THESIS

On

THE COMPARATIVE VALUE OF FORMALDEHYDE
AND OF VARIOUS CHEMICAL DUSTS
FOR THE CONTROL OF ONION SMUT

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By

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Chairman of Committee on Graduate Study
THE COMPARATIVE VALUE OF FORMALDEHYDE AND OF VARIOUS CHEMICAL DUSTS FOR THE CONTROL OF ONION SMUT.

INTRODUCTION

Onion smut is without doubt the most destructive of all onion diseases in the northern onion growing districts of the United States. In many states it is probably responsible for more loss to the growers than all the other diseases of onions combined.

Oregon has experienced its share of the damage since the advent of this new and serious pest into the state. The Department of Botany and Plant Pathology of the Oregon Experiment Station has conducted extensive experiments for determining practical methods of control for this section with definite positive results. The results of these experiments indicate that the use of a solution of formaldehyde 1:128 (1 oz. to 1 gal.) gave the best control of all the materials tested.

The use of formaldehyde involves some difficulties, however. The results of this and of other experiment stations show that formaldehyde may be injurious to onion seeds. The formaldehyde tank on the seeder also adds considerable weight and the solution itself is quite heavy (9 pounds per gallon). So much solution is required that barrels of it must be prepared before seeding time and distributed throughout the fields.

This problem was chosen for the purpose of trying
to find some other means of controlling onion smut, which might, perhaps, be more convenient to apply.

PART ONE.

SUMMARY OF THE PRESENT KNOWLEDGE OF ONION SMUT.

I. HISTORY AND DISTRIBUTION:

Onion smut (Urocystis cepulae, Frost) has been known in Connecticut since 1860, according to Thaxter (4). The first account of very serious injury was in the report of the Massachusetts State Board of Agriculture for 1869-70 (2). In 1879 it was reported in the vicinity of Paris, France where it was presumed to have been introduced from America. Reports are on record of its having been found at Leipzig, Germany in 1880. Thaxter (4) believes, however, that it was indigenous in Europe and America on species of wild onion. In 1879 the onion smut was reported in eastern Iowa (Pammel and King) (23) and has spread very rapidly into all the important northern onion growing sections, viz: Massachusetts, Connecticut, New York, New Jersey, Ohio, Pennsylvania, Indiana, Illinois, Iowa, Oregon and California. Urocystis cepulae, Frost was first found in Great Britain in 1912 in Scotland (A.D. Cotton) (34) although there were doubtless infected centers in Northumberland as early as 1900 (Whitehead) (56). It has also been reported in Denmark (Cotton) (34) and in Holland (Walker) (63). Thaxter (4) relates that in 1876 the fungus was given its present name by Mr. C. C. Frost.
of Brattleborough, Vermont.

The first thorough study of the disease was made by W. G. Farlow (2) in 1876 and the principal additions to our knowledge of the fungus have been made by R. Thaxter of Harvard University, L. R. Jones of the University of Wisconsin, F. A. Sirrine and F. C. Stewart of New York, A. D. Selby of Ohio, L. H. Pammel and G. M. King of Iowa, F. J. Anderson of Massachusetts, and T. Whitehead of England.

II. ECONOMIC IMPORTANCE OF THE PARASITE:

Universal importance: Thaxter (4) in 1889 reported that several thousand acres of good onion land in Connecticut had been diverted to other crops because of ravages of the onion smut fungus. He also found that only five years are needed, after the introduction of the smut to healthy soil, for the fungus to become so widespread as to prevent the successful raising of onions from seed. Losses due to smut in Iowa have been as high as 50% and not less than 10% on untreated fields (Pammel & King) (23). In addition to the direct damage from the smut there is an indirect or secondary loss. Many of the plants which develop without smut are so isolated because of the death of adjacent plants as to develop "bull necks" (R. E. Vaughan) (47). Such thick necked bulbs are slow in drying out and are more liable to be destroyed by storage rots.

Importance of the onion smut in Oregon: Urocystis cepulae, Frost was unknown in the onion growing districts
of Oregon until May 1914 at which time it was reported to the Experiment Station by Mr. Andrew Kauffman of Hubbard, Oregon. (Barss) (28). Hearsay evidence, however, seems to indicate its presence on some farms in the northern Willamette Valley section as early as 1911. Barss (50) reports that on the beaverdam soil where onions were grown it is now a very serious pest. The amount of loss reported from these districts at first was not great but the disease steadily increased since that time until the amount of damage done caused many onion set growers around Hubbard, Oregon to discontinue the growing of that crop and utilize the ground for less profitable crops. At times almost total crop losses have been suffered due to smut. According to growers of that section only four years were necessary from its first appearance for the smut to render the raising of onions unprofitable. Barss also relates that local estimates of the losses suffered due to smut would easily total $125,000 in that one small section alone.

The disease also invaded sections of the Tualatin Valley devoted to the growing of large onions with serious results and recently has appeared in the reclaimed Lake Labish lands northeast of Salem, Oregon where hundreds of acres are devoted to onion production. In all there are approximately one thousand acres devoted to the growing of onions in Oregon, yielding crops valued at nearly five thousand dollars annually. It is, therefore, quite evident
that the onion smut question is an important one in Oregon and one which will require considerable investigation because of the peculiarly mild winters here which are entirely different from the winters in the other districts in this country where control measures have been tried.

III. DESCRIPTION OF THE DISEASE, (SYMPTOMS:)

The first indication of smut infection of onion seedlings is a dark streak within the cotyledon shortly after it appears above ground. This develops into a brownish or blackish elongated blister covered by a thin membrane. After the leaf has increased somewhat in size this membrane splits exposing the black spore mass within. (Plate I, fig. 1.) Many of the seedlings which are attacked die, but a few, which are not so severely infected, may survive until harvest. The new leaves and scales of the latter may continue to be attacked as they develop. Some infected plants outgrow the disease entirely. Although most of the surviving infected bulbs are so small and imperfect that they are thrown out at harvest time, occasional ones are of sufficient size to escape notice and these reach the market. Such specimens are characterized by the slightly raised brown to black pustules most prevalent near the base of the bulbs and usually occurring as deeply as the third or fourth scale. Smut does not cause a storage rot, but smutted bulbs suffer more loss through shrinkage than normal bulbs and are subject to attack by other organisms. Aspergillus niger has been reported as
has been reported as readily attacking smutted bulbs in storage (Fammel & King) (23.)

IV. LIFE HISTORY OF CAUSAL ORGANISM:

Onion smut is due to a fungus of the group Basidiomycetes and of the order Ustilaginales. It attacks only the onion and closely related plants. Like many other smut fungi Urocystis cepulae, Frost has in its life history, as shown by Anderson (49), a saprophytic period during which it may develop extensively and propagate for a long time, deriving its nourishment from dead organic material in the soil or other substrata. It has been shown (Thaxter) (4) that a field infected with smut after a period of twelve years during which no onions were raised on the land, gave 10 - 50% infection when planted to onions again. This saprophytic mycelium has the ability to infect young onion seedlings when the latter are grown in the infected soil (Anderson) (49). After establishing itself within the young plant, the fungus continues to develop parasitically taking its nourishment from the onion seedling. After a period of growth the fungous mycelium produces swellings within the onion leaf, which contain thousands of black round spores. These spores fall to the ground and over-winter there, being very resistant to cold. In the spring and early summer when the onion seeds are germinating, the smut spores may also germinate and infect the young seedlings in the same manner as by the saprophytic mycelium mentioned above.
V. DISSEMINATION:

The smut is spread principally on onion sets or transplants from infected fields, or in soil carried on the feet of men or animals or on farm wagons and agricultural implements. Considerable spreading occurs through returning to the soil of smutted onions thrown on manure or compost heaps. Some spores are carried with dust by the wind from one field to another and surface water will undoubtedly carry spores in smutty trash from field. Very little dissemination occurs from the smut spores being borne on the onion seed. Halstead (15) was unable to introduce smut by planting seed from badly infested plants, yet it is quite possible for onion seed to become contaminated with spores blown from infested onion fields or through accidental contact with smut in the storage houses or topping sheds and in other ways when proper precautions are not taken to prevent it. This danger although not universally present must not be overlooked when planting onion seed on clean soil.

VI. FACTS REGARDING INFECTION AND THE CONDITIONS INFLUENCING IT:

Anderson (49) found that under greenhouse conditions the greater part of infection occurred within two weeks after planting, and that the plants were no longer susceptible after seventeen days. Walker and Jones (55) found permanent immunity after about twenty days at moderate temperature. Anderson's studies (49) showed that suscept-
ibility begins to diminish from the time the knee emerges from the soil, and little if any infection occurs after the first leaf emerges from the side of the cotyledon. He found that knees began to emerge in from seven to twelve days after planting.

Cytological studies from similar experiments by Anderson showed that infection does not occur before the second day after the germination of the onion seedling (fifth day after planting) and may occur until the seedling is in the first leaf (a period of about twelve days in the greenhouse). The infecting hyphae were seen to enter the epidermal cell by boring directly through the outer wall. Cases of multiple infection were observed. In one plant fixed eight days after planting the mycelium was found passing in through the epidermis at six points on a piece of the cotyledon less than one centimeter long.

In the greenhouse the first externally visible symptom of infection occurred in ten days after infection and was characterized by a slight curving and thickening of the cotyledon. Anderson concludes that it is possible that all infection takes place through the cotyledon. He also says that the idea, that when a seedling once becomes infected it never recovers, is false. He has observed instances where seedlings which had infected cotyledons developed into healthy onions. H. P. Barss in his (unpublished) report to the Director of the Oregon Experiment Station for the years 1918-19 also mentions cases of seedlings having
small infections which recovered and showed no smut at maturity. "These so-called recoveries," he states, were much more numerous (as high as 20%) in treated rows (formaldehyde 1 to 128) than in the untreated plots due doubtless to the more abundant infections on the individual plants in the check plots."

**Environmental factors favoring infection:** Environmental factors affecting infection by smut are limited to the soil temperature, Walker and Jones (55) having found that any degree of soil moisture which permits growth of seedlings will allow free development of the fungus. Their experiments showed that in cool soil (60 F.) the smut made its best progress while at 84 F. or above the development of the disease was entirely inhibited. This fact, in connection with Anderson's cytological studies (49), in which he found the onion seedling to be subject to infection for only a short period after germination of the seed, has a definite practical bearing on the fact that in northern sections where the soil temperatures are lower at seeding time, the onion crop suffers more from the disease than in the south where the onion seed is sown in August and September and the infection of onions by the smut has not been reported to the best knowledge of the writer.
VII. PREVIOUS INVESTIGATION IN THE CONTROL OF ONION SMUT:

Numerous experiments for controlling onion smut, with varying degrees of success have been performed in many parts of the United States and in England. Hall, Srrirne, and Stewart (18) found that sulfur alone is quite efficient in the control of smut but that it is better when used with lime. Thaxter (8) on the other hand found the sulfur very hard to apply and he experienced great injury to the seed from sulfur only 10-20% of the seed coming up. He did, however, get an increased yield, in the ratio of 25:8, over untreated plots on very smutty soil.

Air slaked lime and sulfur were recommended by Sirrine and Stewart (17), Fammel and King (23), and Hall, Sirrine, and Stewart (18). The latter recommend the treatment only when losses through smut exceed one third of the crop. They recommend fifty pounds of the lime to one hundred pounds of sulfur per acre in the drill rows at time of seeding. Sturgis (12) after more extensive experiments withdrew his previous recommendation for the use of lime and sulfur and said he could suggest nothing but the transplanting of plants from clean to smutted soil after they had passed the infection stage. Walker (39) also found the lime and sulfur to be inefficient as compared with the formaldehyde-drip method.

The formaldehyde-drip treatment has been tried and recommended by Selby of Ohio (30), Fammel and King of Iowa (23), Stone of Massachusetts (30), Walker of Wisconsin (48),
Anderson of Massachusetts (60), C. T. Gregory of Indiana (58), Barss of Oregon (50), and T. Whitehead of England (57). As a result of these extensive experiments formaldehyde has superseded all other treatments for smut control. The formaldehyde treatment has been tried in various forms and concentrations but the consensus of opinion among the advocates of this method is that one liquid ounce of the formaldehyde to one gallon of water applied to 185 feet of drill row simultaneously with seeding gives the least injury and the greatest yield. As some injury to seed results when this strength solution is employed more seed should be planted when using this system.

Supplementary control measures which have been recommended and which are quite important in preventing the spread of smut to healthy soil are: (1) To observe the sanitary precaution of disposing of the remains of smutted plants by burning, neither allowing them to remain in the field nor throwing them on manure or compost heaps whence they would be returned to the fields, (2). Where transplanting to the field to transplant only seedlings from healthy soil, (3). To plant onion sets instead of seed if the soil is too badly inoculated to grow seedlings at a profit.
PART TWO

EXPERIMENTS ON ONION SMUT CONTROL PERFORMED BY THE WRITER.

In attempting to find some other means than the formaldehyde-drip method which might successfully be used for the control of onion smut, various experiments were conducted in the laboratory in which the fungicidal and toxic properties of copper carbonate dust and sulfur dust were compared with those of formaldehyde under varying conditions. One test on varietal susceptibility of onions to smut was included. In all, nine different tests were conducted, as follows:

1. To compare the three materials under constant cool conditions of temperature and uniform soil moisture.

2. To compare the same materials under laboratory conditions in which the temperature was not controlled.

3. To compare the effects of different periods of exposure at a controlled temperature on the activity of sulfur.

4. To determine the distance in the soil to which the effective action of formaldehyde will extend.

5. To determine the reduction in stand of seedlings due to injury by fungicides.

6. To determine the relation of soil moisture content to seedling injury by formaldehyde.

7. To determine the effect of lime added to copper carbonate as a means of control for onion smut.

8. To determine the comparative susceptibility to onion smut of two leading varieties of onions raised in Oregon.
9. To determine the relation of temperature to formaldehyde injury to onion seeds.

EXPERIMENT NUMBER ONE.

Object: To compare copper carbonate and sulfur with the standard formaldehyde method for smut control under uniform soil moisture and a constant temperature of 65°F.

Materials used:

1. Formaldehyde (37%) 1 fluid ounce to 1 gallon of water (1:128).
2. Copper carbonate manufactured by Mountain Copper Co. O.A.C. Experiment Station No. 13670. Containing 53.4% copper.
3. Sulfur dust (Corona brand).

Nature and condition of soil:

The soil used was black beaver-dam soil secured from a smut-infested field in the onion-growing district of the Tualatin Valley, not far from Beaverton, Oregon. The soil was rich in organic matter and included a considerable amount of smutted onion tops. It was received by the Department of Botany and Plant Pathology of the Oregon Agricultural College in September 1923 and stored in the laboratory until the middle of January 1924 so that it was thoroughly air dried. Then in order to allow the saprophytic development of the fungus to take place, the soil was put in pots and flats and kept moistened for at least ten days before placing in the pots in which the seeds were subsequently planted. After planting, the soil was kept fairly well moistened as is characteristic of
the heavy black soil of this vicinity at the time the seed is planted and during the early growth of the seedling at which time the infection occurs. The same amount of water was added each time to each pot in the experiment.

Seed:

The seed used was secured from Mr. William J. Edwards of Beaverton, Oregon. It was of the Leedy strain of Yellow Danvers variety and was from the 1923 crop.

Method of planting and application of fungicides:

Sulfur: Six inch greenhouse pots were filled with soil to within two inches of the top. The seeds were then planted by scattering them evenly over the surface of the soil. Two and a half grams of sulfur dust was then weighed and applied to the seeds and to the soil above the seeds as follows: the sulfur was placed in a small hand duster (American Beauty) and a quantity was applied to the seeds and the soil directly beneath them to give a uniform yellow coating to the whole. A thin layer of soil was then spread over the seeds and a similar coating of sulfur was blown over it. This process was repeated with successive layers of soil until a total of an inch of soil had been placed above the seeds and all the sulfur in the duster had been applied.
Copper carbonate: The same sized pots were filled the same way and the seeds were planted by scattering as in the case of the sulfur treatment as described above. Two and a half grams of Copper carbonate were weighed and applied to seeds and soil in successive thin layers in the same manner as the sulfur application until the seeds were covered to a depth of one inch and the supply of copper carbonate in the duster was exhausted.

Formaldehyde: Six inch greenhouse pots were filled with soil to within an inch of the top. Furrows were then made so that the seeds could be covered to the depth of one inch. The seeds were planted by scattering them evenly along the bottom of the furrows, the same quantity being used as in the two previously described treatments. The formaldehyde solution (1:128) was then applied from a pipette as in the drip method used in the field. The application was at the rate of one gallon of the solution per 185 feet of drill row as is recommended for field practice. After the formalin had been applied the seeds were immediately covered with the soil adjacent to them which had been piled up at either side when the furrows were opened.

Checks: Untreated checks were planted with each series. The pots were filled and the seeds were planted and covered in the same manner and to the same depth as in the sulfur and copper carbonate treatments.
described above.

Conditions of temperature and moisture:

The smutted soil, containing 42% of soil moisture, by weight, was potted and after planting the seeds, the pots were placed in an incubator in the cold storage basement in order to insure a constant uniform temperature of 65°F. This temperature is the mean temperature for soil for this section for the month of April at the time onions are usually planted. These temperature data were obtained from Mr. G. H. Harris of the Oregon Experiment Station and were secured by him through personal investigations.

Water losses were measured by weight and replaced at regular intervals. When the seedlings had passed the infection stage the pots were removed to the laboratory where they were kept watered and the temperature was recorded by a thermograph.

Observations:

Observations were made every few days and notes taken regarding damping-off, germination, etc. After the period for determining smut infections had arrived, the onion seedlings were pulled and the chlorophyll bleached out in order to facilitate the counting of smutted individuals. This bleaching was done by placing the seedlings in a 50% solution of alcohol acidified with acetic acid and allowing them to stand for three or four days. The number of
seedlings which were smutted under each treatment was counted and the percentage of smut was computed in order to give a basis for comparison between the different treatments.

Results and discussion:

The results obtained in this test are seen in Table I and in Plates VI and VII.

The seedlings in both series in the sulfur and the untreated checks appeared above ground at the same time. The ones in the copper carbonate did not appear until six days later and then only a few. There was a continual succession of germination in this treatment even up to the time of pulling the seedlings. This resulted in a very uneven stand of seedlings as shown in Plate VI fig. 1. No germination occurred in the formaldehyde treated series, due probably to the low temperature as is indicated in experiment nine.

As to smut control the results of this test seem to indicate a fair control with sulfur dust and a slight control with copper carbonate. Due to seed injury from formaldehyde no comparison of effectiveness was obtained in this test between the different chemicals used.

Considerable damping-off occurred in the pots growing the untreated checks. The damped-off seedlings were examined for smut, however, and the proper notations taken. No damping off occurred with the sulfur treatment nor with the copper carbonate treatment.
TABLE I.

Comparative results in smut control of treating soil with Sulfur, Copper carbonate, or formaldehyde solution. Two similar series conducted 9 days apart.

<table>
<thead>
<tr>
<th>Date planted</th>
<th>Date counted</th>
<th>Treatment</th>
<th>Percent smutted</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-6-24</td>
<td>3-5-24</td>
<td>Sulfur</td>
<td>24.3</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>Copper carb.</td>
<td>50.2</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>Formaldehyde</td>
<td>0.0 (no germination)</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>Check</td>
<td>86.4</td>
</tr>
</tbody>
</table>

Series B, temperature 65°F.

<table>
<thead>
<tr>
<th>Date planted</th>
<th>Date counted</th>
<th>Treatment</th>
<th>Percent smutted</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-15-24</td>
<td>3-5-24</td>
<td>Sulfur</td>
<td>31.0</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>Copper carb.</td>
<td>83.8</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>Formaldehyde</td>
<td>0.0 (no germination)</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>Check</td>
<td>90.9</td>
</tr>
</tbody>
</table>

Note: As a preliminary to Experiment Number One a little side test was run to determine if the onion smut would live over in air dried soil for any considerable length of time. Some soil from the smut infested district of Oregon which had been received by the Oregon Experiment Station in the fall of 1921 had been kept in a paper sack in a steam heated laboratory for over two years. Three eight inch pots were filled with this soil and the pots were then seeded with unsmutted seed from the same lot as used in the other experiments. After three weeks in the laboratory under optimum conditions of temperature and
moisture for the fungus the seedlings were examined and found to be approximately 80% smutted.
EXPERIMENT NUMBER TWO.

Object: To compare the effectiveness of copper carbonate, sulfur, and formaldehyde for the control of onion smut under uncontrollable laboratory conditions.

Materials used:
The materials used were the same as those used in Experiment 1.

Nature and condition of soil:
The soil used was some of the same lot as used in the first experiment and in the same condition of smuttness and soil moisture.

Seeds used:
The seeds used were of the same lot as used in the previous test.

Method of planting and application of fungicides:
The fungicides used and the method of applying each was the same as in Experiment Number 1 above.

Conditions of temperature and moisture:
The seeds were potted in smutty soil as in test one and after planting and treating the pots were placed in a laboratory in which the temperature ranged from 55° - 70°F. during the time the seedlings were growing. Soil moisture was maintained the same as in test one.

Observations:
Observations were made regularly every few days while the experiment was in progress. Notes were taken as was thought necessary. The seedlings were
pulled when the infection period was over and the percentage of smut in each case determined the same as in the previous experiment.

Results and conclusions:

The results obtained in this experiment are shown in Table 2 and in Plate VIII.

There proved to be insufficient variation in conditions between this experiment and the previous experiment to give any material differences in results. A comparison of Tables I and II will show how slight a difference was obtained. This seems reasonable when it is considered that temperature is probably the principal factor and that in these two experiments the average temperature was practically the same.

TABLE II.

Comparative results in smut control of treating soil with Sulfur, Copper carbonate, or Formaldehyde solution. Two similar series conducted 14 days apart.

Series A, temperature 55° - 70°F.

<table>
<thead>
<tr>
<th>Date planted</th>
<th>Date counted</th>
<th>Treatment</th>
<th>Percent smutted</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-9-24</td>
<td>3-5-24</td>
<td>Sulfur</td>
<td>72.9</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>Copper carb.</td>
<td>83.1</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>Formalin</td>
<td>0.0 (no germination)</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>Check</td>
<td>97.1</td>
</tr>
</tbody>
</table>
### Table II. (Cont'd.)

Series B, temperature 55°-70°F.

<table>
<thead>
<tr>
<th>Date planted</th>
<th>Date counted</th>
<th>Treatment</th>
<th>Percent Smutted</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-23-24</td>
<td>3-24-24</td>
<td>Sulfur</td>
<td>37.9</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>Copper carb.</td>
<td>90.5</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>Formalin</td>
<td>0.0 (no germination)</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>Check</td>
<td>95.4</td>
</tr>
</tbody>
</table>
EXPERIMENT NUMBER THREE

Object: To determine the effect of different lengths of time exposure to a constant temperature of 70°F. on the fungicidal action of sulfur toward onion smut.

Materials used:
The same sulfur dust as was used in the sulfur treatment set in Experiment One.

Seed:
The seed used was from the same lot as used in Experiment One.

Method of planting and application of fungicide:
The seeds were planted and the sulfur was applied exactly as in previous experiments.

Conditions of temperature and moisture:
The soil used was the same as used in Experiment One and was moistened to 42% by weight as in that test. Immediately after planting the pots were placed in the incubator and the temperature kept at 70°F. One set consisting of a treated pot and a check pot was removed after four hours, another after eight hours, a third after sixteen hours and the last after twenty-four hours exposure to this temperature. Upon removal from the incubator the pots were placed in the laboratory and the temperature during the remaining time the experiment was in progress, as recorded by a thermograph, averaged 55° - 70°F.
Observations:

As in Experiments One and Two, observations were made every few days and notes were taken on germination, damping-off, etc. After the infection period was over the seedlings were pulled, bleached, and counted for smut.

Results and conclusions:

The results are shown in Table III.

There was considerable damping-off in the untreated checks while the treated pots showed no damping-off. The seedlings of the treated pots were almost, if not quite as vigorous as those of the checks showing that little or no injury to seedlings was caused by the sulfur. An appreciable amount of smut control was obtained by the sulfur treatment. The results as shown in Table III seem to indicate better smut control the shorter exposure at 70°F. The reason is difficult to understand. One possible explanation might be that the longer exposure at such a temperature volatilizes the sulfur to such an extent that the seedlings are subsequently not protected over the entire infection period. If one considers, however, the apparent increase in the percentage of smutted seedlings in the untreated pots at the longer periods of exposure to this temperature, another possibility is suggested. Perhaps the longer exposure to a warmer temperature stimulated the activity of the fungus to a greater extent and induced a greater amount of infection in spite of the activity of the sulfur.
TABLE III.

Results of temporary exposure of sulfur treated pots to 70°F. followed by an average temperature of 55°-70°F.

<table>
<thead>
<tr>
<th>Date planted</th>
<th>Date counted</th>
<th>Treatment</th>
<th>Hours exposed to 70°F.</th>
<th>Percent smutted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-22-24</td>
<td>2-23-24</td>
<td>Sulfur</td>
<td>4</td>
<td>23.1</td>
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<tr>
<td></td>
<td></td>
<td>Check</td>
<td>4</td>
<td>95.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sulfur</td>
<td>8</td>
<td>26.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Check</td>
<td>8</td>
<td>96.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sulfur</td>
<td>16</td>
<td>42.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Check</td>
<td>16</td>
<td>97.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sulfur</td>
<td>24</td>
<td>46.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Check</td>
<td>24</td>
<td>100.0</td>
</tr>
</tbody>
</table>
EXPERIMENT NUMBER FOUR

Object: To determine how far from point of application effective control by formaldehyde can be obtained.

Purpose of the experiment:

The present method of seeding onions in Oregon is by means of a multiple row drill. To use a formaldehyde drip pipe for each row would require an enormous amount of solution and this test was performed with the purpose of trying to find out how far apart the drip pipes can be placed and still get effective smut control.

Materials used:

Formaldehyde (37%) 1 ounce to 1 gallon of water (1 - 128).

Seed used:

Seed used was from the same lot as in the previous experiments.

Nature and condition of soil:

The same smutted soil was used as in previous experiments and it contained the same degree of soil moisture.

Method of planting and application of the formaldehyde:

The smutted soil was placed in a greenhouse flat and rows of seed were planted across the short way of the box. An application of formaldehyde was made down the center center of the box across the rows of seed before they were covered. The solution was applied from a pipette at the rate of 1 gallon to 185 feet of drill row
as in the formaldehyde treatment in the first two experiments.

**Conditions of temperature and moisture:**

Two series were run, each prepared and treated in exactly the same manner but with a six weeks interval of time between them. Both series were kept in the laboratory during the whole time the experiment was in progress but the temperature of the laboratory during the time they were there as recorded by the thermometer varied between 55° - 70°F. for series A and between 65° - 80°F. for series B.

**Observations:**

Observations were made as in the previous experiments. After the period of susceptibility to infection was past and smut blisters had formed the seedlings were pulled and counted for smut.

**Results and discussion:**

The results of Series A are shown in Table IV and in Plate IX. Considerable injury to seed was experienced in this test as shown by the bare strip down the center of the flat. This was not expected in the light of field experience but the temperature under which the experiment was conducted was undoubtedly responsible for the high toxicity of the formaldehyde to the seed. This assumption is supported by the results of Experiment Number Nine below.

The results in Series B are shown in Table IV. No
injury to seed was experienced in this set as the temperature was higher and the seeds made rapid germination.

These two tests showed that the effects of the formaldehyde extended into the second inch away from the line of application in the low temperature series while it extended into the third inch in the higher temperature series. These are important facts when consideration is given to the enormous amount of liquid which must be handled in a very short time during the seeding time. There is no efficient method at present for the spacing of drip pipes in the multiple row onion-set drills. It would be possible, perhaps in the light of these results, to skip every other drill row with a pipe and still get reasonable control since in series B fair control (48.4%) was obtained in the second inch from the point of application and many of the infections were so slight in the cotyledons that there would probably be many recoveries.

TABLE IV.

Results of the test to determine the distance the effectiveness of formaldehyde spreads in the soil from point of application. Two series conducted six weeks apart.

Series A. temperature 55°- 70°F.

<table>
<thead>
<tr>
<th>Date planted</th>
<th>Date counted</th>
<th>Percentage of smut</th>
<th>Fourth inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-15-24</td>
<td>3-10-24</td>
<td>none germinated</td>
<td>65.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>93.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>93.9</td>
</tr>
</tbody>
</table>
TABLE IV. (Con't)

Series B, temperature 65° - 80°F.

<table>
<thead>
<tr>
<th>Date planted</th>
<th>Date counted</th>
<th>First inch</th>
<th>Second inch</th>
<th>Third inch</th>
<th>Fourth inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-29-24</td>
<td>4-17-24</td>
<td>17.7</td>
<td>48.4</td>
<td>70</td>
<td>96</td>
</tr>
</tbody>
</table>
EXPERIMENT NUMBER FIVE

Object: To determine the effect of fungicides used on the stand of seedlings.

Reasons for the test:

It was found in former test that there was considerable difference in the number of seeds planted and the number of seedlings coming above ground to be counted. This test was planned to determine the amount of injury due to chemicals which prevented germination or caused the death below ground of the seedlings, using temperature conditions similar to those in Experiments I and II.

Materials used:

Formaldehyde (1 - 128), sulfur dust, and copper carbonate all as in Experiment Number One.

Nature and condition of the soil:

An effort was made to duplicate the soil used in previous tests without having the onion smut present. For this purpose a mixture was prepared consisting of equal parts of clay-loam, leaf-mould, and well-rotted manure.

Seed used:

The seed used was from the same lot as used in the other tests.

Method of planting and application of fungicides:

The soil mixture was potted and the planting of seeds and application of the fungicides was done as in Test Number One.
Conditions of temperature and moisture:

The soil was moistened to 42% by weight before the seeds were planted and the soil moisture was subsequently maintained as in Test 1.

Series A was kept in the incubator in the cold storage at a constant temperature of 65°F until the seedlings were well up as in Test Number One. They were then removed to the laboratory and kept there until time for the seedlings to be pulled. Series B was kept in the laboratory during the entire course of the experiment and the temperature as recorded by the thermograph averaged between 55° - 70°F.

Observations:

Observations were made at regular intervals and the proper notes taken. After the period of susceptibility of onion seedlings to smut was past and the smut galls became evident the seedlings were pulled and examined, the germination or at least the appearance above ground of seedlings being very carefully observed.

Results and discussion:

The results of the test are shown in Table V.

There was some damping-off in the check pot in Series A which accounts for the lower germination count as compared with the check in Series B. The results as shown in this table indicate total killing of seeds by formalin, a slight injury to seeds and seedlings by sulfur (3-14%), and a considerable injury by copper
carbonate (22-43%).

TABLE V.

Injury to seeds by chemicals used as fungicides. Two series, the first under constant cool temperature and the other under varying degrees of temperature.

Series A, temperature 65°F.

<table>
<thead>
<tr>
<th>Date</th>
<th>Date</th>
<th>No. of seeds planted</th>
<th>Treatment</th>
<th>No. of seedlings which emerged</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-27-24</td>
<td>3-24-24</td>
<td>100</td>
<td>Sulfur</td>
<td>87</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>Copper carb.</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>Formaldehyde</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>Check</td>
<td>90</td>
</tr>
</tbody>
</table>

Series B, temperature 55° - 70°F.

<table>
<thead>
<tr>
<th>Date</th>
<th>Date</th>
<th>No. of seeds planted</th>
<th>Treatment</th>
<th>No. of seedlings which emerged</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-27-24</td>
<td>3-24-24</td>
<td>100</td>
<td>Sulfur</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>Copper carb.</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>Formaldehyde</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>Check</td>
<td>99</td>
</tr>
</tbody>
</table>
EXPERIMENT NUMBER SIX

Object: To determine the relation of soil moisture to formaldehyde injury to onion seedlings.

Reasons for the experiment:

The purpose of this experiment was to try to find the reason for the severe injury by formaldehyde to onion seedlings in the previous experiments. It was thought that soil moisture might, perhaps, be a factor.

Materials used:

Formaldehyde (1 : 128) as used in the previous tests.

Nature and condition of the soil:

Some of the same smutted, beaver-dam soil as was used in the preceding tests.

Seed used:

The seed used was from the same lot as used in previous tests.

Method of planting and application of fungicides:

The seeds were planted in opened furrows and the formaldehyde solution was applied over the seeds in the open row as in previous formaldehyde treatments.

Conditions of temperature and moisture:

The soil was analyzed for soil moisture and was found to contain 22% by weight. A treated check and an untreated check were planted leaving the soil moisture at 22%. Other pots were planted with an increase of 5% of water by weight in each case over that
of the preceding one. The pots were kept in the laboratory and the temperature recorded by a thermograph. The temperature during the course of the experiment as recorded by the thermograph varied between 65° and 80°F. Four days after planting the water losses were replaced and the pots were moistened as seemed necessary thereafter.

**Observations:**

Observations were made at regular intervals but nothing of importance was noticed regarding amount or time of germination in the different pots. No damping-off occurred in treated pots or checks in this experiment.

After the period of susceptibility of seedlings to smut was past and the resulting infections had become evident the seedlings were pulled, bleached and counted for smut.

**Results and discussion:**

The results appear in Table VI below.

As far as the results of this experiment are concerned there appears to be no relation between soil moisture at the time of seeding and injury to seedlings by formaldehyde. The surprising thing about this experiment was that no injury was experienced by formaldehyde in any of the pots not even in the one having the same degree of soil moisture as in previous tests (Experiments I, II, IV and V) where severe injury resulted. This suggested the possibility of temperature being
the important factor in the injury to seedlings by formaldehyde. Experiment IX was later performed to test out this possibility. The low germination in the untreated check was doubtless due to the low moisture content of the soil. Naturally this was increased when the weak formaldehyde solution was added and promoted better germination.

**TABLE VI.**

Relation of soil moisture to injury of onion seed by Formaldehyde.

<table>
<thead>
<tr>
<th>Date planted</th>
<th>Date counted</th>
<th>Percent moisture</th>
<th>No. of seeds planted</th>
<th>No. of seedlings which emerged</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-22-24</td>
<td>4-17-24</td>
<td>22</td>
<td>100</td>
<td>51 (Untreated check)</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>22</td>
<td>100</td>
<td>83</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>27</td>
<td>100</td>
<td>86</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>32</td>
<td>100</td>
<td>93</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>37</td>
<td>100</td>
<td>87</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>42</td>
<td>100</td>
<td>.77</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>47</td>
<td>100</td>
<td>97</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>52</td>
<td>100</td>
<td>89</td>
</tr>
</tbody>
</table>

************
EXPERIMENT NUMBER SEVEN

Object: To determine the effect on smut control and seedling injury by a grade of copper carbonate low in copper and high in lime content.

Material used:

Corona brand copper carbonate having Experiment Station Number 13500 and containing 21.5% copper and a high lime content as analyzed by the Experiment Station Chemist in contrast to the standard type of copper carbonate, having 53.4% copper, used in previous tests.

Nature and conditions of the soil:

The same smutted soil as was used in Experiment Number One.

Seed used:

The seed used was from the same lot as was used in Experiment Number One.

Method of planting and application of fungicides:

The seeds were planted as in the previous experiments and the low test copper carbonate was applied in different amounts starting with one gram per pot and increasing the amount in each succeeding pot by half a gram over the preceding one up to 3.5 grams. The dust was applied in the same way as the copper carbonate dust treatment in Experiment One.

Conditions of temperature and moisture:

The soil moisture was kept the same as in Exper-
Experiment Number One as nearly as possible and the pots were kept in the same laboratory in which the former experiments were kept and the temperature was recorded by thermograph.

Observations:

Repeated observations were made and any important details were noted.

Nineteen days after planting, the seedlings were pulled, bleached, counted, and examined for smut.

Results and discussion:

No definite evidence of injury to germination by this fungicide was shown by the results whereas in all previous tests the standard type of copper carbonate always produced positive injury. On the other hand the results seem to indicate poor smut control even though the three and a half grams per pot produced nearly twice as good control as the one gram per pot. The degree of control, moreover, even with the three and a half grams seems to be less than the degree of control obtained previously with the standard type of copper carbonate and certainly is far from satisfactory from a practical standpoint.
TABLE VII.

Temperature 65° - 80° F.

Comparative results in smut control of different amounts of a brand of copper carbonate which is low in copper and high in lime content.

<table>
<thead>
<tr>
<th>Date Planted</th>
<th>Date Counted</th>
<th>Grams of copper carbonate used</th>
<th>No. of seeds planted</th>
<th>No. of seedlings germinated</th>
<th>percent smutted</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-29-24</td>
<td>4-17-24</td>
<td>1.0</td>
<td>100</td>
<td>88</td>
<td>79.5</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>1.5</td>
<td>100</td>
<td>82</td>
<td>60.9</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>2.0</td>
<td>100</td>
<td>82</td>
<td>60.9</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>2.5</td>
<td>100</td>
<td>90</td>
<td>52.2</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>3.0</td>
<td>100</td>
<td>97</td>
<td>60.8</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>3.5</td>
<td>100</td>
<td>88</td>
<td>42.04</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>0 (Check)</td>
<td>100</td>
<td>85</td>
<td>85.8</td>
</tr>
</tbody>
</table>
EXPERIMENT NUMBER EIGHT

Object: To determine the comparative susceptibility to onion smut of two leading commercial varieties grown in Oregon.

Reasons for the experiment:

The Australian Brown variety has been credited with being more resistant to onion smut than is the Yellow Danvers variety.

Outline of experiment:

This was a simple test in which seeds of both the above named varieties were planted in pots of smutted, untreated soil the same as done in check pots in Experiment Number One. The pots were kept in the laboratory and the temperature was recorded by thermograph. After the infection period was past and smut became evident the seedlings were pulled, bleached, and examined for smut as described in Experiment One.

Results and discussion:

The results are indicated in Table VIII and as far as laboratory conditions are concerned they show that Australian Brown is possibly slightly more resistant than the Yellow Danvers, but the difference shown is so small that it very likely falls within the limits of experimental error.
TABLE VIII.

Results of the tests to determine the relative susceptibility of onion smut of two varieties of onions grown in Oregon.

Temperature 65°- 80° F.

<table>
<thead>
<tr>
<th>Variety</th>
<th>No. Germinated</th>
<th>Percent smutted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow Danvers</td>
<td>250</td>
<td>62.4</td>
</tr>
<tr>
<td>Australian Brown</td>
<td>262</td>
<td>58.3</td>
</tr>
</tbody>
</table>

***************
EXPERIMENT NUMBER NINE

Object: To determine the relation of temperature to formaldehyde injury to onion seeds.

Reasons for the experiment:

The results of Experiment Six seemed to indicate that soil temperature rather than soil moisture was possibly the principal factor in the injury to seeds experienced in the first tests performed. It was the purpose of this experiment then to find, if possible, just how much effect temperature would have and incidentally to determine whether the solution first used was at fault.

Materials used:

1. Newly prepared solution of formaldehyde (1 - 128) from freshly opened Perth-Amboy formaldehyde (37%). The solution prepared exactly as in Experiment One.
2. The old original formaldehyde solution which was left from that prepared for Experiments One, Two, etc.

Nature and condition of soil:

The soil used was of the same lot of smutted, beaver-dam soil as was used in the first experiments performed.

Seed used:

The seed used was of the same lot as in Experiments One to Seven inclusive.

Method of planting and application of fungicides:
The smutted soil was potted as in the formaldehyde treated pots in Experiment One. Fifty seeds were accurately counted and planted in rows and the formaldehyde was then applied from a pipette as in the description under experiment one. The application was at the same rate as in the previous experiments, i.e. 1 gallon to 185 feet of drill row. An untreated check was planted for a control. One pot in each series was treated with the new solution and the other pot with the old in order to see if there was any difference in the solutions.

**Conditions of temperature and moisture:**

The smutted soil at time of planting contained approximately 42% of moisture as in Experiments One, Two, etc.

Series A was removed to the cold storage immediately after planting and was kept in the incubator at 65°F, constant temperature until germination was complete in the check pot at which time all the pots were removed to the laboratory.

Series B was kept in the laboratory from the start and the temperature was recorded by the thermograph. The temperature as recorded varied between 70° - 85°F.

**Observations:**

Observations were made daily and notes taken as to time of first appearance of seedlings in checks and each treated pot in both series.
After the germination period was past the seedlings were counted and the percentage germination computed.

Results and discussion:

The results obtained are shown in Table IX and in Plate X. These results seem to indicate that temperature is a very important factor in the injury to seed by formaldehyde and that even a moderately cool temperature like 65°F is responsible for severe injury which disappears when the temperature rises to ten degrees or so higher on the average.

TABLE IX.

Series A, temperature 65°F.
Relation of temperature to Formaldehyde injury to onion seeds.

<table>
<thead>
<tr>
<th>Date planted</th>
<th>Date counted</th>
<th>Treatment</th>
<th>No. of seed planted</th>
<th>Percent germination</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-18-24</td>
<td>5-1-24</td>
<td>Old sol.</td>
<td>50</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>New sol.</td>
<td>50</td>
<td>14.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Check</td>
<td>50</td>
<td>82.0</td>
</tr>
</tbody>
</table>

Series B, temperature 70° - 85°F.

<table>
<thead>
<tr>
<th>Date planted</th>
<th>Date counted</th>
<th>Treatment</th>
<th>No. of seed planted</th>
<th>Percent germination</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-18-24</td>
<td>5-1-24</td>
<td>Old. sol.</td>
<td>50</td>
<td>92.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>New sol.</td>
<td>50</td>
<td>96.0</td>
</tr>
</tbody>
</table>
SUMMARY

The results of these experiments show quite clearly that

1. Under low conditions of temperature (65°F.) the standard strength of formaldehyde (1 - 128) may prevent germination of onion seeds, while at higher temperatures (70° - 85°F.) very little injury is noticeable. It is also quite evident that variations in soil moisture content had no apparent effect on formaldehyde injury.

2. Ordinary standard copper carbonate dust mixed with the soil in quantities sufficient to check smut infection produces not only a reduction in germination but may seriously retard the appearance of the seedlings (under conditions prevailing during the course of this experiment).

   Corona copper carbonate, which is lower in copper and higher in lime than standard copper carbonate produced no apparent reduction in germination but did cause some delay in germination and unevenness in stand although not nearly so severe as with standard copper carbonate.

3. Sulfur dust produced no apparent delay in germination or reduction in stand over a range of temperatures from 65°F. to 70°F.

4. In smut control formaldehyde, applied in solution (1 : 128) at the rate of one gallon to one hundred and eighty-five feet of drill row, has proved far
more efficient than any of the dust treatments under the conditions of these tests, being practically complete under certain conditions as far as the tests would indicate. The effectiveness of formaldehyde as shown in these tests extends beyond the second inch from point of application but gradually decreases with the distance.

5. The next best material as regards smut control appeared to be sulfur dust applied so as to cover the seeds and thoroughly mixed with the soil over the seeds. This treatment gave, in some instances, as high as 75% or more smut free seedlings, even when a uniform temperature of 65°F. was maintained, as compared with 95% smut in the checks. This is especially remarkable since it has been generally considered that elemental sulfur is incapable of fungicidal activity at a temperature very much below 70°F. No greater effectiveness appeared to result from a 24 hour exposure to 70°F of temperature than when a constant temperature of 65°F was maintained. For reasons not entirely clear the 70°F temperature for 24 hours gave a slightly higher percentage of smut than the 4 hour exposure at the same temperature.

6. Standard copper carbonate as well as the
Corona copper carbonate mixed with the soil above the seed as in the case of sulfur showed evidence of a certain amount of smut control. However, the highest percentage of healthy plants obtained with standard copper carbonate was only 50 and with Corona copper carbonate was only 58%. In no case was smut control sufficient to encourage the belief that copper carbonate will prove a satisfactory practical means of onion smut prevention.

7. Incidentally it was learned that attacks of damping-off fungus were completely inhibited by all the fungicides used.

8. It was shown by experiment that the infective power of smut infested soil was retained in dry soil in the laboratory for a period of two years.

CONCLUSIONS

These tests indicate that in all probability neither sulfur dust, nor copper carbonate can be looked upon as a promising substitute for the standard formaldehyde-drip method for the control of onion smut since both have given evidence of very inferior smut prevention while copper carbonate was shown to be distinctly injurious to germination.

In the light of these experiments, however, there is a possibility of a saving of formaldehyde solution in the growing of onion sets as practiced in Oregon since it was found that the effective action of formaldehyde extends approximately two inches from point of application, provid-
ing for a reduction in the number of drip pipes on the multiple row drill.
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<table>
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SMUTTED ONIONS SHOWING SMUT MASSES

Figure 1
SMUTTED PLANTS SHOWING STUNTING AND BULL NECKS

Figure 1

NORMAL HEALTHY ONIONS

Figure 2
YIELD OF ONIONS FROM TREATED PLOT (LEFT) AND FROM AN UNTREATED PLOT (RIGHT)

Figure 1

INFECTED PLANTS SHOWING SMUT BLISTERS

Figure 2
PLATE IV

Figure 1

SHOWING POOR STAND AND SMUTTED PLANTS IN SMUT INFESTED AREA

Figure 2
SMUTTED AREA SHOWING POOR STAND

Figure 1

TREATED ROWS (RIGHT), UNTREATED (CENTER AND LEFT)

Figure 2
PLATE VI

EXPERIMENT ONE, SERIES A
Figure 1
EXPERIMENT ONE, SERIES B
Figure 1
PLATE VIII

EXPERIMENT TWO, SERIES A

Figure 1

Figure 1 shows four plants in pots labeled with different treatments: Formaldehyde, CuCO₃, Sulfur, and Untreated Check. Each label indicates a specific substance used in the experiment.
PLATE IX

EXPERIMENT FOUR, SERIES A

Figure 1
EXPERIMENT NINE