SOME FAULTS IN FORMALDEHYDE DISINFECTION OF POTATOES.

SUMMARIZED BY
F. H. HALL

FROM BULLETINS BY
F. C. STEWART AND W. O. GLOYER.

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Popular Edition*

of

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Some Faults in Formaldehyde Disinfection of Potatoes.

F. H. Hall.

Why formaldehyde disinfection is popular.

Formaldehyde gas and its solutions in water are convenient and effective disinfectants for use under many conditions. As they require no fire in application they are safer to use than sulphur, and they do not corrode or tarnish metal fixtures or apparatus as do sulphur fumes; they are comparatively inodorous, therefore more pleasant to apply and quicker to disappear from notice than carbolic acid and similar compounds; and they are not poisonous, consequently far less dangerous to keep and use in homes and on farms than corrosive sublimate. For these reasons, the formaldehyde preparations have become very popular in human and animal sanitation; and they are used with success, also, in preventing some plant diseases, such as some of the grain smuts.

Use in potato tuber treatment.

In 1897, less than a decade after the discovery of the germicidal value of formaldehyde, its use, in liquid form, was recommended for the prevention of potato scab; and this method of treatment for insuring clean seed has become standard and is widely used. The non-poisonous nature of the liquid recommends it to thousands of growers in place of the dangerous mercury compound, corrosive sublimate.

Soon experimenters began using formaldehyde gas, generated by heating the liquid, for treating potatoes, but in 1905 this was superseded by a new method. By combining the liquid formalin with crystals of potassium permanganate, the formaldehyde gas is quickly set free without the use of external heat. This new method gave marked results in treatment for scab, apparently without injury to the tubers. If equally safe and effective this gas treatment offers

*This is a brief review of Bulletin No. 369 of this Station on The Injurious Effect of Formaldehyde Gas on Potato Tubers by F. C. Stewart and W. O. Gloyer, and of Bulletin No. 370 on The Efficiency of Formaldehyde in the Treatment of Seed Potatoes for Rhizoctonia by W. O. Gloyer. Anyone interested in the detailed account of the investigations will be furnished, on application, with copies of the complete bulletins, so long as these are available.

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decided practical advantages over the treatment with liquid, because of its greater convenience and its lessening of the task of handling the potatoes. It soon promised to supersede these older methods.

In the spring of 1912 the Station Botanist and his associate had occasion to disinfect nearly 90 bushels of potatoes stored in bushel crates in a large cellar under the Station tool-house. As no smaller room was convenient and as the labor of moving the crates would have been considerable, it was decided to use the entire cellar as a disinfection room. This involved much larger amounts of chemicals than needed, since the entire space must be filled with the gas although the tubers occupied only a small part of it.

In the fumigation the method used was that recommended by Prof. Morse of Maine, one of the adapters of the use of permanganate and formalin for potato treatment. To the great surprise of the investigators, they found that many of the tubers were seriously injured by the treatment, particularly those most exposed in the top crates. In many cases the eyes of the potatoes were surrounded by circular, sunken areas of brown, dead tissue, while on these tubers and on many others, the skin was marked, as shown on the title page illustration, with numerous sunken brown spots, of various shapes and ranging in size from mere specks to areas a half-inch across. Many of these spots were circular ones, each surrounding a lenticel, or minute pore-like opening through the skin of the tuber. The potatoes in the forty crates on top were sorted, and one-fourth of them rejected as too seriously injured to be used for seed.

This unfortunate result, so contrary to experience elsewhere, made advisable a very careful study of the conditions to ascertain the reason for the damage.

During the remainder of the spring of 1912 and in the winter and spring of 1913 more than 80 lots of potatoes were fumigated, varying the conditions in many directions in order to cover any change in the factors that might possibly have been concerned in the trouble.

Variations in the temperature of the air in the disinfection chamber were shown to have very slight effect on the amount of injury, even when the range was as great as 45°F. At temperatures below 50° the gas showed a slight tendency to change to paraformaldehyde, in which condition it becomes a whitish, powdery precipitate and is probably useless for disinfection. In some of the tests at low temperatures this "paraform" appeared as a very faint deposit of whitish dust on sheets of black paper in the disinfection chamber; but the reduction of the action of the gas was very slight; since the injury to tubers at 42° where this change was noticed was no less than at 87° where no such change would take place.
A low temperature of the chemicals used, however, may have quite an effect upon the efficiency of the fumigation, since chemical combination is much less active at low temperatures. In one test where the formalin and potassium permanganate crystals were cooled to 34° F. before uniting them, the reaction was a failure; but at 51° the final combination was as complete as at 71°, though the release of the gas was much slower.

**Humidity.**

A high moisture content of the air in a disinfection chamber is held to be helpful in securing perfect results; but the humidity will probably be high enough under conditions usual in fumigating potatoes; for this work will ordinarily be done in a cellar or other room without artificial heat to dry out the air. In none of the Station tests was the humidity, when at its maximum for the test, less than 73 per cent. In most of the tests it reached a maximum of 90 per cent. and in one the air was apparently more than saturated, the recording instrument showing 104 per cent. Under these conditions, with no test in air really low in humidity, it is impossible to say how much increase in moisture content increases the efficiency of the gas; but apparently slightly more injury resulted when the humidity was high.

Tubers wet when placed in the disinfection chamber showed considerably more injury than those in the same test that were thoroughly dry. This point is of some practical importance; for potatoes brought from a cool cellar into warm, moist air quickly become wet through condensation; and if other conditions were favorable might be injured by fumigation because of the moisture.

Sprouted potatoes. Under almost all conditions, tubers that had just begun to sprout, that is, with sprouts an eighth of an inch long or less, were much more seriously injured than those with dormant eyes, or even those with longer sprouts. Such sprouted tubers are undoubtedly really injured for seed; but it is believed that potatoes with dormant eyes, and that show no eye injury within three days after treatment, may still be used for seed even though somewhat spotted about the lenticles. This lenticel spotting is usually least severe at the eye end of the potato, as shown very plainly on the dumb-bell shaped tuber illustrated on the title page.

Some unimportant factors. In tests of a dozen or more varieties, slight differences in susceptibility were shown; but Sir Walter Raleigh, the kind so severely injured in the original fumigation, was found no more liable to the spotting than several other varieties. In this first fumigation the tubers on the tops of the crates were most injured; but in the other experiments no logical explanation for this fact could be discovered. It clearly shows a stronger action of the gas on these outer tubers, however, and would seem to indicate that, to secure
uniform efficiency of treatment, it would be well to expose the potatoes in shallow trays rather than in crates or boxes.

Potatoes placed directly over the fumigating vessel are liable to severe injury from the rising, undiluted gas; and they should never be so placed. This fact was known before the injurious fumigation was made; so that no crates were placed above the mixing pans, nor were any nearer than 2\(\frac{1}{2}\) feet. This injury to tubers directly over the generator was considered so well established that only one test involved such placing of the tubers. In this case two potatoes placed in a wire basket 6 or 7 inches above the chemicals were much more seriously injured than others on the bottom of the chamber. Other tubers near the top of the chamber but not directly over the generator were no more injured than those on the floor; and those placed very close to the generator, on the bottom of the chamber, were as free from injury as those farther away. Any injury to the skin of the potato, like a pin prick, was sure to result in an injured spot; but the tests did not support the view that injury can result only where the skin is broken. If this theory be true, there could have been no tubers with unbroken skins in some of the tests; for every potato showed injury.

The factors hitherto mentioned could not, all together, have caused the injury that followed the first fumigation, though some of them may have had a tendency to increase or to diminish it. As the subsequent tests plainly showed, it was the use of so large a cellar for the disinfection of a comparatively small quantity of potatoes that led to the trouble.

In each test in which 12 lbs. or more of potatoes to each cubic foot of space in the disinfection chamber were exposed to the action of gas at the strength commonly employed, no injury of any kind resulted; when from 5 to 10 lbs. of tubers to each cubic foot were fumigated, lenticel spotting appeared, but little or no eye injury; but when the quantity of potatoes per cubic foot was reduced to 5 lbs. or less the injury was marked about both lenticels and eyes.

In the original fumigation, the 87 bushels of potatoes were treated in a cellar containing 3,500 cubic feet, making only about 1\(\frac{1}{2}\) lbs. of potatoes to a cubic foot, an amount far below the minimum found necessary, in the tests, to insure safety.

At first thought this explanation appears a paradox; for it would seem that 12 lbs. of potatoes per cubic foot would occupy much more of the room than two pounds, would crowd the gas into a smaller volume, concentrate it and cause more rather than less injury. This would be true were it not for a peculiar ability which many, if not all solid bodies possess, to collect upon their surfaces large amounts of certain gases. For example, boxwood charcoal will “adsorb” ninety times its own volume of ammonia gas, fifty volumes of hydrogen sulphide
or nine volumes of oxygen. Potatoes have this power of adsorbing considerable quantities of formaldehyde gas upon their surfaces, until, when it reaches a certain degree of concentration, it enters into a chemical combination with the tissues around a lenticle, an eye or a wounded place and produces death of these tissues. If the number of potatoes be small the concentration readily continues until this danger point is reached and passed; but if the quantity be large and the amount of surface extensive the adsorption ceases, through lack of available gas to draw upon, before this point of dangerous concentration is reached. This power of the potatoes to adsorb formaldehyde gas and thus to reduce the amount of the free gas in the air of the disinfection chamber was quite evident by direct observation when attention was called to it. On opening the chamber after fumigating only a few tubers, the gas was so strong that it was impossible to thrust one's head within because of choking and smarting the eyes, but when the quantity of tubers was large and the same amount of gas was generated, so little of it remained free in the air of the chamber that one could breathe it without great discomfort. In the cellar fumigation, the gas was still so strong in the back part of the room 16 hours after the door had been opened that additional ventilation had to be provided before handling the potatoes.

By other experiments it was proven that it was adsorption, not absorption or chemical union of the gas with the potatoes, that withdrew it from the air; for when 5½ bushels of cobblestones were substituted for the same bulk of potatoes in the chamber they also adsorbed the gas so that its disappearance from the air was equally evident to the senses and the injury to check tubers was almost equally slight.

That injury similar to that in the Station cellar had not been noted in other experimental or commercial fumigating is probably due to the use of small disinfection rooms quite well filled with potatoes in order to economize in the purchase of materials. In the Station work economy seemed to lie in the purchase of more chemicals rather than in fitting up a smaller room and moving the potatoes to it. The experience, though immediately disastrous, may be valuable if it serves as a warning to others not to use large rooms for such disinfection unless the quantity of potatoes is also large.

Gas treatment not certain to destroy Rhizoctonia. This extensive series of fumigation tests gave an excellent opportunity to learn the effectiveness of the gas treatment under varied conditions; and tubers known to be carriers of disease were included in many of the tests. It would have been fortunate if the disease to be studied could have been scab, the one for which seed treatment is most commonly used. Unluckily, however, the fungus producing this disease does not grow readily
in the laboratory, and it was only by laboratory study that the efficiency of the treatments could be determined in such an investigation, where the number of tubers used in each test was small and where the tests were so numerous. To have depended on field trials in this case would have been out of the question.

Accordingly another fungus was selected, Rhizoctonia, which produces several different potato troubles and is believed to be a common cause of "skips" in the stand of plants. The means by which this fungus maintains itself over winter are somewhat different from those of most fungi. It does not penetrate the tuber with its mycelium and remain alive therein as does late blight, nor mar the potato with scars and deformities as does scab, nor does it form spores that cling to the potato as do those of some of the smut fungi to grain. But as the potato matures the Rhizoctonia forms on the surface of the tuber, on which it grows in the soil, small rounded collections of tightly-packed fungus tissue. These little bodies, sclerotia, are very resistant and serve almost as well as spores or seeds to maintain the life of the fungus. They appear on the potato as small, brownish bodies, much like tiny lumps of dirt, but they cannot be dislodged by washing as can dirt. They are frequently so numerous as to make the potato rough and unsightly, and may lessen its market value.

Like other fungus tissues, these sclerotia are destroyed by fungicides, but in them the microscopic cells are so tightly packed together that some of them in the interior may not be reached by the chemical and may remain alive even though the outer portion be destroyed. When placed under proper laboratory conditions they easily start into growth unless completely destroyed; so they make a very good means for studying the efficiency of any treatment. Accordingly tubers showing several of these sclerotia, which are very easily recognized, were used in many of these tests and, for purposes of comparison, others were soaked in formalin solutions and in corrosive sublimate (mercury bichloride) solutions, using different strengths of each.

In many cases when exposed to the formaldehyde gas at standard strength, for 24 hours, the Rhizoctonia sclerotia remained alive on the tubers so that the fungus developed well in the laboratory cultures. In many cases, also, other fungi appeared in these cultures, showing that the gas treatment was not thoroughly reliable. In a general way it may be said that the efficiency diminished as the quantity of tubers treated increased, but there were some notable exceptions to this. In a few cases in which the number of potatoes was so small that the tubers themselves were injured by the gas, quite a percentage of the sclerotia came through alive. Bacteria in large numbers also developed after this gas treatment. As moistened tubers showed more injury from the gas than dry ones, so
the Rhizoctonia sclerotia were much more completely destroyed on tubers that had been put into the fumigator when wet.

Soaking the tubers in formaldehyde solution was no more effective in destroying the Rhizoctonia sclerotia than was fumigation unless the time of immersion was long or strength of solution increased above that usually recommended. In eight tests with a 1-to-240 solution and a two-hour immersion almost one-fourth of the sclerotia grew in the cultures, but when the time was increased to 24 hours all were destroyed, as they were also when the strength of solution was made 1-to-20 and the time was 2 hours.

In corrosive sublimate solution, however, even as low strength as 1-to-2000, the sclerotia were destroyed by less than a 2-hour treatment.

The scab-fungus spores and mycelium are probably less resistant to fungicides than these Rhizoctonia sclerotia, but this series of tests casts considerable doubt upon the efficiency of the treatment with formaldehyde gas for scab; while it surely cannot be relied on to prevent the transmission of Rhizoctonia.

It seems best, therefore, to advise potato growers who wish to disinfect the tubers they use for seed, to use the gas treatment only in cases where it is impracticable to use either the liquid formaldehyde solution or corrosive sublimate. The safety and efficiency of both the liquid treatments for scab have been thoroughly established, while the evidence just given proves the gas treatment unreliable for controlling Rhizoctonia and casts considerable doubt on its effectiveness against scab. When it is desired to treat potatoes for both Rhizoctonia and scab the corrosive sublimate solution should be used; but in treating for scab alone the formaldehyde solution is effective, while the corrosive sublimate solution, though effective, is in many ways less desirable to use.

The method to be used in applying any one of these treatments is summarized in the following paragraphs, which should be carefully read before beginning the work.

*Formaldehyde gas.*—Use a thoroughly tight, unheated room. Place the seed tubers in shallow, slatted crates, not over eight inches deep, and so arranged that the gas may circulate freely on all sides of the potatoes. For each 1,000 cubic feet of space in the disinfection room use three pints of formaldehyde (40 per ct. solution) and 23 ounces of potassium permanganate (slender, needle-shaped crystals). Spread the potassium permanganate over the bottom of a large pan or pail having a capacity equal to about one quart for each ounce of permanganate. Pour on the formaldehyde, close the door at once and keep it closed for 24 hours. It is important that the disinfection room contain approximately 10 lbs.
of potatoes per cubic foot or 167 bushels per 1,000 cubic feet. With smaller quantities the tubers are liable to be injured by the treatment; while with larger quantities the treatment may not be effective. If necessary to treat smaller quantities than ten pounds per cubic foot it is suggested that a smaller room be fitted up for a fumigator if possible, or that the quantity of chemicals be reduced proportionately. No tubers should be placed directly above the generator. If possible, the treatment should be made before the tubers have begun to sprout as sprouted tubers are more liable to injury. The temperature of the chemicals at time of mixing should be above 50° Fahr.

Formaldehyde solution.—Mix one pint of 40-per-cent. formaldehyde solution with 30 gallons of water. Soak the uncut tubers in this solution for two hours. The same solution may be used repeatedly. Treated tubers not required for planting may be used for food or fed to animals with perfect safety.

Corrosive sublimate solution.—Prepare a solution containing 2 ounces of corrosive sublimate in 15 gallons of water. This is best done by first dissolving the corrosive sublimate in a small quantity of hot water and afterward diluting to the required amount. Soak the uncut tubers in this solution 1½ hours. Recent investigations by Gussow and Shutt in Canada indicate that the strength of corrosive sublimate solution decreases so rapidly with use that it is necessary to reject it after using three or four times. As the solution corrodes metals it should be used only in wooden or stone vessels. These should be kept away from animals until very thoroughly cleansed from the solution. It is very poisonous. All treated tubers should be either planted or buried.

With any of the scab treatments care should be taken that treated tubers are not reinfected by coming in contact with bags or crates which have held scabby potatoes.