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MILLET SMUTS AND THEIR CONTROL

By H. E. VASEY

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MILLET SMUTS AND THEIR CONTROL

By H. E. VASEY

This bulletin is prepared after two years of study on the smuts of the common varieties of millets. The study is incomplete in a number of its phases but, owing to the fact that positive results have been obtained in regard to control measures, it has seemed advisable to issue this bulletin now in order that farmers, this season, may take advantage of the methods of seed treatment which have proven effective.

The millets have become valuable forage and grain crops in the North Central States and Great Plains region of the United States. Smut is the chief disease affecting millet in these states, particularly in Colorado, where its occurrence has so increased of late years that serious consideration has been directed towards its control. Doubtless the disease has been fairly abundant for several years past, occurring only in sufficient amounts to attract attention locally, but owing to continued use of smutted grain, the smut has reached relatively large proportions generally over the State.

Owing to repeated calls for information concerning the smut and its control, an investigation was begun in the fall of 1915* for the purpose of ascertaining the kinds of smut affecting millets, the character of these smuts, the losses inflicted by them, facts in their life history, and the most practical methods for their eradication. Heretofore very little study has been given to the smuts affecting millet, and the control measures recommended by others are much at variance and, therefore, uncertain. Formalin has been generally adopted as a suitable dsinfectant, some recommending the steeping of grain in a solution of 1 pint to 45 gallons of water for two hours, others using 1 pint to 30 gallons for ten minutes and others, 1 pint to 48 gallons of water immersed for five minutes.

DISTRIBUTION AND LOSSES

In the United States millet smut undoubtedly occurs in varying amounts wherever millet is grown. It attracted attention in Iowa in 1908 and 1909, and has received some attention in Illinois, North Dakota and Indiana, although, to the writer's knowledge has not been reported to be of serious import in these states. In Colorado, how-

* This study was organized and begun by Dr. W. W. Robbins and Mr. Otto A. Reinking, to whom credit is due.

ever, much complaint of the disease has been received at the Agricultural Experiment Station, especially of late years.

Fig. 1. Experimental millet plots, 1917.

Millet smut occurs most abundantly in El Paso, Phillips, Weld, Washington, and Yuma counties. A few reports have come from the western slope, stating that the disease was present in Montrose, Mesa and Delta counties. (Fig. 2.) One correspondent from Montrose county stated that "German millet was badly smutted during the season of 1917." A correspondent from El Paso county stated that "Millet smut was quite general the past season (1917), the common and Proso varieties being most attacked. About 25 percent of the Proso millet in El Paso county was smutted in 1917. The Siberian millet was also smutted although, much less than the Proso." In Weld county one correspondent estimated the loss to be between 25 and 30 percent in the Proso variety. Siberian and German varieties were not badly attacked. One may find frequently in a field as many as 50 percent of the plants smutted. In the experimental plots at the Colorado Agricultural College the losses ran as high as 65 to 75 percent. A summary of the millet smut losses for the past season would average 6 to 7 percent of the State's production. Obviously, this represents a large loss, because affected plants are not only rendered worthless in grain production but are much impaired in yield of forage as well. Losses such as these are quite unnecessary since, by the

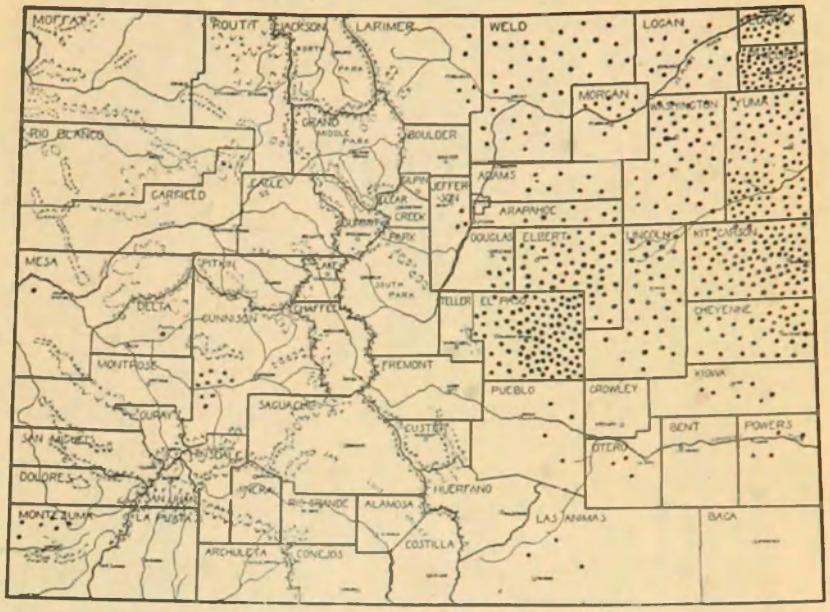

Fig. 2. Acreage of millet in Colorado, 1909; Total acreage, 30,926. Each dot represents 50 acres.

use of a simple seed treatment, we are able to eliminate smut from millet crops with a minimum of expense and trouble.

DESCRIPTION OF THE APPEARANCE OF SMUT IN MILLET

In these experiments, two types of millets chiefly were studied, namely, Foxtail millets *(Setaria italica)*, represented by the common German, Kursk, Goldmine, Hungarian and Siberian varieties, and the Panicum millets *(Panicum miliaceum)*, represented by Proso, hog and broom corn millets.

Foxtail Millets *(Setaria italica)*

In general appearance, smut in the Foxtail varieties resembles the stinking smut of wheat. In affected fields of the common and German varieties there may be seen the somewhat sickly yellow heads early in the season and the slightly darkened heads in the fall. If a smutted head be carefully examined, one sees at the base of the undeveloped grain (ovary) the dark mass of spores dimly showing thru the thin membrane that encloses it. (Fig. 3.) The base of the ovary appears enlarged. Generally, the spores are not disseminated; they usually remain so enclosed that close examination is necessary in order to recognize heads that are smutted. It requires examination of each

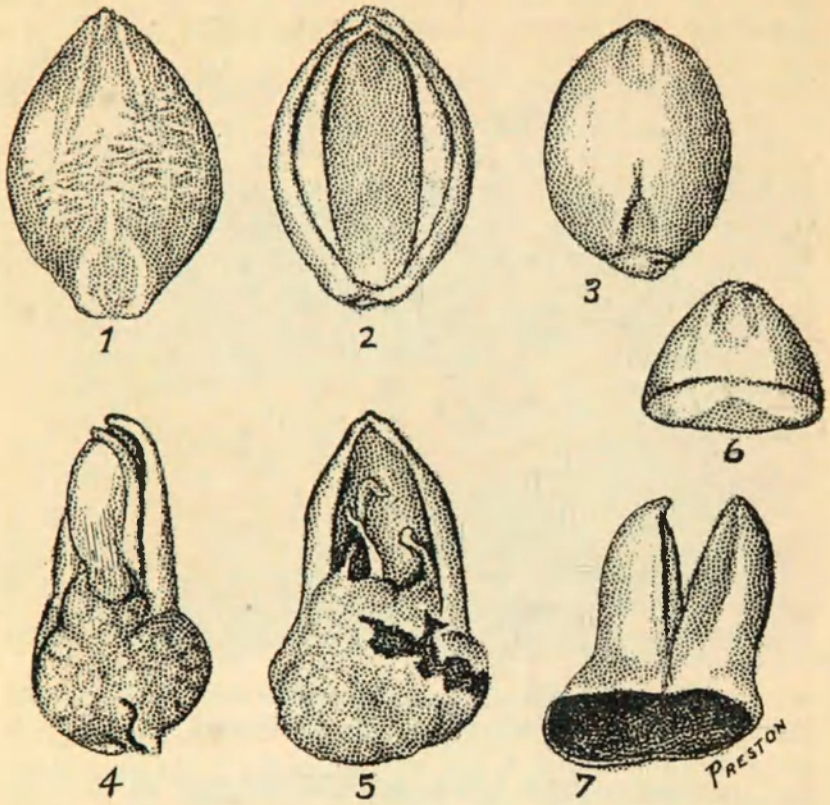

Fig. 3 Healthy and affected grains of common millet; 1, 2, 3, and 6, healthy grains; 4, 5, and 7, smutted grains.

head in the case of Kursk, Hungarian and Siberian millets before one can determine whether plants are smutted or not. This is because the dark orange or yellowish color of the mature heads obscures the characteristic color of affected heads.

Aside from the smut masses evident in the head, affected plants exhibit no other external evidence of the smut. The leaves and stem show no signs of the disease, except that affected plants are usually stunted and the heads frequently misshapen (Figs. 4 and 5 and 6.) Examination of affected heads shows that in most cases every grain of the head is destroyed, altho it often occurs that only a part of the head is smutted and, furthermore, only a few gains free from smut may be found between the diseased ones.

The disease is evident in the heads even before they emerge from the sheath; the glumes enclosing the smut masses appear whitish and translucent. Except for the peculiar yellowing of the heads, as in

the common and German varieties, affected stalks nearly always escape our notice.

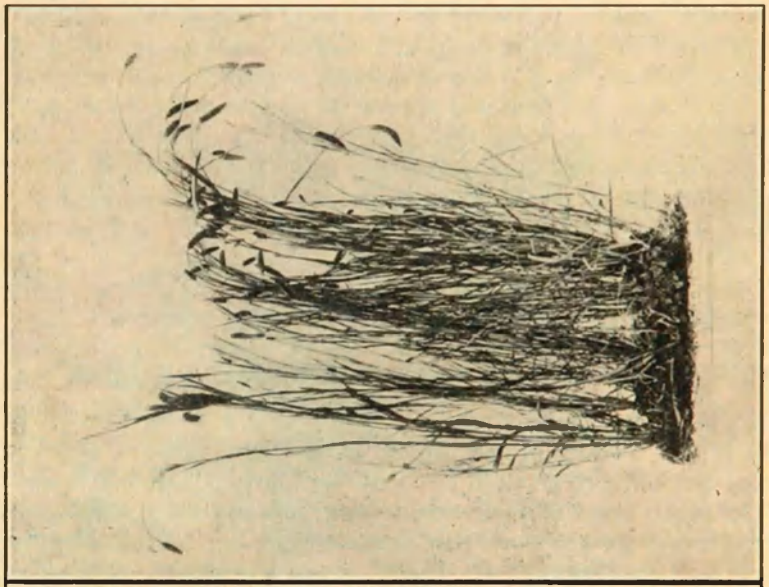

Fig. 5. Smutted plant of Hungarian millet. Note that the plants are stunted and heads are shorter than in the healthy plants shown in Fig. 4.

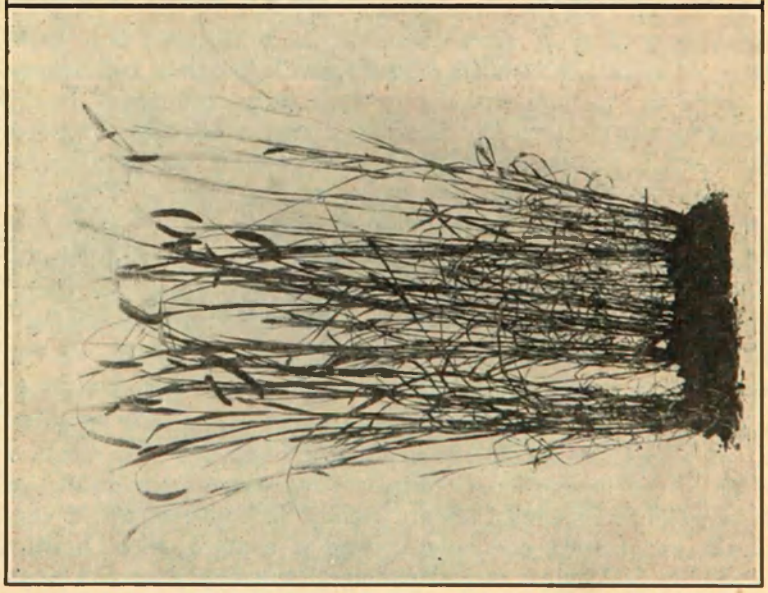

Fig. 4. Healthy plant of Hungarian millet.

Panicum Millets *(Panicum miliaceum)*

The smut in Panicum millets, such as Proso or Red Hog varieties, is especially characteristic in appearance. Here the heads are always empty and fully destroyed. They are noticeably shorter than normal ones, frequently exposed but very little beyond the leaf sheath. The smutted ovaries of the grain are massed together, enclosed by a whiteish membrane, the whole resembling a thickened or an elongated boil. Smutted heads *(panicles)* appear in much contrast to the normal spreading ones and are therefore readily recognized, even at a distance. Usually the smut masses are ruptured or broken before harvest time and the black, powdery mass is scattered by wind and insects to the healthy grain of other plants. Certain insects feed upon millet smut, more or less, and break open the enveloping glumes, exposing the dark spore masses and thereby rendering the affected heads more conspicious and easily recognizable. (Figs. 9 and 10.)

DESCRIPTION OF CASUAL ORGANISMS OF SMUT

It should be generally recognized that all the smut diseases, as well as fungus diseases in general, are caused by minute and parasitic forms of plant life, so small in fact that the individuals cannot be seen with the naked eye. Such disease-causing organisms are collectively referred to the group known as "fungi", while an individual of the group is called a "fungus".

Obviously, the fungi are very simple plants, the plant body itself consisting of minute threads *(mycelium)* which penetrate and destroy living plants and thereby give rise to some form of disease. In the case of the smut diseases, the fungus becomes evident in the grain generally, and is represented by the masses of black, powdery spores which constitute the reproductive bodies of the fungus. From the standpoint of their role in perpetuating the disease, the spores may be likened to the kernels of corn in which lies the power of producing new corn plants. Similarly, the smut spores are the bodies which carry the disease to new plants, resulting in the continued increase of smut, year after year.

The spores of the millet smut fungi are rounded and very small, the individual spores being visible only under high-power magnification. If placed side by side, it would require 20 spores to measure the width of one human hair. (Fig. 11.) Owing to the small size and light weight of spores, they are readily disseminated by air currents, rain, and insects, and upon coming in contact with healthy grains, readily find lodgment under the scales or any protective parts of the grain.

*Smut of the Foxtail millets may be looked upon as distinct from that of Panicum millets, altho, in external appearance, the two are somewhat alike. The former is generally regarded incapable of producing smut in the Panicum varieties, and if this be true, there is no danger of the Foxtail millets becoming smutted from association in the field with smutted Panicum varieties. Our experimemnts in 1916 bore out this conclusion, but in 1917 some negative results were obtained. Further study is to be carried out on this question of cross inoculation.

The parasite grows up within the millet, giving no external evidence of its presence until just before heading-time, at which time the mycelium enters the developing ovaries and forms therein the characteristic masses of spores (Fig.) which give the plant its smutted appearance.

These spore masses remain enclosed by the bracts or scales of the grain usually until the millet is threshed, when they are broken up and the spores disseminated to normal grains. Lodgement of spores takes place upon or underneath the bracts, where they remain in a dormant state until the grain is sown and conditions become favorable for their germination and infection of the seedling millet.

This simpl life cycle occurs alike in the smuts of both Foxtail and Panicum varieties. Obviously, any treatment of the seed that can effectively destroy the spores lodged upon the surface and yet effect no injury so the seed itself will control the smut.

TIME AND PLACE OF INFECTION

Seeding infection is here the most probable, if not the only, type of infection. The germ tubes are capable of growing into the germinating seedling only over a short period of time, probably never taking place after the seedling reaches a height of 3 inches and generally about the time the first leaf is pushing out from its protective sheath. Spore germination begins by the rupturing of the spore wall, from which emerges a stout germ tube (Fig.). The germ tube either penetrates the seedling directly or produces secondary spores *(sporidia)* which later germinate and bring about infection. In either case, the germ tubes penetrate the tender tissues and form a much-branched

* **Ustilago crameri** Korn. Sori dark-olivaceous; ovary infection; spores very irregular, rotund or oblong-angular, pellucid, 10-12 by 6-9 microns, brownish, olivaceous, smooth, sometimes very finely reticulated.

Ustilago panici-miliacei (Pers.) Wint. Sori black, pulverulent; panicles affected, and ovary of flower destroyed; spores globose to ellipsoidal, 9-12 by 8-10 microns, rarely angular, epispore yellowish-brown, smooth to punctate; promycelium filiform, cylindrical, commonly 3 septate; sporidia lateral or terminal, oblong-elliptic to ovoid.

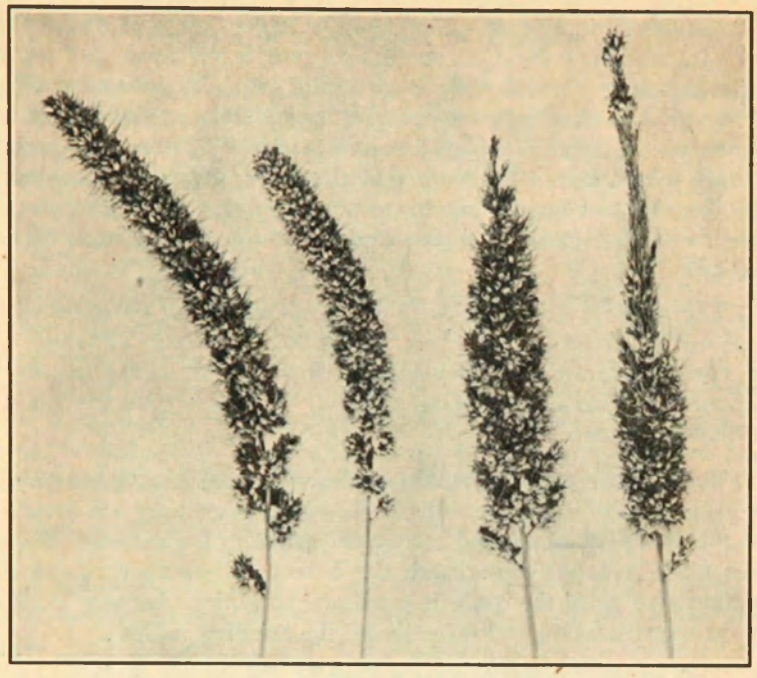

Fig. 6. Smutted heads of common millet.

network of fungus threads within the growing point of the stem. There they grow, keeping pace with the upward growth of the stem.

Brefeld, in his researches on cereal smuts suggested a possibility of blossom infection in the millet smuts, although he obtained negative results. The occurrence of a small number of diseased grains among healthy grains in the head is suggestive of blossom infection, altho our experiments indicate such to be of little importance practically. However, further study on this point will be continued.

SOURCE OF INFECTION

The increased prevalence of millet smut in Colorado has come about largely thru the continued use of seed from fields containing relatively small amounts of smut. Up to the present time, virtually no interest has been taken in controlling the smut. (No mention of seed treatment in Colorado has been made either thru correspondence or thru actual observation of seed treatment.) Naturally, the amounts of smut have steadily increased year after year until now the annual losses are so important that growers are beginning to take steps to control the smut.

Aside from the presence of smut in the crop itself there is much likelihood of infection from related grasses such as the wild Foxtail

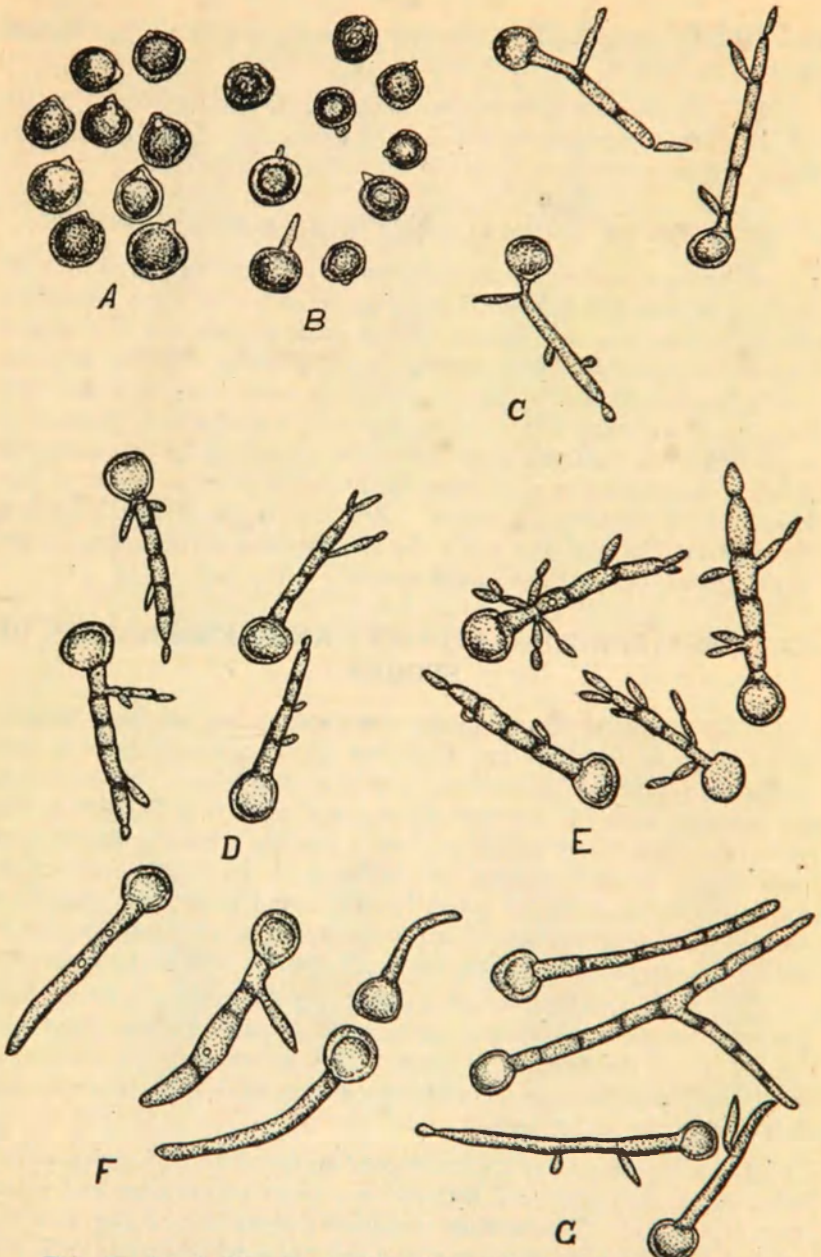

Fig. 7. Germinating spores of millet smut, A. Ustilago crameri after [illegible] hours in 5 percent cane sugar solution; B. Ustilago panici-miliacei, after 5 hours in 5 percent cane sugar solution; C. U. panici miliacei. after 14 hours in water; D. U. panici-miliacei, after 18 hours in water; E. U. panici-miliacei, after 24 hours in water: note the abundance of sporidia; F. U. panici-miliacei, after 18 hours in [illegible] percent can sugar solution; G. U. panici-miliacei after 24 hours in 5 percent cane sugar solution.

and Panicum grasses. This phase of the work will be studied further the coming season.

Millet growers are in further danger of introducing smut by the use of seed imported from without the State, since large amounts of millet are imported into Colorado annually.

EFFECTS OF FORMALDEHYDE GAS UPON SPORES

In order to measure the effectiveness of formalin gas in destroying the germinative power of smut spores, a sterile cage measuring 28x34x32 inches was prepared. Three cubic centimeters of formalin gas was atomized within it and spore suspensions in water were introduced and allowed to stand 4, 6, and 12 hours, and then removed In no case, were any of the spores observed to germinate. Water cultures of spores from the same source and placed under the same conditions, except that no application of formalin gas was made, yielded abundant germination of spores. Frequent trials of this treatment demonstrated beyond any doubt the effectiveness of the formalin gas in destroying the viability of the spores.

FACTORS AFFECTING VITALITY AND GERMINATION OF SPORES

The length of life of millet smut spores has not been studied fully. Our studies thus far show that spores are capable of a high percentage of germination after a period of three years. Undoubtedly, the viability lasts for seven or eight years, altho it is likely that it is seriously impaired at the end of such periods. Spores which were collected 27 years ago could not be made to germinate in water or nutrient cultures. Spores taken from smutted heads just after they had emerged from the leaf sheath were found to germinate readily in distilled water, thus requiring no resting period before germination.

The lasting viability of the smut spores disproves the theory held by some people that the storing of seed for a few years results in ridding it of the liability to smut. This practice should, therefore, be discontinued because the viability of smut spores is certain to outlast that of the millet seed.

Little can be said at present regarding the effects of moisture and temperature and other soil factors upon spore germination and infection in the soil. Temperature conditions prevailing at the time the seed and smut spores germinate may determine whether an attack will result or not. It has been shown in stinking smut of wheat that late sowing results in a greater percentage of smut in the crop than does early sowing. This is explained on the basis of low resistance of the

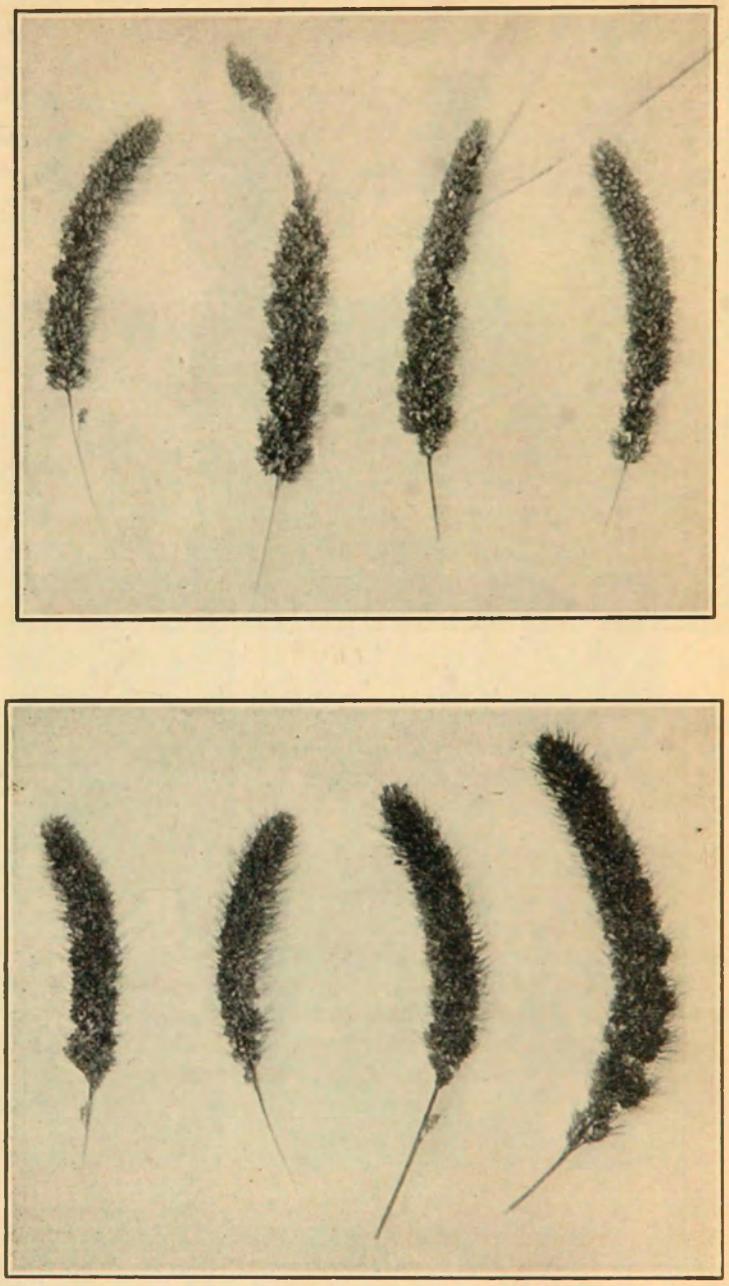

Fig. 8. Smutted heads of Siberian millet (above) and Kursk millet (below).

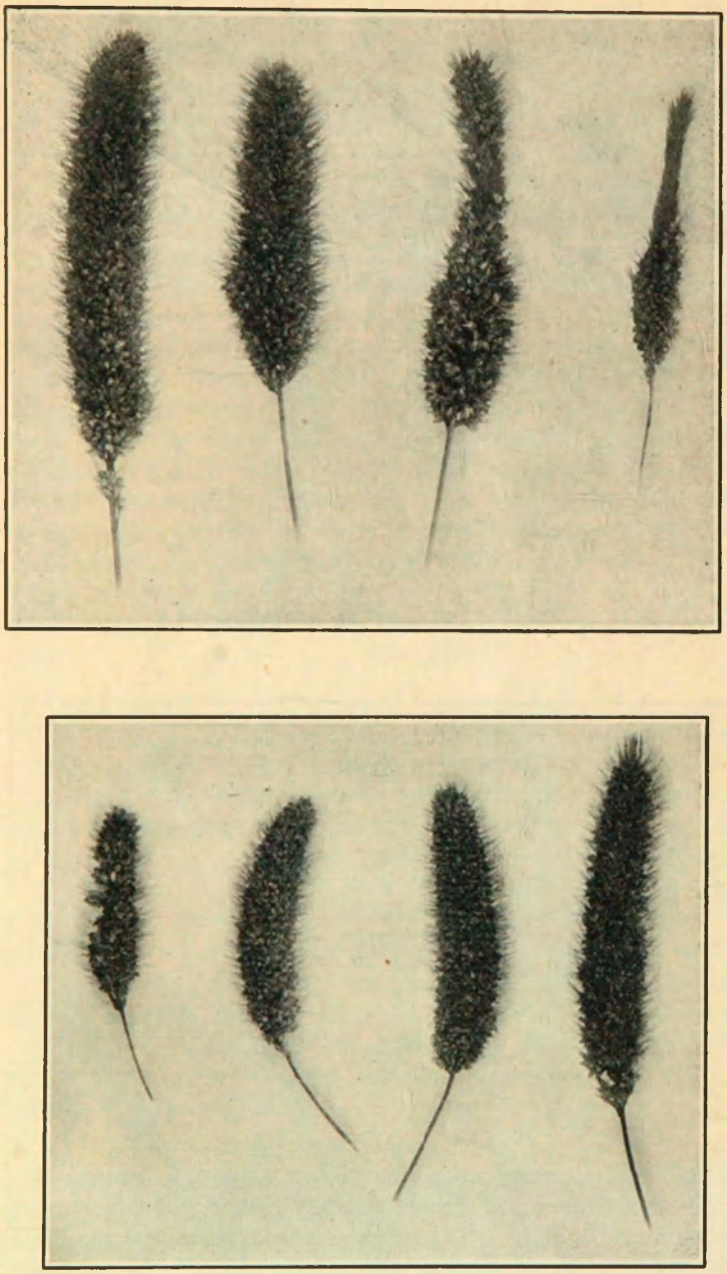

Fig. 9. Smutted heads of Siberian millet (above), and Hungarian millet (below).

wheat, due to impaired growth at low temperature. The same condition may obtain in millet germination and infection. It is less likely to be a serious factor, however, since millet is generally seeded in a warmer part of the season.

However, it is known that the period of infection is limited to a brief stage in the early growth of the plant and that outside conditions, especially moisture and temperature, which obtain at this period may affect materially the amount of infection that takes place.

Fig. 10. Smutted Red Hog millet.

MEANS OF SPORE DISSEMINATION

There are many ways whereby the spores of smut may be disseminated. Very little dissemination is carried on by wind, because

the smut masses are enclosed usually until harvest. In the event of rupture of the membranes, the spores are freed and may then be carried to healthy grains by means of wind, rain, insects or other agents.

A very small form of beetle *(Phalacrus politus Mels)* was found working in large numbers upon the millets of our experimental plots. It was found that they fed upon the smut, breaking open the glumes, and scattering smut spores from plant to plant. Wherever this little beetle was found at work, the smutted heads were noticeably darker than unaffected ones and could be recognized at some distance. The beetle undoubtedly plays an important role in spreading the smut in fields where it is present.

Other common means of disseminating smut spores are those of harvesting and threshing the grain. Whenever healthy and unhealthy stalks are handled together there is danger of contamination. In the

Fig. 11. Smutted Proso millet.

process of threshing, where both smutted and healthy grains are run thru at once, it is to be expected that the grain will be contaminated, and if used for seed, will bring forth a partially diseased crop. The same holds true for all cereal smuts as well, hence this phase of

handling the crop is especially deserving of consideration, particularly should there be only small amounts of smut in the crop.

CONTROL EXPERIMENTS

The following experiments were carried on during the seasons of 1916 and 1917 on the Experimental Station grounds at Fort Collins, Colorado. The experimental plots were irrigated; the soil consisted of a loan-or silty loam.

A large amount of smut material of both species *(U. crameri* and U. *panici-miliacei)* was secured for the purpose of inoculating various varieties of millet. The smut spores of *U. crameri were* thoroly mixed with the seed of the following varieties: Broom Corn, Common United States 1429, German U. S. 33133, Goldmine, Japanese, Hungarian, Kursk, Pearl, Proso, Red Hog, and Siberian. Spores of the other species *(U. panici-miliacei)* were mixed with these varieties in the same manner. The system of plotting the experiments was

TABLE I.—RESULTS OF INOCULATION WITH THE TWO SPECIES OF SMUT FOR 1916 & 1917.

	Ustilago crameri		Ustilago panici-miliacei.
	Percentage of smut 1916	Percentage of smut 1917	Percentage of smut 1916
Broom Corn	0	0	30
Common	45-55	58	0
German	50-60	72	0
Gold Mine	50-60	—	0
Hungarian	55-60	55	0
Japanese	0	0	0
Kursk	30-35	35	0
Pearl	immature	immature	immature
Proso	0	9	35
Red Hog	0	—	35
Siberian	31-35	32	0

modified somewhat the second season from that used in the first. i. e. instead of growing plants inoculated with both species in the same plot, these were plotted separately the second season.

Plot 1.—All varieties inoculated with *U. panici miliacei;* no disinfection of seed.

Plot 2.—All varieties inoculated with *U. crameri;* no disinfection of seed.

Plot 3.—All varieties inoculated with *U. crameri;* seed disinfected with formalin 1 pint to 40 gallons by soaking for 1 hour.

Plot 4.—Same as plot 3 except plants were inoculated with *U. panici-miliacei.*

Plot 5.—All varieties inoculated with *U. crameri;* seed disinfected with formalin, 1 pint to 40 gallons water, by sprinkle method.

Plot 6.—Same as plot 5 except plants were inoculated with *U. panici-miliacei.*

Plot 7.—Check.—Clean seed planted in clean soil.

Careful notes were kept on the plots thruout the season. The percentage of smut in each was determined in August and October.

TABLE II.—RESULTS OF INOCULATION WITH **USTILAGO CRAMERI**—SHOWS DIFFERENCES IN THE AMOUNT OF SMUT APPARENT ON AUG. 15th. AND OCT. 30.

Variety	Percentage of smut Aug. 15	Percentage of smut Oct. 30
Broom corn millet	not headed	0
Common	12	58
German	35	72
Hungarian	27	55
Kursk	[illegible]	35
Pearl	not headed	not headed
Proso	7	9
Siberian	27	32
Japanese	not headed	0

METHODS OF ELIMINATING SMUT

It is a well known fact that one of the b st methods for the prevention of smut in the crop is that of securing seed free from all evidence of smut. Obviously, this must be accomplished by securing seed from fields that had no smut in them. It is difficult to do this owing to the difficulty with which the smut is recognized in the field. The cleanliness of millet seed can hardly be judged by a mere examination. Hundreds of spores may be lodged upon the grain yet be entirely indistinguishable on casual examination. A thoro examination of both field and harvested grain is necessary to judge the presence or absence of smut in any small quantities. If more attention could be given to the source and cleanliness of the seed, the losses would be greatly diminished. It is usually the case that imported seed is bought and sown with no knowledge whatever of the field with respect to smut infection or even subsequent handling of the grain where, if it were associated with smutted grain, it would invariably become contaminated to some extent. Hence, it is advisable to have some knowledge of the field from which the seed millet comes, and if this knowledge is impossible, there is one other alternative, and that is seed treatment.

It is clear from the foregoing that every spore which goes into the soil in contact with the seed is capable of reproducing the smut, since it is from these spores that the millet becomes infected. For

this reason, the best method of control lies in a good, thoro disinfection of the seed whereby the smut spores are killed, but the vitality of the millet is uninjured.

TABLE III.—EFFECTS OF FORMALIN UPON SPORE GERMINATION

Cultures	Treatment	Percentage of Spore Germinations
1.	Formalin 1 pint to 40 gals. water	0
2.	" " " " 50 " "	0
3.	" " " " 60 " "	0
4.	" " " " 80 " "	0
5.	" " " " 100 " "	Slight
6.	" " " " 120 " "	0.1
7.	" " " " 140 " "	Free germination

Ustilago crameri Plot 11, Row 2—1917

The seed treatment recommended herein is very simple, readily performed, effective, and quite inexpensive. Considering these facts, in judging the advisability of treating smutted grain, there should be but one conclusion—treat all affected seed yourself and thereby insure the crop against unnecessary losses from smut.

In organizing experiments on the control of millet smut, it seemed advisable to experiment exclusively with formalin since it is now adopted as a standard method of control for all the cereal smuts where seed treatment is needed. Formalin is a commercial name applied to a 40 percent solution of formaldehyde, which is a gas. While not poisonous, it has a very pungent odor, and is one of the most effective disinfectants and fungicides now in use. In order to determine the best proportion of formalin and water to be used, it was necessary to expose both millet and smut spores to the disinfectant in various strengths for varying lengths of time.

TABLE IV.—EFFECT OF FORMALIN UPON VIABILITY OF MILLET SEED

The seed was soaked in the solutions listed below from 40-60 minutes and then dried

Lot	Treatment	Germination after 4 days			
		Common	German	Siberian	Average
1.	Formalin 1 pint to 20 gals. water	75	73	75	74.3
2.	" " " " 25 " "	78	80	77.5	78.5
3.	" " " " 30 " "	83	86	78.5	82.5
4.	" " " " 35 " "	84	91	85.5	86.8
5.	" " " " 40 " "	86	82	86	84.6
6.	" " " " 45 " "	87	86	87	86.6
7.	" " " " 50 " "	89	92	83	88
8.	Creek untreated	91	94	89	91

Some have recommended a treatment of the grain in this solution for two hours but in these experiments a shorter time was tried

out, and positive results were obtained thru a treatment for 40 to 60 minutes.

Method of Disinfecting the Seed

Solution Required: One pint of 40-percent formalin mixed with 40 to 45 gallons of water. Formalin is sold by nearly all druggists at a price ranging from 50 to 70 cents per pint. The solution should always be of guaranteed 40-percent strength.

Application to Grain: Two methods may be used according to the preference of theh farmer. Both are equally successful; the same strength of formalin solution is used in both methods.

Immersion Method

1. Use a barrel or any vessel of convenient size.

2. Put a sufficient amount of the solution into the vessel to immerse a sack of seed.

3. Leave plenty of room in the sacks; if it is filled too full, the solution will penetrate the interior of the sack with difficulty.

4. Put the sack of grain into the solution, move or dip it so that the solution can readily get to the interior of the sack and thoroly wet the grain. A block and tackle will be found very useful to raise and lower the sack, tho it is not necessary.

5. Leave the seed in teh solution not less than 40 minutes or more than 1 hour.

6. Raise the sack and allow to drain back into the vessel. Then empty in a pile upon a clean floor, and cover with wet cloth or gunny sack in order to prevent the escape of the formalin gas.

7. At the end of two hours spread the grain out to dry. Shoveling over frequently will help materially in drying it, or if a draught can be lead over it the drying will proceed much faster. To further facilitate drying, the grain should be spread as shallow as possible, one inch or so in depth, if possible.

TABLE V.—RESULTS OF EXPERIMENTS IN SEED DISINFECTION
(Percentage of Smut After Treatment)

	Sprinkle Method		Immersion Method	
Varieties	U. crameri	U. panici-miliacei	U. crameri	U. panici-miliacei
Broom Corn Millet	none	none	none	none
Common	"	"	"	"
German	0.1	"	"	"
Hungarian	"	"	"	"
Japanese	"	"	"	"
Kursk	"	"	"	"
Pearl	"	"	"	"
Proso	"	"	"	"
Siberian	"	"	"	"

Sprinkle Method

This method is very simple and easy. Two men can treat large amounts of grain in one day, depending upon the facilities at hand.

1. Use a clean granary floor or wagon-bed, or canvas in the open. A bushel or so of grain should first be spread upon the floor and sprinkled with the formalin solution mentioned above. A common garden sprinkling can is best for this purpose.

2. Apply the solution at the rate of ¾ to 1 gallon to a bushel of grain. While it is being applied, the grain should be shoveled well so that each grain will be thoroly wetted.

3. After all grain has been treated by adding both grain and solution to the pile as long as convenient, the whole should be piled and covered for 2 hours as in the previous treatment.

After drying, the grain should be put in clean sacks and stored in a place where it will be free from danger of contamination by smut spores. Sweeping in the granary, where any amount of smutted grain has been kept, should never be done until the treated seed has been removed. By sweeping, the large numbers of spores which have settled upon the floor and walls are put in motion and are likely to find their way back again to the treated grains.

Tables Nos. 3 and 4 give the result of spore and seed treatments. It will be noticed in Table No. 3 that the formalin solution is effective even to a dilution of 1 pint of formalin to 100 gallons of water. However, with this dilution a small percentage of spores appeared to be germinating, altho they never developed definite germ tubes.

Pammel and King in 1909, treated spores of *Ustilago cramen* with formalin solution diluted to 1 part to 320, 500 and 1000 parts of water. It was found that no germination resulted when spores were treated with the 1-320, (1-40 gals.) and 1-500, (1-63 gals.) proportions but "abundant germination" occurred in those treated with 1 to 1000 (1 to 125 gals.)

Table No. 4 gives the results of different strengths of the formalin solution upon the germination of millet seeds. The averages of many tests demonstrate the injurious effects of the solution when not diluted sufficiently. A solution of 1 pint to 20 gallons of water is entirely too strong, and unnecessary to destroy the spores. It impairs the germinative ability of the grain over 15 percent. On the other hand a solution of 1 pint formalin to 40 to 50 gallons of water causes no appreciable injury when the grain is steeped therein for a period of 40 to 60 minutes.

SUMMARY

Smut is the chief disease affecting millets in the Great Plains states.

Two different smuts affect millet; the Foxtail varieties are attacked by *Ustilago crameri,* and the Panicum millets attacked by *Ustilago panici-miliacei,* both of which infest the individual grains. converting the whole head or panicle into a large black mass, enclosed by bracts in the Foxtail millets and by a thin, white membrane in the Panicum types.

Experiments in the field demonstrate the possibility of infecting plants by inoculating the seeds with spores of the smut.

Smutted plants are difficult to recognize in the field, except by careful examination. This accounts for the fact that smut most always escapes notice in the field.

The spore masses are enclosed by the glumes (Foxtail) or by a thin membrane (Panicum) which prevent spore dissemination before harvest.

Generally only the lower parts of the glumes are destroyed in Foxtail millets, while the ovary is entirely destroyed. In Panicum millets, affected heads are shortened and resemble a dark, thickened boil.

The injurious effects of formalin gas upon the germination of spores was fully demonstrated. Spores in water cultures subjected to the gas for 4, 6, and 12 hours, failed to germinate in all cases.

The viability of smut spores lasts fully three years and probably much longer.

The period of infection is restricted to a brief stage in the early growth of the plant.

Spore dissemination in the field is effected at least to some extent by a small beetle, *(Phalacrus politus Mels).* Other means of disseminations are wind, rain, and the harvesting and threshing of grain.

Seed treatment is required in order to free the grain from smut. Seed may be thoroly cleaned by means of formalin disinfection. A solution of 1 pint of formalin to 40 to 45 gallons of water is recommended for treatment.


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