MICROFLORAL AND SOIL TREATMENT
STUDIES RELATIVE TO
THE CONTROL OF
COMMON SCAB OF POTATO
TO ACTINOMYCES SCABIES

MICROFLORAL AND SOIL TREATMENT STUDIES RELATIVE TO THE CONTROL OF COMMON SCAB OF POTATO DUE TO ACTINOMYCES SCABIES

by

Henry James Miles

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INTRODUCTION

According to the work of several investigators, the common scab of potatoes is apparently caused by a number of species of soil-borne Actinomyces of which Actinomyces scabies (Thax.) Gussow is typical, and the most common in its occurrence. Owing to the complexity of factors influencing microorganisms in the soil, the problem of finding a control for the disease is a difficult one. Many investigators have been able to reduce the occurrence of scab by means of various measures such as seed treatments, green manuring, crop rotation, and by applying various chemicals to the soil. Other workers differ in opinion as to the value of such methods, some even reporting increases in scab as a result of their use. Such controversial results seem to indicate the importance of other factors such as the chemical and physical make-up of the soil, climatic conditions, and soil microfloral relationships as phases of the problem.

PURPOSE OF STUDIES

The purpose of these studies is two-fold; first, to determine by cultural and soil tests whether or not the occurrence of scab is affected by antagonism between Actinomyces spp., causing scab, and other soil micro-organisms; second, to determine the effectiveness of applying chemicals to the soil as a control measure for scab and the relationship, if any, between the activity of the chemicals as measured by scab control and the oxidation-reduction potentials of the soils used.

The dual nature of the studies to follow necessitates dividing this thesis into two parts.

PART I

The Effects of Soil Microorganisms upon the Pathogenicity and Growth of Actinomyces scabies.

Antagonism between microorganisms has attracted the attention of many present day investigators and has been suggested as a basis for a possible control measure for several injurious plant diseases. Studies upon the antagonistic action of various organisms, singly or in combination, towards parasites attacking the aerial parts of plants have yielded significant results. The analysis of such action between soil microorganisms, however, is a more difficult problem, owing to the complex physical and chemical properties of the soil. Observations of antagonism between soil organisms have been made by growing them in artificial media, but such observations cannot be accepted as representing precisely the behaviour of the same organisms when associated in the soil, where many other factors come into play.

Review of Literature

The effects of mixtures of microorganisms inoculated into citrus trees was recognized as early as 1912 by Fawcett (11) who worked with Phomopsis citri causing stem-end rot of citrus trees. Of all the combinations of organisms which he used, Phomopsis citri, Diploidia natalensis and Cladosporium herbarum var. citricolum was found to be the most virulent, killing the tree in two weeks.

Vasudeva (29) found that Botrytis allii markedly interferes with the vigour of the parasitic attack on apple

by Monilia fructigena.

Gioelli (13) observed that the mutual antagonism between Penicillium digitatum and Penicillium italicum, when inoculated into oranges, is increased as the temperature is lowered.

In 1930, Bamberg (3) isolated a bacterium which, when inoculated with smut spores into corn, prevented normal infection by smut.

Sanford and Broadfoot (22) tried the effects of many bacteria on Ophiobolus graminis, causing foot-rot of wheat, and found that some almost entirely suppressed it.

Types of inhibition exhibited by microorganisms have been studied in culture. Porter (21), while studying the characters of certain fungi, recognized five types of inhibition: mutual intermingling, overgrowing, slight inhibition, inhibition at a distance and growth around. Arrillage (2) recognized four of these types and three others.

The soil organism Trichoderma lignorum has been studied quite extensively in relation to antagonism. Weindling (32), investigating the damping-off of citrus seedlings, found a strain of Trichoderma lignorum which is able to parasitize Rhizoctonia solani, Phytophthora parasitica, Pythium spp., Rhizopus spp. and Sclerotium rolfsii, all of which are pathogenic soil fungi. The same investigator, working with Fawcett, was able to obtain complete control of damping-off of citrus seedlings in acid soils by inoculating them with Trichoderma lignorum. The effect of pH on Trichoderma

lignorum and *Rhizoctonia solani* was studied by Weindling (33) in 1933. The former organism is favoured by acid conditions and the latter by alkaline conditions.

Allen and Haenseler (1) obtained marked reduction of seed decay of both cucumber and peas by inoculating Trichoderma into the soil.

Several theories have been advanced to explain the antagonistic action of one microorganism towards another. The ability of *Trichoderma lignorum* to secrete a toxic substance has been studied extensively by Weindling (33). From the liquid medium on which this organism had been growing he isolated a substance which inhibited the growth of *Rhizoctonia solani*. Evidence which he obtained suggested that the inhibitory material is a single chemical substance. The lethal principle is weakened by boiling, but is not entirely destroyed by prolonged autoclaving.

Other workers have investigated the properties of the lethal principle responsible for the parasitic activity of *Trichoderma lignorum*. Allen and Haenseler (1) think that the lethal principle is composed of several chemical substances which have different thermo-inactivation points. More recently, Weindling and Emerson (35) isolated a crystalline substance produced by Trichoderma which is lethal to *Rhizoctonia solani* and other soil fungi.

The existence of substances toxic to plants in the media on which certain organisms had been growing was pointed out by Endo (10), Vanterpool (28), Arrillage (2) and others.

Johnson (14), investigating the effect of antagonism on smut of corn, suggests that the bacterium may produce a substance which is probably an enzyme, capable of breaking down the cell wall. According to Scarsmella (24), Rhizopus nigricans produces pectinases when grown on carrot juice. Various other workers, such as Porter (21) and Sanford and Broadfoot (22) have attributed the parasitic activity of certain organisms to toxic or enzymatic substances elaborated during their growth.

Several experiments have been carried out in connection with the antagonistic action of various organisms towards Actinomyces scabies. Millard and Taylor (19) found that a mixture of Actinomyces scabies and a saprophyte, Actinomyces praecox, reduced scab on potatoes as compared with the action of the parasite when applied alone. Earlier investigations indicated that green manuring increased the acidity of the soil and thus prevented scab. However, Millard (18) and Sanford (23) obtained results in more recent experiments which proved that green manuring does not result in altered soil reaction.

A recent article by Daines (8) gives substantial evidence that Trichoderma lignorum produces a diffusible

substance which is toxic to Actinomyces in an artificial liquid medium. "Due to the fact, however, that the toxic principle produced by Trichoderma is rapidly destroyed by aeration at the pH of potato soils and is removed from solution by charcoal and destroyed or removed by the soil itself, it seems rather doubtful that this fungus will be found to be of much assistance in combating potato scab."

Greenhouse Studies on Pathogenicity

The possibility of antagonism existing between common soil fungi and the scab pathogen led to an attempt to discover if a relationship could be established between certain of these fungi and the occurrence of scab. For this purpose four fungi were chosen because they had been found, through isolations made in the laboratory from various soils, to be of common occurrence in the potato soils of the Montreal district where the control of scab is a major problem for the potato growers. On the basis of the known prevalence of scab in them and laboratory analyses of their microfloral content, soils from four fields were chosen as being suitable for the purpose of these studies. The names of the organisms and details relative to the soils used are given in connection with the discussion of the various experiments.

With the knowledge that temperature, moisture, and soil reaction have a bearing upon the soil microflora and upon the prevalence of scab, the experiments were set up under two temperatures, 60° F. and 75° F. and with high and low soil moisture contents. In the fourth experiment sulphur was

used as a means of increasing the acidity of the soil with the idea of aiding the test organism used in this trial, which is known to be favoured in its development by acid conditions, to counteract the scab organism, should an antagonistic relationship exist between these two.

With the exceptions of experiments 1 and 3, two successive crops were raised on the same soil without further inoculation in order to find out whether or not the originally inoculated organisms remained in the soil and showed their effects over this period, or became extinct due to antagonistic relationships which might exist..

Materials and Methods Common to all Greenhouse Experiments

Seed used.

For the first crop non-certified Irish Cobbler dormant tubers had to be used. They were free of scab. In order to break the dormancy, the cut seed was soaked in a two per cent solution of sodium thiocyanate for two hours. The seed pieces were then planted in flats and later transplanted to eight-inch pots containing the treated soils. The seed for the second crop was nondormant, certified seed of the same variety. It was planted directly into the pots without any treatment.

Method of maintaining constant soil moisture in pots.

In order to maintain a known high water content in some pots and a low water content in others, it was necessary to determine the water-holding capacity of the soils, which was done as follows.

Unknown amounts of soils Nos. 1 to 6 inclusive were dried thoroughly in an oven at 80° C. A weighed quantity of each dried soil was put into a funnel and water was allowed to drop slowly on it from a burette until the saturation point of the soil was reached. The amount of water required to saturate each soil was noted and the water-holding capacity calculated from the relation between the dry weight and the amount of water required for saturation. Pots were maintained at the proper water content by weighing and watering frequently.

Preparation of inocula.

For inoculating the soils with the scab organism, the inoculum used was finely ground-up scab lesions from scabby tubers.

The other organisms were cultured on a medium consisting of equal proportions of wheat and hulless barley. When sufficient growth had occurred, the inoculum was prepared by grinding up the cultures (grain and fungus together). Freshly prepared inoculum was used in all cases. The amount to be applied to the soil was arrived at as follows. The number of spores per gram of Trichoderma inoculum was determined by the dilution-plate method. From this figure, the weight of inoculum to be added to each pot containing a known weight of soil in order to give a certain number of Trichoderma spores per gram of soil was calculated. Corresponding amounts of inoculum by weight were used for all organisms, grown on the wheat-barley medium, in similar tests.

Inoculation proceedings.

Each pot was inoculated separately. All inocula were weighed out according to the requirements set out for the various experiments and mixed thoroughly with the soil.

General plan of experiments

Two greenhouses were used for these tests. One was maintained at a temperature of 75° F. and the other at a temperature of 60° F. In experiments Nos. 2 and 4, half the pots were placed in one greenhouse and half in the other. Experiment No. 1, which had no specific temperature requirements, was set up first in the greenhouse maintained at 60° F. and later moved, owing to the shortage of space, to another, which was held at a slightly higher temperature.

Each treatment was replicated three times for each condition of temperature and moisture.* For each treatment controls were maintained, to which no inoculum or chemical was added, excepting in experiment No. 4. In this experiment controls, to which no Trichoderma was added but which included sulphur, were established. All possible combinations of treatments were used in each experiment. These combinations for each experiment appear in the tables of results.

Soil microfloral determinations.

In order to determine the effects of inoculating the various test organisms into the soil upon the soil microfloral content, plate counts for bacteria, fungi and actin-

*Throughout this thesis, the word replication is not used in its true sense. Whenever the number of replications is mentioned, that number includes the original and replicates.

omyces were made for each soil at the time of planting and harvesting each crop. Soil isolations were made for each treatment within experiments Nos. 1 to 3 inclusive. A sample of soil was taken from each replication of each treatment after the crop was harvested. The three samples from each treatment were mixed together and 10 grams of the mixture weighed. This amount of soil was placed in a 500 cc. flask containing 100 ccs. of sterile distilled water. After shaking for four minutes, 1 cc. was transferred to another flask containing 99 ccs. of sterile distilled water. Another 1 cc. transfer to 99 ccs. of sterile distilled water was made after shaking for one minute. The third flask was also shaken for one minute. From this dilution 1 cc. portions were taken to inoculate each of three flasks containing different agars, from each of which three petri dishes were poured.

Thornton's medium (27) was used for isolating actinomyces, potato-dextrose agar for bacteria, and potato-dextrose agar, to which lactic acid had been added to make it distinctly acid, for the fungi.

Counts of the various organisms were made for each treatment.

Experiment 1: The Effect of *Aspergillus niger* and two Species of Penicillium on Scab Occurrence.

Materials and Methods

Organisms used.

For testing the possibility that the pathogenicity of *Actinomyces scabies* (Thax.) Gussow may be affected by the presence of associated soil microorganisms, three moulds, *Aspergillus niger* and two species of Penicillium, designated *Penicillium* 17-1 and *Penicillium* 27-1, were used.*

Number of soil and reasons for its use.

The soil used in this experiment was soil No. 7. It consisted of pasture turf prepared in the usual manner for greenhouse use. This soil was used merely as a medium in which to test for actagonistic relationship between the above organisms and *Actinomyces scabies* when associated in the same soil and also to see if satisfactory results for this type of experiment could be obtained in greenhouse compost soil.

The soil was sterilized before being inoculated with the various organisms. This was done to eliminate other soil microorganisms which might interfere with the correct analysis of the results as related to the relationships between the moulds and the scab organism. The formalin method of sterilization was adopted, a two per cent solution of the chemical

* The numbers affixed to the two species of Penicillium were two of the numbers used to distinguish between the members of a series of Penicillia isolated from potato soils during the summer of 1936.

For convenience, the moulds used in testing antagonistic effects towards *Actinomyces scabies* are referred to as test organisms in this thesis.

being used at the rate of two quarts per square foot. All necessary precautions were taken to ensure thorough sterilization during the process and proper aeration of the soil afterwards.

General set-up.

Certain pots were inoculated with each of the test organisms at the rates of 0, 50, and 125 grams of inoculum per pot. Scab inoculum was applied at 0, 25, and 50 grams per pot where required. The general plan of the set-up follows that already described for the greenhouse experiments and the details are shown along with the results in Table 1.

Results

The results for this experiment appear in Table 1.

The effect of Aspergillus niger on scab occurrence.

Aspergillus niger was not recovered in the analysis of the soil for microfloral content at harvest of crop. It seems, therefore, that any effects on scab occurrence were not due to Aspergillus. The addition of 50 grams of scab inoculum increased scab. The effects which the inoculum of the test organism had upon the numbers of the soil actinomyces, fungi and bacteria were evidently brought about by the wheat and barley contained in the inoculum. This inoculum tended to increase the numbers of actinomyces and bacteria in all pots but fungi increased only in the pots to which no scab inoculum was added. This indicates a possible antagonistic action by Actinomyces scabies. The addition of scab inoculum decreased consistently the numbers of actinomyces, usually decreased the numbers of fungi but increased the

numbers of bacteria excepting in the pots to which no inoculum of the test organism had been added. This is probably a case of synergistic action between the scab organism and the bacteria in the presence of the ground-up wheat and barley.

The complete disappearance of Aspergillus niger suggests a very strong antagonistic action on the part of Actinomyces scabies or some other organism against this mould.

The effect of Penicillium 17-1 on scab occurrence.

Penicillium 17-1 increased scab but the amount of its inoculum seemed not to be important in this regard. On the other hand, Penicillium itself decreased in numbers as the amount of scab inoculum was increased, although it increased with increased amounts of its own inoculum. Increased amounts of scab inoculum decreased scab.

The numbers of soil actinomyces and bacteria were increased by the addition of Penicillium inoculum but the numbers of fungi generally remained highest in the checks. This is a sign of antagonism between the Penicillium and fungi already in the soil. The addition of scab inoculum decreased the numbers of fungi but increased the bacteria excepting in the checks, which showed no definite effect. (Probably another case of synergism as noted before in the Aspergillus niger trial).

The effect of Penicillium 27-1 on scab occurrence.

The results for Penicillium 27-1 were the same as those for Penicillium 17-1 with two exceptions. The first of them is that the addition of scab inoculum showed no apparent effect upon the numbers of fungi when the former organism was inoculated into the soil, whereas the numbers of fungi were usually decreased when the latter was used as inoculum. The second exception deals with the numbers of bacteria as affected by the addition of scab inoculum. In the case of Penicillium 27-1, the scab inoculum did not have a definite effect upon the numbers of bacteria while in the case of Penicillium 17-1 the bacteria were increased by the addition of scab inoculum, excepting in the checks which showed no definite effect.

There was no relationship between the numbers of soil actinomyces and the occurrence of scab in any part of this experiment.

The soil used in this experiment was sterilized but showed a high amount of scab in the checks at the time of harvest. This was no doubt due to the introduction of Actinomyces scabies after sterilization.

Experiment 2: The Effect of *Trichoderma lignorum* on Scab Occurrence.

Materials and Methods.

Organisms used.

In this experiment *Actinomyces scabies* was used along with a strain of *Trichoderma lignorum* commonly found in local soils.

Numbers of soils and reasons for their use.

Two soils, soil No. 5 and soil No. 6 were used in this experiment. The first was chosen because scab was known to be high in it, and because, through laboratory analysis of the microfloral content, *Trichoderma lignorum* was known to be able to grow in it. This soil was used in its natural state in order to compare it with a second soil, soil No. 6, which had been sterilized. Both the scab organism and *Trichoderma lignorum* were known to be present in soil No. 6 in abundance when in its natural state. It was therefore thought that if the soil should be sterilized, it would provide a good medium in which to determine whether or not any antagonistic relationship existed between the two organisms concerned, without interference from other microflora already existing in the soil. Soil No. 5 was inoculated with *Trichoderma lignorum* only, while soil No. 6 was inoculated with both *Trichoderma lignorum* and scab. The method of sterilization was the same as that described for the previous experiment.

General set-up.

Four amounts of Trichoderma inoculum, 0, 100,000, 1,000,000 and 10,000,000 spores per gram of soil, and three amounts of scab inoculum, 0, 25, and 50 grams per pot were used in this experiment. The combinations of treatments, temperatures and soil moistures used are shown in Tables 2, 2-A, 3 and 3-A. Two crops were grown successively on the same soils.

Results

(a) The effect of Trichoderma lignorum on scab occurrence in an unsterilized soil.

First crop. Tables 2 and 4 give the results for the first crop.

Scab was increased slightly by adding Trichoderma inoculum to the soil. The same inoculum increased slightly the Trichoderma in the soil but the numbers of this organism never became high. There was no effect in this experiment from adding scab inoculum to the soil as none was added.

The numbers of soil actinomyces were usually increased by increased amounts of Trichoderma inoculum, the highest amount producing the most definite increase. The fungi and bacteria were not affected. A summary of these results is given in Table 4.

Second crop. Tables 2-A and 4-A give the results for the second crop.

Scab was not affected by adding Trichoderma inoculum to the soil. The addition of Trichoderma inoculum to the soil increased Trichoderma as compared to the checks. The effect of inoculating the soil with Trichoderma was usually to in-

crease the soil actinomyces, fungi and bacteria.

Tables 4 and 4-A show that high temperature and low soil moisture favoured scab development.

(b) The effect of Trichoderma lignorum on scab occurrence in a sterilized soil.

First crop. Tables 3 and 5 give the results for this crop.

The addition of Trichoderma to the soil did not affect scab nor did it affect the numbers of Trichoderma recovered as compared with the checks. Adding scab inoculum, on the other hand, increased scab usually in proportion to the amount added. This point was most significant in the low moisture pots.

In general, the soil actinomyces and bacteria were increased by the addition of scab inoculum. The Trichoderma increased the numbers of actinomyces and decreased the numbers of bacteria as compared with the checks. All of these tendencies are most apparent under high temperature conditions, low moisture also favouring this. ~~fact~~. Although the fungi in the scab-inoculated pots were higher than in the checks, there did not seem to be any effect due to the Trichoderma inoculum excepting in the pots held at the low temperature. In general, low temperature definitely favoured the development of the fungi but had little effect on the Trichoderma.

Second crop. The results for this crop appear in Tables 3-A and 5-A. Table 6 gives a comparison of the general tendencies for both crops.

As in the first crop, adding Trichoderma inoculum to the soil did not affect scab. However, there was more scab on the tubers of the second crop than on those of the first crop. The numbers of Trichoderma recovered in the second crop were lower than in the first but showed an increase as the amount of inoculum was increased. The results of adding scab inoculum were similar to those of the first crop but the increase in scab was more apparent, being most significant under low moisture conditions.

The reaction of the soil actinomyces to both kinds of inoculum was the same in the second crop as in the first. The numbers of bacteria increased in the second crop for both inocula, whereas Trichoderma decreased their numbers in the first. As in the first crop, scab inoculum increased the numbers of fungi while Trichoderma had no effect.

As in soil No. 5 (unsterilized) high temperature and low moisture were the most definite factors in producing high scab on the tubers.

Experiment 3: Effect of Wheat and Barley when used as a Cultural Medium for Test Organisms.

A weakness in the results of the first two experiments lies in the fact that the effects of the inclusion of wheat and barley in the inocula of the different test moulds was not determined. Consequently, further greenhouse trials were carried out during the fall and early winter of 1937 in order to determine the effects of additions of similar amounts of wheat and barley, alone and in combination with the test organisms, upon the microfloral content of the soils. The trials included pots which were inoculated with wheat and barley prepared in exactly the same manner as that which was used as a medium for culturing the various organisms. Two soils were used, namely, Nos. 6 and 7, already described. They were sterilized as in the two previous experiments. Two of the organisms, Trichoderma lignorum and Aspergillus niger, were the same as used in previous tests, while a third organism, designated Penicillium 40, was used instead of Penicillium 17-1 and Penicillium 27-1. The trials were carried out in a greenhouse, the temperature of which was kept at 75° F. The combinations of treatments used in this experiment are shown in Tables 7 and 7-A.

Results

The results of these experiments appear in Tables 7 and 7-A. Despite the fact that the soils were sterilized, a slight amount of scab occurred on the tubers of pots to which no scab inoculum had been added. It would appear from

these results that both Aspergillus niger and Penicillium 40 decreased the scab coverage to a small degree. Trichoderma lignorum, on the other hand, although its effect was negligible under high moisture conditions, otherwise generally decreased markedly the occurrence of scab. The effect of the wheat and barley mixture by itself was to increase the amount of scab infection in both soils used. Thus the 1937 tests would indicate that Trichoderma lignorum tends to decrease the amount of scabbed surface, while the other moulds have little or no effect.

The soil actinomyces were increased by the addition of wheat and barley to the compost soil, provided that no scab inoculum was present; when the scab inoculum was present the increase was negligible, indicating antagonism on the part of the Actinomyces scabies towards other actinomyces. Aspergillus niger had no effect on the soil actinomyces,, while Penicillium 40 antagonized their development. Trichoderma seemed to increase the number of soil actinomyces when scab inoculum was absent rather than to have decreased it. The effect on the soil microflora of the wheat and barley in soil No. 6 was much less marked than it was in soil No. 7. The addition of wheat and barley to pots not inoculated with scab increased the soil fungi in soil No. 7, but had no effect in soil No. 6. Penicillium 40 and Trichoderma lignorum apparently antagonized the other soil fungi, while Aspergillus niger merely added to the fungi already existing in the soil. Among the pots inoculated with scab, the number of fungi was usually smaller in those pots containing the inocula of the test organisms than in those to which scab inoculum alone had been added. The variations in the number of bacteria were not marked.

Experiment 4: The Effect of *Trichoderma lignorum* in Conjunction with Sulphur on Scab Occurrence.

Materials and Methods

Organisms used.

Actinomyces scabies and *Trichoderma lignorum*, as previously described, were used in this experiment.

Number of soil and reasons for its use.

One soil, namely, soil No. 1, was used in this experiment. This soil, selected chiefly because it was high in scab, was a black muck soil taken from the farm of Mr. Chalifoux. It was used in its natural state.

Sulphur treatment.

The soil was treated with sulphur, for the purpose already explained, at the rate of 500 and 800 lbs. per acre before inoculating with *Trichoderma lignorum*. The chemical was thoroughly mixed with the soil.

General set-up.

After treatment with sulphur the required number of pots were inoculated with *Trichoderma lignorum* at the rate of 10,000,000 spores per gram of soil. Tables 8 and 8-A give the combinations of treatments used. The general explanation as to temperature, moisture and replications used appears under "Materials and Methods Common to all Greenhouse Experiments." Two successive crops were grown on the soil and the results obtained for each

Results

The results for this experiment appear in Tables 8, 8-A and 9.

First crop.

Sulphur increased the numbers of Trichoderma in the soil at 75° F. but had no effect at 60° F. The larger amount of sulphur also decreased scab. The effect of the Trichoderma and sulphur in combination effected greater reduction of scab than did sulphur alone at the higher temperature but had no effect at the lower temperature.

The larger amount of sulphur increased the numbers of soil actinomyces and bacteria but decreased the numbers of fungi. The wheat and barley used to culture the Trichoderma organism and the temperature seemed to be responsible for the variations among the soil microflora upon the addition of the inoculum.containing wheat and barley.

Second crop.

Sulphur had no effect on Trichoderma in the case of the second crop but apparently increased scab at 75° F. and decreased it at 60° F. The combination of sulphur and the inoculum effected a greater decrease than sulphur alone at 60° F. but a smaller decrease at 75° F.

The larger amount of sulphur increased the soil actinomyces when Trichoderma was absent but decreased them when it was present. The same was true for the numbers of bacteria and fungi. The addition of the inoculum to the soil usually decreased the actinomyces, fungi and bacteria and increased the numbers of Trichoderma.

Low temperature was the factor effecting the greatest and most consistent decrease in the amount of scab on the tubers.

Pure Culture Studies on Antagonism.

In order to find out if antagonistic relations do exist between Actinomyces scabies (Thax.) Gussow and the moulds used in the greenhouse studies on antagonism, pure culture experiments were set up. The first of these was in the form of preliminary tests established with the idea of finding out if antagonism did exist between the scab organism and the moulds. These cultures were run at room temperature. The second experiment was broader in its scope, involving various conditions of temperature, moisture and pH, as well as distance between inocula. These conditions were studied in order to compare the results obtained with those from greenhouse studies.

A third experiment was set up to determine the effect which sulphur by itself might have upon the antagonistic relationships between Actinomyces scabies and Trichoderma lignorum, since sulphur was used in one of the greenhouse experiments on scab control.

Experiment 1: Preliminary Studies on Antagonism in Pure Culture.

Materials and Methods

Organisms used.

The organisms used in this experiment were from pure cultures of Actinomyces scabies (Thax.) Gussow, Trichoderma lignorum, Aspergillus niger, Penicillium 17-1 and Penicillium 27-1. These organisms are the same as those considered in the greenhouse studies.

Details of experiment.

Ten cubic centimetre portions of potato-dextrose-peptone agar were poured into petri dishes. The dishes were inoculated with the test organisms, alone or in association with Actinomyces scabies. Each test was replicated three times. The plates were incubated at room temperature.

Results

Trichoderma lignorum was repelled in the earlier stages of growth by Actinomyces scabies but finally grew over the Actinomyces. The growth of Aspergillus niger was generally inhibited at a distance by Actinomyces. In one plate an Aspergillus colony which was growing close to the Actinomyces colony restricted the growth of the latter. The same was true for a colony of Penicillium 17-1 growing close to Actinomyces scabies; the former grew beneath the latter. In general, Actinomyces repelled Penicillium 17-1 at a distance. Penicillium 27-1 was also strongly repelled by Actinomyces. Thus, Actinomyces scabies was definitely antagonistic towards the moulds used.

Experiment 2: Detailed Studies on Antagonism in Pure Culture.

Materials and Methods

Organisms used.

The same organisms were used in this experiment as in the preceding one.

Artificial media.

Waksman's peptone-glucose-acid agar (30) was used in this experiment. Two lots of this medium were made, one lot containing 25 gms. or agar per litre and the other 64 gms. per litre. The former was used as a medium of high moisture and the latter as a medium of low moisture content.

Temperature.

The tests were carried out at two temperatures, namely, 15° C. and 26° C. which might be considered typical temperatures of "cool" and "warm" soils.

Moisture.

A high and low moisture was introduced into the test by the use of agar of two strengths.

Hydrogen-ion concentration.

Hydrogen-ion concentrations of the media of pH 5.5, pH 6.2 and pH 7.3 were used. The pH was adjusted by pouring a small amount of the agar into a petri dish and using the quinhydrone method to measure the pH. The medium was brought to the desired pH value by adding small amounts of N/10 NaOH or N/10 HCl, as required.

Inoculation.

Ten cubic centimetre portions of the required agar were poured into petri dishes. The plates were inoculated with Actinomyces scabies in combination with each of the other organisms under test. In one set of plates the test organism was placed at a distance of 2 cms. from the Actinomyces, in the second set at a distance of 7 cms. from the latter.

General features of set-up.

Each test was replicated three times for each condition of temperature, moisture, pH and distance between inocula.

Results

(a) Antagonism between Actinomyces scabies and Trichoderma lignorum.

Effect of temperature.

The growth of Actimomyces scabies and Trichoderma lignorum was slower at 15° C. than at 26° C. but when sufficient growth had occurred the Actinomyces repelled Trichoderma in the same manner at the former temperature as at the latter.

Effect of pH.

Actinomyces inhibited the growth and sporulation of Trichoderma at all pH values, this repulsion being strongest at pH 5.5 and becoming progressively weaker as the alkalinity of the medium increased. (See Fig. 1). In view of the fact that the growth of Actinomyces scabies is generally

Fig. 1

1. Inhibition of growth and sporulation of Trich. lignorum inoculated 7 cms. from A. scabies at high temperature, high moisture and pH 5.5

2. Strong inhibition of Pen. 17-1 by A. scabies inoculated at a distance of 2 cms. apart; high temperature, high moisture and pH 6.2

favoured by alkaline conditions and that of Trichoderma by acid conditions, this result is somewhat unexpected. The growth of Trichoderma became gradually slower as it approached the colony of Actinomyces, but the former usually grew around and in contact with the latter. This process, however, took longer at the lower pH values. There was a zone of inhibition of Trichoderma sporulation surrounding the colonies of Actinomyces. This zone decreased in width as alkalinity increased, and in two plates, one with a pH of 6.2 and the other with a pH of 7.3, Trichoderma sporulated above the Actinomyces colonies. In some plates which had been inoculated with a larger amount of Actinomyces inoculum than the others, there was a zone of inhibition across which Trichoderma could not grow, regardless of the pH or time factor.

Petri dish No. 3 in Fig. 2 shows Trichoderma growing over the Actinomyces colony at pH 6.2, while dish No. 1 shows the ability of Trichoderma to surround the colony of Actinomyces at a high pH. Dish No. 2 demonstrates the effect of a larger amount of Actinomyces inoculum.

Effect of moisture.

The moisture difference produced by agars of different strengths had no effect upon the antagonism between the two organisms.

Effect of distance between inocula.

When the organisms were placed 7 cms. apart the growth of Trichoderma was rapid at first until it was within a short distance of the Actinomyces colony; it then proceeded more

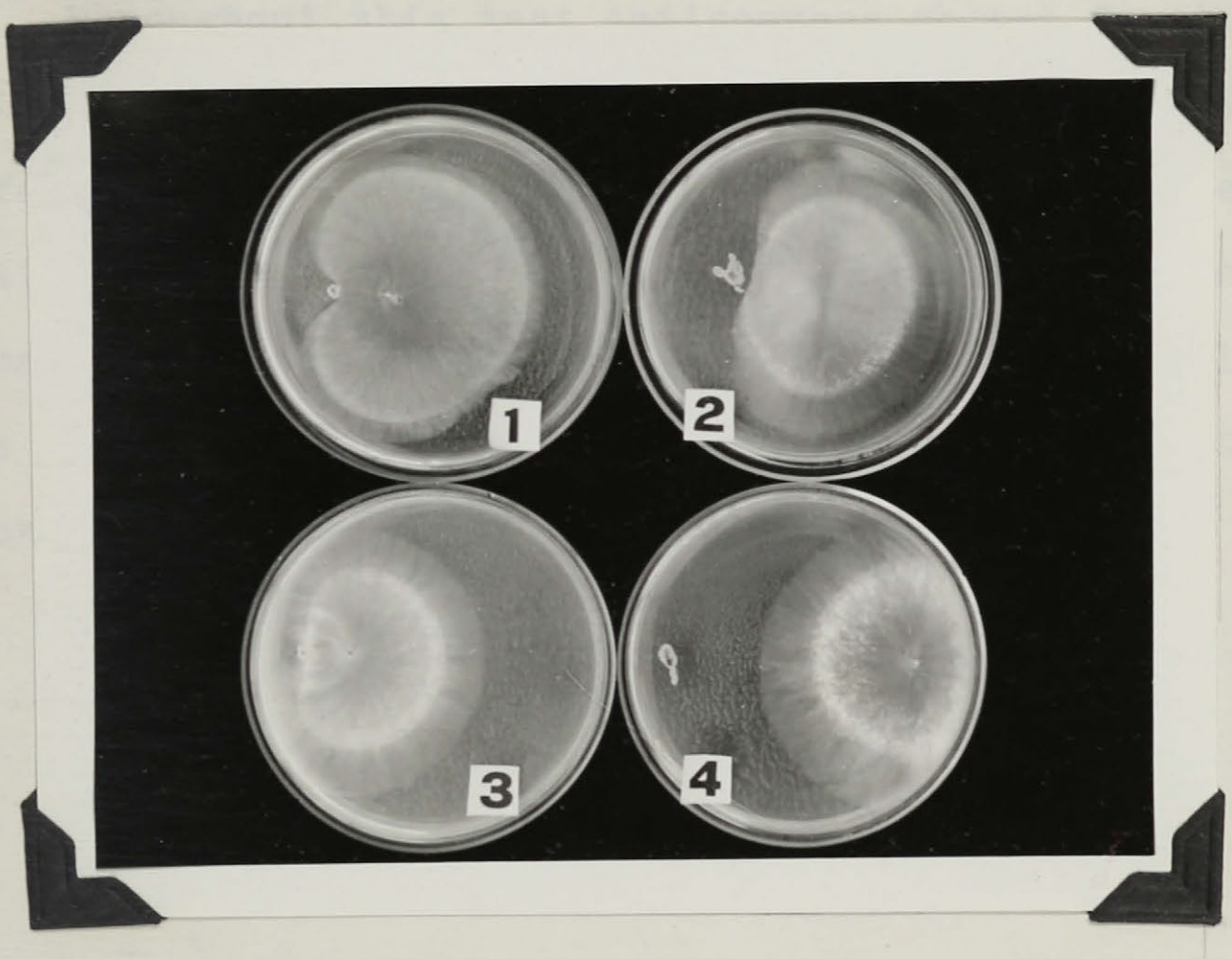

Fig. 2

1. Trich. lignorum, at high temperature, high moisture and pH, growing around the Actinomyces colony; inoculated 2 cms. apart.

2. Trichoderma, at high temperature, high moisture and pH 5.5, unable to surround the large amount of Actinomyces; inocula placed 2 cms. apart.

3. Trichoderma growing over A. scabies at high temperature, high moisture and pH 6.2.

4. Rapid growth of Trichoderma; inocula placed 7 cms. apart.

slowly owing to the antagonistic action of the latter. However, the type or strength of antagonism did not seem to differ from that obtaining when the organisms were placed 2 cms. apart. Petri dish No. 4 in Fig. 2 shows rapid growth of Trichoderma when placed 7 cms. from the Actinomyces colony.

Throughout this test Actinomyces showed few signs of being antagonized by Trichoderma. The only noticeable effect of Trichoderma upon Actinomyces was to cause the latter to produce a fine type of growth which advanced steadily and finally grew under the Trichoderma colonies. The fine growth occurred only after Actinomyces had been growing for some time.

Results

(b) Antagonism between *Actinomyces scabies* and *Aspergillus niger*.

Effect of temperature.

Aspergillus niger failed to grow at 15° C., excepting on the low-moisture agar. On this agar growth was sufficient to study antagonism only in the petri dishes in which the moulds were placed 7 cms. apart. The growth of Actinomyces was also slow at the low temperature but not as slow as that of Aspergillus. Both organisms grew well at 26° C.

Effect of pH.

The growth of *Aspergillus niger* was favoured by acid conditions, the best growth occurring at pH 5.5 . The zone of inhibition exhibited in the earlier stages of growth between a colony of Aspergillus and one of Actinomyces was the same width as that between two colonies of Aspergillus. After six days Aspergillus grew and sporulated on top of the colonies of Actinomyces, neither organism being inhibited in any way by the other. However, in two plates in which there were larger amounts of Actinomyces inoculum, Aspergillus was repelled and was unable to grow into contact with Actinomyces. Thus, in general, the range of hydrogen-ion concentration used did not influence antagonism between the organisms when they were placed 2 cms. apart, but when 7 cms. apart, Actinomyces inhibited the growth of Aspergillus at all pH values, inhibition being most pronounced at pH 5.5 and pH 7.3. In this case a clear zone was maintained between the colonies throughout the test. Sporulation of Aspergillus was not in-

hibited but took place wherever the mycelium was able to grow.

Effect of moisture.

The low moisture agar did not alter the antagonistic action between the two organisms as compared with the high moisture agar.

Effect of distance between inocula.

Actinomyces scabies antagonized Aspergillus niger when these organisms were placed 7 cms. apart but not when placed 2 cms. apart. It is probable that, when inoculated close to Actinomyces, Aspergillus was able to become established before any toxic substance was secreted by the former organism.

Throughout this test, Aspergillus niger did not inhibit the development of Actinomyces scabies in any way.

Results

(c) Antagonism between Actinomyces and Penicillium 17-1.

Effect of temperature.

Actinomyces scabies repelled the growth of Penicillium causing a piling-up of the hyphae of the latter at both temperatures. The only effect of temperature was that repulsion occurred in a shorter time at 26° C. than at 15° C.

Effect of pH.

The growth of Penicillium decreased as the pH increased but acidity of the medium had no effect upon the antagonism displayed by Actinomyces scabies.

Effect of moisture.

The moisture of the medium seemed not to affect the antagonistic action exhibited by Actinomyces.

Effect of distance between inocula.

The zone of inhibition between the two organisms was proportionately wider when they were inoculated 7 cms. apart as compared to 2 cms. This was probably due to the greater amount of some toxic substance produced by Actinomyces when growing for a longer time, or to the exhaustion of the nutrients required for the growth of Penicillium. The first suggestion is more likely to be true than the second because there was a characteristic piling-up of the hyphae of the Penicillium. Strong inhibition of the growth of Penicillium occurred at both distances.

The Penicillium showed a slight antagonistic action towards Actinomyces for after growth had proceeded for some time, colonies of Actinomyces developed a fine type of growth which persisted and finally grew under the Penicillium colonies. This appeared under all conditions of the test.

Dish No. 2 in Fig. 1 shows Penicillium 17-1 being strongly repelled by Actinomyces scabies when inoculated 2 cms. apart. Fig. 3 shows the piling-up of the hyphae of Penicillium 27-1 and the wide zone of inhibition when the two organisms were inoculated 7 cms. apart.

Results

(d) Antagonism between Actinomyces scabies and Penicillium 27-1.

The behaviour of Penicillium 27-1, when grown in combination with Actinomyces, was the same as stated above for Penicillium 17-1.

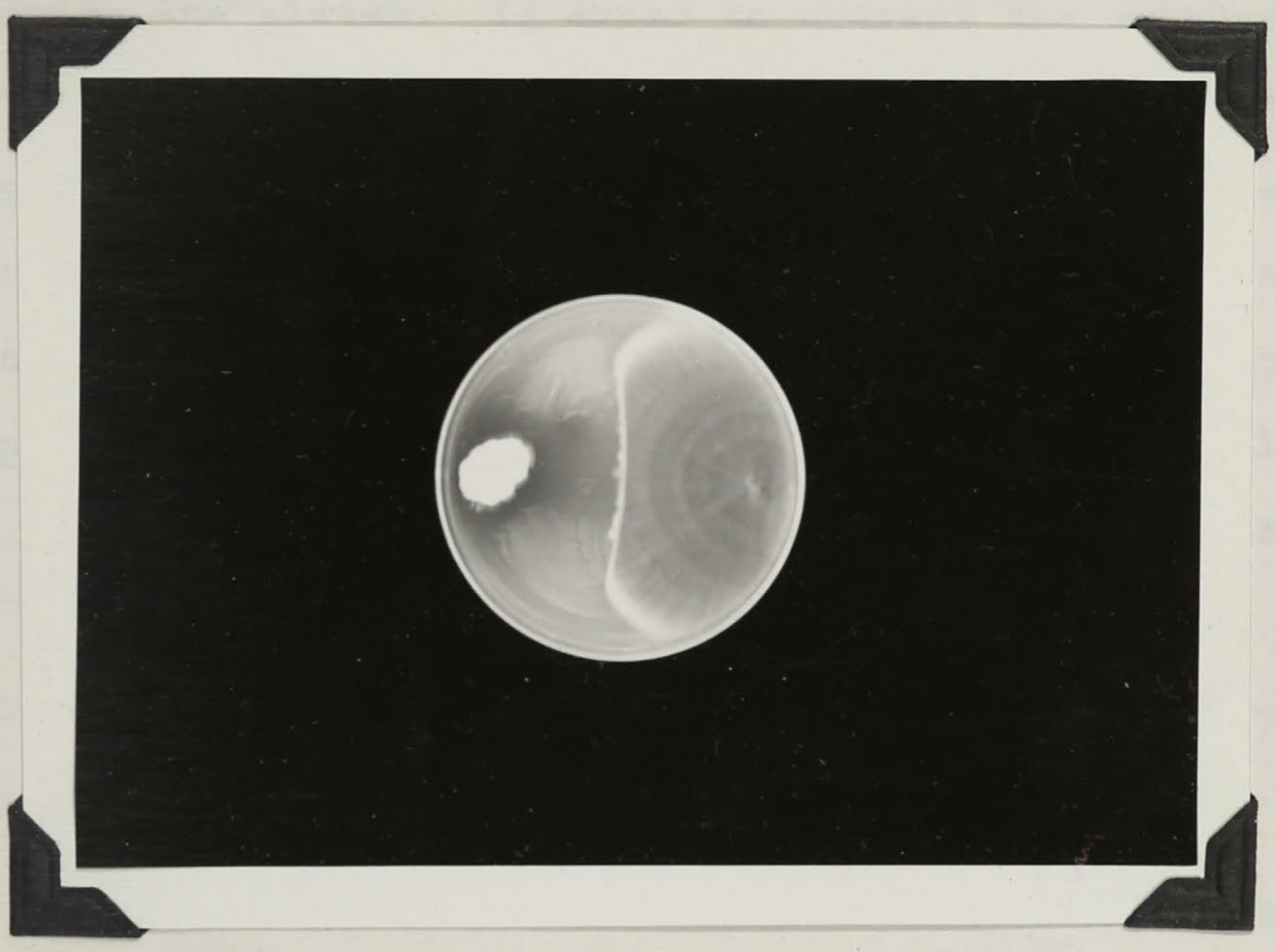

Fig. 3

Piling up of Pen. 27-1 mycelium due to antagonistic effects of A. scabies.

Experiment 3: Effect of Sulphur on the Antagonistic Action between Actinomyces scabies and Trichoderma lignorum.

Materials and Methods

Ground sulphur, at the rate of 3.2 gms. per litre, was added to potato-dextrose agar immediately before pouring the plates. In order to prevent the sulphur from settling out and to maintain an even distribution throughout, the agar was shaken constantly while the plates were being poured. Sulphur was present in half the total number of plates. Three plates were poured for each test. Actinomyces scabies and Trichoderma lignorum were inoculated, alone and in combination, onto plates with and without sulphur.

Results

The sulphur suspension caused a slight increase in the growth and sporulation of Trichoderma, but had no effect upon Actinomyces. The interaction between the two organisms was the same whether or not sulphur was present.

PART II.

The Effect of Applying Chemicals to the Soil upon the Occurrence of Scab and Various Soil Microorganisms.

Within recent years many investigators have demonstrated the possibility of reducing common scab of potatoes by the application of various chemicals to the soil. However, the results obtained by the various workers, experimenting in different localities and with different soils, have shown great variation, ranging from an increase in scab to almost complete control of it.

Review of Literature.

Newton (20), working in Alberta in 1931, obtained excellent control of scab by applying sulphur to the soil at the rate of three tons per acre, but this amount reduced the yield. One ton per acre did not give effective control. Taylor (26) found that sulphur applied after spring plowing reduced scab quite effectively. White (34) obtained a greater reduction by applying green manure in combination with sulphur than by applying either alone. Duff and Welsh (9) carried out tests with sulphur in widely scattered fields and obtained variable results.

In tests conducted by Taylor (25), aluminium sulphate reduced scab to some extent, but also greatly reduced yields.

Mader and Blodgett (16) reduced scab by spraying the potato plants with Bordeaux mixture. This may have been due to the action in the soil of the copper from the Bordeaux which had fallen to the ground while spraying.

In 1936, Cunningham (5) reported on some experiments which he carried out on Long Island. He controlled scab quite effectively by mixing four pounds of yellow oxide of mercury or six pounds of calomel with one ton of fertilizer and applying the mixture to one acre of land. Martin (17) stated that a mixture of three to six pounds of calomel with one ton of fertilizer applied to one acre of land gave promising control of scab. MacLeod and Howatt (15) obtained control by applying mercurous or mercuric chloride in the rows at the rate of ten pounds per acre with diatomaceous earth. These chemicals were not as effective when mixed with fertilizer. Taylor (26, 25) found that mercurial compounds alone, or mixed with the fertilizers, increased scab.

From the above review of literature it is evident that chemical treatments of the soil may control scab, at least in certain instances. For this reason it was deemed worth while testing the effectiveness of some of these in the Montreal district where scab control is a major problem in potato growing. The field trials were commenced in the summer of 1936 and continued in 1937. The fields selected for the trials were known to produce severe scab and were chosen as providing potato soils typical of the district. The field studies were supplemented by greenhouse tests using soils from the same or other typical fields. The field studies will be dealt with first.

Field Studies.

Experiment 1: Field Studies, 1936.

Materials and Methods

The chemicals selected for these experiments were chosen for two main reasons. First, from an economic standpoint, they could be applied to the soil at low cost if successful. Second, nearly all had been used by previous workers and each one had given some degree of control. These chemicals are as follows.

Chemicals used.

1. Calomel - 5 lbs. to the acre.
2. Calomel - lo lbs. to the acre.
3. Yellow oxide of mercury - 5 lbs. to the acre.
4. Copper sulphate - 100 lbs. to the acre.
5. Copper sulphate - 35 lbs. to the acre plus Calomel - 5 lbs. to the acre.
6. Nickel hydrate - 20 lbs. to the acre.
7. Sulphur - 500 lbs. to the acre on acid soils and 800 lbs. to the acre on alkaline soils.
8. Aluminium sulphate - 50 lbs. to the acre.
9. Calomel - 5 lbs. to the acre mixed with infusorial earth (Celite) as a carrier.
10. Sulphur - 500 lbs. to the acre plus 1 ton of lime to the acre. This treatment was used on Mr. Macdonald's field only.

Method of application.

In all treatments, except two, the sulphur and the calomel in infusorial earth, the chemical was mixed in the proper amounts with the fertilizer, a 6-8-10 mixture, which was applied at the rate of 1000 lbs. to the acre. The sulphur and the calomel in the celite as carrier were not mixed with fertilizer. These two treatments were applied after the fertilizer had been spread.

Each plot was a single row 175 feet long. The rows were 30 inches apart. This made each plot 1/100 of an acre in area. The series of plots were replicated five times in each field and the plots randomized within each replication. Two neighbouring plots were separated by a buffer row receiving only fertilizer.

In all the fields, excepting that of Mr. Chalifoux, the fertilizer and chemicals were applied by hand in the open furrow made with the plow, and then covered lightly with the foot or by means of a rake. The seed-pieces were then planted by hand and the rows covered with the plow. In the Chalifoux field the furrows were opened with the plow and the chemicals and fertilizer were spread on the bank of the furrow. The low side of the furrow was then turned over onto the seed-pieces. The bank side was turned over next, thus placing the fertilizer and chemicals above the seed-pieces but not in contact with them.

Yield and scab records were based upon the tubers obtained from twenty feet of the single row comprising each plot. Irish Cobbler seed was used throughout.

The three fields included in this experiment are situated on the farms of the following owners:

1. Fernando Bellanger, St. Martin, Que.
2. J.B.Chalifoux, St. Michel, Napierville, Que.
3. Mr. Macdonald, Beaurepaire, Que.

Soil and cultural features of the fields.

Field No. 1. This soil is a sandy loam known as "grey soil." The field has good drainage. The pH of the soil was 6.1. This land had been in potatoes for five years; no manure had been used. Scab coverage in 1934 was 6.6% and in 1935, 25.1%.

Field No. 2. This soil is a deep black muck soil. It is a low flat field but has good drainage. The pH was 6.0. The field had been in potatoes and had received commercial fertilizer only, for several years. According to the grower the scab had been severe.

Field No. 3. This soil is a sandy loam. The field is flat and has good drainage. The pH was 4.8. The scab, according to the grower, had been severe.

Results

(Summer, 1936)

The results obtained from the field work of 1936 are in general agreement with those obtained by other investigators. All treatments reduced scab in varying degrees, but some of the treatments reduced the total yield of the tubers. The latter was reduced in field No. 1 by calomel applied at the rate of 10 lbs. to the acre, by calomel mixed with celite

and, particularly, by copper sulphate. In field No. 2 the total yield was reduced by all treatments except aluminium sulphate, and in field No. 3 by calomel applied at the rate of 5 lbs. to the acre. The percentages of scab infection are given in Table 10.

During the course of these experiments it was thought worth while to determine, if possible, whether or not any correlation existed between the effects of the chemicals on the microfloral content of the soil and the occurrence of scab. Consequently, soil samples taken from the fields were brought into the laboratory where they were analyzed by the dilution plate method for the prevalence of soil actinomyces, fungi, and bacteria. The counts of these organisms along with the percentage of scabbed surface are shown in Table 10-A. The effects of the chemicals upon the numbers of soil actinomyces, fungi, and bacteria were variable, in some soils causing an increase, in others a decrease and in still others no effect whatsoever. These effects showed no correlation with the prevalence of scab.

Experiment 2: Field Studies, 1937.

Materials and Methods

The treatments used for the field experiments of 1937 were somewhat different from those used in 1936. Some chemicals proved of little value in reducing scab while others, and particularly the copper sulphate treatment, reduced the yield of the tubers. Only those treatments which had given best results were repeated in the 1937 trials. The chemicals selected and the ways in which they were applied are given below.

Chemicals used.

1 Calomel - 5 lbs. to the acre mixed with infusorial earth (Celite).

2. Calomel - 10 lbs. to the acre mixed with infusorial earth.

3. Calomel - 10 lbs. to the acre mixed with fertilizer (6-8-10), 1000 lbs. to the acre.

4. Yellow oxide of mercury - 5 lbs. to the acre mixed with infusorial earth.

5. Sulphur - 800 lbs. to the acre.

6. Sulphur - 800 lbs. to the acre plus 1 ton lime (applied separately).

Method of application.

The chemicals and fertilizer were applied separately by hand within the open rows Each plot was a single row 87 feet long by 30 inches wide or 1/200 of an acre. The rows were opened with a plow and closed either with a plow or a potato planter. The general procedure was similar to that of the previous summer.

Fields used.

1. Mr. R. Lortie, St. Vincent de Paul, Que.
2. Mr. R. Legault, St. Vincent de Paul, Que.
3. Mr. J. Charbonneau, St. Rose, Que.
4. Mr. F. Bellanger, St. Martin, Que.
5. Mr. E. Charbonneau, St. Vincent de Paul, Que.
6. Mr. A. Dagenais, St. Elzear, Que.
7. Dr. Viau, St. Remi, Que.

Soil and cultural features of the fields.

Field No. 1. A heavy sandy-clay loam with a pH of 7.7, locally known as "grey soil." The field is flat and has good drainage. This grower applied manure and 2 tons of limestone to the acre in 1935, 8 tons of manure to the acre in 1936, and chemical fertilizer in 1937. A rotation of potatoes, grain, three years of hay, potatoes, and potatoes had been practised. Scab had been high in this field.

Field No. 2. A light sandy-clay loam to clay loam with a pH of 6.3, locally known as "grey soil." The field is sloping and well drained. Chemical fertilizer is applied each year instead of manure. A rotation of potatoes, tomatoes, cabbages, and potatoes had been practised. Scab is high according to the grower.

Field No. 3. A heavy clay to clay loam with a pH of 6.7, locally known as "grey soil." The field is flat and has good drainage. Potatoes were planted on this land in 1934, and beans and corn in 1936. Manure was applied before the sowing of the corn and beans, and again in the spring of 1937. Chemical fertilizers have not been used on this farm. Scab is high.

Field No. 4. A light sandy loam with a pH of 6.4, locally known as "grey soil." The field is sloping and well drained. A rotation of potatoes, buckwheat, and potatoes is practised. Chemical fertilizer was used instead of manure. Scab is high in this field according to the grower.

Field No. 5. This soil is a heavy clay loam with a pH of 7.8, locally known as "grey soil." The field has good drainage. The farmer applied manure in the fall of 1936 and chemical fertilizer in the spring of 1937. The rotation had been potatoes, grain, two years of hay, and potatoes. Scab is high according to the grower.

Field No. 6. A light sandy-clay loam to clay loam with a pH of 6.5, locally known as "grey soil." The field is sloping and well drained. Manure and chemical fertilizer were applied before planting the 1937 crop of potatoes. A rotation of potatoes, oats, oats, corn, and potatoes has been practised. Scab is high in this field.

Field No. 7. A heavy clay loam with a pH of 5.7. This field is flat and well drained. It had been planted in potatoes for the past three years, during which time chemical fertilizer had been applied. Scab is high according to the grower

Results.

Summer of 1937.

The results of the 1937 field tests were more successful than those of 1936 in demonstrating the value of treating the soil with chemicals to control scab. All treatments, with the exception of sulphur plus lime, tended to decrease the amount of scab coverage and to increase the marketable yield of sound tubers. The results of the treatments for each farm appear in Tables 11 to 17 inclusive. There was a considerable variation in the effectiveness and value of the various chemicals used in controlling scab as is shown in Table 18. Calomel at the rate of 10 lbs. to the acre, mixed with fertilizer, was the most efficient agent in reducing scab, giving promising control, while sulphur mixed with lime caused a considerable increase in scab. The amount of calomel per acre, when mixed with celite, seemed to be of little account, as indicated by the figures in Table 18.

The averages for total yield, as shown in Table 19, indicate that the chemicals tend to increase the yield rather than to decrease it, while the per cent marketable yield by weight, appearing in Table 20, varies within narrow limits. Calomel at the rate of 5 lbs. and 10 lbs. to the acre, mixed with celite, caused the marketable yield of tubers (size only considered) to fluctuate within narrow limits; sometimes it was slightly higher, at other times either equal to or lower than the checks. In most cases calomel mixed with fertilizer lowered slightly the marketable

yield of tubers, while yellow oxide of mercury tended to increase it in the majority of fields. Sulphur and sulphur mixed with lime usually decreased the marketable yield of tubers below the checks. The effects of the chemicals on the marketable yield of tubers (Grades Nos. 1 and 2) are shown in Table 21.

While the above figures concerning yield are interesting, the most significant yield figures are given in Table 21-A, which shows the marketable yield of scab-free tubers. It is seen that all treatments gave an increase of marketable yield excepting sulphur plus lime, which reduced markedly the yield. All mercury treatments were effective in increasing the yield of healthy tubers, the calomel mixed with the fertilizer being the most outstanding. It is interesting to note that sulphur, which has been reported as giving good results and has been recommended as a scab control measure, did not prove to be satisfactory.

The results for the last four treatments in Table 15 indicate that chemical fertilizer, spread with the chemicals, aids in reducing scab. In this one field referred to in the table, no chemical fertilizer was applied excepting in the four rows used to try out the effect of fertilizer in combination with the chemicals. A comparison between the scab coverage figure for the chemical used alone and that for the same chemical used in combination with fertilizer shows that there is less scab when the fertilizer is present.

Greenhouse Studies

Experiment 1: Effect of Oxidation-reduction Potentials of Soil on Control of Scab by Calomel.

When chemicals are added to the soil they are subjected to the influence of the many complex chemical and physical properties of the soil. Consequently, it is impossible to predict the value of any fungicidal material when applied to the soil for the control of a soil-borne parasite. It has been conjectured that the oxidation-reduction properties of the soil may be an important factor. During the fall and winter of 1936-37 an experiment was run to test this point. The idea was to compare the ability of calomel to control scab in a soil when it had a high oxidation-reduction potential with its ability to do the same when the soil had a low oxidation-reduction potential. An attempt was made to establish a low oxidation-reduction potential by maintaining high soil moisture and/or by adding glucose and a high oxidation-reduction potential by maintaining a low soil moisture. The actual E_h values established by these measures were determined electrometrically in the laboratory and are given in Table 23. Each test was run at two temperatures, 60° F. and 75° F.

Materials and Methods.

Chemicals used.

1. Calomel - 10 lbs. to the acre.
2. Calomel - 10 lbs. to the acre plus glucose at the rate of 0.1% of the weight of the soil. The glucose was added as a reducing agent.

Method of application.

The calomel was mixed with a convenient amount of infusorial earth as a carrier. The materials were mixed thoroughly into the soil contained in the pots. The glucose, where required, was added to the soil after the calomel had been applied. For calculating the weight of materials to be added to each pot it was assumed that an acre of soil weighed 2,000,000 lbs.

Numbers and descriptions of soils used.

The soils used in this experiment were taken from the fields of the following growers:

Soil No. 1 - J.B.Chalifoux, St. Michel, Napierville, Que.

Soil No. 2 - J.B.Chalifoux, St. Michel, Napierville, Que.

Soil No. 3 - F. Bellanger, St. Martin de Laval, Que.

Soil No. 4 - E. Demers, Côte Petit Bois, St. Martin, Que.

Soil No. 5 - Z. Taillefer, Rang Haut, St. Martin, Que.

The descriptions of the above soils are as follows:

Soil No. 1. A black muck soil, high in organic matter giving high scab. It had a pH of 6.0 and E_h of .63 at the beginning of the experiment. This soil was selected as one being high in organic matter, producing severe scab, and also because calomel and yellow oxide of mercury were ineffective when used as control measures for scab in it.

Soil No. 2. A black muck soil somewhat lighter in weight and colour than soil No. 1. It had produced low scab, had a pH of 6.5 and an E_h of .61. This soil was selected for comparison with soil No. 1.

Soil No. 3. A sandy loam known locally as "grey soil." It had a pH of 6.1 and E_h of .66. The scab coverage in 1934 was 6.6% and in 1935, 25.1%. It was selected because chemical treatments had given effective control of scab in it. In this respect it contrasted with soil No. 1.

Soil No. 4. A fine sandy loam known locally as "yellow soil." Its pH and E_h values were 5.0 and .61 respectively. Scab coverage in 1935 was 21.1%. This selection was made to find out whether or not soil treatments are of value in this type of soil.

Soil No. 5. A very fine sandy loam known locally as "grey soil " Its pH was 6.5 and E_h .66. It was selected to find out if chemical treatments are effective in this type of soil.

Seed, etc.

The seed, the methods of breaking the dormancy period of the seed, the determination of the water content of the soil, and the general plan of experiment were the same as described under "Materials and Methods Common to all Greenhouse Experiments."

Results.

The results of this experiment indicate that the soil redox potential has a bearing upon the action of calomel when used alone or in combination with sugar in controlling scab. Although Table 23 gives the data for both high and low moistures, it was necessary to base the analysis of the results entirely on those obtained from the low moisture series owing to the negligible amount of scab found on the tubers grown under high moisture conditions. If one compares the E_h values as shown in Table 23, it is seen that calomel reduced the E_h of the soil in six instances, increased it in two, and in one had no effect. The calomel plus sugar in-creased the E_h in three instances and reduced it in seven as compared to the E_h produced by calomel alone in otherwise comparative treatments.

A further study of Table 23 reveals that, in the majority of cases there was a direct correlation between the increase or decrease in scab and the increase or decrease in the E_h of the soil due to the addition of calomel or calomel plus sugar. In five instances there was an increase in scab accompanied by an increase in the E_h, while a de-crease in scab was accompanied by a decrease in E_h in seven other instances. In six others an inverse correlation existed.

In the first crop calomel plus glucose was, as a rule, less effective than calomel alone, while in the second crop the reverse was true excepting in one soil - No. 3. Calomel caused an increase in scab in soils Nos. 4 and 5. There was no correlation between the natural E_h of the soil and the

amount of scab which the untreated soil produced. The figures for scab in Table 23 show that calomel alone or with sugar reduced infection in varying degrees as compared with the checks, excepting in one instance. Temperature did not seem to affect the action of either on E_h or on scab control.

The E_h values were measured after the first crop was harvested but not following the harvest of the second crop. The relationships between the E_h of the soil and the calomel and those between the E_h and the scab, therefore, were not obtained for this crop. Tables 22 and 22-A give the amount of scab occurring on the tubers for the two conditions of moisture and temperature. The former table deals with the first crop and the latter with the second. Insofar as the amount of scab shown under high moisture conditions is negligible, the results for the low moisture conditions are the only ones worth consideration. Tables 22 and 22-A bring out clearly that high temperature and low soil moisture are conditions favouring scab development.

Experiment 2: Effectiveness of Field Chemical Treatments in Controlling Scab under Greenhouse Conditions.

In the fall of 1937 an experiment was set up to determine if there was a similarity of behaviour when chemicals were applied to the same soil under field and greenhouse conditions. The most effective chemicals in controlling scab in the field were chosen for this purpose along with two others. The latter two were merely curiosities. The soil was analyzed for microfloral content at the completion of this experiment in order to compare the effects of the different chemicals upon the soil micro-organisms.

Materials and Methods.

The methods used for this experiment were the same as those described for experiment 1. The soil, however, was taken from the farm of Mr. Legault because effective control was obtained in this soil in the field and because it was high in scab. It is the same soil as is described for this grower under "Field Studies, 1937." The temperature of the greenhouse was maintained within the range of 65° F. to 70° F., while the moisture conditions were not specific. The treatments were as follows:

1. Calomel - 10 lbs. to the acre mixed with infusiorial earth.
2. Calomel - 5 lbs. to the acre mixed with infusorial earth.
3. Yellow oxide of mercury - 5 lbs. to the acre mixed with infusorial earth.

4. Sodium chloride - 500 lbs. to the acre.

5. Soot - 1,000 lbs. to the acre.

Results.

The results of experiment 2 appear in Table 24. They can be compared conveniently with the results of the field experiment carried out on Mr. Legault's farm (Table 12) from which the soil for the greenhouse tests was taken. The field results show that calomel (5 lbs. to the acre) mixed with celite gave better control in the greenhouse than in the field, while calomel (10 lbs. to the acre) mixed with celite and yellow oxide of mercury (5 lbs. to the acre) mixed with celite gave considerably less control in the greenhouse than in the field. One of the treatments, soot, tried out in the greenhouse, compared favourably with calomel (10 lbs. to the acre) mixed with celite according to the figures in Table 24. All treatments reduced the number of soil actinomyces and bacteria, while the effect upon the fungi was variable.

DISCUSSION

Soil microflora and scab control.

In an extensive field survey on potato scab conducted in the Montreal district during the past few summers scab has been found severe in fields where con--ditions, notably pH, were, according to present-day information upon the influence of environmental factors upon scab development, thought to be unfavourable . Other fields in which conditions, notably pH and cultural practices seemed very favourable for development of this disease were found which produced little or practically no scab. It has long been recognized that certain environmental factors of the soil exert a major influence in determining the severity of potato scab. Observations of this kind are very common in the literature, although accurate experimental work to test these are not very numerous. While most of the experimental evidence is in agreement that scab is favoured by low soil moisture, warm temperature and neutral or slightly alkaline reactions of the soil, it is quite often difficult if not impossible to correlate the actual field occurrence of the disease with the experimental findings obtained under controlled conditions. This indicates that other factors are operating. One of these may possibly be the interactions, antagonistic or synergistic, between the scab organism and other soil microorganisms.

The soil with its large mixed population of micro-organisms has given many examples of such competition. The antagonistic interrelationships existing among the soil

microorganisms has received considerable attention in recent years from the standpoint of the possibility of suppressing the growth and virulence of soil-borne plant pathogens by the activities of antagonistic soil micro-organisms. A few observations have been made relative to common scab of potatoes in this regard. Sanford (23) and Millard (18) obtained control of this disease by plowing under a green crop and both believed that this occurred because of inhibiting effects on A. scabies through the development of other organisms such as bacteria or saprophytic actinomyces in the green manure. Daines (8) has also reported an antagonistic action of a species of Trichoderma against A. scabies and Rhizoctonia solani. With the above facts in mind studies on possible antagonism between A. scabies and four moulds which had been commonly isolated from potato soils were carried out.

The four moulds were Aspergillus niger, Penicillium 17-1, Penicillium 27-1 and Trichoderma lignorum. The last named has particular signigicance as it has been investigated widely in connection with its antagonistic properties towards soil-borne parasites. Some investigators have already suggested that Trichoderma lignorum reduces scab in some soils. The soils chosen were from typical potato fields in the district of Montreal. These were known to be high in scab and possessed the other necessary requirements for the ex-periments as planned. The trials with the first three of the above mentioned organisms were conducted in a sterilized greenhouse compost soil in order to provide a medium which would be free from the organisms present in the soil in its

natural state. The trials with Trichoderma lignorum were carried out in both a sterilized and an unsterilized soil for the purpose of comparison under the two sets of conditions. Contamination set in in both of the sterilized soils as can be seen in the checks to which no inocula were added.

Throughout these experiments there was only slight if any effect upon scab occurrence by the four moulds used in the tests. The Penicillia, and Trichoderma lignorum in one test seemed slightly to increase scab, while Aspergillus niger and Trichoderma in three tests had no effect. There was evidence, however, that the moulds themselves were antagonized by other soil microorganisms. Failure to recover Aspergillus at the end of the first experiment (Table 1) is a strong indication in this direction. Further evidence of this point is that, while the other moulds were recovered through soil analysis, their numbers were considerably lower after the harvest of the second crop as compared with the first. On the other hand there is also evidence of antagonism and of synergism displayed by the moulds towards other of the soil microflora. In tests with Aspergillus niger and Penicillium 17-1 the soil bacteria increased with increased amounts of scab inoculum only in pots to which the test organism had been added, indicating possible synergistic activities between the test organisms and the bacteria in antagonizing the soil actinomyces which showed a decrease in numbers. There is, however, some doubt as to the soundness of this suggestion in view of the

fact that Penicillium 17-1 apparently was antagonized by the inoculum of Actinomyces scabies, and, since Aspergillus was not recovered it is possible that the wheat and barley included in the test inoculum were responsible for the increased numbers of bacteria which in turn may have antagonized the actinomyces in the soil The fact that the addition of scab inoculum generally decreased the number of fungi, in the case of the tests with Penicillium 17-1, excepting in pots to which none of the test organism inoculum had been added, is an indication that the soil fungi were antagonized by Penicillium 17-1.

Although the test organisms did not control scab it is interesting to note the general effect which their inocula had upon the various groups of soil microflora. The soil actinomyces were consistently increased, while the bacteria increased in all but two of the tests. The fungi, on the other hand, decreased in three of the tests, increased in another and were not affected in three others. The test organism increased in four of the seven tests. The greater variations in the behaviour of the bacteria, fungi and recovered test organism occur between the sterilized and unsterilized soils, used in the tests with Trichoderma lignorum.

A close study of Tables 2, 2-A, 3, 3-A, 4, 4-A 5 and 5-A, keeping in mind the above generalizations, has led to the conjecture to follow. Since the bacteria neither increased nor decreased in the first crop but increased in the second when Trichoderma was added to the unsterilized soil, and since the test organism was fairly numerous in the first crop but much less so in the second, it appears that the

bacteria were antagonized by Trichoderma when the latter was present in sufficient numbers. The same suggestion might also apply to the soil fungi in the unsterilized soil as well as for the bacteria in the sterilized soil but reasons for the behaviour of the other microorganisms in the latter soil are difficult to explain.

The general effects of inoculating Actinomyces scabies into the soils are worth while considering because they add support to a general statement to be made later concerning the relationship between the soil microflora and the occurrence of scab. The addition of scab inoculum decreased the soil actinomyces in the case of the test with Aspergillus, but increased the scab;in both tests with the two Penicillia, both the Actinomyces and the amount of scab decreased with increased inoculum. The Penicillia recovered also decreased. All of the organisms along with the amount of scab increased for both crops in the sterilized soil to which Trichoderma had been added. Thus it would appear that the addition of scab inoculum favoured the development of the three types of organisms in this soil. The fluctuations in the numbers of soil actinomyces, bacteria and fungi show quite definitely that there is no correlation between these organisms and the occurrence of scab. This statement is further borne out by observations made during the summer of 1936 but which are not directly connected with the work undertaken as a basis for this thesis.

The preceding observations are based on results which do not showed the exact effects of the mixture of wheat and barley which formed a part of the inoculum used for each test organism. It is easy to conceive of the wheat and barley becoming an effective medium not only for the organisms cultured on it but also for the other groups of soil organisms thus leading to an alteration in the soil microfloral content due merely to the wheat and barley introduced into the soil An experiment was therefore carried on in 1937 to determine the effect of wheat and barley as related to the foregoing results. In these tests Penicillium 40 was used instead of Penicillia 17-1 and 27-1 along with Aspergillus niger and Trichoderma lignorum.

It would appear from the results of this experiment that wheat and barley aided the scab organism, causing an increase in the amount of scab. (Tables 7 and 7-A). In one of the soils (the soils were those used as sterilized soils in 1936 - both sterilized) the addition of the Trichoderma inoculum decreased scab under low moisture conditions. This would seem to indicate that Trichoderma lignorum acted antagonistically towards Actinomyces scabies. The soil appeared to be important in this test as is shown by the much less marked results of soil No. 7 as compared with those of soil No. 6 When the scab inoculum was present in the pots to which either the wheat and barley mixture or the test inoculum was present, the numbers of soil actinomyces were lower than in the pots which contained no scab inoculum. This is an indication that Actinomyces scabies antagonized the other soil actinomyces. Thus it would seem from this

experiment that, while Trichoderma did not affect the occurrence of scab to any noticeable extent in the experiments of 1936, it may have counteracted a tendency of the wheat and barley included in the inoculum to increase scab. The same might have been true for the other moulds used but the results concerning Aspergillus niger and Penicillium 40 in in the 1937 tests are not as definite.

The generally accepted conditions favouring the development of scab are low moisture, high temperature and high pH. The last of these was not generally considered but the results of the various experiments are in definite agreement with the accepted concept of temperature and moisture influences. A separate experiment was run to find out if increased acidity of the soil brought about by adding sulphur to it would have any effect upon the possible antagonistic action of Trichoderma lignorum towards scab.

The results of this experiment indicated that at the higher temperature the numbers of Trichoderma increased with an increase in the amount of sulphur, at the same time reducing scab, but when (as is evidenced by the results of the second crop) sulphur did not increase the Trichoderma at this temperature the scab increased. Due to the fact that similar results were obtained for the lower temperature in the second crop it is possible that the effectiveness of the sulphur in scab control depends on a high temperature at first and later on a lower temperature.

The value of pure culture experimentation in connection with soil microorganisms cannot be too readily accepted due to the deviation from natural soil conditions. It cannot be

expected that microorganisms will behave in exactly the same way when grown in pure cultures as they do when in the soil where many complex environmental factors including a complex mixture of microorganisms come into play. However, a series of pure culture tests were run in order to throw some light, if possible, upon the results of the soil experiments. The same test organisms were used as were used in the greenhouse. The pure culture results gave evidence that, with very few exceptions, Actinomyces scabies antagonized strongly each of the four moulds, while they in turn had little if any influence upon it.

In conclusion it might be said that the results of the experiments with soil microflora indicate that the moulds used have no definite effect on scab. However, while this may be true in the case of the four organisms used in this study it does not of course follow that no such effects occur in the soil, for there are many other soil organisms which might play this role. Further experiments using different methods would be necessary to prove whether or not the results of these trials are conclusive. The pure culture tests were in agreement with those carried on in the greenhouse, but yet it is quite possible that the relationships and behaviour of these same organisms may be entirely different in the soil.

Chemicals and scab control.

In recent years efforts have been made to control various soil-borne diseases by employing fungicidal materials as soil dressings. Among these mercury salts and sulphur have received a good deal of attention as prospective agents for the control of actinomycosis of the potato. In experiments calomel, yellow oxide of mercury, bichloride of mercury and sulphur have all given some measure of control.

Observations made in the growing period during both seasons showed that mercury salts and sulphur had no stimulating or depressing effect upon the growth of the plants. There was, however, a variability in both the total yields and the marketable yields based on size of tubers alone. (Tables 19 and 21). Some of the chemicals tended to decrease these yields, others to increase them, while still others had little or no effect. Sulphur usually decreased the yields while the mercuric compounds varied in effect according to the method of applying them. The factor of major importance in connection with effect of the chemicals on yields was the type of soil, as is illustrated by the results for the several fields used.

Owing to the fact that mercury salts are only necessary in small quantities, the obvious difficulty of spreading them necessitated the use of other substances as carriers. In these experiments infusorial earth (celite) and fertilizer were employed for this purpose and to find out which was the more satisfactory. The tables on yields referred to show that while calomel mixed with celite did not tend to in-

fluence the yields, it reduced them consistently when mixed with fertilizer. This would imply quite definitely that calomel is more evenly distributed throughout the fertilizer and its effect on yield is more general than is the case when celite is used as the carrier. Besides trying the effects of different carriers, it was thought that the method of application might have some bearing upon the problem at hand. Thus the mercury salts were applied in two different ways in Mr. Dagenais' field (Table 16), in the centre and along the bank of the open furrow, covering of seed-pieces being done so that the chemical was not in contact with the tuber. The yields were reduced in two cases out of three when the chemical was placed in the centre of the row as compared with the bank of the furrow. In cases where the chemical was applied in the centre of the furrow the chemical was beneath the seed-pieces and probably in contact with them to some extent, while in cases where the chemical was applied to the bank and covered as described elsewhere, it was above the seed-pieces and not in contact with them. The results therefore would indicate that the yield was affected adversely by the roots of the plants growing down to the chemicals and by whatever contact the seed-pieces made with the mercury salts. Since only one variety, Irish Cobbler, was used it is impossible to state what might happen when other varieties are used.

Copper sulphate was used in 1936 but it reduced growth and yields and showed no merit as a control agent, either alone or mixed with calomel, so that it was left out of the 1937 trials.

Sulphur plus lime generally depressed yields and increased scab over the checks. This dressing was included as it was thought that lime might counteract the tendency of the sulphur to make the soil acid (a feature which might prove to be undesirable in some soils or in connection with certain crop rotation schemes) and at the same time not interfere with any lethal action of the sulphur against the scab organism. This dressing, however, proved to be entirely economically unsatisfactory.

The relatively poor scab control given by sulphur deserves special mention as it has been reported as giving good results in certain soils by some investigators, and its use as a soil dressing has been recommended as a scab control measure. It has given no promise of having any economic value in the soils of the district concerned in these studies.

The mercury salts have given the most promising, though not in all cases satisfactory, results. Grouping all tests together and listing them in decreasing order of merit they are as follows: (1) calomel mixed with fertilizer; (2) calomel, 10 lbs. per acre mixed with celite; (3) yellow oxide of mercury, 5 lbs. per acre mixed with celite; (4) calomel, 5 lbs. per acre mixed with celite; (5) sulphur; (6) sulphur mixed with lime.

In connection with the effectiveness of calomel mixed with fertilizer, it is likely that this is due chiefly to the fact that the calomel is better distributed throughout than it is when celite is used as the carrier. It is interesting to note that in Mr. J. Charbonneau's field where, with the exception of the last four treatments, fertilizer was not applied, the fertilizer in the fertilizer plus calomel treatment effected a considerable reduction in scab as compared with the celite plus calomel (10 lbs. per acre). This indicates that the fertilizer aids in reducing scab unless the effect is entirely due to its better suitability as a carrier

However, a perusal of the figures in Tables 11 to 17 inclusive shows that no one salt had any constant advantage over another and the order of their relative effectiveness altered somewhat with the different fields; one chemical may be more effective in one soil than in another; one may fail where another succeeds, while each may be effective in certain soils. This indicates that soil type or the soil environment has something to do with the action of these salts, and the chemicals, for best results, would need to be selected according to a full knowledge of the interactions between such salts and the particular soils involved. This, of course, cannot be done with present day knowledge.

In the main, however, each soil tended to affect all the mercury treatments in the same direction. For example, in Mr. Chalifoux's field, No. 2, all treatments effected little and entirely unsatisfactory control, while in certain

other fields they gave very good control. This further complicates the matter and is against the adoption of the use of these chemicals by growers in general. If one knew the soil factors determining the therapeutic potentialities of these salts it might then be possible to predict their performance with a workable degree of certainty and to make recommendations relative to their feasibility and proper use in any specific field.

Since soils are so extremely complex biologically, physically and chemically, it is impossible to conjecture as to just why it is that the fungicides have worked with such variable results, and it probably would take much experimentation to obtain any clue to this. However, two attempts were made along this line. The first of these was the inclusion of the copper sulphate and copper sulphate plus calomel treatments in the 1936 field tests. As such a small amount of the calomel is so effective in scab control, it seems fairly evident that the therapeutic action must be due to some volatile material, and this is most likely to be the mercury. If this be true then the addition of some element higher in the electromotive series, such as copper, might be expected to improve the action of the calomel, as its tendency would be to keep the mercury in the unbound state. The fact that the copper salt improved the action of the calomel seems to indicate that the conjecture, namely, that the mercury could not act in certain soils because it was thrown out of action by forming non-disinfecting compounds with other substances in the soil, was correct.

The second effort to throw some light upon the interaction of soil and calomel involved a greenhouse experiment carried out during the winter of 1936. The idea back of this experiment was that the oxidation-reduction potential of the soil might be important in this regard. By the use of high moisture and glucose in the soil, either alone or in combination, an attempt was made to establish a low oxidation-reduction potential and to establish a higher one by maintaining low soil moisture. The control of scab in the same soil under these conditions was determined and correlated with the actual E_h established. The results are given in Table 23. In the majority of cases there was a direct correlation between the increase or decrease in scab and the increase or decrease in the corresponding E_h values when corresponding treatments are compared with each other or with their checks. In other words, in general, the lower the E_h value the better was the control for any one soil. In one test (soil No. 4, temperature 60^o F.), scab was increased by calomel. In this instance, the soil had a very low natural E_h which was increased by the addition of the calomel. In all other cases calomel had controlled scab and this was accompanied by a lowering of the E_h of the soil.

Microfloral soil analyses to determine alterations in the soil microfloral content due to the chemicals did not show any definite tendencies. The microfloral content did change but there is no correlation between the occurrence or control of scab and these changes, either when the total, individual,

or relative numbers for the actinomyces, bacteria and fungi are considered.

Throughout all the greenhouse studies it was observed that moisture and temperature were very important factors influencing scab development. The conditions favouring scab were high temperature and low moisture.

Finally it should be stated that the mercury dressings did not give in any case perfect control. They gave decided economic control in certain fields while in others they failed in this regard. More work is justified to determine the range of soils and conditions over which they will work as they hold out much promise of being effective measures, at least in certain soils. The discovery of the factor or factors determining this variability in their therapeutic action is much to be desired.

SUMMARY.

1. Four moulds, Trichoderma lignorum, Aspergillus niger, Penicillium 17-1 and Penicillium 27-1, common in soils devoted to potato growing in the Montreal district showed no antagonism towards Actinomyces scabies as measured by occurrence of common scab of potato in pot tests conducted in the greenhouse during the winter of 1936. Each test involving high and low moistures was run at 60° F. and 75° F. In a similar test in 1937 Trichoderma lignorum showed slight signs of antagonism.

2. The addition of Actinomyces scabies inoculum to the pots usually increased scab but had little, if any, effect upon the actinomyces, fungi and bacteria in the soils.

3. In pure culture, Actinomyces scabies showed strong antagonism towards the above mentioned moulds, which in turn did not appear to be antagonistic towards the scab organism.

4. Aspergillus niger was apparently strongly antagonized by the soil microorganisms in certain tests, as it could not be recovered from the pots into which it had been inoculated.

5. In some instances sulphur added to the soil increased Trichoderma lignorum and at the same time reduced scab. This may be due to an antagonistic action of the Trichoderma.

6. There was no correlation between the occurrence of scab and the total, relative or individual numbers of bacteria, actinomyces and fungi in the soil.

7. The microfloral content following a second crop was often markedly changed from what it was after the first crop. This did not appear to affect scab occurrence or to be determined by the test organisms.

8. Calomel, 10 lbs. per acre plus celite, calomel, 10 lbs. per acre plus fertilizer, calomel, 5 lbs. per acre plus celite, yellow oxide of mercury, 5 lbs. per acre plus celite, sulphur and sulphur plus lime when applied as soil dressings gave various degrees of control of scab in a number of soils.

9. The degree of control varied from very good to slight, depending on the chemical, the carrier, but mainly on the soil.

10. The mercurial salts gave very satisfactory economic control in certain soils while the sulphur did not prove satisfactory in any instance.

11. Calomel was much more effective when mixed with the fertilizer as a carrier than with infusorial earth (celite) as the carrier.

12. Copper sulphate at the rate of 35 lbs. per acre improved control of scab by calomel but reduced growth and yield.

13. There was some evidence that the E_h of the soil influenced the effectiveness of calomel.

14. Throughout the greenhouse experiments most scab developed under conditions of low soil moisture and warm temperature.

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Table 1.

Effect of Aspergillus niger and two species of Penicillium on Scab Occurrence - Soil 7

Scab Inoculum	Plate Counts: Actinomyces — Organism inoculum: None	50 gm.	125 gm.	Totals	Fungi — Organism inoculum: None	50 gms	125 gm.	Totals	Bacteria — Organism inoculum: None	50 gm.	125 gm.	Totals	Test Organism — Organism inoculum: None	50 gm.	125 gm.	Totals	Per cent Scab coverage — Organism inoculum: None	50 gm.	125 gm.	Totals
Effect of Aspergillus niger.																				
None	43	81	138	262	716	792	1024	2532	19	21	22	62	0	0	0	0	0.33	3.33	2.33	5.99
25 gms.	26	27	48	101	776	64	440	1280	8	31	72	111	0	0	0	0	0.33	2.33	2.16	4.82
50 gms.	24	64	93	181	316	352	29	697	16	43	152	211	0	0	0	0	5.00	0.83	1.00	6.83
Totals	93	172	279		1808	1208	1493		43	95	246		0	0	0		5.66	6.49	5.49	
Effect of Penicillium 17-1																				
None	43	47	107	197	716	251	444	1411	19	62	56	137	-	218	324	542	0.33	3.33	2.33	5.99
25 gms.	26	98	72	196	776	54	477	1307	8	93	256	357	-	54	471	525	0.00	2.83	1.00	3.83
50 gms.	24	28	35	87	316	2	67	385	16	140	260	416	-	2	60	62	0.16	2.33	1.00	3.49
Totals	93	173	214		1808	307	988		43	295	572		-	274	855		0.49	8.49	4.33	
Effect of Penicillium 27-1																				
None	43	146	199	388	716	212	872	1800	19	116	272	407	-	153	855	1008	0.33	3.33	2.33	5.99
25 gms.	26	177	192	395	776	12	76	864	8	136	232	376	-	3	22	25	0.00	1.66	0.50	2.16
50 gms.	24	180	180	384	316	333	420	1069	16	160	204	380	-	277	307	584	1.00	0.16	0.86	2.02
Totals	93	503	571		1808	557	1368		43	412	708		-	433	1184		1.33	5.15	3.69	

Note:- All plate count figures in this paper represent the actual number of colonies counted. The dilution factor in all experiments is 100,000.

Note 2:- ~~The average per cents have not been calculated but have been left as total percentages in the "totals" column. This explains the high percentages occurring throughout these tables.~~

Table 2.

First crop

Effect of Trichoderma lignorum on Scab Occurrence - Soil No. 5

Temperature	Moisture	Plate Counts: Actinomyces, Trichoderma inoculum: none	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.	Fungi, Trichoderma inoculum: none	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.	Bacteria, Trichoderma inoculum: none	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.	Trichoderma, Trichoderma inoculum: none	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.	Per cent Scab Coverage, Trichoderma inoculum: none	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.
75°F.	high	2020	32	55	160	2680	1047	9800	117	18	3400	64	278	0	1	5	14	0.00	1.00	0.00	0.00
"	low	7	15	23	0	84	325	272	281	100	24	97	313	0	0	4	24	0.00	0.33	2.00	0.16
60°F.	high	51	2	27	192	1550	45	1520	1060	144	27	13	348	4	0	0	20	0.00	0.16	0.08	0.16
"	low	23	32	37	472	370	10900	2060	1740	172	248	88	460	0	18	20	19	0.00	0.35	0.00	0.33
Totals		2101	81	142	824	4684	12317	13652	3198	434	3699	262	1399	4	19	29	77	0.00	1.84	2.08	0.65
Averages		525	20	35	206	1171	3079	3413	799	108	925	65	349	1	5	7	19	0.00	0.46	0.52	0.16
Average X dilution factor (millions)		52.5	2.0	3.5	20.6	117.1	307.9	341.3	79.9	10.8	92.5	6.5	34.9	0.1	0.5	0.7	1.9				

Second crop

Table 2-A.

75°F.	high	12	24	32	38	21	142	105	75	10	15	59	40	2	3	20	2	0.00	0.00	0.00	0.86
"	low	29	168	45	148	200	52	536	182	59	170	32	56	2	3	3	8	3.92	4.33	2.33	2.72
60°F.	high	11	23	51	6	205	244	464	28	48	45	52	25	0	0	2	0	0.00	0.00	0.16	0.16
"	low	21	31	30	280	116	77	77	72	80	53	51	376	0	0	3	3	3.66	1.42	0.83	5.33
Totals		73	246	158	472	542	515	1182	357	197	283	194	497	4	6	28	13	7.58	5.75	3.32	9.07
Averages		18	61	39	118	135	129	295	89	49	71	48	124	1	1.5	7	3	1.89	1.44	0.83	2.27
Average X dilution factor (millions)		1.8	6.1	3.9	11.8	13.5	12.9	29.5	8.9	4.9	7.1	4.8	12.4	.1	.15	.7	.3				

Table 3.

First Crop — Effect of *Trichoderma lignorum* on Scab Occurrence - Soil No. 6

Temperature	Moisture	Scab inoculum	Plate Counts: Actinomyces, Trichoderma inoculum: none	Actinomyces, Trichoderma inoculum: 100,000 sp./gm.	Actinomyces, Trichoderma inoculum: 1,000,000 sp./gm.	Actinomyces, Trichoderma inoculum: 10,000,000 sp./gm.	Fungi, Trichoderma inoculum: none	Fungi, Trichoderma inoculum: 100,000 sp./gm.	Fungi, Trichoderma inoculum: 1,000,000 sp./gm.	Fungi, Trichoderma inoculum: 10,000,000 sp./gm.	Bacteria, Trichoderma inoculum: none	Bacteria, Trichoderma inoculum: 100,000 sp./gm.	Bacteria, Trichoderma inoculum: 1,000,000 sp./gm.	Bacteria, Trichoderma inoculum: 10,000,000 sp./gm.	Trichoderma, Trichoderma Inoculum: none	Trichoderma, Trichoderma Inoculum: 100,000 sp./gm.	Trichoderma, Trichoderma Inoculum: 1,000,000 sp./gm.	Trichoderma, Trichoderma Inoculum: 10,000,000 sp./gm.	Per cent Scab Coverage, Trichoderma inoculum: none	Per cent Scab Coverage, Trichoderma inoculum: 100,000 sp./gm.	Per cent Scab Coverage, Trichoderma inoculum: 1,000,000 sp./gm.	Per cent Scab Coverage, Trichoderma inoculum: 10,000,000 sp./gm.
75°F.	high	none	192	120	212	52	188	724	1124	164	120	96	68	178	7	14	0	19	0.00	0.00	0.00	0.00
"	"	25 gms.	176	60	148	832	230	348	360	164	2074	416	388	736	6	16	28	32	8.33	26.83	4.25	7.50
"	"	50 gms.	132	148	100	552	293	54	99	13	128	208	308	568	5	3	23	43	9.79	9.16	8.50	2.75
Sub-totals			500	328	460	1436	711	1126	1583	341	2322	720	764	1482	18	33	51	94	18.12	35.99	12.75	10.25
75°F.	low	none	16	6	172	488	1690	37	468	-	296	96	129	708	7	16	20	27	0.00	0.00	0.16	1.08
"	"	25 gms.	348	560	320	544	454	693	380	160	3368	824	688	832	15	21	28	28	7.25	1.83	1.00	0.66
"	"	50 gms.	128	392	656	628	324	160	172	168	728	824	584	1288	27	18	33	32	8.66	3.50	3.83	13.33
Sub-totals			492	958	1148	1660	2468	890	1020	328	4392	1744	1401	2828	49	55	81	87	15.91	5.33	4.99	15.07
60°F.	high	none	1	4	144	284	1522	1360	544	1668	2	5	13	7	2	5	23	0	0.00	0.00	0.00	0.00
"	"	25 gms.	60	48	52	256	568	4544	2040	2633	43	14	14	18	6	2	5	3	4.25	0.33	0.00	0.25
"	"	50 gms.	32	15	9	140	2760	1668	480	368	48	11	14	47	6	0	12	32	0.33	0.50	1.83	0.83
"	Sub-totals		93	67	205	680	4850	7572	3064	4669	93	30	41	72	14	7	40	35	4.58	0.83	1.83	1.08
60°F.	low	none	64	60	128	552	176	844	16	17	45	44	143	114	9	2	44	51	0.00	0.00	0.00	0.33
"	"	25 gms.	40	148	188	440	1592	1024	2240	560	184	88	100	36	25	5	13	31	3.33	0.66	15.00	6.66
"	"	50 gms.	152	92	84	506	37	4840	1960	870	204	16	220	160	11	0	7	42	0.50	5.83	13.50	4.50
Sub-totals			256	300	400	1498	1805	6708	4216	1447	433	148	463	310	45	7	64	124	3.83	6.49	28.50	11.49
Totals			1341	1653	2213	5274	9834	16296	9883	6785	7240	2642	2669	4692	126	102	236	340	42.44	48.64	48.07	37.89
Averages			112	138	184	439	820	1358	823	617	603	220	222	383	10	9	19	28	3.54	4.05	4.01	3.16
Average X dilution factor (millions)			11.2	13.8	18.4	43.9	8.2	135.8	82.3	61.7	60.3	22.0	22.2	38.3	1.0	.9	1.9	2.8				

Table 3-A.

Second crop. Effect of *Trichoderma lignorum* on Scab Occurrence - Soil No. 6

Temperature	Moisture	Scab Inoculum	Plate Counts: Actinomyces — Trichoderma inoculum: None	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.	Plate Counts: Fungi — Trichoderma inoculum: None	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.	Plate Counts: Bacteria — Trichoderma inoculum: None	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.	Plate Counts: Trichoderma — Trichoderma inoculum: None	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.	Per cent Scab Coverage — Trichoderma inoculum: None	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.
75°F	high	none	10	2	24	12	50	86	127	1	19	24	42	17	0	0	0	0	0.00	0.00	0.00	0.00
"	"	25 gms.	34	6	29	28	1	205	436	223	152	56	96	216	0	5	4	35	5.33	2.00	0.16	4.66
"	"	50 gms.	39	19	15	27	372	67	540	480	89	44	57	139	1	1	4	19	0.92	0.50	0.16	6.83
Sub-totals			83	27	68	67	423	358	1103	704	260	124	195	372	1	6	8	54	6.25	2.50	0.32	11.49
75°F	low	none	9	12	39	150	316	12	304	148	13	18	55	286	1	4	9	22	2.16	4.50	4.00	2.42
"	"	25 gms.	7	43	17	96	1220	39	3	48	47	46	127	596	5	13	5	20	64.44	93.33	83.33	60.00
"	"	50 gms.	26	14	42	51	448	764	272	36	32	84	198	153	7	0	10	16	75.55	97.77	70.00	53.33
Sub-totals			42	69	98	297	1984	815	579	232	92	148	380	1035	13	17	24	58	142.15	195.60	157.33	115.75
60°F	high	none	10	8	18	62	59	120	352	404	29	58	67	210	6	4	11	15	0.00	0.00	0.00	0.00
"	"	25 gms.	15	11	25	39	14	284	548	24	45	34	61	139	3	2	1	20	0.25	0.00	0.16	0.21
"	"	50 gms.	12	12	21	144	244	224	340	244	58	46	45	65	2	2	1	6	0.16	0.00	0.00	0.47
Sub-totals			37	31	64	245	317	628	1240	672	132	138	173	414	11	8	13	41	0.41	0.00	0.16	0.68
60°F	low	none	15	39	29	61	17	536	65	39	31	46	111	153	8	0	8	38	3.25	1.08	10.61	1.21
"	"	25 gms.	13	48	57	144	700	287	56	83	91	51	42	80	0	2	15	28	71.66	51.66	42.77	46.66
"	"	50 gms.	71	106	84	220	116	110	270	2213	128	147	133	248	10	3	6	0	0.00	53.50	73.33	69.55
Sub-totals			99	193	170	425	833	933	391	2335	250	244	286	481	18	5	29	66	74.91	106.24	126.71	117.42
Total			261	320	400	1034	3557	2734	3313	3943	734	654	1034	2302	43	36	74	219	223.72	304.34	284.52	245.34
Averages			22	27	33	86	295	228	276	329	60	55	86	192	4	3	6	18	18.64	25.36	23.71	20.45
Average X dilution factor (millions)			2.2	2.7	3.3	8.6	29.5	22.8	27.6	32.9	6.0	5.5	8.6	19.2	.4	.3	.6	1.8				

Table 4.

Effect of Trichoderma lignorum on Scab Occurrence - Soil 5.

First crop	Plate Counts: Actinomyces — Trichoderma Inoculum: none	100,000 sp. per gm.	1,000,000 sp. per gm.	10,000,000 sp. per gm.	Totals
Totals	2101	81	142	824	3148
75°F.	2027	47	78	160	2312
60°F.	74	34	64	664	836
High	2071	34	82	352	2539
Low	30	47	60	472	609

First crop	Plate Counts: Fungi — Trichoderma Inoculum: None	100,000 sp. per gm.	1,000,000 sp. per gm.	10,000,000 sp. per gm.	Totals
Totals	4684	12317	13652	3198	33851
75°F.	2764	1372	10072	398	14606
60°F.	1920	10945	3580	2800	19245
High	4230	1092	11320	1177	17819
Low	454	11225	2332	2021	16032

First crop	Plate Counts: Bacteria — Trichoderma Inoculum: None	100,000 sp. per gm.	1,000,000 sp. per gm.	10,000,000 sp. per gm.	Totals
Effect of Inoculum					
Totals	434	3699	262	1399	5794
Effect of Temperature					
75°F.	118	3424	161	591	4294
60°F.	316	275	101	808	1500
Effect of Moisture					
High	162	3427	77	626	4292
Low	272	272	185	773	1502

First crop	Plate Counts: Trichoderma — Trichoderma Inoculum: None	100,000 sp. per gm.	1,000,000 sp. per gm.	10,000,000 sp. per gm.	Totals
Totals	4	19	29	77	129
75°F.	0	1	9	38	48
60°F.	4	18	20	39	81
High	4	1	5	34	44
Low	0	18	24	43	85

First crop	Per cent Scab Coverage — Trichoderma Inoculum: None	100,000 sp. per gm.	1,000,000 sp. per gm.	10,000,000 sp. per gm.	Totals
Totals	0.00	1.84	2.08	0.65	4.57
75°F.	0.00	1.33	2.00	0.16	3.49
60°F.	0.00	0.51	0.08	0.49	1.08
High	0.00	1.16	0.08	0.16	1.40
Low	0.00	0.68	2.00	0.49	3.17

Table 4-A

Second crop	Actinomyces — Trichoderma Inoculum: none	100,000 sp. per gm.	1,000,000 sp. per gm.	10,000,000 sp. per gm.	Totals
Totals	73	246	158	472	949
75° F.	41	192	77	186	496
60° F.	32	54	81	286	453
High	23	47	88	44	202
Low	50	199	75	428	752

Second crop	Fungi — Trichoderma Inoculum: None	100,000 sp. per gm.	1,000,000 sp. per gm.	10,000,000 sp. per gm.	Totals
Totals	542	515	1182	357	2596
75° F.	221	194	641	257	1313
60° F.	321	321	541	100	1283
High	226	386	569	103	1284
Low	316	129	613	254	1312

Second crop	Bacteria — Trichoderma Inoculum: None	100,000 sp. per gm.	1,000,000 sp. per gm.	10,000,000 sp. per gm.	Totals
Effect of Inoculum					
Totals	197	283	194	497	1171
Effect of Temperature					
75° F.	69	185	91	96	441
60° F.	128	98	103	401	730
Effect of Moisture					
High	58	60	111	65	294
Low	139	223	83	432	877

Second crop	Trichoderma — Trichoderma Inoculum: None	100,000 sp. per gm.	1,000,000 sp. per gm.	10,000,000 sp. per gm.	Totals
Totals	4	6	28	13	51
75° F.	4	6	23	10	43
60° F.	0	0	5	3	8
High	2	3	22	2	29
Low	2	3	6	11	22

Second crop	Per cent Scab Coverage — Trichoderma Inoculum: None	100,000 sp. per gm.	1,000,000 sp. per gm.	10,000,000 sp. per gm.	Totals
Totals	1.89	1.44	0.83	2.27	6.43
75° F.	3.92	4.33	2.33	3.58	14.16
60° F.	3.66	1.42	0.99	5.49	11.56
High	0.00	0.00	0.16	1.02	1.18
Low	7.58	5.75	3.16	8.05	24.54

Note: Totals were taken from Tables 2 and 2A; they are also the totals for the two temperatures and two moistures given in the above tables (4 and 4A).

Table 5.

First crop — Effect of *Trichoderma lignorum* on Scab Occurrence - Soil No. 6.

Scab Inoculum	Plate Counts: Actinomyces, Trichoderma inoculum: none	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.	Totals	Fungi, Trichoderma inoculum: none	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.	Totals	Bacteria, Trichoderma inoculum: none	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.	Totals	Trichoderma, Trichoderma inoculum: none	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.	Totals	Per cent Scab coverage, Trichoderma inoculum: none	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.	Totals
Effect of Inoculum																									
None	273	190	656	1376	2495	3576	2965	2152	1849	10542	463	241	353	1007	2064	25	37	87	97	246	0.00	0.00	0.16	1.41	1.57
25 gms.	624	816	708	2072	4220	2844	6609	5020	3517	17990	5669	1342	1190	1622	9823	52	44	74	94	264	23.16	29.65	20.25	15.07	88.13
50 gms.	444	647	849	1826	3766	3414	6722	2711	1419	14266	1108	1059	1126	2063	5356	49	21	75	149	294	19.28	18.99	27.66	21.41	87.34
Totals	1341	1653	2213	5274		9834	16296	9883	6785		7240	2642	2669	4692		126	102	236	340		42.44	48.64	48.07	37.89	
Effect of Temperature																									
75° F.	992	1286	1608	3096	6982	3179	2016	2603	669	8467	6714	2464	2165	4310	15653	67	88	132	181	468	34.03	41.32	17.74	25.32	118.41
60° F.	349	367	605	2178	3499	6655	14280	7280	6116	34331	526	178	504	382	1590	59	14	104	159	336	8.41	7.32	30.33	12.57	58.63
Effect of Moisture																									
High	593	395	665	2116	3769	5561	8698	4647	5010	23916	2415	750	805	1554	5524	32	40	91	129	292	22.70	36.82	14.58	11.33	85.43
Low	748	1258	1548	3158	6712	4273	7598	5236	1775	18882	4825	1892	1864	3138	11719	94	62	145	211	512	19.74	11.82	33.49	26.56	91.61

Second crop

Table 5-A.

Scab Inoculum	none	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.	Totals	none	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.	Totals	none	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.	Totals	none	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.	Totals	none	100,000 sp./gm.	1,000,000 sp./gm.	10,000,000 sp./gm.	Totals
Effect of Inoculum																									
None	44	61	110	285	500	442	754	848	592	2636	92	146	275	666	1179	15	8	28	75	126	5.41	5.58	14.61	3.63	29.23
25 gms.	69	108	128	307	612	1935	815	1043	378	4171	335	186	326	1031	1878	8	22	25	103	158	141.68	146.99	126.42	111.53	526.62
50 gms.	148	151	162	442	903	1180	1165	1422	2973	6740	307	321	433	605	1666	20	6	20	41	87	76.63	151.77	143.49	130.18	502.07
Totals	261	320	400	1034		3557	2734	3313	3943		734	653	1034	2302		43	36	73	219		223.72	304.34	284.52	245.34	
Effect of Temperature																									
75° F.	125	96	166	364	751	2407	1173	1682	936	6198	352	272	575	1407	2606	14	23	32	112	181	148.40	198.10	157.65	127.24	631.39
60° F.	136	224	234	670	1264	1150	1561	1631	3007	7349	382	382	459	895	2118	29	13	42	107	191	75.32	106.24	126.87	118.10	426.53
Effect of Moisture																									
High	120	58	132	312	622	740	986	2343	1376	5445	392	262	368	786	1808	12	14	21	95	142	6.66	2.50	0.48	12.17	21.81
Low	141	262	268	722	1393	2817	1748	970	2567	8102	342	392	666	1516	2916	31	22	53	124	230	217.06	301.84	284.04	233.17	1036.11

Table 6.

General Comparison between the Results of the First and Second Crops - Soil 6.

Summary of results based on the figures shown in Tables 5 and 5-A.

First Crop	Second Crop
Effect of Trichoderma	
1. Actinomyces increased as inoculum increased.	1. Actinomyces increased as inoculum increased.
2. Fungi lower in checks than in pots containing 100,000 spores per gram excepting in checks containing no scab inoculum. Increasing the Trichoderma inoculum had no effect on the fungi.	2. Fungi inconsistent but showing a general tendency to decrease when 100,000 spores per gram were added, followed by an increase when the inoculum was increased.
3. Bacteria higher in the checks than in the pots containing 100,000 spores per gram, but increased as the inoculum increased.	3. Bacteria increased as the inoculum increased.
4. Scab coverage without a definite tendency, neither increasing nor decreasing significantly.	4. Scab coverage without a definite tendency.
Effect of Scab Inoculum	
1. Actinomyces in inoculated pots higher than in checks, and highest in pots inoculated with 25 grams of scab inoculum.	1. Actinomyces increased as scab inoculum increased.
2. Fungi usually higher in inoculated pots than in checks.	2. Fungi usually higher in inoculated pots than in checks.
3. Bacteria lower in checks than in inoculated pots.	3. Bacteria usually higher in inoculated pots than in checks.
4. Scab coverage increased by the addition of the inoculum, but the greater amount of inoculum was not necessarily the more effective.	4. Scab coverage usually increased as the inoculum increased.
Effect of Temperature	
1. General tendency for all types of microorganisms to increase with temperature, except fungi.	1. General tendency for actinomyces and fungi to decrease, and bacteria to increase with higher temperature. Fungi, however, increased with temperature in the checks.
2. Scab coverage increased as temperature increased.	2. Scab coverage increased as temperature increased.
Effect of Moisture	
1. General tendency for all microflora to decrease with increased moisture except fungi, which increased.	1. General tendency for all microflora to decrease with increased moisture.
2. General tendency for scab coverage to decrease with increased moisture.	2. Large decrease of scab coverage with increased moisture.

Table 7.

Effect of Wheat and Barley when used as a Cultural Medium for Aspergillus and Penicillium upon the Soil Micro-flora - Soil 7.

Scab Inoculum	Plate Counts												Per cent Scab Coverage			
	Actinomyces				Fungi				Bacteria							
	no treatment	Wheat & barley 50 gms.	A. niger 50 gms.	Pen.-40 50 gms.	no treatment	Wheat & Barley 50 gms.	A. niger 50 gms.	Pen.-40 50 gms.	no treatment	Wheat & Barley 50 gms.	A. niger 50 gms.	Pen.-40 50 gms.	no treatment	Wheat & Barley 50 gms.	A. niger 50 gms.	Pen.-40 50 gms.
None	148	328	307	192	68	376	546	28	28	25	9	54	0.00	0.10	0.11	0.05
25 gms.		196	192	76		15	62	6		47	17	20		2.99	1.84	1.27

Table 7-A

Effect of Wheat and Barley when used as a Cultural Medium for Trichoderma upon the Soil Micro-flora - Soil 6.

Scab Inoculum	Plate Counts												Per cent Scab Coverage		
	Actinomyces			Fungi			Bacteria			Trichoderma					
	no treatment	Wheat & Barley 50 gms.	Trichoderma 50 gms.	no treatment	Wheat & Barley 50 gms.	Trichoderma 50 gms.	no treatment	Wheat & Barley 50 gms.	Trichoderma 50 gms.	no treatment	Wheat & Barley 50 gms.	Trichoderma 50 gms.	no treatment	Wheat & Barley 50 gms.	Trichoderma 50 gms.
High Moisture															
None	17	20	72	264	260	72	5	2	5	0	14	3	0.05	0.00	0.00
25 gms.		62	35		175	244		10	6		3	7		7.80	8.67
Low Moisture															
None	22	28	140	60	71	13	8	1	5	4	18	8	0.05	0.08	0.00
25 gms.		40	35		36	6		1	18		22	5		25.45	2.75

Table 8.

Effect of Trichoderma in Conjunction with Sulphur

First Crop.		Plate Counts								Per cent Scab Coverage	
		Actinomyces		Fungi		Bacteria		Trichoderma			
		Trichoderma inoculum		Trichoderma inoculum		Trichoderma inoculum		Trichoderma inoculum		Trichoderma inoculum	
Temperature	Sulphur per acre	none	10,000,000 sp. per gm.	none	10,000,000 sp. per gm.	none	10,000,000 sp. per gm.	none	10,000,000 sp. per gm.	none	10,000,000 sp. per gm.
75° F.	500 lbs.	55	116	704	1304	16	55	3	26	14.50	31.66
"	800 "	78	112	223	324	48	45	0	26	9.16	7.58
60° F.	500 "	51	36	500	520	36	13	1	18	20.54	2.11
"	800 "	92	52	600	25	9	38	2	45	4.25	3.50
Totals		276	316	2027	2173	109	151	6	115	48.45	44.85
Averages		69	79	507	543	27	38	1.5	29	12.11	11.21
Averages x dilution factor (millions)		6.9	7.9	50.7	54.3	2.7	3.8	0.15	2.9		

Second Crop. Table 8-A

75° F.	500 lbs.	49	70	64	58	7	3	4	11	6.25	60.00
"	800 "	73	29	400	53	3	5	1	30	50.11	51.25
60° F.	500 "	55	34	2	110	14	5	0	20	21.33	33.52
"	800 "	103	69	80	90	9	3	0	20	15.00	17.55
Totals		280	202	546	311	33	16	5	81	92.69	162.32
Averages		70	50	136	78	8	2	1.2	20	23.17	40.58
Averages x dilution factor (millions)		7.0	5.0	13.6	7.8	0.8	0.2	0.12	2.0		

Table 9.

Effect of Trichoderma in Conjunction with Sulphur on Scab Occurrence

First crop	Plate Counts												Per cent Scab Coverage		
	Actinomyces			Fungi			Bacteria			Trichoderma					
	Trichoderma inoculum			Trichoderma Inoculum			Trichoderma Inoculum			Trichoderma Inoculum			Trichoderma Inoculum		
	none	10,000,000	Totals	none	10,000,000	Totals	none	10,000,000	Totals	none	10,000,000	Totals	none	10,000,000	Totals
						Effect of Inoculum									
Totals	276	316	592	2027	2173	4200	109	151	260	6	115	121	48.45	44.85	93.30
						Effect of Temperature									
75° F.	133	228	361	927	1628	2555	64	100	164	3	52	55	23.66	39.24	62.90
60° F.	143	88	231	1100	545	1645	45	51	96	3	63	66	24.79	5.61	30.40
						Effect of Sulphur									
500 lbs. per acre	106	152	258	1204	1824	3028	52	68	120	4	44	48	35.04	33.77	68.81
800 lbs. per acre	170	164	334	823	349	1172	57	83	140	2	71	73	13.41	11.08	24.49
Second crop															
						Effect of Inoculum									
Totals	280	202	482	546	311	857	33	16	49	5	81	86	92.69	162.32	255.01
						Effect of Temperature									
75° F.	122	99	221	464	111	575	10	8	18	5	41	46	56.36	111.25	167.61
60° F.	158	103	261	82	200	282	23	8	31	0	40	40	36.33	51.07	87.40
						Effect of Sulphur									
500 lbs. per acre	104	104	208	66	168	234	21	8	29	4	31	35	27.58	93.52	121.10
800 lbs. per acre	176	98	274	480	143	623	12	8	20	1	50	51	65.11	68.80	133.91

Note: Totals were taken from Tables 8 and 8A; they are also the totals for the two temperatures and two rates of sulphur given in the above table (9).

Table 10
Comparison of Percent Scab Coverage
for the three farms (1936)

Treatment	Percent Scab Coverage		
	J.B.Chalifoux	F. Bellanger	Mr. Macdonald (x)
Check	29.2	7.28	3.13
Yellow Oxide of Mercury	20.2	2.1	0.82
Calomel - 5 lbs. per acre	21.9	4.1	1.00
Calomel - 10 lbs. per acre	26.9	2.3	-
Celite + Calomel	24.3	1.2	-
Copper Sulphate + Calomel	16.5	2.1	-
Copper Sulphate	28.2	4.1	-
Sulphur	20.6	5.4	1.89
Nickel Hydrate	9.1	5.7	2.92
Aluminium Sulphate	23.9	4.4	1.85

(x) Not all the treatments were carried out on Mr. Macdonald's farm.

Table 10-A

Effect of Chemical Treatments of the Soil upon the Microfloral Content and Scab Occurrence.
Field Trials - 1936.

Grower	Chemical	Corresponding soil number in greenhouse test	Plate Counts				Percent Scab Coverage
			Actinomyces	Fungi	Bacteria	Trichoderma	
F. Bellanger	Check	3	7	39	27	0	7.28
"	Calomel, 10 lbs. per acre	3	9	65	19	0 - 1	2.30
"	Yellow oxide of mercury	3	9	121	43	0 - 3	2.10
"	Sulphur	3	22	24	29	0 - 2	5.40
J. Chalifoux	Check	1	50	217	17	0	29.20
"	Calomel, 10 lbs. per acre	1	48	8	105	0	26.90
"	Yellow oxide of mercury	1	4	11	63	0	20.20
"	Copper sulphate plus Calomel	1	7	72	89	0	16.50

Note 1:- The figures for treatments on Mr. Bellanger's farm represent the averages of four replications. Those for the treatments on Mr. Chalifoux's farm represent only one of the replications.

Note 2:- The plate counts represent the number of organisms in 1/100,000 of a gram of soil.

Table 11

Soil Treatments for Control of Common Scab of Potatoes - Field Experiments - 1937.
Farm of Mr. R. Lortie

Treatment	Percent Scab		Total yield (bushels)	Ave. wt. of tubers	Yield of marketable tubers	% of marketable tubers, by weight	Marketable yield, disease considered
	No. of tubers	Scab coverage					
Check	98.14%	17.20%	188.5 bu.	.211 lb.	153.7 bu.	81.30%	14.3 bu.
Celite + Calomel 5 lbs. per acre	80.23	6.52	156.6	.260	124.7	80.19	54.8
Celite + Calomel 10 lbs. per acre	80.49	6.58	165.2	.247	139.2	79.09	66.96
Fertilizer + Calomel 10 lbs. per acre	76.22	2.14	156.6	.232	127.6	81.24	96.8
Celite + Yellow Oxide of Mercury 5 lbs. per acre	80.44	8.07	211.7	.215	174.0	81.63	68.6
Sulphur, 800 lbs. per acre	95.47	10.25	171.7	.244	142.1	82.62	31.6
Sulphur + Lime	93.33	14.33	142.1	.213	118.9	82.61	31.1

Table 12

Soil Treatments for Control of Common Scab of Potatoes - Field Experiments - 1937.
Farm of Mr. P. Legault

Treatment	Percent Scab		Total yield (bushels)	Ave. wt. of of tubers	Yield marketable tubers	% of marketable tubers, by weight	Marketable yield, disease considered
	No. of tubers	Scab coverage					
Check	100.00%	33.48%	318.5 bu.	.208 lb	257.0 bu.	80.69%	13.1 bu.
Celite + Calomel 5 lbs. per acre	70.18	3.27	347.5	.201	293.2	84.37	143.9
Celite + Calomel 10 lbs. per acre	60.29	4.33	380.1	.225	302.1	79.47	251.7
Fertilizer + Calomel 10 lbs. per acre	37.75	2.82	289.6	.213	242.5	83.73	207.8
Celite + Yellow Oxide of Mercury 5 lbs. per acre	69.48	4.17	340.2	.220	293.2	86.18	201.5
Sulphur 800 lbs. per acre	92.56	14.91	307.7	.187	249.7	81.15	75.8
Sulphur + Lime	99.67	35.00	249.6	.223	246.1	98.59	13.2

Table 13

Soil Treatments for Control of Common Scab of Potatoes - Field Experiments - 1937.
Farm of Mr. Ernest Charbonneau

Treatment	Percent Scab		Total yield (bushels)	Ave. wt. of tubers	Yield of marketable tubers	% of marketable tubers by weight	Marketable yield, disease considered
	No. of tubers	Scab coverage					
Check	95.54%	8.48%	299.4 bu	.253 lb.	267.2 bu.	89.24%	82.5 bu.
Celite + Calomel 5 lbs. per acre	80.97	3.42	264.0	.256	228.6	86.59	152.5
Celite + Calomel 10 lbs. per acre	86.45	3.42	273.7	.251	241.5	88.23	152.3
Fertilizer + Calomel 10 lbs. per acre	67.13	2.35	238.2	.231	202 8	85.13	158.2
Celite + Yellow Oxide of Mercury 5 lbs. per acre	81.24	1.80	280.1	.301	247.9	88.50	204.7
Sulphur 800 lbs. per acre	90.73	6.29	286 5	.249	251.1	87.64	147.2
Sulphur + Lime	99.39	15.65	216.6	.224	209.3	96.62	44.1

Table 14

Soil Treatments for Control of Common Scab of Potatoes - Field Experiments - 1937.
Farm of Mr. F. Bellanger

Treatment	Percent Scab		Total yield (bushels)	Ave. wt. of tubers	Yield of marketable tubers	% of marketable tubers by weight	Marketable yield, disease considered
	No. of tubers	Scab coverage					
Check	98.40%	6.17%	238.0 bu	.294 lb	226.1 bu.	95.00%	71.2 bu.
Celite + Calomel 5 lbs. per acre	83.02	4.53	262.4	.308	237.9	90.66	123.6
Celite + Calomel 10 lbs. per acre	76.54	2.97	256.6	.317	221.8	86.43	147.0
Fertilizer + Calomel 10 lbs. per acre	70.59	2.80	236.3	.303	212.9	90.09	170.4
Celite + Yellow Oxide of Mercury 5 lbs. per acre	84.99	4.97	307.3	.340	274.0	89.16	135.5
Sulphur 800 lbs. per acre	91.76	11.48	237.7	.306	208.7	87.79	71.8
Sulphur + Lime	99.37	16.07	207.3	.275	179.7	86.68	11.4

Table 15

Soil Treatments for Control of Common Scab of Potatoes - Field Experiments - 1937.
Farm of Mr. Joseph Charbonneau

Treatment	Percent scab		Total Yield (bushels)	Ave. wt. of tubers	Yield of marketable tubers	% of marketable tubers, by weight	Marketable yield, disease considered
	No. of tubers	Scab coverage					
Check	89.64%	6.31%	190.0	.226 lb.	153.8 bu.	80.94%	70.8 bu.
Celite + Calomel 5 lb. per acre	76.36	3.92	230.7	.280	199.0	86.25	102.5
Celite + Calomel 10 lb. per acre	78.19	4.42	203.6	.242	178.7	87.77	123.3
Fertilizer + Calomel 10 lb. per acre	53.09	1.67	229.8	.277	195.4	85.03	170.9
Celite + Yellow Oxide of Mercury, 5 lb. per acre	70.42	7.72	242.1	.213	171.9	71.00	111.3
Sulphur, 800 lb.per acre	68.69	1.77	246.6	.252	217.1	88.03	160.9
Sulphur + Lime	91.09	10.99	195.4	.222	159.2	81.47	32.2
Celite + Calomel, 5 lb. per acre + Fertilizer	80.00	0.84	253.4	.208	217.2	85.71	204.1
Celite + Calomel,10 lb. per acre + Fertilizer	74.35	1.46	325.8	.268	271.5	83.33	222.6
Celite + Yellow Oxide of Mercury, 5 lb. per acre + Fertilizer	65.51	2.79	217.2	.260	181.0	83.33	155.6
Sulphur + Fertilizer	68.00	1.18	271.5	.250	217.2	80.00	182.4

Note: First 7 treatments replicated 4 times; remaining 4 - 1 replication of each.

Table 16

Soil Treatments for Control of Common Scab of Potatoes - Field Experiments - 1937
Farm of Mr. Albert Dagenais

Treatment	Percent scab		Total yield (bushels)	Ave. wt. of tubers	Yield of marketable tubers	% of marketable tubers, by weight	Marketable yield, disease considered
	No. of tubers	Scab coverage					
Check	94.91%	10.46%	226.2 bu.	.246 lb.	203.0 bu.	89.74%	63.7 bu.
Celite + Calomel 5 lbs. per acre	86.94	7.48	232.0	.262	203.0	87.50	81.7
Celite + Calomel 10 lbs. per acre	83.45	5.89	232.0	.255	211.7	91.25	107.1
Fertilizer + Calomel 10 lbs. per acre	87.50	7.59	217.5	.302	191.4	88.00	92.0
Celite + Yellow Oxide of Mercury, 5 lbs. per acre	88.63	7.22	217.5	.240	200.1	92.00	87.1
Sulphur, 800 lbs. per acre	84.89	6.31	214.6	.242	194.3	90.54	100.7
Sulphur + Lime	96.89	14.58	211.7	.243	194.3	91.78	34.4
Celite + Calomel 5 lbs. per acre (C)*	84.51	7.00	240.7	.297	214.6	89.15	104.9
Celite + Calomel 10 lbs. per acre (C)	86.68	7.90	220.4	.235	197.2	89.47	93.1
Celite + Yellow Oxide of Mercury, 5 lbs. per acre (C)	85.49	5.48	203.0	.233	179.8	88.57	96.8

Note: * "C" indicates that the chemical was applied in the centre of the row instead of on the side of the row as in the usual manner.

Table 17

Soil Treatments for Control of Common Scab of Potatoes - Field Experiments - 1937
Farm of Dr. Viau - St. Remi.

Treatment	Percent scab		Total yield (bushels)	Ave. wt. of tubers	Yield of marketable tubers	% of marketable tubers, by weight	Marketable yield, disease considered
	No. of tubers	Scab coverage					
Check	100.00%	15.94%	298.6 bu.	.198 lb	234.8 bu.	78.63%	42.8 bu.
Celite + Calomel 5 lbs. per acre	90.13	8.75	316.0	.168	233.4	73.86	92.6
Celite + Calomel 10 lbs. per acre	87.37	7.67	298.6	.173	220.3	73.77	76.5
Fertilizer + Calomel 10 lbs. per acre	80.52	8.17	297.2	.179	226.2	76.11	111.3
Celite + Yellow Oxide of Mercury, 5 lbs. per acre	91.39	9.04	294.3	..166	195.7	66.49	80.6
Sulphur, 800 lbs. per acre	94.34	11.65	287.0	.165	213.1	74.25	85.5
Sulphur + Lime	91.94	21.60	310.2	.173	231.9	74.75	39.2

Table 18.

Per Cent Scab Coverage Resulting from the Various Soil Treatments.

Farm	Check	Cel.+Cal. 5 lb.per acre	Cel.+Cal. 10 lb.per acre	Fert. + Cal.	Cel. + HgO.	Sulphur	Sulphur + Lime
Lortie	17.20	6.52	6.58	2.14	8.07	10.25	14.33
Legault	33.48	3.27	4.33	2.82	4.17	14.91	35.00
E.Charbonneau	8.48	3.42	3.42	2.35	1.80	6.29	15.65
Bellanger	6.17	4.53	2.97	2.80	4.97	11.48	16.07
J.Charbonneau	6.31	3.92	4.42	1.67	7.72	1.77	10.99
Dagenais	10.46	7.48	5.89	7.59	7.22	6.31	14.58
Viau	15.94	8.75	7.67	8.17	9.04	11.65	21.60
Totals	98.04	37.89	35.28	27.54	42.99	62.66	128.22
Averages	14.01	5.41	5.04	3.93	6.14	8.95	18.32

Table 19

Total Yield Resulting from the Various Soil Treatments

Farm	Check	Cel.+Cal. 5 lb. per acre	Cel.+Cal 10 lb.per acre	Fert. + Cal.	Cel. + HgO .	Sulphur	Sulphur + Lime
Lortie	188.5 bu	156.6 bu	165.2 bu	156.6 bu	211.7 bu	171.7 bu	142.1 bu
Legault	318.5	347.5	380.1	289.6	340.2	307.7	249.6
E.Charbonneau	299.4	264.0	273.7	238.2	280.1	286.5	216.6
Bellanger	238.0	262.4	256.6	236.3	307.3	237.7	207.3
J.Charbonneau	190.0	230.7	203.6	229.8	242.1	246.6	195.4
Dagenais	226.2	232.0	232.0	217.5	217.5	214.6	211.7
Viau	298.6	316.0	298.6	297.2	294.3	287.0	310.2
Totals	1759.2	1809.2	1809.8	1665.2	1893.2	1751.1	1532.9
Averages	251.3	258.5	258.5	237.9	270.5	250.2	219.0

Table 20.

Per Cent Marketable Yield (by weight)
Resulting from the Various Soil Treatments

Farm	Check	Cel.+Cal 5 lb.per acre	Cel.+Cal. 10 lb.per acre	Fert. + Cal.	Cel. + HgO.	Sulphur	Sulphur + Lime
Lortie	81.30	80.19	79.09	81.24	81.63	82.62	82.61
Legault	80.69	84.37	79.47	83.73	86.18	81.15	98.59
E.Charbonneau	89.24	86.59	88.23	85.13	88.50	87.64	96.62
Bellanger	95.00	90.66	86.43	90.09	89.16	87.79	86.68
J.Charbonneau	80.94	86.25	87.77	85.03	71.00	88.03	81.47
Dagenais	89.74	87.50	91.25	88.00	92.00	90.54	91.78
Viau	78.63	73.86	73.77	76.11	66.49	74.25	74.75
Totals	595.54	589.42	586.01	589.33	574.96	593.02	612.50
Averages	85.08	84.20	83.71	84.19	82.14	84.72	87.50

Table 21.

Yield of Marketable Tubers Resulting from the Various Soil Treatments.

Farm	Check	Cel.+Cal. 5 lb.per acre	Cel.+Cal. 10 lb.per acre	Fert. + Cal.	Cel. + HgO.	Sulphur	Sulphur + Lime
Lortie	153.7 bu	127.7 bu	139.2 bu	127.6 bu	174.0 bu	142.1 bu	118.9 bu
Legault	257.0	293.2	302.1	242.5	293.2	249.7	246.1
E.Charbonneau	267.2	228.6	241.5	202.8	247.9	251.1	209.3
Bellanger	226.1	237.9	221.8	212.9	274.0	208.7	179.7
J.Charbonneau	153.8	199.0	178.7	195.4	171.9	217.1	159.2
Dagenais	203.0	203.0	211.7	191.4	200.1	194.3	194.3
Viau	234.8	233.4	220.3	226.2	195.7	213.1	231.9
Totals	1495.6	1522.8	1515.3	1398.8	1556.8	1476.1	1339.4
Averages	213.6	217.5	216.5	199.8	222.4	210.9	191.3

Note:- Marketable yields here are tubers of grades No. 1 and 2.

Table 21-A.

Marketable Yield of Sound Tubers Resulting from the Various Soil Treatments.

Farm	Check	Celite + Calomel 5 lbs. per acre	Celite + Calomel 10 lbs. per acre	Fertilizer Calomel	Calomel + Yellow Oxide of Mercury	Sulphur	Sulphur Lime
Lortie	14.3 bu.	54.8 bu.	66.9 bu.	96.8 bu.	68.6 bu.	31.6 bu.	31.1 bu.
Legault	13.1	143.9	251.7	207.8	201.5	75.8	13.2
E. Charbonneau	82.5	152.5	152.3	158.2	204.7	147.2	44.1
Bellanger	71.2	123.6	147.0	170.4	135.5	71.8	11.4
J. Charbonneau	70.8	102.5	123.3	170.9	111.3	160.9	32.2
Dagenais	63.7	81.7	107.1	92.0	87.1	100.7	34.4
Viau	42.8	92.6	76.5	111.3	80.6	85.5	39.2
Totals	358.4	751.6	924.8	1007.4	889.3	673.5	205.6
Averages	51.2	107.4	132.1	143.9	127.0	96.2	29.4

Table 22.

Efficiency of Calomel for Control of Scab in Different Soils.

First Crop		Percentage Surface Coverage					Percentage Scabbed Tubers			
		Temp. 75° F.		Temp. 60° F			Temp. 75° F.		Temp. 60° F.	
Soil No.	Treatment	High moisture content	Low moisture content	High moisture content	Low moisture content	Averages; all conditions considered	High moisture content	Low moisture content	High moisture content	Low moisture content
1	Check	3.50	41.66	0.55	2.83	12.13	33.00	100.00	11.00	66.00
1	Calomel	0.08	13.33	0.00	1.83	3.81	16.00	66.00	0.00	66.00
1	Calomel + Sugar	0.29	16.66	0.00	0.33	4.32	42.00	100.00	0.00	66.00
2	Check	0.00	3.62	0.04	1.16	1.20	0.00	88.00	8.00	50.00
2	Calomel	0.00	0.66	0.00	0.16	0.20	0.00	100.00	0.00	33.00
2	Calomel + Sugar	0.16	0.33	0.16	0.66	0.33	33.00	66.00	33.00	50.00
3	Check	1.16	26.66	0.00	5.83	8.41	66.00	100.00	0.00	66.00
3	Calomel	1.33	3.66	3.33	5.16	3.37	66.00	100.00	66.00	66.00
3	Calomel + Sugar	1.83	15.08	0.16	2.00	4.78	50.00	83.00	33.00	50.00
4	Check	0.50	17.00	1.75	5.00	6.06	50.00	100.00	16.00	100.00
4	Calomel	20.00	7.58	0.41	10.00	9.49	44.00	100.00	50.00	100.00
4	Calomel + Sugar	14.33	11.66	0.16	10.00	9.04	66.00	100.00	33.00	66.00
5	Check	0.08	0.22	0.83	5.00	1.53	33.00	27.00	35.00	66.00
5	Calomel	0.00	0.25	0.00	0.16	0.10	16.00	33.00	0.00	33.00
5	Calomel + Sugar	0.50	3.66	0.25	0.50	1.23	50.00	100.00	66.00	66.00
	Moisture averages	2.92	10.80	0.51	3.37		38.00	84.00	23.00	63.00
	Temperature averages	6.86		1.94			61.00		43.00	

Table 22-A.

Efficiency of Calomel for Control of Scab in Different Soils

Second Crop		Percentage Surface Coverage					Percentage Scabbed Tubers			
		Temp. 75° F.		Temp. 60° F.			Temp. 75° F.		Temp. 60° F.	
Soil No.	Treatment	High moisture content	Low moisture content	High moisture content	Low moisture content	Averages; all conditions considered	High moisture content	Low moisture content	High moisture content	Low moisture content
1	Check	0.00	46.66	0.00	37.77	21.11	0.00	100.00	0.00	100.00
1	Calomel	1.00	28.88	0.00	36.03	16.48	33.33	100.00	0.00	100.00
1	Calomel + Sugar	0.00	42.22	0.00	20.72	15.73	0.00	100.00	0.00	72.22
2	Check	0.16	14.22	0.00	8.33	5.68	16.66	100.00	0.00	44.44
2	Calomel	0.00	5.58	0.00	5.96	2.88	0.00	100.00	0.00	100.00
2	Calomel + Sugar	0.00	1.80	0.00	8.55	2.59	0.00	100.00	0.00	100.00
3	Check	0.00	21.77	0.00	30.16	12.98	0.00	100.00	0.00	100.00
3	Calomel	0.00	13.33	0.00	16.66	7.49	0.00	83.33	0.00	100.00
3	Calomel + Sugar	0.00	25.16	0.00	17.44	10.65	0.00	100.00	0.00	100.00
4	Check	0.00	48.33	0.00	11.77	15.02	0.00	100.00	0.00	100.00
4	Calomel	0.00	19.16	0.00	12.77	7.98	0.00	100.00	0.00	100.00
4	Calomel + Sugar	0.00	7.50	0.00	20.00	6.87	0.00	83.33	0.00	100.00
5	Check	0.16	5.50	0.00	0.75	1.60	33.33	83.33	0.00	50.00
5	Calomel	0.16	5.33	0.00	2.25	1.93	16.66	66.66	0.00	72.22
5	Calomel + Sugar	0.00	3.66	0.00	1.00	1.16	0.00	72.22	0.00	100.00
	Moisture averages	0.10	19.27	0.00	15.34		6.66	92.59	0.00	89.26
	Temperature averages	9.68		7.67			49.62		44.63	

Table 23.

Relation of Scab Occurrence to E_h under Various Conditions.

Soil No.	Treatment	Temperature 75° F.				Temperature 60° F.			
		High Moisture		Low Moisture		High Moisture		Low Moisture	
		Per cent scab coverage	E_h	Per cent scab coverage	E_h	Per cent scab coverage	E_h	Per cent scab coverage	E_h
1	Check	3.50	.632	41.66	.588	0.55	.550	0.58	.550
1	Calomel	0.80	.537	13.33	.508	0.00	.536	1.83	-
1	Calomel + Sugar	0.29	.524	16.66	.545	0.00	.542	0.33	.510
2	Check	0.00	.582	3.62	.555	0.04	.650	1.16	.654
2	Calomel	0.00	.596	0.66	.549	0.00	.529	0.16	.663
2	Calomel + Sugar	0.16	.560	0.33	.545	0.16	.497	0.66	.624
3	Check	1.16	.527	26.66	.531	0.00	.662	5.83	.555
3	Calomel	1.33	.537	3.66	.535	3.33	.559	5.16	.559
3	Calomel + Sugar	1.83	.523	15.08	.554	0.16	.550	2.00	.552
4	Check	0.50	.487	17.00	.481	1.75	-	5.00	.480
4	Calomel	20.00	.560	7.58	.506	0.41	.584	10.00	.538
4	Calomel + Sugar	14.33	.506	11.66	.537	0.16	.464	10.00	.444
5	Check	0.08	.471	0.22	.568	0.83	.540	5.00	.560
5	Calomel	0.00	.566	0.25	.535	0.00	.553	0.16	.569
5	Calomel + Sugar	0.50	.552	3.66	.551	0.25	.552	0.50	.524
		Averages for 5 Soils							
1-5	Checks	1.05	.539	17.83	.545	0.63	.600	3.51	.559
1-5	Calomel	4.42	.559	5.09	.527	0.75	.552	3.46	.582
1-5	Calomel Sugar	3.42	.533	9.48	.546	0.15	.521	2.69	.531

Table 24.

Efficiency of Various Soil Treatments in Controlling Scab.

Treatment	Plate Counts			Percent Scab Coverage
	Actinomyces	Fungi	Bacteria	
Check	51	5	24	15.13
Celite + Calomel, 5 lbs. per acre	3	199	5	2.63
Celite + Calomel, 10 lbs. per acre	3	4	15	8.38
Celite + Yellow Oxide of Mercury 5 lbs. per acre	4	33	6	13.33
Salt, 500 lbs. per acre	0	1	7	13.22
Soot, 1000 lbs. per acre	22	72	6	9.23

Note: The plate counts represent the number of organisms in 1/100,000 of a gram of soil.

Table 25. (Page 1)

Per Cent Scab Coverage for Survey Fields with Corresponding Plate Counts

Farm No.	Plate Counts - 1st Inspection (July)					Plate Counts - Harvest Inspection (September)				
	Actinomyces	Fungi	Bacteria	Trichoderma	Per cent Scab Coverage (July)	Actinomyces	Fungi	Bacteria	Trichoderma	Per cent Scab Coverage (Sept.)
1	-	-	-	-	2.50	27	17	35	0	25.50
2	48	18	45	0	0.53	50	217	17	0	0.53
3	-	-	-	-	0.72	5	39	4	0	7.10
5	3	17	9	1	0.00	-	-	-	-	4.00
6	3	141	4	0	0.00	0	135	2	0	0.19
7	15	291	24	0	0.00	18	43	26	1	0.58
8	1	155	4	0	-	12	331	4	0	0.43
9	5	89	20	0	-	-	-	-	-	4.80
10	7	25	13	0	0.00	5	19	9	0	0.00
11	-	-	-	-	0.00	1	216	9	0	0.00
12	15	5	30	0	0.16	10	103	8	0	0.89
13	1	11	2	0	0.00	10	383	15	0	0.15
14	8	86	51	0	0.10	3	7	4	0	0.09
15	8	12	4	0	0.00	4	369	4	0	trace
16	12	179	8	0	-	1	137	3	0	trace
17	12	68	8	0	0.00	20	659	9	0	0.52
18	23	98	10	1	0.00	16	56	17	0	5.80
19	15	5	30	0	0.30	32	23	51	0	1.10
20	7	108	4	0	0.00	1	26	9	0	0.06
21	12	101	25	1	0.10	5	7	9	1	0.81
22	9	20	4	0	2.60	-	-	-	-	2.60
23	3	53	5	0	0.04	12	681	15	0	1.60
24	5	7	9	0	severe	2	137	6	0	0.18
25	4	28	2	6	2.00	8	273	6	0	4.30

Table 25. (Page 2)

Per Cent Scab Coverage for Survey Fields with Corresponding Plate Counts

Plate Counts - 1st Inspection (July)						Plate Counts - Harvest Inspection (September)				
Farm No.	Actinomyces	Fungi	Bacteria	Trichoderma	Per cent Scab Coverage (July)	Actinomyces	Fungi	Bacteria	Trichoderma	Per cent Scab Coverage (Sept.)
26	3	23	3	0	0.00	17	146	19	0	5.10
27-1	3	157	5	0	0.13	3	10	11	0	0.05
27-2	2	209	1	0	6.80	8	45	20	0	3.38
28	3	3	12	0	0.85	15	28	58	0	2.30
29	2	66	6	0	2.90	32	31	66	0	6.60
30	3	43	4	0	7.40	2	6	12	0	3.20
31	4	196	0	0	1.10	16	30	52	0	2.70
32	1	16	35	0	0.22	2	256	10	0	3.80
33	4	2	4	0	1.30	6	91	22	0	10.00
34	0	33	5	1	2.70	11	82	12	0	0.87
35	9	67	13	0	15.10	17	201	13	1	5.80
36	-	-	-	-	-	8	21	12	0	0.17
Totals	250	2242	399	1 to 10	47.55	379	4825	569	3	105.20
Averages	7.8	70.0	12.5		1.53	11.5	146.2	17.2	1 to 3	3.09
Averages X dilution factor (millions)	.78	7.0	1.25	.1 - 1.0		1.15	14.62	1.72	.1 - 3.0	