

difference in size and development could be detected between the plants of the two plats. Of the plants from the untreated seeds two per cent. were attacked by the smut while none of those of the untreated seeds showed any signs of the fungus. These results with corn show the possibilities in this direction. Of course infection during the growth of the plant would not be prevented by this treatment. The treatment is not difficult, and the actual expense for the cost of material is not over six cents per acre.

Comments on the value of formalin as a fungicide are not necessary in view of the facts as presented.

Extensive arrangements are being made for experiments the coming spring on ground that has in years past produced crops showing a loss of from forty to sixty per cent. from smut.

THE RESISTANCE OF CEREAL SMUTS TO FORMALIN AND HOT WATER.

BY WILLIAM STUART.

In connection with some studies on the comparative merits of formalin and hot water in the prevention of smut in wheat and oats, the subject of the resistance of the smut spores when treated separately was considered of sufficient importance to warrant investigation. The smuts of wheat and oats were selected from the fact that these two cereals are the only ones of economic importance in the State which it is possible to treat successfully for smut. While it is possible to kill the spores of corn smut by treating the seed, it affords no guaranty that the plants will be free from smut. This is owing to the fact that the method of infection by corn smut is unlike that of the other two cereals, inasmuch as the corn plant is liable to infection at any point where there is young, growing tissue, and at any stage of its development.

In order to test the relative resistance of smut spores as compared with the grain itself, separate lots of each were treated side by side in the same solution.

The smut spores used were those of the loose smut of wheat and oats. These were obtained from a quantity of smutted heads collected last summer from badly infected fields. When required for use the smutted por-

tions were removed and passed through a sieve to get rid of the coarse particles. The spores after being well mixed were collected in a box and formed a supply from which successive portions were taken as required for treatment.

In treating the smut spores and grain, considerable care was exercised in furnishing conditions which would insure similar treatment for all. This was especially necessary, as in the case of the hot water treatment it was found that in the high temperature treatments a difference of about five degrees occurred between the upper and lower surfaces of the water in a three-gallon bucket. To obviate any possibility of one lot receiving different treatment from that of another, especially when both were treated at the same time, the following method was adopted: The smut spores were enclosed in fine muslin sacks, weighted by tying a few grains of shot in the corner of them. The grain, about half an ounce being used, was put in loose muslin sacks, similarly weighted. The sacks were suspended on a rod, at a uniform level. When ready for treatment they were dropped into the solution, the weights instantly carrying the sacks below the surface, while the rod rested across the top of the vessel, thus holding them in place. The water at the level of the sacks was maintained at the desired temperature. In each instance the five and ten minute treatments were made at the same time, the removal of the former being readily done without in any way disturbing the remaining ones.

The treated spores were germinated in hanging drop cultures in moist Van Tieghem cells. Control cultures of untreated spores were mounted in the same manner. The spores were germinated in distilled water. Whenever any doubt existed in regard to the behavior of the cultures, fresh mounts were made. Cultures of the treated spores were made as soon as possible after their removal from the solution.

The grain was germinated in the laboratory in a Geneva germinator. As only a small quantity of seed was treated, but two hundred seeds were used in the germination experiments. The germinating seeds were counted and removed from the germinator each day until germination ceased.

The results of the work performed are given in Tables I. and II. It will be noticed that these do not include anything upon wheat smut. In explanation of this, the writer wishes to state that, at the beginning of the experiment, the germination of the wheat smut spores was very unsatisfactory; frequently none would germinate in the control cultures. As the

work progressed the viability of the spores decreased until practically none grew. Under these circumstances it was thought best not to present any of the data.

TABLE I.

Germination of Oat Seed and Smut Spores After Immersion in Formalin Solution.

Per Cent. of Formalin.	Length of Immersions.	Number of Spore Cultures.	Number of Cultures Showing Germination.	Per Cent. of Grain Germinated.
Control		12	12	99.5
One-fourth	15 min....	4	0	92
One-fourth	30 min....	4	0	93.5
One-fourth	1 hour....	4	0	90.5
One-fourth	2 hours....	2	0	95
One-half	15 min....	4	0	92.5
One-half	30 min....	2	0	91
One-half	1 hour....	2	0	91
One-half	2 hours....	2	0	86.5

As will be seen by Table I. but two strengths of formalin were used, these being a one-fourth and a one-half per cent. solution. These two strengths were chosen because they were considered sufficiently strong to prove effective against smut when it was immersed but a short time, and would therefore more nearly represent comparable conditions with hot water treatments. In these two solutions the grain and smut were immersed for periods of time varying from one-quarter to two hours, the intervening points being one-half and one hour, making in all four treatments.

Taking the shorter treatment by the weaker solution, it was found that even when a minute quantity of spores was treated, if they were mounted at once in a hanging drop culture, quite a large per cent. of the spores would germinate. If, on the other hand, the spores were allowed to remain in the sacks until dry and then mounted, no germination was

obtained. The same results were also obtained in the half-hour treatment, and not infrequently an occasional spore in the hour treatment.

Spores treated one-quarter hour in the one-half per cent. solution would show slight germination if cultures were made as soon as removed from the solution, but if allowed to become dry and then mounted no spores germinated. The longer periods of treatment gave no germination whether cultures were made at once or after the spores were allowed to become dry.

In the treatment of smut spores with formalin it was found that if what ordinarily might be called a small quantity of spores were taken very variable results were obtained. This seemed to be due to the imperviousness of the spores, when any number were collected together, to the formalin. This feature did not appear to enter into the hot water treatment, apparently they were not impervious to the hot water. Probably this was largely due to the somewhat oily properties of the formalin.

Another notable feature of the formalin was its action on the spores after their removal from the solution, and which in the shorter periods of treatment resulted in no germination of the spores, as against fair germination in those mounted as soon as removed from the solution.

The formalin used was that known to the trade as "Formaldehyde. Merck," a supposedly genuine forty per cent. formaldehyde solution.

Some indirect references have been found in regard to the action of formalin on smut spores. In one of these references the author¹ found that the spores of species of *Ustilago* and *Tilletia* were killed after treatment for two hours in a one-tenth per cent. solution of formalin. In a discussion following the presentation of the paper, Krüger stated that spores of *Ustilago carbo* were not killed by immersion for twenty-four hours in a .05 per cent. formalin solution.

E. A. de Schweinitz² says that a formalin solution of 1:10,000 has been recommended for destroying the spores of smut.

The effect of formalin upon germination of the seed was not very well marked. A slight injury was noticeable, but the percentage of germination was good.

¹ Geuther; Ber. Pharm. Gesell., 5: 325-330, 1895; Abs. in Chem. Centr. Bl., 1896; Abs. in Jahresh. Agr. Chem., 19: 418; Abs. in Bull. Ind. Agr. Sta., 65: 34; Abs. in Exp. Sta. Record, 9: 569.

² Yearbook Dept. Agr., 259, 1896.

TABLE II.

Germination of Oat Seed and Smut Spores After Immersion in Hot Water.

Temperature of Water.	Length of Immersions.	Number of Spore Cultures.	Number of Cultures Showing Germination.	Per Cent. of Grain Germination.
Control.....	.....	14	14	99.5
110° F.....	5 min....	2	2	.....
110° F.....	10 min....	2	2	.....
115° F.....	5 min....	2	2	.....
115° F.....	10 min....	2	2	.....
120 F.....	5 min....	4	3 ¹	.....
120° F.....	10 min....	4	0	.....
125° F.....	5 min....	1	0	93.5
125° F.....	10 min....	2	0	94.5
130° F.....	5 min....	1	0	90.5
130° F.....	10 min....	1	0	88
135° F.....	5 min....	1	0	95
135° F.....	10 min....	1	0	93
140° F.....	5 min....	1	0	53
140 F.....	10 min....	1	0	42.5

In Table II. is presented the result of the hot water treatment, the range of temperature being from 110°—140° F. The lowest point of effectiveness was found to be 120° F. for ten minutes. This is a point at least ten degrees below the effective point of treatment of the grain for the prevention of smut³. The grain itself showed little injury from treatment at an increased temperature of fifteen degrees over the effective point for smut. The inference to be deduced from this fact is that in the hot water treatment there is quite a marked range in temperature between the limit of spore resistance and that of the resistance of the grain. The effectiveness of the treatment between these two limits would seem to depend wholly upon the ability of the operator to bring each seed in contact

³ Arthur, Ind. Agr. Exp. Bull., 35: 86, 1891.

with the hot water a sufficient length of time to reach all the smut spores.

Of formalin it may be said that, although it is a comparatively new fungicidal and germicidal agent, it has nevertheless been employed to quite an extent in the prevention of parasitic diseases. So far as known it was first employed in this State by the botanical department of the Agricultural Experiment Station at Purdue during the winter of 1895-'96 in the treatment of scabby potato tubers for the prevention of the scab⁴. The treated tubers were grown in the greenhouse, and the resultant crop gave such satisfactory results that more extensive trials were made in the open field during the season of 1896. The results of these trials have been reported in the bulletin already cited.

Two experiment station bulletins are known to have been issued containing reports of trials with formalin for the prevention of wheat and oat smut. The first of these⁵ reports the use of formalin in the treatment of wheat and oats. The author found a solution of one pound to fifty gallons to be effective when the seed was given a two-hour treatment. The other bulletin⁶ referred to contains an account of the use of formalin for the prevention of smut in oats. It was found that smut spores were destroyed by immersing the seed two hours in a 0.2 per cent. solution.

In an experiment performed last summer by the Botanical Department of Purdue University and not yet reported, it was found that oats immersed ten minutes in a solution containing one pound of formalin to fifty gallons of water, only eight-tenth per cent. of smutted plants were produced as against over twelve per cent. in the untreated ones.

A recent newspaper article⁷ contains a brief notice of some experiments with formalin by Prof. Thomas of Wabash College, in which he found that oats treated half an hour in a one-half per cent. solution produced plants entirely free from smut as against about six per cent. in the untreated ones.

A few references have been found on the influence of formalin on the germination of the seed. Geuther⁸ found that soaking the seed grain two hours in a 0.1 per cent. solution did not injure its germination. In a

⁴ Arthur, Ind. Agr. Exp. Sta. Bull., **65**: 23, 1897.

⁵ Bolley, North Dakota Exp. Sta. Bull., **27**: 1897.

⁶ Close, N. Y. Agr. Sta. Bull., **131**: 1897.

⁷ Indianapolis News, Dec. 9, 1898.

⁸ *l. c.*, 325-330.

one-fourth per cent. solution for the same length of time the seed was seriously affected.

Bolley⁹ reports the effects of formalin on oats, barley and wheat. Seed of oats and barley immersed half an hour in a solution containing three parts formalin to one thousand parts of water gave normal germination nine days and nine months after treatment. Wheat immersed ten minutes in a two per cent. solution gave eighty-two per cent. germination.

Thomas¹⁰ finds a one-half per cent. solution for oats and a treatment of about two hours produces no injury to the seed.

For wheat a one-fourth to one-half per cent. solution and an immersion of one-half hour is recommended. Rye was injured in a one-fourth per cent. solution when immersed but an hour.

SUMMARY.

A brief resumé of the data presented shows that the results obtained in the treatment of the spores are well within the bounds of successful practice.

The spores are much more easily injured either with hot water or formalin than is the grain.

It is apparent that the essential feature in the successful treatment of grain for smut is to bring each seed in contact with the solution used a sufficient length of time to enable it to reach the smut spores.

The advantage possessed by formalin over hot water in the treatment of seed grain lies in the greater ease of its application, doing away with the necessity of heating water and maintaining a reasonably uniform temperature during the period of treatment.

LAKE MAXINKUCKEE. BY J. T. SCOVELL.

During the summer of 1898 I traced out the sandbars in the southern portion of the lake. In doing this work I made about 100 soundings. In all we now have about 900 recorded soundings of the lake. The contour

⁹ *l. c.*, 130-132.

¹⁰ Thomas, Proc. Ind. Acad. Sc., 148, 1897.