



SOIL TREATMENTS FOR THE  
CONTROL OF POTATO SCAB

Thesis for the Degree of M. S.  
MICHIGAN STATE COLLEGE  
Glenn KenKnight  
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Thesis Presented for the Degree of  
Master of Science  
Michigan State College

by  
Glenn Ken Knight

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## TABLE OF CONTENTS

Review of the literature on the control of potato scab

    Resistant varieties

    Clean seed and crop rotation

    Green manuring and antibiosis

    Bacteriophage

    Fertilizers

    Sulphur soil treatments

    Soil disinfection with chemicals

        Mercuric chloride

        Other mercurials

        Other chemicals

    Soil conditions influencing scabbing

The problem

Greenhouse studies

    Procedure

    Experiment I

    Experiment II

    Experiment III

    Experiment IV

Field studies

Relation of soil reaction to the effect of mercurial

    soil treatments on scabbing of potatoes

Summary

## SOIL TREATMENTS FOR THE CONTROL OF POTATO SCAB

Altho the Actinomyces scab of potatoes is probably the oldest known disease of that crop, no very effective methods which have more than local application have been devised for its control. Numerous control measures have been recommended, any one of which may be effective under certain conditions. These include the use of resistant varieties, clean or disinfected seed, crop rotation, green manuring, physiologically acid fertilizers, sulphur soil treatments, and soil disinfection by chemical means. In addition bacteriophagy has been suggested as a possible means of inhibiting the development of potato scab.

### Review of the Literature on the Control of Potato Scab

#### Resistant varieties

The solution of the potato scab problem may eventually be solved through the development of resistant varieties. Russet Burbank and Russet Rural, which are at present our most resistant varieties, are sometimes heavily scabbed. Breeding for scab resistance has been under way in this country for several years (17, 25, 26). It is to be expected that progress will be slow due to the difficulties involved in breeding potatoes (such as bud abscission, pollen sterility and polyploidy), and because of the high standards of yield and quality set by the present commercial varieties, and the fact that potatoes are attacked by a large number of strains of Actinomyces which differ widely in their physiological characteristics as pointed out below.

#### Clean seed and crop rotation

The importance of clean seed and crop rotation has been recognized for over a century (69), but even clean seed on virgin soil has produced scabby crops (71, 104). In soils that are relatively free from plant pathogenic Actinomyces, seed-tuber disinfection will control potato scab;

but, where the scab organisms grow saprophytically in the soil, seed treatment is of little or no value (114, 115, 151). In fact, mercurial seed treatments in some localities increase the severity of the disease (28, 35, 134, 136).

There is generally less scab where potatoes are not raised oftener than every four or five years on a given field. The pathogenic actinomycetes may maintain their existence as saprophytes in the soil, or, if given an opportunity they may attack other crops. Beets (2, 10, 49, 97), turnips, rutabagas and radishes (44, 49, 101) have frequently been reported as being susceptible to potato scab. Carrots (58, 76), sweet potatoes (1, 73, 103, 132), and leeks (101) are also said to be parasitized by species of Actinomyces. The sequence of non-susceptible crops in the rotation may influence the amount of scabbing of potatoes (5, 42).

In selecting crops for rotation with potatoes, the effect of the rotation upon the yield and quality of all the crops in the rotation should be considered. Potatoes are relatively tolerant of soil reaction, the optimum reaction apparently varying according to the locality. Most investigators find that scab causes little damage where the soil reaction is pH 5.3 or lower. Along the Atlantic seaboard potatoes are most productive on soils with a reaction of pH 5.0 to 5.5 (31, 53, 85, 147). This gives a narrow margin of safety in which a good yield of scab-free potatoes can be produced. On Long Island Hardenburg (51) observed that scab was not an important factor until the soil pH reached 5.8 or higher, thus giving a wider margin of safety there. With reference to this region, Hardenburg (52) concluded that "so long as soil organic matter can be maintained through the use of green manure crops, it is not always necessary or even desirable to grow crops in an established rotation".

He suggested two independent rotations, one including potatoes along with acid-tolerant crops such as beans, cereals, cannery crops except beets, soybeans, and alsike clover, and the other including crops favored by soils with a higher reaction such as alfalfa, sweet clover, red clover, cabbage, and beets. The soil acidity could then be adjusted to suit each rotation.

Berlmer (5) in Germany found that potatoes were most productive on soils with a reaction of about pH 6.0 and that scab was less troublesome than on more alkaline soils. With a view to maintaining a reaction of about but not exceeding pH 6.0 on light, dry soils he suggested a rotation of rye, oats, potatoes, lupines, and serradella.

In regions where the soils are highly buffered it is not easy nor always desirable to acidify the soil for potatoes. The yield of potatoes is not always favored by lowering the soil reaction. Bushnell (15) in Ohio found little difference in the yield of potatoes due to soil reaction from pH 5.3 to 8.0. Furthermore, in Nebraska Goss (42) found more scab on soils of pH 5.9 than on more alkaline soils. Acidification of the soil is detrimental to alfalfa which crop may be desirable in a rotation with potatoes. Under dry weather conditions in Michigan, Bird (7) reported that higher yields are generally obtained where potatoes follow alfalfa than where potatoes follow any other crop. Under irrigation conditions in Nebraska Goss (43) found that short rotations and rotations where beets immediately precede potatoes were undesirable, and that longer rotations including alfalfa were desirable both from the standpoint of high yield and less scab. The same writer (42) from a field survey in western Nebraska found clear indication that cultivation of fields the year preceding potatoes tends to increase scab as contrasted with non-cultivated crops. In the same region Hastings (46) obtained similar

results from a study of 15 different cropping systems.

Green manuring and antibiosis

Altho there are relatively few experimental data on the subject, green manuring has been widely recommended as a control measure for potato scab. Millard (94, 95), in England, obtained a reduction in scabbing by adding organic matter to the soil in the form of green grass or spent hops at the rate of 10 to 20 tons per acre. Later Millard and Taylor (97) found that grass alone exerted no inhibitory action on scabbing, but that when Actinomyces praecox (a saprophytic species) and Actinomyces scabies were both inoculated into soil mixed with grass, less scab occurred. Meyers (92) in Holland, reduced the amount of scab by the addition of soybean or turnip meal to the soil. White (156) found that green manuring reduced the amount of scab in Kansas, and that green manure in combination with sulphur was more effective than alone. Sanford (112) reported that green manuring with rye at 50 tons per acre had no tendency to reduce the amount of scab on heavily infested soil of pH 5.0-5.4 in Minnesota. Řina (107) reported negative results with green manure for scab control in Czechoslovakia. Dippenaar (28) got no control of scab in Wisconsin with green pea vines as a manure, nor with sulphur in combination with peas as a green manure. As pointed out by Huisman (57) it is well known that the disease is prevalent on plowed up grass lands, altho the contrary might be expected from the large quantities of plant remains in the soil. However, he reported that it had been noted that infection had been reduced by a green manure of oats. It may well be that green manuring is effective in reducing the scabbing of potatoes only where the green manure serves as a medium for the growth of organisms that are antibiotic to plant pathogenic actinomycetes.

That actinomycetes may be antagonized by other organisms in culture media is a well established fact. Sanford (116) suggested that the influence of cultural methods on scabbing is brought about by antagonism to the scab organisms on the part of other organisms favored by the conditions.

Millard and Taylor (96) found Actinomyces praecox a saprophytic species, to be antibiotic to A. scabies in culture media and in field trials. Sanford (113) reported that certain bacteria inhibit the growth of A. scabies in culture principally through change in pH of the medium, though one bacterium inhibited the Actinomyces by some other means. Wieringa and Wiebols (153) noted that certain bacteria parasitized actinomycetes in culture. McCormick (91) made a study of the associative action of some species of Actinomyces in culture media. He concluded that the antagonistic action of certain bacteria and of actinomycetes to other actinomycetes is a result of a change in the oxidation-reduction character of the medium due to the metabolic products of growth. Weindling (148, 149) and Weindling and Emerson (150) found that Trichoderma lignorum produces a substance lethal to certain fungi which enables it to parasitize them. However, Daines (24) obtained no reduction in potato scab on the resulting crop by dipping the potato seed pieces in suspension of Trichoderma spores.

Sanford (116) suggested that antibiosis may play an important part in natural control of potato scab. However, in the case of natural control brought about by a wet soil condition, he theorized that the reduction in scabbing was due to the exclusion of air from the soil thus inhibiting the growth of Actinomyces scabies which is said to be strongly aerobic. However, Dippenaar (28) obtained no increase in infection by aerating the soil. Moreover, he observed that bacterial flora predominated over fungous

and actinomycetous flora in soils with a high moisture content. The reduction in scabbing under such circumstances could be explained by assuming that certain of the bacteria were antibiotic to the parasitic Actinomycetes. However, Lutman, Livingston, and Schmidt (72) made monthly bacteria and Actinomycetes counts over a period of eight years from a field where a badly scabbed crop of potatoes had been harvested at the beginning of the experiment. They found no indication of antagonism between soil bacteria, fungi, and Actinomycetes under field conditions, for the Actinomycetes counts roughly paralleled those of the total number of organisms. Furthermore, Waksman and Dubois (145) observed that actinomycetes are not exterminated by soil amoebae as are other soil bacteria.

The possibility of controlling potato scab by means of promoting the growth of soil organisms antibiotic to plant pathogenic Actinomycetes is perhaps worthy of further study.

#### Bacteriophagy

Recently Wieringa and Wiebols (158) have isolated a polyvalent bacteriophage for species of Actinomycetes, including A. scabies, and they suggest the possibility of using bacteriophagy in controlling potato scab. However, as yet no bacteriophage for any plant pathogene has been utilized in controlling a disease under field conditions.

#### Fertilizers

When physiologically acid fertilizers such as ammonium sulphate, super phosphate and potassium phosphate are used for potatoes, if there is any effect on scabbing it is usually a tendency to reduce the severity of the disease, many investigators having reported partial to complete control (3, 5, 6, 12, 22, 32, 47, 57, 81, 82, 107, 120, 129, 153). On the other hand chlorides (21, 32) and nitrates are reported to have the

opposite tendency (123).

Lime generally aggravates scabbing, so much so that many early observers supposed that its chemical effects on the potato were responsible for the trouble. However, excessive liming inhibits scabbing (9), and scab is said never to occur on weathered limestone (9, 123). Blodgett and Cowan (9) found evidence that calcium itself has no effect on scabbing except as it alters the soil reaction. This is borne out by Sibilia's observation (123) that scab was prevalent in one locality where the soil contained only one percent calcium carbonate, altho the soil had a pH value of 8.3. Sibilia in Italy (123) and Schlumberger in Germany (120) recorded experiments where a reduction in scabbing was effected by applications of lime, and Bolley (11) and Rang (106) obtained some control with calcium cyanamide. It is noteworthy that Schlumberger obtained reductions in scabbing both with lime and with acid fertilizers indicating that change in soil reaction was not the factor involved in control.

Stable manure is an excellent medium for Actinomyces and has generally been conceded to cause an increase in scabbing when applied on potato land (3, 41, 47, 48, 64, 66, 123, 130), yet Hühne and Chélard (56) in Germany recommended liberal use of green manure and stable manure for scab control. Goss (42) from a survey in Nebraska found no indication that the use of manure for crops in rotations with potatoes had resulted in more scab, but rather the reverse as less scab occurred than following alfalfa.

#### Sulphur soil treatments

The vast literature on the use of sulphur for the control of potato scab was well reviewed in 1927 by the Canadian workers, Duff and Welch (30), who carried on experiments with sulphur in six Canadian provinces, and concluded that sulphur at rates of 400, 600, 900, 1200 pounds per acre

was not uniformly effective, but "promising in clay soils infested by moderate numbers of attenuated strains of the organism, and under conditions of light rainfall." Sporadic studies for half a century in Michigan have indicated that sulphur soil treatment for the control of potato scab is not an economic practice here (131, 146, 152). On the other hand, the New Jersey workers in most cases have reported economic control of potato scab with sulphur, especially with inoculated sulphur (48-51, 67, 73-80, 83-86). A reduction in total yield often accompanies sulphur treatments, though the yield of salable tubers may be greater than on untreated plots. Caution must be exercised in applying large quantities of sulphur to the soil, for other crops in the rotation may be injured by the treatment (36, 40, 121, 122). Orton and Field (99) reported injury to the tubers of the potato crop from application of sulphur in the furrow, and Morse and Shapovalov (98) obtained an increase of 20 to 30 percent in the number of plants diseased with *Rhizoctonia* following sulphur soil applications.

Where sulphur is effective in controlling scab, the proper time, method, and quantity of application appears to vary according to the soil and climate. Taubenhaus (133) was unable to reduce scabbing by broadcasting sulphur on neutral and calcareous soils in Texas, though he obtained complete control by applying sulphur in the furrow at rates of 500-1500 pounds per acre two or three weeks before planting. Martin finds that sulphur in the furrow is injurious to potatoes in New Jersey, and he gets best results by broadcasting 300-600 pounds of sulphur per acre with a lime distributor and harrowing it in before planting. Merely rolling the seed tubers in sulphur gives control of scab under some circumstances (16, 43, 130), whereas up to 1200 pounds per acre may be ineffective (23, 45).

Since potato scab is seldom of much importance on upland soils more acid than pH 5.2 (28, 37-39, 135), it might be supposed that when the reaction of the soil can be lowered to this point by applications of sulphur a clean crop of potatoes could be produced. However, sulphur may inhibit scabbing without having any appreciable effect on the soil reaction (30, 45). On the other hand, sulphur may bring the soil reaction down well below pH 5.0 without affecting the amount of scabbing (30). From the evidence at hand, it seems probable that acidification of the soil does not kill the scab organisms, but inhibits their growth so that if such soil is heavily infested, the potato tubers, which have a pH of about 6.5 (112, 151) will come in contact with the spores which then germinate and cause infection. If this is the case, control might be obtained by keeping the soil acid for a considerable period of time before planting a susceptible crop so as to eliminate the scab-producing organisms by starvation. This hypothesis is rendered some support by the results obtained by Martin who, by means of applications of sulphur and ammonium sulphate, reduced the soil reaction of a field badly infested with scab to pH 5.1. After the soil had been limed to bring the reaction back to a pH favorable for scabbing, there was scarcely a trace of scab on the first crop of potatoes. However, the second crop was badly scabbed. Perhaps scab might have been eliminated completely until reinfestation took place if the soil had been kept strongly acid for a longer period of time.

Since sulphur soil treatments control scab in some cases where the soil is so highly buffered that no appreciable change in soil reaction takes place, factors other than soil acidity must be involved. Wilcoxon and McCallan (159) have shown evidence that sulphur is toxic to fungous spores because it exhibits an appreciable vapor pressure and is readily reduced to  $H_2S$  by living material.

Williams and Young (160) found that sulphur yields varying amounts of toxic factors depending upon the reaction, oxidation, temperature and moisture conditions. Sulphur treated with such oxidizing agents as potassium permanganate, manganese dioxide, and arsenious acid was found to be extremely toxic to certain fungous spores. It was found further that the toxic factor was destroyed by alkalis and strong acids. Furthermore, as shown by Lipman, McLean and Lint (68) sulphur oxidation affects the availability of mineral salts in the soil. Thus, in some instances, sulphur may inhibit scabbing through its effect on the nutrition of soil actinomycetes.

#### Soil disinfection with chemicals

Many toxic chemicals have been tried as soil disinfectants for potato scab. Of these several mercurials, copper sulphate, aluminum sulphate, and formaldehyde in some instances have been reported to inhibit scab. None have proved successful in Michigan.

#### Mercuric Chloride:

In 1895 Halsted began a series of trials of mercuric chloride as a soil treatment for potato scab in New Jersey. That year on a plot near Freehold he got good control of scab with applications of 30, 60, and 120 pounds of mercuric chloride per acre, but the yield in all cases was materially reduced (47). He also controlled scab with sulphur at rates of 150, 300, and 600 pounds per acre, in which case the reduction in yield was slight. However, since Halsted planted scabby seed-pieces and got almost complete control of scab by seed treatments with mercuric chloride, copper sulphate, kainit, or sulphur dust, it is apparent that he was not dealing with soil-borne scab.

The same year, which was a very favorable one for potato scab,

Halsted tried some seed and soil treatments on the potato plots at the Station Farm. The scab was certainly soil-borne, for his seed treatments failed completely. Here the trifling quantity of 36 gallons of .1% mercuric chloride solution per acre, and like quantities of Bordeaux and cuprain reduced the amount of scab from 97% in the checks to 80, 70, and 80% respectively, while sulphur at 300 pounds per acre reduced the per cent of scab to five.

At New Brunswick in 1896 Halsted (48) applied a 0.1% solution of mercuric chloride to the soil at the rate of 4320 gallons per acre and obtained a reduction of scab from 80% in the checks to 10% in the treated area. However in 1897 (49) mercuric chloride at 60, 30, and 15 pounds per acre reduced the amount of scab only slightly altho the same plots had received a similar amount of the mercurial two years earlier. He concluded that "corrosive sublimate acts only feebly and not to an extent to be observed by the untrained eye".

MacLeod and Howatt (74) in Canada reported that they obtained good control of common scab and *Rhizoctonia* scurf by mixing mercuric or mercurous chloride through the soil, the chemicals being applied at the rate of 10-15 pounds per acre, diluted 3 to 1 with diatomaceous or other earths to facilitate application. The fungicides caused a slight reduction in yield.

van der Slikke (124) in Holland poured 0.1% or 0.05% mercuric chloride solutions in the potato holes before planting and got good control of *Rhizoctonia* scurf and common scab at rates of 1/8 to 1/4 liter of 0.1% solution per hill, and with 1/4 liter of 0.05% solution.

Johnson (61), in trials over a four year period in England, almost eliminated common scab and *Rhizoctonia* scurf with applications to the soil of mercuric chloride either dry or in solution, at rates amounting

to 10-40 pounds per acre.

Taylor (135) in New York failed to control scab with mercuric chloride at 5 pounds per acre. In another field there was significantly more scab where mercuric chloride was added to the soil at 9 pounds per acre than in untreated soil.

#### Other Mercurials:

Apparently the various mercury compounds that have been used as soil disinfectants for potato scab give similar results under similar circumstances. Thus in New Brunswick, Canada, calomel and corrosive sublimate were equally effective in controlling scab at 10-15 pounds per acre (74); so also on Long Island calomel and yellow oxide of mercury each controlled scab at 4-6 pounds per acre. In Ohio neither Semesan Bel nor calomel at 4 pounds per acre appreciably affected the severity of the disease; while in western New York and at various points in Michigan soil treatments with mercurials increase the severity of potato scab (34, 35). In New Jersey where Halsted had gotten erratic results with mercuric chloride, Martin (37-39) has gotten varying results with several organic mercuries, calomel, and yellow oxide of mercury. In some soils he has consistently controlled scab with mercurials, while in other soils the treatments have failed.

Where mercury compounds fail to control scab they generally show their effect by causing an increase in scabbing, often two or three-fold. In view of the fact that mercurial seed treatments also consistently increase scabbing in some soils, it may be that the effect of the mercury is to make the host plant more susceptible to the disease. Otherwise it must be assumed that the mercury migrates through the soil from the furrow in which it is applied and affects the soil flora over all the area where tubers are set. In the latter case, either the weak mercury solution

stimulates the growth of Actinomyces, or has an adverse effect on other soil organisms which compete with or are antagonistic toward the pathogenic Actinomyces. Evidence presented by Frutchev and Muncie (35) indicates that mercurials do affect the soil flora, the effect depending upon the moisture content of the soil. However, the amount of mercury added to the soil on potato tubers that have been soaked one or two hours in a 0.1% solution of bichloride of mercury must be very small.

Another factor to be considered is the marked effect of other salts on the solubility of mercury compounds as shown by the work of Clark (18), Rosa (109), and many others. Consequently, the chemical composition of the soil solution may be an important factor influencing the effectiveness of mercurial soil treatments for potato scab.

The effect of the use of mercurials on yield has been as various as its effect on scabbing, Taylor (134) reporting an increase in yield in proportion to the effectiveness of the mercurials in increasing scabbing, Martin sometimes getting a reduction in yield, and Eddins (31) reporting marked injury.

#### Other Chemicals:

Aluminum sulphate, which has been used effectively in controlling Rhizoctonia damping-off of conifers (157), was found ineffective at 20 pounds per acre for potato scab in Michigan (34). Dippenaar in Wisconsin (28) failed to control scab with applications at rates up to 1030 pounds per acre. However, Taylor (134) reports that in western New York aluminum sulphate gives partial control of scab but also causes a reduction in yield.

Halsted (49) applied copper sulphate to the soil at rate of 300, 150, and 75 pounds per acre and reduced the percent of scabby tubers to 5, 5,

and 2% respectively as compared with 47% scab in the check. However, seed treatment alone gave even better control so that he obviously was not dealing with a soil infestation of the scab organisms. Halsted in New Jersey (49) and Mader and Blodgett in western New York (77) reported a reduction in scab following frequent heavy applications of Bordeaux mixture to the foliage. Halsted found that Bordeaux mixture applied to the soil at 4320 gallons per acre at planting reduced the amount of scab in some instances only. Lutman and Cunningham (70) failed to control scab in Vermont with applications of 600 pounds per acre of copper sulphate.

Halsted (99) reported that carbon bisulphide, benzene, and kerosene each at 120 pounds per acre had little effect on potato scab. Millard (93) got negative results with creosote and bleaching powder. Halsted (49), van der Slikke (124), and Johnson (61) failed to control scab with formaldehyde as a soil treatment, while Říha (108) found formalin partially effective at high concentrations.

Acids, when used in controlling potato scab, if effective are probably so through their effect on the soil reaction. Halsted (49) obtained negative results with oxalic acid at 120 pounds per acre, Říha got partial control with phosphoric acid. Reports on the use of sulphuric acid are almost as numerous and equally as erratic as those for sulphur.

#### Soil conditions influencing scabbing

Soil type, temperature, reaction, moisture content, and infestation are all important factors influencing the incidence of potato scab. Scab occurs on almost any type of soil - gravel, sand, loam, clay, muck - except on weathered limestone. It is more likely to be severe on sandy and on other well-aerated types of soil than on heavier types, even though Fousek (33) found a much lower ratio of Actinomyces to bacteria in sandy

soil than in loam.

From field observations made in Europe and America, Jones and McKinney (62) concluded that scab is more prevalent in regions having warm growing seasons than in regions where cool summers prevail, and likewise a greater amount of scab seems to develop in a given locality during a warm season than during a cool one. The same investigators (63) produced scab experimentally at constant temperatures ranging from 11° C. to 35.5° C. and considered 22° C. the optimum temperature for scab development. Dippenaar (28) obtained scab over a range of 13° C. to 25° C. with approximately 20° C. as the optimum. Sanford (110) under controlled moisture and temperature conditions obtained a maximum amount of scab at 14° C., 17° C., and 25° C. The scab organisms thrive better at a somewhat higher temperature. Dippenaar (28) using three strains of Actinomyces scabies found their optimum temperatures to be 28°, 28° to 32°, and 32° to 36° C. respectively. Cocchi (19) studying three strains of plant pathogenic Actinomyces (A. flavus, A. clavifer, and an unidentified species) found them to grow from 10° C. to 40° C. with the best development at around 25° - 30° C. However, Wingerberg (161) found that the optimum temperature for Actinomyces in culture was dependent upon the medium upon which they were grown as well as upon the reaction of the medium.

Scab is most prevalent on slightly acid to alkaline soils. Generally soils with a reaction lower than pH 5.0 or even 5.3 give little or no scab (8, 37-39, 134-136), but the disease has frequently been reported severe at much lower readings (12, 154), down to pH 3.3 (30). Boysen (12) on experimental plots recorded scab at pH 3.6 and severe scab at pH 3.7 with the most severe scab at pH 4.4-4.5. Reports as to the upper limit of soil reaction for scabbing are equally as variable as those for the lower limit. Smith (125), from field observations in western New York, concluded

that the optimum soil reaction for scabbing is pH 6.03-6.51 below and above which the disease is less severe. Wessels (154) in Long Island found that the severity of scabbing continued to increase with rise in pH up to 6.9 or 7.0. Goss (42) found the reverse to be true in Nebraska. He reported a very evident and consistent decrease in both the amount and severity of scab as the pH values increased from 5.92 to 8.25. Millard (94) concluded that soil reaction is not a direct factor in scab control for scab may occur at pH 4.4 and is found in only slight amounts in soils of high pH, while on more nearly neutral soils there is no relation between soil pH and scab. In the present study the writer found no correlation between soil reaction and scabbing over the range of pH 6.2-8.4 on his experimental plots. Blodgett and Cowan (9) in field surveys found little scab on soils more alkaline than pH 8.3. However, Sibilia (123) reported that scab was prevalent in one locality where the soil pH was 8.3. Sanford (111) has shown that the scab organisms thrive on media as alkaline as pH 8.0-8.7. Cocchi (19) found that the maximum reaction at which the strains of *Actinomyces* that he studied would grow to be about pH 9.0. Waksman (144) reported that the limiting acid reaction for Actinomyces scabies in culture solutions, properly buffered, and in sterile soil varies with the strain of the organism. In the majority of cases the limiting acid reaction was about pH 5.0-5.2; some strains grew even at pH 4.8, while others began to develop only at pH 5.3-5.6. The optimum pH of soil cultures was 5.8-7.7, and the limiting reaction pH 8.8. This is in accord with the report by Snow (126) who studied the flora of wind-blown soils from 6 regions. In Arizona arroyo banks with a soil pH of 8.6-9.0 she found 52% of the organisms to be *Actinomyces*. However, only 10% of the soil organisms were *Actinomyces* in soil from Death Valley,

and only 0.6% in soil from Shackleford Bank, N. C. The reactions of these two soils were pH 8.9-9.0 and pH 9.0-9.2 respectively. Soils from sand banks in three other regions gave 15 to 45% Actinomyces, with a soil reaction range of pH 5.9-8.0. From these results it appears that in the type of soil studied, actinomycetes do not thrive at a pH higher than 8.9 or 9.0. As pointed out by Millard (94), many neutral soils produce little or no scab.

From empirical observation potato scab has generally been regarded as a disease of relatively dry soils. Sanford (110), Martin (30), and Dippenaar (28) have all demonstrated experimentally that scabbing decreases with increased soil moisture. On the other hand, Schacht, 1854, (117) ascribed the disease to "heavy moisture of rich soil". Lutman and Cunningham (70) stated that "apparently excessive moisture does materially increase scabbing". Voelkel and Klemm (141) recorded very severe scabbing during an unusually wet year. MacMillan (75) found that formaldehyde seed treatment was non-effective against scab under irrigation where mismanagement in the use of water caused an excess of soil moisture for an extended period at any time during the early stages of tuber development, and that steadily growing plants, either treated or untreated, maintained free from excess of drought or moisture appeared to escape the disease a longer time than where improper application of water had occurred.

Soils thoroughly infested with plant pathogenic Actinomyces may remain so over a considerable period of years and produce a scabby crop any time potatoes are planted. Several investigators have expressed doubt as to the value of crop rotation for scab control (119, 139). However, crop rotation is sometimes fairly effective in controlling scab. In a case of this kind Lutman, Livingstone, and Schmidt (72) made monthly counts of the soil organisms during eight years beginning in 1924. 99.2%

of the 1916 crop was badly scabbed. The field was not planted to potatoes again until 1935. That year only 3.3% of the tubers were scabbed although many of the tubers counted as clean in the latter crop showed a russetting of the skin either in spots, over large areas, or over the entire tuber; yet during the 8 year period the number of actinomycetes in the soil had neither increased nor decreased. The authors suggest the possibility that the scab-producing actinomycetes are weakened in pathogenicity after a long period of deprivation of their host, the potato tuber, and live saprophytically in the soil, gradually acquiring pathogenicity once more when potatoes are planted again.

Actinomycetes constitute a considerable portion of any soil flora amounting to 20-30%, 30%, and 37.5% of the total organisms according to counts by Hiltner and Stromer (55), Krainsky (65), and Conn (20) respectively. Waksman and Curtis (143) found 3.5-46% actinomycetes in 25 soil samples from various parts of North America and Hawaii. Both Beijerinck (4) and Waksman and Curtis (143) found the ratio of actinomycetes to bacteria in the soil to increase with depth. Beijerinck reported actinomycetes common at a depth of one meter in garden soil, and present at a depth of two meters below the surface of sand, at three meters in alluvial mud, and abundant in river water. The ratio of actinomycetes to total organisms has been found by Fouseck to vary with soil type (33), and with soil acidity by Jensen (59). Snow (126) found 52% of the colonies derived from wind-blown desert sand in Arizona to be Actinomyces. Accordingly virgin soil could be readily infested with pathogenic actinomycetes by means of wind-blown spores. However the occurrence of potato scab on virgin soil could also be explained by Lutman's (72) acquired pathogenicity hypothesis.

A large number of strains of Actinomyces are capable of causing potato scab. American authors, although fully cognizant of the fact that

there are several types of potato scab from the standpoint of appearance, and that the organisms vary greatly in their morphology and physiology in culture, have generally considered these as being races of a single species. On the other hand, European authors have named about twenty species of Actinomyces that are pathogenic on potato tubers (95, 162). Recently Taylor (137) in this country has undertaken an extensive study of soil actinomycetes with a view to separating them into species on their physiologic characteristics.

The species of Actinomyces that have been described as parasitic on potatoes vary greatly in their ability to utilize various carbon and nitrogen sources (19, 29, 96, 138, 162), as to their oxygen, temperature, hydrogen-ion potential, and redox potential relations (91, 157), as to their response to association with other organisms (91), and as to the type of scab produced (19, 27, 53, 95, 162). As demonstrated by Wingerberg (161), the optimum temperature and optimum pH of a given strain is dependent upon the medium on which it is grown. Consequently different soils might be expected to harbor different strains of Actinomyces, with the result that the soils would respond in various ways to treatments for the control of potato scab.

Quoting from Jensen (60), "The ---- practice adopted by Millard and Burr, 1926, of establishing species differences on the basis of every observed constant difference, is certainly logical, but hardly practical, since nearly every strain of Actinomyces isolated from a plating from an ordinary soil could then be raised to the rank of species." It is clear that the number of strains of soil Actinomyces is a legion and that many of them are capable of causing scabbing of potatoes. Since fungicides are generally specific, controlling certain disease organisms and not others, it is hardly to be expected that a

single chemical applied as a soil treatment would control all the strains of plant pathogenic actinomyces in every soil.

### THE PROBLEM

McCallan and Wilcoxon (91), in studying the relation of fungicidal action to the periodic system of the elements, tested the toxicity of about 50 elements to the spores of Sclerotinia americana, Botrytis paeoniae, Pestalotia stellata, and Uromyces caryophyllinus. They listed the elements in the descending order of their toxicity to the four fungi: Ag, Os, Hg, Ce, Ru, La, Cd, U, Cu, Y, Er, Nd, Pb, Au, Th, Al, Th, Pd, Mn, Zn, Ni, Co, Cr, As, Pl, Ta, Va, and Ti. The sulphur group and the halogens are omitted from the list because the toxicity of these elements varies greatly according to the compounds used.

Of this list only mercury, copper, and aluminum compounds had been tested for potato scab control, and these had all given conflicting results. The purpose of this study was to test other chemicals for their value as soil disinfectants for potato scab.

## GREENHOUSE STUDIES

### Procedure:

Trials in the greenhouse were conducted in 6-inch and 8-inch pots, with three pots for each treatment. The soil was a light sandy loam with a moisture equivalent of about 30% and a pH value of about 7.5. The tap water used for irrigating the pots had a reaction of about pH 7.8. Infestation of the soil was insured by mixing a tablespoonful of macerated scabby potato peelings through the soil in each pot. Rates of treatment per acre were based on the surface area of the pots. The dry chemicals were diluted 9 to 1 with oven-dry sand to facilitate distribution and were mixed thoroughly through the top four inches of soil in the pots. The creosotes were diluted 9 to 1 with acetone so that 20 gallons per acre of creosote would also mean 180 gallons per acre of acetone. Untreated tubers of Katahdin potatoes were planted in all cases. With the exception of experiments III and IV, the potatoes were planted the same day that the soil was treated.

In recording the amount of infection that occurred during the various treatments, exact methods of measuring scabbing were considered unnecessary since control was the goal sought. The scab readings, which are recorded in tabular form, are arbitrary estimates.

### Experiment I

Chemicals tried: Potassium permanganate, copper sulphate, cerium oxalate, nickel cyanide, potassium dichromate, and sodium fluoride each at rates of 5, 15, and 50 pounds per acre, Formacide (a proprietary compound containing formaldehyde) at 50, 325, and 650 pounds per acre, and coal tar and wood creosote each at 1, 5, 20 gallons per acre. The potatoes were

planted in 8-inch pots January 20, 1936 and harvested March 30. The pots were randomized at the beginning of the experiment and again a month later to compensate in a measure for variations in light and soil temperature. The temperature of the greenhouse was maintained at about 25° C. by day and 20° C. by night.

As shown in Table I the control plants were heavily scabbed. Many of the treatments gave as much scab as the controls or perhaps more. No chemical reduced the amount of scabbing at all the rates of treatment employed, but copper sulphate and nickel cyanide each at 50 pounds per acre appeared to reduce somewhat the amount of scabbing.

#### Experiment II

This was largely a repetition of Experiment I using most of the chemicals at higher rates, substituting red copper oxide for copper sulphate, and adding aluminum chloride and calomel to the list. The potatoes were planted in 6-inch pots March 27, 1936 and harvested June 6.

As shown in Table II the only case of apparent control occurred where nickel cyanide was applied at 500 pounds per acre, although 150 pounds was ineffective. Calomel at 150 pounds per acre was markedly injurious to the potato plants. The tubers were very small, and one plant that bore no tubers had very scabby rhizomes.

#### Experiment III

One-half liter per 6-inch pot of 0.1% solutions of each of nine metallic salts - copper sulphate, potassium permanganate, nickel nitrate, lead acetate, potassium dichromate, sodium fluoride, zinc sulphate, cobalt chloride, and mercuric chloride, was applied as soil disinfectants for potato scab. The soil was treated a week before planting. On the basis of surface area of the pots, the quantity of the chemicals

employed amounts to about 250 pounds per acre. A half liter of water was added to each control pot. The potatoes were planted February 28, 1936 and harvested April 17. The complete absence of scab on the checks at the end of six weeks may have been due to the fact that the soil was kept rather wet. However that may be, in equally wet soil one or more of the plants under each of the treatments except mercuric chloride produced scabby tubers as shown in Table III.

#### Experiment IV

Aniline dyes have been shown to be highly toxic to many micro-organisms, but gentian violet at 1 and 10 pounds per acre and malachite green at 1, 10, 50, and 150 pounds per acre as soil disinfectants showed no tendency to control potato scab (Table IV). At the same time, New Improved Ceresan (5% ethyl mercury phosphate) was tried at 5, 15, 50, and 150 pounds per acre. 150 pounds of this material per acre was markedly injurious to the potato plants but did not eliminate scab. The chemicals were applied dry to the soil on March 1. The potatoes were planted in 6-inch pots March 3, 1937 and harvested May 15.

## FIELD STUDIES

Some of the same chemicals were tested in the field to determine whether or not they would give results similar to those obtained in the greenhouse. Yellow oxide of mercury and borax were added to the list. Corrosive sublimate was tested by the same method that van der Slikke used, (12<sup>4</sup>), pouring one liter of 1-1000  $\text{HgCl}_2$  in the planting holes before planting. All the other chemicals were tried at three rates each. They were mixed with dry soil and applied in a band about four inches wide in the bottom of the furrow. Calomel and yellow oxide of mercury were employed at 5, 10, and 20 pounds per acre and red copper oxide, lead sulphide, potassium dichromate, potassium permanganate, borax, zinc oxide, and sodium fluoride were used at 5, 15, and 50 pounds per acre. Each treatment consisted of a block of 20 hills, 4 rows wide and 5 hills long, and was replicated twice giving 60 hills. Six similar blocks were left untreated as controls. All the blocks were randomized.

The land available for this experiment had been treated with varying amounts of sulphur and lime two years earlier in a study of the effect of soil reaction on gladiolus scab. At the time the potatoes were harvested, the soil pH varied from 6.0 to 3.4. This was regarded rather as an advantage because it gave an opportunity to observe whether soil reaction would affect the results from the soil treatments. An attempt was made to determine the "average" pH of the soil of each block, and the results which may be regarded as approximations are recorded with the results of the trials in Table IV. The soil was a light sandy loam with a moisture equivalent of about 50%. The chemicals were applied and Katahdin potatoes planted on June 9. In an effort to insure infestation, a water suspension of macerated scabby potato peelings was sprinkled in the furrows, and all

the seed pieces were dipped in this suspension. However, this method of soil infestation was apparently of little value in the dry summer of 1936 since there was no more scab and no less variation in scabbing from hill to hill in the check plots of the experiment than there was in the border rows where the relatively clean seed tubers were soaked one hour in a cold 1-240 formaldehyde solution and where no inoculum was employed. The crop was harvested September 30.

Due to very dry weather following planting, a poor stand was obtained so that the number of hills per block at harvest varied from 8 to 20. The blocks were harvested separately and the tubers graded for scab as heavy (50-100% of the surface scabbed), medium (20-50%), light (2-20%), trace (less than 2%), and clean. The per cent of scabby tubers from each treatment does not give so vivid a picture of the effect of mercurials on scabbing as can be obtained by expressing the scabbing in per cent of the surface area of the tubers scabbed. These latter figures are estimates obtained by arbitrarily assigning 70%, 30%, 10%, and 1% as the average area of the tubers scabbed in the heavy, medium, light, and trace classes respectively. Variation in soil reaction was ignored in obtaining these figures, since any effect pH may have had was not obvious.

Potassium permanganate and the mercurials appear to have caused an increase in scabbing, whereas there was less scab with lead sulphide at 15 and 50 pounds per acre, potassium dichromate at 50 pounds and zinc oxide at 5 and 15 pounds. None of the treatments gave control of potato scab in any of the replications. Where reductions in scabbing occurred the differences are not statistically significant. None of the treatments affected the stand of potatoes. The numbers involved were too small to determine what effect, if any, the treatments may have had on the yield. However, Hester and Carolus (54) found that copper, manganese and zinc

sulphate applied to the soil at 50 pounds per acre separately or 25 pounds per acre of each of the three in combination had no effect on the yield of potatoes in Florida. Vandecaveye (140) found that lead as a soil treatment retarded the growth of barley and alfalfa seedlings. The erratic effect of mercurial soil treatment on potato yields is discussed earlier in this paper.

The relation of soil reaction to the effect of mercurial soil  
treatments on scabbing of potatoes

As stated in the preceding experiment, the ground on which the experiment was conducted varied widely in soil reaction. In order to determine the influence of this variation in soil pH on the effectiveness of mercurial soil treatment, calomel and corrosive sublimate were applied at rates of 5, 10, and 20 pounds per acre in 5 hill plots, with 12 replications, and 24 plots left untreated. The plots were randomized. The methods employed in applying the chemicals and infesting the soil were identical with those of the preceding experiment. The plots were planted to Katahdin potatoes June 9, 1936. The hills were harvested separately September 30. A soil sample was taken from around the tubers in each hill and its pH determined colorimetrically.

The methods employed in arriving at the pH of the soil of each hill are open to certain objections. Only one sample was taken from each hill, and these were collected in paper bags and permitted to dry out. The effect of air drying soil samples on the pH readings is thoroughly discussed by Snyder (127). Drying the soil samples generally has a tendency to slightly lower the pH readings especially in highly alkaline soil, but with some soils there may be a slight tendency in the opposite direction. Soil pH may vary during the growing season (127). In the present instance, a few of the random samples taken in June gave pH readings of 5.7 whereas the lowest reading obtained in October was pH 6.0. Only the readings from the samples taken at harvest time are recorded in the data presented here. It would perhaps have been less objectionable to have taken the samples during the period of tuber formation. In determining the pH of the samples colorimetrically two indicators were used in each instance, and where the

results were not comparable the determinations were repeated.

In Table VI the results of the mercurial soil treatments are given without regard to soil reaction. It will be noted that one-half of the tubers in the check hills and from 26-40% of the tubers under the various treatments completely escaped scab. Because of this great variability the differences obtained are not statistically significant. However, the data show that there were decidedly more medium to badly scabbed tubers where mercurials were used than in the checks. In Table VII the scab rating for hills at each pH reading is given separately for each treatment. These are summarized in Table VIII. The data are presented in Table IX in bar graphs and the hills classified in groups according to the soil reaction in one-half instead of one-tenth pH units. Using these larger groupings it will be noted that with every treatment over the entire pH range there was decidedly more scab than in the checks. There appears to have been little if any relation between scabbing and soil reaction in the checks, heavily scabbed hills occurring over the entire pH range. In hills treated with mercurials the amount of scab increased with rise in pH up to about pH 7.4, at which point with all the treatments where several hills were concerned there was a decided dropping off in scabbing with a rise again at about pH 8.0.

Greenhouse Trials  
of  
Chemical Soil Treatments

TABLE I

Results of Experiment I

| Treatment                         | Pounds per<br>acre | Scab   |   |   |
|-----------------------------------|--------------------|--------|---|---|
|                                   |                    | a      | b | c |
| Check                             |                    | 2<br>4 | 3 | 4 |
| $\text{CuSO}_4$                   | 5                  | 0      | 0 | 3 |
|                                   | 15                 | 0      | 3 | 4 |
|                                   | 50                 | 0      | 1 | 2 |
| $\text{K}^+\text{InO}_4$          | 5                  | 0      | 0 | 4 |
|                                   | 15                 | 1      | 2 | 2 |
|                                   | 50                 | 1      | 3 | 4 |
| $\text{CeC}_2\text{O}_4$          | 5                  | 0      | 0 | 3 |
|                                   | 15                 | *      | 1 | 3 |
|                                   | 50                 | 2      | 2 | 3 |
| $\text{Ni}(\text{CN})_2$          | 5                  | -      | 1 | 2 |
|                                   | 15                 | 2      | 2 | 3 |
|                                   | 50                 | 1      | 1 | 1 |
| $\text{K}_2\text{Cr}_2\text{O}_4$ | 5                  | 0      | 3 | 4 |
|                                   | 15                 | 0      | 3 | 4 |
|                                   | 50                 | 0      | 4 | 4 |
| NaF                               | 5                  | 0      | 1 | 2 |
|                                   | 15                 | 3      | 4 | 4 |
|                                   | 50                 | 2      | 3 | 3 |
| Formicide                         | 50                 | 1      | 2 | 2 |
|                                   | 325                | 4      | 4 | 4 |
|                                   | 650                | 2      | 4 | 4 |
| Coal tar<br>creosote              | 1 gal.             | 2      | 4 | 4 |
|                                   | 5 gal.             | 2      | 2 | 2 |
|                                   | 20 gal.            | 1      | 4 | 4 |
| Wood creosote                     | 1 gal.             | 1      | 2 | 3 |
|                                   | 5 gal.             | -      | 1 | 2 |
|                                   | 20 gal.            | 1      | 2 | 3 |

0 = clean  
 1 = trace of scab  
 2 = slightly scabbed  
 3 = moderately scabbed  
 4 = heavily scabbed  
 \* = no tubers  
 - = plant died

Greenhouse Trials  
of  
Chemical Soil Treatments

TABLE II

Results of Experiment II

| Treatment                         | Pounds per<br>acre | Scab   |        |   |
|-----------------------------------|--------------------|--------|--------|---|
|                                   |                    | a      | b      | c |
| Check                             |                    | 0<br>4 | 2<br>4 | 3 |
| $\text{Cu}_2\text{O}$             | 5                  | 1      | 1      | 4 |
|                                   | 15                 | -      | 1      | 4 |
|                                   | 50                 | 0      | 0      | 3 |
| $\text{KMnO}_4$                   | 5                  | 1      | 3      | 4 |
|                                   | 150                | -      | 3      | 4 |
|                                   | 500                | 1      | 2      | 2 |
| $\text{CeC}_2\text{O}_4$          | 5                  | 0      | 2      | 3 |
|                                   | 500                | 0      | 3      | 3 |
| $\text{Ni}(\text{CN})_2$          | 50                 | 1      | 1      | 1 |
|                                   | 150                | 1      | 3      | 3 |
|                                   | 500                | 0      | 0      | 0 |
| $\text{K}_2\text{Cr}_2\text{O}_4$ | 5                  | 2      | 4      | 4 |
|                                   | 15                 | 1      | 3      | 4 |
|                                   | 50                 | 1      | 3      | 3 |
|                                   | 150                | 1      | 3      | 4 |
| NaF                               | 150                | 1      | 3      | 3 |
|                                   | 500                | 1      | 2      | 3 |
| PbS                               | 5                  | 1      | 1      | 4 |
|                                   | 15                 | 1      | 4      | 4 |
|                                   | 50                 | 3      | 4      | 4 |
|                                   | 150                | 4      | 4      | 4 |
| $\text{AlCl}_3$                   | 150                | 1      | 1      | 3 |
|                                   | 500                | 0      | 0      | 2 |
| $\text{HgCl}$                     | 5                  | 1      | 1      | 3 |
|                                   | 50                 | 0      | 2      | 4 |
|                                   | 150                | 0      | **     | 2 |

- 0 = clean  
 1 = trace of scab  
 2 = slightly scabbed  
 3 = moderately scabbed  
 4 = heavily scabbed  
 \* = no tubers  
 \*\* = no tubers but rhizomes heavily scabbed  
 - = plant died

Greenhouse Trials  
of  
Chemical Soil Treatments

TABLE III

Results of Experiment III

| Treatment                                     | Scab |   |   |
|-----------------------------------------------|------|---|---|
|                                               | a    | b | c |
| Check                                         | 0    | 0 | 0 |
| $\text{CuSO}_4$                               | 0    | 2 | 2 |
| $\text{KMnO}_4$                               | 0    | 0 | 2 |
| $\text{Ni}(\text{NO}_3)_2$                    | 0    | 1 | 2 |
| $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$ | 2    | 2 | 2 |
| $\text{K}_2\text{Cr}_2\text{O}_7$             | 0    | 0 | 2 |
| $\text{NaF}$                                  | -    | 4 | 4 |
| $\text{ZnSO}_4$                               | 2    | 2 | 3 |
| $\text{CoCl}_2$                               | 0    | 2 | 2 |
| $\text{HgCl}_2$                               | 0    | 0 | 0 |

- 0 = clean
- 1 = trace of scab
- 2 = slightly scabbed
- 3 = moderately scabbed
- 4 = heavily scabbed
- = plant died

Greenhouse Trials  
of  
Chemical Soil Treatments

TABLE IV

Results of Experiment IV

| Treatment               | Pounds per<br>acre | Scab |     |     |
|-------------------------|--------------------|------|-----|-----|
|                         |                    | a    | b   | c   |
| Check                   |                    | 4    | 4   | 4   |
| New Improved<br>Ceresan | 5                  | 2    | 2   | 4   |
|                         | 15                 | 4    | 4   | 4   |
|                         | 50                 | 2    | 4   | 4   |
|                         | 150                | 0**  | 1** | 1** |
| Gentian Violet          | 1                  | 2    | 3   | 3   |
|                         | 10                 | 3    | 3   | 4   |
| Malachite Green         | 1                  | 3    | 3   | 4   |
|                         | 10                 | 3    | 4   | 4   |
|                         | 50                 | -    | 2   | 4   |
|                         | 150                | 3    | 4   | 4   |

0 = clean  
1 = trace of scab  
2 = slightly scabbed  
3 = moderately scabbed  
4 = heavily scabbed  
\*\* = Tubers very small  
- = plant died

TABLE V

Field Trials of Chemical Soil Treatments

| Treatment         | lbs per acre   | pH of soil | No. of tubers | No. of hills | No. of Scabby Tubers |        |       |       | Clean | % clean | Av. % of surface area scabbed |
|-------------------|----------------|------------|---------------|--------------|----------------------|--------|-------|-------|-------|---------|-------------------------------|
|                   |                |            |               |              | Heavy                | Medium | Light | Trace |       |         |                               |
| Check             | -              | 6.8        | 39            | 14           | 2                    | 2      | 2     | 1     | 32    |         |                               |
|                   |                | 7.7        | 73            | 14           | 3                    | 8      | 6     | 3     | 53    |         |                               |
|                   |                | 6.7        | 55            | 14           | 5                    | 5      | 3     | 11    | 31    |         |                               |
|                   |                | 7.5        | 57            | 11           | 0                    | 5      | 9     | 1     | 42    |         |                               |
|                   |                | 6.6        | 50            | 20           | 0                    | 8      | 10    | 7     | 25    |         |                               |
|                   |                | 7.3        | 57            | 16           | 6                    | 29     | 9     | 4     | 9     | 58      | 9.8                           |
| HgCl              | 5              | 7.6        | 67            | 15           | 11                   | 7      | 15    | 3     | 31    |         |                               |
|                   |                | 6.8        | 71            | 18           | 1                    | 13     | 20    | 4     | 33    |         |                               |
|                   |                | 7.0        | 62            | 14           | 12                   | 16     | 17    | 5     | 12    | 38      | 17.5                          |
|                   | 10             | 6.5        | 50            | 15           | 4                    | 2      | 5     | 2     | 37    |         |                               |
|                   |                | 6.5        | 53            | 16           | 3                    | 6      | 11    | 3     | 30    |         |                               |
|                   |                | 6.8        | 57            | 14           | 14                   | 9      | 12    | 7     | 15    | 51      | 14.2                          |
|                   | 20             | 7.8        | 87            | 14           | 3                    | 5      | 16    | 4     | 59    |         |                               |
|                   |                | 6.6        | 52            | 18           | 2                    | 2      | 1     | 0     | 47    |         |                               |
|                   |                | 6.9        | 54            | 13           | 10                   | 11     | 9     | 8     | 16    | 63      | 9.7                           |
|                   | 5              | 6.6        | 38            | 15           | 1                    | 3      | 4     | 5     | 25    |         |                               |
|                   |                | 6.5        | 32            | 15           | 0                    | 1      | 3     | 4     | 24    |         |                               |
|                   |                | 7.5        | 68            | 18           | 11                   | 31     | 16    | 2     | 8     | 41      | 15.5                          |
| HgO               | 10             | 7.6        | 62            | 14           | 0                    | 11     | 8     | 8     | 35    |         |                               |
|                   |                | 6.5        | 63            | 20           | 7                    | 4      | 7     | 10    | 35    |         |                               |
|                   |                | 6.6        | 65            | 15           | 12                   | 17     | 20    | 4     | 12    | 43      | 14.0                          |
|                   | 20             | 7.7        | 58            | 12           | 6                    | 9      | 13    | 6     | 23    |         |                               |
|                   |                | 6.9        | 88            | 17           | 51                   | 28     | 5     | 4     | 0     |         |                               |
|                   |                | 6.5        | 47            | 13           | 3                    | 5      | 19    | 9     | 11    | 28      | 30.5                          |
|                   | 1 gm. per hill | 6.9        | 58            | 13           | 24                   | 18     | 3     | 8     | 5     |         |                               |
|                   |                | 7.0        | 41            | 9            | 5                    | 4      | 10    | 2     | 20    |         |                               |
|                   |                | 6.5        | 67            | 15           | 0                    | 9      | 18    | 15    | 15    | 26      | 21.1                          |
|                   | 5              | 7.1        | 38            | 15           | 1                    | 1      | 3     | 1     | 32    |         |                               |
|                   |                | 6.5        | 26            | 12           | 0                    | 4      | 0     | 0     | 22    |         |                               |
|                   |                | 7.1        | 37            | 8            | 7                    | 12     | 8     | 5     | 5     | 58      | 11.7                          |
| Cu <sub>2</sub> O | 15             | 7.9        | 68            | 14           | 4                    | 9      | 9     | 7     | 39    |         |                               |
|                   |                | 7.0        | 43            | 17           | 1                    | 2      | 1     | 3     | 36    |         |                               |
|                   |                | 7.1        | 52            | 19           | 0                    | 11     | 15    | 7     | 19    | 58      | 7.8                           |
|                   | 50             | 6.8        | 56            | 19           | 1                    | 2      | 4     | 0     | 49    |         |                               |
|                   |                | 6.7        | 60            | 17           | 1                    | 2      | 6     | 3     | 48    |         |                               |
|                   |                | 7.3        | 44            | 12           | 6                    | 8      | 8     | 3     | 9     | 66      | 8.8                           |

| Treat-<br>ment                                | lbs.<br>per<br>acre | pH<br>of<br>soil | No. of<br>tubers | No.<br>of<br>hills | No. of Scabby Tubers |        |       |       | Clean | %<br>clean | Av. % of<br>surface area<br>scabbed |
|-----------------------------------------------|---------------------|------------------|------------------|--------------------|----------------------|--------|-------|-------|-------|------------|-------------------------------------|
|                                               |                     |                  |                  |                    | Heavy                | Medium | Light | Trace |       |            |                                     |
| PbS                                           | 5                   | 7.7              | 44               | 9                  | 0                    | 2      | 4     | 5     | 33    | 62         | 9.4                                 |
|                                               |                     | 6.7              | 74               | 16                 | 7                    | 8      | 5     | 3     | 51    |            |                                     |
|                                               |                     | 6.5              | 26               | 10                 | 1                    | 10     | 9     | 1     | 5     |            |                                     |
|                                               | 15                  | 7.9              | 61               | 14                 | 1                    | 1      | 3     | 3     | 53    | 62         | 5.9                                 |
|                                               |                     | 6.9              | 40               | 17                 | 3                    | 1      | 3     | 4     | 29    |            |                                     |
|                                               |                     | 7.2              | 56               | 18                 | 1                    | 10     | 14    | 15    | 16    |            |                                     |
|                                               | 50                  | 8.2              | 52               | 14                 | 3                    | 1      | 4     | 0     | 44    | 71         | 3.6                                 |
|                                               |                     | 6.8              | 57               | 13                 | 0                    | 4      | 6     | 14    | 33    |            |                                     |
|                                               |                     | 6.5              | 52               | 12                 | 0                    | 1      | 7     | 6     | 38    |            |                                     |
| K <sub>2</sub> C <sub>2</sub> O <sub>7</sub>  | 5                   | 6.9              | 63               | 20                 | 2                    | 3      | 11    | 8     | 39    | 44         | 12.0                                |
|                                               |                     | 6.7              | 57               | 18                 | 0                    | 1      | 4     | 6     | 46    |            |                                     |
|                                               |                     | 6.8              | 92               | 17                 | 11                   | 35     | 28    | 9     | 9     |            |                                     |
|                                               | 15                  | 6.9              | 56               | 20                 | 0                    | 2      | 4     | 9     | 41    | 53         | 12.2                                |
|                                               |                     | 6.8              | 64               | 16                 | 0                    | 5      | 14    | 2     | 43    |            |                                     |
|                                               |                     | 7.2              | 64               | 20                 | 15                   | 24     | 6     | 5     | 14    |            |                                     |
|                                               | 50                  | 6.8              | 52               | 16                 | 0                    | 3      | 6     | 0     | 43    | 69         | 4.0                                 |
|                                               |                     | 7.3              | 45               | 11                 | 1                    | 4      | 10    | 7     | 23    |            |                                     |
|                                               |                     | 7.2              | 45               | 16                 | 0                    | 2      | 6     | 5     | 32    |            |                                     |
| KMnO <sub>4</sub>                             | 5                   | 7.4              | 29               | 11                 | 3                    | 6      | 6     | 3     | 11    | 30         | 35.5                                |
|                                               |                     | 7.0              | 47               | 10                 | 0                    | 4      | 9     | 4     | 30    |            |                                     |
|                                               |                     | 6.6              | 59               | 10                 | 59                   | 0      | 0     | 0     | 0     |            |                                     |
|                                               | 15                  | 6.9              | 40               | 13                 | 1                    | 2      | 4     | 0     | 33    | 52         | 11.0                                |
|                                               |                     | 6.8              | 32               | 14                 | 0                    | 2      | 2     | 1     | 27    |            |                                     |
|                                               |                     | 7.3              | 51               | 14                 | 6                    | 16     | 19    | 6     | 4     |            |                                     |
|                                               | 50                  | 7.6              | 70               | 14                 | 0                    | 3      | 10    | 2     | 55    | 56         | 14.6                                |
|                                               |                     | 7.5              | 72               | 17                 | 1                    | 7      | 6     | 0     | 38    |            |                                     |
|                                               |                     | 6.9              | 58               | 19                 | 1                    | 18     | 22    | 10    | 7     |            |                                     |
| Na <sub>2</sub> B <sub>4</sub> O <sub>7</sub> | 5                   | 6.9              | 74               | 17                 | 0                    | 0      | 4     | 2     | 68    | 70         | 4.6                                 |
|                                               |                     | 7.2              | 48               | 16                 | 1                    | 4      | 9     | 7     | 27    |            |                                     |
|                                               |                     | 7.1              | 54               | 12                 | 1                    | 7      | 18    | 0     | 28    |            |                                     |
|                                               | 15                  | 7.0              | 70               | 16                 | 4                    | 8      | 5     | 4     | 49    | 60         | 7.2                                 |
|                                               |                     | 7.6              | 79               | 15                 | 0                    | 5      | 4     | 10    | 60    |            |                                     |
|                                               |                     | 6.7              | 48               | 13                 | 0                    | 16     | 16    | 7     | 9     |            |                                     |
|                                               | 50                  | 6.9              | 35               | 14                 | 6                    | 3      | 5     | 3     | 18    | 49         | 13.7                                |
|                                               |                     | 6.9              | 63               | 18                 | 3                    | 0      | 0     | 12    | 48    |            |                                     |
|                                               |                     | 7.2              | 51               | 13                 | 5                    | 22     | 11    | 6     | 7     |            |                                     |
| ZnO                                           | 5                   | 7.0              | 43               | 17                 | 0                    | 7      | 5     | 3     | 28    | 51         | 6.6                                 |
|                                               |                     | 6.9              | 43               | 10                 | 0                    | 5      | 7     | 5     | 26    |            |                                     |
|                                               |                     | 6.7              | 60               | 20                 | 1                    | 12     | 17    | 10    | 20    |            |                                     |
|                                               | 15                  | 8.0              | 62               | 16                 | 2                    | 4      | 8     | 9     | 39    | 62         | 4.4                                 |
|                                               |                     | 6.3              | 52               | 17                 | 1                    | 0      | 7     | 5     | 39    |            |                                     |
|                                               |                     | 6.7              | 68               | 19                 | 0                    | 5      | 15    | 13    | 35    |            |                                     |

| Treat-<br>ment | lbs.<br>per<br>acre | pH<br>of<br>soil | No. of<br>tubers | No.<br>of<br>hills | No. of Scabby Tubers |        |       |       | Clean | %  | Av. % of<br>surface area<br>scabbed |
|----------------|---------------------|------------------|------------------|--------------------|----------------------|--------|-------|-------|-------|----|-------------------------------------|
|                |                     |                  |                  |                    | Heavy                | Medium | Light | Trace |       |    |                                     |
|                | 50                  | 7.6              | 58               | 10                 | 4                    | 2      | 5     | 5     | 42    | 47 | 12.0                                |
|                |                     | 7.6              | 69               | 19                 | 3                    | 5      | 5     | 5     | 39    |    |                                     |
|                |                     | 7.1              | 77               | 18                 | 11                   | 19     | 23    | 9     | 15    |    |                                     |
| NaF            | 5                   | 6.6              | 36               | 14                 | 0                    | 2      | 5     | 4     | 25    | 50 | 14.6                                |
|                |                     | 6.4              | 57               | 16                 | 0                    | 0      | 4     | 1     | 52    |    |                                     |
|                |                     | 7.2              | 77               | 14                 | 18                   | 29     | 17    | 5     | 8     |    |                                     |
|                | 15                  | 7.9              | 60               | 14                 | 3                    | 9      | 4     | 5     | 39    | 72 | 5.9                                 |
|                |                     | 6.5              | 49               | 15                 | 0                    | 0      | 2     | 5     | 42    |    |                                     |
|                |                     | 7.3              | 32               | 10                 | 3                    | 0      | 7     | 2     | 20    |    |                                     |
|                | 50                  | 6.9              | 64               | 18                 | 4                    | 3      | 2     | 2     | 53    | 68 | 7.9                                 |
|                |                     | 6.7              | 43               | 15                 | 2                    | 2      | 2     | 3     | 34    |    |                                     |
|                |                     | 7.3              | 59               | 18                 | 5                    | 5      | 19    | 4     | 26    |    |                                     |

TABLE VI

The Influence of Mercurial Soil Treatments on Scabbing

| Treatment              | No. tubers | Scab ( % ) |        |       |       | Clean | % of surface area scabbed |
|------------------------|------------|------------|--------|-------|-------|-------|---------------------------|
|                        |            | Heavy      | Medium | Light | Trace |       |                           |
| Check                  | 791        | 5.4        | 12.9   | 24.6  | 6.6   | 50.4  | 10                        |
| HgCl, 5 lb.            | 338        | 15.4       | 17.8   | 23.7  | 5.9   | 37.3  | 19                        |
| HgCl, 10               | 363        | 29.2       | 26.7   | 23.7  | 44.1  | 36.3  | 31                        |
| HgCl, 20               | 352        | 26.4       | 27.9   | 21.6  | 3.1   | 35.2  | 29                        |
| HgCl <sub>2</sub> , 5  | 407        | 27.8       | 27.3   | 20.1  | 3.7   | 40.7  | 30                        |
| HgCl <sub>2</sub> , 10 | 261        | 18.8       | 24.5   | 24.2  | 6.1   | 26.1  | 23                        |
| HgCl <sub>2</sub> , 20 | 239        | 23.4       | 32.6   | 28.8  | 3.3   | 23.9  | 29                        |

- 38 -  
TABLE VII

Relation of Soil Reaction to the Effect of Mercurial Soil Treatments on Potato Scab

| Soil Reaction | Soil Treatment           | No hills | No tubers | No. of Scabby Tubers |        |       |       | % of Surface area scabby | % clean tubers |
|---------------|--------------------------|----------|-----------|----------------------|--------|-------|-------|--------------------------|----------------|
|               |                          |          |           | Heavy                | Medium | Light | Trace |                          |                |
| pH 6.0        | Check                    | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | HgCl, 5lbs               | 1        | 12        | 0                    | 8      | 33    | 0     | 6                        | 58             |
|               | " 10 "                   | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 20 "                   | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | HgCl <sub>2</sub> , 5lbs | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 10 "                   | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 20 "                   | 1        | 12        | 33                   | 17     | 25    | 0     | 21                       | 25             |
| pH 6.1        | Check                    | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | HgCl, 5                  | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 10                     | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 20                     | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | HgCl <sub>2</sub> , 5    | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 10                     | 1        | 3         | 0                    | 33     | 0     | 33    | 10                       | 33             |
|               | " 20                     | 0        | -         | -                    | -      | -     | -     | -                        | -              |
| pH 6.2        | Check                    | 3        | 35        | 0                    | 3      | 26    | 11    | 4                        | 60             |
|               | HgCl, 5                  | 1        | 6         | 17                   | 17     | 17    | 0     | 18                       | 50             |
|               | " 10                     | 1        | 9         | 11                   | 67     | 22    | 0     | 30                       | 0              |
|               | " 20                     | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | HgCl <sub>2</sub> , 5    | 2        | 20        | 20                   | 20     | 25    | 0     | 23                       | 35             |
|               | " 10                     | 2        | 13        | 8                    | 15     | 31    | 0     | 13                       | 46             |
|               | " 20                     | 4        | 23        | 26                   | 44     | 22    | 0     | 34                       | 9              |
| pH 6.3        | Check                    | 4        | 28        | 4                    | 21     | 39    | 4     | 13                       | 32             |
|               | HgCl, 5                  | 3        | 21        | 10                   | 19     | 24    | 0     | 15                       | 48             |
|               | " 10                     | 1        | 5         | 40                   | 20     | 40    | 0     | 38                       | 0              |
|               | " 20                     | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | HgCl <sub>2</sub> , 5    | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 10                     | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 20                     | 1        | 8         | 0                    | 25     | 63    | 0     | 34                       | 9              |
| pH 6.4        | Check                    | 3        | 34        | 0                    | 9      | 29    | 9     | 6                        | 53             |
|               | HgCl, 5                  | 4        | 38        | 21                   | 13     | 26    | 13    | 21                       | 26             |
|               | " 10                     | 3        | 18        | 11                   | 28     | 28    | 6     | 19                       | 28             |
|               | " 20                     | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | HgCl <sub>2</sub> , 5    | 1        | 8         | 0                    | 13     | 13    | 0     | 5                        | 75             |
|               | " 10                     | 4        | 33        | 24                   | 24     | 6     | 4     | 25                       | 8              |
|               | " 20                     | 3        | 16        | 6                    | 31     | 31    | 6     | 17                       | 25             |
| pH 6.5        | Check                    | 4        | 36        | 3                    | 6      | 8     | 3     | 4                        | 80             |
|               | HgCl, 5                  | 1        | 5         | 20                   | 20     | 0     | 0     | 20                       | 60             |
|               | " 10                     | 2        | 16        | 25                   | 25     | 25    | 6     | 28                       | 20             |
|               | " 20                     | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | HgCl <sub>2</sub> , 5    | 1        | 10        | 0                    | 30     | 30    | 0     | 31                       | 40             |
|               | " 10                     | 1        | 6         | 0                    | 0      | 0     | 0     | 0                        | 100            |
|               | " 20                     | 2        | 14        | 21                   | 50     | 21    | 0     | 32                       | 7              |

Relation of Soil Reaction to the Effect of Mercurial Soil Treatments on Potato Scab

| Soil Reaction | Soil Treatment        | No hills | No tubers | No. of Scabby Tubers |        |       |       | % of Surface area scabby | % clean tubers |
|---------------|-----------------------|----------|-----------|----------------------|--------|-------|-------|--------------------------|----------------|
|               |                       |          |           | Heavy                | Medium | Light | Trace |                          |                |
| pH 6.6        | Check                 | 6        | 52        | 8                    | 13     | 27    | 2     | 12                       | 50             |
|               | HgCl, 5               | 2        | 14        | 0                    | 0      | 21    | 0     | 2                        | 79             |
|               | " 10                  | 5        | 39        | 34                   | 36     | 26    | 3     | 37                       | 3              |
|               | " 20                  | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | HgCl <sub>2</sub> , 5 | 3        | 27        | 15                   | 33     | 26    | 7     | 23                       | 19             |
|               | " 10                  | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 20                  | 0        | -         | -                    | -      | -     | -     | -                        | -              |
| pH 6.7        | Check                 | 5        | 41        | 5                    | 10     | 17    | 0     | 8                        | 68             |
|               | HgCl, 5               | 1        | 7         | 14                   | 14     | 0     | 0     | 14                       | 71             |
|               | " 10                  | 5        | 53        | 23                   | 23     | 36    | 9     | 26                       | 9              |
|               | " 20                  | 5        | 51        | 26                   | 26     | 24    | 2     | 26                       | 24             |
|               | HgCl <sub>2</sub> , 5 | 3        | 28        | 4                    | 18     | 29    | 18    | 11                       | 32             |
|               | " 10                  | 3        | 32        | 25                   | 19     | 25    | 6     | 26                       | 25             |
|               | " 20                  | 1        | 8         | 25                   | 13     | 63    | 0     | 28                       | 0              |
| pH 6.8        | Check                 | 7        | 58        | 5                    | 10     | 5     | 5     | 7                        | 74             |
|               | HgCl, 5               | 4        | 36        | 8                    | 20     | 22    | 11    | 14                       | 39             |
|               | " 10                  | 7        | 67        | 37                   | 18     | 15    | 5     | 33                       | 25             |
|               | " 20                  | 4        | 39        | 27                   | 21     | 23    | 0     | 26                       | 31             |
|               | HgCl <sub>2</sub> , 5 | 5        | 33        | 36                   | 12     | 21    | 6     | 31                       | 21             |
|               | " 10                  | 4        | 22        | 23                   | 55     | 23    | 0     | 35                       | 0              |
|               | " 20                  | 2        | 19        | 27                   | 37     | 21    | 5     | 32                       | 11             |
| pH 6.9        | Check                 | 5        | 37        | 8                    | 22     | 19    | 14    | 14                       | 38             |
|               | HgCl, 5               | 2        | 14        | 14                   | 0      | 43    | 14    | 14                       | 29             |
|               | " 10                  | 4        | 26        | 62                   | 19     | 4     | 4     | 49                       | 8              |
|               | " 20                  | 3        | 22        | 9                    | 32     | 27    | 9     | 19                       | 23             |
|               | HgCl <sub>2</sub> , 5 | 3        | 51        | 31                   | 18     | 27    | 4     | 30                       | 20             |
|               | " 10                  | 4        | 18        | 6                    | 28     | 39    | 6     | 16                       | 22             |
|               | " 20                  | 4        | 31        | 6                    | 39     | 26    | 3     | 19                       | 26             |
| pH 7.0        | Check                 | 18       | 150       | 7                    | 13     | 29    | 9     | 12                       | 42             |
|               | HgCl, 5               | 4        | 32        | 28                   | 19     | 25    | 6     | 27                       | 22             |
|               | " 10                  | 5        | 46        | 24                   | 26     | 39    | 0     | 29                       | 11             |
|               | " 20                  | 8        | 66        | 35                   | 33     | 17    | 5     | 36                       | 11             |
|               | HgCl <sub>2</sub> , 5 | 8        | 45        | 22                   | 33     | 27    | 0     | 28                       | 18             |
|               | " 10                  | 4        | 16        | 6                    | 13     | 13    | 6     | 9                        | 63             |
|               | " 20                  | 6        | 27        | 48                   | 26     | 11    | 0     | 43                       | 7              |
| pH 7.1        | Check                 | 11       | 89        | 3                    | 12     | 25    | 7     | 9                        | 53             |
|               | HgCl, 5               | 2        | 23        | 9                    | 22     | 30    | 9     | 16                       | 30             |
|               | " 10                  | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 20                  | 5        | 51        | 24                   | 20     | 14    | 0     | 24                       | 43             |
|               | HgCl <sub>2</sub> , 5 | 1        | 7         | 14                   | 28     | 57    | 0     | 24                       | 0              |
|               | " 10                  | 1        | 5         | 0                    | 40     | 20    | 20    | 15                       | 20             |
|               | " 20                  | 0        | -         | -                    | -      | -     | -     | -                        | -              |

Relation of Soil Reaction to the Effect of Mercurial Soil Treatments on Potato Scab

| Soil Reaction | Soil Treatment        | No hills | No tubers | No. of Scabby Tubers |        |       |       | % of Surface area scabby | % clean tubers |
|---------------|-----------------------|----------|-----------|----------------------|--------|-------|-------|--------------------------|----------------|
|               |                       |          |           | Heavy                | Medium | Light | Trace |                          |                |
| pH 7.2        | Check                 | 8        | 67        | 2                    | 5      | 21    | 8     | 5                        | 66             |
|               | HgCl, 5               | 5        | 35        | 6                    | 20     | 34    | 3     | 13                       | 37             |
|               | " 10                  | 3        | 34        | 27                   | 24     | 18    | 6     | 28                       | 27             |
|               | " 20                  | 8        | 72        | 29                   | 40     | 25    | 1     | 34                       | 8              |
|               | HgCl <sub>2</sub> , 5 | 1        | 11        | 55                   | 18     | 18    | 0     | 46                       | 9              |
|               | " 10                  | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 20                  | 2        | 8         | 25                   | 75     | 0     | 0     | 40                       | 0              |
| pH 7.3        | Check                 | 8        | 63        | 11                   | 17     | 33    | 10    | 17                       | 28             |
|               | HgCl, 5               | 3        | 33        | 33                   | 3      | 18    | 6     | 34                       | 39             |
|               | " 10                  | 3        | 31        | 10                   | 36     | 19    | 7     | 20                       | 29             |
|               | " 20                  | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | HgCl <sub>2</sub> , 5 | 8        | 69        | 23                   | 55     | 20    | 7     | 35                       | 23             |
|               | " 10                  | 1        | 12        | 0                    | 8      | 58    | 0     | 8                        | 33             |
|               | " 20                  | 1        | 3         | 0                    | 33     | 66    | 0     | 50                       | 0              |
| pH 7.4        | Check                 | 1        | 3         | 0                    | 0      | 0     | 0     | 0                        | 100            |
|               | HgCl, 5               | 1        | 5         | 40                   | 60     | 0     | 0     | 0                        | 46             |
|               | " 10                  | 1        | 4         | 75                   | 0      | 25    | 0     | 55                       | 0              |
|               | " 20                  | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | HgCl <sub>2</sub> , 5 | 4        | 31        | 38                   | 26     | 6     | 3     | 35                       | 26             |
|               | " 10                  | 0        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 20                  | 1        | 7         | 0                    | 28     | 28    | 28    | 11                       | 14             |
| pH 7.5        | Check                 | 3        | 25        | 0                    | 16     | 24    | 4     | 7                        | 56             |
|               | HgCl, 5               | 2        | 17        | 19                   | 19     | 23    | 0     | 22                       | 4              |
|               | " 10                  | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 20                  | 2        | 18        | 33                   | 33     | 33    | 0     | 37                       | 0              |
|               | HgCl <sub>2</sub> , 5 | 1        | 8         | 0                    | 25     | 25    | 0     | 11                       | 50             |
|               | " 10                  | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 20                  | -        | -         | -                    | -      | -     | -     | -                        | -              |
| pH 7.6        | Check                 | 3        | 36        | 14                   | 11     | 28    | 6     | 16                       | 42             |
|               | HgCl, 5               | 1        | 6         | 0                    | 33     | 0     | 17    | 10                       | 50             |
|               | " 10                  | 1        | 2         | 50                   | 50     | 0     | 0     | 50                       | 0              |
|               | " 20                  | 4        | 16        | 13                   | 31     | 19    | 13    | 20                       | 25             |
|               | HgCl <sub>2</sub> , 5 | 1        | 6         | 0                    | 17     | 17    | 0     | 7                        | 67             |
|               | " 10                  | 4        | 32        | 19                   | 34     | 25    | 13    | 26                       | 9              |
|               | " 20                  | -        | -         | -                    | -      | -     | -     | -                        | -              |
| pH 7.7        | Check                 | 1        | 8         | 0                    | 0      | 25    | 0     | 75                       | 3              |
|               | HgCl, 5               | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 10                  | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 20                  | 1        | 9         | 11                   | 0      | 22    | 22    | 10                       | 44             |
|               | HgCl <sub>2</sub> , 5 | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 10                  | 1        | 12        | 0                    | 0      | 8     | 0     | 1                        | 92             |
|               | " 20                  | -        | -         | -                    | -      | -     | -     | -                        | -              |

Relation of Soil Reaction to the Effect of Mercurial Soil Treatments on Potato Scab

| Soil Reaction | Soil Treatment        | No hills | No tubers | No. of Scabby Tubers |        |       |       | % of Surface area scabby | % clean tubers |
|---------------|-----------------------|----------|-----------|----------------------|--------|-------|-------|--------------------------|----------------|
|               |                       |          |           | Heavy                | Medium | Light | Trace |                          |                |
| pH 7.8        | Check                 | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | HgCl, 5               | 2        | 20        | 0                    | 10     | 5     | 0     | 3                        | 85             |
|               | " 10                  | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 20                  | 1        | 5         | 0                    | 0      | 40    | 0     | 4                        | 60             |
|               | HgCl <sub>2</sub> , 5 | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 10                  | 2        | 11        | 0                    | 27     | 27    | 27    | 11                       | 18             |
| pH 7.9        | Check                 | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | HgCl, 5               | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 10                  | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 20                  | 1        | 3         | 100                  | 0      | 0     | 0     | 70                       | 0              |
|               | HgCl <sub>2</sub> , 5 | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 10                  | -        | -         | -                    | -      | -     | -     | -                        | -              |
| pH 8.0        | Check                 | 1        | 10        | 20                   | 50     | 30    | 0     | 32                       | 0              |
|               | HgCl, 5               | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 10                  | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 20                  | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | HgCl <sub>2</sub> , 5 | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 10                  | 1        | 1         | 0                    | 0      | 1     | 0     | 10                       | 0              |
| pH 8.1        | Check                 | 1        | 9         | 0                    | 0      | 33    | 22    | 3                        | 44             |
|               | HgCl, 5               | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 10                  | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 20                  | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | HgCl <sub>2</sub> , 5 | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 10                  | -        | -         | -                    | -      | -     | -     | -                        | -              |
| pH 8.2        | Check                 | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | HgCl, 5               | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 10                  | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 20                  | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | HgCl <sub>2</sub> , 5 | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 10                  | 1        | 5         | 0                    | 40     | 20    | 0     | 14                       | 40             |
| pH 8.3        | Check                 | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | HgCl, 5               | 3        | 16        | 13                   | 56     | 25    | 0     | 38                       | 6              |
|               | " 10                  | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 20                  | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | HgCl <sub>2</sub> , 5 | -        | -         | -                    | -      | -     | -     | -                        | -              |
|               | " 10                  | -        | -         | -                    | -      | -     | -     | -                        | -              |



TABLE VIII

The Influence of Soil Reaction on the Effectiveness of Mercurials  
as Soil Disinfection for Potato Scab Control

|        | control |      | HgCl<br>5 lbs. |    | HgCl<br>10 lbs. |    | HgCl<br>20 lbs. |    | HgCl <sub>2</sub><br>5 lbs. |    | HgCl <sub>2</sub><br>10 lbs. |    | HgCl <sub>2</sub><br>20 lbs. |    | Hg<br>av. # |    |
|--------|---------|------|----------------|----|-----------------|----|-----------------|----|-----------------------------|----|------------------------------|----|------------------------------|----|-------------|----|
|        | H*      | Sc** | H              | Sc | H               | Sc | H               | Sc | H                           | Sc | H                            | Sc | H                            | Sc | H           | Sc |
| pH 6.0 | 0       |      | 1              | 6  | 0               |    | 0               |    | 0                           |    | 0                            |    | 1                            | 21 | 2           | 20 |
| 6.1    | 0       |      | 0              |    | 0               |    | 0               |    | 0                           |    | 1                            | 10 | 0                            |    | 0           | 10 |
| 6.2    | 3       | 4    | 1              | 18 | 1               | 30 | 0               |    | 2                           | 23 | 2                            | 13 | 4                            | 34 | 10          | 26 |
| 6.3    | 4       | 13   | 3              | 15 | 1               | 38 | 0               |    | 0                           |    | 0                            |    | 1                            | 14 | 5           | 19 |
| 6.4    | 3       | 6    | 4              | 21 | 3               | 19 | 0               |    | 1                           | 5  | 4                            | 25 | 3                            | 17 | 15          | 20 |
| 6.5    | 4       | 4    | 1              | 20 | 2               | 28 | 0               |    | 1                           | 31 | 1                            | 0  | 2                            | 32 | 7           | 24 |
| 6.6    | 6       | 12   | 2              | 2  | 5               | 37 | 0               |    | 3                           | 23 | 0                            |    | 0                            |    | 10          | 26 |
| 6.7    | 5       | 8    | 1              | 14 | 5               | 26 | 5               | 26 | 3                           | 11 | 3                            | 26 | 1                            | 28 | 18          | 23 |
| 6.8    | 7       | 7    | 4              | 14 | 7               | 33 | 4               | 26 | 5                           | 31 | 4                            | 35 | 2                            | 32 | 26          | 29 |
| 6.9    | 5       | 14   | 2              | 14 | 4               | 49 | 3               | 19 | 3                           | 30 | 4                            | 16 | 4                            | 19 | 20          | 26 |
| 7.0    | 18      | 12   | 4              | 27 | 5               | 29 | 8               | 36 | 8                           | 28 | 4                            | 9  | 6                            | 43 | 35          | 30 |
| 7.1    | 11      | 9    | 2              | 16 | 0               |    | 5               | 24 | 1                           | 24 | 1                            | 15 | 0                            |    | 9           | 21 |
| 7.2    | 8       | 5    | 5              | 13 | 3               | 28 | 8               | 34 | 1                           | 46 | 0                            |    | 2                            | 40 | 19          | 29 |
| 7.3    | 8       | 17   | 3              | 34 | 3               | 20 | 0               |    | 8                           | 35 | 1                            | 8  | 1                            | 50 | 16          | 31 |
| 7.4    | 1       | 0    | 1              | 46 | 1               | 55 | 0               |    | 4                           | 35 | 0                            |    | 1                            | 11 | 7           | 36 |
| 7.5    | 3       | 7    | 2              | 22 | 0               |    | 2               | 37 | 1                           | 11 | 0                            |    | 3                            | 27 | 8           | 26 |
| 7.6    | 3       | 16   | 1              | 10 | 1               | 50 | 4               | 20 | 1                           | 7  | 4                            | 26 | 2                            | 51 | 13          | 27 |
| 7.7    | 1       | 13   | 0              |    | 0               |    | 1               | 10 | 0                           |    | 1                            | 0  | 0                            |    | 2           | 5  |
| 7.8    | 0       |      | 2              | 3  | 0               |    | 1               | 4  | 0                           |    | 2                            | 11 | 0                            |    | 5           | 7  |
| 7.9    | 0       |      | 0              |    | 0               |    | 1               | 0  | 0                           |    | 0                            |    | 0                            |    | 1           | 0  |
| 8.0    | 1       | 32   | 0              |    | 0               |    | 0               |    | 0                           |    | 1                            | 0  | 0                            |    | 1           | 0  |
| 8.1    | 1       | 3    | 0              |    | 0               |    | 0               |    | 0                           |    | 0                            |    | 1                            | 0  | 1           | 0  |
| 8.2    | 0       |      | 0              |    | 0               |    | 0               |    | 0                           |    | 1                            | 14 | 0                            |    | 1           | 14 |
| 8.3    | 0       |      | 3              | 38 | 0               |    | 0               |    | 0                           |    | 0                            |    | 0                            |    | 3           | 38 |
| 8.4    | 1       | 0    | 0              |    | 0               |    | 0               |    | 0                           |    | 1                            | 34 | 0                            |    | 1           | 34 |

\* Number of hills

\*\* % of surface area of tubers scabbed

# Weighted average (based on the number of tubers involved) of all mercury treatments.

% of surface area scabbed

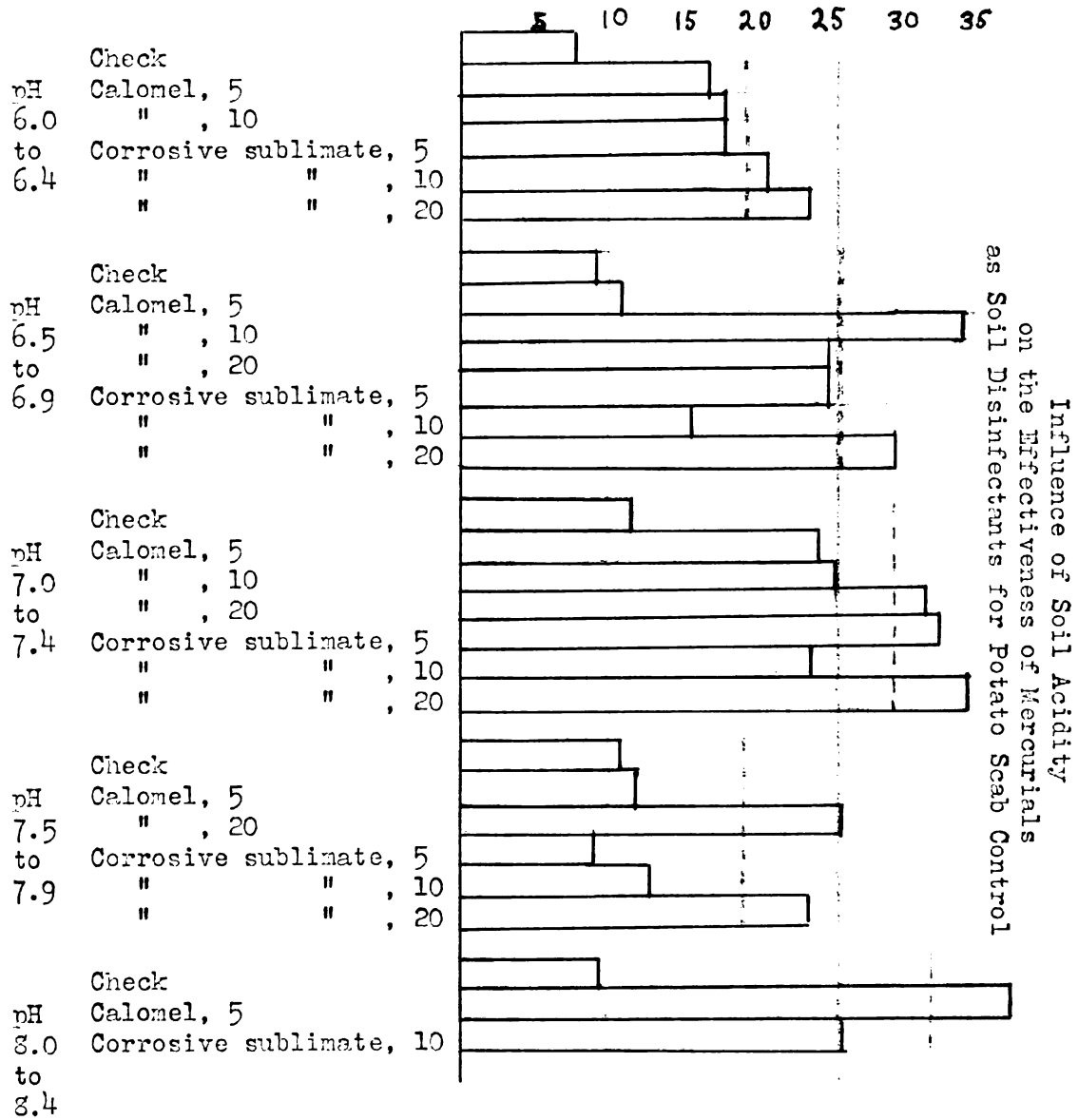


TABLE IX

Influence of Soil Acidity  
on the Effectiveness of Mercurials  
as Soil Disinfectants for Potato Scab Control

— Ave. of check  
- - - Ave. of all Hg treatment  
in each pH range  
— Grand Ave. of all Hg  
treatments

# SUMMARY

1. Twenty-four chemicals were tested as soil disinfectants for the control of potato scab:

| <u>Chemical</u>        | <u>Greenhouse</u>        | <u>Field</u> |
|------------------------|--------------------------|--------------|
| Aluminum chloride      | 150, 500*                |              |
| Borax                  |                          | 5, 15, 50    |
| Cerium oxalate         | 5, 15, 50, 500           | 5, 15, 50    |
| Cobalt chloride        | 250                      |              |
| Copper sulphate        | 5, 15, 50, 250           |              |
| Copperous oxide        | 5, 15, 50                | 5, 15, 50    |
| Lead acetate           | 250                      |              |
| Lead sulphide          | 5, 15, 50, 150           | 5, 15, 50    |
| Mercuric chloride      | 250                      | 20           |
| Mercuric oxide         | 5, 10, 20                | 5, 10, 20    |
| Mercurous chloride     | 5, 10, 20, 50, 150       | 5, 10, 20    |
| New Improved Ceresan   | 5, 15, 50, 150           |              |
| Nickel cyanide         | 5, 15, 50, 150, 500      | 5, 15, 50    |
| Nickel nitrate         | 250                      |              |
| Potassium permanganate | 5, 15, 50, 150, 250, 500 | 5, 15, 50    |
| Potassium dichromate   | 5, 15, 50, 150, 250      | 5, 15, 50    |
| Sodium fluoride        | 5, 15, 50, 150, 250, 500 | 5, 15, 50    |
| Zinc oxide             |                          | 5, 15, 50    |
| Zinc sulphate          | 250                      |              |
| Formicide              | 50, 325, 650             |              |
| Gentian violet         | 1, 10                    |              |
| Malachite green        | 1, 10, 50, 150           |              |
| Coal tar creosote      | 1, 5, 20 (gallons)       |              |
| Wood creosote          | 1, 5, 20 (gallons)       |              |

\* The figures opposite the names of the chemicals indicate the rates in pounds per acre at which the chemicals were employed.

2. None of the chemicals tested controlled potato scab at any of the rates employed, except nickel cyanide at 500 pounds per acre in the greenhouse, - a rate too high to be considered for practical control.
3. Mercurial soil treatment increased the scabbiness of the crop two to three-fold.
4. Plots in a field which varied widely in soil reaction were treated with calomel and corrosive sublimate at rates of 5, 10, and 20 pounds per acre. The hills were harvested separately and a soil sample was taken from around the tubers in each hill for pH determination. The results indicate that within the pH range of 6.0-8.4 soil reaction did not appreciably affect the tendency of mercurials to cause an increased amount of scabbing.
5. The literature on control measures for potato scab is reviewed and discussed.

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