THE GRAIN SMUTS: THEIR CAUSES AND PREVENTION.

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To the ordinary observer nothing could seem more unlike a definitely organized plant than the black, dusty mass filling the kernels of wheat or replacing an entire head of oats. Yet, as a matter of fact, the black dust is composed of thousands of germs of a minute parasitic plant. These germs, or spores, which have the same function as the seeds of higher plants, are blown about by the wind and lodge on the healthy kernels of the grain. When the kernel sprouts the spores adhering to it germinate and send a slender thread into the young plant. The slender threads of the parasite follow the growth of the plant, but their presence can scarcely be detected until the head begins to develop. The flower or grain is then filled by a mass of the threads, which absorb the nourishment intended for the grain and are soon converted into a mass of spores, again ready to fly about and infect next year's seed.

The enormous amount of damage caused by these parasites has attracted attention since the time of the Greeks and Romans, and the history of the study of smuts and of the discovery of remedies for them within the last eight years forms one of the most fascinating pages in the records of vegetable pathology.

In the few pages at command it is hoped to present in brief outline the present state of our knowledge of smuts, and to give some account of the latest and best methods of preventing their ravages.

There are two classes of smuts which attack our common cereals, viz, the stinking smuts, which destroy only the kernel, and which have a pronounced disagreeable odor, and the loose smuts, which destroy not only the kernel but also more or less of the chaff, and which are more dusty and loose. The stinking smuts occur on wheat only, while the loose smuts are found on wheat, oats, and barley. As the different smuts have to be treated differently, it is of advantage to the agriculturist to be able to recognize them readily. Wheat, for instance, is attacked by three species—two stinking smuts and one loose smut.

STINKING SMUTS OF WHEAT.

The two species¹ are very similar and can usually be distinguished only by the aid of a microscope. The smutted kernels (usually all in

¹*Tilletia fœtens* (B. & C.) Schroeter (which is the more common in this country), with globose or oval, smooth spores, and *Tilletia tritici* (Bjerk.) Winter, having globose spores, with net-like ridges on the outer surface of the wall. Harwood states that wheat attacked by the latter species has shorter stalks than healthy grain, while that attacked by the former species grows as tall as unaffected wheat.
the head are affected) are slightly larger and more irregular in shape than healthy grains, and are easily broken open, disclosing a dark-brown powder, which possesses a disagreeable, penetrating odor. Even a small per cent of smutted kernels will give a whole bin of wheat this characteristic odor. The stinking smuts are thus easily recognized if present in any considerable quantity in the thrashed grain. This is not true of any other grain smuts, however. Figures 92 and 93 show the appearance of heads of wheat attacked by the stinking smuts.

These smuts occur more or less abundantly in all wheat-growing countries. They are widely distributed in the United States, though fortunately there are many regions where they are still unknown.

There are no accurate statistics as to the amount of damage caused by these smuts. In many localities the loss is very large, and it can not be doubted that in the whole United States it amounts to many millions of dollars annually. Sometimes 50 or even 75 per cent of the heads are smutted, and besides the sound grain is so contaminated with the fetid spores as to be nearly worthless for flour and worse than useless for seed. The disease is often spread from farm to farm by thrashing machines. When once introduced, if left unchecked, it increases year by year until a large percentage of the crop is destroyed. It can usually, however, be more or less held in check by some form of bluestone treatment of the seed, but the treatment very rarely gives
entire protection. Directions will be given at the close of this article for entirely preventing the smuts, no matter how bad they may have been in the crop used for seed.

LOOSE SMUT OF WHEAT.

This is very different from the stinking smuts. It has no fetid odor; attacks both kernel and chaff; ripens when the healthy wheat is just flowering; and is composed of a loose, dusty mass of spores. These spores are usually entirely blown away by harvest time, leaving only the naked stalk where the head should be. Figure 94 shows the appearance of a head of wheat at flowering time which has been attacked by this smut, while figure 95 shows the appearance of another head at harvest time.

Loose smut is known to occur in Europe, North America, north Africa, central Asia, and the East Indies. It occurs in many parts of the United States, though fortunately it is rare or entirely absent in many localities. It does not usually destroy so large a proportion of the crop as do the stinking smuts; still, it often causes a loss of 10 per cent or more of the crop, and has even been reported as destroying over 50 per cent of a crop in Michigan. It may be present in considerable amount and yet be entirely overlooked, since the smutted heads are reduced to bare stalks at harvest time and there is no trace of it visible in the thrashed grain. The only way the agriculturist can be sure his crop is free from it is to examine carefully his fields when the wheat is flowering. The loose smut is to be feared, not so much on account of the great damage it causes, but because it is very difficult to prevent, and if once introduced into a field it is likely to remain year after year; for, as has long been known, the old bluestone treatments, though often very effective against stinking smuts, do not affect this species. It has also been shown by Kellerman and Arthur that the ordinary forms of hot-water treatment are not effective against it. From the experiments of Professor Kellerman and the writer, it can,

\[1\] *Ustilago tritici* (Pers.) Jensen. A variety of this smut, which attacks the leaves and sheaths as well as the heads, has recently been reported from Egypt.
however, be safely concluded that certain forms of the hot-water treatment are effective against loose smut, but injure the germinative power of the seed. Wheat growers should therefore be on their guard against this enemy, and try to secure seed wheat from fields known by careful examination at flowering time to be free from loose smut. It can, however, be combated by treating enough wheat to furnish seed for the following year, and this should be done when any considerable per cent of the crop is affected.

LOOSE SMUT OF OATS.¹

This smut is very similar in general appearance to the loose smut of wheat, and like that species it ripens when the grain is in flower, and is blown about by the wind. At harvest time the head is often entirely bare. There is, however, a form² of this smut which destroys only the kernel and leaves the outer chaff unaffected. This is very hard to recognize, since the smutted heads look almost exactly like those of healthy plants, and can be detected only by cutting open the husks, when a mass of smut will be found in place of the kernel. Sometimes more than two-thirds of the smut is of this hidden form. This is likely to cause the grower to greatly underestimate the amount of smut.

The appearance of the ordinary form of oat smut at flowering time is shown in figures 96 and 97; its appearance at harvest time is shown in figure 98. The hidden smut can not be distinguished from a healthy head in an illustration.

This smut has probably the widest distribution of any of the thousands of species known to students of the group. It is known on every continent and occurs all over the United States. In fact it is an uncommon thing to find a field of oats entirely free from it, and the amount of damage it causes is very great. Not one in a thousand of those engaged in growing oats has any adequate idea of the extent of its ravages. Hundreds of examinations have been made in oat fields in various parts of the United States, and as a result we have very reliable estimates as to the amount of this smut in various localities. Estimates made by Professor Kellerman and the writer put the actual loss from oat smut in Kansas at $1,382,328 in 1888, $850,554 in 1889, and $911,299 in 1890; Dr. Arthur estimates the damage in Indiana at $797,526 in 1889 and $605,352 in 1890; Harwood estimates the damage in Michigan at $800,000 in 1891 and $1,000,000 in 1892. In these States the average amount of smutted heads varied from 6.5 per cent to 15 per cent. The only State where decidedly lower per cents of smutted oats have been reported is Vermont. Here Jones found an average of 1.6

¹ *Ustilago avenae* (Pers.) Jensen.
² *Ustilago avenae, levis* Kell. and Swing. All hidden smuts belong to this variety, but not all *levis* is hidden smut. This variety seems to be what Wille has called *U. kílleri*. Jensen, however, infected oats with covered smut spores and obtained one-sixth completely naked smut.
per cent smutted in 1892. This would represent a loss of $26,454.\textsuperscript{1} It is undoubtedly a conservative estimate to place the direct loss from oat smut at 8 per cent of the crop. Even at this estimate the loss in the United States is over $18,000,000 annually, averaging $18,504,140 for the

Fig. 93.—Head of oats affected with smut, but having the chaff only partially destroyed.

Fig. 97.—Head of oats affected with smut, having the chaff only partially destroyed; decidedly smutty.

Fig. 98.—Final stage of smut, showing condition of head at harvest time.

years 1890 to 1893.\textsuperscript{2} This, however, though it represents the amount that would be saved if every smutted head of oats were replaced with

\textsuperscript{1} Using the estimates of this Department, putting the value of the crop at $1,626,944 (see Annual Report of Secretary of Agriculture for 1892, p. 420).

\textsuperscript{2} Using the estimates made by this Department, putting the average value of the oat crop for these years at $212,797,614 (see Annual Report of the Secretary of Agriculture for 1893, p. 483).
a sound one, does not by any means represent what would be saved by
a universal system of seed treatment. It has been conclusively proved
that a much greater increase in yield is obtained by treating the seed
than would result from merely replacing the smutted heads with sound
ones. This will be explained later.

It should be remembered that it costs as much for every farming
operation to raise a badly smutted crop as a clean one. The smut does
not thin out the stand and give the healthy plants more soil and
better light; a smutted plant takes up as much room and requires as
much moisture and nourishment from the soil as does a healthy plant.
The loss by smut can therefore be said to be taken directly from the
profit on the crop. Moreover, the seed from a badly smutted field is
likely to produce a badly smutted crop the following year, while that
from a clean field will produce a crop almost if not entirely free from
smut.

By means of two newly discovered treatments of the seed, viz, with
potassium sulphide, and with hot water, oat smut can be completely
prevented at very little expense. The methods will be explained here-
after. Fortunately, both the common and hidden forms of smut can be
eradicated with equal ease. It is certain that oat growers could save
many millions of dollars annually above all expenses by treating their
seed oats.

SMUTS OF BARLEY, RYE, AND CORN.

Barley is attacked by two loose smuts, both very similar to the loose
smut of oats. In the covered barley smut the spores are often retained
till harvest by a thin membrane, inclosing the smutted kernel and chaff.
The naked barley smut, on the other hand, is like the ordinary form of
oat smut, and is usually all blown away long before harvest. Both
kinds of barley smuts can be completely prevented by the treatment
recommended further on.

Rye smut attacks the leaves and stems of this cereal, and some-
times weakens the plants considerably. Jensen thinks it can be pre-
vented by treating five minutes with hot water at 127° F.

Corn smut is of widespread occurrence, but rarely causes more than
a fraction of 1 per cent loss. No method of prevention is as yet known.

PRACTICAL DIRECTIONS FOR TREATING SEED FOR SMUT.

POTASSIUM SULPHIDE TREATMENT FOR OAT SMUT.

The potassium sulphide should be of the fused form known as "liver
of sulphur." It can be obtained of any druggist for from 25 to 50 cents
per pound, depending on the quantity purchased. It should be kept

1 Ustilago hordei (Pers.) Kell. & Swing.  2 Urocystis occulta (Wallr.) Rabenh.
2 Ustilago nuda (Jens.) Kell. & Swing.  3 Ustilago maydis (DC.) Cda.
in a tight glass vessel, protected from the air, until ready for use. Dissolve 1½ pounds in 25 gallons of water in a wooden vessel; a tight barrel is very good for the purpose. The lumps of potassium sulphide dissolve in a few minutes, making the liquid a clear yellowish-brown color. After thoroughly stirring, put in about 3 bushels of oats and agitate well to insure wetting every grain. The solution must completely cover the grain and be several inches above it, as the grain soaks up some of the liquid. Leave the oats in this solution twenty-four hours, stirring several times during the day to be sure every kernel is wetted. Then spread out to dry. In treating large quantities of seed, a hogshead or a wooden tank might be used. The solution should not be used more than three times. In no case should any metal be allowed to come in contact with the liquid. This treatment is thoroughly effective for oat smut, and is worthy of trial for stinking smut of wheat.

THE HOT-WATER TREATMENT FOR STINKING SMUT OF WHEAT AND OAT SMUT.

Provide two large vessels, preferably holding at least 20 gallons. Two wash kettles, soap kettles, wash boilers, tubs, or even barrels, will do. One of the vessels should contain warm water, say at 110° to 120° F., and the other scalding water, at 132° to 133° F. The first is for the purpose of warming the seed preparatory to dipping it into the second. Unless this precaution is taken it will be difficult to keep the water in the second vessel at the proper temperature. A pail of cold water should be at hand, and it is also necessary to have a kettle filled with boiling water from which to add from time to time to keep the temperature right. Where kettles are used a very small fire should be kept under the kettle of scalding water. The seed which is to be treated must be placed, half a bushel or more at a time, in a closed vessel that will allow free entrance and exit of water on all sides. For this purpose there can be used a bushel basket made of heavy wire, inside of which is spread wire netting, say 12 meshes to the inch; or an iron frame can be made at a trifling cost, over which the wire netting can be stretched. This will allow the water to pass freely and yet prevent the passage of the seed. A sack made of loosely woven material, as gunny sack, can be used instead of the wire basket. A perforated tin vessel is in some respects preferable to any of the above. In treating stinking smut of wheat, the grain should first be thrown into a vessel filled with cold water; then, after stirring well, skim off the smutted grains that float on top and put the grain into the basket or other vessel for treatment with hot water. This skimming is entirely unnecessary with other grains, and even with wheat when affected only by the loose smut. Now dip the basket of seed in the first vessel, containing water at 110° to 120° F.; after a moment lift it, and when the water has for the most part escaped plunge it into the water again, repeating the operation several times. The object of the lifting and plunging, to which
should be added also a rotary motion, is to bring every grain in contact with the hot water. Less than a minute is required for this preparatory treatment, after which plunge the basket of seed into the second vessel, containing water at 132° to 133° F. If the thermometer indicates that the temperature of the water is falling, pour in hot water from the kettle of boiling water until the right degree is attained. If the temperature should rise higher than 133°, add a little cold water. In all cases the water should be well stirred whenever any of a different temperature is added. The basket of seed should very shortly after its immersion be lifted and drained, and then plunged and agitated in the manner described above. This operation should be repeated six or eight times during the immersion, which should be continued ten minutes. In this way every portion of the seed will be subjected to the action of the scalding water. In practice it will be found best to have a man

![Diagram showing arrangement for treating smut.](image)

or boy devote his whole time to keeping the temperature at the right point, adding a little hot water if it falls below 132° and a little cold if it gets above 133° F. Another man should handle the grain and immerse and drain the portion being treated as directed above. After removing the grain from the scalding water, spread on a clean floor or piece of canvas to dry. The layer of grain should not be over 3 inches thick. If it can not be spread out at once, dip in cold water and set to one side until it can be attended to. It dries better if spread while still hot. Another portion of grain can then be treated, and so on until all the seed has been disinfected. Directions for drying the seed will be given further on.

A good thermometer should be used, preferably one having the bulb protected against injury from striking the sides of the vessel. The large thermometer used in dairy work is very good for this purpose.
The important precautions to be taken are as follows: (1) Maintain the proper temperature of the water (132° or 133° F.), in no case allowing it to rise higher than 135° or fall below 130°; (2) see that the volume of scalding water is much greater (at least six or eight times) than that of the seed treated at any one time; (3) never fill the basket or sack containing the seed entirely full, but always leave room for the grain to move about freely; (4) leave the seed in the second vessel of water ten minutes.

When steam is available, it can be conducted into the second vessel (containing the scalding water) by a pipe provided with a stopcock, and this answers better than any other method for heating the water and for elevating the temperature from time to time. A good arrangement for hot-water treatment is shown in figure 99.

A pole is provided having a large hole at one end, which passes over a small peg in the top of the first post. This should allow the pole to move both up and down and sidewise. By swinging the pole around the basket can be filled at the bin, then immersed a moment in vessel No. 1, and then swung over to vessel No. 2, where the grain is treated ten minutes. Every minute or so the basket must be raised entirely out of the water and allowed to drain. The pole can be supported on a peg or fork in the second post while the basket is draining. Finally, the pole is lifted entirely over the second post and the grain is spread out to dry. Of course this arrangement is necessary only when large amounts of seed are to be treated. For small amounts a tub of warm water and a common wash boiler on a cook stove for the scalding water will answer every purpose.

There are many possible modifications of the hot-water treatment that are more easily used than the one here given, but whenever they have been tested on a large scale they have proven uniformly less successful in preventing smut than the method here given, and do not give as great an increase in yield. They are, moreover, not nearly as convenient as the potassium sulphide or bluestone and lime methods.

**HOT-WATER TREATMENT FOR LOOSE SMUT OF WHEAT AND FOR BARLEY SMUTS.**

In treating wheat for loose smut, the grain must be soaked four hours in cold water, then set away about four hours more in wet sacks, and finally treated as directed above, but only for five minutes, at 132° F. In planting, use one-half more seed per acre to compensate for the seed killed by the treatment. For preventing both of the smuts affecting barley the grain should be soaked as directed above and treated five minutes at 130° F., 2° lower than for wheat.

**COPPER-SULPHATE TREATMENT FOR STINKING SMUT OF WHEAT.**

This consists in immersing the seed wheat twelve hours in a solution made by dissolving 1 pound of commercial copper sulphate in 24 gallons of water, and then putting the seed for five or ten minutes into
limewater made by slaking 1 pound of good lime in 10 gallons of water. The treatment is cheap, easily applied, and very effective. The wheat does not grow quite so well as when treated with hot water, but the difference is inconsiderable. This treatment is only for stinking smuts of wheat and covered barley smut. It should never be used for oat smut.

Drying the treated seed.

All of the seed treatments leave the seed wet and necessitate drying before planting. The grain should be spread in a layer 2 or 3 inches deep, and should be shoveled over twice or three times a day. It will then dry very quickly. A clean floor is a good place to dry the grain, but a better method is to take canvas sheets about 5 feet by 12 or 15 feet and spread out in the sun. Such sheets, with the grain, can be taken in at night. If spread over an open lattice work a few feet from the ground, drying is greatly facilitated. Such sheets, of the heaviest ducking, should not cost over $1.75 each, and can be used for years. The grain can be sown broadcast long before it is thoroughly dry, but for drilling it must be nearly dry. The seed can be treated months before being used, and dried and stored ready for planting. In case of the stinking smut of wheat there is danger of the seed being reinfected by contact with living spores, though with other smuts the danger is almost absent. In treating wheat against this smut, tools and sacks should be disinfected, and if a floor is used for drying, it should first be washed with a solution of bluestone (1 pound to 10 gallons of water) before spreading the grain. Canvas sheets and sacks can be disinfected easily by plunging into boiling water.

Extra increase in yield as a result of seed treatment.

One of the most remarkable and unexpected results of the hot-water and potassium-sulphide seed treatments was an increase in the yield beyond the amount that would result from merely replacing every smutted head with a sound one. This extra increase was first noticed by Professor Kellerman and the writer in experiments made with oats in 1889, where the hot-water treatment gave an increase in yield more than twice as great as would be calculated from the per cent of smut in adjoining untreated plats. This remarkable result was obtained in all subsequent trials, and was noted also by Jensen and Dr. Arthur. In the various experiments of the investigators named the extra increase in yield ranged from one-half to six times the amount to be expected from replacing the smutted heads with sound ones, and even higher ratios when the percentage of smut has been small. On an average the increase in yield has been double or treble what would result from suppressing the visible smut. In consequence of this remarkable benefit, comparable with what Mr. Galloway has shown to occur in using Bordeaux mixture on the potato and some other plants, it will
undoubtedly be profitable to treat oats for seed when only 1 or 2 per cent is smutted.

Potassium-sulphide treatment has given uniformly a large extra increase in yield when used in treating oats for seed. The extra increase has been very decided, almost equal to that resulting from treatment of seed with hot water. The copper-sulphate and lime treatment gives no extra increase whatever with oats.

Jensen has found a similar extra increase to result from treating seed barley with hot water, and Professor Kellerman has reported extra increase in yield in treating wheat for stinking smuts with hot water and also with several copper compounds. There was, however, an enormous amount of smut present in many of the untreated plats, reaching 75 to 80 per cent. Where there is only a small per cent of smut in the untreated wheat it is probable that little if any extra increase in yield would result from treating the seed.

As to the cause of the extra increase in yield as a result of seed treatment opinions are divided. It is probably due in part to an increased germinative power of the seed, causing them to sprout sooner and the young plant to grow faster. It has been shown that oats treated with hot water germinate much more quickly than do untreated oats, even if the grain has been dried. Professor Kellerman has shown that potassium sulphide has the same effect on both oats and corn, and further that, even after five and one-half months, seed which had been treated with hot water or potassium sulphide germinated quicker than untreated seed. Dr. Arthur claims that this hastened germination is due to the liberation at once of large quantities of diastase by the action of heat, enabling the young plant to avail itself rapidly of the reserve of starch stored in the seed. This does not, however, account for the action of potassium sulphide. Another possible explanation of the observed extra increase in yield has been put forth by Jensen. He suggests that the smut may attack many plants, which it simply weakens and stunts, without ever developing its spores in the head. Such injury would of course be prevented by any treatment that killed all the smut adhering to the grain. It is highly probable that a part of the extra increase is due to the higher germinative energy of treated seed and a part to the prevention of all injury, however slight, from the smut.

**DUTY OF SEEDSMEN.**

It is confidently believed that by the aid of these improved methods of seed treatment the enormous losses from the grain smuts will eventually be prevented in a great measure. Every year more growers treat the grain intended for planting, and others often profit by purchasing clean seed from the resulting crop for use the following year.

It is to be hoped that all reputable seed firms will treat the grain they sell for seed. Oats purchased at high prices for seed have been known to yield crops more than half smutted. In Kansas in 1890 Professor Kellerman and the writer found that nearly one-fourth of the
sorts of oats grown from seed obtained from dealers was badly smutted, one-fifth showing over 11 per cent of injury, and one-tenth over 20 per cent. The danger exists in even greater degree with other cereals, for the wheat smuts, for instance, do not occur at all in some regions and can readily be brought in by obtaining seed from infested fields.

**SUMMARY.**

1. Smuts of cereals are caused by minute parasitic fungi, the spores of seeds of which form the black, dusty mass which replaces the head or kernels of grain.

2. These spores are very minute and blow about and adhere to the kernel before it is planted. When the kernel sprouts the spores also germinate and send delicate threads into the young seedling. These threads follow the growth of the plant and fill the head or kernel as soon as formed, and there develop a mass of spores instead of kernels.

3. Two stinking smuts attack the kernels of wheat, filling them with a mass of fetid spores. These smuts cause great damage, but are easily prevented by treating the seed wheat.

4. Loose smut of wheat attacks the whole head and converts it into a mass of loose and dusty spores. It causes considerable damage in some localities and is more difficult to prevent than other smuts.

5. Loose smut of oats is very similar to that of wheat. It causes over $18,000,000 loss annually in the United States. It can be prevented easily and cheaply.

6. Barley is attacked by two smuts and rye by one, all of which can be prevented. Corn smut is widespread, but fortunately causes only a very slight loss. As yet no effective preventive is known.

7. Oat smut can be most easily prevented by soaking the seed twenty-four hours in a 1 per cent solution of potassium sulphide.

8. Stinking smut of wheat and oat smut can be easily prevented by treating with hot water at 132° F. for ten minutes. By previously soaking the seed in cold water, loose smut of wheat, barley smuts, and rye smuts can be prevented by a shorter immersion in hot water.

9. Stinking smuts of wheat can be prevented by soaking the seed twelve hours in a 1 per cent solution of copper sulphate and then dipping the seed in limewater. This treatment is useless for other smuts.

10. In treating oats for smut by either potassium sulphide or hot water, an increase in yield is obtained beyond and above the amount that would result from replacing the smutted heads with sound ones. The increase in yield from seed treatment is usually two or three times as much as the apparent loss from smut in untreated fields.

11. Seed dealers should treat all cereals offered for sale, both to increase the yield and to prevent the introduction of smuts into localities where they are now unknown.