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Preliminary Experiments with Vapor Treatments for Prevention of Stinking Smut of Wheat

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Preliminary Experiments with Vapor Treatments for the Prevention of the Stinking Smut of Wheat.

W. A. WHEELER.

The stinking smut of wheat is a disease so common as to be very familiar to the farmers of South Dakota. Its presence can be easily detected by the characteristic smutted kernels in the threshed grain and by the disagreeable odor. So much has been written upon the details of the growth of the parasite which causes the disease that these facts will not be taken up or discussed in this bulletin.

Several treatments have been recommended for the prevention of some of the smuts of our cultivated grains. Among these are formalin or formaldehyde solution, corrosive sublimate, copper sulphate, hot water, ceres pulver and others. All of these treatments which have been recommended from time to time require the soaking, sprinkling or in some other manner wetting the grain. This has been a serious drawback to the general use of such treatments. Liquid treatments are objectionable: first, because the grain cannot be immediately sown after treatment but must be carefully drained and partially dried before sowing; second, the treatments cannot be applied to the seed grain any great length of time before seeding without danger of injuring the germination of the seed unless great pains is taken to thoroughly dry the grain before sowing; third, seedsmen or dealers in seed grain cannot safely use treatments of this kind without great labor or inconvenience, thus great losses from smut have been the rule with the better and newer varieties sold on the market. It is said that certain advantages such as quicker germination and a more rapid early growth are to be secured by the wetting of the grain before

seeding. Whether there is often any decided advantage in this is very doubtful.

In view of these facts the writer in the winter of 1903-04 began a series of experiments to secure a treatment for smut which would not necessitate the wetting of the seed grain. The experiments were begun before any search of the literature upon the subject was made to determine whether similar experiments had been conducted previous to this time. Later upon investigating the literature it was found that various botanists had conducted experiments with this object in view but in no case had these progressed beyond the first stages of experimentation. Some of the experiments recorded here are therefore to a certain extent a repetition of the experiments of others. It was also discovered that a powder commercially known as "Ozonet gas powder" had been offered for sale to be mixed with seed grain for the prevention of smut.

Bolley* writes as follows about dry treatment for smut: "While the formalin (formaldehyde gas solution) method recommended in this bulletin is very effective and the cost is very slight, it would yet be a great gain if grain could be treated in large volumes dry. In 1897-98 we ascertained that a gas treatment is effective but it is yet necessary to show that such treatment can be controlled in practice upon a large scale."

In connection with certain experiments at the Illinois Experiment Station to reduce to a minimum the wetting of seed oats in treatment, Clinton† writes as follows: "The character of formalin, as regards its very pungent fumes and its excellency as a fungicide, suggested that perhaps, if used in stronger solutions but not in sufficient quantity to dampen the seed, it might still destroy the smut without injury to the seed. Experiments along this line were conducted in 1898. Usually with the sprinkling method a gallon or more of the liquid is used per bushel of grain. In these experiments the rate was only a quart per bushel, which was not sufficient to wet the seed so but that it could be sacked and left without drying. Different strengths of solutions were used, the stronger proving fatal or injurious to the seed. Most of the treatments were made so late

*Henry L. Bolley, The Prevention of Smuts of Cereal Grains and Prevention of Potato Scab, North Dakota Agricultural Experiment Station, Bulletin No. 37, March 1899, p. 378.

†G. P. Clinton. The Smuts of Illinois Agricultural Plants, Illinois Agricultural Experiment Station, Bulletin No. 57, March 1900, pp, 312, 313.

in the season that the exact effect on the seed and smut could not be told, since seed planted so late naturally does poorly and is likely to have less smut. In one or two cases, however, (see plats 33, 37, Table 12) some very suggestive results were obtained and offer encouragement for further investigation along this line. The results also show the comparative inefficiency of the fumes of carbon bi-sulfide in this direction."

The records from plats 33 and 37 referred to above are as follows: "Plat No. 33, planted April 26. Treatment, one pint of oats wet with ½ pint of 25 per cent. formalin and then placed in box and 7 pints smutty oats placed on top. Planted 1 quart taken from top 11 days later. Results, no smut was found in this plat, and apparently the treatment had not injured germination of oats."

"Plat No. 37, planted May 10. Treatment, 2 per cent. formalin sprinkled at rate of one quart to 1 bushel, then sacked and planted at end of 24 hours. Results, found no smut, but this and 36 planted too late to tell exact effect on seed."

Kellerman and Swingle* in their experiments with fungicides for the stinking smut of wheat tried chloroform, carbon bisulphide, ether, ammonium hydrate and sulphurous oxid (SO_2) vapors but found them all to be ineffective. The vapors of formaldehyde were not tried in connection with their vapor tests.

"When treated with vapors the grain was placed on a piece of wire netting supported on a tripod under which was placed the vessel of liquid yielding the vapor. Over the whole a large bell jar was placed."

The same authors† in their experiments with oat smut in 1890 recorded results of tests with vapors in the treatment of oat smut. The results show that vapors of carbon bisulphide, ammonium hydrate, chloroform, and ether are ineffective as preventives of oat smut.

From a knowledge of the nature of smut diseases, it appears that gases or vapors administered to seed grain in closed vessels offer greater promise of furnishing a satisfactory dry

*Kellerman and Swingle, Preliminary Experiments with Fungicides for Stinking Smut of Wheat, Kansas Agricultural Experiment Station, Bulletin No. 12, August 1890, p. 36.

†Kellerman and Swingle, Additional Experiments and Observations on Oat Smut made in 1890, Kansas Agricultural Experiment Station, Bulletin No. 15, December 1890, pp. 112-113.

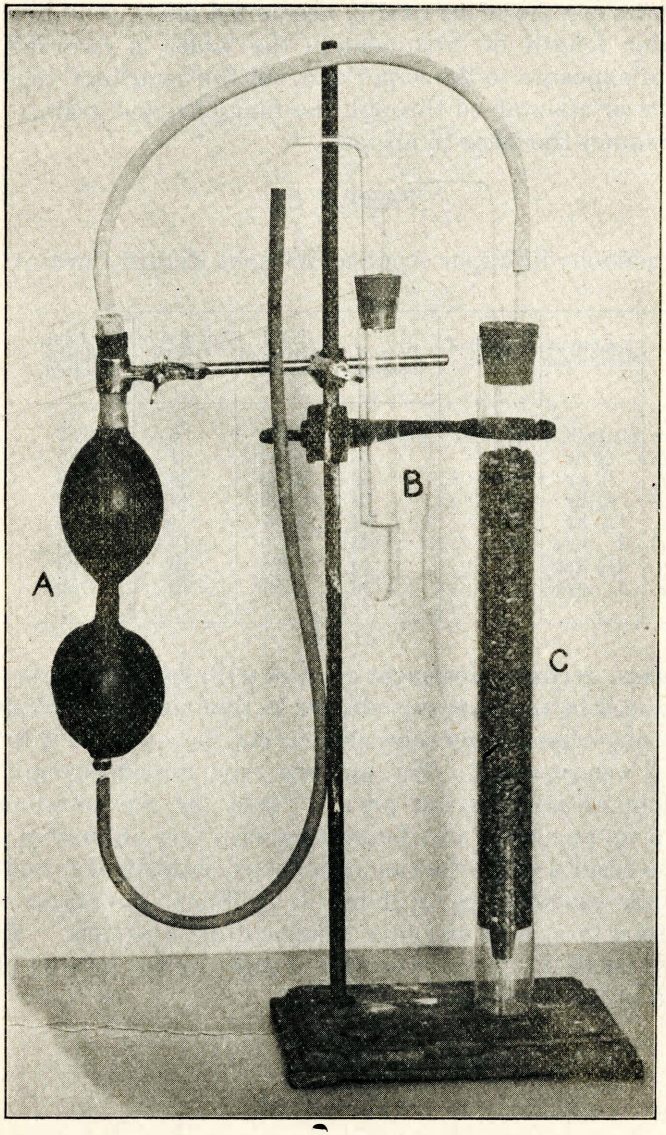
treatment than the mixing of powders with the grain as it is practically impossible or at least extremely difficult to mix a small quantity of a solid material such as a powder uniformly with a large quantity of grain. Liquids or gases can be much more uniformly applied. The gases or vapors which it was thought might give satisfactory results are chloroform, ether, carbon bisulphide, sulphur dioxide, hydrocyanic acid gas, chlorine, formaldehyde and ammonia. Not all these were used in the experiments. Ammonia, formaldehyde, carbon bisulphide and chloroform were selected for trial. The "Ozonet gas powder" was also tested.

Prior to taking up the treating of seed for field planting, germination experiments were conducted in the greenhouse and laboratory to determine what length of exposure could be used without injury to the seed grain. The results of these germination tests are given in the latter part of this bulletin.

The apparatus used in most of the experiments for the application of vapors to seed grain for field planting is shown in the plate. It consists of a hand-blower (A), a cylinder containing the grain (C), a test-tube to contain the fungicide (B), and tubes for connection. The air is forced by means of the blower through the liquid fungicide in the test tube. From there it is conducted by a tube to the lower part of the cylinder containing the grain and up through the seed grain. The air permeated with the fungicide vapor is taken up from the cylinder by the blower and again forced through the liquid fungicide. By repeatedly passing the same air through the fungicide it was thought that a saturated atmosphere would be secured and greater uniformity of results obtained than if the air were passed only once through the fungicide.

The grain used in the experiments was grown near Brookings in 1903 and was very badly infected with smut. The experiments conducted were confined entirely to the stinking smut of wheat. About four ounces of grain were used in each treatment. The grain was sown in plots of three rows each forty feet long. The season was so favorable to the early growth of the wheat that the amount of smut even in the untreated plots is very small.

A few factors which it has been found would influence the results were partly lost sight of in performing these experiments. The results therefore are not perfectly uniform. This



APPARATUS FOR APPLYING VAPORS TO SEED GRAIN

A. Hand-blower for producing a current of air. B. Test-tube containing fungicide in liquid form. C. Cylinder containing seed grain.

slight lack of uniformity and the apparent contradiction of certain results are therefore readily accounted for.

Under length of treatment in the tables is recorded the length of exposure to the vapor and not the length of time the current was maintained through the fungicide and grain. The latter was not the same in all tests.

TABLE I.

Formaldehyde Vapor Applied Without Return Current.

	Lengtn of Treatment	Length of Row	Date of Seeding	Total Number of Heads	Number of Heads Smutted	Per Cent. of Heads Smutted
a	Untre't'd	20 feet	April 16	1,136	36	2.37
b	¼ hr	40 "	" 16	2,303	31	1.35
c	½ hr	40 "	" 16	2,245	26	1.16
d	¾ hr	40 "	" 16	2,509	18	.72
e	1½ hr	40 "	" 16	2,501	4	.16
f	2 hrs	40 "	" 16	2,570	17	.66
g	2½ hrs	40 "	" 16	2,791	19	.68
h	hrs	40 "	" 16	2,727	16	.59

Table I. records treatment of seed with formaldehyde vapors produced in an apparatus similar to that shown in the plate. In these experiments the tube connecting the cylinder C to the blower A was removed. The air was thus forced through the formaldehyde solution but once. Fresh air was continually taken up by the blower and the used vapors were allowed to pass off. The results show that an insufficient quantity of formaldehyde vapor was taken up by the air at ordinary temperatures by this method to secure absolute efficiency of treatment. However, a decrease in the percentage of smut in the treated plots is shown in the results.

TABLE II.

Formaldehyde Vapor Applied with Return Current.

	Length of Treatment	Length of Row	Date of Seeding	Total Number of Heads	Number of Heads Smutted	Per Cent. of Heads Smutted
a	¼ hr	40 feet	April 16	2,397	17	.7
b	½ hr	40 "	" 16	2,103	6	.29
c	¾ hr	40 "	" 16	2,638	5	.19
d	1 hr	40 "	" 18	2,640	0	0.
e	1½ hr	40 "	" 18	2,571	2	.08
f	2 hrs	40 "	" 18	2,407	1	.04
g	Untre't'd	40 "	" 16	2,606	25	.96

The treatments outlined in Tables II. and III. were applied with apparatus as shown in the plate and at ordinary room temperatures. In both of these series a very decided falling off will be noticed in the amount of smut in the treated plots. In fact, in the series given in Table III., absolute immunity was secured except in the one-half hour and two hour treatments. The probable explanation of the presence of smutted heads in occasional plots whatever the treatment, is given under Table V.

TABLE III.

Formaldehyde Vapor Applied with Return Current.

	Length of Treatment	Length of Row	Date of Seeding	Total Number of Heads	Number of Heads Smutted	Per Cent. of Heads Smutted
a	¼ hr	20 feet	April 18	1,315	0	0.
b	½ hr	20 "	" 18	1,051	2	.19
c	¾ hr	20 "	" 18	920	0	0.
d	1 hr	20 "	" 18	1,268	0	0.
e	1½ hr	20 "	" 18	1,187	0	0.
f	2 hrs	20 "	" 19	1,101	2	.18
g	Untre't'd	20 "	" 19	1,186	16	1.35

TABLE IV.

Formaldehyde Vapor.

	Temperature of Formaldehyde Solution	Strength of Solution	Length of Treatment	Length of Row	Date of Seeding	Total Number of Heads	Number of Heads Smutted	Per Cent of Heads Smutted
a	19° C.	40 p. c.	½ hr	20 feet	April 19	1,210	0	0
b	20° C.	20 "	½ hr	20 "	" 19	1,263	0	0
c	30° C.	40 "	½ hr	20 "	" 19	1,208	0	0
d	60° C.	40 "	½ hr	20 "	" 19	1,280	0	0
e	75° C.	40 "	½ hr	20 "	" 19	1,084	0	0
f	19° C.	20 "	3 hrs	20 "	" 19	1,193	12*	1 00
g	.....	5 "	24 hrs	20 "	" 19	1,319	3	.22
h	Untreated	.....	.....	20 "	" 19	1,074	13	1.21

The experiments outlined in Table IV. were performed to test the effect of the solution at different temperatures and of different strengths.

Treatment (*d*) was raised to 60 degrees C. at the start and a second time after the treatment had been under way five minutes. Treatment (*e*) was maintained at 75 degrees C. for five minutes. All others were simply started at the temperature designated. The room temperature at the time was about 19 degrees or 20 degrees C. Some condensation took place on the grain under treatment (*e*) which may have injured germination.

TABLE V.

		Length of Row	Date of Seeding	Total Number of Heads	Number of Heads Smutted	Percent of Heads Smutted
a	Uninfected	6 feet	April 30	380	0	0.
b	Form. Vapor ½ hr. ..	6 "	" 30	365	1	.27
c	Form. Vapor. 1 hr	6 "	" 30	362	7	1.9
d	Form. Vapor 2 hrs	6 "	" 30	370	6	1.6
e	Form. Liquid 1-400.	6 "	" 30	377	5	1.3
f	Ammonia 1 hr	6 "	" 30	383	8	2.09
g	Uninfected	6 "	" 30	481	0	0.

Table V. gives the results of experiments conducted to determine whether fungicidal vapors or liquids penetrate the

*This result does not compare favorably with (*b*) of the same series. An accident in treatment or planting may account for this.

smutted grains (often called smut balls) in treatment. The seed grain used in these treatments appeared to be perfectly free from smut. Tests (*a*) and (*g*) show this assumption to be correct. In tests from (*b*) to (*f*) smutted grains were taken from treatments designated, ground to powder, and applied to the clean grain. It was thought in this way results would be obtained which would show whether the vapors or liquids penetrated the smutted grains or not. The results show that even with the formalin vapor and liquid treatments which were efficient in preventing the smut, the fungicide did not penetrate the smutted grain sufficiently to kill the spores. The results of these experiments may account for the fact that a few smutted heads were found in certain plots which were subjected to stronger treatments than other plots in which there were no smutted heads found, as the smutted grains were not removed from the grain sown and may have been occasionally broken in seeding. The fact that the fungicides did not penetrate the smutted grains in either liquid or vapor treatments is not a serious objection as they can be very readily removed from the seed grain with a fanning mill before treatment.

TABLE VI

Formaldehyde Solution.

	Strength of Solution	Quantity Used for 4 oz. of Grain	Length of Row	Date of Seeding	Total Number of Heads	Number of Heads Smutted	Per Cent. of Heads Smutted
a	1 part to 500	9.5 c. c.	20 feet	April 26	1,490	0	0
b	1 " 400	9.5 c. c.	20 "	" 26	1,172	0	0
c	1 " 400	19. c. c.	20 "	" 26	1,154	0	0
d	1 " 300	9.5 c. c.	20 "	" 26	1,387	0	0
e	Untreated	.....	20 "	" 23	1,338	20	1.48

Table VI. gives the results obtained by the use of formaldehyde solution applied in the liquid form according to the ordinary methods. One part of formaline to four hundred of water is the strength usually recommended for use. These tests were made simply as a means of comparison with the other treatments.

TABLE VII.

Ammonium Hydrate Vapor.

	Length of Treatment	Length of Row	Date of Seeding	Total Number of Heads	Number of Heads Smutted	Per Cent. of Heads Smutted
a	¼ hr	20 feet	April 23	1,278	5	.4
b	½ hr	20 "	" 23	1,136	8	.7
c	¾ hr	20 "	" 23	1,356	13	.96
d	1 hr	20 "	" 23	1,046	2	.19
e	1 hr	20 "	" 23	1,042	5	.48
f	Untre't'd	20 "	" 23	1,338	20	1.48

The ammonia and chloroform treatments were applied with apparatus for return current. 6 c. c. of stronger ammonia (28 per cent.) were used for each ammonia treatment and 4 c. c. of chloroform for each chloroform treatment. The current was maintained for three minutes for each treatment.

TABLE VIII.

Chloroform Vapor.

	Length of Treatment	Length of Row	Date of Seeding	Total Number of Heads	Number of Heads Smutted	Per Cent. of Heads Smutted
a	1-6 hr	20 feet	April 28	1,189	3	.25
b	⅓ hr	20 "	" 28	1,170	7	.6
c	½ hr	20 "	" 28	1,364	5	.37
d	¾ hr	20 "	" 28	1,494	4	.27
e	1 hr	20 "	" 30	941	3	.32
f	Untre't'd	20 "	" 28	1,151	4	.35

TABLE IX.

Carbon Bisulphide Vapor.

	Length of Treatment	Length of Row	Date of Seeding	Total Number of Heads	Number of Heads Smutted	Per Cent. of Heads Smutted
a	16 hrs	20 feet	April 28	1,195	6	.5
b	21 hrs	20 "	" 28	1,354	2	.15
c	26 hrs	20 "	" 28	1,165	4	.34
d	Untre't'd	20 "	" 28	1,151	4	.35

In the tests with carbon bisulphide 5 c. c. of carbon bisulphide and 4 ounces of grain were used for each treatment. The carbon bisulphide was placed in a flat dish over the grain in a closed vessel and allowed to remain for the specified time. As the vapors of carbon bisulphide are heavier than air this method should give as accurate results as any.

TABLE X.

Ozonet Powder.

	Amount of Powder Used	Length of Row	Date of Seeding	Total Number of Heads	Number of Heads Smutted	Per Cent. of Heads Smutted
a	.2 grams	20 feet	May 4	986	6	.61
b	.4 "	20 "	" 4	1,200	3	.25
c	.6 "	20 "	" 4	1,254	8	.64
d	.8 "	20 "	" 4	1,302	7	.54
e	None	20 "	" 4	1,375	19	1.37

Six hundred grams of wheat were used for each Ozonet powder treatment. The amounts of powder used viz., .2, .4, .6 and .8 gram are equivalent respectively to 2, 4, 6, and 8 pounds per hundred bushels of grain. The powder was mixed with the grain and allowed to stand in a closed vessel for 48 hours. Two pounds per hundred bushels is the amount specified by the manufacturers for the prevention of smut.

Experiments to Determine the Effects of the Vapors Used Upon the Germination of Wheat.

Prior to making treatments upon smutted grain for field planting several series of germination tests were conducted in the laboratory and greenhouse to determine the limits within which the vapor treatments could be used without injuring the seed grain. This was desirable in order to reduce the number of field experiments to a minimum and avoid the possibility of planting seed in the field which would not germinate.

The treatments were made as follows: One hundred grains of wheat were used for each test. The chemical used as the

source of vapor was placed in a flat dish beneath a bell jar and allowed to stand for a few hours undisturbed. The wheat was then placed upon a similar flat dish and slid under the bell jar, raising the bell jar just enough to allow the admission of the dish containing the wheat. Very little vapor was lost in this manner. The wheat was allowed to remain the required length of time and then removed. After treatment the wheat was planted in flats in the greenhouse. The seed was sown on black soil and covered with sand. Germination tests of untreated seed were made in every flat used. The grain treated was sown either the same day of the treatment or the day following.

Table No. XI. gives the results of the first series of tests started February 27, 1904. From this table it will be noticed that all the chemicals used seemed to injure the germination somewhat in treatments of five or six hours or over. It may be doubtful if this is true of carbon bisulphide, however. Ammonia treatments up to one hour lessened the germination little, if any.

TABLE NO. XI.

CHEMICAL USED	Length of Treatment	Per Cent. Germination 5 Days After Sowing	Per Cent. Germination 7 Days After Sowing	Vigor of Growth 10 Equals Normal
Chloroform	6¼ hr	30	36	7
Chloroform	25½ hr	19	22	7
Formaldehyde	6¼ hr	3	5	6
Formaldehyde	25½ hr	0	0	..
Ozonet Gas Powder	25 hr	0	0	..
Ozonet Gas Powder	69 hr	0	0	..
Carbon Bisulphide	5¾ hr	64	71	9
Carbon Bisulphide	25 hr	67	72	9
Ammonia	1-6 hr	75	88	10
Ammonia	⅓ hr	66	75	10
Ammonia	⅔ hr	71	77	9+
Ammonia	1 hr	66	69	9+
Ammonia	2 hr	59	59	9+
Ammonia	4 hr	11	17	7
Ammonia	20 hr	0	0	..
Ammonia	22½ hr	0	0	..
None	.....	69	82	10
None	.....	86	89	10

Following this series another series of tests was started March 7 with formaldehyde only, the results of which are giv-

en in table No. XII. In this series it appears that formaldehyde vapors of the strength used can be applied for one hour without injury to germination or growth. In treatments of over one hour there was a decided falling off in per cent. of germination and vigor of growth.

TABLE NO. XII.

Chemical Used	Length of Treatment	Per cent. Germination 6 Days After Sowing	Per Cent. Germination 7 Days After Sowing	Per Cent. Germination 10 Days After Sowing	Vigor of Growth 10 Equals Normal
Formaldehyde.	⅓ hr	79	85	90	10
"	⅔ hr	72	76	81	10
"	1 hr	65	75	80	10
"	1½ hr	29	39	55	9
"	2 hr	27	37	45	7
"	2½ hr	21	23	24	7
"	3 hr	26	31	33	7
"	4 hr	18	22	24	7
"	5 hr	15	20	23	7
None.....	.....	75	83	84	10

On March 17 a third series (Table XIII.) was started to compare the effect of formaldehyde, ammonia and chloroform vapor treatments up to one hour. In this series the formaldehyde and ammonia seem to have little effect upon the time or per cent. of germination. The chloroform delayed the germination but did not lower the per cent. to any great extent. The growth of the latter, however, seemed to be weakened. This was not apparent in the later field planting of chloroform-treated seed. The growth of the ammonia-treated grain was somewhat accelerated by the treatment. This was not apparent in the field tests but was very marked in the series grown in the greenhouse.

TABLE NO. XIII.

Chemical Used.	Length of Treatment	Per Cent. Germination 4 Days After Sowing	Per Cent. Germination 5 Days After Sowing	Per Cent. Germination 8 Days After Sowing	Vigor of Growth 10 Equals Normal
Formaldehyde.	1-6 hr	73	85	90	10
"	1/3 hr	78	81	87	10
"	2/3 hr	60	66	76	10
"	1 hr	63	72	78	10
Ammonia.....	1-6 hr	91	92	99	10+
"	1/3 hr	82	86	91	10+
"	2/3 hr	80	82	83	10+
"	1 hr	79	82	87	10+
Chloroform....	1-6 hr	67	73	76	9
"	1/3 hr	33	74	83	8
"	2/3 hr	.....	72	81	8
"	1 hr	.....	68	78	8
None.....	.....	84	86	91	10
"	.....	88	93	94	10

Following these germination tests the grain to be used in the field tests was treated and placed in bottles to be kept until time for planting. The manner of applying the treatments to the grain planted in the field was entirely different from that used in the greenhouse germination tests. The apparatus shown in the plate was used for field treatments with vapors unless otherwise specified in the text. It was not noticed, however, that any field planted grain was injured in germination or growth. This does not quite coincide with the results obtained in the greenhouse germination tests. This observation seems to show that the vapors obtained by the apparatus used for the field tests were not as strong as those obtained by the bell jar method.

The strength of any chemical used throughout the series was the same. This was not exactly determined, however. The formaldehyde was the commercial 40 per cent. solution obtained from the Bausch & Lomb Optical Company. Later analyses showed this to contain slightly over 30 per cent. formaldehyde. The chloroform and carbon bisulphide were both ordinary commercial articles. The ammomnia was of the strength known as stronger ammonia. The Ozonet gas powder was obtained direct from the manufacturers.

Later experiments and references have shown that several

factors were partly lost sight of in the conducting of these experiments. With formaldehyde it was found that a 30 per cent. solution increased in strength after a current of air had passed through it for some time. An analysis of one sample taken after a current of air had passed through it for two hours showed it to contain 38 per cent. of formaldehyde. New chemicals should therefore have been used in each treatment to secure uniformity of results. In some of the first series this was not done.

A higher temperature than the ordinary room temperature at which most of the experiments were performed would undoubtedly aid in the giving off of formaldehyde vapors. Table No. 4, which gives the results of trials with the use of solutions at higher temperature does not demonstrate this, however, as all the treated grain in this series was practically free from smut whether treated at a high or low temperature. Rosenau* says in his observations upon the use of formaldehyde as a disinfectant: "Temperature is an important factor in disinfecting with formaldehyde. The gas condenses at -20° C. to the solid polymeric paraform. Disinfection with this gas should never be attempted if the temperature is under 10° C. The action of the gas seems to be about the same between the temperatures of 10° C. and 27° C. Higher degrees of heat materially aid the disinfecting power of the gas."

"From its watery solution at ordinary temperatures formaldehyde gas is given off very slowly, and in very uncertain quantity. Warmth not only facilitates the evaporation of the fluid. but aids the disinfecting power of the gas."

The conditions required for disinfection of rooms would very likely be similar to those for the killing of smut spores on seed grain with possibly one restriction, that is, in the treatment of seed grain care must be taken not only to kill the smut but to prevent injury to the seed grain. The facts as given by Rosenau about the use of formaldehyde vapors in disinfection are probably as applicable to the treatment of grains for smut as to general disinfection. In regard to the amount of moisture necessary for gaseous disinfection with formaldehyde he also says: † "There is no such thing as chemically dry formaldehyde

*M. J. Rosenau, "Disinfection and Disinfectants," Philadelphia, 1902, 90 and 112.
†l. c. 90.

gas. Efforts to dry the gas result in its conversion to the solid polymeric state. A certain amount of moisture is therefore essential to obtain successful gaseous disinfection. The exact amount of moisture necessary has not yet been accurately determined, but it is probable that the full disinfecting power of formaldehyde gas is only obtained if the atmosphere contains 75 per cent. of moisture, and that only when the atmosphere is saturated with moisture is the maximum effect obtained."

Further experiments will be conducted during the season of 1905 to determine the best methods to use the vapors on a large scale. A machine to treat from 15 to 20 bushels of grain at each treatment has been designed by a manufacturing company and is now in process of construction. A sample of this machine will be furnished to the Experiment Station for trial the coming season. If the results are as satisfactory as those already obtained upon a smaller scale, the treatment will then be recommended for general use.

I wish to express my thanks to my assistant, Mr. Arthur C. Dillman, for aid in both field and laboratory, to Mr. F. A. Norton for analysis of fungicides and to Mr. A. B. Holm for photograph of apparatus.

SUMMARY.

1. The formalin, copper sulphate and hot water treatments as recommended to date for the prevention of the stinking smut of wheat, though effective in preventing the disease, are objectionable because of their requiring the wetting of the grain in such treatment.

2. Wet treatments in their application are practically restricted to the treating of the grain immediately or very shortly before sowing. Seedsmen and others offering seed grain for sale are thus debarred from treating their seed grain and thus being able to guarantee their seed to be free from smut.

3. A dry treatment if effective, inexpensive and practical in its application, would overcome these objections.

4. Vapors or gases seem to offer the key to the solution of the problem. Volatile powders or other dry materials to be mixed with the grain, would be objectionable because of the difficulty in securing a uniform mixture of material and grain.

5. Formaldehyde vapor in experiments during 1904 proved effective in destroying the stinking smut of wheat. It will very likely be equally as effective with all smuts which can be prevented by the formaldehyde liquid treatment.

6. The method by which the formaldehyde vapor was applied in the treatments appears to be sufficiently practicable to be applied upon a large scale.

7. The experiments with formaldehyde vapors in the treatment of grain smuts will be continued in 1905 with variously constructed machines to determine how extensively the facts outlined here can be used in practice.