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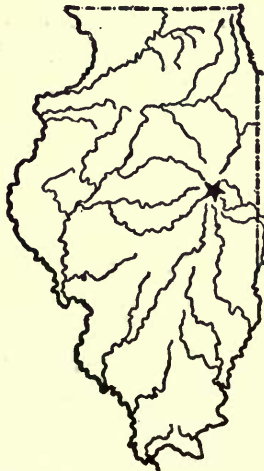
BULLETIN No. 242

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FLAG SMUT OF WHEAT, WITH SPECIAL  
REFERENCE TO VARIETAL  
RESISTANCE

IN COOPERATION WITH OFFICE OF CEREAL INVESTIGATIONS  
BUREAU OF PLANT INDUSTRY, U. S. DEPARTMENT OF AGRICULTURE

By W. H. TISDALE, G. H. DUNGAN, AND  
C. E. LEIGHTY



URBANA, ILLINOIS, APRIL, 1923

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## SUMMARY

Flag smut has caused severe damage to wheat in Australia and local damage in Japan and South Africa. It is known to occur in India and China but the extent of the loss caused is not known.

The disease was found first in the United States in 1919, near Granite City, Madison county, Illinois, and is thought to have been introduced from Australia. It has now spread over an area in Illinois about fifty miles long and five to fifteen miles wide. An infested area in Missouri adjacent to that in Illinois includes only four fields. The disease is spreading at a rather steady rate.

As yet severe losses by the disease have not been extensive in the infested area in this country. However, rare cases of an infection up to 30 percent in parts of fields indicates that the disease may cause severe loss if no precautions are taken to hold it in check. In Australia the effects are said to be cumulative.

One of the chief sources of infection is the spores that cling to the seed, which contaminate threshing machines, wagon beds, grain bins, etc. A second source is the spores in the soil, which may come from infested straw and manure, or be carried by wind or streams, or by animals or vehicles passing thru the infested area.

It is not known how long the spores will live in the soil, but it is known that some of them survive the winter months.

Because of the fact that the spores easily survive the summer and are present to infect fall-sown wheat, it is especially important that fields growing smutty wheat be sown to other crops the following year. Any other crop may be used, as flag smut affects only wheat.

In experiments in which seed was first smutted and then treated with fungicides, it was found that the disease was practically controlled in the plots where copper sulfate and lime, and where copper carbonate had been used. The treatments, however, failed to control the disease when the seed was sown in furrows in which spores of flag smut had been previously dusted.

In a three-year experiment to determine the effect of the time of sowing on the development of flag smut, it was found that the wheat sown after the first of November or in the spring was much less subject to flag smut than the wheat sown in the early fall. This was doubtless owing to the fact that temperatures at that time are too low for spore germination. Sowings made after the middle of November were smut free, but the yields were very low.

In the course of three years' experiments nearly two hundred varieties or strains of wheat were tested for susceptibility to flag smut. The seed was thoroly smutted with the spores of the fungus and sown in the infested area. Some fourteen varieties or strains were found to be immune and forty-one others were highly resistant. Some of these are adapted to the conditions existing in the infested area, while others are not. Several of the adapted varieties are being increased for wider sowing and for further testing in this locality.

Immune varieties that are adapted to the infested area include Beechwood, Fulcaster (Marvelous and Stoner), Imperial Amber, Red May (Early Harvest), Red Rock, and Shepherd.

Of the varieties commonly grown in the infested area, Harvest Queen (Red Cross or Salzer's Prizetaker) was found to be the most susceptible variety. Flint (May), Gipsy (Niagara), Red Wave, Jones Fife, and Fultz also showed a high percentage of infection.

# FLAG SMUT OF WHEAT, WITH SPECIAL REFERENCE TO VARIETAL RESISTANCE

BY W. H. TISDALE, G. H. DUNGAN, AND C. E. LEIGHTY\*

## INTRODUCTION

The discovery of flag smut (*Urocystis tritici* Keke.) in May, 1919, in some of the wheat fields of Madison county, Illinois, added another pest to the already rather long list of troubles known to affect wheat in the United States. Knowing the importance of flag smut as a destructive parasitic fungus in Australia, American plant pathologists and agronomists, on learning of its occurrence in this country, at once became interested in what might be its capacity for crop destruction under changed conditions of environment, in its epidemiology, and in methods for its control.

Fortunately, flag smut thus far has been found in but a limited area in southwestern Illinois and on four farms in St. Louis county, Missouri. To be sure, it has never, even under the most favorable conditions, proved so destructive as bunt or stinking smut of wheat, but its effects are none the less worthy of serious consideration. Losses amounting to as much as 10 to 20 percent are not uncommon; and these losses, added to those caused by rusts and by other smuts, by scab, and other diseases peculiar to the wheat crop, form no inconsiderable part in an aggregate reduction of yield that on the whole is enormous. The research herein reported has contributed materially to the existing knowledge of the habits and life history of the flag smut organism, the etiology of the disease, and methods for its control. Quite the most important result of these studies has been the discovery of a number of important varieties of wheat that are either immune from, or highly resistant to, flag smut. These varieties offer the most promising means of controlling this destructive disease.

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\*W. H. Tisdale, Pathologist in Charge of Cereal Smut Investigations, Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture; G. H. Dungan, Associate in Crop Production, University of Illinois Agricultural Experiment Station; C. E. Leighty, Agronomist in Charge of Eastern Wheat Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.

## HISTORY AND PURPOSE OF INVESTIGATIONS

Immediately after the discovery of flag smut of wheat in Madison county, Illinois, in 1919, arrangements were made for a cooperative investigation of the disease by the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, and the University of Illinois Agricultural Experiment Station. The purpose of this bulletin is to discuss the results of these investigations: namely, the history of the occurrence of flag smut, the losses caused, a description of the disease and the causal organism, the dissemination of the smut fungus, and finally, but most important, the results obtained thru experiments conducted in the infested area, near Granite City, Illinois, for the purpose of controlling the disease. It is very desirable that the wheat farmers of the United States be informed as to the nature of flag smut and the available means of holding it in check.

## OCCURRENCE OF FLAG SMUT

Flag smut of wheat is now known to occur in a number of countries thruout the world. The first reports of its occurrence came from Australia, where it was reported by the South Australian Commission on Diseases of Cereals in 1868.<sup>16</sup> Since that time it has been found to be widely distributed in South Australia and to occur in Northern Victoria, New South Wales, and Queensland.<sup>16</sup> It was found by Hori<sup>11</sup> in Japan in 1895, and by Sydow and Butler<sup>23</sup> in India in 1906. In 1920 Putterill<sup>21</sup> reported the occurrence of the disease in South Africa, where it is commonly known as "Tulp brand" or "Stoel brand." He thinks that it has been present in South Africa for a number of years.<sup>8</sup>

Flag smut was first found in the United States in Madison county, Illinois, on May 5, 1919.<sup>12</sup> In that year it was found in a number of fields in the vicinity of Granite City, where it was first noted.<sup>22, 24</sup> In 1920, in an extensive survey made by the Office of Plant-Disease Survey, Bureau of Plant Industry, U. S. Department of Agriculture, in cooperation with the Illinois State Department of Agriculture, flag smut was found in 111 fields in the county in an area comprizing about 47 square miles.<sup>22, 24</sup> In 1921 the disease was found to be spread over an area of 65 square miles in Madison county and 15 square miles in St. Clair county, Illinois.<sup>8</sup> The survey of 1922<sup>8</sup> showed flag smut to be present in two additional counties in Illinois: viz., Jersey, north of Madison county, and Monroe, south of St. Clair county, and also in St. Louis county, Missouri. The infested area in

<sup>16</sup>This and similar reference numbers refer to "Literature Cited," page 538.

<sup>8</sup>Since the preparation of this manuscript the authors have had access to a translation of a Japanese paper written by Miyake, in 1912, in which he notes the occurrence of flag smut in China.<sup>26</sup>

Illinois is about fifty miles long and five to fifteen miles wide. The infested area in Missouri is adjacent to that in Illinois and includes only four fields. The enlargement of the area from year to year probably has not been due entirely to spread of the disease but to wider and more thoro search. The survey has been limited because of lack of funds and men available for the work. The indications are that some of the recently discovered infestations have existed for a number of years. The records do indicate, however, that the disease is spreading at a rather steady rate.

According to Brittlebank,<sup>2</sup> it is probable that flag smut was introduced into this country from Australia. He states that during the year 1918, 5½ million bushels of wheat were exported to the United States from Australia. This wheat was supposed to be used for milling purposes only, but some of the contaminated by-products such as bran, or even the grain itself, might have escaped into the fields thru some of the numerous possible agencies. The fact that flag smut was found the next season following the importation of Australian wheat seems to furnish considerable evidence for Brittlebank's theory that the disease was introduced into this country from Australia.

#### LOSSES DUE TO FLAG SMUT

It is possible for the damage caused by flag smut to be heavier than might be suspected from looking at the mature wheat crop. Diseased plants generally are much dwarfed and the smutty plants seldom produce heads, but die before the wheat is ripe. Thus the diseased plants may easily be overlooked and the thin stand and light harvest not be attributed to the smut.

According to Brittlebank,<sup>1</sup> the disease may cause unsuspected damage thruout the growing season. In 1905 McAlpine<sup>15</sup> stated that in some seasons in Australia severe losses had been caused by the disease. In 1910 the same writer<sup>16</sup> made the following statement: "In Victoria as much as half the crop may be lost thru it and in New South Wales, Cobb has shown it to be equally bad. Where wheat is grown year after year and no precautions taken against this disease, the effects are cumulative. This will account for the widespread and injurious effects of this disease in many wheat growing districts." Later reports made by Australian writers seem to bear out the statements made by McAlpine that the effects are cumulative. Brittlebank,<sup>1</sup> in 1920, says, "Considering that rust epidemics are few and far between, while flag smut is annually taking toll of from 5 percent to nearly 70 percent, the total loss caused by rust sinks into insignificance when compared with that resulting from flag smut." Rust is regarded by some as being the most destructive disease of wheat in Australia.<sup>1</sup>

Hori<sup>11</sup> reports considerable local damage to the wheat crop from flag smut in Japan as early as 1895. No recent reports have been received from that country. The disease is known to occur in India<sup>23</sup> but there are no available reports of the losses caused by it. Putterill<sup>21</sup> makes the following statement regarding the losses due to flag smut in South Africa: "During the last two or three years, wheat farmers at Zeerust, in the Marico District of the Transvaal, have been considerably alarmed at the loss in their wheat crops sustained thru the ravages of this smut. While the total loss up to now may not be considered very great in that district, yet in some wheat fields lately visited almost half the crop was found to be affected."

Flag smut has not yet caused any very serious losses in the United States. In most fields, infections have been scattered and difficult to find. In some cases, however, fields have been found showing as many as 5 percent of the plants infected. In extremely rare cases, from 5 to 30 percent of infected plants in parts of fields has been reported, and in one field of thirty-five acres an average infection of 17 percent was found.<sup>8</sup> The fact that seed treatment and other measures, such as the use of resistant varieties, have been adopted for holding the disease in check no doubt accounts, to a marked extent, for the low percentages. Furthermore, the facts concerning the cumulative effects of the disease in Australia may be significant in this country. It is not known how long the spores of the flag smut fungus will live in the fields in the infested area, but it is known that some of them will live over winter in the soil and still be capable of germinating and infecting wheat plants.<sup>6</sup> If the fungus is able to live in the soil in this country, as it does in Australia, its effects no doubt will be cumulative, as they are there, provided effective control measures are not employed.

### SYMPTOMS

Flag smut of wheat occurs in the leaf blades and sheaths, forming black stripes running lengthwise. (Figs. 1 and 2.) In the early stages these stripes are somewhat lighter than the green color of the normal leaf; later they become lead-colored and finally black because of the presence of the dark-colored spores produced by the fungus. They are commonly more noticeable in the upper leaves and may be seen even before jointing is apparent in the plants. The stems (culms) often show these black stripes also. Infected plants usually are more or less dwarfed. The leaves and sheaths become twisted in some cases, and the infected culms rarely head out or produce seed. Where heads do appear on infected culms, the black stripes may be present on the glumes at the base of the head and usually are present on the culms just below the head. One or more sound culms with normal

<sup>8</sup>Unpublished data furnished by Miss M. A. Griffiths, Office of Cereal Investigations, U. S. Department of Agriculture.

heads often may be found on smutty plants, but it is not uncommon to find infected plants without a single sound culm. The degree of culm infection seems to vary with the variety.

Stem smut of rye, with which flag smut was formerly thought to be identical, differs from it in that the rye disease is most noticeable on the culms, which it more or less distorts, while the leaves show practically no distortion and the culms generally produce heads even though they are not well filled. It is caused by a different though related organism, as is shown below, and will not pass from rye to wheat.

#### THE CAUSAL FUNGUS (*Urocystis tritici* Keke.)

Flag smut of wheat is caused by a minute parasitic plant, or fungus, belonging to the group of fungi which produces the disease of plants commonly known as smut. More familiar examples of diseases caused by this type of fungus are loose smut and bunt of wheat and the loose and covered smuts of oats. More closely related, however, are the smut of onions, which causes considerable damage to the onion crop of the United States, and the stem smut of rye, which is less destructive. Wolff,<sup>25</sup> in 1873, thought that the fungus causing flag smut of wheat was identical with the one causing stem smut of rye and called it *Urocystis occulta* Rabh., which is the rye form. Körnicke,<sup>13</sup> in 1877, after making a careful morphological study of the forms from wheat and rye, decided that there was sufficient difference to justify making the wheat form a distinct species, so he called it *Urocystis tritici* Keke. McAlpine,<sup>16</sup> after repeated cross inoculations of wheat and rye with their respective *Urocystis* forms, agreed with Körnicke in concluding that they were different. Previous to these studies by McAlpine the disease was reported on wheat in Japan<sup>11</sup> and India<sup>23</sup> as being caused by *Urocystis occulta* Rabh. Since McAlpine's<sup>16</sup> report it has been agreed generally that the *Urocystis* species on wheat and on rye are different.

The black stripes appearing on infected wheat plants are filled with numerous minute, dark colored spores of the fungus (Fig. 3, A), which, in mass, appear black and produce the black color of the stripes. The spores contain from one to five large cells, which are capable of germinating. These large cells are incased in an outer layer of smaller, bladder-like, sterile cells, making what is commonly termed a spore ball. These spore balls are 15 to 35 microns, or an average of 24 microns (.001 inch), in diameter. The outer protective envelop of sterile cells serves, no doubt, as an aid to dissemination by wind and water by causing the spores to float.

Germination of the spores takes place by small germ tubes, or promyelia, arising from the larger, inner cells (Fig. 3, B). Generally one to two, and occasionally all, of the cells in the spore ball

germinate. The promycelium, which may or may not be septate, bears at its apex two to six, more commonly three, thread-like appendages, or secondary spores, known as sporidia. These sporidia, usually of unequal length, are at first unicellular, but may divide later into two or three cells. In some cases they grow out into variously curved filaments. These sporidia in turn germinate, producing minute, thread-like tubes, or hyphae, which, if in contact with the young wheat seedling as the seed germinates, penetrate its tender tissue. These hyphae, which scarcely can be seen with the aid of the microscope, grow up thru the tissues of the young wheat plant, from which they obtain food. In the spring, the smut fungus, after it has spread thru the tissues of the wheat and after its food supply has become somewhat exhausted, begins to produce the dark colored spores, which, in mass, appear as long black stripes, so typical of the disease. With the ripening of spores, the epidermis of the leaf along the stripes breaks open, thus setting free the spores for a further contamination of seed and soil.<sup>27</sup>

### DISSEMINATION

Wheat plants are attacked by flag smut chiefly from two sources. One source is thru smut spores that cling to the seed. In threshing grain from infested fields a large proportion of the spores are knocked out of the diseased plants and scattered over the grain. They also lodge in the threshing machine and later become mixed with seed threshed from clean fields. Contaminated wagon beds, grain bins, bags, or other objects with which grain comes in contact may serve as disseminating agents for the fungus.

When contaminated grain is sown and germinates, the adhering spores also germinate. The germ tube penetrates the young wheat seedling, grows up thru its tissues, and appears in the spring as smut stripes in the wheat plant.

The other source of infection is thru spores in the soil. McAlpine<sup>16</sup> proved that infested straw and manure from horses fed on diseased straw, when placed on wheat land, were sources of infection. Hamblin<sup>9</sup> also says: "It is known that horses and cattle fed on diseased hay have passed the spores uninjured and capable of germination." Putterill<sup>21</sup> states that the spores may be blown about by wind, carried on the hoofs of animals, or transported by irrigation-water. While the latter agent would not be a factor in the present infested area and surrounding territory in this country, flood water from streams may serve the same purpose. There is no particular reason why spores may not be carried from field to field or from one locality to another on the clothes of man and by animals, including birds, and on any vehicle or exposed product leaving or passing thru the infested area, especially during and near harvest time, when abundant



FIG. 1.—PORTIONS OF WHEAT PLANTS SHOWING THE BLACK STRIPES  
CAUSED BY FLAG SMUT

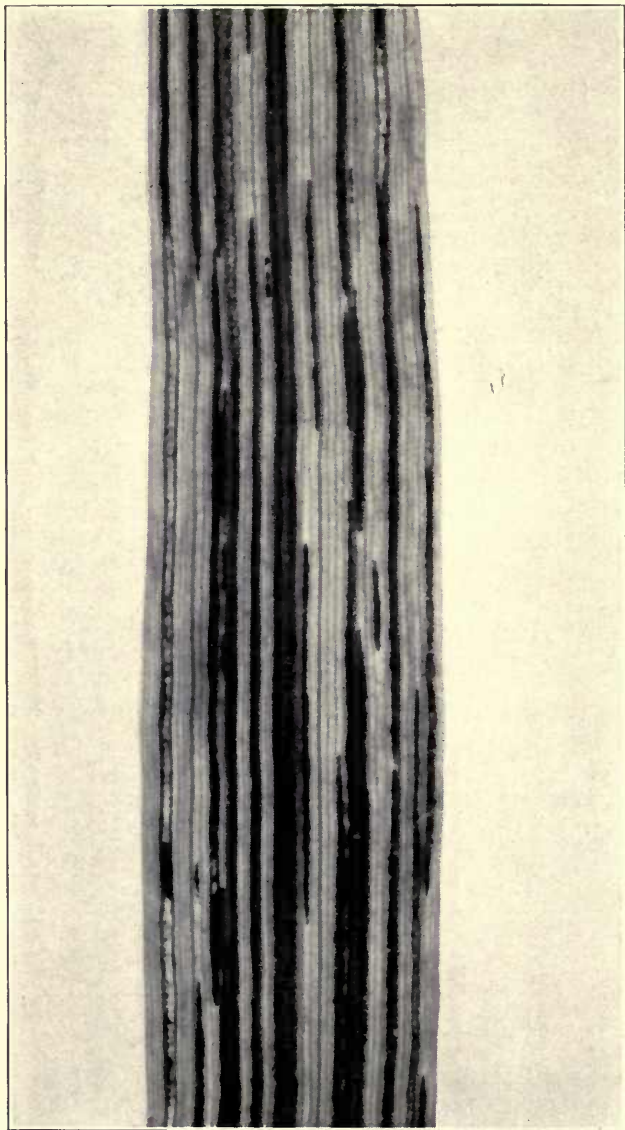


FIG. 2.—PORTION OF WHEAT LEAF, GREATLY ENLARGED, SHOWING THE BLACK STRIPES CAUSED BY FLAG SMUT. NOTE THAT SOME OF THESE STRIPES HAVE RUPTURED

spore material is being liberated from the diseased plants. The spores carried by these agencies may fall on land where wheat is to be sown and thus spread the disease.

In fields where a diseased crop has been harvested the spores live over on the stubble and in the soil until fall. A small percentage of spores is known to overwinter in the soil at Granite City, Illinois, as previously mentioned, but it is not known whether these spores which have overwintered will live until time for sowing wheat the next autumn. In Australia, Brittlebank<sup>1</sup> says, "Contamination of the soil is the most difficult problem in dealing with the control of flag smut." The climatic conditions in the infested area in this country may or may not permit the organism to live in the soil in abundance and for long periods of time, as it does in Australia. These questions remain to be answered.

### CONTROL MEASURES

Flag smut may be held in check and reduced to a minimum by employing judicious quarantine, crop rotation, seed treatment, and other sanitary measures, and by growing resistant varieties of wheat. The soil and weather conditions under which the wheat is sown also influence the development of the disease. Certain quarantine and farm sanitation measures have been employed in the infested area in this country in cooperation with the Illinois State Department of Agriculture. They consist in the regulation of shipments of infested grain and straw, the disinfection of farm machinery leaving the infested area, etc. The burning of infested straw and stubble, which is recommended in Australia,<sup>9, 10</sup> would be of value in reducing the spore material present. These measures are discussed in detail in Circular No. 4 of the Illinois State Department of Agriculture, "Flag Smut of Wheat."<sup>8</sup>

#### EXPERIMENTS IN CONTROL BY SEED TREATMENT

The following experiments were undertaken to learn whether spores of flag smut carried on seed wheat can be destroyed by treating the seed with certain fungicides. For this purpose a lot of seed of the Harvest Queen (Red Cross) variety was thoroly smutted with viable spores of *Urocystis tritici*. After treating this infested seed with the different fungicides in the manner described below, it was sown in the soil in the infested area at Granite City, Illinois. The various treatments and the results obtained are shown in Table 1.

A number of different strengths of copper-sulfate solution and formaldehyde were used and also a number of methods of application, but none of them proved to be more satisfactory than the strengths and methods of application commonly employed and only these latter are reported in the table. Copper sulfate was used at the rate of 1 pound to 5 gallons of water. The seed was submerged for ten min-

TABLE 1.—EFFECTS OF SEED TREATMENT ON THE CONTROL OF FLAG SMUT IN HARVEST QUEEN (RED CROSS) WHEAT WHEN THE SEED WAS THOROLY SMUTTED Seed sown in soil where flag smut had occurred the previous year. Experiment plots, Granite City, Illinois.

Treatment	Percentage of infected plants			
	1920	1921	1922	3-year average
Untreated.....	27.0	17.2	25.6	23.26
Chlorophol (.3 percent solution)....	....	....	1.9	....
Copper carbonate (dust).....	....	....	.4	....
Copper sulfate-lime (dip).....	trace	0.0	.8	.26
Formaldehyde (1:320 dip).....	trace	0.0	1.8	.60
Sterilac (1:500).....	....	....	21.7	....
Sterilac (1:1000).....	....	....	17.6	....

\*This name is now applied to the flag smut susceptible variety, with white glabrous chaff, red kernels, and beardless heads, which was largely grown in southern Illinois, at the time flag smut was discovered, under the name "Salzer's Prizetaker." The true Salzer's Prizetaker is beardless, with glabrous red chaff and white kernels. This white-chaffed variety is sometimes known also as "Red Cross," but this name is objectionable as there is a red-chaffed variety known by the same name.

utes in this solution and then for five minutes in lime water containing 1 pound of lime to 10 gallons of water. Formaldehyde was used at the rate of 1 part in 320 parts of water (1 pint in 40 gallons of water). The seed was soaked for ten minutes in this solution and then covered for four hours, after which it was spread out to dry before sowing.

From the table it will be noted that, in 1922, seed from all treatments produced some infected plants. These infections, however, except in the case of the treatment with Sterilac, where the percentage of infection was very high, may reasonably be accounted for by the presence of spores in the soil, since the treated seed was sown in soil where flag smut had occurred in wheat the previous year. From these results it may be said, in general, that nearly all the spores carried on the seed can be destroyed by seed treatment.

Copper carbonate dust, which has been used successfully in Australia<sup>6</sup> and in the Pacific coast states<sup>10, 18</sup> for controlling bunt in wheat, gave good results in the single season it was tried. (It was used at the rate of 2 ounces per bushel of seed.) Chlorophol, an organic mercury compound of recent development, was fairly effective in destroying seed-borne spores. (The seed was soaked in a .3-percent solution of Chlorophol for one hour and dried before sowing.) Sterilac, another newly developed compound, was used without success.

Of the treatments used, copper carbonate is the easiest to apply and does not cause seed injury; rather, it sometimes appears actually to stimulate the seedlings. The grain is more easily handled during and after this dust treatment than it is when treated with copper sulfate or by other wet methods. Heald and Smith<sup>10</sup> have devised a

TABLE 2.—EFFECTS OF SEED TREATMENT ON THE CONTROL OF FLAG SMUT IN HARVEST QUEEN (RED CROSS) WHEAT WHEN THE SEED WAS SOWN IN SOIL HEAVILY INOCULATED WITH SPORES OF FLAG SMUT

Seed treated and sown in experiment plots, Granite City, Illinois, October 4, 1921.

Treatment	Percentage of infected plants	Percentage of smutty culms on infected plants
Untreated.....	19.3	36.7
Copper sulfate-lime.....	13.0	38.6
Copper carbonate.....	16.0	32.4

machine for dusting grain which consists of a wooden drum so mounted that by revolving it the dust and grain are thoroly mixed. A revolving barrel churn or any device which will insure a thoro mixing will serve the purpose if no special machine is available. It is very important to have the dust so thoroly applied that each kernel of wheat will be covered with a thin film over its entire surface.<sup>1</sup>

Altho treatments with copper sulfate and lime and with copper carbonate were very successful when the seed was sown in soil where infected wheat had grown the preceding year, they failed to prevent the disease when the treated seed was sown in furrows in which spores of flag smut had been previously dusted and mixed with the soil by means of a small hand plow. To be effective under these conditions the fungicide necessarily would have to remain active until after the time the seed had germinated, when infection would take place. However, even tho the disinfectant should remain active until that time, there might be infection from the spores in the soil that were near enough the young plant to infect it but too far from the seed to be destroyed by the disinfectant. The results of this one-year study of the duration of protection by these fungicides are shown in Table 2. The amount of inoculum present in the furrows in which the grain was sown was larger than ordinarily would be expected under natural conditions; still, it shows that control by seed treatment cannot be assured where the soil becomes infested with viable spores.

In accordance with quarantine regulations, commercial seed wheat sown by wheat growers in the infested area was treated with copper sulfate and lime, yet traces of smut were found in some of these fields. This, in all probability, was due to the presence of spores in the soil. Australian writers are agreed that seed treatment kills seed-borne spores but that it is less effective in controlling smut where the soil is infested.

#### CONTROL BY CROP ROTATION

Wheat sown in the infested area but in fields in which flag smut has not occurred for one or more years previously is less subject to smut

<sup>1</sup>Care should be taken in handling copper carbonate dust to prevent inhaling it, as it may cause irritation of the nose and throat.

than if sown in fields known to have been infested the preceding year. Because of the fact that the spores easily survive the summer and are present to infect fall-sown wheat, it is especially important that fields growing smutty wheat be sown to other crops the following year.

McAlpine,<sup>16</sup> Brittlebank,<sup>1</sup> and Hamblin<sup>9</sup> of Australia, and Putterill<sup>21</sup> of South Africa all recommend crop rotation as a means of reducing the amount of flag smut to a minimum. There are some indications from survey records<sup>8</sup> that rotation will be of some value in this country, as fields in the infested area which previously had grown crops other than wheat were found to have less flag smut than fields which had been cropped to wheat for a number of years and in which flag smut was known to occur. These records indicate that the effects of flag smut in this country, as in Australia, may be cumulative when susceptible wheat is grown continuously on infested land.

Whether or not smut spores can survive in the soil thru the second year and infect a wheat crop when the land has not grown wheat for one year remains to be determined. Final advice concerning rotations, therefore, cannot be given at this time. However, it is evident that at least one year should intervene between wheat crops on the same land, and it is probable that two or more years must pass before the land is entirely free of viable spores. Inasmuch as this disease does not affect other crops than wheat, no limitation is imposed, so far as the disease is concerned, as to what crops should be grown in the rotation. However, straw, manure, or other material that may contain smut spores should not be returned to the soil in the meantime, as infection may come from these sources. A straw mulch on potatoes, for example, may add the smut spores to the soil. If manure or other material that possibly may contain the smut spores is to be applied, the safest place in the rotation to apply it is on the wheat stubble.

#### EXPERIMENTS IN CONTROL BY DATE OF SEEDING

Wheat sown early in the fall is more subject to infection by flag smut than that sown later. According to Australian writers<sup>1, 9, 16</sup> early and self-sown (volunteer) wheat suffers most from flag smut. They also state that wheat sown in dry soil is more subject to the disease than wheat sown following a rain. This, they claim, is because of the fact that during a dry season the spores remain ungerminated in the soil and when the rains come both spores and seed germinate and infection of the seedlings takes place, while, on the other hand, if the wheat is sown after the rain the spores in the soil have had time to germinate and become exhausted before the wheat germinates.

In order to determine the effect of the time of sowing on the development of flag smut in wheat at Granite City, Illinois, seed of a

large number of varieties was smutted with spores of flag smut and sown on different dates. During the first two years of the experiment all these varieties behaved relatively in about the same way so that in the third and last year only the most susceptible variety, Harvest Queen (Red Cross), was used. The effect of the date of sowing on this variety is shown in Table 3.

TABLE 3.—EFFECT OF DATE OF SOWING ON THE SMUT INFECTION OF HARVEST QUEEN (RED CROSS) WHEAT, A HIGHLY SUSCEPTIBLE VARIETY

Seed inoculated and sown in experiment plots at Granite City, Illinois.

Date of sowing	Percentage of infected plants			
	1920	1921	1922	Average for 2 or 3 years
October 4 to 12.....	32.73	24.70	27.20	28.21
October 15 to 20.....	15.50	.....	6.25	10.87
November 1 to 10.....	.....	4.70	5.29	4.99
November 15 to 20.....	0.00	.....	.55	.27
November 23 to 30.....	.....	0.00	0.00	0.00
April 4.....	.....	.....	0.00	.....

Wheat sown early in October smutted more than wheat sown later in the fall. There was little difference, however, in the amount of smut in sowings made sufficiently early to insure a good crop of grain. Sowings made after the first of November showed much less smut than earlier sowings. Sowings made after the middle of November were smut-free, but the yields were very low. Spring-sown smutty seed produced a smut-free crop. This failure of wheat sown in late fall or in spring to become infected doubtless is due largely to the fact that soil temperatures at that time are too low for spore germination and infection. Fields of spring wheat in the infested area, other than the experimental plots, were examined but no flag smut was found. These results indicate rather decisively that temperature is one of the important factors in spore germination and infection.

### VARIETAL RESISTANCE

The discovery of varieties of wheat which are desirable commercially and at the same time are resistant to flag smut offers the most promising means of controlling the disease. McAlpine<sup>16</sup> discusses the possibility and desirability of producing resistant varieties in Australia. Pridham<sup>20</sup> found considerable varietal differences in the field infection of some of the Australian wheats. He did not smut the seed before sowing, however, so these varieties might not have been equally exposed to infection. Brittlebank,<sup>1</sup> in 1920, suggested breeding wheat for resistance to the disease.

EXPERIMENTAL WORK TO DETERMINE VARIETIES  
COMPLETELY RESISTANT

In the fall of 1919, seed of several varieties of wheat was thoroly smutted with spores of the flag smut fungus and sown in the infested area at Granite City, Illinois. In the fall of 1920 several other varieties were added to the list. In 1921 those varieties which had shown more than 3 percent of smut were dropped from the list and only the more resistant wheats were sown. Among these varieties which were grown two or three years several remained free from flag smut even tho the seed was heavily smutted before sowing. A still larger number of varieties developed less than 1 percent of smut, while the remaining varieties were more or less susceptible. The seed was sown between October 4 and 12 each year.

Table 4 contains a list of varieties which showed no infection during two or three years' experiments. For the present purpose, the varietal names under which the various samples were collected have been retained, but they are grouped in the following tables under varieties to which, upon careful examination, they were found properly to belong.

*Hard Red Winter Wheats.*—Considering first the hard red winter wheats listed in Table 4, it should be stated that all those listed are probably about equal in adaptation for growing in the area where flag smut is found in Illinois, altho Kanred probably should have preference on account of its good performance in Kansas and the availability of certified seed. From the farmer's standpoint, however, the hard red wheats are not fully desirable. This class of wheat is not so well adapted to this section of Illinois as are the soft red wheats. A considerable acreage of hard red winter wheat was sown by farmers in the fall of 1921 and some good yields were reported in 1922. The season favored these wheats to some extent, as it was favorable to severe leaf rust development, and these wheats are resistant to this rust. It is reported, however, that very little was sown in the fall of 1922. The lack of interest in these wheats probably is due to the presence of beards and to their weak straw, which, in wet seasons, causes lodging on low land. The quality of grain, also, from this class of wheat is not of the best, when grown on wet lowlands, as there is a tendency toward "yellow berry," which is undesirable from the market standpoint. For the reasons stated these hard red wheats are considered undesirable for the present flag smut area in Illinois and Missouri.

*Soft Red Winter Wheats.*—Varieties of soft red winter wheats have been grown almost exclusively by farmers in the flag smut section. All those listed in Table 4 probably would be adapted for growing there, with the certain exception of Squarehead Master and

TABLE 4.—VARIETIES OF WHEAT WHICH REMAINED FREE FROM FLAG SMUT WHEN GROWN FROM SMUTTED SEED FOR TWO OR THREE YEARS AT GRANITE CITY, ILLINOIS

Seed sown between October 4 and 12.

Variety	Source or C. I. No. <sup>a</sup>	Years tested
<i>Hard Red Winter</i>		
Kanred		
Kanred.....	Kansas	2
Kanred.....	Illinois	2
P-1068.....	5880	2
Turkey		
Illinois 12-41.....	Illinois	2
<i>Soft Red Winter</i>		
Beechwood.....	Missouri	2
Fulcaster		
Eversole.....	3011	2
Marvelous.....	Indiana	2
Stoner.....	Virginia	2
Grandprize (St. Louis Grandprize).....	5627	3
Imperial Amber.....	3447	3
Penquite (Velvet Chaff).....	3068	2
Red May		
Early Harvest.....	4852	2
Red Rock.....	5597	3
Shepherd.....	6163	3
Squarehead Master.....	3283	3
Ulta No. 834 <sup>b</sup> .....	5747	2

<sup>a</sup>Seed of varieties with C. I. Nos. was furnished by the Office of Cereal Investigations. Where a state is given as the source, the seed was obtained from the experiment station of that state, with the exception of Marvelous, the seed of which was obtained from a farmer in Indiana.

<sup>b</sup>The variety recorded here as Ulta No. 834 is beardless with red glabrous chaff and red kernels. The name Ulta is usually applied to a variety of the Turkey type.

the possible exception of a strain known as Ulta No. 834. The most desirable varieties from the local farmer's standpoint are Beechwood, Early Harvest, and Shepherd, as they are beardless and produce a good quality of soft red grain. They also yield well in this section of the country.

Unfortunately, there is no commercial supply of seed of the three varieties last named.—Shepherd is being increased as rapidly as possible, however, from nursery stocks. At least 8 bushels were grown in 1922 on a farm near Granite City, Illinois, and this seed was sown on the same farm in the fall of 1922. A small plot of this wheat was sown also on another farm near Edwardsville, Illinois, and an increase plot was sown on Arlington Farm, Rosslyn, Virginia, from nursery supplies available. Shepherd is known also to be immune from rosette disease.<sup>a</sup> Up to the present time the seed

<sup>a</sup>The information given here and in the following pages concerning the behavior of varieties toward the rosette disease is derived from unpublished data furnished by H. H. McKinney and R. W. Webb of the Office of Cereal Investigations, U. S. Department of Agriculture.

supplies of Early Harvest and Beechwood have not been increased, altho these varieties are likely to be satisfactory. Early Harvest has been immune from rosette disease in experiments in this locality; Beechwood has not been tested in the experiments with rosette. Ulta No. 834 represents a selection concerning which little is known.

Among the bearded wheats listed in Table 4, Fuleaster (Stoner or Marvelous, C. I. No. 2980) should probably be given preference. Seed of this variety is available in commercial quantities from seedsmen and farmers. The seed of Red Rock also is available. Large stocks are in the hands of farmers in Michigan and to a lesser extent of farmers in other states and it is also handled by seedsmen. Eversole and Imperial Amber probably are desirable varieties but the value of Penquite (Velvet Chaff) is doubtful, altho none of these three have been tested for yield in this section. All the above-named bearded varieties have been found to be immune from the rosette disease with the exception of Imperial Amber and Penquite (Velvet Chaff), which have not been tested.

#### VARIETIES APPARENTLY HIGHLY RESISTANT

In Table 5 are listed the varieties of wheat which showed less than 1 percent of smut when grown from smutted seed in the two and three years' experiments. Apparently they are highly resistant to flag smut. The small percentage of infection shown may represent, in some cases, accidental mixtures in the stocks used. Several excellent wheats appear in this list and of some of them commercial seed supplies are available.

One group of bearded wheats with glabrous white chaff, purple straw, and red kernels embraces a number of varieties. Bearded Purplestraw, Dietz, Fulcaster, Lancaster, Mammoth Red, Nigger, and Stoner are practically synonymous names. They are of the Fuleaster type. The high resistance of these strains, coupled with the fact that Eversole and Stoner (Marvelous) are found in Table 4, among the varieties which showed no infection, indicates that this variety group is at least highly resistant to flag smut. Most of them are also immune from rosette disease, the only possible exceptions being Nigger (C. I. No. 5689) and Bearded Purplestraw, which have not been tested for rosette resistance. A pure-line strain of Nigger (C. I. No. 5366), however, descended from a single plant selection, is very susceptible to rosette.

The Fuleaster variety is widely grown under one or another of its names, and there are available in Illinois and Missouri stocks of pure seed practically sufficient to sow the entire flag smut area, if such a course were necessary. Some of these commercial stocks are



FIG. 3.—SPORES OF *Urocystis tritici* Keke.

A, Photomicrograph showing the spore balls as they appear under the microscope. Magnified approximately 230 diameters.

B, Drawing showing germinating spores of *Urocystis tritici*, Keke. Note the promycelium bearing two or three secondary spores, or sporidia, at the apex. Magnified approximately 460 diameters.



TABLE 5.—VARIETIES OF WHEAT SHOWING A TRACE OF FLAG SMUT BUT AVERAGING LESS THAN 1 PERCENT WHEN GROWN FROM SMUTTY SEED FOR TWO OR THREE YEARS IN THE EXPERIMENT PLOTS AT GRANITE CITY, ILLINOIS

Variety	Source or C. I. No. <sup>a</sup>	Years tested
Arcadian (Early Arcadian).....	3390	3
Beloglina.....	5786	2
Brown Fife.....	1933	2
Flint		
Little Red.....	6349	2
Fulcaster		
Bearded Purplestraw.....	1911	3
Dietz.....	Missouri	2
Dietz.....	1981	3
Dietz.....	3387	2
Fulcaster.....	Tennessee	2
Fulcaster.....	....	2
Lancaster-Fulcaster.....	1945	3
Stoner <sup>b</sup> .....	2980	3
Genesee Giant.....	1744	3
Gipsy		
Gipsy.....	5579	3
Gipsy.....	3440	2
Reliable.....	3508	2
Goens		
Miller's Pride.....	4865	2
Jones Paris Prize.....	3568	2
Mammoth Red.....	2008	3
Mediterranean		
Mediterranean.....	1395	2
Mediterranean.....	3467	2
Missouri Bluestem.....	1912	3
Missouri Bluestem.....	1912-2	3
Nebraska No. 28.....	5147	3
New Amber Longberry.....	1973	3
Nigger.....	5689	2
P-1066.....	5879	2
Penquite (Velvet Chaff).....	....	2
Pesterboden		
Budapest.....	5789	3
Poole.....	3489	3
Red May		
Michigan Wonder.....	5589	3
Red Cross.....	3579	2
Red May.....	5596	2
Red Rock <sup>b</sup> .....	5976	3
Rural New Yorker No. 6.....	3515	3
Turkey		
Malakof 5-460.....	Illinois	2
Turkey 10-110.....	Illinois	2
World's Champion.....	Illinois	2
Valley		
Valley.....	5658	2
Indiana Swamp.....	5969	2
Windsor (Extra Early Windsor).....	3345	3

<sup>a</sup>Seed of varieties with C. I. Nos. was furnished by the Office of Cereal Investigations. Where a state is given as the source, the seed was obtained from the experiment station of that state.

<sup>b</sup>The slight infection of this lot of Stoner and of Red Rock may be due to accidental mixture, as other lots of these varieties and of Marvelous, a synonym of Stoner, are found in the immune list (Table 4).

being tested in the plots sown in the fall of 1922, and data will be available on them before the next harvest. Furthermore, field tests of Fulcaster wheat made in southern Illinois show it to be one of the varieties best adapted for that section. It is also an excellent milling wheat for bread flour. The bearded heads probably are the principal obstacle to its adoption by farmers in this section.

Mammoth Red wheat is grown in Maryland, where it has been distributed by the Maryland Agricultural Experiment Station to farmers of that state. It has become considerably mixed, however, and the pure seed stock, so far as known, can be found only in small quantities. About 8 bushels of Mammoth Red were produced in the flag smut area this year from seed furnished from nursery stocks by the U. S. Department of Agriculture, and this, and an additional 6 bushels furnished by the Maryland Station, was sown in the fall of 1922 in this area. Another small plot also was sown in this area from nursery stocks. With proper handling there should be sufficient seed of this variety for extensive sowings in a few years. This variety, like others in this group, is immune from rosette disease.

The varieties Gipsy, Reliable, and Valley, which appear in Table 5, probably are well adapted to the area in question. They are much like the Fulcaster group in appearance, but do not have purple straw. They are important wheats in some sections of Ohio, Illinois, and Indiana. Reliable has proved immune from rosette, but the other two varieties have not been tested.

A group of bearded wheats having glabrous red chaff and red kernels, of which Mediterranean is the principal variety, probably would be found to be adapted to this area. Red Rock and Miller's Pride belong to this group. Miller's Pride is highly susceptible to rosette disease, however, while Mediterranean is slightly susceptible. Red Rock appears to be immune.

The Red May group of beardless wheats with glabrous red chaff and red kernels shown in Table 5 includes Michigan Wonder, Red Cross (C. I. No. 3579), and Red May. They are similar in appearance to Shepherd and other varieties listed in Table 1. They would be adapted to the flag smut section and appear to be immune from rosette disease. Poole (C. I. No. 3489) is similar in appearance and adaptation to this group but it has not been tested in rosette experiments.

Other varieties appearing in Table 5 are either hard red winter wheats or are of other types not considered desirable for growing in this area.

#### WHEAT VARIETIES GENERALLY GROWN IN THE FLAG SMUT AREA

Wheat is grown very intensively in Madison and St. Clair counties. In 1919 (Census data) wheat occupied 38.2 percent of the im-

proved land on the farms of Madison county and 41.7 percent in St. Clair county. Of the acreage of all land in crops, wheat occupied 45 and 47 percent, respectively, in these two counties. This must mean that wheat frequently follows wheat in the rotation and that wheat fields are practically contiguous or only slightly separated one from another over almost the entire area. Both these conditions favor the development and spread of flag smut and other diseases and also lead to their accumulation in the soil. Inasmuch as wheat is such an important crop in this area, it is not practicable to discontinue growing it in order to combat the disease.

In Table 6 are given the results of an experiment to determine the susceptibility of the principal soft red winter varieties now grown by farmers in the flag smut area. All of them were found to be more or less susceptible to the disease. Harvest Queen (Red Cross or Salzer's Prizetaker), which is most susceptible, fortunately has al-

TABLE 6.—WHEAT VARIETIES GROWN COMMERCIALY IN THE INFESTED AREA, ALL OF WHICH ARE SUSCEPTIBLE TO FLAG SMUT AND SHOULD NOT BE SOWN IN THIS AREA

Variety	Number of selections	Average percentage of smut	Number of years tested
Flint (May).....	Average of two selections....	20.4	1
Fultz.....	Average of several selections.	9.5	2
Harvest Queen (Salzer's Prizetaker or Red Cross).....	Average of several selections.	23.77	3
Jones Fife.....	Average of two selections....	6.97	2
Red Wave.....	Average of several selections.	4.27	2

most disappeared from the worst infested section, since the farmers have seen how heavily it smuts. Red Wave and Fultz are still widely grown.

The use of resistant varieties, especially those varieties that have shown immunity in the flag smut experiments, offers the most effective means of control. It is possible that by the use of these varieties, kept pure and free of susceptible mixtures, the disease may be entirely eradicated.

#### INDEX OF ALL WHEAT VARIETIES TESTED SHOWING RESISTANCE AND SUSCEPTIBILITY TO FLAG SMUT

All varieties of wheat which have been grown in these experiments on resistance to flag smut are listed in Table 7, with a record of the annual infection and the average infection for the two or the three years during which they were tested. This table contains not only all the varieties recorded in the preceding tables, but many susceptible varieties not presented before.

TABLE 7.—COMPLETE LIST OF WHEAT, SPELT, AND EMMER VARIETIES GROWN FROM SEED INFESTED WITH FLAG SMUT, SHOWING HEAD AND KERNEL CHARACTERS AND SUSCEPTIBILITY TO SMUT: EXPERIMENT PLOTS AT GRANITE CITY, ILLINOIS, 1920-1922

Crop and variety	Source or C. I. No.*	Description		Percentage of infected plants			
		Head <sup>b</sup>	Ker- nel <sup>c</sup>	1920	1921	1922	Average for 2 or 3 years
WHEAT							
Acme.....	3115-2	BRG	SR	1.6	14.6	....	8.10
Ahrens.....	4848	ARG	SR	....	1.4	4.9	3.15
Arcadian (Early Arcadian)	3390	ARG	W	trace	0.0	0.0	trace
Bearded Winter Fife.....	1942	BWV	SW	....	9.2	....	....
Beechwood.....	Missouri	ARG	SR	....	0.0	0.0	0.00
Beloglina.....	Illinois	BWG	HR	....	2.2	2.0	2.10
Brown Fife.....	1933	ARV	SR	3	0.0	....	.15
China							
China.....	180	ARG	SR	trace	3.2	....	1.60
China (Seed from Tenn.)	180	ARG	SR	5.0	....	....	....
Pennsylvania Bluestem.	5342	ARG	SR	....	.9	4.7	2.80
Climax							
K. B. No. 2.....	5955	AWG	SR	11.1	2.5	....	6.80
Currell (Currell's Prolific).	2906	ARG	SR	....	1.4	....	....
Currell (Currell's Prolific).	3326	ARG	SR	1.4	4.0	....	2.70
Currell (Pearl Prolific)....	3484	ARG	SR	....	3.7	....	....
Currell × Diehl-Mediterranean.	3614	BRG	SR	0.0	....	....	....
Dawson (Dawson's Golden Chaff).....	6161	ARG	W	3.5	8.1	....	5.80
Dawson (Dawson's Golden Chaff).....	Illinois	ARG	W	....	17.5	....	....
Democrat.....	3384	BWG	W	0.0	12.5	....	6.25
Diehl-Mediterranean							
Eclipse.....	3396	BRG	SR	6.6	7.3	....	6.95
Diehl-Mediterranean × Jones Fife.....	3608	BWG	SR	.4	....	....	....
Flint							
Indiana May.....	Granite City	AWG	SR	....	13.4	....	....
Little Red.....	6349	AWG	SR	....	0.0	.7	.35
May.....	Granite City	AWG	SR	....	24.0	....	....
May.....	Granite City	AWG	SR	....	16.8	....	....
Red May.....	Granite City	AWG	SR	....	16.5	....	....
Red May.....	Granite City	AWG	SR	....	11.9	....	....
Red May.....	Granite City	AWG	SR	....	13.7	....	....

\*Seed of varieties with C. I. Nos. was furnished by the Office of Cereal Investigations. Where a state is given as the source, the seed was obtained from the experiment station of that state, with the exception of ten lots from Indiana, as follows, which were obtained from farmers: Burbank Super, Harvest King (two lots), Marvelous, Michigan Amber, New York No. 10, Poole, Red Chaff, Red Wave, and Rudy. Varieties with Granite City given as a source were collected from farmers in the vicinity of that city in Illinois.

<sup>b</sup> A = awnless  
 B = bearded  
 W = white or yellow chaff  
 R = red or brown chaff  
 Bl = black chaff  
 G = glabrous chaff (not velvety)  
 V = velvet or pubescent chaff

<sup>c</sup> R = red  
 W = white  
 H = hard  
 S = soft

TABLE 7.—Continued

Crop and variety	Source or C. I. No.	Description		Percentage of infected plants			
		Head	Kern- nel	1920	1921	1922	Average for 2 or 3 years
Red May.....	Granite City	AWG	SR	....	14.2	....	....
Fulcaster							
Bearded Purplestraw...	1911	BWG	SR	trace	1.6	1.1	.90
Bearded Purplestraw...	1911-1	BWG	SR	.9	2.2	0.0	1.03
Dietz.....	1981	BWG	SR	trace	2.5	0.0	.83
Dietz.....	Missouri	BWG	SR	....	1.0	0.0	.50
Dietz.....	3387	BWG	SR	....	1.4	0.0	.70
Dietz (Seed from Tennessee).....	1981	BWG	SR	0.0	....	....	....
Eversole.....	3011	BWG	SR	....	0.0	0.0	0.00
Fulcaster.....	Missouri	BWG	SR	....	2.1	1.2	1.65
Fulcaster.....	3013	BWG	SR	....	8.2	....	....
Fulcaster.....	Tennessee	BWG	SR	trace	1.0	....	.50
Fulcaster.....	6162	BWG	SR	0.0	3.6	0.0	1.20
Fulcaster.....	....	BWG	SR	....	.8	.5	.65
Fulcaster.....	4862	BWG	SR	....	3.7	....	....
Lancaster-Fulcaster...	1945	BWG	SR	trace	0.0	1.5	.50
Marvelous.....	Indiana	BWG	SR	....	0.0	0.0	0.00
Stoner.....	2980	BWG	SR	.4	.5	.7	.53
Stoner.....	Virginia	BWG	SR	....	0.0	0.0	0.00
Fultz							
Fultz.....	1923	AWG	SR	.8	11.45	....	6.12
Fultz.....	3598	AWG	SR	3.3	1.6	....	2.45
Fultz.....	3604	AWG	SR	....	4.0	....	....
Fultz.....	Missouri	AWG	SR	....	23.3	....	....
Fultz.....	3349	AWG	SR	....	7.9	....	....
Fultz.....	3423	AWG	SR	....	13.7	....	....
Fultz.....	3594	AWG	SR	....	10.0	....	....
Fultz-Mediterranean...	5643	AWG	SR	0.0	3.7	....	1.85
Genesee Giant (Early Genesee Giant).....	1744	BRG	W	trace	0.0	1.0	.35
Gipsy							
Defiance.....	Missouri	BWG	SR	....	3.4	....	....
Gipsy.....	5579	BWG	SR	1.3	0.0	.8	.70
Gipsy.....	3440	BWG	SR	....	0.0	1.7	.85
Gipsy.....	Illinois	BWG	SR	....	4.1	....	....
Gipsy.....	3439	BWG	SR	....	....	4.2	....
Lebanon.....	Missouri	BWG	SR	....	0.0	4.1	2.05
Niagara.....	5307	BWG	SR	....	26.8	....	....
Reliable.....	3508	BWG	SR	....	0.0	.3	.15
Gladden.....	Illinois	BWG	SR	....	8.5	....	....
Gluten.....	5613	BWG	SR	....	1.0	....	....
Goens							
Goens.....	3428	BRG	SR	1.3	3.8	....	2.55
Miller's Pride.....	4865	BRG	SR	....	1.5	0.0	.75
Red Chaff.....	Indiana	....	....	....	13.3	....	....
Golden Wave.....	6684	BRG	SR	....	1.8	....	....
Grandprize (St. Louis Grandprize).....	5627	ARV	SR	0.0	0.0	0.0	0.00
Harvest Queen							
Harvest Queen.....	Missouri	AWG	SR	....	28.3	....	....
Harvest Queen.....	4882	AWG	SR	....	12.6	....	....
Red Cross.....	5957	AWG	SR	27.0	23.3	24.5	24.93
Red Cross.....	Granite City	AWG	SR	....	30.7	....	....

TABLE 7.—Continued

Grop and variety	Source or C. I. No.	Description		Percentage of infected plants			
		Head	Ker- nel	1920	1921	1922	Average for 2 or 3 years
Red Cross.....	Illinois	AWG	SR	....	24.7	27.2	25.95
Salzer's Prizetaker.....	Granite						
	City	AWG	SR	....	14.1	....	....
Salzer's Prizetaker.....	Granite						
	City	AWG	SR	....	18.1	....	....
Hussar (Red Hussar).....	Illinois	BWG	R	....	3.0	....	....
Hussar (Red Hussar).....	4843	BWG	R	....	....	0.0	....
Illini Chief							
Illini Chief.....	5406	ARG	SR	.3	5.7	....	3.00
Illini Chief.....	Illinois	ARG	SR	....	7.2	....	....
Imperial Amber.....	3447	BRG	SR	0.0	0.0	0.0	0.00
Indiana Swamp Selection	4834	BRG	SR	....	3.2	....	....
Jones Fife							
Burbank Super.....	Indiana	AWV	SR	....	10.8	....	....
Jones Fife.....	Granite						
	City	AWV	SR	....	7.2	....	....
Jones Fife.....	Granite						
	City	AWV	SR	....	5.7	....	....
Jones Fife.....	Granite						
	City	AWV	SR	....	7.6	....	....
Jones Fife.....	5608	AWV	SR	4.3	5.2	....	4.75
Jones Fife × Dawson.....	3610	ARG	SR	2.7	....	....	....
Jones Paris Prize.....	3568	ARG	W	....	0.0	1.1	.55
Kanred							
Kanred.....	5146	BWG	HR	trace	0.0	7.4	2.46
Kanred.....	5591	BWG	HR	....	1.7	....	....
Kanred.....	Illinois	BWG	HR	....	0.0	0.0	0.00
Kanred.....	Kansas						
	2401	BWG	HR	....	0.0	0.0	0.00
Kanred.....	5592	BWG	HR	....	4.0	....	....
King Harvester.....	Granite						
	City			....	15.9	....	....
Leap (Leap's Prolific)....	4823	AWG	SR	.7	6.9	....	3.80
Leap (Leap's Prolific)....	5584	AWG	SR	0.0	....	....	....
Link (Missing Link).....	3472	BRG	SR	2.3	0.0	4.6	2.30
Longberry No. 1.....	5823	BRG	SR	....	1.6	.8	1.20
Mammoth Amber (mixed in 1922).....	3355	BWG	W	0.0	0.0	4.6	1.53
Mammoth Red.....	2008	BWG	SR	0.0	0.0	.8	.26
Martin (Martin Amber)...	1974	AWG	W	0.0	....	....	....
Martin (Martin Amber)...	Washing- ton 1092	AWG	W	....	....	0.0	....
Mealy							
Mealy.....	5824	AWV	SR	7.1	7.5	....	7.30
Mealy.....	Missouri	AWV	SR	....	6.4	....	....
Mealy.....	3563	AWV	SR	....	12.1	....	....
Mealy.....	3565	AWV	SR	....	15.8	....	....
Mealy.....	5404	AWV	SR	....	4.9	....	....
Mediterranean							
Mediterranean.....	Missouri	BRG	SR	....	1.8	1.4	1.6
Mediterranean.....	1395	BRG	SR	....	0.0	.7	.35
Mediterranean.....	3467	BRG	SR	....	0.0	.3	.15
Mediterranean.....	Illinois	BRG	SR	....	3.6	....	....
Missouri Bluestem.....	1912	BRG	SR	0.0	2.5	.3	.90
Rocky Mountain.....	1930	BRG	SR	8.2	7.2	....	7.70

TABLE 7.—Continued

Crop and variety	Source or C. I. No.	Description		Percentage of infected plants			
		Head	Kernel	1920	1921	1922	Average for 2 or 3 years
Missouri Bluestem (Selection).....	1912-2	BWG	SR	0.0	0.0	.3	.10
Nebraska No. 28.....	5147	BWG	R	.3	1.2	.3	.60
New Amber Longberry							
New Amber Longberry.....	1973	BRG	W	trace	.8	0.0	.26
New Amber Longberry.....	3361	BRG	W	....	4.6	....	....
New York No. 10.....	Indiana			....	5.8	....	....
Nigger.....	5689	BWG	SR	....	1.4	0.0	.70
Oatka Chief.....	3481	BWG	W	0.0	8.8	....	4.40
P-1066.....	5879	BWG	HR	....	.5	0.0	.25
P-1068.....	5880	BWG	HR	....	0.0	0.0	0.00
Penquite (Velvet Chaff)							
Velvet Chaff.....	5629	BRV	SR	....	0.8	....	....
Velvet Chaff.....		BRV	SR	....	0.0	1.0	.50
Velvet Chaff.....	3068	BRV	SR	....	0.0	0.0	0.00
Pesterboden							
Budapest.....	5789	BWG	HR	0.0	0.0	.3	.10
Hungarian.....	Illinois	BWG	HR	....	2.7	3.1	2.90
Pesterboden.....	Illinois	BWG	HR	....	5.8	....	....
Poole.....							
Harvest King.....	Missouri	ARG	SR	....	2.0	....	....
Harvest King.....	Indiana	ARG	SR	....	0.0	....	....
Harvest King.....	Indiana	ARG	SR	....	4.1	....	....
Harvest King.....	Granite City	ARG	SR	....	8.8	....	....
Harvest King.....	Granite City	ARG	SR	....	17.6	....	....
Hedge Prolific.....	4859	ARG	SR	....	4.3	....	....
Poole.....	1979	ARG	SR	.6	1.8	2.6	1.66
Poole.....	3489	ARG	SR	trace	0.0	0.0	trace
Poole.....	Tennessee	ARG	SR	0.0	2.6	5.8	2.80
Poole.....	Indiana	ARG	SR	....	3.1	....	....
Poole Type (Selection).....	1733	ARG	SR	2.4	4.1	....	3.25
Portage.....	5370	ARG	SR	....	6.3	....	....
Prosperity (American Bronze).....	3339	AWG	SR	0.0	....	....	....
Prosperity (American Bronze).....	5638	AWG	SR	....	6.5	....	....
Purdue No. 1.....	4871	AWG	SR	....	0.0	6.0	3.00
Purplestraw							
Purplestraw.....	1915	AWG	SR	7.2	12.1	....	9.65
Purplestraw.....	1957	AWG	SR	3.2	9.6	....	6.45
Red Clawson							
Early Red Clawson.....	5640	ARG	SR	....	10.4	....	....
Red May							
Early Harvest.....	4852	ARG	SR	....	0.0	0.0	0.00
Early Ripe.....	Missouri	ARG	SR	....	1.3	....	....
Early Ripe.....	5319	ARG	SR	....	2.5	....	....
Enterprise.....	3399	ARG	SR	....	7.1	....	....
Michigan Amber.....	Indiana	ARG	SR	....	2.9	....	....
Michigan Amber.....	Illinois	ARG	SR	....	....	.9	....
Michigan Wonder.....	5589	ARG	SR	1.2	.9	0.0	.70
Orange.....	4868	ARG	SR	....	2.5	0.0	1.25
Pride of Indiana.....	3492	ARG	SR	....	7.0	....	....
Red Cross.....	3579	ARG	SR	....	0.0	1.8	.90
Red May.....	5596	ARG	SR	0.0	1.9	....	.95

TABLE 7.—Continued

Crop and variety	Source or C. I. No.	Description		Percentage of infected plants			Average for 2 or 3 years
		Head	Ker- nel	1920	1921	1922	
Red Rock							
Red Rock.....	5976	BRG	SR	trace	0.0	.7	.23
Red Rock.....	5597	BRG	SR	0.0	0.0	0.0	0.00
Red Rock (mixed).....	Illinois	{BRG BWG	SR	....	3.7	....	....
Red Wave							
Red Wave.....	5582	ARG	SR	trace	....	....	....
Red Wave.....	Indiana	ARG	SR	....	5.2	1.1	3.15
Red Wave.....	Illinois	ARG	SR	....	4.0	2.8	3.40
Red Wave.....	Granite City	ARG	SR	....	3.3	....	....
Red Wave.....	Granite City	ARG	SR	....	4.8	....	....
Red Wave.....	Granite City	ARG	SR	....	6.7	....	....
Rochester (Rochester Red)	5693	ARG	SR	....	10.1	....	....
Rudy							
Rudy.....	5599	BWG	SR	....	2.3	....	....
Rudy.....	Indiana	BWG	SR	....	1.3	....	....
Rupert (Rupert's Giant)	5343	ARG	SR	2.7	4.0	....	3.35
Rural New Yorker No. 6							
Rural New Yorker No. 6	3515	ARG	SR	trace	0.0	2.6	0.86
Rural New Yorker No. 6	5736	ARG	SR	....	8.1	....	....
Russian.....	5737	ARG	SR	....	1.3	....	....
Shepherd.....	6163	ARG	SR	0.0	0.0	0.0	0.00
Squarehead Master.....	3283	ARG	SR	0.0	0.0	0.0	0.00
Texas Red.....	Granite City			....	18.0	....	....
Treadwell.....	3527	BWG	SR	trace	0.0	8.2	2.75
Turkey							
Illinois 10-110.....	Illinois	BWG	HR	....	.5	0.0	.25
Illinois 12-41.....	Illinois	BWG	HR	....	0.0	0.0	0.00
Malakof No. 5-460.....	Illinois	BWG	HR	....	.4	0.0	.20
Minnesota Reliable.....	Illinois	BWG	HR	....	3.5	....	....
Turkey.....	5603	BWG	HR	....	0.0	....	....
Turkey.....	Illinois	BWG	HR	....	2.0	.3	1.15
Turkey Hybrid No. 402	Illinois	BWG	HR	....	2.3	1.5	1.90
Turkey Hybrid No. 509	Illinois	AWG	R	....	2.3	1.5	1.90
Turkey Hybrid No. 514	Illinois	BWG	HR	....	2.7	1.4	2.05
World's Champion.....	Illinois	BWG	HR	....	1.3	.4	.85
Ultra No. 834.....	5747	ARG	SR	....	0.0	0.0	0.00
Valley							
Indiana Swamp.....	5969	BWG	SR	0.0	1.6	....	.80
Indiana Swamp (mixed)	Illinois	{BWG BRG	SR	....	5.8	....	....
Valley.....	5658	BWG	SR	....	0.0	.6	.30
Wheedling.....	4846	ARG	SR	....	1.8	....	....
White Bearded.....	3135	BWG	SR	....	2.9	....	....
Windsor							
Extra Early Windsor...	3345	ARG	W	trace	0.0	0.0	trace
Winter Chief.....	4878	ARG	SR	....	0.0	2.9	1.45
Woods.....	Tennessee			0.0	3.4	....	1.70
Wyandotte							
Wyandotte Red.....	5696	AWG	SR	....	6.6	....	....
Zimmerman.....	2907	AWG	SR	....	21.2	....	....

TABLE 7.—*Concluded*

Crop and variety	Source or C. I. No.	Description		Percentage of infected plants			
		Head	Kernel	1920	1921	1922	Average for 2 or 3 years
<b>SPELT</b>							
Alstrom.....	1773	AWG	SR	....	0.0	0.0	0.00
Bearded Winter.....	1724	BWG	SR	....	0.0	0.0	0.00
Red Winter.....	1772	ARG	SR	....	0.0	0.0	0.00
<b>EMMER</b>							
Black Winter.....	2337	BBIV	R	....	0.0	0.0	0.00

## CONCLUSIONS

Flag smut can be controlled by treatment of the seed with copper sulfate and lime or with copper carbonate, if the spores are carried only on the seed.

Control by seed treatment cannot be depended on where spores are present in the soil. To be effective under these conditions the fungicide would necessarily have to remain active until the seed had germinated, for it is at the time of germination that infection from the spores in the soil takes place. However, even tho the disinfectant should remain active until that time, there might be infection from the spores in the soil that were near enough the young plant to infect it but too far from the seed to be destroyed by the disinfectant.

The use of other crops following wheat and the careful disinfection of threshing machines, wagon beds, bins, etc., which may have been contaminated tends to reduce the amount of infection.

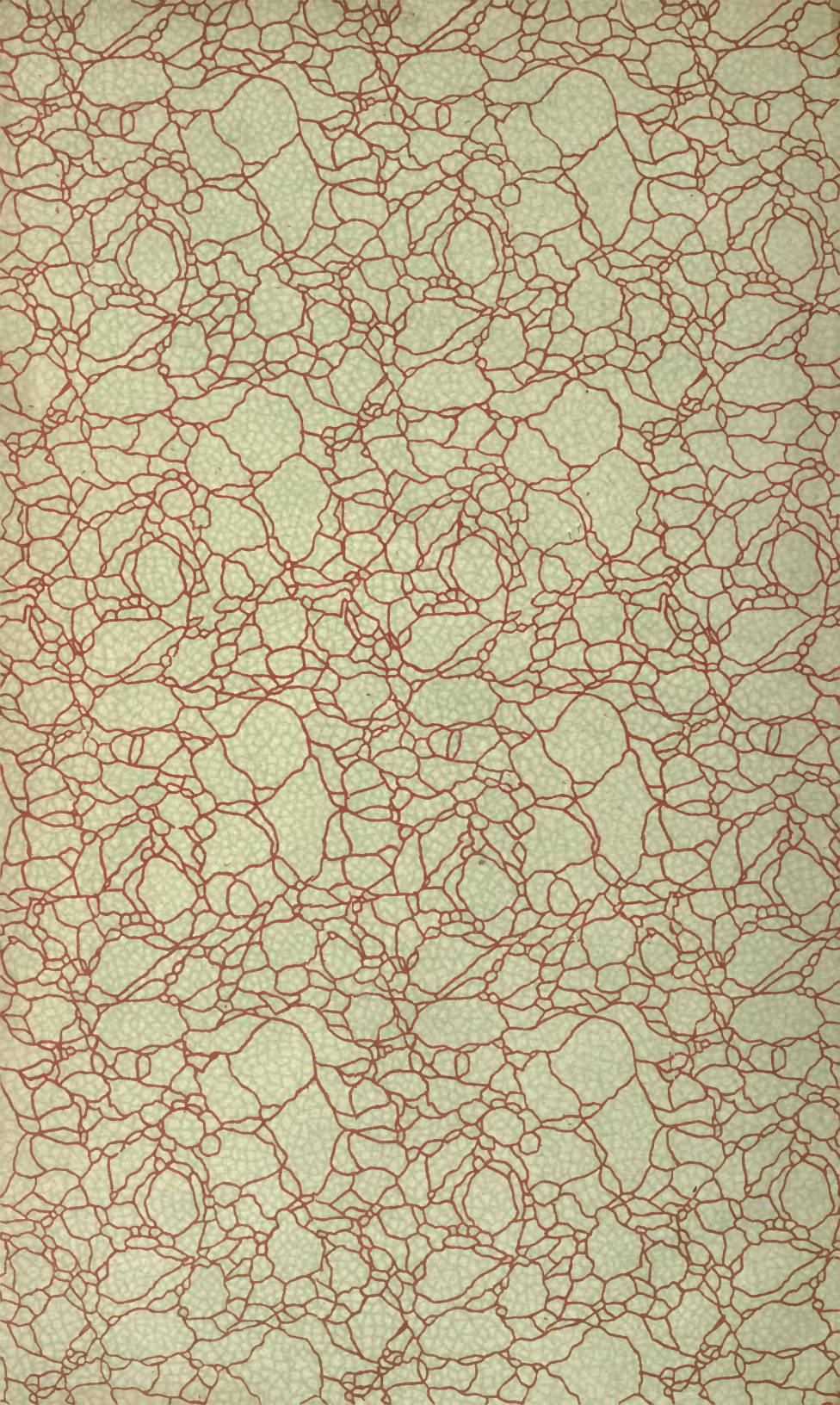
Time of planting is one of the important factors in spore germination and infection. Unfortunately, however, when wheat is sown late enough in the fall to escape infection, the risk of loss in production is too great to make this a practical means of control.

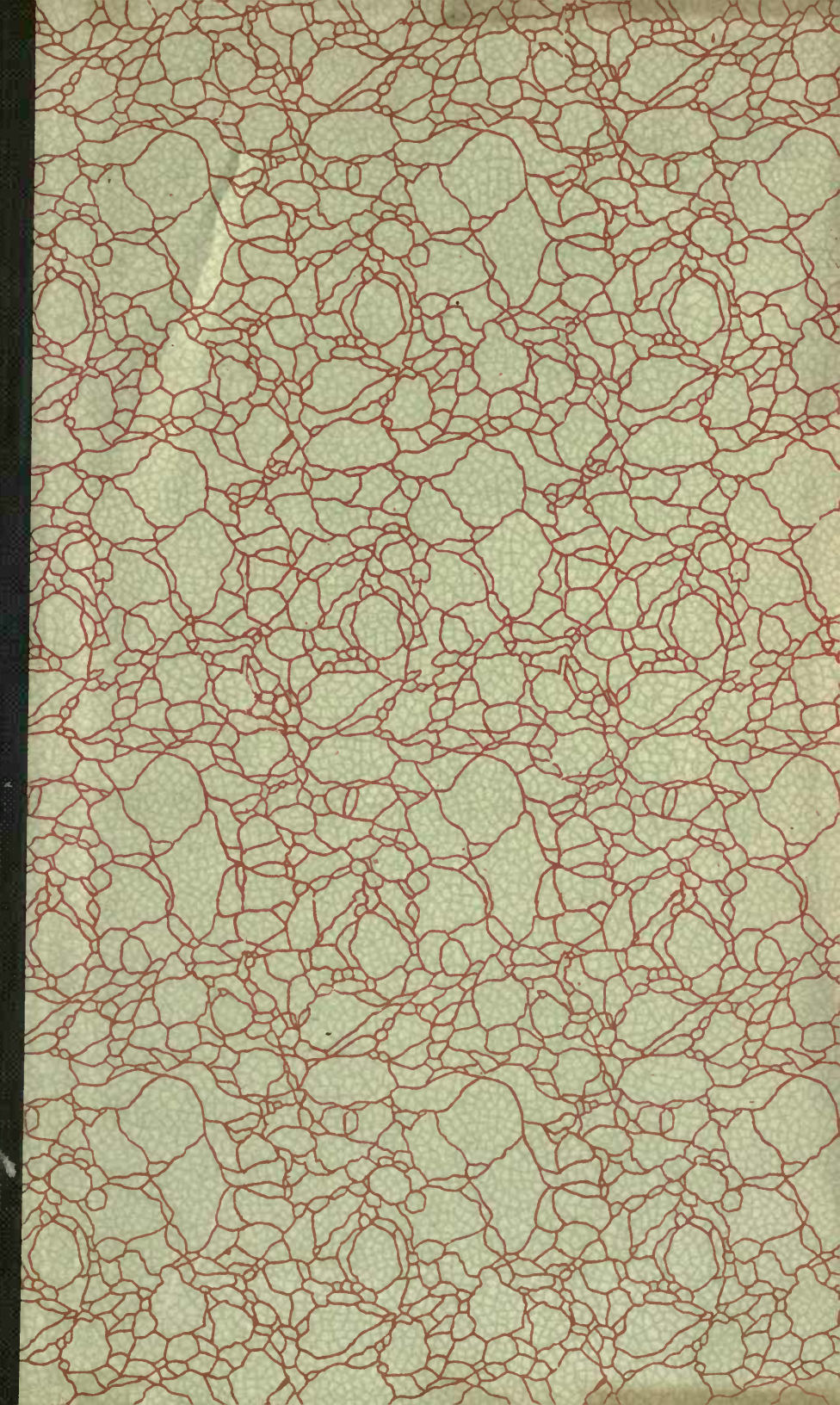
The discovery of varieties of wheat which are desirable commercially and at the same time are resistant to flag smut offers the most promising means of controlling the disease. The results of experiments so far conducted show fourteen varieties or strains to be immune and forty-one others to be highly resistant. If wheat growing were discontinued for a number of years thruout the infested area and all volunteer wheat were destroyed the disease might be eradicated, but even this is not certain. The ultimate solution probably will be the using of resistant varieties.

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