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SMUTS OF COLORADO GRAINS

By L. W. DURRELL

COLORADO EXPERIMENT STATION
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The Colorado Agricultural College

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SMUTS OF COLORADO GRAINS

By L. W. DURRELL

The smuts of grains cause great yearly loss to Colorado farmers. There are several of these grain smuts; the stinking smut of wheat, the loose smut of wheat, loose and covered smut of oats, loose and covered smut of barley, millet smut, sorghum smut and corn smut. These smuts are distinct, each being caused by a special parasite of the different grains, producing black smutted masses on the plant.

There is some confusion in the mind of the average grain grower regarding these smuts and little distinction is generally made between one smut and another. Smut on barley, however, is not the same as that on wheat and loose smut of wheat, for instance, is not the same as stinking smut. Neither do the smuts attack the grains in the same way nor are the control methods applicable to one smut necessarily effective for another.

In order to enable the Colorado grower to understand better the nature of our grain smuts and make available the current knowledge of methods of control, the following descriptions are offered of our more important smuts of grains.

What Smuts Are

Smuts are caused by fungi or molds, microscopic organisms that live as parasites in the cells of the grain plant. They cause the head of the grain or other affected tissues to develop abnormally and produce masses of black smutty material composed of spores. These spores are the "seeds" of the fungus. They are very minute, round cells as shown in Fig. 1. where they are compared in size to a human hair.

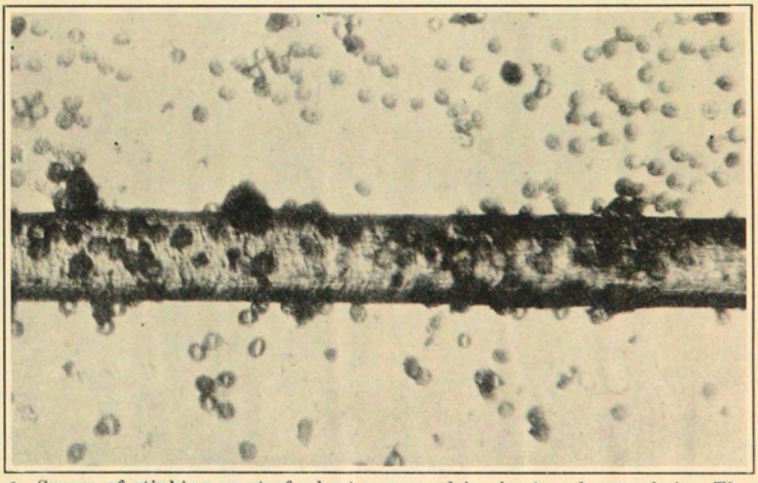


Fig. 1—Spores of stinking smut of wheat compared in size to a human hair. The hair and spores are magnified about 100 times. Note that a hair is about 5 times as wide as a spore which gives some idea of the minuteness of these "seeds" of the smut fungus.

Smuts are spread by the means of these spores. They may be borne for some distance by the wind, distributed by the threshing machine or they may fall to the soil where they can live for considerable time. The most common method of distribution and infection is by the spores sticking to the healthy seed and being planted with it.

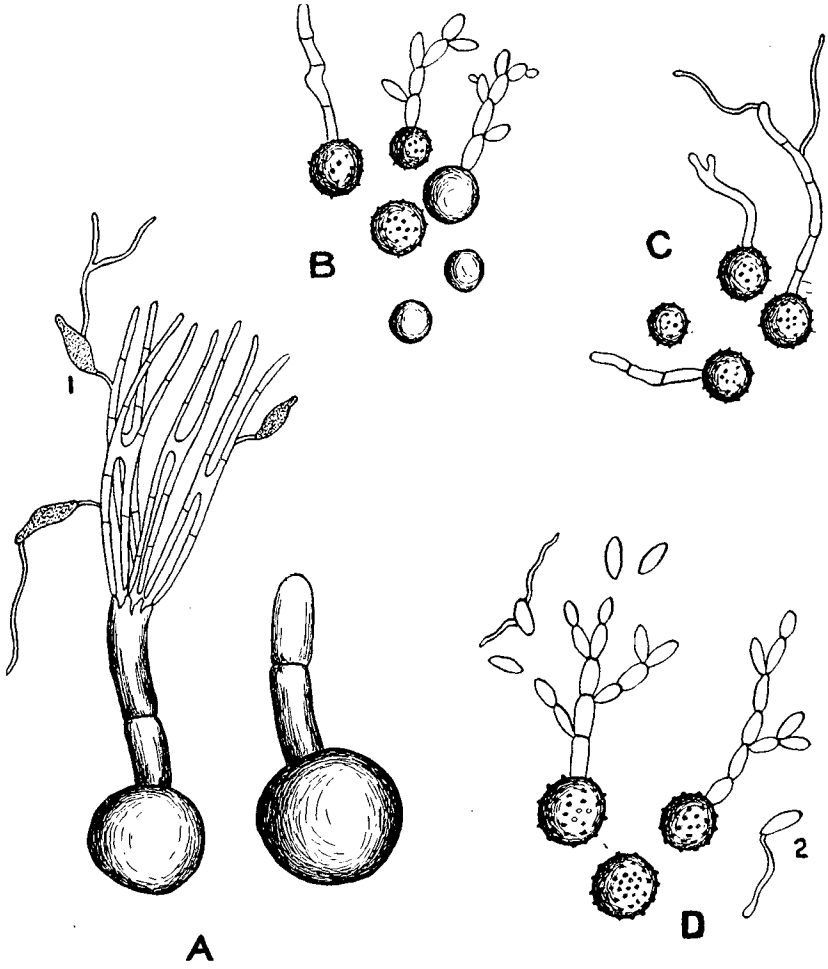


Fig. 2.—Spores of different kinds of grain smut magnified about 1000 times.

A. Spores of stinking smut of wheat, germinating, producing secondary spores and infection tubes (1).

B. Spores of loose and covered smut of oats.

C. Spores of loose smut of wheat growing infection tubes that can enter the wheat flower.

D. Corn smut spores producing a number of secondary cells (2) a secondary spore germinating, producing an infection tube that can penetrate the tissue of the corn plant.

How Spores of Smut Germinate and Infect Grain

Smut spores are round, ball-like cells produced by the smut fungi. Tho not true seeds they serve the purpose of seeds for the smut fungus. They are very minute as shown in Fig. 1. and are easily blown by the wind for considerable distances.

Those of different species of smut have different sizes and shapes, some are covered with minute spines over their surface. In Fig. 2 are shown drawings of different kinds of spores of grain smuts.

These spores when moistened in the soil or on a grain plant germinate, producing minute sprouts consisting of chains of cells (Fig. 2).

In the case of loose smut of wheat and loose smut of barley these tube-like growths enter the ovary of an open wheat or barley flower as the case may be, and, after growing for a time, lie dormant until the grain is planted.

The spores of corn smut on germination in the corn flowers or down in the moist leaf sheath produce chains of small colorless cells. These can grow for some time before infecting the corn. They can germinate and grow this way also in moist soil and in manure heaps. The secondary cells produced from the spore can infect the corn by growing into the soft growing tissues of the flower or stalk.

The spores of the other smuts considered in this bulletin become attached to the seed of the grain and germinate there when the grain is planted. They produce normally a group of several cells, these in turn produce some small secondary spores that send out sprouts or fungus threads that penetrate the seedling grain.

In Fig. 2 are shown the methods of germination of the spores of different grain smuts.

General Questions About Smuts

One of the common questions regarding smuts is how are they spread? As seen above, the spores of the smuts are very small and they can easily be blown by the wind. The spores of loose smut of wheat and barley are known to be blown from field to field infecting healthy heads of grain.

Spores are also carried from farm to farm and from one lot of grain to another by threshing machines.

The combine spreads the chaff, straw, and smut spores back on the ground increasing the chances of smut infection in the case of stinking smut of wheat.

The chief way smut is spread is by the seed. With the exception of corn smut, infected seed is the chief source of smut infection.

Corn smut is spread from the old smut boils in the field or, since it can live in manure, it is often spread over the field when the

manure is spread. It cannot live long in silage and where smutted corn is siloed, the chances of spread and infection are reduced.

It is generally thot that smut spores eaten by animals are killed by the stomach juices. Corn smut living in manure gets in by trampling of waste fodder and the live smut has not passed thru the animals.

A frequent question regarding smut, especially corn smut, is this: Is smut poisonous to animals? Some injury has been reported from feeding badly smutted oat hay. Numerous experiments, however, seem to indicate that smuts are not injurious. On the other hand, it cannot be said to be very nutritious. Animals have been fed large amounts of corn smut without injury.

Types of Smuts

There are three general types of smuts, based on their method of infection.

Seed Infection.—In this the spores adhere to the outside of the seed, germinate and infect the young seedling. Stinking smut of wheat and loose smut of oats are examples of this type of smut.

Flower Infection.—Smuts of this class infect the flowers of the plant on which they are parasitic. The spores are borne to open flowers and grow into the developing seed. In the spring the fungus, which has lain dormant in the seed, starts to grow at the same time as the seedling, grows up with the plant and produces a smutty mass in the grain head. Loose smut of wheat and loose smut of barley are the two grain smuts of this kind. Two seasons are required for their complete development.

Local Infection of Growing Parts.—The third type of smut is corn smut. Here infection takes place at any growing point after the plant is above ground. The tassels, the ears, and the growing joints of the stalk are the chief points of attack. The smut spores are blown from the soil, where they have over-wintered, to the corn plant where they germinate and infect the growing tissues. After infection abnormal growths are produced on the corn plant by the fungus which result in a mass of smut spores.

Stinking Smut of Wheat

Stinking smut of wheat (Tilletia laevis) is one of the limiting factors in winter-wheat production in Colorado, causing large yearly

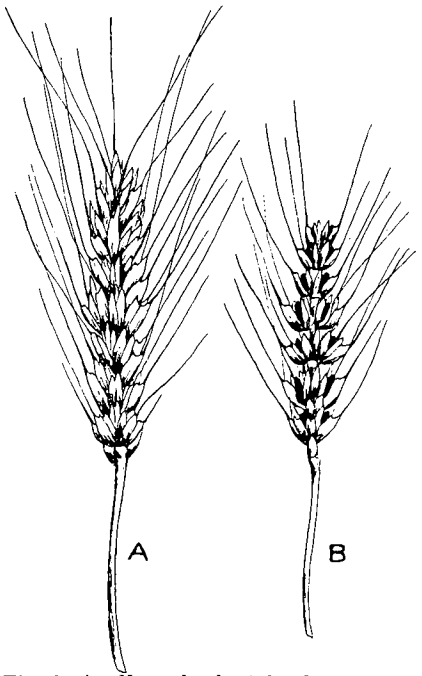


Fig. 3—A. Normal wheat head.
B. Wheat head infected with stinking smut. Note black smut balls and the smaller size of the head.

losses, not only in reduced yields but in dockage at the elevator. The fungus causing stinking smut lives as a parasite in the wheat plant causing dwarfing of the plant and destruction of the grain. In the wheat kernels the organism produces its spores at the time the wheat is heading. Masses of these spores are contained in the smutted heads and show as a dark powder when diseased heads or grains are crushed. The heads are frequently smaller than normal heads and the smutted kernels show under the chaff, Fig. 3. The wheat kernels affected with the smut retain their original shape tho they are usually smaller and more rounded, Fig. 4. Instead of the starchy content of the normal seed, the diseased kernels are filled with dark brown smut spores. In threshing, the smut spores are dusted over the grain and stick to the surface of the kernel. When such seed covered with smut spores is planted the spores germinate at the same time the seed germinates and infect the young seedling. In Fig. 5 is given an illustration of the life history of the smut fungus from the time it infects the seedling until the smutted heads are produced and infection takes place the following year. The manner of infection and the stooling of the wheat sometimes results in a partial smutting of the plant not all the heads in a stool being smutted.

How to Determine Smut Losses in Grain Fields

Farmers often make the mistake of thinking they have very small amounts or no smut at all in fields of grain, when, on careful examination of a field, it is discovered that from 10 to even as high as 25 percent of the field may be infected with smut. It is of value to the farmer to know how to make accurate determinations of the amount of smut in his grain crop to make sure that his method of seed treatment for smut prevention is effective. The following plan is quick and fairly accurate and is recommended for the farmers' use in this examination.

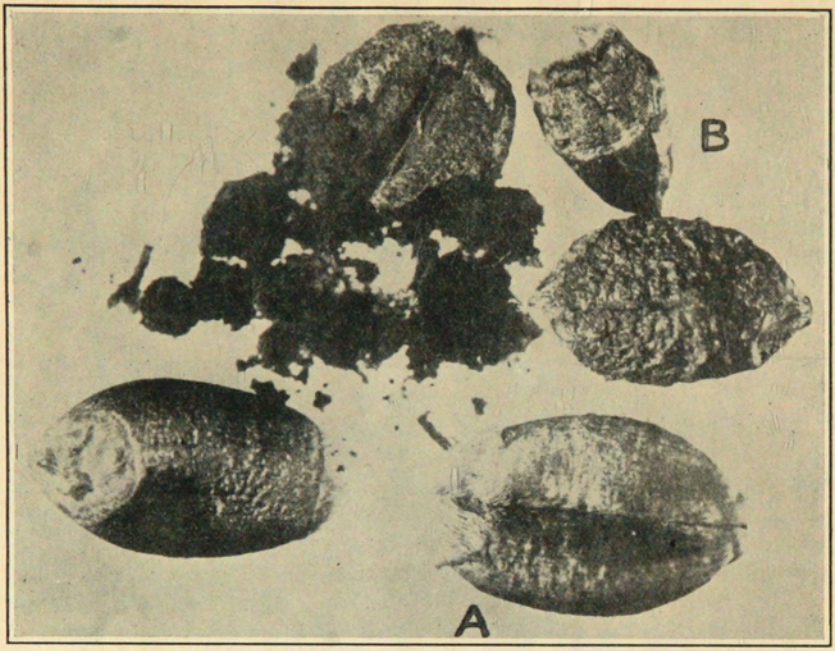


Fig. 4—A. Normal wheat kernels.
B. Smut balls or diseased kernels. These smut balls are smaller than normal kernels and when crushed are found to contain a black mass of smut spores as shown in picture.

Where stinking smut is present in a field the smutted plants may be recognized by their stunted growth, being sometimes only half as tall as healthy plants. The smutted heads, before ripening, are shorter than normal heads and appear a bluish green in color. On ripening, the smutted heads show the diseased kernels bulging out from the chaff, being black and easily seen. The smutted heads are usually more distinct than others but by crushing a suspected head, if any smut is present it is easily detected.

In estimating the amount of smut in a field the following very simple method requires but little time and is quite accurate.

1. Measure off at different places in the field a yard of row. This yard can be made uniform by taking a yardstick or simply by marking off one pace.

2. The total number of heads in this yard of row should be counted and noted on a piece of paper.

3. The number of smutted heads in the yard of row should be determined.

4. The percentage of smut infection may be determined by dividing the number of smutted heads in the yard of row by the total

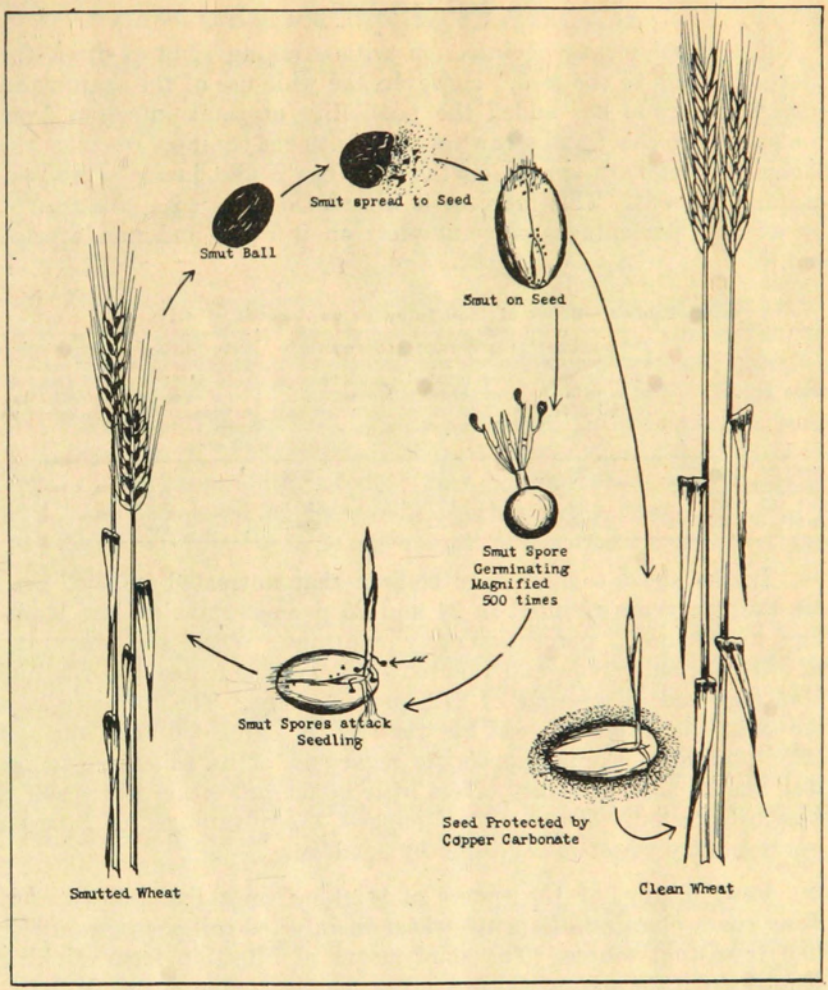


Fig. 5—Diagram showing the life history of stinking smut.

number of heads and multiplying by 100. This gives the percentage of smut in that part of the field examined.

5. Make at least ten such counts in the field and determine the average, which is fairly accurate for the field.

Determining the amount of smut in the field will not take a great deal of time, will give an idea of how seed treatment is working and will make the farmer more careful in the production of smut-free grain.

Soil Infection

The usual means of infection with stinking smut is from the spores sticking to the seed. However, the wide use of the combine in eastern Colorado has added the possibility of smut infection from the soil. The chaff and straw together with the smut spores from the threshed wheat are spread on the land again and increase the percentage of smut. This increase is illustrated in the following table, by average percentages of smut plots on infected and non-infected soil.

Table 1.—Effect of Soil Infection on Amount of Smut

Date	Percentage smut on untreated seed in non-infected soil	Percentage smut on seed treated 4 oz. copper carbonate in infected soil	Percentage smut on seed treated formalin in infected soil	Percentage smut on seed treated 4 oz. copper carbonate in non- infected soil	Percentage smut on seed treated formalin in non-infected soil
Oct. 22, 1926	24	21.3	23.4	0.4	0.6
Sept. 23, 1926	0.2	0.2	0.5	0.0	0.0
Oct. 23, 1927	26.	17.5	32.5	3.9	1.8
Sept. 18, 1927	6.	2.1	4.2	5.7	0.0

In the above table it may be seen that untreated infected seed for the two years resulted in 24 and 26 percent smut on late plantings, and 6 and 0.2 percent on early plantings. Where seed was treated with formaldehyde and planted on heavily infected soil the late plantings had an average of 27.9 percent smut. The formalin kills the smut spores on the seed but the seed is reinfected from the soil after planting. Copper carbonate regardless of its adherence to the seed and its slow solubility offers little better protection where soil is heavily infected. These figures suggest the advantages of rotation where smutty wheat is harvested by combine.

Few, if any, of the spores of stinking smut live over winter. Four years planting of spring wheat in infected soil shows no infection from that source. The chief means of infection from stinking smut is from the spores which stick to the seed. The degree of smuttiness of plants from such seed is more or less proportional to the amount of smut sticking to it. Those seeds which show black from smut sticking to them are most liable to result in smutty plants. Most satisfactory results will be obtained from carefully cleaned seed as free from smut as possible.

Unbroken smut balls in grain also are a source of infection. Tho they may escape breakage in threshing they may be broken later. Such smut balls contain thousands of spores which can be scattered over the seed. Smut spores may live for considerable time in unbroken smut balls in the soil.

Conditions Affecting Smut Infection

Several conditions influence the degree of smut infection; the above mentioned smuttiness of seed and also the amount of moisture in the soil and the soil temperature. Smut spores germinate best in a soil having a moisture content of approximately 19 to 25 percent The limits of this are rather narrow, few of the smut spores germinating in drier soil than this and their germination is quickly stopped in much wetter soil.

The soil temperature at which the spores of stinking smut germinate and infect wheat are within limits equally as narrow as the limits of soil moisture. The optimum temperature for smut germination and infection is in the neighborhood of 50° to 55°F. Field tests in Colorado have shown that in soils of this temperature greatest smut infection occurs. At higher soil temperatures not only does the smut fail to germinate and infect the wheat but the wheat grows rapidly and soon passes out of the small seedling stage where infection is possible. This relation to soil temperature has direct bearing on date of planting.

Soil temperatures over a period of years at Fort Collins show that the average temperature for August is 69°F., for September 61°F. October soil, however, has considerably lower temperature averaging 48°F. at a depth of 3 inches. This later temperature is very close to the optimum temperature for smut infection, and is reflected in the field results on infection of wheat planted at different dates. In Table 2 is given the average percentage of smut on untreated plots of wheat planted at different dates.

Table 2.—Smut on Untreated Wheat Planted at Different Dates

Year	Location	Date	Average Percentage Smut
1924	Fort Collins	Oct. 1	9.
	Fort Collins	Oct. 24	14.
	Fort Collins	Oct. 30	48.
1925	Fort Collins	Oct. 23	27.
	Rocky Ford	Sept. 23	0.4
	Rocky Ford	Oct. 23	26.
1926	Akron	Oct. 9	62.
	Fort Collins	Sept. 11	35.
	Fort Collins	Oct. 9	58.

A comparison of the above mentioned monthly soil temperatures shows the soil temperatures in August and September to be too warm for the most favorable germination of the spores of stinking smut and the accompanying infection of the wheat. October soil temperatures, however, are ideal for smut infection of winter wheat

and date of planting should be as early as possible to avoid the cooler soil temperature favoring smut.

In a survey covering inspection of some 20,000 acres of winter wheat the relation of soil temperature and date of planting to smut infection was markedly evident. Wheat planted on north slopes where soil is cooler frequently has more smut than wheat on south exposures.

A summary of all untreated plots of wheat in 3 years tests showed that wheat planted between September 11 and October 9 had an average of 25.3 percent smut while wheat planted between October 9 and November 2 had 35.1 percent smut.

Under favorable conditions smut spores germinate in about 6 days. The growth of the wheat under these low temperature conditions is slow. The wheat is susceptible to smut while it is in the seedling stage before emerging from the ground. Low soil temperatures favorable to smut spore germination will hold back the wheat and prolong the susceptibility period for smut infection; such conditions frequently exist in the case of late planted wheat.

Seed treated with copper carbonate did not show the effect of planting date to any marked degree. This chemical in all plot tests for 3 years seemed to offer good protection even under moisture and temperatures favorable for smut infection.

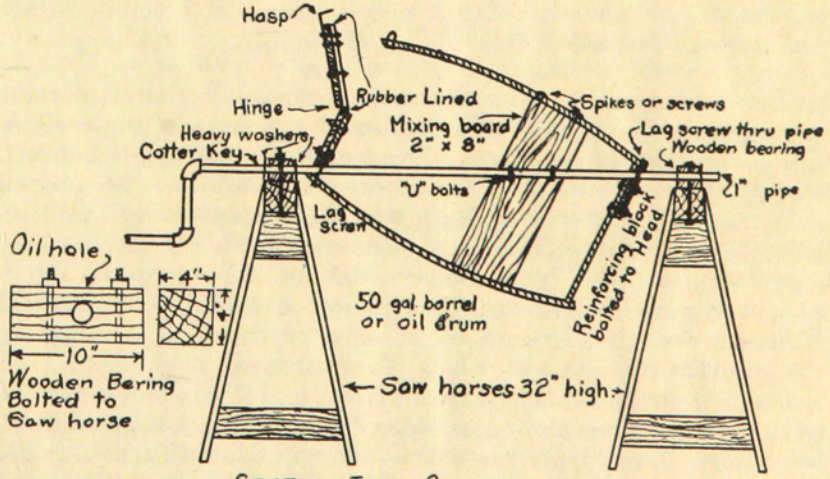
Control for Stinking Smut

A number of methods have been used in the past for treating wheat for stinking smut. Of these the bluestone or copper sulphate and the formaldehyde methods were the most successful. Both of these methods, however, are wet treatments. They have the disadvantage of being difficult to use, cause the grain to swell and often result in heating. Experiments at the Colorado Experiment Station have shown that the germination of seed so treated is materially reduced. Germination tests over a period of 3 years show a cut in germination and stand of as much as 25 percent in wheat treated with bluestone or formaldehyde. Cracked or broken seeds are especially subject to injury by these methods. In the last few years a dry method of treatment has been developed, using copper carbonate dust as a coating for the seed wheat. This has been found to give excellent control, does not injure germination and is both cheap and easy to apply. The fine dust sticks to the wheat kernels and kills the smut on them. (Fig. 6).

Fig. 6—Kernels of wheat covered with particles of copper carbonate dust. Magnified about 15 times.

How to Treat Seed Wheat With Copper Carbonate.—Wheat to be used for seed should first be carefully cleaned to remove weed seed, dirt, and unbroken smut balls. Do not use badly smutted wheat for seed. Dust the wheat with copper carbonate at the rate of 2 to 4 ounces of dust for each bushel of seed. One heaping tablespoonful of copper carbonate weighs about 1 ounce and is a fairly good measure to use. A complete covering of the seed with the copper carbonate dust must be secured to give results.

Good covering may be obtained by thoroly mixing the grain and the recommended amount of dust in an air-tight mixer such as a barrel churn constructed from an ordinary barrel or steel drum as indicated in the accompanying Fig. 7. Mixing on the floor or wagon box or in the drill is not satisfactory. A comparison of these methods has shown that when properly treated, smut can be reduced by copper carbonate to as low as 2 or 3 percent or even less



SECTION THRU CENTER OF HOMEMADE

Fig. 7— BARREL WHEAT DUSTER

than 1 percent. Where treated in the drill, however, as much as 11 percent smut resulted. A simple home made mixing machine for dusting seed wheat is shown in Fig. 7. This consists of a tight barrel mounted diagonally on an axle and turned with a crank. The dry carbonate dust and the grain are put into the machine thru a hinged door cut in the end of the barrel. After closing the door, the barrel is turned over 40 or 50 turns by means of the crank. The diagonal position of the barrel is of particular advantage in unloading it as the grain easily pours out when the door end of the barrel is tipped down. A barrel with the axle thru the center of the head has sometimes been used but is much harder to load and unload. A baffle board bolted across the inside of the barrel helps to stir the grain and the dust.

By the use of the above described mixer the seed can be successfully treated with copper carbonate at a small expense without the inconvenience of a wet treatment and without risk of injury to germination. The possibility of the clogging of the drill where copper carbonate is used is sometimes given as an objection against this method. Such clogging usually occurs where the drill with dust in it is left standing in the field over night. Surplus dust will collect in the gears of the drill and tends to set. If the drill is slowly rocked back and forth after standing this way, before loading and starting the team, danger of breakage is avoided.

Copper carbonate when breathed to any great extent is irritating to the throat and nose and may cause the person using it to become nauseated. A handkerchief tied over the nose and mouth readily prevents any discomfort from the use of the dust.

The widespread use of seed treatment for stinking smut of wheat has stimulated production of a number of commercial compounds in addition to copper carbonate. Some of these are wet treatments, others dry treatments. Fourteen of these chemicals have been tested by the Colorado Experiment Station for their effectiveness. See Bulletin, 333. The dry treatments alone are worth considering. Of these "Copper Carb," pure copper carbonate, Bayer dust and Bayer compound gave best results. The test of efficiency of a chemical treatment for stinking smut is not only its effectiveness in killing the smut but the ease with which it can be used, its cheapness, and availability on the market. Freedom from seed injury and reliability of the product must also be considered in selecting a suitable treating agent. Pure copper carbonate and "Copper Carb" fulfill these conditions. In 3 years tests of these two chemicals little difference is found in their effectiveness when properly applied.

Smut of Oats

Oats are attacked by two kinds of smut (Ustilago avenae and Ustilago levis), the loose smut and covered smut Fig. 8. Tho these smuts differ microscopically, there is not a great difference in them in their general appearance in the field except that the chaff of the oats is not completely destroyed by the covered smut (Ustilago levis). Their life history and method of attack on the oat plant are the same, and in the following discussion they will be considered as one smut.

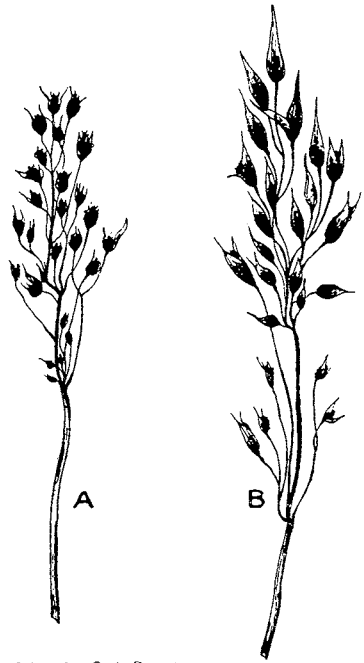


Fig. 8—Oat Smut.
A. Head of oats attacked by loose smut.
B. Head of oats attacked by covered smut. This smut does not completely destroy the chaff.

Life History of the Smut.—Oat smut, like the stinking smut of wheat, infects the seedling plant. The spores of this smut fungus are spread at the time of flowering and become caught under the edge of the healthy oat hull or stick to the outside. They germinate and attack the young seedling at the time of sprouting. The smut grows up with the oat plant and develops as a smutty mass instead of normal oat heads. The infection of oats by smut is favored by a soil temperature of approximately 60 to 72°F. Some varieties of oats show resistance to smut.

Method of Control.—Oat smut cannot be controlled by the copper carbonate dust treatment. Smut on hulless oats, however, is an exception. The formaldehyde treatment is successful in treating oat smut. Clean the seed before treating and pile on a clean floor or on a canvas. The oats are then sprinkled with a solution of formaldehyde, 1 pint to 40 gallons of water. Use about 1 gallon of the solution to each bushel of seed to be treated. While sprinkling the solution over the seed the grain should be thoroly shoveled (Fig 9) until each kernel is wet, after which the pile of grain should be covered with sacks or tarpaulin and allowed to remain for 4 to 12 hours. The seed may then be planted. If it is to be held, however, for any length of time after treating, care must be taken that it be dried out thoroly and quickly. For hulless oats there is danger of seed injury from formaldehyde, and copper carbonate is a satisfactory treatment. Application may be made the same as described for stinking smut of wheat.

Fig. 9—Using formaldehyde solution for oats and barley.

Fig. 10—Covered smut of barley. The masses of smut are covered by a thin bluish membrane.

Covered Smut of Barley

Covered smut of barley (Ustilago hordei) is one of the most common disease of barley in Colorado. The injury from this disease some years is quite high. The smut attacks the barley head in a manner similar to the oat smut, causing the kernels to become a black smutted mass. The diseased heads, as the smut develop, become covered with a thin bluish membrane which encases the diseased kernels. See Fig. 10.

The life history of covered smut of barley is proctically the same as the oat smut. The spores of the smut stick to the surface of the barley seed or get caught under the edges of the hulls and germinate when the seed germinates, infecting the seedling. As the infected plant grows, instead of maturing a normal head of barley a mass of smut spores is produced in their place.

Control.—The formaldehyde treatment as above described for oats is effective for the covered smut of barley. The smut on hulless barley can effectively be controlled by copper-carbonate dust method, with less chance of

injury to the naked seed than would be the case where formaldehyde was used.

Millet Smut

The smut of millet (Ustilago crameri) is of frequent occurrence. The disease attacks the heads of millet, resembling stinking smut of wheat in its appearance and manner of attack and spread. The diseased plants are stunted and the heads appear yellowed. At time of maturity the diseased seeds of the millet become filled with masses of dark smut spores that appear as a black powder when the seeds are crushed.

Fig. 11—Head of sorghum infected with kernel smut. Each sorghum kernel has become filled with a mass of smut spores.

The spores are spread in threshing to the healthy seed in the manner of stinking smut of wheat and stick to the surface of the seed. When the planted seed sprouts the smut spores also germinate and infect the young seedling.

Control Measures.—Little attention is generally paid to treating millet seed for smut because the treatment with formalin is laborious and millet seeds sprout quickly and are easily injured. Copper carbonate gives good control for smut of millet. Application of the dust is easy and made in the manner described for stinking smut of wheat. Four ounces to the bushel of seed give best results.

Sorghum Smut

One of the most common diseases of sorghums is sorghum smut. There are three smuts of sorghum; however, the one common to Colorado is the kernel smut, Fig. 11, (Sphacelotheca sorghi). This disease is quite prevalent and not only decreases seed production but lowers the quality of the fodder.

The life history of sorghum smut is very similar to the stinking smut of wheat. The spores of the smut fungus become dusted on the surface of the seed kernels and infect the young seedling at the time of seed germination. As in the case of the stinking smut of wheat the smut grows up with the developing plant

producing in the kernels masses of dark brown smut spores which on threshing are distributed to the uninfected seeds.

Control Measures.—Copper carbonate dust has been found effective as control for kernel smut of sorghum. This is particularly true of the grain sorghums. The saccharine sorghums are not as effectively treated as the hull furnishes protection for the smut spore and their glossy, smooth surfaces prevent copper carbonate from adhering to the seed. Formaldehyde as described above for oat smut can be used.

Loose Smut of Wheat and Loose Smut of Barley

Loose smut of wheat caused by Ustilago tritici (Fig. 12) and loose smut of barley, Ustilago nuda, are frequently found in wheat and barley fields in this state, tho not as common as stinking smut of wheat and the covered smut of barley. The loss from these two smuts is chiefly in stand. These two smuts are microscopically different in their structure from stinking smut of wheat and covered smut of barley and their manner of infection is also entirely different from these other smuts. As both infect the grain in the same way and are generally quite similar they will be considered together.

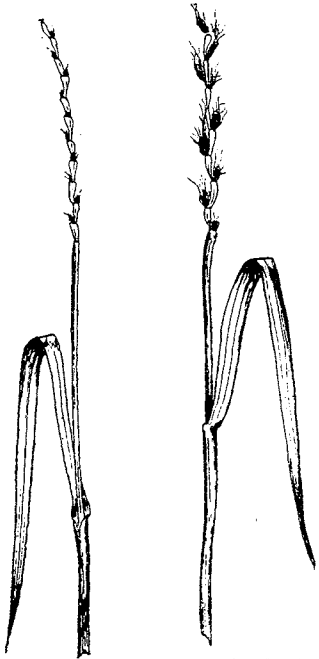


Fig. 12—Loose smut of wheat. In the head on the left the smut spores have been shattered out and blown away by the wind. Many of them fall on normal wheat heads and infect them.

Method of Infection.—The loose smut of wheat and loose smut of barley infect their respective hosts at the time of flowering. They produce their spores at time of flowering and these are blown from smutted heads in the field or neighboring fields to healthy heads which are in bloom. The smut spore germinates on the open flower of the healthy head and grows down into the young ovary and new seed being formed. There it remains dormant until the following year. There is no visible evidence of the smut being present in the seed, no production of blackened smut masses but when such diseased seed are planted they grow the following year into smutted plants. It is thot that under some rare circumstances seedling infection may occur and has been produced on dehulled barley seed. The spores of the fungus do not retain their vitality long, only a few months. Great

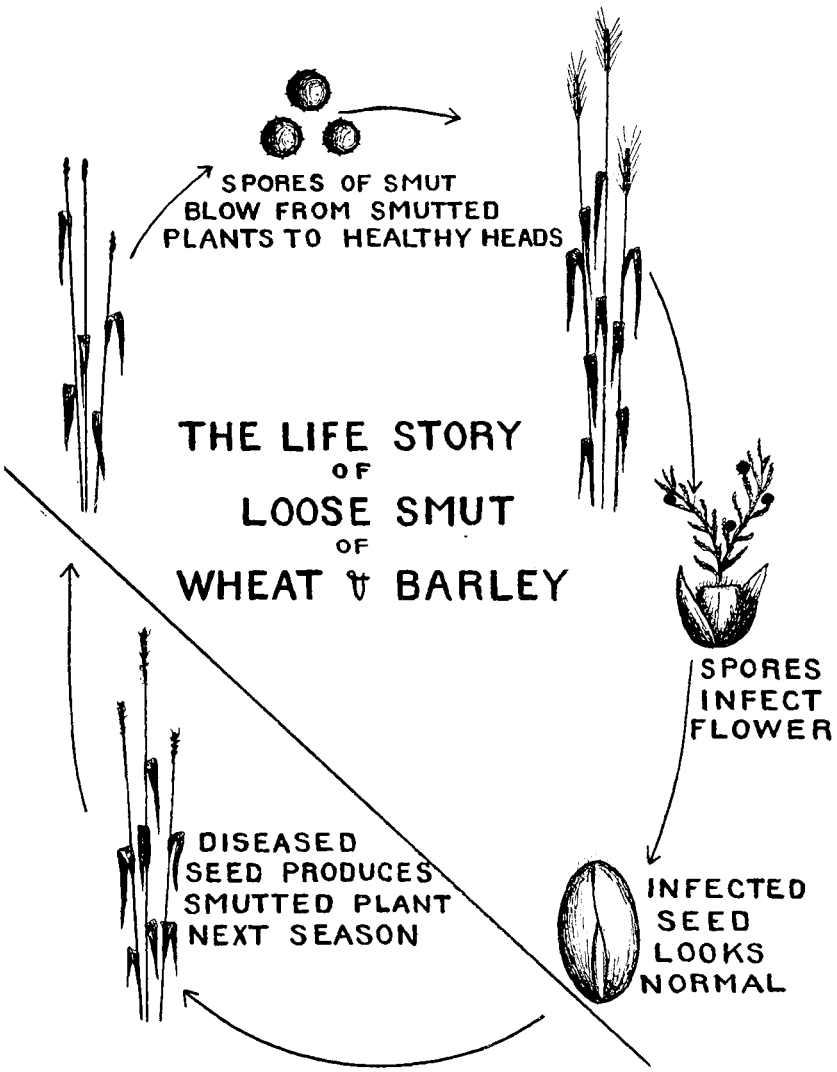


Fig. 13

vitality of the spore is not necessary however, as it infects the flower almost as soon as it is produced.

Control Measures.—As the smut in the case of these two diseases is inside what appears to be a normal seed it is impossible to treat with formaldehyde or copper sulphate to disinfect the smut from the surface of the seed as in the case of the other smuts.

What is known as the "hot water treatment" is the only treatment that can be effectively used with these two loose smuts. This consists of dipping the seed wheat or barley into hot water. First soak the seed in warm water 68 to 86°F. for four to six hours then immerse the grain in a warming vat of water about 115°F. Lastly, dip the grain for ten minutes in water kept at a temperature not lower than 123°F. and not higher than 126°F. The effect of this hot water treatment is to first soften the tissues of the seed and the smut by the first soaking. The smut begins to come out of its dormant condition and is easily injured by the higher temperatures. An accurate thermometer is necessary for this treatment. The use of an ordinary house thermometer is dangerous, as it is not sufficiently accurate and the wheat may be heated too high and killed. Sufficient water should be used to dip the wheat in and the amount of wheat dipped each time in the hot water should not be so large as to change the temperature of the water. It is best to dip only a bushel or even a peck at a time. In treating barley the seed should be soaked in the hot water for 15 minutes at a temperature of 124° to 129°F.

The drying of the treated grain is one of the greatest difficulties of the hot water treatment. The bags of treated grain should be thoroly drained after dipping and the grain spread out to dry. If the weather is sunny, spreading the grain out on tarpaulins in the open and turning over with a rake will hasten drying. If the grain does not dry rapidly it is liable to become heated and its germination seriously injured. The germination of the wheat is lowered often as much as 10 percent by the hot water method. Broken or cracked grains are injured to even greater degree by hot water treatment, and often untreated wheat yields more than that treated with hot water. When the hot water treatment is used no other treatment such as copper carbonate is necessary as the hot water also kills the other smuts that may be on the surface of the seed. The control of loose smut of wheat or barley lies chiefly in growing one's own seed grain. Isolated seed plots for the following year's seed should be grown. Start with clean seed. Carefully treated seed should be planted having the field as far from other wheat as it is possible, or separated from other wheat fields by a corn field or trees. Such a seed plot will enable the farmer every year to have clean seed, free from these loose smuts. Any smutted heads that may appear in the seed plot must be rogued out. The hot water treatment is difficult and not to be generally recommended except for treating seed for the seed plot. These smuts are greatly confused with the covered smut of barley and stinking smut of wheat and the complaint is always heard that wheat which was carefully treated with copper carbonate or for-

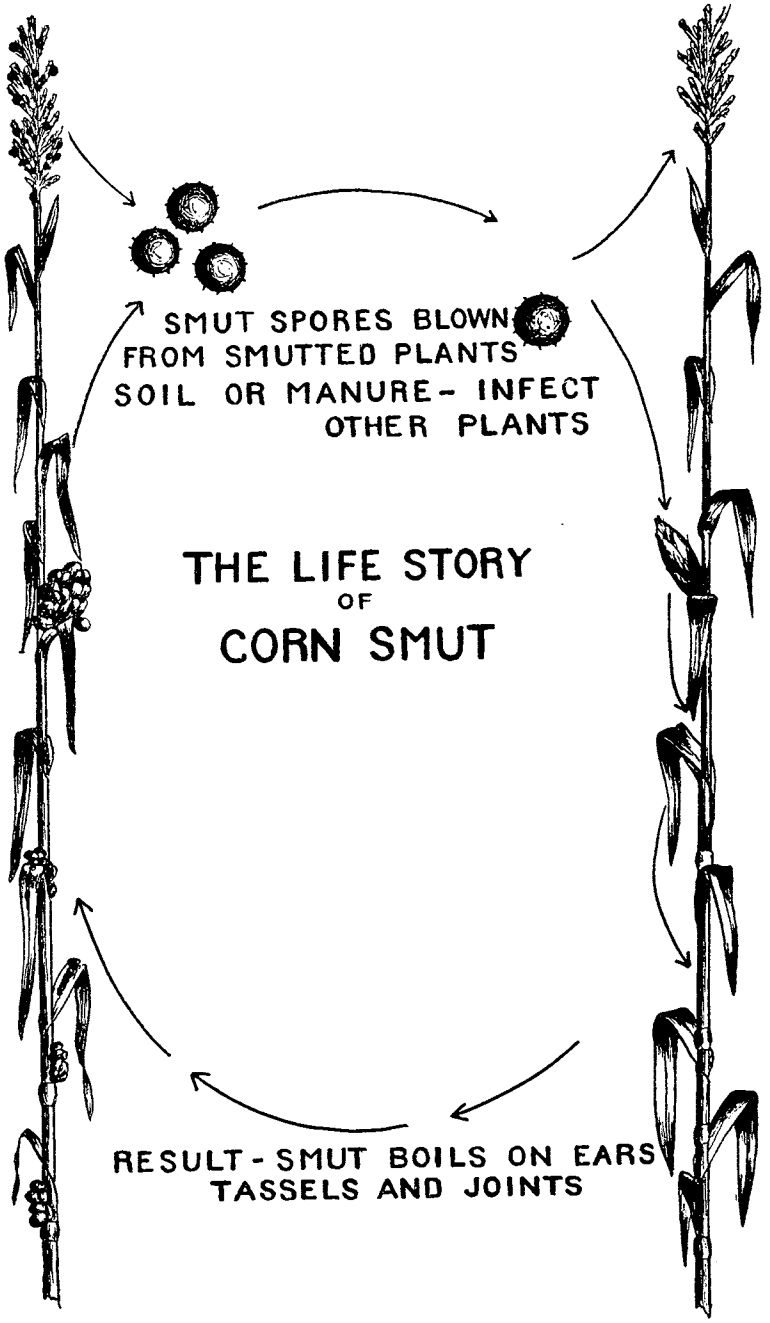

SMUT SPORES BLOWN FROM SMUTTED PLANTS SOIL OR MANURE- INFECT OTHER PLANTS
THE LIFE STORY OF CORN SMUT
RESULT - SMUT BOILS ON EARS TASSELS AND JOINTS

Fig. 14

maldehyde still had considerable smut. In many cases this is found to be loose smut. Loose smut of wheat and barley may blow in from neighboring fields and because the field of grain is clean one year or has been carefully treated there is no assurance that smut may not blow in from a neighbor's field and show up in the next year's crop.

Corn Smut

The smut of corn (Ustilago zeae) is found practically thruout the state where this crop is grown, being particularly severe on sweet corn. Often the fields have as high as 10 to 20 percent smut. Corn smut frequently follows hail injury. The disease appears as boils or blisters on the ears, in the tassel, or at the joints of the stalks. Even the leaves are occasionally attacked. The plants often become yellowed and stunted especially if attacked when young. Where the ear is attacked it is usually a total loss. The smut boils consist of masses of smut fungus and abnormal plant tissues and at maturity become filled with blackened masses of smut spores. Many of these smut spores are able to germinate before the smut boil is dried and hardened, they are retained, however, in most cases within the smut boil, being slowly shattered out by wind and rain at the end of the growing season.

The smut spores fall to the ground or are carried in the fodder to the feed yard. There they lie dormant over winter or if the weather is favorable they may start to germinate. Unlike other smuts the corn smut fungus may live in manure or on the old stalks in the ground. There they can even germinate and grow for some time. (Fig. 14). Spores in silage, however, are killed. The spore on germinating produces a much jointed group of cells lightly joined together and able to increase in number. These small secondary spores can infect the corn plant when blown by the wind or spattered by the rain from the soil, manure or corn refuse. Ungerminated spores may also be carried up in the air with the dust from the cultivator and lighting on the corn plant cause infection at any growing point. The growing points of the corn plant are the tassel, ears, and the bases of the joints. These soft, rapidly growing tissues are susceptible to the smut. Corn in rich soil is more susceptible to smut probably because of its rapid growth. Weather affects the smut infection. Moisture, and proper heat for rapid growing conditions favor the smut infection. Coupled with this is the fact that the smut spores germinate best at about 85°F. and also need moisture in which to germinate. These conditions are identical with those favorable for rapid growth of the corn. Dry weather, on the other hand, is unfavorable to the disease. Corn plants are most susceptible to smut

from the time they are 2 to 3 feet tall until tasseling, very young infected plants frequently die.

Control Measures.—From the manner of infection it is obvious that seed treatment is of no benefit for corn smut as the smut is not seed-borne. No definite treatment can yet be recommended. Where the fields are small, the smut boils can be removed and burned or buried. In larger fields however, particularly where the infection is heavy, the smut can best be destroyed by using the corn for ensilage. The conditions of the silo will destroy the fungus. Do not put manure from infected corn fodder back on the corn land, as the smut spores can grow and multiply in manure, and will be a source of infection the following year. There appears to be a difference in the susceptibility of different varieties and this is a hopeful means for combatting the disease.

Seed-Treatment Chart

Crop Affected	Kind of Smut	Treatment
Wheat	Stinking Smut	**Copper Carbonate Dust.**—Mix dry dust thoroly with seed wheat in tight mixer, 2 to 4 ounces of dust per bushel of seed. Seed can be kept after treating and sown when convenient.
Wheat	Loose Smut	**Hot-Water Treatment.**—(1) Place from 1 peck to 1 bushel of wheat in loose woven sack or basket. (2) Soak in warm water 68 to 86°F. 4 to 6 hours. (3) Dip in water of about 115°F. for a few minutes to warm up mass of seed. (4) Soak 10 minutes in water 123 to 126°F. (5) Spread out and dry rapidly.
Oats	Covered Smut	Sprinkle seed with formalin solution till moist. One gallon of solution will wet 1 bushel of seed. (Solution consists of 1 pint of commercial formalin in 40 gallons of water). Shovel over seed while sprinkling to thoroly mix. Cover pile of seed with sacks or tarpaulin for 4 to 12 hours, to keep in formalin fumes. Plant at end of this time. If not convenient to plant then spread out seed and dry thoroly. Use isolated seed plots for seed supply. Hulless oats can be treated with copper carbonate as for stinking smut of wheat.
Barley	Covered Smut	Treat with formalin solution as for oats smut. Hulless barley can be treated with copper carbonate the same as wheat for stinking smut.
Barley	Loose Smut	Hot water treatment as for loose smut of wheat, except hold seed for 15 minutes in water 124° to 129°F. Use isolated seed plots for seed supply.
Millet	Millet Smut	Copper carbonate dust as for stinking smut of wheat. Four ounces of dry dust to a bushel of seed. Formalin solution 1 pint to 40 gallons of water as for oat smut can also be used but is not as satisfactory as copper carbonate dust.
Sorghum	Kernel Smut	Copper carbonate dust as for stinking smut of wheat. Saccharine sorghums frequently more effectively treated with formalin as for oat smut.
Corn	Corn Smut	No seed treatment effective. Crop rotation; do not put manure from smutty fodder on corn land. Very smutty corn should be siloed.