The female worms lay eggs in the young kernel. As the infected kernel grows, it develops into a round, hard, dark gall filled with young nematodes; the nematodes become dormant as the plant matures. Nematodes have been known to remain alive for 14 years or more in stored grain.

Control.—The nematode disease is easily controlled by using clean seed and sowing it on uninfested soil. A crop rotation that keeps susceptible crops off infested land for 3 years will starve out nematodes. Usually the worms can live in the soil but 1 year without their host plant. If galls are found in seed wheat, it is advisable to eliminate them or to obtain new seed free of the galls. The galls can be destroyed by the hot-water seed treatment. Or they can be removed by thorough fanning or by the brine treatment, page 147.

3

Oat Diseases

OATS IN ILLINOIS are attacked by 25 recognized diseases. Some of these diseases, while not important now, may become important, as they have occurred with increasing frequency in recent years. Both winter and spring varieties of oats are grown in the state. Winter varieties do not possess enough hardiness to be sown successfully in the fall except in the southern fourth of the state.

In the past 20 years the widespread and commonly destructive diseases of oats in Illinois caused an estimated annual reduction in potential yield of 9 per cent. In a 4-year period, 1950–1953, when oats outranked the other small grains in Illinois in acres planted, in production, and in money value, this reduction amounted to an annual loss of over 13,042,000 bushels valued at $102,645,750. Blast, a noninfectious disease, caused a further loss by making an average of 20 per cent of the spikelets sterile.

The recently developed hybrid oats possess considerable resistance to some diseases which were important on the older varieties. However, they are more susceptible to other diseases.

The descriptions in table 2 and on the following pages deal mainly with oat diseases that are common and widespread in Illinois. A few diseases presently local in occurrence are included because of the importance they may acquire in the future.

Table 2.—Infectious diseases of oats, with brief descriptions of the symptoms produced on leaf, head, stem, entire plant, and seedling. Each page number is a reference to a discussion of the disease mentioned.

Disease	Symptoms	Page
	Leaf	
Crown rust	Small, oval, orange-yellow, elevated pustules	68
Stem rust	Elongated, brick-red, ragged-edged pustules	71
Septoria black stem	Round to elliptical, chocolate-brown spots with black pimples; grayish brown spots on sheath, stem usually discolored under these spots	76
Helminthosporium leaf blotch	Spots reddish-brown, long and narrow or broad and irregular; sometimes margins indefinite	80
Anthracnose	Spots reddish-brown, elongated, often lens shaped; elongated, black, elevated specks in dead areas	84

Halo blight	Spots oval and with gray or brown centers and clear or yellowish halos	87
Stripe blight	Stripes of various lengths, some with yellowish margins; old stripes translucent rusty brown	89
Downy mildew	Leaves fleshy, upright, stiff; flag leaf sometimes curled or twisted about a deformed head	85
Powdery mildew	Delicate, whitish mold on upper surfaces of leaves	87
Yellow dwarf	Leaves with various shades of yellow-red, scarlet, orange, red, or reddish brown; the orange or reddish color finally involving entire blades; the number of red leaves varying with stage of development when plant becomes infected; some plants dwarfed	89
	HEAD	
Loose smut	Grain and chaff transformed to a sooty powder	72
Covered smut	Grain and chaff transformed to a black powder; each affected spikelet enclosed in a delicate, white membrane	74
Stem rust	Elongated, brick-red, ragged pustules	71
Crown rust	Small, oval, elevated, orange-yellow pustules	68
Anthracnose	Spikelets bleached, prematurely ripe; small, elongated, black elevations in dead areas	84
Scab	Spikelets bleached, prematurely ripe; hulls of seed ashen gray, sometimes covered with pinkish mold	78
Blast	Spikelets small, delicate, paper white, blasted	92
Septoria black stem	Dark discoloration on chaff, pedicel, and hull	76
Downy mildew	Heads variously deformed, distorted; leaves stiff, upright	85
Halo blight	Small spots on chaff, each spot with yellow halo, or chaff with translucent tissue between veins	87
Ergot	Each affected seed replaced by a dark, plump, hard body	87
	STEM	
Stem rust	Elongated, brick-red, ragged pustules	71
Crown rust	Small, oval, elevated, orange-yellow pustules	68
Septoria black stem	Dark brown blotches on one or more joints, sometimes girdling joints; black pimples in spots; grayish brown to black discoloration on stem under spots on sheath	76
Anthracnose	Dark, discolored lower joints with small, elongated, black, elevated fruiting bodies; base of stem bleached, later turning brown, covered with fruiting bodies	84
Victoria blight	Basal part of stem developing translucent brownish color; lower leaves and joints with velvety black appearance	82
	ENTIRE PLANT	
Yellow dwarf	Plants variously dwarfed; some heads severely blasted; leaves various shades of red or yellow; field sometimes patchy in appearance	89
Blue dwarf	Plants dwarfed, uniformly dark bluish green, and long-lived; leaves usually short and rigid	91

Anthracnose	Plants prematurely ripe; basal portions at first bleached and then brown, covered with tiny, black, elevated fruiting bodies	84
Downy mildew	Plants usually dwarfed; heads distorted; leaves short, fleshy, stiff, and remaining upright; severely dwarfed plants tiller excessively and may die prematurely	85
Victoria blight	Plants prematurely ripe; bases brownish, translucent; lower joints and leaves with velvety brown appearance	82
	SEEDLING	
Scab	Plants stunted, yellowish; roots rotted, reddish-brown	78
Victoria blight	Leaves dull bluish-gray, with narrow, reddish-brown stripes running length of blades; hulls of seeds sometimes velvety black	82
Helminthosporium leaf blotch	Irregular to oval, reddish-brown spots on leaves	80

CROWN RUST

Puccinia coronata

Crown rust of oats corresponds to the leaf rusts of wheat, barley, and rye and is often called oat leaf rust. The name crown rust is of scientific origin. It was used to designate the oat leaf rust fungus because of a crown, visible under the microscope, on the tip of the overwintering spore. Numerous wild grasses closely related to oats are attacked by the various races of this fungus, but no cereal crop other than oats is affected. This rust fungus exhibits very strong host preferences, and over 180 specialized races have been recognized, some local and others general in distribution.

Crown rust is present on the Illinois oat crop every year and, like all other epiphytotic diseases, varies from year to year both in prevalence and in the intensity of its attack, fig. 21. In years favorable to the rust 90 to 100 per cent of the plants in the oat fields of the state become diseased, and the presence of the rust in the leaves reduces their effective food-manufacturing area by 16 to 30 per cent. In years unfavorable to the rust as few as 3 per cent of the oat plants become infected, with an accompanying reduction in effective leaf area of 0.04 per cent. The average annual prevalence of crown rust in Illinois, based on 25 years of data, is 74 per cent, and the average reduction in leaf area is about 11 per cent. During this period reductions in yield have ranged from a trace in some years to 20 per cent of the potential yield in others; in a year of heavy rust attack, the loss may be equivalent to 27,263,000 bushels, having a market value of $16,900,000.

Appearance.—In some years the first infections of crown rust, fig. 22, may occur as early as the latter part of April in southern Illinois. They are seen as small, scattered, oval, elevated, orange-yellow blisters on the blades. When these blisters break open, they appear as pustules surrounded by the leaf epidermis. As the season progresses, the pustules become more numerous. Most of the pustules are found on the leaf blades, but some occur on the sheaths, the stems, and the chaff. They contain the summer spores, which are responsible for spreading the disease during the remainder of the growing period. As oats mature, the winter, or black spore, stage of the rust is formed.

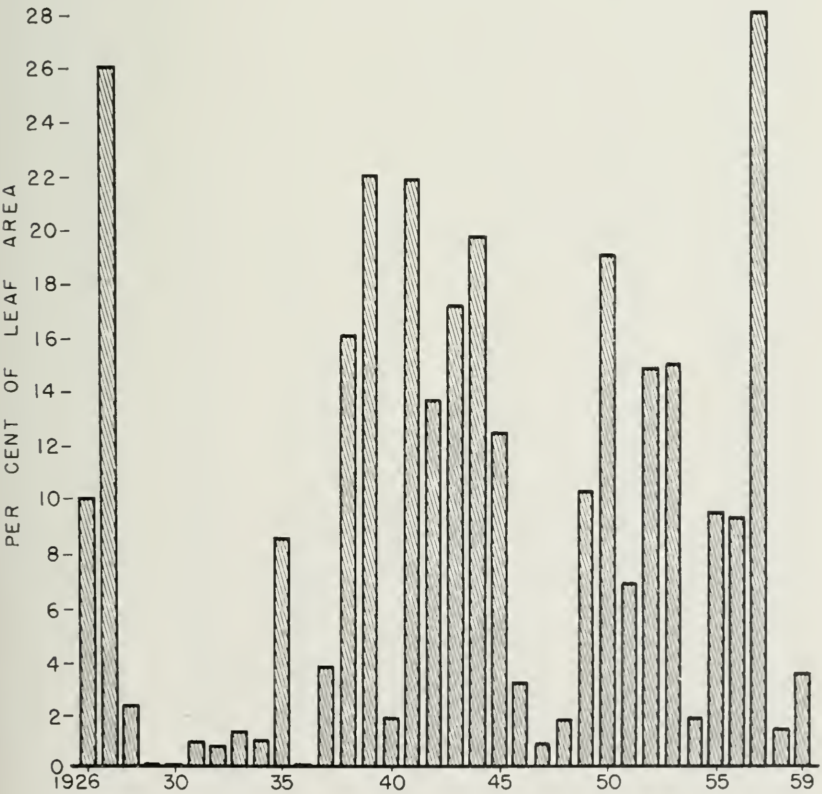

Fig. 21.—Per cent of leaf area occupied by crown rust of oats in Illinois fields, 1926–1959. The rust varies from year to year in the amount of functional leaf tissue it destroys.

Most of the winter spores form in small, oblong, raised, grayish-black to black, covered pustules, but some may form around the summer spore pustules. The winter spore pustules are most abundant on the leaf sheaths.

Life History.—In many respects, the life cycle of crown rust is similar to that of stem rust. The summer spores spread the disease from plant to plant and from field to field. Following infection a new crop of summer spores can be produced in 7 to 14 days, depending upon weather conditions; the reproductive proc-

Fig. 22.—Crown rust of oats. The dark spots scattered over the leaves, between the veins, are oblong rust pustules. These contain the orange-yellow summer spores by which the disease is spread. Crown rust pustules are most abundant on the leaf blade but may occur on the sheath, the stem, and the chaff.

ess is repeated throughout the growing season. As oats approach maturity the crown rust fungus produces its winter spores. These do not germinate until spring; at that time they produce still smaller spores, which may be carried by the wind to nearby buckthorn bushes. If infection of a buckthorn leaf occurs, cluster cups are formed and in them are produced spores, which in turn are carried by the wind to oats or susceptible wild grasses. When oats or other grasses are infected, summer spores are formed in pustules on the leaves, and a new season's epiphytotic is begun. In warm regions the summer spores survive the winter and start the new season's infection, in which case the rust does not need the buckthorn as a bridging host. Summer spores produced on oats in the southern states are carried northward on the wind; some of them fall on oats in Illinois and produce new infections as soon as favorable weather occurs.

Control.—The removal of buckthorn bushes, both cultivated and wild, in the vicinity of oat fields helps to prevent repeated heavy local infection and the formation of new races of the crown rust fungus. Nevertheless, infection by wind-borne spores from the south is certain to occur under Illinois conditions. The use of early oats that mature before the rust has had a chance to increase to epiphytotic proportions is an excellent means of reducing loss; early sowing of late varieties serves the same purpose. Resistant varieties of oats are very helpful in reducing losses by crown rust.

STEM RUST

Puccinia graminis avenae

Stem rust of oats is caused by a variety of the stem rust fungus that cannot attack any of the other small grains. This variety is able, however, to attack wild oats, orchard grass, and meadow fescue. There are at least 14 special races of stem rust of oats. This disease is not a limiting factor in oat production in Illinois.

The severity of stem rust in this state varies from year to year. In years favorable to rust, 68 to 86 per cent of the plants in oat fields of the state become infected, and 1 to 43 per cent of the stem areas are occupied by rust pustules. The reduction in oat yield due to rust is generally slight, ranging from a trace to 2 per cent. The estimated annual loss due to stem rust over a period of 30 continuous years is 1 per cent. In years of severe rust infection, plants ripen prematurely and lodge to such an extent that considerable loss results. In 1926, for example, a loss estimated at 16 per cent of the potential yield occurred from stem rust of oats.

Appearance.—The symptoms of stem rust of oats are identical with those of stem rust of wheat, page 19.

Life History.—The life history of stem rust of oats is similar to the life history of stem rust of wheat, page 20. Because of the lateness of oats, common barberry, the alternate host, is less important with oats than with wheat. Each year, stem rust infection in Illinois originates largely from spores of the red rust stage blown northward from infected fields in southern states. The infection increases during the growing season through the continuous production of spores of this stage.

Control.—Measures for control of stem rust, page 22, include eradication of the common barberry, to prevent local epiphytotics, and the planting of resistant and early-maturing varieties of grain.

LOOSE SMUT

Ustilago avenae

Loose smut of oats is sometimes called naked smut or black head. It is the most conspicuous disease present in Illinois oat fields and one of the most important ones. The causative fungus attacks no other cereal crop. Oat varieties differ in susceptibility to it. In individual fields loose smut infection may be so heavy that over 25 per cent of the plants are smutted. Usually, however, the degree of infection is much less than this. For Illinois as a whole in recent years 0.6 to 4 per cent of the heads have been infected. Data for 15 years indicate an average annual infection of 2 per cent of the heads.

Appearance.—As an oat head infected with loose smut emerges from its enclosing sheath, it presents a brownish-black mass of powder which has replaced the chaff and grain of each spikelet, fig. 23. The smut masses of each spikelet may be surrounded by a delicate, white membrane, but this soon breaks and liberates the sooty powder, each grain of which is a fungus spore. Diseased panicles do not spread as much as healthy heads heavy with developing grain. Usually all the heads on an infected plant are smutted, but sometimes one or two are normal. Generally, too, all the spikelets of a panicle are diseased, but occasionally the upper ones appear healthy. Diseased plants cannot be told from healthy ones before heading out; they are often overlooked at harvest because they are shorter than healthy plants and by that time have lost their black masses of spores.

Life History.—The spores produced by the loose smut fungus on diseased heads are dispersed chiefly by the wind. Many

Fig. 23.—Loose smut of oats. Loose smut is conspicuous when oat plants are heading. Usually the spikelets of a diseased head are entirely transformed into a mass of black powder, which consists of spores by which the smut fungus is spread. By harvest most of the spores have been shattered off, and a bare spike remains.

of them lodge on healthy heads, either on the chaff or between the chaff and the young kernels. Some of these spores germinate immediately, growing into the hulls or into the seed coats of the kernels and remaining inactive there until the seed is sown the following year. Other spores do not germinate immediately but remain on the seed, in the grooves or between the kernels and the hulls, until the seed is sown. In any case, after the oats are sown, the fungus grows into and infects the young oat shoots before they are very old. The young plants are not susceptible to infection after their first leaves have emerged three-eighths inch beyond their sheaths. In an infected plant the smut fungus grows up with the growing tip and by heading time has replaced the oat spikelets with black masses of spores. These in turn, when shed, lodge on the grain of healthy heads and, when the grain is sown, infect the seedlings.

Control.—Loose smut can be satisfactorily controlled by treating the seed with volatile fungicidal compounds, page 151. Seed treatment is recommended even if no smut has been observed in the previous crop. Smut-resistant varieties of oats should be grown.

Sowing oats in a well-prepared seedbed helps the young plants to reach quickly the stage of nonsusceptibility. A warm, wet soil greatly inhibits growth of the fungus.

COVERED SMUT

Ustilago kolleri

Covered smut is so similar to loose smut that to distinguish between the two as they occur in oat fields is often very difficult. Certain identification usually requires microscopic examination of the spores. Covered smut probably is as abundant as loose smut in Illinois oat fields. Because of the difficulty in distinguishing between the two, there is no doubt that some of the losses attributed to loose smut are due to covered smut. An evaluation of the prevalence of the two smuts in Illinois has been attempted each year since 1938. For the state as a whole, infection of oats by covered smut has ranged from a trace to 3 per cent of the heads. Data for 15 years show an annual infection of slightly more than 1 per cent of the heads.

Appearance.—Although it eventually may become very similar to loose smut, covered smut, fig. 24, often can be clearly distinguished early in the season. Except that diseased heads do not spread widely, those infected with covered smut appear almost normal when they emerge from the boots. The chaff, not greatly affected at this stage, retains within it the grains that have been transformed into smut masses. As the oat plants mature, the chaff dries and tends to disintegrate, exposing the transformed kernels, each encased in a thin, grayish-white, persistent membrane. This membrane, unless broken by accident, continues to cover the kernels until harvest, thus giving the disease its name.

Life History.—The covered smut spores produced on oat heads are scattered by the wind or by harvesting operations. Some of the spores that alight on an uninfected head lodge between a kernel and its hull and, under conditions favorable to

Fig. 24.—Covered smut of oats. Each affected oat kernel is transformed into a mass of black powder, enclosed in a delicate, white, persistent membrane; the glumes remain more or less intact until the oat crop is nearly mature.

the fungus, germinate and produce a mass of mold growth (mycelium) over the surface of the seed coat. Other spores lodge on the outer surface of the hull, where they remain dormant until after the seed is sown. When a seed carrying these spores on the hull germinates, the fungus spores germinate and produce a mycelium. This mycelium, as well as that produced on the seed coat beneath the hull, grows into the young seedling, keeps pace with the growing plant, and, when the head forms a mass of black spores, replaces the kernels. Spores germinate readily in a moist soil between 60 and 75 degrees F.

SEPTORIA BLACK STEM

Leptosphaeria avenaria

Septoria black stem of oats, formerly called speckled blotch or Septoria leaf blotch, was first observed in September, 1921, in Wisconsin as a leaf spot on volunteer oats. It was found in 1945 in northern Illinois. It is observed more frequently as a leaf spot than as a stem disease. It is one of the most destructive diseases of oats in the northern third of the state. The causal fungus attacks oats and some closely related grasses but no other cultivated grain. It affects the leaves, stems, joints, spikelets, and kernels. As many as 93 per cent of the leaves and 31 per cent of the joints were affected by the disease in one Illinois field examined in a recent year. Almost 20 per cent of the leaf area was dead. In this field the black stem phase of the disease also was severe and had killed many of the stems above the top joints and caused severe lodging. The disease has been found as a leaf spot as far south as Wayne County, in the southern third of the state.

Appearance.—On the leaf blades Septoria black stem, fig. 25, produces round to elliptical, chocolate-brown spots. These are very small at first but may become one-half inch or more in length. Spots may coalesce, but the dark brown, oval center usually remains recognizable. Small, black fruiting bodies of the fungus are scattered over the spots. Presence of these fruiting bodies aids in recognizing the disease. Infection at the base of a blade often spreads into the adjoining leaf sheath and becomes dark chocolate, grayish-brown, or reddish-brown in color. The fruiting bodies in the sheath are often lighter in color than those on the blade. They sometimes have a pinkish color due to the mass of spores that have exuded from them. Sometimes infec-

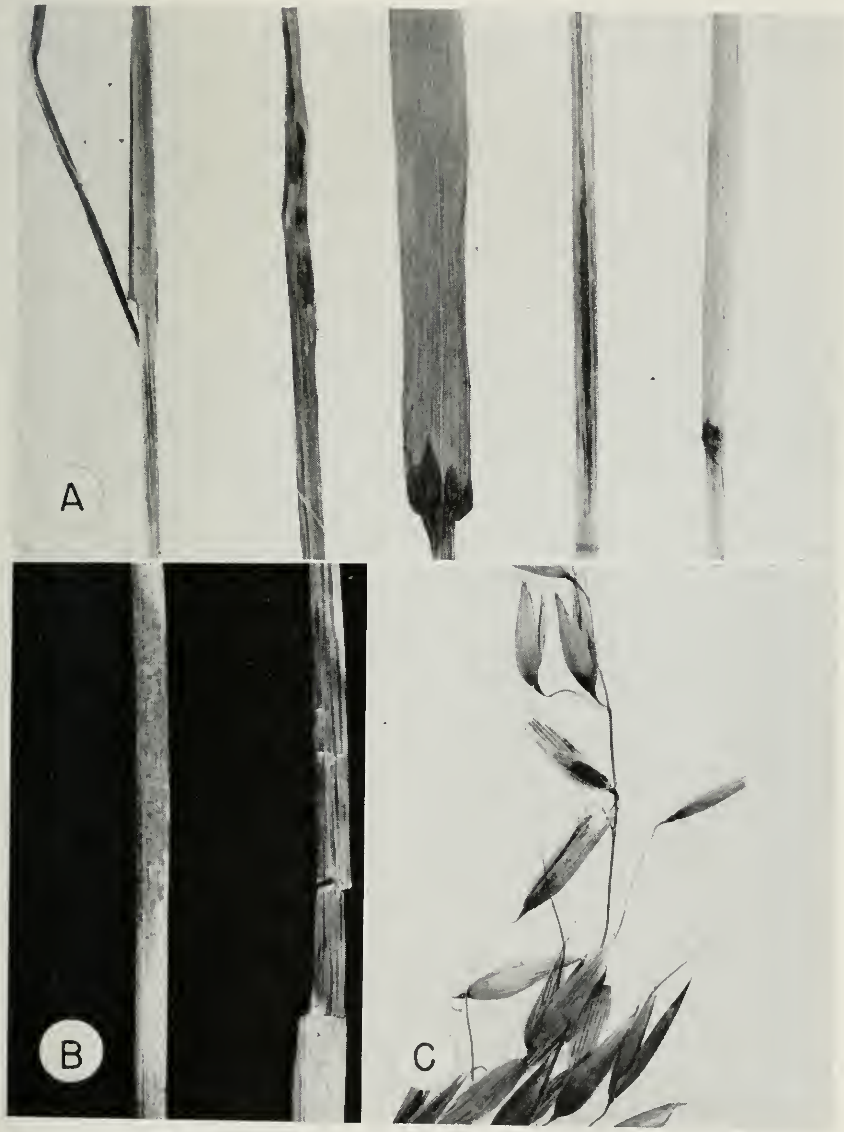

Fig. 25.—Septoria black stem on oats. The disease attacks the leaves, sheaths, joints, stems, and heads. The oval to elliptical dark spots on a leaf blade, *A*, and the dark blotch at the base of a leaf, *A*, and extending into the sheath are produced by the fungus. Infection of the node is shown on the stem at extreme right, *A*, and infection of the sheath on the stem to the left of it. Sheath infections, *B*, are usually lighter brown than infections on leaves. The black stem phase of the disease is shown by the stem at right, *B*. Infection on glumes and hulls appears as dark discolorations, *C*. Light brown to black pimples may be in the spots on leaves, sheaths, nodes, and glumes.

tion occurs on the sheath. The color of these spots is grayish-brown.

The black stem phase of this disease occurs most commonly on the stems beneath infected leaf sheaths. It may be seen as grayish-brown to shiny black lesions on the stems, mostly above the upper two joints. If stem infection is severe, the heads ripen prematurely, and severe breaking of stems occurs as the plants reach maturity. Infection at the joints appears as dark brown blotches, which may girdle the joints. Fruiting bodies are visible in the blotches. In years of severe infection, the head, chaff, and seed are infected.

Life History.—The fungus causing Septoria black stem lives from one year to another as spores in the black fruiting bodies and as mycelium in dead oat tissue. It produces two kinds of spores, summer spores and winter spores, both kinds on oat leaves. Plants are susceptible to infection in all stages of development. After a leaf becomes infected, a new crop of spores develops in about 16 days under conditions favorable to the fungus. This reproductive process can continue as long as the temperature is conducive to spore development or until the crop nears maturity.

Control.—Little attention has been given to the control of Septoria black stem. Sanitation, crop rotation, thorough fanning of seed, and seed treatment are recommended to help hold the disease in check. Infection on the seed usually has no effect on the germination of the seed, but it reduces seedling emergence. Manure containing infected straw should not be applied to a field that is to be planted to oats. Resistant varieties of oats offer the best means of preventing losses by this disease and should be used in areas where the disease is severe.

SCAB

Gibberella zeae

The scab disease that affects oats is identical with the one that affects wheat, barley, and rye; oats are the least susceptible of the cereal crops. The disease affects the seedlings as they emerge from the soil; it affects the joints and the heads as the plants mature. On seedlings the disease is often known as Fusarium blight.

Scab is generally more prevalent in the northern half of Illinois than in the southern half. Field surveys show that it has been much more destructive of oats since 1938 than in the period 1922–1937. In an average recent year 9 per cent of the oat heads and 0.4 per cent of the spikelets are infected. The percentage of plants that are infected is usually low and there are usually not more than two diseased spikelets per head. However, 46 per cent of the plants and 3 per cent of the spikelets have been found infected in a field.

In 1958, the worst scab year in Illinois, according to Natural History Survey records, 19 per cent of the heads and slightly

Fig. 26.—Scab on oats. The white spikelets shown above are diseased; the darker ones are healthy.

more than 1 per cent of the spikelets were diseased. Scab was so abundant in some fields in northern Illinois that hogs refused to eat the oats produced.

Appearance.—The symptoms of scab on oats, fig. 26, are in general the same as on wheat. The disease is not, however, as readily detected on oats as it is on wheat, because the oat kernel is covered by a hull. The hulls of infected spikelets are ashen gray and may be partially covered by a pink mold; in severe cases they are shriveled and rough in appearance. The hulls do not turn brown. Seedlings from infected seed are stunted, and many of them turn yellow and die. If seed is heavily infested, the young plants may be killed below the surface of the ground. Roots of scab-infected seedlings are apt to be rotted and to be reddish-brown in color; late in the season they may be covered by the pink mold characteristic of the disease. Sometimes the scab fungus attacks a joint; the portion of the plant above the infection dies and turns white. Often the purplish-black fruiting bodies of the fungus form on the surface of the affected joint.

Life History.—On oats the scab fungus has a life history that is identical with that given on page 39.

Control.—Control measures given under the discussion of scab as it occurs on wheat, page 40, are applicable to scab on oats. In fields where old cornstalks are abundant on the surface of the ground, scab of oats is usually much more prevalent than in fields where the stalks have been plowed under.

HELMINTHOSPORIUM LEAF BLOTCH

Helminthosporium avenae

The Helminthosporium leaf blotch or leaf spot is one of several leaf spots important on oats in Illinois. Oats are the only cereal the causative fungus attacks; both leaves and seed may become diseased. Diseased plants, because of the destruction of leaf tissue, are handicapped in the manufacture of food substances, and the reduction in food results in light or shriveled kernels, as does also direct attack of the fungus on the kernels. Helminthosporium leaf spot is present every year in Illinois oat fields, but usually the loss due to it is slight. In this state the disease has been light in recent years. It fluctuates from year to year both in prevalence and in severity. In Illinois fields as few as 13 per cent of the plants in one year and as many as 89 per cent in another have been infected; the corresponding destruc-

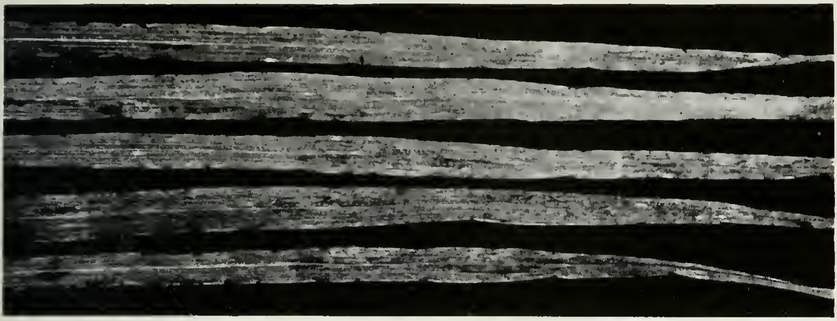

Fig. 27.—Helminthosporium leaf blotch of oats. Leaf infection by Helminthosporium causes dying of narrow, oblong strips of leaf tissue between veins. The dead tissue turns rusty brown.

tion of leaf area has ranged from 0.4 to 19 per cent. Data collected since 1928 indicate that, as an annual average, 46 per cent of the oat plants grown in the state are infected and that this infection destroys about 5 per cent of the oat leaf area.

Appearance.—The oblong to elongate, light reddish-brown spots characteristic of Helminthosporium leaf blotch, fig. 27, begin to appear on the seedling leaves soon after the leaves emerge. Spores of the fungus produced in dead areas in the centers of these spots are carried to other leaves, where they cause new infections. Spots on stem leaves may be long and narrow or broad and irregular in shape. The outer edges of the spots often are poorly defined, brown merging gradually into yellow or reddish shades, which frequently spread over the greater part of an infected blade. Sometimes invasion by the fungus does not produce well-defined spots but instead causes a leaf to assume a withered appearance, as if injured by adverse weather conditions. As badly diseased leaves die, they change from green to pale yellow or gray, and the brown of the diseased spots fades. The oat heads sometimes become infected. Then the fungus enters the hulls surrounding the kernels and may even penetrate the kernels slightly. An attacked kernel turns brown at the basal end.

Life History.—The fungus causing Helminthosporium leaf spot of oats overwinters as spores on the outside of the seed, as mycelium beneath the seed coat, and as mycelium and spores on crop refuse. Seedlings may become infected from any of these sources. When infected kernels sprout, the fungus within the seed renews its growth, or the spores on the seed germinate and produce infected spots on the seedling leaves. Spores produced in these spots are dispersed by various means to other leaves of the same plant, as well as to other plants, and they produce new spots. Successive crops of spores borne on both old and new spots provide an abundance of infective material for new leaves as they form and for the grain as it develops.

Control.—Seed treatment with chemicals tends to reduce the amount of infective material borne by the seed; it may not kill all the Helminthosporium leaf blotch fungus growth beneath the seed coat. Thorough fanning removes many of the light, shriveled, and heavily infected seeds. Unless this Helminthosporium disease is very severe, the chemical seed treatment recommended, page 151, will give satisfactory results.

VICTORIA BLIGHT

Helminthosporium victoriae

Victoria or Helminthosporium blight of oats was first observed in Illinois in 1943 in Bond County. The causative fungus attacks oats in all stages of development. It is reported to be a saprophyte or weak parasite on timothy, barley, sorghum, soybean, and several grasses, including orchard grass and green foxtail. In 1946 and 1947 this disease caused almost complete loss of the crop in many oat fields in central and northern Illinois. The Victoria variety of oats and most of the hybrids in which it is incorporated are susceptible to Victoria blight. Farmers should watch for Victoria blight, especially in new varieties of oats, because it is very destructive.

Appearance.—The fungus responsible for Victoria blight, fig. 28, probably causes death of some seedlings beneath the surface of the soil. Infected seedlings that emerge from the soil have dull bluish-gray leaves with narrow, reddish-brown stripes running the entire length of the blades. A stripe of this kind may cover half of a blade. Seedling leaves develop reddish color, and badly diseased plants soon die. Seed hulls of diseased plants may be black, due to the abundance of fruiting structures of the fungus. Later in the season the fungus attacks the basal parts of stems, which develop a translucent brownish color. The lower joints and the leaf sheaths become covered with the dark fruiting structures, which give them a velvety black appearance. Severe infection causes death of roots and stems and results in severe lodging and premature ripening of plants.

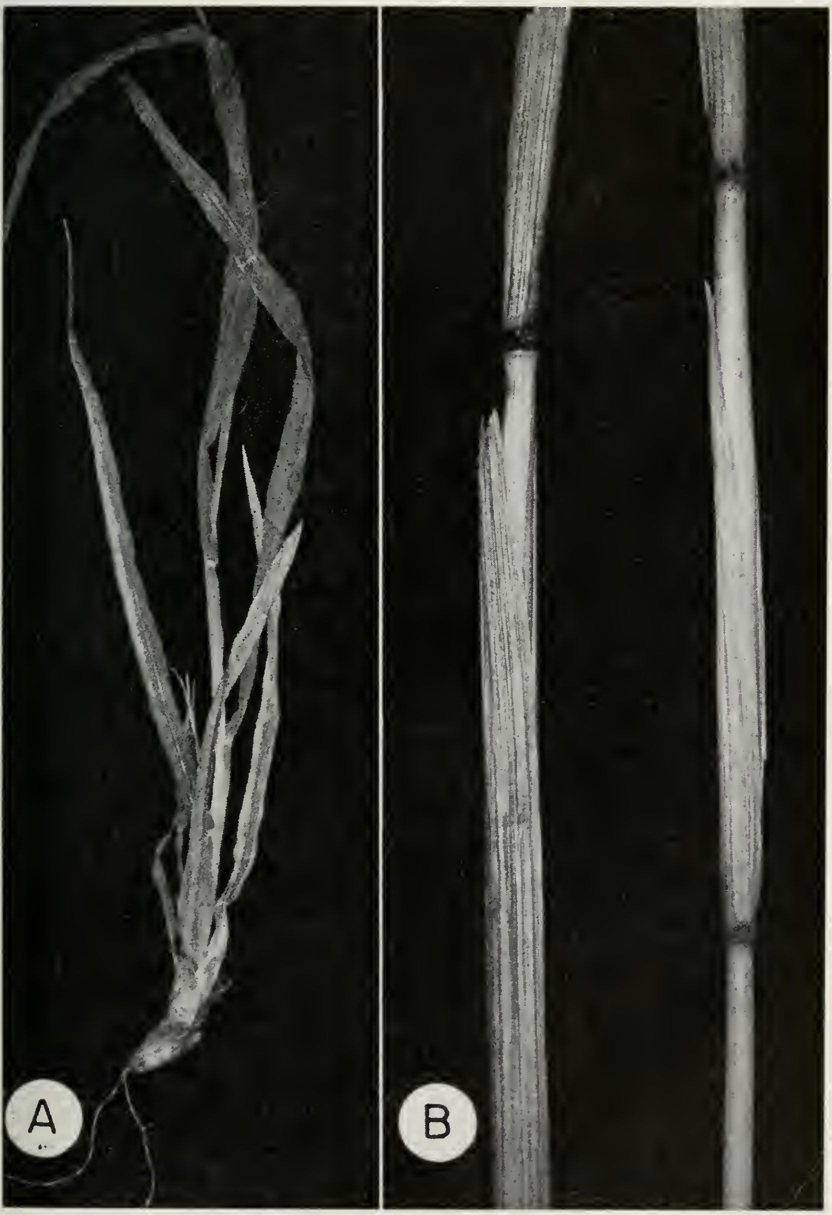

Fig. 28.—Victoria blight of oats. An infected seedling, *A*, has dull bluish-gray leaves with narrow, reddish-brown stripes running the entire length of the blades. Leaves may develop a reddish color, and plants may die. Infected joints, *B*, are dark and may have a velvety appearance if the fungus is fruiting abundantly.

Life History.—The fungus that causes Victoria blight lives from one year to the next as spores on the seed or as spores or mycelium on refuse of oats or other susceptible plants. Seedlings may become infected from either source. Infection of older plants may occur from spores carried by the wind from crop refuse of the previous year or from spores produced on plants infected in the current year.

Control.—Oat varieties resistant to the causative fungus provide the best means of preventing damage by Victoria blight. Sanitation and crop rotation are useful as supplementary control measures. Seed treatment with organic mercury compounds, page 151, will kill spores on seed but will not prevent infection from wind-borne spores.

ANTHRACNOSE

Colletotrichum graminicola

Anthracnose on oats is caused by the same fungus that causes anthracnose on wheat, rye, and barley. The fungus has many grass hosts. Samples of it have been collected in 40 Illinois counties. It attacks the leaves, sheaths, joints, and heads of host plants; also, the roots, crowns, and basal stem tissues.

Anthracnose is much more prevalent and severe on winter varieties of oats, which are sown in the fall in southern Illinois,

Fig. 29.—Anthracnose on oats. The fungus produces reddish-brown spots of various shapes and sizes on leaves. Elongated, black fruiting bodies are visible in the older dead areas of the spots. Infection frequently occurs at the base of a leaf.

than on spring varieties. In some years approximately 100 per cent of the plants of fall-sown fields are infected, and many of the plants are killed prematurely. As a leaf spot on spring-sown oats, anthracnose has in recent years increased in prevalence in Illinois, but it is still relatively rare. The over-all oat loss caused by anthracnose in the state is slight.

Appearance.—On the leaves of oats, anthracnose, fig. 29, produces spots that are elongated, often lens-shaped, and reddish-brown. After causing the death of leaf tissue, the fungus produces black fruiting bodies in the spots. In many instances spots are formed on a leaf blade at its junction with the sheath. In severe infection the greater part of the leaf is covered by the fungus fruiting bodies. Infected basal and crown tissue becomes bleached in appearance; later it turns brown and is speckled with the black fruiting bodies. The appearance of anthracnose is described in more detail on page 50.

Life History and Control.—The life history and control of anthracnose on oats are similar to those for anthracnose on wheat, pages 51 and 52.

DOWNY MILDEW

Sclerospora macrospora

Downy mildew on oats was first observed in the United States in 1939. Since then it has been found in many states. The disease has been found in Illinois, but it has not caused serious losses to oats except locally. It does the greatest damage in wet years and in wet areas of fields. Growers should watch for downy mildew on oats and send specimens of plants suspected of being affected by the disease to the Illinois Natural History Survey, Urbana, for confirmation. Host plants of the disease are given on page 42.

Appearance.—The symptoms produced by downy mildew, fig. 30, are variable. A good time for detecting the disease in oats is when the plants are ripening. Plants affected by downy mildew usually remain green for several days after healthy plants are ripe. Severely diseased plants are dwarfed and usually tiller excessively. They may be less than a third as tall as healthy plants. Leaves on diseased plants are short, fleshy, and stiff and they remain upright. These plants rarely head out, and the heads that are produced are distorted. Some plants die prematurely. Many plants are not dwarfed or they are only slightly dwarfed; they appear stiff and they produce distorted heads that may stand above healthy heads. Leaves on these plants are more fleshy and upright than those on healthy plants; the flag leaf may be curled and twisted about a poorly developed head. Heads produced on these plants are variously deformed, even to the extent that no spikelets are recognizable, and no viable seed is produced.

Life History and Control.—The life history and control of downy mildew on oats are like those described on page 44.

Fig. 30.—Downy mildew on oats. Diseased plants may be dwarfed. They appear stiff and they produce distorted heads. Diseased leaves are short, fleshy, and upright; the flag leaf of an affected plant may be curled or twisted. Infected plants may remain green a few days longer than healthy plants.

POWDERY MILDEW

Erysiphe graminis avenae

Powdery mildew, though relatively common on wheat and barley, has rarely been found on oats in Illinois. A specialized race of the powdery mildew fungus is necessary for infection of oats; it produces the characteristic appearance described on page 41. In this state it has been found only on the leaves of oats.

ERGOT

Claviceps purpurea

Ergot, described as a disease of rye, page 136, attacks oats, but this attack occurs so rarely that there is only one record of it in Illinois. Of the small grains, oats are the least susceptible to ergot. Control measures for ergot on oats are not required.

HALO BLIGHT

Pseudomonas coronafaciens

Halo blight, or blade blight, a bacterial disease, occurs on oats in Illinois each year. While typically a leaf disease, halo blight can also infect the leaf sheaths and chaff. It occasionally attacks several other grasses in varying degrees.

Halo blight is important chiefly because of its destruction of leaf tissue. In Illinois oat fields it behaves as an epiphytotic disease, being present every year but fluctuating both in prevalence and intensity from year to year in conformity with prevailing weather. In 1925, the worst year on record for halo blight, 47 per cent of the plants examined were diseased and 12 per cent of the leaf area was destroyed. Severe infection when oats are heading results in reduced yields. Halo blight infection has not been severe in Illinois in recent years.

Appearance.—Halo blight, fig. 31, is first noticeable on the oat leaves as small, pale green, oval spots with slightly sunken centers. The spots enlarge, sometimes reaching an inch in length. As the tissue in the center of a spot dies, the color changes to gray or brown. The clear or light yellow translucent tissue around the dead center resembles a halo and gives the disease its name. Spots may be prolonged into points at one end, and sometimes in large spots a faint trace of several halos may be seen; or a halo may be extensive and run as a streak nearly the length of a leaf. When spots occur close together or join each other, all of the leaf beyond these spots dies. In severe infections the entire leaf dries up and turns brown, but the halo usually is distinguishable even on the dead leaf. On the chaff each minute spot of infection is surrounded by a light green to yellowish-green halo; if an entire glume is infected, the tissue between the veins turns yellow and becomes translucent. No bacterial exudate is present on the spots.

Life History.—Tests have shown that halo blight bacteria live over winter on the oat seed and cause infection in the spring on the first leaves. On seed these bacteria are able to remain

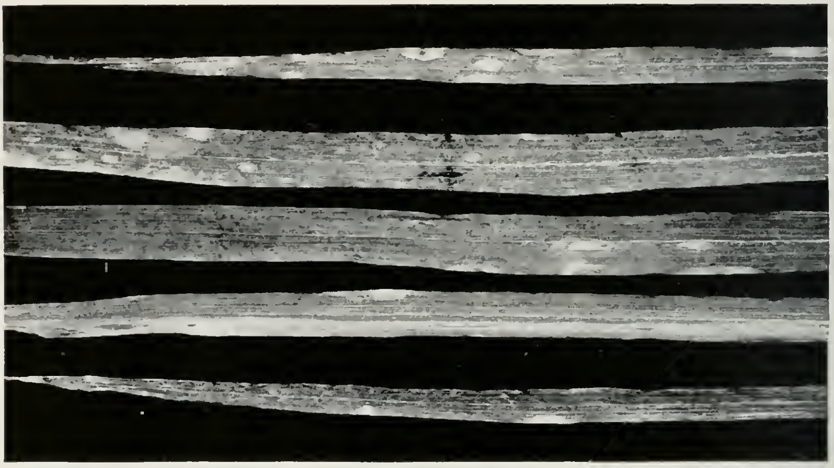

Fig. 31.—Halo blight of oats. Bacterial infection of oat leaves results in the appearance of yellow-green, oval spots surrounded by clear, translucent halos.

alive for at least 2 years, and it seems quite possible that they may live over in the soil and on diseased plant refuse for an equal period. Infection in oat fields shows an increase after rainy periods, indicating that moisture favors development and spread of the disease. Both rain and wind easily may spread the bacteria from plant to plant as well as to different parts of the same plant. Insects play an important part in spreading infection by carrying the bacteria from plant to plant.

Control.—Since the halo blight bacterium may be carried on the oat seed, in the soil, and on plant refuse, seed treatment, field sanitation, and crop rotation are control measures that should be used. In any area in which losses are heavy, resistant varieties of oats may be useful.

STRIPE BLIGHT

Pseudomonas striafaciens

Stripe blight, which is a bacterial disease of oats, is widely distributed but generally of little consequence in the central and western United States. It is chiefly a leaf disease, but it may occur on the stems, sheaths, chaff, and pedicels (stems which bear the flowers). Sometimes it kills the entire tops of plants. Although the disease is generally of little importance in oat fields of Illinois, in 1939 it appeared in epiphytotic proportions on oats in central Illinois and it was so severe in some fields as to render them worthless for harvesting.

Appearance.—Stripe blight first appears on a leaf as sunken, water-soaked dots. If these spots are abundant, the infected leaf will die. The dots enlarge into water-soaked stripes or blotches, which may extend the length of the blade. These stripes often have narrow, yellowish margins. With age they become a translucent rusty brown. In moist weather the bacteria exude in droplets from the stripes; later these droplets dry, forming white scales. Stripe blight is closely related to halo blight. It can be distinguished from halo blight by the type of spot produced and by the presence of the bacterial exudate. The bacteria causing the two diseases are very similar, except that the stripe blight organism is smaller than the halo blight bacterium.

Life History.—The life history of the organism causing stripe blight is similar to that causing halo blight, page 88.

Control.—If control measures for stripe blight are necessary, those recommended for halo blight should prove effective.

YELLOW DWARF (RED LEAF)

Virus (unnamed)

Yellow dwarf occurs on barley, wheat, oats, rye, and many other grasses. There are a number of grasses that carry the disease but do not show any external symptoms. Among these are Kentucky fescue 31, orchard, annual rye, witch, sweet vernal, Sudan, Bermuda, and annual and Kentucky bluegrasses. Yellow dwarf is caused by a virus that has been transmitted by at least five species of cereal-infesting aphids, notably the greenbug; the virus has not been transmitted experimentally by mechanical methods, in seed or in the soil. Symptoms produced by the yellow dwarf virus vary with host plants.

Oat plants with symptoms of yellow dwarf have been observed in Illinois for many years. In 1949 an outbreak of the disease occurred in Illinois and in many other states in the upper Mississippi River valley. At that time the disease was called gray spot. Later the disease was called red leaf. In recent years it was established that the red leaf disease of oats in Illinois and the yellow dwarf disease of cereals in California were caused by the same virus.

The prevalence and severity of the disease varies from year to year and from field to field. If an aphid infestation occurs early in the growing season when the plants are small and the aphid populations build up rapidly, as in 1959 in Illinois, many fields are a complete loss. Largely because of yellow dwarf, the state oat yield per acre harvested in 1959 was less than two-thirds of the yield in 1958.

Other virus diseases have been reported on oats. In the southeastern United States a soil-borne virus occurs on winter oats. This virus produces symptoms on oats very similar to those produced on wheat by the soil-borne mosaic virus.

Appearance.—Yellow dwarf on oats (cover photograph) often may be first noticed in plants along the edge of a field. The first sign of the disease on an individual plant is the development of small, yellowish-green blotches or spots usually near the tip of a leaf. These blotches are not sharply separated from normal tissue, are variable in size and shape, and are seen most clearly by holding an affected leaf up to light. Enlarging rapidly, the blotches coalesce and turn various shades of yellow-red, scarlet, orange, red, or reddish-brown. The entire tip of the leaf may have a reddish cast. As these changes occur, more yellowish-green blotches appear on the blade nearer the base of the leaf. At this stage, the green of the plant usually has a darker green cast than healthy plants. The orange or red color usually involves the entire blade, progressively from the tip to the base. Margins of the infected leaf may curl up and inward. Sometimes in a young, unfolding leaf, the tissue between the veins is yellowish-green, while the tissue above the veins is a normal green. The tip or entire leaf may die and have a reddish-brown color. The number of red leaves varies with the stage of development of plants when infected; occasionally only one or two leaves on a plant may show the symptoms. Plants infected early may be severely dwarfed and some die prematurely. Heads of severely diseased plants have many blasted spikelets; on some heads almost 100 per cent of the spikelets are blasted. The amount of blasting and the reduction in test weight of grain varies considerably even within a variety.

Severely diseased fields have a reddish cast. Many plants are dead. Affected plants not killed are severely dwarfed and have poorly developed heads, which produce no grain or only a few poorly developed kernels. Less severely diseased fields have a patchy and uneven appearance. The patches vary in size from a few feet to 150 feet or more in diameter. Plants in these areas are dwarfed, and most of the leaves have a reddish color. Those plants in the center of a diseased area may be much smaller than those at the outer edge. Plants in such an area ripen prematurely and as they ripen have a dull grayish color instead of the bright golden yellow of healthy plants. Sometimes diseased plants occur singly or for short distances along a row. A few healthy plants may be found among diseased ones. Usually late-planted fields show higher percentages of diseased plants than early-planted fields.

There are other factors which can cause the development of various shades of red color in oat leaves. Some of these are poor physical condition of the soil, low level of soil fertility, wet soil, low temperature, and injury caused by insects and fungus diseases, such as leaf spot, crown rot, and root rot.

Life History.—The virus causing yellow dwarf, carried from plant to plant by any one of several species of grain aphids, overwinters on perennial grasses. Aphids in their feeding undoubtedly carry the virus from these infected grasses to the cereals. A general description of viruses is given on page 5.

Control.—No effective measures for the control of yellow dwarf are known. In some years early sowing of oats will prevent serious yellow dwarf infection; the more advanced a plant is when it becomes infected, the less injury is apt to result. However, early sowing will not prevent serious yellow dwarf infection if aphids are abundant early in the season, as was the case in Illinois in the spring of 1959. Resistant or tolerant varieties of oats should be used when they become available.

BLUE DWARF

Virus (unnamed)

The disease of oats called blue dwarf, of virus origin, was first observed in the United States in 1951. It is known to occur in several states in the upper Mississippi River valley. It has been observed several times in Illinois oat fields. While it is not prevalent enough yet to be of economic importance, it has the possibility of becoming very destructive, as blue dwarf plants produce practically no grain.

Affected plants are dwarfed and uniformly dark bluish green; they remain alive much longer than healthy plants. The leaves, especially the flag leaf, are usually shorter and more rigid than those of healthy plants.

The disease has been transmitted experimentally by a leafhopper. No control measures are known.

BLAST

(Cause unknown)

Blast, or sterility, of oats is a disease about which little is known. No infectious organism has been proved to be the cause of it.

Blast may be caused by one or more of a number of unfavorable environmental conditions that adversely affect the normal metabolism of the oat plants when heads are forming. Inheritance of sterility characters may help to determine the amount of blast. The prevalence and severity of blast in Illinois oat fields have increased since 1945. Blast of oat spikelets results in a direct reduction in yield. The conditions that cause blast appear to reduce the yield of the spikelets that show no sign of blast. Observations in Illinois oat fields over a 30-year period indicate that in the various years 38 to 99 per cent of the oat heads had blasted spikelets and 7 to 31 per cent of the spikelets were blasted. During this period an average of 76 per cent of the heads had blasted spikelets and 16 per cent of the spikelets were blasted.

Appearance.—As the name suggests, spikelets affected by blast have a blasted or blighted appearance and fail to develop, fig. 32. These spikelets can be recognized, as soon as a head emerges from its boot, by their light color and delicate texture, as well as by the fact that they contain no rudiments of grain. Usually only a few spikelets on the lower half of the head are blasted, but occasionally half and rarely the entire head is sterile. Some blasted spikelets are so small as to be unnoticed at maturity, but others are nearly normal in size and are recognizable chiefly by their pale yellow to white, paper-like chaff.

Fig. 32.—Oat blast. On the two heads at the right, many blasted spikelets are shown; on the head at the left only a few blasted spikelets can be seen.

Control.—There are no control measures to recommend for blast of oats. The amount of blast varies from year to year in Illinois. Oat varieties apparently exhibit specific degrees of resistance or susceptibility to this disease.

4

Barley Diseases

THE ACREAGE DEVOTED TO BARLEY IN ILLINOIS, compared with that devoted to wheat and oats, is not great and it varies considerably from year to year. Both winter and spring barleys are grown in the state. Winter barleys, sown in the fall, do not possess enough hardiness to be grown successfully in the northern half of the state. Much of the fall-sown barley in southern Illinois is pastured in the fall and early spring.

There are 22 recognized diseases that affect barley. Those of significance to Illinois are described in table 3 and on the pages that follow. Diseases that affect barley include some that are found on all small grains; the most common are stem rust, anthracnose, the mildews, ergot, and scab. Diseases that are common to barley and at least one other cereal are spot blotch and basal glume rot, which occur also on wheat, and bacterial blight and scald, which occur also on rye. Diseases peculiar to barley are a leaf rust, three smuts, net blotch, and stripe. Because barley has a tendency to develop brown pigment in association with injured tissue, the appearance of some diseases on barley is somewhat different from the appearance of these diseases on other cereals.

Annual losses due to barley diseases in Illinois are estimated at 10 per cent of the potential yield. Based on the production and value of barley during 1950–1953, these losses amount to an annual average of 834,000 bushels valued at $1,073,000.

Table 3.—Infectious diseases of barley, with brief descriptions of the symptoms produced on leaf, head, stem, entire plant, and seedling. Each page number is a reference to a discussion of the disease mentioned.

Disease	Description of Symptoms	Page
	Leaf	
Leaf rust	Small, oval, light yellow pustules	103
Stem rust	Elongated, brick-red, ragged pustules	105
Spot blotch	Spots of various sizes and shapes, many lens shaped; dark brown, with lighter centers	107
Net blotch	Brown spots or blotches, these becoming short, narrow streaks, usually with light yellowish borders; streaks, if abundant, coalescing to form wider dark brown stripes with irregular margins	109

Scald	Young spots ovate or irregular blotches, bluish-green; old spots light gray or bleached straw color, each surrounded by a dark brown border	114
Nonparasitic brown spot	Numerous minute, dark brown, short, narrow, more or less rectangular spots	123
Septoria leaf blotch	Spots elongated, light brown, with definite margins; numerous brown pimples in rows between the veins in straw-colored areas	117
Anthracnose	Bleached dead areas on sheath and base of leaf; small, elongated, black, elevated fruiting bodies present	116
Stripe	Narrow, yellowish to straw-colored, longitudinal, parallel stripes running full length of leaf, these stripes becoming reddish or dark brown; leaf splitting along stripes	111
Bacterial blight	Small water-soaked spots on young leaves; the spots becoming long, narrow, glossy, translucent stripes; old stripes yellowish to brown	118
Yellow dwarf	Some or all of leaves bright golden yellow, almost orange; some plants severely stunted; in late-infected plants only flag leaves yellow	120
Stripe mosaic	Light brown mottling or spotting developing into irregular streaks; brown streaks continuous or broken and with irregular margins	121
Powdery mildew	Whitish or grayish-brown powder on upper surface	105
Downy mildew	Upper leaves fleshy, stiff, upright, curled, and twisted; heads deformed; plants variously dwarfed	106

Head

Loose smut	Spikelets replaced by loose, black powder	96
Covered smut	Spikelets replaced by a black powder enclosed in a delicate, white membrane	99
Leaf rust	Small, oval, light yellow pustules on chaff	103
Stem rust	Elongated, brick-red, ragged pustules on chaff and beards	105
Ergot	Kernel replaced by a dark, plump, hard body	116
Scab	One or more spikelets brownish, ripening prematurely; dead, lusterless in appearance	100
Spot blotch	Dark brown spots on glumes, especially at bases; kernels dark at germ ends	107
Basal glume rot	Base of chaff or entire chaff brownish-black; severely infected spikelets dwarfed	116
Net blotch	Small, brown spots on glumes	109
Bacterial blight	Water-soaked areas on glumes; some kernels brown and shrunken	118
Downy mildew	Heads twisted and distorted, parts of heads thick, short, and malformed	106

Stem

Leaf rust	Small, oval, light yellow pustules	103
Stem rust	Elongated, brick-red, ragged pustules	105
Stripe	Heads barren, plants dwarfed, leaves with long, dark stripes	111
Anthracnose	Affected parts dead, studded with small, elongated, black, elevated fruiting bodies	116

	Entire Plant	
Stripe	Plants dwarfed, dying prematurely, usually failing to head; leaves splitting along longitudinal stripes that are reddish or dark brown	111
Yellow dwarf	Plants severely dwarfed, tillering excessively; leaves bright golden yellow; no heads produced; root system poorly developed; or Plants less dwarfed; new leaves typically yellow; heads producing less grain than normal heads	120
Spot blotch	Plants ripening prematurely; crown or basal stem rot at or below ground line; dead tissue dark brown; some roots rotted	107
Anthracnose	Plants stunted, bleached, ripening prematurely; lower joints and base of each affected plant studded with small, black, elevated fruiting bodies	116
Downy mildew	Plants dwarfed and deformed; upper leaves fleshy; flag leaves stiff, upright, and curled or twisted	106
	Seedling	
Scab	Seedlings stunted, yellowish, some dying or dead; reddish brown spots on roots and on bases of stems	100
Yellow dwarf	Seedling leaves bright golden yellow; tissue above veins last to turn yellow; severely dwarfed plants tillering excessively	120
Spot blotch	Seedlings dwarfed, tillering freely, some dying or dead; leaves dark green, erect; roots rotted; dark brown to black spots on sheaths and bases of leaves	107
Net blotch	Small, more or less circular to oblong, dark brown spots or blotches mostly at tips of leaves	109
Bacterial blight	Yellow spots on leaves, these spots so small as usually to be overlooked	118

LOOSE SMUTS

Ustilago nuda *Ustilago nigra*

Two loose smuts occur on barley. They are the true loose smut or deep-seated smut and the black or semiloose smut. They cannot be accurately differentiated in the field. Hence, no reliable data are available on the prevalence of either one. Both occur on barley and a few wild grasses. Both destroy the heads and are very similar in appearance to loose smut on other cereals. However, they differ in their manner of infection. Neither of the fungi causing these smuts is known to attack any of the other grain crops.

Year after year, loose smuts are among the most destructive diseases present in Illinois barley fields. Infected heads are completely destroyed by the diseases. In individual fields the diseases may affect as many as 15 to 20 per cent of all heads, and for the state as a whole the average ranges from less than 1 per cent in certain years to as high as 10 per cent in others. Field counts of the two smuts made in representative fields in a 25-year period, beginning with 1930, show an average annual prevalence of 2 per cent.

Appearance.—True loose smut of barley, fig. 33, is caused by *Ustilago nuda*. It first becomes evident as a head emerges from the boot; emergence of the head may occur slightly earlier in

Fig. 33.—Loose smut of barley. Spikelets of the heads on infected plants are transformed to masses of olive-black powder, which shatters off, leaving only the bare head-stem, as shown at the right. The head at the left appears healthy and normal.

diseased than in healthy plants. The normal chaff and rudimentary grain of a diseased head is replaced by a mass of medium brown to dark brown, powdery spores. The spores are enclosed for a time in a delicate, silvery membrane, which soon ruptures. Diseased heads stand erect above healthy heads. The membrane about the spores ruptures and releases the spores by the time healthy heads are in bloom, and by harvest a naked spike is all that remains of a diseased head.

Plants affected by black or semiloose smut, *Ustilago nigra,* generally head a little later than plants affected by true loose smut. The membrane surrounding the spore masses is very delicate, but it is more persistent than that in true loose smut. Each head contains millions of small, loosely held, dark brown or black spores.

Life History.—The life history of *Ustilago nuda,* the fungus causing true loose smut of barley, is similar to that of the fungus causing loose smut of wheat, page 31. The smut powder, each grain of which is a spore of the smut fungus, is distributed by air currents to flowers of healthy heads. If temperature and moisture are favorable to the fungus, the spores germinate at once and develop long, slender infection threads which enter the grain and grow into the germs or embryos of the kernels. This infected seed, if sown, will produce diseased plants.

In the life history of *Ustilago nigra,* the fungus causing black or semiloose smut, spores are scattered mostly by air currents during the blooming period or during harvest. Those that alight on the heads lie dormant on the surface or become lodged under the glumes. Spores may live over in the soil under dry conditions. The spores germinate when the seed germinates. The fungus grows through the first leaf into the growing point of each young seedling. It grows with the growing point of the plant and replaces the grain and chaff with spore masses by the time the head emerges from the boot.

Control.—The use of seed of resistant varieties of grain or seed from certified, smut-free fields is among the best means of reducing losses from loose smuts of barley. There are no practical, effective surface seed treatments that can be used on the farm to control true loose smut. The only satisfactory seed treatment for control of this disease is the hot-water treatment, page 149, since the causative fungus is in the embryo of the seed. An objection to the hot-water treatment is that it is very exacting and must be carried out with extreme care. Most farmers are not equipped to use it. The germination rate of seed is reduced by the treatment, especially if seed coats have been broken in threshing. Maintenance of a special seed plot, page 147, is a means of assuring a supply of seed free of true loose smut.

Semiloose smut, like covered smut, can be controlled satisfactorily by properly treating the seed with volatile organic mercury fungicides, page 151.

COVERED SMUT

Ustilago hordei

The fungus causing covered smut of barley does not infect any other cereal. It occurs on 11 wild grasses west of Illinois, but it has not been found on them in Illinois. In symptoms and life history it is similar to the fungus causing covered smut of oats. There are at least seven physiologic races of the fungus that attacks barley. Covered smut occurs on barley throughout Illinois, but it is most prevalent on winter barley grown in the southern part of the state. Smutty heads are a complete loss. Individual fields may have as many as 25 per cent of all heads infected; for the entire state the prevalence averages range from 0.2 to 9 per cent. Field counts made in 20 consecutive years show an average annual prevalence of 3 per cent of the heads infected.

Appearance.—As the name suggests, the smut masses that characterize this disease, fig. 34, are enclosed when they emerge

Fig. 34.—Covered smut of barley. Although the spikelets of infected heads are transformed to masses of black powder, they remain more or less intact until harvest. The head at the left is normal; the others are smutted.

and they remain covered for a long time, often until harvest. Diseased plants head at about the same time as healthy plants. The heads sometimes burst through the sides of the boots instead of pushing through the ends. The chaff, the kernels, and often the bases of beards are replaced by smut masses, which are held in place by persistent, tough, grayish-white membranes. The smut masses and spores are dark brown to coal black.

The covered smut masses are not released from their enclosing membranes until threshing time, unless the membranes are broken accidentally. Because these membranes are often prematurely ruptured, covered smut is difficult to distinguish from loose smut.

Life History.—When the masses of covered smut are broken open as the barley is threshed, innumerable fine particles are released, each particle being a spore of the covered smut fungus. Many of these spores lodge on healthy kernels, especially in the grooves, where they remain dormant until the seed is sown. When the barley seed begins to germinate the spores also germinate and infect the young shoots as they emerge from the seed coats, or shortly afterwards. After the fungus has entered the seedlings, it continues to grow with the shoots and eventually replaces the grain and chaff with spore masses. Some of these spores lodge on healthy grain and infect the seedlings that develop. A warm, moist, acid soil favors seedling infection. This fact may account for higher prevalence of the disease in winter barley than in spring barley.

Control.—Since the covered smut spores are carried on the barley seed, treatment of the seed with a volatile organic mercury fungicide will control the disease, page 151. Use of resistant varieties will help reduce losses.

Sowing seed in a moderately dry soil will aid in checking the disease, since moist soils are known to favor infection. Less smut develops in plants growing in a neutral or alkaline soil than in an acid soil. The greatest numbers of seedlings become infected when soil temperatures range between 50 and 70 degrees F. during the germination period.

SCAB

Gibberella zeae

Scab on barley, called also Fusarium head blight, is caused by the fungus that causes scab on wheat and other small grains.

The fungus attacks many grasses. It produces a seedling blight and root rot in addition to head blight. Scab occurs on barley in all parts of Illinois but is most severe in the northern part of the state. The amount of scab that develops in a crop is determined largely by the weather.

Scab reduces yields, quality, and feeding value of grain. Scabby barley is discounted severely in the market and cannot be exported. Heavily infested grain will not be eaten by hogs.

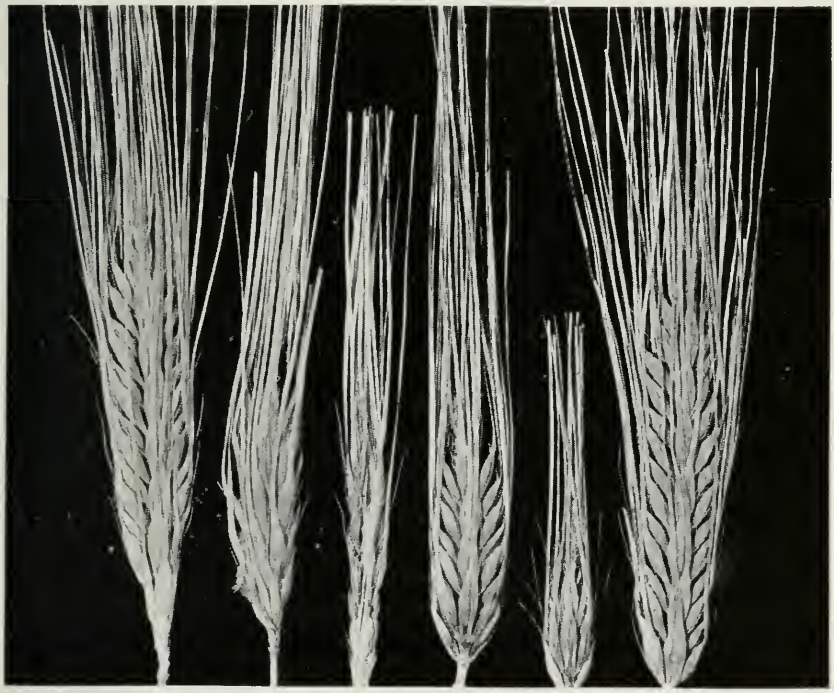

Fig. 35.—Scab on barley. The four heads in the center show the effect of scab attack. A normal head is at each end of the row.

Barley that has as much as 10 per cent of the kernels scabby cannot be used profitably as a feed for hogs but it may be used for cattle, sheep, and poultry without harmful effects. In certain years, such as 1928, 1938, 1939, 1942, 1943, and 1957, scab caused considerable reduction in yield of barley in Illinois. Losses in the state have ranged from a trace to 20 per cent of potential annual yield, with an average of about 4 per cent. Scab is one of the most important diseases of barley.

Appearance.—The characteristics of scab as it appears on barley, fig. 35, are very similar to those given for wheat scab, page 37. The disease is not so conspicuous on barley as it is on wheat, because each kernel is covered by a hull, and diseased barley spikelets are brownish instead of white. One or more spikelets or an entire head may be infected. If the entire head is infected, it is dwarfed, and the spikelets are compressed instead of spread. Hulls of infected spikelets change to a light or dark brown color. They have a dead, lusterless appearance. The light brown color appears first at the bases of the spikelets. Many of the kernels of infected spikelets turn brown at the bases; in severe cases entire kernels become shrunken and brown. Badly scabbed kernels of barley have much the same appearance as scabby wheat kernels. When infection takes place late in the development of the grain, a hull may show the brown color only at the base, or the surface of the hull may become rough and gray colored at the base. Diseased kernels, if examined closely, reveal the grayish, shriveled, scabby condition typical of the disease. In moist weather, pink spore masses develop on spikelets and sometimes dark fruiting bodies are formed at the bases of spikelets.

The seedling blight phase of the disease results largely from seed-borne infection. If infected seed is sown in cool, moist soil, reddish-brown spots develop on the surface of the root and stem tissues. However, if seed is sown in a warm soil, seedlings may be killed while still below the soil surface or shortly after emergence. If temperatures are high, seedlings may become infected from mycelium in the soil. Late in the crop season, crown and basal stem rot caused by the scab fungus is common.

Life History.—Details of the complicated life history of the scab fungus as a wheat parasite, page 39, do not differ from those of its history when it attacks barley.

Control.—Scab control measures advised on page 40 for wheat are applicable also for barley. Use of resistant varieties, when available, offers the best hope for reducing losses from this disease. The difference in resistance shown by standard barley varieties is not great. In cornfields to be sown to barley, cutting the stalks and removing them for feed, as well as carefully plowing the field to cover all corn refuse, tends to check the epiphytotic occurrence of scab or head blight. The early sowing of barley tends to reduce the amount of crown infection and the head blight or scab phase of the disease.

LEAF RUST

Puccinia hordei

This leaf rust, also called dwarf leaf rust, affects barley and possibly a few closely related wild grasses. It occurs on barley every season wherever this crop is grown in Illinois. It comes

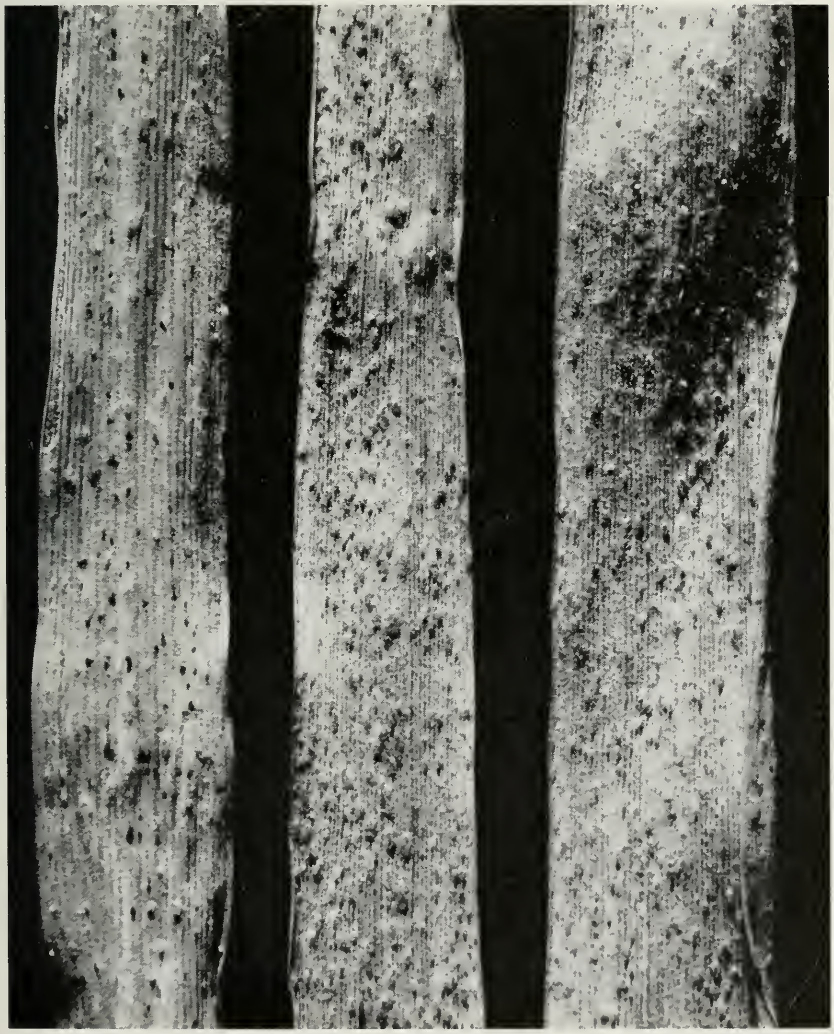

Fig. 36.—Leaf rust of barley. Rust pustules contain the light yellowish-brown spores by which the disease is spread. In the illustration above, pustules that have ruptured appear as black dots; the few that have not ruptured appear as white dots.

late in the growing season and usually it does not cause serious losses. It behaves in the same manner as other epiphytotic diseases, fluctuating with the weather from year to year. The averages of the annual prevalence and intensity figures for leaf rust indicate infection of 76 per cent of all barley plants of the state and a reduction of nearly 7 per cent in leaf area. The disease has had a prevalence in some years of as much as 100 per cent and an intensity that has reduced leaf area by 24 per cent. The average annual loss due to leaf rust of barley is estimated to be approximately 2 per cent of the potential yield.

Appearance.—Leaf rust of barley, fig. 36, appears first as small, oval, light yellow pustules scattered irregularly on either surface of a leaf. Infection usually occurs late, and the rust pustules seldom are seen much before the plants begin to head. The infection is confined to the leaves, stems, and chaff. A winter pustule stage is produced as plants near maturity, and the pustules, slate gray in color, tend to run together, forming gray patches.

Life History.—The life history of the barley leaf rust fungus is similar to that of other cereal rusts. The fungus produces both summer spores and winter spores, but spread of infection from field to field and development of the annual epiphytotics apparently depend entirely on the summer spores. In Europe, an alternate host, star-of-Bethlehem, is subject to infection from winter spores, but in America the rust is uncommon on this or related hosts. The fungus has not been found on star-of-Bethlehem in Illinois.

Rust pustules rarely are found on the barley heads; any present are similar to those on leaves.

In all probability the fungus is able to live through the winter on volunteer and fall-sown barley, and the summer spores may survive winter conditions in southern parts of Illinois. Summer spores produced in southern states are carried northward by the wind and are a source of infection early in the crop year. Summer spores produced in Illinois are a source of subsequent infection. Rust in barley fields is apt to be abundant during the growing season if the weather is warm and humid.

Control.—Chemical control measures for leaf rust of barley have not been developed, but the present relative unimportance of the disease makes them unnecessary. Resistant varieties are the best means of preventing damage by this disease.

STEM RUST

Puccinia graminis tritici *Puccinia graminis secalis*

Barley, in common with other small grains, is subject to stem rust. The rust fungus, as stated on page 18, has developed specialized races adapted to particular crops, but for barley there are few such specialized races. Barley infection is brought about principally by races adapted to rye, wheat, and perhaps also timothy. The fungus that attacks cultivated barley also attacks wild barleys.

In Illinois the stem rust on barley varies greatly from year to year, both in number of plants affected and in injury done to the stems. The disease is generally of very little importance in the southern half of the state, but northward it is responsible for reductions ranging up to 3 per cent of the potential yield. Average annual figures show 39 per cent of the plants infected and 3 per cent of the stem area occupied by rust pustules. In most years the attack of the causative fungus is so light that functioning of stem tissue is not seriously hampered. However, in northern Illinois rust occupied 30 per cent of the stem area in 1926 and 18 per cent in 1927.

Appearance.—Stem rust on barley occurs chiefly on stems and leaf sheaths; it may also occur on leaf blades, glumes, and beards. Early season infections break out as brick-red pustules with ragged edges, very similar to those on wheat, fig. 4. This red rust stage is succeeded by the black rust stage, in which the color of the pustules changes to black.

Life History.—The life cycle of the stem rust fungus on barley is the same as that of the stem rust fungus on wheat, page 20.

Control.—General measures for stem rust control, given on pages 22 and 23, include eradication of the common barberry to avoid local epiphytotics and the use of early-maturing varieties of grain.

POWDERY MILDEW

Erysiphe graminis hordei

Powdery mildew of barley, fig. 37, is similar to powdery mildew of wheat. Usually powdery mildew does not damage the barley crop in Illinois sufficiently to be counted among the serious diseases. Heavy infection occurs on tender tissues if the soil and air are cool and moist and if there is no deficiency in available

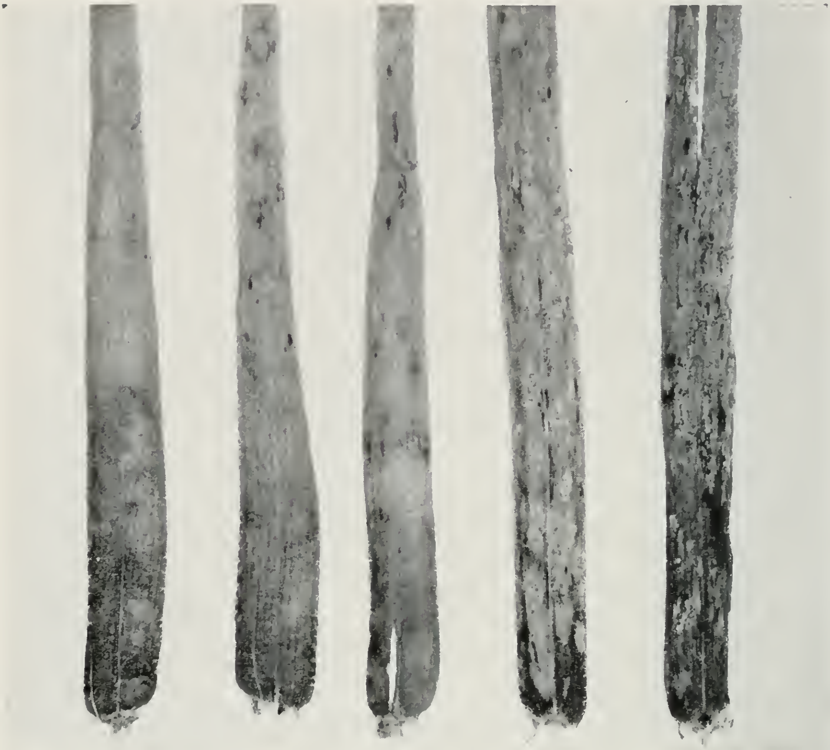

Fig. 37.—Powdery mildew on barley. Light-colored areas on the three leaves at the left are young colonies of the powdery mildew fungus. The two leaves at the right show older mildew spots, upon which minute, black spore-bearing bodies are visible.

nitrogen. Powdery mildew is most abundant and sometimes covers most of the leaf areas in portions of fields where plant growth is rank. Yields are reduced when mildew infection is severe during the period of active growth and grain formation.

Life History and Control.—The life history of the fungus causing powdery mildew of barley is similar to that of the fungus causing powdery mildew of wheat, page 42. Also, control measures for the diseases are similar.

DOWNY MILDEW

Sclerospora macrospora

Downy mildew has been collected a few times on barley in Illinois. It occurs in Missouri south of Cairo, Illinois. In certain seasons it might cause considerable damage in wet areas of fields.

Appearance.—Barley plants affected by downy mildew are dwarfed and deformed, the severity of malformation depending upon the severity of infection. Severely diseased plants, much shorter than healthy plants, have stiff, thickened leaves, stems, and heads. Affected parts of severely diseased plants are variously twisted and distorted; no seeds are formed. In less severely diseased plants dwarfing may be slight; one or more of the upper leaves are stiff and upright or variously curled and twisted; the heads and the stems below the heads may not be severely deformed.

Life History and Control.—The life history of the fungus causing this disease is discussed on page 44. Control measures for the disease are similar to those for downy mildew of wheat, page 44.

SPOT BLOTCH

Helminthosporium sativum

The spot blotch disease on barley, though somewhat different in appearance from the Helminthosporium disease on wheat, page 44, is caused by the same parasite. This parasite attacks a large number of grasses. On barley, the disease is more conspicuous on the leaves than on other parts of plants. On lower parts of plants, the disease is known as crown rot or root rot.

While spot blotch has been reported in many Illinois localities, its importance in this state has not been carefully evaluated. In states where barley is grown more extensively than in Illinois, annual losses attributable to spot blotch are estimated to range from 1 to 3 per cent of the potential yield. Undoubtedly similar losses occur in Illinois.

Appearance.—Spot blotch infection, fig. 38, starts as dark brown to black spots on the sheaths that cover the young shoots. The infection progresses inward and sometimes kills the seedlings below the surface of the ground, but more often it kills the seedlings after emergence. Infected seedlings have dark green, erect leaves with dark brown spots on the sheaths near the soil line. These spots may extend into the leaf blades. Diseased seedlings are dwarfed and they tiller excessively. Roots of diseased plants may show rotting and may have brown spots on them.

On barley plants that escape serious seedling infection, the disease is not very noticeable until about heading time. Then characteristic spots of various sizes and shapes and with definite margins appear on the leaves, fig. 38. The center of each spot is dark brown, and this color gradually merges toward the edge into the normal green of the leaf. Many spots are oblong or lens shaped. The centers of these spots often are lighter brown than the margins. If the spots are abundant, they may coalesce, producing irregular blotches which may cover the greater part of a blade. Old lesions develop an olivaceous cast as a result of the abundant development of conidiophores and conidia of the fungus.

Fig. 38.—Spot blotch on barley. This disease appears on the upper leaves about heading time as dark brown spots of various sizes and shapes and with definite margins. The dead or oldest area of each spot has an olivaceous cast, the result of the fruiting of the fungus.

Infection may occur on the sheaths. The disease starts on the old leaves and spreads to the younger ones. Spot blotch lesions never have the netted appearance characteristic of the net blotch disease. Heads as well as leaves may become infected. Dark brown spots appear on the glumes, especially at their bases and at the germ ends of the kernels. The "black point" at the germ end of a kernel is characteristic of the disease.

As crown rot, the disease develops at or near the ground line. Crown roots may be rotted and tillers killed. The crown tissues and basal parts of stems are rotted. Sheaths of basal leaves have dark brown spots. As the affected tissues die they become dark brown. In cases of severe attack plants are dwarfed, heads may not emerge completely, and kernels are poorly developed.

Life History and Control.—The life history of the spot blotch fungus is the same on barley as on wheat. The life history and the control measures outlined on pages 47 and 48 apply to the fungus as it occurs on barley.

NET BLOTCH

Pyrenophora teres

Net blotch of barley is principally a leaf disease and is of the kind generally known as leaf spot; in this disease the spots are marked internally with a characteristic netting. The netted pattern, formed by the arrangement of brown pigment in transverse and longitudinal lines, can best be seen if the leaf is held against light. Barley is the only crop attacked by the fungus causing this disease; leaves, stems, and seeds are affected. It is most abundant in cool climates or where the crop is grown during the cool periods of the crop season.

In Illinois net blotch is of minor importance in most years. However, it affected 75 per cent of the barley plants of the state in 1930 and 44 per cent in 1945. It usually causes slight reduction in leaf area of diseased plants, but in 1945 it killed over 3 per cent of the leaf area. Estimated annual losses caused by net blotch range from a trace to 0.5 per cent of the potential barley yield of the state.

Appearance.—Net blotch, fig. 39, may be seen first on seedling leaves as brown spots or blotches. Usually the blotches occur at or near the tips of leaves; in spot blotch the blotches usually appear at the bases of the leaves. Each young spot shows the irregular distribution of the dark brown pigment as narrow, indefinite lines that run both longitudinally and transversely within the area of lighter brown of the spot; these lines give the spot a netted or crosshatched appearance. The spots increase in length and form short, narrow streaks. If infections are abundant, the spots may coalesce and form long, brown stripes with irregular margins, fig. 39. The crosshatched appearance is visible only at the margins of the older spots. The stripes do not extend into the sheaths, and the leaf tissue does not split along the stripes as is the case with the stripe disease. The fungus fruits sparsely in

Fig. 39.—Net blotch of barley. The disease appears as brown spots or blotches, which increase in length and form narrow streaks.

the dead spots. Infections occur on young leaves of plants until the plants are near maturity. Small, brown streaks without the netted appearance develop on the chaff. Infected kernels may have dark spots at their bases.

Life History.—The net blotch fungus lives from one crop year to the next as mycelium in the hulls of infected seed and as very small, dark, flattened, flask-shaped fruiting bodies partially embedded in old straw and stubble. Spores produced in these fruiting bodies are called winter spores to distinguish them from the ones produced in the spots on leaves, called summer spores. Infection on seedling leaves results from infected seed or from winter spores carried to plants by the wind. If the weather is cool and damp, infections are abundant on both fall- and spring-sown barley. The fungus produces summer spores on small stalks on the surface of the dead spots on the leaves. The mycelium grows into leaf sheaths and stem tissues as the disease develops and the plants ripen. Both summer spores and winter spores are scattered by the wind and other means to other leaves and other plants and produce new infections if conditions are favorable. Successive crops of summer spores and new infections are produced throughout the growing season. Spores that fall on the chaff may germinate and grow into the hulls. After the fungus grows into a hull, it remains dormant until the seed is sown. As a plant reaches maturity the fungus grows into the sheath and stem tissue; in the fall and again in the early spring it produces the fruiting bodies that have winter spores.

Control.—Seed treatment with organic mercury compounds controls seed-borne infection of net blotch, page 151. Sanitation and crop rotation help to reduce the number of winter spores. Resistant varieties of barley, when available, should be used if the disease is severe. Most barley varieties in common use are susceptible. Since the fungus lives through the winter within the seed and on old straw and stubble, control is more difficult in this disease than in stripe. Little or no seedling leaf infection occurs if seed is sown in a soil with a temperature above 67 degrees F.

STRIPE

Helminthosporium gramineum

The destructive disease known as stripe, sometimes called blight, is found only on barley. It is a systemic infection and affects entire plants. There are at least 20 specialized races of the fungus that causes the disease.

Barley stripe is more important than growers normally think, for the reason that many diseased plants are overlooked at harvest. It is, as a matter of fact, one of the most destructive barley diseases when seed treatment is neglected. Yearly observations of its prevalence in Illinois barley fields show, for the state as a whole, infections that range from a trace to 9 per cent of the plants. Infections in individual fields range from a trace to as high as 53 per cent of the plants, with infections of 10 to 20 per cent by no means rare. In Illinois stripe is more prevalent in winter barley than in spring barley. In recent years prevalence of barley stripe has not been high because many commercial varieties carry some resistance to the disease, and seed treatment has been more generally used than previously. Data taken in 15 different seasons indicate that in Illinois barley fields stripe causes an average annual loss amounting to 2 per cent of the potential yield.

Appearance.—The earliest evidence of stripe infection, small, yellow spots on the leaves of seedlings, is usually overlooked. Several weeks before the barley heads, conspicuous and characteristic symptoms appear. These consist of narrow, yellowish to straw-colored, longitudinal streaks or stripes in the blade and sheath of a leaf. There may be one or several such stripes, running parallel with each other and extending the entire length of the blade. At this stage the variegation of pale yellow and green of diseased leaves contrasts sharply with the uniform green of healthy leaves. The light yellow stripes soon change to reddish or dark brown along the margins, the center remaining a lighter brown, and the diseased tissue dies and usually splits longitudinally in the lighter colored area, fig. 40.

Affected plants usually are severely stunted, few reaching half the height of healthy plants. Heads generally fail to emerge; those that do are grayish brown, withered, and barren. All the stems of a diseased plant are affected; such a plant dies prematurely and shrivels to such an extent that it is inconspicuous by harvest time. If severely infected seed of susceptible varieties is sown, some of the seedlings that result may be killed by the fungus.

Life History.—Summer spores of the stripe fungus are produced in the dark stripes on the barley leaves. These spores are carried by air currents, wind, or other agencies to the heads of healthy plants. Under conditions favorable to them, spores lodg-

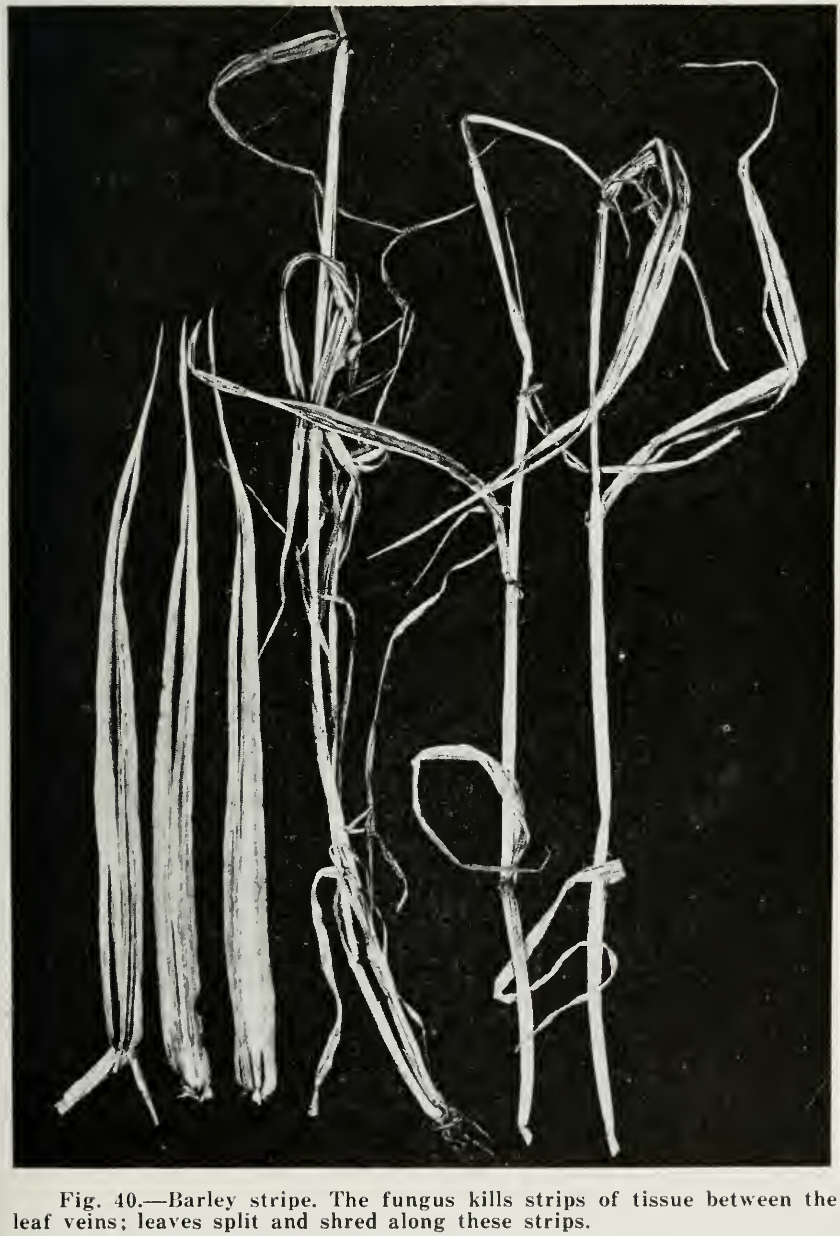

Fig. 40.—Barley stripe. The fungus kills strips of tissue between the leaf veins; leaves split and shred along these strips.

ing near the tips of the glumes germinate and produce a fungus growth which develops between the hulls and the kernels or even penetrates the seed coats of the grain. This fungus growth, which is associated with the seed in a resting or dormant state, is the chief means of carrying the disease over from one year to another. The head is susceptible to infection over a considerable period of time, although most of the infection occurs at or soon after bloom.

A winter spore stage of the stripe fungus has been found and is known to be able to cause infection, but it generally is thought to be unimportant in maintaining the disease.

Upon germination of the barley seed the fungus resumes its active state, grows first into the sheath which surrounds the leaves of a seedling, then into the first leaf, and from it into the next leaf. This process goes on until all leaves of the plant are infected. If the fungus invades the growing point of the plant, death of the stem results. The spores of the fungus are able to remain viable for as long as 34 months, and the mycelium has been known to remain alive 5 years in dry seed.

Control.—Stripe can be controlled adequately by seed treatment with organic mercury compounds, page 151. The use of seed from disease-free fields may result in an absence of stripe. Sowing seed when the soil is warm (68 degrees F. or above) and wet (at least 90 per cent saturated) will reduce the amount of disease, since the stripe fungus does not thrive in warm, wet soil. Resistant varieties of barley offer a promising means of reducing loss.

SCALD

Rhynchosporium secalis

In most years scald has not been a serious disease on barley in Illinois. Occasionally it causes considerable reduction in functioning leaf area of barley in some fields or portions of fields. The disease on barley was first observed in Illinois in 1940. Additional hosts of the fungus are given in the discussion of the disease on rye, page 127.

Appearance.—Scald spots occur on the blades and sheaths of barley leaves as conspicuous blotches of various sizes and shapes, fig. 41. Young spots occur as ovate or irregular blotches, having a water-soaked appearance and a bluish-green color. As the tissues die, the center of each spot becomes a light gray or bleached-straw color bordered by dark brown. Sometimes the spots have a zonate appearance. On the tips of glumes, inconspicuous, medium brown scald spots sometimes occur. Such spots

Fig. 41.—Scald on barley. The fungus produces spots on leaf blades, sheaths, and glumes. Dead areas are longer than wide; the center of each spot is light gray, which is bordered by dark brown.

were found on nearly 4 per cent of the heads in one Illinois field in 1958.

Life History and Control.—The life history and control of scald on barley are similar to those for this disease on rye, pages 128 and 129.

ERGOT

Claviceps purpurea

Ergot on barley is caused by the fungus that causes ergot on wheat and rye, page 136. The earliest visible sign of ergot infection in barley is a yellowish, sticky honeydew that oozes from infected flowers. Near maturity each affected kernel is replaced by the characteristic black, hornlike body known as an ergot. Ergot grains in barley heads do not become so long as those in rye heads.

Because of the slight susceptibility of barley, the disease on this cereal is of little economic importance. Only a few records of its occurrence in Illinois are available.

ANTHRACNOSE

Colletotrichum graminicola

Anthracnose affects all parts of the barley plant, just as it affects wheat, oats, rye, and numerous wild grasses. While it is rather inconspicuous and not very common on barley in Illinois, it can be recognized from the description given under wheat diseases on page 50.

BASAL GLUME ROT

Pseudomonas atrofaciens

Basal glume rot on barley is caused by a bacterium. A disease caused by the same bacterium occurs commonly on wheat. Basal glume rot was recorded on barley in Illinois for the first time in 1937. The disease is probably more prevalent than records indicate, since it is not readily distinguished from some other head diseases. It is capable of producing serious injury under conditions favorable to the causative bacterium. One Illinois field examined in 1954 had 74 per cent of the heads severely diseased. Loss in this field was estimated to be 50 per cent of the potential yield.

Appearance.—The appearance of this disease on barley is similar to its appearance on wheat, page 59.

Life History and Control.—The life history of the bacterium causing this disease is discussed on page 59. Control for the disease is the same as that suggested on page 57.

SEPTORIA LEAF BLOTCH

Septoria passerinii

Septoria leaf blotch or speckled leaf blotch is not common on cultivated barley and it causes little damage on its host. On this crop plant it has been collected 10 times in Illinois, four times

Fig. 42.—Septoria leaf blotch of barley. Blotches on the leaves are elongated and are yellowish to light brown in color; they have numerous small, black fruiting bodies in the oldest portions.

in the southern and six times in the northern part. It occurs on several species of wild barley.

Appearance.—The spots characteristic of Septoria leaf blotch are elongated and yellowish brown, and their ends have indefinite margins, fig. 42. Numerous dark brown pycnidia, or fruiting bodies, develop in rows between the veins of the leaves in the dead, straw-colored parts of the spots.

Life History and Control.—The life history and control of this disease are similar to those for speckled leaf blotch of wheat, pages 25 and 26.

BACTERIAL BLIGHT

Xanthomonas translucens

Although bacterial blight of barley is chiefly a leaf disease, it affects the chaff, also. Bacterial blight of rye and the black chaff disease of wheat are caused by specialized varieties of the parasite that causes bacterial blight of barley. The bacterium attacks all types of cultivated barley and some wild barleys. Some degree of resistance is exhibited by certain varieties of this grain.

Bacterial blight of barley is chiefly a Midwestern disease, but it does very little damage in Illinois. Although in certain years, as in 1928, the percentage of Illinois barley plants infected may be as high as 90 to 100 per cent, the destruction of leaf area is generally negligible, and practically no reduction in yield results from the attack.

Appearance.—Bacterial blight of barley, fig. 43, is characterized by small, water-soaked streaks or spots that occur on tender, green leaves and sheaths of plants and sometimes on leaves of seedlings. Usually they occur after several days of damp or rainy weather. These spots enlarge and coalesce, usually longitudinally, becoming glossy, translucent stripes of various lengths, which turn yellowish to brownish. They may extend the entire length of a leaf. Normally they are very narrow, seeming to be limited by the leaf veins. Occasionally a spot may enlarge and become blotchlike, causing much of the leaf to shrivel and turn light brown. Infected tissue gradually changes from healthy green through translucent yellow to brown. Translucency, even of brown spots, is a fairly constant and distinctive characteristic of the disease. Severely diseased leaves die; the dying starts at the tips. The symptoms that occur on the blades and the sheaths

Fig. 43.—Bacterial blight of barley. Infection of barley leaves results in the production of translucent stripes of various sizes; the stripes may become covered with small, yellow granules of dried bacterial ooze.

of leaves may be similar. Ordinarily the disease does not attract attention until plants are about two-thirds grown. Under humid conditions, especially early in the morning, droplets of milky bacterial exudate may be seen on the surface of diseased spots. These droplets dry into hard, yellowish, resinous granules, which may be removed easily as dry flakes from the leaf surfaces.

The disease produces water-soaked areas on the chaff of the barley heads similar to those on the leaves except that on the chaff the bacterial exudate is not so plentiful. Spotting of the chaff does not destroy the grain, which, however, may be brown and shrunken and may carry the disease to the next year's crop. In case severe infection of the flag leaf occurs, a head may be unable to emerge from the sealed boot and then may break through the side of the sheath. When this happens, the head is apt to be distorted and partially blighted.

An easy method of diagnosing bacterial blight is as follows: If a leaf showing a freshly developed stripe is cut in two pieces crosswise, either piece squeezed between the fingers will exude a bead of milky ooze at the cut edge. From a leaf showing older spots, the exudate has the consistency of cream and it hardens quickly into a yellowish, resinous mass.

Life History.—The barley blight bacterium reproduces in the manner customary for bacteria, page 4. It is able to live on stored grain for 2 years and it overwinters in crop refuse. Initial infections each year probably come from bacteria carried on the seed, rather than from those in the soil, and spread of the disease from leaf to leaf and plant to plant is brought about by contact between plants, by splashing rain or dripping dew, or by sucking and chewing insects, which play an important part in spreading the bacteria. In this disease, infection occurs through the stomata (natural openings) present on leaves, stems, and chaff and through wounds.

Control.—The barley blight bacteria cannot be prevented from spreading from plant to plant after the disease has become established in a field. Under Illinois conditions, if the use of seed from diseased fields is avoided, very little difficulty from bacterial blight will be experienced. When the cleanliness of seed is doubtful, the seed should be treated with mercuric compounds to destroy bacteria borne on the surface of the seed, page 151.

YELLOW DWARF

Virus (unnamed)

The name yellow dwarf is very descriptive of this disease on barley. Yellow dwarf occurs probably each year on barley in Illinois. In 1959 it was common in the southern part of the state. Under conditions favorable to it, it could cause considerable reduction in yield. The discussion of yellow dwarf on oats, page 89, contains information applicable to yellow dwarf on barley.

Appearance.—Symptoms of yellow dwarf on barley vary with the variety of the grain and the age of the plant when infection occurs. Yellowing of the leaves is the first visible sign that a plant is diseased. When infection occurs in a plant in the seedling stage, the leaves turn a bright golden yellow, usually beginning at the tips and progressing back along the edges. Gradually entire leaves become yellow. The tissue adjoining the main veins is the last to become yellow. In certain varieties, the yellow color in a leaf may appear as blotches that develop midway in the blade as well as at the tip. These yellow areas finally coalesce, and the entire leaf becomes yellow. The green areas of the leaf, especially in a plant growing in very fertile soil, are often darker green than the green of healthy plants. In some varieties, the disease produces a longitudinal green and yellow striping in the new leaves. The tissue between the veins is yellow, and that adjoining main veins is green. Leaves of diseased plants often appear thicker, stiffer, and more erect than those of healthy plants. In very susceptible varieties, plants infected in the seedling stage are severely dwarfed and may grow less than 6 inches tall. They produce more tillers than healthy plants but form no heads. They may remain alive for a long time. The root system of affected plants is poorly developed.

The color of barley leaves affected by yellow dwarf—usually a bright golden yellow—is in contrast to the sickly, pale, yellowish green color that develops in case of nitrogen deficiency, wet soil, or cold weather.

When infection occurs between tillering and jointing, the new growth becomes typically yellow. Stunting is much less severe than when infection occurs in the seedling stage; plants head but produce less grain and grain of lower test weight than healthy plants. When infection occurs after jointing, the uppermost leaves, especially the flag leaves, develop a bright yellow color. No stunting is apparent.

Life History and Control.—The life history and control for the virus causing yellow dwarf on barley are similar to those causing yellow dwarf on oats, page 91.

STRIPE MOSAIC

Virus (unnamed)

Barley stripe mosaic or false stripe is a seed-borne virus disease. It has been experimentally transmitted to wheat, rye, oats, sweet corn, crab grass, brome grass, and a number of other grasses. There are at least two strains of the virus. The disease has been observed on barley in Illinois, but no data are available on its prevalence and severity. It occurs commonly in the spring barley areas of the United States and Canada. It causes serious reduction in plant growth and yield of grain in some varieties of barley.

Appearance.—The most common signs of this disease, fig. 44, are the mosaic type of yellowish mottling, spotting, and streaking of the leaves. The yellowish markings may be few or numerous, short or long, wide or narrow, continuous or broken. The color may be light green, cream, yellow grayish, or even bleached white. The virulent strains of the virus produce on the leaves brown stripes, continuous or broken, with irregular margins. These stripes help to differentiate stripe mosaic from other virus diseases that occur on barley. This disease somewhat resembles stripe, a Helminthosporium disease of barley. In stripe the brown streaks are long and narrow, the plants are much more dwarfed, and they form few heads.

Life History.—The virus is carried in the seed, where it can survive for at least 8 years. A short discussion of viruses is given on page 5.

Fig. 44.—Stripe mosaic of barley. The causative virus produces a mottling, spotting, or streaking in leaves. The color of the streaks may be light green, cream, yellow, gray, or brown.

Control.—Since the disease is seed-borne, seed known to be infected should not be used. Thorough fanning of seed will remove some of the light, infected kernels. No chemical treatment of seed is known that will control the disease. Resistant varieties, when available, offer the best means of reducing the amount of damage by the disease.

NONPARASITIC BROWN SPOT

(Cause unknown)

Nonparasitic brown spot of barley is a disease for which, thus far, no cause has been found. As the name implies, the disease is characterized by a brown spotting of the leaves; this spotting may be attributed to the physiological condition of an affected plant, to its environment, or to some inherent trait.

Fig. 45.—Nonparasitic brown spot of barley. Affected leaves become spotted in varying degrees by tiny, oval spots of a distinctive brown.

Although nonparasitic brown spot occurs on barley throughout Illinois, it has been observed most abundantly in the northern counties. Field counts indicate that the percentage of plants that are diseased varies from 15 to 100 per cent in different fields. Injury by the disease results from the reduction of useful leaf area. In Illinois fields, injury appears thus far to have been very slight.

Appearance.—The nonparasitic brown spot disease, fig. 45, appears as numerous small, dark brown to black, short, narrow, and more or less rectangular, dry areas on a barley leaf. Spots are scattered irregularly over the leaf and are visible on both surfaces. They may be limited at the sides by the leaf veins and at the ends they may be sharply limited or may fade gradually into the normal green of the leaf. They vary in length but are seldom more than an eighth inch long; the smallest spots appear almost circular. Occasionally spots coalesce, forming elongated streaks or irregular blotches.

Control.—No control measures for this disease are known.

5

Rye Diseases

RYE IS EXTREMELY WINTER HARDY and in Illinois is sown in the autumn. The acreage devoted to rye in Illinois varies from year to year; recently it has been greater than that given over to barley.

Rye diseases are sufficiently destructive to merit more serious consideration than they have received in the past. Although these diseases are of less economic importance than those of the other small grains, their number and kinds make certain that the resulting losses are by no means insignificant.

Rye is subject to a number of diseases that are best known for their destructiveness to wheat, a cereal closely related to rye. It is subject also to diseases common to the other small grains and has some diseases that are distinctly its own. In Illinois it is affected by at least 20 recognized diseases, the most important of which are described in table 4 and the pages following.

Control measures for rye diseases are essentially the same as those for wheat and barley diseases, except that rye diseases cannot be combated as successfully by the growing of resistant varieties; little is known regarding the reactions that rye types and varieties have toward diseases.

Table 4.—Infectious diseases of rye, with brief descriptions of the symptoms produced on leaf, head, stem, entire plant, and seedling. Each page number is a reference to a discussion of the diseases mentioned.

Disease	Symptoms	Page
	Leaf	
Leaf rust	Small, oval, orange-brown pustules on both surfaces of leaf	129
Stem rust	Elongated, brick-red, ragged pustules	131
Scald	Spots broadly oval or lens shaped; centers of spots bleached or light brown, edges darker and with yellow halos; spots at base of each blade more elongated and extending into sheath	127
Stem smut	Long, lead-colored or black stripes filled with black powder; flag leaf usually twisted	134
Anthracnose	Bleached dead areas on sheath and base of leaf; small, elongated, black, elevated fruiting bodies present	132

Bacterial blight	Narrow, glossy, translucent stripes of various lengths, becoming yellowish to brownish with age	141
Spot blotch	Light brown, lens-shaped spots with lighter edges	131
Septoria leaf blotch	Yellowish to light brown spots or blotches, some long and narrow and with tiny, black pimples	139
Powdery mildew	Whitish to grayish brown powder on upper surface	138
Soil-borne mosaic	Leaves mottled with yellow, longitudinal stripes of various lengths	140
Nematode disease	Youngest leaves buckled within tightly closed sheaths of older leaves	141
	HEAD	
Ergot	One or more kernels transformed into long, black, hornlike bodies	136
Scab	One or more spikelets bleached, ripening prematurely; in some cases salmon color appearing at bases of spikelets and edges of glumes	131
Anthracnose	Bleached areas on spikelets; small, elongated, black, elevated fruiting bodies present	132
Loose smut	Part or entire head transformed into a black powder	135
Nematode disease	Head small, open, remaining green longer than healthy head; each affected kernel a small, thick, hard gall	141
	STEM	
Leaf rust	Pustules elongated, filled with orange-brown powder, shorter than stem rust pustules	129
Stem rust	Elongated, brick-red, ragged pustules	131
Stem smut	Long, lead-colored or black stripes on leaf, sheath, and stem; stripes breaking open and exposing black powder	134
Spot blotch	Brown spots on joints, sometimes girdling joints; velvety appearance if fungus fruits profusely	131
Anthracnose	Purplish to brownish blotches on or near lower joints; small, elongated, black, elevated fruiting bodies present	132
	ENTIRE PLANT	
Anthracnose	Plant stunted, bleached, ripening prematurely; joints and base of plant dark, studded with small, black, elevated fruiting bodies	132
Stem smut	Plants stunted, rarely producing heads; long, lead-colored stripes on leaves and stems; stripes becoming black, rupturing, and exposing dusty masses of spores	134
Crown rot or spot blotch	Plant dwarfed, reddish-brown; lower leaves with dark chocolate-colored spots, roots usually rotted; diseased plants often in circular patches	131
Take-all	Plants stunted, tillering sparsely, bleached yellow, becoming ashen white; base of stem brown to black, with dark to black layer of fungus mycelium between stem and leaf sheath; roots rotted; diseased plants usually occurring in circular areas in field	138

Soil-borne mosaic	Patches of light green to yellowish stunted plants; new leaves mottled yellow; irregular stripes or blotches running parallel with long axes of leaves	140
Nematode disease	Plant stunted, enlarged at base; heads small, open, remaining green longer than normal; leaves crinkled	141
	SEEDLING	
Spot blotch	Seedlings rotted off at ground line, where dark brown rot is present; leaves with dark brown spots	131
Scab	Seedlings stunted, yellowish; roots reddish brown	131

SCALD

Rhyncosporium secalis

Scald occurs on rye in the form of a leaf spot. A disease with the same common name occurs on barley, but it has not caused serious damage on this cereal in Illinois. There are a number of specialized races of the scald fungus, each restricted to a single or closely related host species. The most important wild hosts of the races of the fungus that causes scald of rye are quack grass, cheat, wild rye, smooth brome grass, canary grass, and wild oats. A specialized race of the fungus has been reported attacking redtop.

Scald damages rye by destroying leaf tissue, thus reducing the plant's ability to manufacture food. In most years many of the lower leaves of plants are killed prematurely. In recent years scald has affected 75 to 100 per cent of the plants in individual fields and 40 to 65 per cent of the leaf area. The average annual loss caused by scald has not been accurately assessed, but in some years losses have been estimated at 2 to 3 per cent of the potential yield. These figures undoubtedly are too low.

Appearance.—Young scald spots are dark bluish-gray, water-soaked blotches. They occur mostly on the leaf blades and may occur on the sheaths. They are broadly oval or lens shaped; the long axis of each spot parallels the long axis of the affected leaf, fig. 46. As a spot ages its center becomes white or very light brown. Around this center is a straw-colored border enclosed in a yellowish-green band or halo, which gradually fades into the green of the leaf. Leaf spots develop abundantly in cool weather. Some spots have a zonate appearance as a result of successive enlargements.

Spots that develop at the base of a leaf may extend across the blade and down into the sheath, causing the death of the entire leaf. If a spot becomes somewhat elongated, much of the tissue above and below it loses its green color. If a spot is very broad, all of the leaf beyond the spot dies.

Life History.—The scald fungus apparently overwinters on dead or living tissue of rye and wild hosts. Initial infection each year occurs from spores. On leaves infected in the fall, typical scald spots appear early the following spring. In the cool weather of spring, spores of the fungus are produced abundantly in these

Fig. 46.—Scald on rye. Infection of leaves by the parasitic fungus responsible for this disease results in the appearance of broadly oval, bleached spots with straw-colored borders, each of which may be surrounded by a yellowish-green halo. An abundance of these spots greatly reduces the food-making capacity of affected leaves.

scald spots and on crop refuse. They are carried considerable distances by air currents and are distributed from plant to nearby plant by rain. Subsequent infections can be caused by spores that are produced on scald spots as long as conditions are favorable to the fungus. Apparently the scald fungus is not seed borne.

Control.—Sanitation, crop rotation, and use of resistant varieties of the cereal afford the best means for preventing damage caused by scald of rye. Destroying perennial grass hosts helps reduce the amount of overwintering inoculum.

LEAF RUST

Puccinia rubigo-vera secalis

The leaf rust of rye is known also as brown rust. The variety of fungus causing the disease in rye attacks none of the other cereals. However, it attacks many species of wild rye. It is comparable to the leaf rust of wheat, crown rust of oats, and leaf rust of barley. Although it has, like the other cereal rusts, a complicated life history which involves another host, the full life history seldom is completed.

Leaf rust is one of the most destructive of the diseases of rye in Illinois. Epiphytotic in nature, it varies from year to year both in prevalence and in intensity. Data taken in field examinations during 25 seasons show that as an annual average 90 per cent of the rye plants of the state become diseased and that the disease reduces leaf area by 11 per cent. The annual prevalence of the disease has ranged from 19 to 100 per cent, and the destruction of leaf area has ranged from 2 to 20 per cent. In recent years the disease has increased in importance in this state.

Appearance.—Leaf rust of rye, fig. 47, is similar in appearance to leaf rusts of other cereals, with the exception of color. On both surfaces of a rye leaf, small, oval, orange-brown pustules are formed. These pustules break open as the rust develops, and powdery masses of reddish-brown summer spores are exposed. Elongated pustules may develop on the stem, also, and these resemble short pustules of stem rust. Toward maturity of the plant, small, elongated, dark gray pustules appear, which do not immediately break through the epidermis. These pustules contain the winter spores.

Life History.—Leaf rust of rye is unique among cereal rusts because most of its winter spores germinate when they are formed in the summer and because it overwinters by means of its summer spores and as mycelium in the leaf tissue. Original infection of rye plants in the spring results in the production of open, orange-brown pustules on the leaves; within the pustules large numbers of summer spores are formed. Distribution of these spores results in further rye infection, from which new pustules arise after a period of 7 to 10 days. Continued repeti-

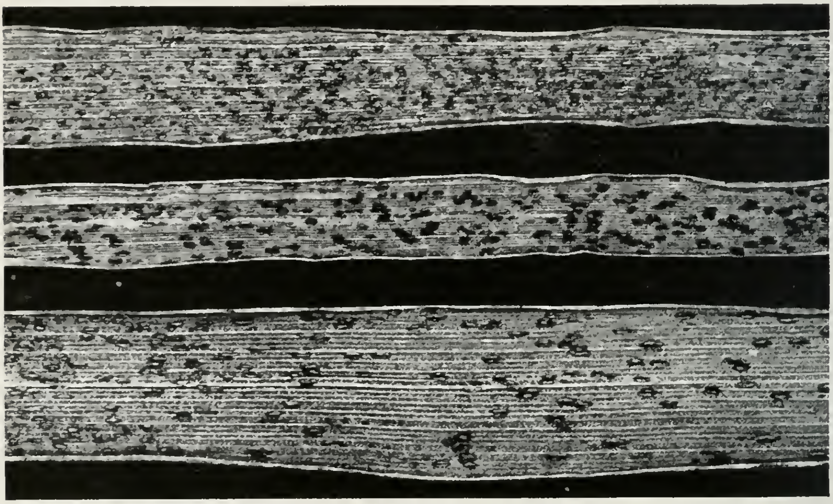

Fig. 47.—Leaf rust of rye. The dark spots scattered over each leaf shown above are the yellowish-brown, summer spore pustules from which are shed the spores that serve to spread the rust during the growing season.

tion of this summer cycle under weather conditions favorable to the fungus may result in destructive rust epiphytotics. As rye plants mature, orange-brown pustules are no longer produced, but in their places dark gray, covered pustules appear, within which winter spores are formed. Unlike the winter spores of most cereal rusts, the majority of spores of this rust germinate upon maturing and, without first infecting any host, bear other very perishable spores that are capable of infecting species of *Anchusa* or bugloss. Upon the leaves of these herbs, cluster cup structures bear still another kind of spore, which reinfects rye plants and, in so doing, starts another annual rust cycle.

In North America natural infection of *Anchusa* seldom occurs. Hence, this herb is not an important factor in perpetuating the rust. Overwintering of summer spores occurs, and the annual cycle does not differ from the summer cycle, except for the intervention of winter dormancy.

Control.—Because of the relative unimportance of rye as a crop, control of its leaf rust has received little attention. Rye varieties exhibit only slight differences in susceptibility.

STEM RUST

Puccinia graminis secalis

Stem rust of rye is caused by a variety of the stem rust fungus. This variety occurs on barley, quack grass, species of wild barley, and the rye grasses, as well as domestic rye. There are over 14 physiologic races of the variety in the United States. During 25 years of field surveys in Illinois prevalence of the disease has varied widely; in some years a trace and in others as many as 60 per cent of all plants are affected. In an average year, 17 per cent of the rye plants of the state have stem rust infection. However, there is only a trace of rust in most years.

Appearance and Life History.—In appearance and life history stem rust of rye does not differ from the stem rust of wheat described on pages 19–22.

Control.—Rye matures so early in Illinois that it seldom is damaged severely by stem rust. In northern Illinois, eradication of the common barberry may eliminate the possibility of destructive local attacks. Resistant rye varieties offer the best means of reducing losses from stem rust on this crop.

SPOT BLOTCH

Helminthosporium sativum

This disease, sometimes called crown rot, is caused by the same fungus as that which causes spot blotch on barley and wheat. It attacks the leaves, crown, roots, and joints of rye, barley, and wheat. The symptoms given for the disease on wheat, page 46, appear on rye. Much of the general discussion given under wheat applies also to rye. There are only a few records of the occurrence in Illinois of this Helminthosporium disease on rye, and the loss caused by it is very small.

SCAB

Gibberella zeae

Scab on rye, fig. 48, also called Fusarium blight and head blight, is caused by the same fungus that causes scab on other cereals. A discussion of the disease and the fungus are given under wheat, page 36.

Rye kernels severely affected by the disease are wrinkled and shriveled, have a rough surface, and are covered with a powdery, carmine growth. Lightly affected kernels are dark

Fig. 48.—Scab on rye. Infected spikelets are light colored and blighted; they produce shriveled grain. Rye heads seldom become diseased throughout.

brown. In most years, rye scab is of little economic importance in Illinois, although the disease can be found every year.

Control.—The same control measures given for scab on wheat, page 40, apply to scab on rye.

ANTHRACNOSE

Colletotrichum graminicola

Anthracnose on rye, fig. 49, is very similar to anthracnose on wheat, page 50. Resulting stem discoloration is, however, more pronounced on rye than on wheat. Many affected rye plants are stunted and blighted, and the portion of the head above a

Fig. 49.—Anthracnose on rye. The fungus attacks all basal parts of the plant as well as the heads. Many small, black, elongated fruiting bodies are visible on the stems, *A*, and on the two heads at the right, *B*. The bleached, sterile head shown in *A* was on a severely infected plant that ripened prematurely.

localized point of attack is killed, resulting in badly shriveled grains in that part of the head. This disease on rye has been reported from 31 counties, representing all parts of Illinois, but the loss attributable to it is slight. Only occasionally a field is found in which most of the plants are killed before any grain is formed. Control measures include sanitation, crop rotation, use of clean seed, and seed treatment, as described in the section on "Disease Control" beginning on page 142.

STEM SMUT

Urocystis occulta

Stem smut of rye, also called stalk smut and stripe smut, closely resembles flag smut of wheat and is caused by a fungus of the same genus but a different species. The species of fungus causing stem smut of rye does not attack wheat, nor does the species causing flag smut of wheat attack rye. Rye is the only host of the smut species that attacks rye. Stem smut has been of little consequence in Illinois, but of the three smuts attacking rye it is the most important. Prior to 1935 there were only a

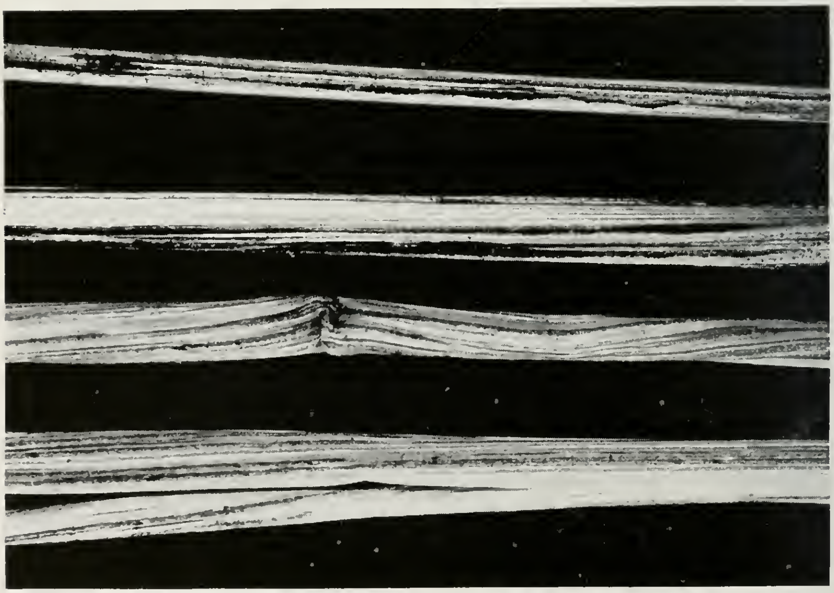

Fig. 50.—Stem smut of rye. Infection of the rye plant results in the production of lead-colored stripes running lengthwise of the leaves and stems. Eventually the stripes break open, setting free the masses of black, powdery smut spores with which they are filled.

few records of its occurrence, but in 1935 it was found in five counties in the southern half of the state and in one county in the northern half. Prevalence of infection ranged from a trace to 9 per cent of the plants examined in that year. The highest percentage of plants diseased in any field on record for the state is 25 per cent.

Appearance.—First signs of stem smut infection on rye, fig. 50, appear when the stems approach a foot in height. Diseased plants have a darker green color than healthy ones, and traces of lighter green streaks may be observed in the upper leaves. Soon these plants develop the characteristic symptoms of the disease: long, lead-colored stripes on leaves, sheaths, and stems; the stripes soon become black and break through the tissue, exposing dusty masses of spores. Affected parts may be twisted and distorted and the leaves split along the stripes, fig. 50. Stems and leaves are affected most frequently; if heads are produced, smut pustules may be found on the chaff. Diseased plants usually are stunted; they rarely head out. Usually every stalk of an affected plant is smutted. The disease often is overlooked because diseased plants are stunted.

Life History.—The disease carries over from year to year largely in the form of spores, which adhere to the seed or infest the soil. Germination of these spores and infection of rye seedlings are as described for flag smut of wheat, page 33. Subsequent growth of the fungus takes place in the growing plant, and the new crop of spores is not formed until just previous to the heading of the plant.

Control.—Because they are borne externally on rye seed, the stem smut spores can be killed by seed treatment with organic mercury dusts, page 151. The mercury dusts give some protection against infection from spores in the soil. Crop rotation, in addition to seed treatment, is recommended for control of the disease. Sowing rye when the temperature of the soil is relatively low and the soil is fairly dry usually results in heavy smut infection.

LOOSE SMUT

Ustilago tritici

Loose smut or head smut on rye, fig. 51, is caused by the same fungus that causes loose smut on wheat. Rye, however, is only slightly susceptible. In Illinois, the entire rye head is sel-

Fig. 51.—Loose smut on rye. As a rule only part of a diseased head appears to be affected; severely diseased spikelets are transformed into black spore masses that shatter off, leaving part of the stem bare, as in loose smuts of other cereals.

dom replaced by the fungus, as is the wheat head. The disease is so rare on rye that control measures are not required; however, those recommended on page 31 for loose smut of wheat are applicable.

ERGOT

Claviceps purpurea

The fungus that causes ergot attacks the kernels but no other part of the rye plant. It sometimes attacks wheat, barley, and oats, which are much less susceptible than rye. Grasses such as meadow fescue, quack grass, orchard grass, timothy, redtop, bluegrass, squirrel tail, wild rye, brome grass, and meadow foxtail are hosts of ergot, and from some of these infection may spread to rye. Ergot grains contain a very poisonous substance known as ergotin, and ergot poisoning may prove fatal to livestock fed on heavily infected grain. Usually, the disease is not prevalent enough in Illinois to endanger livestock. In most years ergot causes only a negligible reduction of rye yield in the state. Although severe infections have been reported occasionally, it generally is very difficult to find ergot-infected heads in rye fields. The disease occurs throughout the state, but often it is abundant only on volunteer rye growing in wheat fields.

Appearance.—The first sign of ergot infection usually becomes evident soon after flowering of the grain, when yellowish drops of a sticky fluid called honeydew ooze from infected flowers. This honeydew may cover the greater parts of the heads, which later become dark from adhering dust. The most charac-

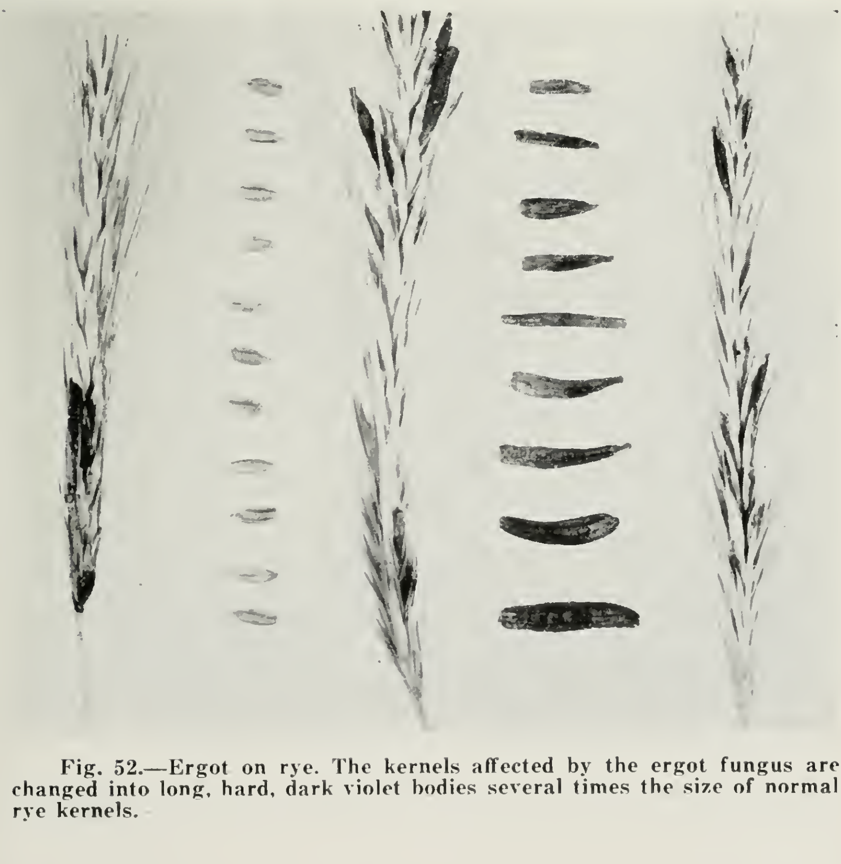

Fig. 52.—Ergot on rye. The kernels affected by the ergot fungus are changed into long, hard, dark violet bodies several times the size of normal rye kernels.

teristic and easily recognized symptom is not noticed, however, until the grain begins to ripen, when each affected kernel is replaced by a hard, violet, hornlike body, usually several times the size of a normal kernel. These bodies, known as ergots, are elongated and somewhat curved, fig. 52; they resemble the rye grain in general outline.

Life History.—The ergots may drop to the ground during harvest or they may be sown with the seed. They remain dormant during the following winter. In the spring, each ergot near the surface of the soil sends up several small, mushroom-like growths with small, thin stalks and globular heads. In these heads, spores are produced, which in late spring are shot forcibly into the air and carried by air currents to blossoming rye heads. The spores, germinating on a flower, infect the kernel and replace it with a mold growth which secretes a spore-laden, sticky honeydew, which insects and rain distribute to other plants. New infections are produced as long as host plants are in blossom and susceptible. The infected grains are transformed into ergots before maturity of the host.

Control.—Rotation of crops, removal of all ergots by fanning or a brine bath, page 147, and sanitation are the chief control measures. Susceptible wild grasses that serve as hosts should be destroyed. Ergots do not remain viable for more than a year.

POWDERY MILDEW

Erysiphe graminis secalis

While powdery mildew of rye does not differ noticeably from the disease of the same name on wheat, oats, and barley, the fungus that causes it is a highly specialized variety unable to attack the other cereals. Rye is probably more resistant to the powdery mildew organism than are wheat and barley. On rye, powdery mildew is rarely found in Illinois and is of little economic importance in the state. The discussion given under wheat diseases, page 42, indicates the life history and control of the powdery mildew fungus of rye.

TAKE-ALL

Ophiobolus graminis

Take-all has been reported on rye in Illinois. Because this disease is obscure in nature and difficult of certain diagnosis, its importance in the state of Illinois probably has been underestimated.

The appearance, life history, and control of the take-all fungus on rye are similar to those of the take-all fungus on wheat, page 52.

SEPTORIA LEAF BLOTCH

Septoria secalis

Septoria leaf blotch of rye is very similar in appearance to lesions produced by *Septoria* on the other cereals and on wild grasses. It has been collected in 11 counties in the southern half of Illinois. It seldom causes very much damage in the state. Occasionally as many as three or four leaves per culm are diseased, but usually only the oldest leaf is affected.

Appearance.—Spots or streaks on rye leaves affected by Septoria leaf blotch are light brown, irregular blotches. Many of the streaks are long and narrow, fig. 53. Many tiny brown or black specks, each not nearly as large as a pinhead but plainly

Fig. 53.—Septoria leaf blotch of rye. The fungus produces light yellow or light brown, irregular blotches on the leaves. Many tiny brown or black specks, the fruiting bodies of the fungus, are scattered through the infected leaf spots.

visible to the unaided eye, are scattered through the spots and streaks. Spots and streaks in dead leaves are much lighter (often almost white) than the surrounding tissue. Some leaf sheaths become infected with this disease.

Life History and Control.—The life history of the *Septoria* fungus that affects rye is similar to that of the *Septoria* fungus that causes speckled leaf blotch of wheat, page 25. Controls for the two diseases are similar, page 26.

SOIL-BORNE MOSAIC

Marmor tritici

Soil-borne mosaic on rye, fig. 54, is caused by the virus that causes soil-borne mosaic on wheat, page 59. The symptoms are the same on the two cereals. None of the rye varieties is known to be resistant to the mosaic virus, which can persist in soil for

Fig. 54.—Soil-borne mosaic on rye. Plants infected with the mosaic virus have leaves mottled with yellow or dark green. The mottling consists of stripes or blotches that run parallel with the long axis of a leaf. Such mottling is a characteristic symptom of the disease.

many years. Consequently, fields heavily infested with mosaic should not be planted to either rye or susceptible wheat for a number of years. Cropping with nonsusceptible plants will help reduce the amount of virus in the soil.

BACTERIAL BLIGHT

Xanthomonas translucens secalis

Although the bacterial blight of rye is similar to the bacterial blight of barley, the variety of the causal bacterium that attacks rye is not the same as the variety that attacks barley. Therefore, diseased rye does not endanger barley, and diseased barley does not endanger rye. In Illinois bacterial blight was first observed on rye near Bloomington in 1921. It is of little economic importance. The appearance, life history, and control of bacterial blight of rye are similar to those of bacterial blight of barley, page 118.

NEMATODE DISEASE

Anguina tritici

The nematode disease in rye, as in wheat, is caused by a small, eellike worm. In some states rye is attacked by nematodes almost as readily as wheat, emmer, and spelt; oats, barley, and certain wild grasses are attacked only occasionally. The characteristics of the disease are as described, page 63, under wheat, except that the galls are straw-colored in rye instead of dark brown or black. There are no records of the occurrence of nematode infection of rye in Illinois.

6

Disease Control

THE ANNUAL COST OF CROP DAMAGE by plant diseases in the United States is estimated at approximately 4 billion dollars. About half of this loss, most of it caused by fungi and bacteria, could be prevented by the proper use of available chemicals and other control measures. In Illinois, agriculture suffers an estimated yearly loss of about 200 million dollars due to plant diseases.

An understanding of the life history of the disease organism, its method of injury, its means of dissemination, and conditions favorable for its development and spread is essential to the choosing of proper measures for the control of any disease. Recommendations for control or prevention of plant diseases are based upon a knowledge of causal organisms; the fungicide or other treatments recommended are the result of years of experimenting and testing by many workers.

With cereals, as with most other plants, protecting from infection is more practical than attempting to cure. The value of an individual plant is so small that, even if cure were possible, the cost of cure would be prohibitive. The old adage, "An ounce of prevention is worth a pound of cure," is applicable to the control of cereal diseases; most preventive measures now in use, even seed treatments, are inexpensive. Many diseases now can be wholly or partially controlled by the use of specific measures, but certain diseases cannot be controlled practically by any means known today.

Control measures for combating diseases of wheat, oats, barley, and rye are discussed in the following pages under three categories: good farm practices, seed treatment, and regulation.

GOOD FARM PRACTICES

Because of differences in the life histories and habits of disease-producing organisms, no set of measures will apply to all diseases. The measures a grower uses should be determined from a study of the number and severity of diseases in his locality, their habits of spread and infection, local soil and climatic conditions, and particularly the diseases prevalent on the crops grown on his own farm.

In plans for a disease control program, the source of infection must be considered. Most seed-borne diseases can be controlled by one or more of the seed treatments, and diseases caused by soil-inhabiting fungi often can be controlled to a limited extent by certain chemicals that coat the seed with a dust residue. Diseases caused by wind-borne spores, however, are not affected by seed treatment, and other control measures discussed in the following paragraphs must be employed. Some of these measures may not always be worth while for disease control alone but are profitable because of their beneficial effect on the crop plants.

Sanitation.—One of the important preventives of plant diseases is sanitation. By sanitation is meant the elimination or destruction of disease-carrying materials. Bacteria and spores of fungi, the chief means of infection for many diseases of aboveground plant parts, are carried to plants principally by air currents. Often, the source of this inoculum is crop refuse, weeds, volunteer crop plants, or alternate hosts. Practicing sanitary measures reduces the amount of inoculum present for air currents to carry; the inoculum must be eliminated before the new crop is present if sanitation is to be effective.

One of the most effective sanitary measures is that of burning. This, however, results in destruction of valuable, badly needed organic matter and sends nitrogen up in smoke. Burning crop refuse is not generally recommended unless the grower can make provision to replace the organic matter destroyed. Thorough plowing, so as to cover all straw, stubble, and other diseased material, prevents spores from getting into the air. In some cases, plowing under infested material and later planting a susceptible crop on the land result in infection of young seedlings or roots that come in contact with the infested material in the soil. However, the benefit derived from plowing under crop refuse usually more than offsets any loss occurring from underground infection. Weeds, alternate hosts, and volunteer crop plants that might serve as sources of inoculum should be destroyed. Manure containing infested straw or cornstalks should not be used as a top dressing.

The value of sanitary measures depends upon thoroughness of the work and size of the project. The more thorough the work and the larger the area over which sanitation is practiced the greater will be the benefits derived.

Rotation of Crops.—Crop rotation does much to control weeds and to reduce the destructive work of insects and infectious organisms. Continuous use of land for a particular crop results in building up in the soil a population of organisms parasitic on that crop. Other things being equal, the higher this population becomes the greater is the loss to the crop. By rotation the continuity of favorable hosts is broken and the destructiveness of the organisms is reduced.

Certain disease-producing organisms can live in the soil for indefinite periods on almost any type of organic matter. Other soil organisms, not so omnivorous but limited to a smaller range of plant material, diminish in abundance as the host material disappears. A rotation system long enough to allow the refuse of a crop to decay before the same crop is replanted in a field reduces to a minimum the ravages of these organisms.

Resistant Varieties.—Losses from certain plant diseases may be greatly reduced, or in some cases completely eliminated, by the use of geographically adapted resistant or immune crop varieties. The production of new crop varieties resistant to disease is largely a task for the plant breeder, but many resistant selections have been made by observant farmers through choosing outstanding individuals among large populations of diseased plants. Wnen plants are found that seem to be immune or resistant to disease, the seed from them should be saved and planted separately. Should the absence of disease be due to inherent resistance, this characteristic should persist. It is this inheritance of characters that makes it possible for the plant breeder to produce new varieties which are resistant to disease.

The grower of small grains should consult his county farm adviser or the Illinois Agricultural Experiment Station at Urbana, Illinois, for the latest recommendations on approved resistant varieties. The list is changing constantly. New disease organisms or new races of old disease organisms are appearing from time to time and may attack crop varieties that have previously appeared resistant to disease. When this situation occurs, a change to other varieties may be desirable.

Cultural Methods.—The term cultural methods is used to include certain farm practices that aid crop plants in resisting disease attack or that tend to produce profitable returns even in the presence of disease. That plants do not grow well if one or more factors of the environment are unfavorable is well known to every grower. Parasitic bacteria and fungi also are affected by environmental factors.

The two great constituents of the environment of cereal crops are soil and weather. Temperature and moisture, in the soil and in the air, influence both host and parasite. Environment can be modified by indirect methods, as through cultural practices. This modification may influence the host more than the parasite but, regardless of which is affected, even slight modification may greatly reduce losses due to disease.

Soil, the medium in which plants grow, contains the water and minerals necessary for plant development. Fertility, composition, acid reaction, drainage, temperature, moisture content, and other characteristics of the soil affect plant growth and, directly or indirectly, also influence prevalence and severity of disease. In general, the more favorable conditions are for plant development the greater the produce will be, even though some diseases may be intensified by these conditions. Most treatments that can be given the soil to balance the supply of minerals, correct acidity, or furnish proper drainage and aeration will be beneficial to small grains. However, nitrogen applied to wheat fields in spring may increase the intensity of powdery mildew. Manure containing infested straw, especially when applied as a top dressing, may increase the amount of infective material to such an extent that the damage caused by disease is greater than the benefits derived from the manure.

Preparation of the seedbed has a marked influence on plant growth and, indirectly, on the amount of disease. With certain diseases such as smuts of oats and stinking smut of wheat, in which the fungus must enter a seedling before the latter emerges from the soil, the more favorable the seedbed is for rapid growth the shorter the period of susceptibility will be and the less apt infection is to occur. A thorough job of plowing that buries weed seeds and disease-bearing debris lessens the possibility of later competition with weeds and reduces the danger of infection for aerial parts of the cereal plants.

The date of seeding influences the amount of certain diseases. Early sowing, when the soil is warm, is favorable to heavy seedling blight of wheat. Barley stripe infection is apt to be less when seed is sown in warm soil than when sown in cold soil. Oats sown as early in spring as possible usually have less severe rust infection than late-sown oats, since the crop sown early is likely to mature before the rust becomes very destructive.

While rate of seeding should be determined largely by soil fertility, available moisture, and crop variety, it should be determined in part by its effect upon disease organisms. Dense vegetative growth produces humid conditions favorable to fungus and bacterial infection. Rate of seeding can control this factor of the environment to some extent.

The depth of seeding has a bearing on the amount of infection. The shallower the seed is sown, provided there is sufficient moisture available for germination, the sooner the seedlings pass the stage of susceptibility to certain smuts.

The use of early-maturing cereal varieties will in most years lessen the amount of damage from rusts and certain other diseases. Infection of stem rust of all cereals, crown rust of oats, and leaf rust of barley seldom occurs early in the development of the plants. The more advanced the development of the plant when initial infection occurs the fewer are the generations of rust organisms and the smaller is apt to be the resulting loss.

Importance of Good Seed.—Good seed is a most important requirement in cereal crop production. Even if all other factors are optimum, a poor crop will result if poor seed is used. It is essential to select a cereal variety that is adapted to the locality and that has other characteristics that fit the needs of the grower. Among these characteristics are its date of maturity, its ability to withstand extremes of the climate, its ability to yield, its resistance or susceptibility to the most important diseases, the quality of its grain, and the stiffness of its straw.

Cleaning Seed.—All seed should be well cleaned before being sown. This is best done by fanning and screening, a practice now used by many farmers but one that should be universal. The ordinary fanning mill is adequate for farm use and, with screens of proper size and proper amounts of air, satisfactory results can be obtained. For best results the mill should be run at the recommended speed and at less than its full capacity. By fanning, weed seeds, foreign materials, smut balls, nematode galls, and many inferior grains are removed. It may be necessary to fan the seed more than once to remove all the smut balls and nematode galls that may be present. Among the inferior grains will be those that are light in weight and shriveled as a result of disease attack. Many of these would not germinate or, if they did, would produce poor stands, weak plants, and small yields. Only large, heavy, plump, clean grains should be sown. The seed should be treated with a fungicide after it has been cleaned.

If a central cleaning plant is available, farmers can have their seed cleaned and treated for a few cents per bushel. Such a plant cleans seed more thoroughly than can be done by the equipment on an average farm. In some areas, cleaning equipment is mounted on a truck, and the operator comes to the farm to clean and treat the seed, fig. 56.

Seed can be cleaned by the brine method. However, this method is not recommended except for seed from which fanning has failed to remove smut balls or nematode galls. To use the brine method, prepare a 20 per cent salt solution by dissolving 8 pounds of common salt to each 5 gallons of water in a suitable container—a small tank or barrel. Pour a small quantity of seed, preferably a peck or less, into the container while vigorously stirring the solution. With a strainer skim off all floating seed and debris. Repeat the stirring and skimming process until all smut balls and nematode galls have been removed. Drain off the salt solution and rinse the seed in several changes of fresh water to remove all traces of salt. Salt allowed to remain on the seed will interfere with germination. When all of the salt has been removed, dry the seed and sow it immediately or store it for later use.

Special Seed Plots.—The use of disease-free or nearly disease-free seed is a means of preventing or minimizing damage by seed-borne diseases. Seed of this kind may be purchased as certified seed or it may be produced on the farm in a special seed plot. The seed plot is most useful in preventing losses from loose smut of wheat and true loose smut of barley, deep-seated diseases that cannot be controlled by chemical treatments.

The site for the special seed plot must not have had the crop that is to be planted, or another susceptible crop, growing on it for a period of 2 or more years. The possibility of windborne infection is minimized if the seed plot is a considerable distance from fields planted to the same crop and if a tall crop of another kind or a windbreak is on the windward side of the plot.

The best seed obtainable should be used to plant the special seed plot. Before being planted, the seed should be treated with a fungicide, as described in the section "Seed Treatment," or, if loose smut (of wheat) or true loose smut (of barley) is present, it should first be given the hot-water treatment.

Every day or two during the heading period, the special seed plot should be carefully examined and all smut-infected plants removed before the spores are spread to healthy heads. Plants that are not true to variety can be removed at the same time.

Seed from the special seed plot should be free of smut infection if the plot is distant from infected fields and it has been thoroughly rogued during heading. The crop produced from this seed and from succeeding crops should remain free of smut until infection is brought in from outside sources—usually at least a year or two. A good supply of smut-free seed can be assured if the special seed plot is maintained each year; seed from this plot should be used to sow each next year's plot and thorough roguing should be practiced each year.

Certified seed bought from reliable dealers will aid in preventing serious damage by diseases. Such seed carries a minimum amount of infection, since the fields in which it is grown are examined by competent inspectors, who issue certificates only when fields meet certain specifications with respect to freedom from disease.

Fungicides on Growing Plants.—Although fungicidal sprays or dusts are used extensively by horticulturists to control diseases, they have not been adopted by grain growers for use on growing plants. Experiments performed many years ago showed that certain fungicides applied to small grains at the proper times resulted in marked increases in yield. However, cost, methods of application, and other factors made it impractical to use the chemicals then available.

In recent years new chemicals, better equipment, and improved methods of application have been developed. Much research is under way with the newer fungicides and antibiotics to determine their value in controlling diseases of small grains. Some of these materials are very promising. A material should be available in a few years which can be applied economically and which will reduce the toll taken by cereal diseases caused by air-borne spores.

SEED TREATMENT

Because most fungi and bacteria that cause diseases of small grains are present on or in the seed or in the soil, treatment of the seed before it is sown is recommended. Either of two types of treatment, chemical and hot-water, may be used; the type to be used depends upon the disease or diseases to be controlled.

Volatile chemicals that are marketed in dry form are effective against disease organisms that are carried on the seed, immediately beneath the seed coat, or in the soil. Some of these organisms cause leaf spots, damping-off or seedling blight, crown rots, and root rots. Nonvolatile chemicals marketed in dry or liquid form are effective only against organisms on the seed.

The hot-water treatment is effective against all seed-borne disease organisms of small grains, including those that are deep within the seed. This treatment usually is recommended only against the two deep-seated diseases, loose smut of wheat and true loose smut of barley. Disease organisms on the surface of the seed or immediately beneath the seed coat can be more easily controlled by volatile chemicals. Hot-water treatment does not protect the seed against soil-borne organisms.

Hot-Water Treatment.—Although the hot-water seed treatment kills both external and internal seed infection, it is generally not recommended for use on farms because the average farm lacks facilities for performing the treatment satisfactorily. However, as the only treatment that will control the deep internal infections, loose smut of wheat and true loose smut of barley, it is recommended to producers of certified seed, seed dealers, and others who are able to assemble the tanks or vats and other equipment necessary for satisfactory results. If hot-water treatment can be made a community project, each farmer in the community can have treated seed for his fields or at least enough treated seed for a seed plot from which disease-free seed can be obtained.

Since the effectiveness of the hot-water treatment depends upon raising the temperature of the seed high enough to kill any internal infection but not high enough to kill the germ of normally healthy seed, many of the weak and cracked kernels and those with broken seed coats will be damaged by the treatment. It is therefore advisable to test the seed for germination after it has been treated and to increase the rate of seeding to compensate for the seed that has been damaged.

The equipment necessary for the hot-water treatment includes three tanks large enough to accommodate the amount of seed to be treated, a standardized, accurately graduated thermometer, and equipment for maintaining hot water at the required temperatures.

For wheat, the water in the first tank is unheated. That in the second tank is maintained at 120 degrees F. and that in the third at approximately 131 degrees F. The temperatures in the second and third tanks must be kept as nearly constant as possible, preferably by the addition of hot water, which is more effective than live steam in maintaining uniform temperatures.

The wheat seed, thoroughly cleaned and sacked in half-bushel lots, each half-bushel in a loosely woven 2-bushel burlap sack, is soaked in the unheated water tank for 6 hours; the sacks should be turned every half hour to prevent caking of the seed. It is then removed and allowed to drain for a minute or two. Next the sacks of seed, one at a time, are transferred to the second tank (water temperature 120 degrees F.), submerged, and agitated for a few minutes to raise the temperature of the seed nearly to that of the water. The sacks of seed are then quickly transferred to the third tank (water temperature about 131 degrees F.), and the water, cooled by the seed, is quickly brought up to 130 degrees F. The sacks are agitated in the water and in 10 minutes are removed from the tank. The seed, still in the sacks, is cooled by being dipped immediately into cold water or by being removed from the sacks and spread in a thin layer on a clean surface and stirred occasionally. It should be dried as soon as possible. The sacks should lie on their sides in each of the three tanks.

Some farmers have found that with an iron kettle of the type used in butchering they have no difficulty in maintaining water at the proper temperatures for treating wheat seed, if a supply of cold water and hot water is kept available and if the fire under the kettle is such that it can be removed in case of necessity.

The hot-water treatment for barley must be done with extreme care. The process is the same as for wheat, except that the seed is soaked in the first tank for 5 hours in water at about 70 degrees F., the temperature of the water in the third tank is kept at exactly 126 degrees F., and the seed is removed in exactly 11 minutes.

Treated seed can be sown as soon as it is dry enough to pass through the drill; the rate of seeding must be increased by about 25 per cent over the normal seeding rate to allow for the swollen condition of the seed and by an additional percentage to allow for the seed that has been damaged by the treatment.

Chemical Treatment.—Chemical treatment is designed (1) to kill disease-producing organisms on the surface of seed and (2), when applied as a dust or slurry, to form a dust coating on each seed that will help protect the seed during the period of germination from soil-inhabiting organisms that produce disease.

Most of the chemical preparations at present recommended for treating small grains contain some form of mercury and are volatile. Now commonly used by commercial distributors of small grain seed and by grain growers on their farms, they have replaced formaldehyde, copper carbonate, and copper sulfate, once in general use. The newer chemical preparations, commonly called fungicides, are effective against many bacteria as well as fungi. Some are available in dry form and others as liquids. A dry fungicide may be applied as a dust or as a thick suspension called a slurry. A liquid fungicide may be applied as a concentrate or as a dilution. The volatile fungicides are effective against disease organisms directly beneath the seed coat as well as those on the surface of the seed.

For farm application of a dry fungicide as a dust, a definite quantity of the dry fungicide is added to a definite amount of grain in a dust-tight batch treater, and the treater is rotated until all seeds are uniformly coated with the fungicide; usually 30 or more complete turns of the treater are required. The batch treater, which may be a concrete mixer or a device made from an oil drum, fig. 55, should not be more than half filled and it should be dust tight. With such a device, two men can treat about 30 bushels of seed per hour. Volatile dust fungicides, which include the mercurials, may be applied in one of the gravity-type treaters or they may be applied to seed spread over a clean surface in a well-ventilated place, as described below for a slurry. Seed and fungicide cannot be mixed as thoroughly in a gravity treater as in an oil drum mixer. Before the treated seed is sown, it should be sacked, or placed in piles and covered with canvas, and held for a day or two to allow the gases of the volatile fungicide to permeate the seed. When the fungicide dust is thoroughly distributed throughout the seed, the particles form a coating on the individual kernels and help to protect them against soil-borne infection during germination. Some mercury dusts in use today are *Ceresan M*, *Ceresan M2X*, *Agrox*, *Mergamma*, and *Puraseed*.

The chief objection to dust treatments is that the dust, which rises into the air while the seed is being treated and while it is being handled as it is sown, is hazardous to the person handling the seed unless he is properly protected by an approved dust mask and rubber gloves.

A slurry is a suspension made by adding a dry fungicide to water. For seed treatment, a definite amount of the fungicide in a slurry form is added to a definite amount of grain, and the two are mixed together. One pound of fungicide mixed in a gallon of water will treat 32 bushels of seed at the rate of one-half ounce of the fungicide per bushel; the treatment will add less than 1 per cent moisture to the seed. If a greater dosage of fungicide is required, a greater amount of the chemical is added to a gallon of water.

The best method of applying a slurry is with a commercial slurry treater. However, a slurry can be applied in one of the batch treaters mentioned above. It can also be applied to seed spread over a clean surface, such as a floor or wagon bed, in a well-ventilated place; the seed and chemical are shoveled over several times, put in a pile, and, to permit the gases from the fungicide to permeate the pile, the seed is covered with a canvas for at least 2 days before it is sown. Like the dust treatment, the slurry treatment, if thorough, helps to protect the seed against soil-borne infection. The slurry treatment eliminates most of the dust hazard in treating the seed but not in handling treated seed that is being sown. Seed treated with slurry does not need to be dried before it is sown.

When seed is treated with a liquid fungicide, a relatively small amount of the concentrated liquid may be added to the seed and thoroughly mixed with it, or the fungicide may be used in diluted form and applied in a homemade batch treater or in a commercial slurry treater. *Panogen* and *Sterete* are liquid volatile chemicals containing mercury. A nonvolatile fungicide, such as *Vancide 51*, can be used on wheat and rye, but it is not recommended for barley and oats, which have hulls. A liquid fungicide offers little protection against soil-borne infection.

Because new fungicides are developed from time to time, the grower should contact his county farm adviser or the Illinois Agricultural Experiment Station, Urbana, Illinois, for the latest recommendations on materials and methods of application.

Fig. 55.—Oil drum seed treater. This is one type of device that can be used to treat seed with dust, slurry, or liquid fungicides. (Photograph from Emil Mosser, Farm Adviser, White County.)

Apparatus for Applying Fungicides.—Equipment for applying fungicides as dusts or slurries may be made on the farm or it may be purchased from manufacturers. Homemade batch mixers treat 25 to 30 bushels per hour, while commercial outfits treat up to 500 bushels in the same period. Barrels, oil drums, concrete mixers, barrel churns, gravity mixers, and commercial cleaning and treating machines may be used in applying the chemicals. The important precautions to remember in using the batch mixers are that the containers should not be over one-half full and that they should be rotated long enough to evenly coat each grain with the chemical—30 or more complete turns of the machine. Only dust-tight containers should be used.

An oil drum mixer, fig. 55, can be constructed at very reasonable cost and is quite satisfactory for treating all kinds of grain. Probably its greatest disadvantage is the labor required in turning the drum during the mixing operation. A 30-gallon barrel will treat 1 bushel of seed in one operation. If a concrete mixer is used for seed treatment, the lid should be fastened tight enough to prevent escape of the fungicide while the seed is being treated.

A gravity-type mixer (there are several different kinds), may be used for mercury fungicides that give off a disinfectant gas, but not for those fungicides that do not. Seed and chemical cannot be mixed as thoroughly with this machine as with an oil drum treater. As grain is poured into the hopper of the gravity mixer, the volatile mercury dust should be added slowly and continuously at the rate recommended by the manufacturer. The hopper should never be allowed to become empty during the process. The correct rate of application of the disinfectant may be determined by computing the time required for several bushels of grain to pass through the machine and then calculating the time required for 1 bushel.

Commercial cleaning and treating machines require only one operation to prepare seed for sowing. Some of these machines, suitable for custom treating, are mounted on trucks, fig. 56, and brought to the seed granaries on farms. The cost for this service generally may be considered low if the convenience, thoroughness, and rapidity of the operation are taken into account.

Special machinery for cleaning and treating seed is available to grain elevators, seed houses, and commercial treating

Fig. 56.—Seed cleaner and treater mounted on a truck. It treats about 55,000 bushels of seed a year. (Photograph from Emil Mosser, Farm Adviser, White County.)

plants. Seed that has been cleaned and treated commercially and bought from reliable dealers need not be retreated.

Seed Treatment Suggestions.—All seed to be treated on the farm should first be thoroughly cleaned to remove smut balls, nematode galls, weed seeds, crop fragments, and light, shriveled grain. Even grain that appears to be free of serious diseases usually carries enough invisible disease-producing organisms to cause appreciable loss if it is not treated.

The amount of fungicide specified by the manufacturer should be used. Directions and precautions on the container should be followed carefully. Using too little fungicide is false economy, since it gives unsatisfactory disease control; using too much is wasteful and may cause severe damage to the germ of the seed. It is false economy to assume that, if a little is good, double the amount is better.

The fungicide should be thoroughly mixed with the grain. This is very important if a nonvolatile disinfectant, such as *Vancide 51*, is used. A chemical cannot be thoroughly mixed with grain by putting the chemical on top of the grain in the drill. Grain that has been treated with volatile dusts should be stored in sacks or in a pile covered with canvas for a couple of days before being sown; gas given off by the chemical counteracts to some extent any lack of thoroughness in coating each grain.

Seed subjected to the hot-water treatment may be sown immediately after it becomes dry enough to pass through the drill; preferably, however, it should be thoroughly dried and tested for germination before it is sown.

WARNINGS

Consider all chemicals used in seed treatments as poisonous. Read carefully and follow the manufacturer's recommendations. Avoid inhaling the dust or fumes of chemicals. Work in the open or in a well-ventilated place. Wear rubber gloves when treating seed or handling freshly treated seed. Wear an approved dust mask or respirator. Do not allow chemicals to touch the skin. They may burn or blister. Wash frequently and dry skin thoroughly. Do not use treated seed for feed or food. Properly label sacks containing treated seed. Thoroughly clean sacks before using them for other purposes.

REGULATION

Among the regulative measures designed to prevent serious losses from crop diseases are inspection, eradication, and quarantine. State and federal agencies are co-operating with farmers in applying these measures to prevent the introduction and spread of serious infections and to control outbreaks.

Inspection.—Inspection or examination services may be divided into two classes; namely, inspection of plants and plant materials raised within the United States, and inspection of plants and plant materials imported from foreign countries. These services are very valuable, since certain serious diseases are still not widely spread in the United States, and some diseases known in foreign countries have not entered the United States. The state and federal governments have trained men who inspect plants for insect and disease infection and thus protect growers against the introduction of serious pests with purchased material.

Any grain grower buying seed of unknown origin should treat it before sowing it and should examine plants in the field several times during the growing season for any abnormalities that may appear. Vigilant inspection of crops may lead to stamping out a new disease before it becomes widely distributed. Anyone finding a disease that appears to be new is requested to report it to the Illinois Natural History Survey, Natural Resources

Building, Urbana. A qualified plant pathologist will examine the crop free of charge.

Quarantine.—The state and federal governments co-operate in establishing quarantined areas for destructive diseases whenever segregation is deemed necessary or beneficial. One way in which diseases new to an area are distributed is through man's activities. If suitable regulations are made regarding such diseases, or the plants that harbor them, the diseases may be eradicated before they can go beyond control. Some introduced parasites appear to attack their host plants more virulently in new territory than in their native lands, and so are generally regarded as more dangerous than native parasites. Quarantined areas are inspected from time to time to determine whether the diseases for which the quarantines have been established have been eliminated or reduced to such an extent that the quarantines may safely be removed.

Eradication.—Eradication, although generally carried on over large areas by state and federal governments, can be adopted to good advantage by individual farmers. Weeds, wild plants, and unimportant cultivated plants often serve as hosts to disease-producing organisms of valuable crop plants. Some diseases live on less valuable plants during the time of year that the crop plants are not available to them. Eradication of alternate hosts reduces the amount of infectious material present to attack the crop plants. Eradication of common barberry and buckthorn, alternate hosts of stem and crown rusts, tends to reduce the amount of these rusts on crops grown nearby.

The federal government has carried on an extensive program of barberry eradication in Illinois and other states. In many regions, the common barberry has been nearly eliminated. Thus, the danger of severe local stem rust epiphytotics and development of new races of rust fungus have been greatly lessened.

Some Publications of the Illinois Natural History Survey

BULLETIN

Volume 26, Article 3.—Natural Availability of Oak Wilt Inocula. By E. A. Curl. June, 1955. 48 pp., frontis., 22 figs., bibliog.

Volume 26, Article 4.—Efficiency and Selectivity of Commercial Fishing Devices Used on the Mississippi River. By William C. Starrett and Paul G. Barnickol. July, 1955. 42 pp., frontis., 17 figs., bibliog.

Volume 26, Article 5.—Hill Prairies of Illinois. By Robert A. Evers. August, 1955. 80 pp., frontis., 28 figs., bibliog.

Volume 26, Article 6.—Fusarium Disease of Gladiolus: Its Causal Agent. By Junius L. Forsberg. September, 1955. 57 pp., frontis., 22 figs., bibliog.

Volume 27, Article 1.—Ecological Life History of the Warmouth. By R. Weldon Larimore. August, 1957. 84 pp., color frontis., 27 figs., bibliog.

Volume 27, Article 2.—A Century of Biological Research. By Harlow B. Mills, George C. Decker, Herbert H. Ross, J. Cedric Carter, George W. Bennett, Thomas G. Scott, James S. Ayars, Ruth R. Warrick, and Bessie B. East. December, 1958. 150 pp., 2 frontis., illus., bibliog. $1.00.

Volume 27, Article 3.—Lead Poisoning as a Mortality Factor in Waterfowl Populations. By Frank C. Bellrose. May, 1959. 54 pp., frontis., 9 figs., bibliog. 50 cents.

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CIRCULAR

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42.—Winter Foods of the Bobwhite in Southern Illinois. By Edward J. Larimer. May, 1960. 36 pp., 11 figs., bibliog.

MANUAL

3.—Fieldbook of Native Illinois Shrubs. By Leo R. Tehon. December, 1942. 307 pp., 4 color pls., 72 figs., glossary, index. $1.75.

4.—Fieldbook of Illinois Mammals. By Donald F. Hoffmeister and Carl O. Mohr. June, 1957. 233 pp., color frontis., 119 figs., glossary, bibliog., index. $1.75.

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