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POTATO EXPERIMENTS

FOR THE CONTROL OF RHIZOCTONIA, SCAB, AND BLACKLEG, 1922 TO 1927

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SUMMARY

1. Corrosive sublimate solutions weaken rapidly with use.

2. Cold corrosive sublimate solutions (1-1,000) will control Rhizoctonia satisfactorily if the potatoes are immersed for 1½ hours. Shorter periods of immersion do not satisfactorily control Rhizoctonia.

3. Hot formaldehyde solutions of 1-120 strength at temperatures of 124° to 126° F. will control Rhizoctonia satisfactorily, if the potatoes are immersed for a period of 3 to 4 minutes. Lower temperatures or shorter periods of immersion have not, in general, given satisfactory control.

4. Hot corrosive sublimate solutions are no more efficient in Rhizoctonia control than hot formaldehyde solutions, and have several distinct disadvantages.

5. Control of Rhizoctonia by either of the recommended treatments has generally resulted in significantly greater yields, although this has not always been the case, due to factors other than disease control.

6. Spring treatments, shortly before planting, cause "induced dormancy" in the tuber, which in turn causes a delay in emergence of the sprouts from the soil. The more severe the treatment, the greater the "induced dormancy" and the greater the delay in emergence.

7. Fall treatments are as effective in Rhizoctonia control as spring treatments and have an advantage in not causing "induced dormancy."

8. Control of Rhizoctonia is more important than any seed or sprout injury that occurs due to either of the recommended treatments, provided the recommendations given are followed.

9. Seed treatments have not reduced the set of tubers per plant.

10. Scab, resulting from infections from the soil, has been lessened by the use of green manures and sulphur.

11. Green manures that can be plowed under in the spring, shortly before potato planting, have proved more efficient in scab control than green manures plowed under in the fall.

12. No difference, in regard to scab control, was observed between inoculated and uninoculated sulphur, at the rates used.

13. Certain organic mercury compounds have given very satisfactory control of Rhizoctonia and blackleg when used as instantaneous dips.

POTATO EXPERIMENTS FOR THE CONTROL OF RHIZOCTONIA, SCAB, AND BLACKLEG, 1922 TO 1927[1]

R. P. WHITE[2]

INTRODUCTION

Seed treatments for the control of Rhizoctonia, scab, and blackleg of potatoes, have undergone radical changes in the past decade. Old inefficient methods have been perfected and new methods and new materials have been discovered. Until recently the cold corrosive sublimate dip has been the generally accepted standard treatment. However, it has certain inherent disadvantages, such as (1) weakening due to use, (2) its corrosive action on metals, (3) its extremely poisonous properties, and (4) its retarding effect upon germination when used on seed immediately before planting.

The most important of these disadvantages from a commercial standpoint is the weakening of the solution due to the adsorption of mercury ions by material immersed in it. This necessitates treating in bulk, or in wooden crates, which means extra handling of the seed potatoes. The more soil that is adhering to the potatoes at the time of the treatment, and the smaller the seed potatoes, the more rapid is the decrease in strength, due to the greater adsorption area coming in contact with the solution.

Attempts have been made to overcome this difficulty by the addition of formulated amounts of corrosive sublimate after each dipping *(2, 9),* but so many factors are involved that all formulæ so far recommended are at best only approximate. Practical field methods of testing the strength of corrosive sublimate solutions have not been devised, although attempts hare been made in this direction *(2).*

Because of the inherent objections to this method, experiments were undertaken in the Kaw valley to determine the adaptability and efficiency of other methods of seed treatment. The purpose of this bulletin is to present the results of these investigations and to discuss their application to practical potato seed treatment.

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EXPERIMENTAL METHODS

These studies extended from 1922 to 1927, inclusive. The objectives were to determine: (1) The degree of weakening of corrosive sublimate solutions with use; (2) the comparative effect of immersion in corrosive sublimate, hot formaldehyde, and organic mercury solutions on the viability of the sclerotia of Rhizoctonia, and the yield of potatoes in field plats; (3) the influence of duration of immersion, temperature, and strength of hot formaldehyde solutions on sclerotial viability and yield of potatoee; (4) the Comparative value, from a disease control viewpoint, of fall versus spring treatments; (5) the influence of the treatments on tuber set; (6) the influence of hot corrosive sublimate solutions on sclerotial viability; (7) the influence of sulphur applications to the soil on soil acidity and scab control; and (8) the influence of green manures on soil acidity and scab control.

In determining the per cent of sclerotia that was killed by any individual treatment, a large number were removed from the tuber and platted on sterile media. Representative samples were secured by removing all the sclerotia, both large and small, found upon the particular potatoes examined. In this way more than 200 were frequently taken from a single tuber. Less than 200 per lot of treated potatoes were considered too few for accurate determinations, although the average of a large number of such lots treated alike is considered of value.

In examining field experiment's for Rhizoctonia control, it was necessary to expose the stems of the plants. In many instances the plants were entirely removed from the ground, and discarded after the number and per cent of disease-free stalks mere determined. In Kansas, the initial lesions on the sprouts are the most important type of injury from a commercial standpoint. Second in importance are the lesions on the stolons, a type of infection the seriousness of which has been disregarded. Later infections of the stems from the soil are of minor importance. Since the bulk of the commercial potato crop of Kansas is harvested and shipped during July and early August, sclerotia are very rarely produced on the tubers, due to the high soil temperatures prevailing at this time. Rhizoctonia control, therefore, is considered successful if it results in a high per cent of clean sprouts early in the season. Readings have been taken in general when the plants were approximately six inches high. In some cases they were taken at a later stage of growth.

The yield data for the most part are from single-plat experiments with the plats varying from one-tenth to one-fourth acre in size. The most desirable size of plat and number of replications for field experimentation with potatoes have been investigated, but, the results are reserved for a future report.

In the experiments conducted at Manhattan in 1926 (Tables XV and XVII) the 25-hill plat method of experimentation was followed. By this method the plats are of 25 hills each, with sufficient replications to insure uniformity of distribution of the plats in the experimental field. At harvest each hill is weighed as a unit, and the data are presented as average weight of potatoes produced per hill. The probable error of these experiments was calculated by the use of Bessel's formula, basing the calculations upon the variability of the individual hills in each plat, as well as upon the variability of the average yield per hill in each of the several plats receiving the same treatment.

In determining the per cent of scab, in experiments relating to this disease, the crop was divided into three lots, namely, disease-free potatoes with no scab lesions, slightly scabby potatoes having one to three scab lesions per tuber, and badly scabbed potatoes having four or more lesions per tuber. All the soil acidity determinations were made with the hydrogen electrode.

EXPERIMENTAL RESULTS

WEAKENING OF CORROSIVE SUBLIMATE SOLUTIONS WITH USE

One of the earliest points to be investigated was the weakening of corrosive sublimate solutions when used to dip potatoes in bulk. Cut and uncut seed was used since it was found that several growers were dipping cut seed.

The treating period in each case was 90 minutes. A gallon glazed crock was used in order to eliminate the slight weakening of the solution due to wooden containers. Three lots of potatoes were used, viz., (1) uncut, (2) cut and treated at once, (3) cut and dried for 24 hours before treating. All lots were relatively free from soil. Samples of the solutions were taken before and after treating and analyzed for mercury, those taken after the treatment being filtered to remove the suspended soil particles and the inactive mercury ions absorbed thereon. The results appear in Table I.

It is evident that dipping cut seed even though dried, is an unwise practice, not because of seed injury but on account of the more rapid weakening of the solution which must inevitably result in less satisfactory control of Rhizoctonia.

TABLE I.—WEAKENING OF SOLUTIONS OF MERCURIC CHLORIDE USED FOR TREATING POTATOES.

SAMPLE.	Potatoes uncut.		Potatoes cut.		Potatoes cut, dried.	
	Grams of mercuric chloride in 100 cc. of solution.	Per cent of No. 1.	Grams of mercuric chloride in 100 cc. of solution.	Per cent of No. 1.	Grams of mercuric chloride in 100 cc. of solution.	Per cent of No. 1.
1. Solution as prepared	.1096	100.0	.1074	100.0	.1088	100.0
2. After first treatment	.0812	74.2	.0762	70.9	.0666	61.3
3. After second treatment	.0728	66.5	.0442	41.2	.0478	43.8
4. After third treatment	.0710	64.6	.0284	26.4	.0272	25.0
5. After fourth treatment	.0628	57.4	.0146	12.5	.0164	15.1

EFFECT OF VARIOUS TREATMENTS ON SCLEROTIAL VIABILITY

The most direct method of testing the efficiency of various seed treatments upon the control of Rhizoctonia is the examination for viability of the sclerotia following the treatment. This can easily be done by rinsing the treated tubers two or three times with sterile distilled water and transferring the sclerotia by means of sterile forceps to sterile media. Those sclerotia which are alive will start to grow by putting out mycelium in two to three days. Final readings of viability have been made usually at the end of five days. Where there has been any doubt as to the results at the end of five days, the cultures have been kept for a longer period.

Following this method of procedure 18,215 sclerotia from tubers receiving various treatment's have been examined. The results appear in Table II.

The data presented in Table II show that only the most drastic treatment will kill all the sclerotia present on the tubers. This, however, appears to be unnecessary and moreover would be impracticable. It is arbitrarily considered that satisfactory control is secured when 90 per cent of the sclerotia are killed by any treatment. Such control has been secured with treatments in hot formaldehyde of 3 minutes or longer and with temperatures of 124° F. and above. With corrosive sublimate 1-1,000 satisfactory control has been obtained when immersed for 90 minutes.

Further work upon this phase of the project was conducted in 1925. It was intended to make a yield test as well as to determine the effect of the treatment on the viability of the sclerotia. Unfor-

TABLE II.—THE EFFECT OF VARIOUS SEED TREATMENTS ON SCLEROTIAL VIABILITY.

TREATMENT.	1922.		1924.		1925.	
	Number of sclerotia.	Per cent dead.	Number of sclerotia.	Per cent dead.	Number of sclerotia.	Per cent dead.
None	50	0	208	9.6	4,665	4.2
Mercuric chloride (*a*): 30 minutes	50	52			105	38.1
Mercuric chloride: 60 minutes	50	62			241	85.1
Mercuric chloride: 90 minutes	50	90	132	95.9	2,343	95.1
Formaldehyde (*a*): 2 minutes 120° F.	50	18			101	87.2
Formaldehyde: 3 minutes 120° F.					268	95.5
Formaldehyde: 3 minutes 122° F.			407	94.4	204	76.0
Formaldehyde: 2 minutes 125° F.					206	79.7
Formaldehyde: 2½ minutes 125° F.					152	90.2
Formaldehyde: 3 minutes 125° F.			62	90.4	2,548	91.7
Formaldehyde: 3½ minutes 125° F.					464	95.1
Formaldehyde: 4 minutes 125° F.					4,273	91.5
Formaldehyde: 3 minutes 128° F.					337	84.9
Formaldehyde: 3 minutes 130° F.					562	79.3
Formaldehyde: 4 minutes 130° F.					150	92.9
Formaldehyde: 6 minutes 130° F.					150	97.4
Formaldehyde: 12 minutes 130° F.					172	100.0
Formaldehyde: 3 minutes 132° F.					157	96.2
Formaldehyde: 4 minutes 132° F.					208	96.7

(*a*) Mercuric chloride solutions were 1-1,000 strength; formaldehyde solutions, 1-120.

tunately the plats were so badly injured by a frost on May 24 that no yield data were secured.

Three strengths of formaldehyde, 1-120, 1-100, 1-80; three temperatures, 122° F., 124° F., and 126° F.; and three lengths of time, 2, 4, and 6 minutes, were compared in all possible combinations, making 27 distinct comparisons. A 120-minute treatment with mercuric chloride 1-1,000 was also included, as well as a suitable number of untreated checks.

Sclerotial platings were made from all the different lots and the per cent killed was determined as previously described. The data obtained are given in Table III.

The number of sclerotia obtained from the different lots were in many cases too few for the most accurate information. It is noteworthy, however, that all the hot formaldehyde treatments in this particular case gave satisfactory control, namely, 90 per cent of the sclerotia killed.

TABLE III.—EFFECT OF HOT FORMALDEHYDE TREATMENT ON SCLEROTIAL VIABILITY, 1925.

TREATMENT.	Number sclerotia plated.	Number alive.	Per cent killed.
Untreated	100	100	0.0
Mercuric chloride, 1-1000, 2 hours	150	21	86.0
Hot formaldehyde, 2 min. 1-120, 122° F.	62	4	93.6
Hot formaldehyde, 4 minutes 1-120, 122° F.	163	0	100.0
Hot formaldehyde, 6 minutes 1-120, 122° F.	104	0	100.0
Hot formaldehyde, 2 minutes 1-100, 122° F.	86	4	95.4
Hot formaldehyde, 4 minutes 1-100, 122° F.	211	3	98.6
Hot formaldehyde, 6 minutes 1-100, 122 ° F.	67	3	95.6
Hot formaldehyde, 2 minutes 1-80, 122° F.	70	0	100.0
Hot formaldehyde, 4 minutes 1-80, 122° F.	197	15	92.4
Hot formaldehyde, 6 minutes 1-80, 122° F.	167	8	95.3
Hot formaldehyde, 2 minutes 1-120, 124° F.	132	0	100.0
Hot formaldehyde, 4 minutes 1-120, 124° F.	135	3	97.8
Hot formaldehyde, 6 minutes 1-120, 124° F.	76	1	98.7
Hot formaldehyde, 2 minutes 1-100, 124° F.	147	11	92.5
Hot formaldehyde, 4 minutes 1-100, 124° F.	206	11	94.7
Hot formaldehyde, 6 minutes 1-100, 124° F.	132	0	100.0
Hot formaldehyde, 2 minutes 1-80, 124° F.	50	1	98.0
Hot formaldehyde, 4 minutes 1-80, 124° F.	171	7	95.9
Hot formaldehyde, 6 minutes 1-80, 124° F.	95	1	99.0
Hot formaldehyde, 2 minutes 1-120, 126° F.	140	5	96.5
Hot formaldehyde, 4 minutes 1-120, 126° F.	71	1	98.6
Hot formaldehyde, 6 minutes 1-120, 126° F.	158	3	98.1
Hot formaldehyde, 2 minutes 1-100, 126° F.	74	2	97.2
Hot formaldehyde, 6 minutes 1-100, 126° F.	110	2	98.2
Hot formaldehyde, 2 minutes 1-80, 126° F.	90	1	98.9
Hot formaldehyde, 4 minutes 1-80, 126° F.	222	1	99.1
Hot formaldehyde, 6 minutes 1-80, 126° F.	76	3	96.1

INDUCED DORMANCY AS A RESULT OF HOT FORMALDEHYDE TREATENTS

It became evident that the hot formaldehyde treatment being used (2 min. at 118° to 122° F.) in the early part of these investigations was not, in general, controlling Rhizoctonia successfully. Consequently, experiments were designed to test the effect of stronger solutions, longer immersions, and higher temperatures in addition to those already reported.

The first experiment was undertaken during the winter of 1922-'23.

Potatoes of the Early Ohio variety were treated for 2 minutes in hot formaldehyde solutions of 1-120 strength, at temperatures varying from 118° to 150° F. Similarly, other lots were treated at 122° F. for periods of time varying from 2 to 7 minutes.

All treated potatoes were then planted in the greenhouse. When the tallest sprouts were approximately 6 inches long all were removed from the soil and measured. No injury was observed when the duration of immersion was held at 2 minutes until a temperature of 134° F. was reached. Likewise when the temperature was maintained at 122° F. no injury was observed with immersion of less than 6 minutes. When the time or the temperature exceeded these values the sprouts were shorter, although there was the same number of sprouts per seed piece. It is doubtful if this can properly be called seed injury. The buds were not killed, but merely delayed in growth, and the resulting sprouts were as stocky and healthy appearing as those arising from untreated seed pieces. It is more likely a manifestation of "induced dormancy," as previously reported by the author *(10)*. As will be shown later, this has a marked relation to later development and yield.

RELATION OF SEED TREATMENT AND YIELD

The above data on the effect of seed treatment have been extensively supplemented by field experiments in which attempts have been made to determine the effect of various seed treatments on yield. They have been conducted for the most part in cooperation with potato growers in the Kaw Valley.[3] Needless to say, tubers heavily infested with Rhizoctonia were always used in the experiments. Single plats with untreated or check plats at stated intervals have been generally employed. Probable errors unless otherwise stated have been calculated from the check plats. It is recognized that the numbers are in general much too small for reliable probable errors, but the calculations are nevertheless presented for what they are worth. The preliminary results secured in 1922 to 1925 are given in Tables IV to XI, inclusive.

Although the increases in yield obtained in this experiment were, in some cases, relatively large, they were not statistically significant, provided the probable error is computed from the variability of the five untreated plats. The value of the probable error, based upon the variability of the five untreated plats, equals 18.1 bushels in this case. It is questionable whether one is justified in computing a

3. Acknowledgment is made of the assistance rendered by growers and county agricultural agents in conducting these field experiments.

TABLE IV.—THE EFFECT OF SEED TREATMENT ON THE YIELD OF POTATOES
Farm of Grant Kelsey, Topeka, 1922.

TREATMENT.	Yield per acre.	Average yield per acre of adjacent checks.	Increase per acre.
	Bus.	*Bus.*	*Bus.*
Corrosive sublimate, 90 minutes	139.1	98.6	40.5
Untreated	98.6	....	....
Corrosive sublimate, 60 minutes	142.6	107.3	35.3
Untreated	116.0	....	....
Corrosive sublimate, 30 minutes	126.5	124.6	1.9
Untreated	133.3	....	....
Hot formaldehyde, 2 minutes 118° to 122° F., dried at once	136.3	133.1	3.5
Untreated	133.0	....	....
Hot formaldehyde, 2 minutes 118° to 122° F., covered and dried	130.5	112.8	17.7
Untreated	91.8	....	....

probable error from such a small number of replications. Aside from any mathematical consideration, however, it is interesting to note that the longer the potatoes were immersed in corrosive sublimate solution, up to 90 minutes, the greater was the increase in yield that resulted, presumably due to the control of Rhizoctonia.

In this test injury due to too severe a treatment was apparent in the plat treated with corrosive sublimate for 90 minutes. Whether

TABLE V.—THE EFFECT OF SEED TREATMENT ON THE YIELD OF POTATOES.
Farm of M. G. Dreyer, Kansas City, 1922.

TREATMENT.	Yield per acre.	Average yield per acre of adjacent checks.	Increase per acre.
	Bus.	*Bus.*	*Bus.*
Hot formaldehyde, 2 minutes 118° to 122° F	144.0	108.6	35.4
Untreated	108.6	....	....
Mercuric chloride, 90 minutes	(*a*) 92.2	107.7	—11.5
Untreated	106.8	....	....
Mercuric chloride, 60 minutes	129.2	106.0	23.2
Untreated	105.2	....	....
Mercuric chloride, 30 minutes	95.2	99.5	4.3
Untreated	93.8	....	....

(*a*) Yield reduced by injury due to sprouted seed or to retardation in germination.

this was due to direct injury of the sprouts (the seed was well sprouted) or to a retardation in germination as a result of the treatment cannot be definitely ascertained. The author is inclined to believe, in the light of subsequent experiments, that a greater part of this so-called injury due to seed treatment can be attributed to a retarding effect upon the germination of the buds of the tuber.

The probable error of this series of plats, if computed as in the previous experiment, is 6.3 bushels per acre, giving significance to the yield increase obtained on the plats treated with hot formaldehyde and corrosive sublimate for 1 hour.

TABLE VI.—THE EFFECT OF SEED TREATMENT ON THE YIELD OF POTATOES.
Farm of Grant Kelsey, Topeka, 1923.

TREATMENT.	Yield per acre.	Average yield per acre of adjacent checks.	Increase per acre.
	Bus.	*Bus.*	*Bus.*
Formaldehyde, 2 minutes 118° to 122° F.	216	164	52
Untreated	164		
Mercuric chloride, 30 minutes	157	150	7
Untreated	136		
Mercuric chloride, 60 minutes	155	139	16
Untreated	142		
Mercuric chloride, 90 minutes	159	142	17

In this experiment the outstanding result is the increase in yield obtained on the hot-formaldehyde treated plat. The same relative positions, in point of yield, are again held by the three plats treated with corrosive sublimate, the longer treatments again being the most satisfactory from a yield standpoint. The probable error, computed as for previous tests, is 7.2 bushels, but due to the very small number of plats from which it was necessarily computed has little, if any, value.

The same relations between the various treatments are again demonstrated in this series of plats. Therefore, for future tests only the 90-minute dip in corrosive sublimate was used, as it was felt that shorter periods of time in this solution were unreliable from a disease-control standpoint.

Further experiments upon the values of various seed treatments were largely related to the influence of increasing the temperature, duration of immersion, and strength of solution, of the hot-formal-

TABLE VII.—THE EFFECT OF SEED TREATMENT ON THE YIELD OF POTATOES.
Farm of William Shideler, Silver Lake, 1923.

TREATMENT.	Yield per acre.	Average yield per acre of adjacent checks.	Increase per acre.
	Bus.	*Bus.*	*Bus.*
Untreated	168.1	....	....
Hot formaldehyde, 2 minutes 118° to 122° F.	215.2	176.8	38.4
Untreated	185.5	....	....
Mercuric chloride, 30 minutes	217.4	200.4	17.0
Untreated	215.4	....	....
Mercuric chloride, 60 minutes	236.3	204.0	32.3
Untreated	192.6	....	....
Mercuric chloride, 90 minutes	249.5	192.6	56.9

dehyde method of dipping seed. This method, if efficient from a disease-control standpoint, has much to recommend it. In the first place the solutions do not weaken with use and do not, therefore, need to be changed frequently or strengthened by the addition of new chemical. In the second place the treatment is very rapid in comparison to the standard corrosive sublimate treatment saving time when time is most needed.

The first experiment conducted on the influence of increasing the duration of the dip, using a temperature of 118° to 122° F. and a strength of solution of 2 pints of 40 per cent formaldehyde to 30 gallons of water, was in 1923. The data obtained from this preliminary field test appear in Table VIII.

TABLE VIII.—EFFECT OF HOT-FORMALDEHYDE TREATMENT ON YIELD OF POTATOES.
Farm of George Allen, Topeka, 1923.

TREATMENT.	Yield per acre.	Average yield per acre of adjacent checks.	Increase per acre.
	Bus.	*Bus.*	*Bus.*
Untreated	126.9	....	....
Hot formaldehyde, 2 minutes	265.4	172.8	92.6
Untreated	87.5	....	....
Hot formaldehyde, 4 minutes	274.3	142.1	132.2
Untreated	196.7	....	....
Hot formaldehyde, 6 minutes	259.6	107.2	152.4
Untreated	149.0	....	....

In this experiment only the hot-formaldehyde dip was used, the three treated plats differing in one factor only, namely, the length of time the seed was left in the solution. The increase due to the 6-minute immersion is the largest recorded in all the experiments carried out over the period of years these tests were conducted. The probable error, based on the variability of the four check plats is 24.3 bushels; its value, though, is subject to the limitations previously noted. However, even with this large probable error, the increases obtained are significant.

TABLE IX.—THE EFFECT OF SEED TREATMENT ON THE YIELD OF POTATOES.
Farm of C. V. Cochran, Topeka, 1924.

TREATMENT.	Time.	Strength.	Yield per acre.	Increase per acre due to treatment.
	Min.		*Bus.*	*Bus.*
Mercuric chloride	90	1-1,000	274.2	13.7
Hot formaldehyde	2	1-80	283.2	22.7
Mercuric chloride	90	1-1,000	296.7	30.2
Hot formaldehyde	2	1-100	290.3	29.8
Untreated	......	....	245.1	....
Hot formaldehyde	4	1-120	206.4	—54.1
Untreated	......	....	296.7	....
Hot formaldehyde	2	1-120	225.8	—34.7
Untreated	......	....	238.7	....
Mercuric chloride	90	1-1,000	238.7	—21.8

In Table IX are presented yield records of a series of plats planted with seed treated in various ways. The plats in this test varied widely, being on an uneven piece of land, with considerable soil variation. The probable error computed from the variability of the untreated plats (30 bushels) is more than large enough to negate the values obtained from all the plats in this experiment, whether a positive or negative increase was recorded.

In another similar series of plats conducted in the same year (Table X) the corrosive sublimate dip for 90 minutes was compared with the hot-formaldehyde dip for 2 minutes. In both cases the corrosive sublimate treated seed yielded at a higher rate than the hot-formaldehyde treated seed, although both treatments gave substantial increases in yield when compared to untreated seed.

In 1925, five field experiments, arranged more as field demonstrations on the comparative value of the standard corrosive sublimate

TABLE X.—THE EFFECT OF SEED TREATMENT ON THE YIELD OF POTATOES.
Farm of W. R. Stiner, Lawrence, 1924.

TREATMENT.	Yield per acre.	Increase per acre.
	Bus.	*Bus.*
Untreated	262	....
Mercuric chloride (1-1000), 90 minutes (Ohio)	354	92
Hot formaldehyde (1-120), 2 minutes (Ohio)	296	34
Mercuric chloride (1-1000), 90 minutes (Cobbler)	329	39
Hot formaldehyde (1-120), 2 minutes (Cobbler)	307	17
Untreated	290	....

treatment and the hot-formaldehyde treatment, were harvested with the results reported in Table XI.

The information gathered from these tests bears out the field experiments previously reported, namely, that from a disease-control standpoint, there is little difference between the two treatments. In some cases the standard corrosive sublimate treatment proved to be better than hot formaldehyde, judging from yield, and this is the final test in the grower's conception, while in other cases the hot-formaldehyde treated seed outyielded the corrosive sublimate treated seed. Factors such as maturity of the seed when harvested, storage conditions, and growing conditions throughout the season are of more importance than the method of treating, when yields alone are considered.

TABLE XI.—THE EFFECT OF SEED TREATMENT ON THE YIELD OF POTATOES, 1925.

COOPERATOR.	TREATMENT.	Yield per acre.
		Bus.
W. G. Philibert, Turner	Mercuric chloride, 90 minutes	209.1
	Formaldehyde, 3 minutes	239.2
James Trant, Edwardsville	Mercuric chloride, 90 minutes	305.0
	Formaldehyde, 3 minutes	286.0
Geo. Bigham, Muncie	Mercuric chloride, 90 minutes	210.0
	Formaldehyde, 3 minutes	199.0
Bell & Son, Perry	Mercuric chloride, 90 minutes	208.0
	Formaldehyde, 3 minutes	240.0
Chas. Speaker, Turner	Mercuric chloride, 90 minutes	340.0
	Formaldehyde, 3 minutes	340.0

Experiments in 1926 related especially to the length of time potatoes should be immersed in hot-formaldehyde solutions (1-120) at a temperature of 125° F. for the most satisfactory results. Previous experiments and observations had shown that increasing the strength of the solution was not practicable, and that temperatures of 124° to 126° F. were entirely satisfactory.

Three experiments were conducted. In one case the potatoes were treated for 2, 3, and 4 minutes; in the second, 2, 4, and 6 minutes; and in the third from 2 to 6 minutes with 1-minute intervals.

The last experiment was conducted at Manhattan, Kan., on the 25-hill replicated row plan in order to avoid, as much as possible,

TABLE XII.—THE EFFECT OF SEED TREATMENT ON THE YIELD OF POTATOES.
Farm of M. S. Kelsey, Topeka, 1926.

TREATMENT.	Yield per acre of U. S. No. 1.	Computed checks.	Increase per acre due to treatment.
	Bus.	*Bus.*	*Bus.*
Untreated	214.6	....	....
Formaldehyde, 2 minutes	248.3	209.5	38.8
Formaldehyde, 3 minutes	265.3	204.3	61.0
Formaldehyde, 4 minutes	257.3	199.2	58.1
Untreated	194.0	....	....

TABLE XIII.—THE EFFECT OF SEED TREATMENT ON THE YIELD OF POTATOES.
Farm of C. V. Cochran, Topeka, 1926.

TREATMENT.	Yield per acre.	Computed checks.	Increase per acre.
	Bus.	*Bus.*	*Bus.*
Untreated	268.9	....	....
Hot formaldehyde (1-120) 125° F., 2 minutes	269.3	268.9	0.4
Hot formaldehyde (1-120) 125° F., 4 minutes	270.0	268.9	1.1
Hot formadehyde (1-120) 125° F., 6 minutes	292.1	268.9	23.2
Untreated	268.9	....	....
Hot formaldehyde (1-120) 125° F., 2 minutes	290.3	269.4	20.9
Hot formaldehyde (1-120) 125° F., 4 minutes	291.8	269.4	21.9
Hot formaldehyde (1-120) 125° F., 6 minutes	314.3	270.4	43.9
Untreated	270.9	....	....
February treated, hot formaldehyde 3 minutes	306.0	275.1	30.9
Fall treated, hot formaldehyde 3 minutes	320.8	299.4	31.4
Untreated	283.6	....	....

differences due to soil variations. Three replications constituted the experiment, the results of which are expressed as average-hill yields. The probable error is calculated as previously indicated for this type of experiment. The results of the three experiments appear in Tables XII, XIII and XIV.

TABLE XIV.—THE EFFECT OF SEED TREATMENT ON THE YIELD OF POTATOES. Manhattan, 1926.

TREATMENT.	Yield in grams per hill.			Average yield in grams per hill.
Untreated	216±24.86	308±23.45	392±35.92	305.3±16.52
Mercuric chloride, 90 minutes	222±18.64	228±18.59	288±21.73	246.0±11.37
Hot formaldehyde (1-120) 125° F., 2 minutes	279±20.99	322±23.64	381±21.92	327.3±12.82
Hot formaldehyde (1-120) 125° F., 3 minutes	285±14.64	293±20.38	392±28.59	324.1±12.68
Hot formaldehyde (1-120) 125° F., 4 minutes	235±23.03	312±16.74	384±24.25	310.3±12.46
Hot formaldehyde (1-120) 125° F., 5 minutes	323±25.57	340±30.50	397±29.92	353.3±16.59
Hot formaldehyde (1-120) 125° F., 6 minutes	323±33.32	281±25.17	408±25.79	337.3±16.36

From the data presented in the three preceding tables (Tables XII to XIV), inclusive, the conclusion can be drawn that the most desirable duration of immersion in the hot-formaldehyde solution lies between 4 and 6 minutes. The use of a 6-minute dip is hardly warranted. The delay in germination of tubers treated for 6 minutes in hot formaldehyde may become a serious factor in seasons when there is a drought, and will be expressed in low yields. The extra 2 or 3 minutes the tubers are left in the solution slows down the process of treating considerably, adds extra labor costs to the procedure, interferes with the maintenance of the temperature of the bath, and does not kill a much larger per cent of the sclerotia. For all practical purposes a dip of 3 to 4 minutes will give a satisfactory control of Rhizoctonia sclerotia borne on the tubers.

The increase in the duration of the dip has eliminated the necessity of covering the tubers after treatment, as originally recommended *(6)* and has also abolished the disagreeable practice of presprinkling.

A number of replications of the standard corrosive sublimate treatment, the hot-formaldehyde treatment, and untreated seed, was made on the 25-hill-plat plan of experimentation in 1926. The results from these tests appear in Table XV.

The corrosive sublimate treatment in these experiments failed to give an increase in yield. This was probably due to (1) delay in

TABLE XV.—A COMPARISON OF CORROSIVE SUBLIMATE (1-1,000 FOR 90 MINUTES), HOT FORMALDEHYDE (1-120, 125° F. FOR 3 MINUTES), AND UNTREATED SEED.

Manhattan, 1926.

TREATMENT.	Untreated.	Corrosive sublimate, 90 minutes.	Hot formaldehyde 125° F., 3 minutes.
Yield in grams per hill	232±17.24	249±31.20	350±23.72
	216±24.86	222±18.64	285±14.64
	268±24.46	266±19.37	261±20.88
	193±25.28	274±18.01	287±22.75
	308±23.45	228±18.59	293±20.38
	305±30.02	295±25.42	313±20.90
	....	346±28.53	375±25.46
	392±35.92	288±21.73	392±28.59
	382±28.86	335±26.44	....
	322±28.94	351±22.42	318±20.18
Average	290.9± 9.00	285.4± 7.41	319.3± 7.41

germination, which was very prolonged, and (2) drought in June when the tubers were setting. The hot-formaldehyde treatment gave a significant increase in yield over the untreated plats.

In 1925 work was started on testing the value of dust treatments for the control of Rhizoctonia. Certain proprietary compounds of organic mercury were appearing on the market at this time and were recommended for use on potatoes. The work in 1925 was purely preliminary and consisted of four replications of the treatments in short rows of 25-hill length. The untreated checks were replicated twelve times and were uniformly distributed over the plat. The dusts were applied at the rate of 3 ounces per bushel of cut seed, although it was impossible to get this quantity of copper stearate dust to adhere to seed.

The data secured in this year were limited to the determination of the per cent of clean sprouts resulting in the various treatments. No yield records were obtained, but per cent of stand was recorded. The results of this preliminary trial appear in Table XVI.

The three copper dusts used did not control initial infection with Rhizoctonia satisfactorily, although the treatments did reduce the amount in comparison to the untreated checks. The copper carbonate dusts caused a slightly reduced germination as expressed in per cent of stand, and a much retarded emergence through the soil. Likewise the sulphur dusts failed to give satisfactory control of initial infections on the sprouts. Of the three organic mercury dusts

TABLE XVI.—RESULTS OF DUST TREATMENTS OF SEED POTATOES UPON RHIZOCTONIA CONTROL.

Manhattan, 1925.

TREATMENT.	Number of rows.	Per cent stand.	Per cent Rhizoctonia.
Check	12	89.1	81.5
Copper stearate	3	91.3	59.0
Corona Coppercarb	3	84.0	63.0
Copper carbonate	3	86.6	63.3
Sulfodust	3	95.0	75.0
Superfine dusting sulphur	3	96.0	65.0
Bayer dust	3	97.0	92.6
Semesan	3	86.6	5.0
Semesan 15	3	90.3	72.0
Mercuric chloride	3	90.6	36.6

used, Semesan alone proved of value, this compound giving a per cent of clean sprouts much higher than that recorded for the standard mercuric chloride treatment.

In 1926 the experiments on dust treatments of seed potatoes was expanded and instantaneous dip treatments in various organic mercury compounds were also included. Dust treatments, if effective from a disease-control standpoint, would eliminate many undesirable features of the liquid treatments. The treatment would be rapid, means for maintaining a high temperature of the treating bath would be eliminated, and the objectionable, disagreeable task of working around wet tanks would be obviated. The instantaneous dip treatments have certain advantages, also, over the long-time cold corrosive sublimate treatment, or the rapid hot-formaldehyde treatment. In the first place, such treatments are more time-saving than the hot-formaldehyde method and do not require the maintenance of a high temperature of the bath.

The experiments in 1926 were conducted on the 25-hill-plat method, each treatment replicated six times. When the plants were from 3 to 5 inches high three complete replications, or 75 hills, were removed from the ground and the sprouts examined for presence or absence of Rhizoctonia lesions. The three remaining replications were used for yield data. Yield records were taken on each individual hill in grams per hill. The probable error of the final hill yield of the plants in the various treatments was computed by means of Bessel's formula, and is based upon the variability between hills in each plat as well as the variability between the three replications. The results of the 1926 tests appear in Table XVII.

The outstanding things of note in these tests were: (1) There was a reduction of stem lesions due to Rhizoctonia, on the plats receiving the following treatments: Corrosive sublimate 1-1,000 for 90 minutes, hot formaldehyde 1-120 for 3 minutes at 125° F., DuPont Dust, Disinfectant No. 37 Bel when used as an instantaneous dip, Semesan Z-1 when used as a dip. (2) Significant increases in yield were obtained on those plats receiving the following treatments: Hot formaldehyde, DuPont Dust Disinfectant No. 12 Bel as an instantaneous dip, Semesan Bel when used as an instantaneous dip, Semesan No. 15 as a dust, Semesan dust, Semesan 13UA as a dust, and Semesan Z-1 as a dust. Failure to realize an increased yield on the corrosive sublimate treated plat was undoubtedly due to a retardation in germination, often caused by this treatment. (3) It is also noteworthy in these trials that in all cases where the same disinfectant was used, either in the dust form or as an instantaneous

TABLE XVII.—INFLUENCE OF CERTAIN ORGANIC MERCURY COMPOUNDS ON CONTROL OF RHIZOCTONIA, BLACKLEG, SEED PIECE DECAY, AND YIELD.

Manhattan, 1926.

TREATMENT.	Number of tests.	Per cent stand.	Number of sprouts to the plant.	Per cent black-leg.	Per cent sprouts with Rhizoctonia.	Per cent seed piece decay.	Yield per plant in grams.
Check	14	82.2	2.39	9.2	35.4±2.7	16.4	252.0±9.46
$HgCl_2$, 90 minutes	15	86.1	2.09	0.0	15.3±1.7	1.6	252.3±7.36
Hot formalin, 1-120, 3 min., 125° F	9	87.5	2.74	0.7	15.8±2.0	2.4	330.3±(a) 9.39
DDD No. 37 (dust)	3	81.3	2.31	2.8	33.3±3.2	5.6	303.6±14.45
DDD No. 37 Bel (dip)	3	90.6	1.91	1.5	13.7±3.9	4.5	286.6±12.36
DDD No. 37 Bel (dust)	3	88.0	2.31	0.0	30.0±1.9	3.2	254.3±11.15
DDD No. 12 Bel (dip)	3	84.0	2.11	2.2	30.9±5.3	2.2	322.6±(a) 10.55
DDD No. 12 Bel (dust)	3	88.0	2.56	1.1	56.4±7.9	8.8	283.3±9.22
Semesan Bel (dip)	3	89.3	2.00	0.7	25.1±4.1	2.1	329.3±17.56
Semesan Bel (dust)	3	98.6	1.94	1.3	38.9±1.1	5.5	271.6±11.49
Semesan No. 15 (dust)	3	92.0	2.37	0.6	44.0±1.0	7.3	335.3±(a) 12.50
Semesan (dust)	3	73.3	1.89	0.0	4.0±4.6	1.9	321.3±(a) 15.24
Semesan 13UA (dust)	3	82.6	2.59	0.0	52.2±4.6	6.2	355.3±(a) 12.92
Semesan Z-1 (dip)	3	85.3	2.18	0.7	21.5±5.2	5.0	318.6±(a) 11.59
Semesan Z-4 (dip)	3	84.0	2.09	4.5	35.8±4.8	9.8	287.6±10.46

(a) Significant increases in yield over diseased check as calculated by Bessel's formula.

dip, fewer diseased plants and consequently higher yields were obtained by the use of the material as an instantaneous dip. This can be accounted for by the more even and complete distribution of the disinfectant over the surface of the tuber. (4) Another fact, brought out by these trials was the reduction in the amount of blackleg on the treated plats as compared to the untreated. In most instances the reduction was from 9.2 per cent in the untreated plats to around 1 per cent or lower in the treated plats. (5) Seed-piece decay was also reduced by the treatments, from 16.4 per cent in the untreated check plats to 1.6 per cent as the lowest and 9.8 per cent as the highest of the treated plats. Data on this point were taken early in the season when the seed piece was still being d r a m upon by the young plant. Such early decay of the seed piece is detrimental to the future vigor of the plant, and is undoubtedly expressed in lowered yields.

In 1927 the experiments[4] on seed treatment related only to the efficiency of instantaneous dips as compared to the standard corrosire sublimate treatment and the hot-formaldehyde treatment. The experiments were conducted by the single-row-plat method. Each treatment was replicated six times, each replication consisting of 40 hills. An additional three replications were planted for determination of the per cent of Rhizoctonia lesions on the stems. These three replications were dug early in the season, and the per cent of diseased plants determined. The remaining six replications were used for the yield records. Yields were taken in pounds per plat, not by the single-hill method as in 1926. These tests were dupli-

TABLE XVIII.—RESULTS OF RHIZOCTONIA CONTROL EXPERIMENT, 1927.

TREATMENT.	Yield U. S. No. 1—pounds.			Plants infected—per cent.		
	Manhattan.	Topeka (a).	Kansas City.	Manhattan.	Topeka.	Kansas City.
Hot formaldehyde..	38.18±1.17	20.16±2.54	43.00±1.47	25.00	16.98	13.50
Semesan Bel.......	32.91± .34	16.06± .61	49.03± .12	68.08	37.93	41.70
Semesan 12 Bel....	34.74± .78	20.07± .48	46.56±2.38	46.57	23.72	31.09
Semesan 37 Bel....	41.80±1.27	17.53±1.32	48.55±1.82	40.78	22.80	21.75
Bayer Dipdust.....	33.21± .91	17.00± .71	47.26±1.18	46.95	16.07	22.46
Untreated.........	40.54± .10	16.36± .86	49.50±2.17	53.63	56.14	53.19
$HgCl_2$...........	36.14	....	....	35.49	....	....

(a) Only three replications used. The other three were discarded because of water injury.

4. The 1927 experiments were harvested by Dr. O. H. Elmer, to whom thanks are due for the data of Table XVIII.

cated, with minor variations, at Manhattan, Topeka and Kansas City. In Table XVIII the results of these tests are given, the figures representing the averages of the several replications of each treatment.

In connection with the 1927 tests the following facts are of interest: (1) The hot-formaldehyde treatment reduced the per cent of plants infected by Rhizoctonia more than any other treatment. In one case (Topeka) Bayer Dipdust gave a slightly lower per cent of diseased plants. In the other two experiments, however, the plats receiving this treatment showed a much larger per cent of diseased plants than the hot-formaldehyde treated plats. The only treatment in these experiments which consistently reduced the per cent of diseased plants when compared to the untreated check plats was the hot-formaldehyde treatment. (2) No great differences were obtained in the yield of U. S. No. 1 potatoes from the various treatments, this in spite of the fact that the treated plats in general and the hot-formaldehyde treated plat in particular, contained fewer diseased plants. This indicated quite clearly that factors other than disease control were exerting an important influence upon growth during this season. What these factors are the author is not in a position to state.

FALL VERSUS SPRING TREATMENT

It has frequently been observed that seed treatments in the spring, shortly before planting, caused a delay in emergence of the sprouts which, as already mentioned, is termed "induced dormancy." The explanation of this delay seems to be as follows: At the time of planting the potatoes have passed through their dormant period and have started growth. This growth may be evident as sprouts of various lengths, or minute sprouts in the eyes. Seed treatment throws the tubers back into their resting period. It then takes a week to ten days for them to recover. As a result plants from untreated seed invariably emerge before plants from treated seed, the difference often being as much as two weeks, depending upon the treatment and the stage of development of the tubers.

This delay is undesirable. Especially is this true in seasons of limited rainfall. In seasons of average precipitation during the growing period, plants from treated seed soon overtake or surpass those from untreated in growth. In dry seasons, however, the delay is not made up until the last of June. Harvest begins at this time in the Kaw valley and as a consequence treated seed is at a disadvantage throughout the season. Another factor may also enter.

The young tubers ordinarily set on plants the last of May. Treatment may delay this until the first week in June, which is ordinarily extremely hot and dry. The set of tubers per plant may be influenced by the temperature conditions at this time, although what information has been gathered upon this point would indicate that such was not the case.

Experiments have been conducted to determine the effect and practicability of fall and winter treatments, while the potatoes were entering or were in their rest period, in order to avoid this delay.

The initial experiment, was conducted in 1924, using mercuric chloride (1-1,000) for 90 minutes and hot formaldehyde (1-120) for 2.5 minutes at 118° to 122° F. Potatoes were treated in the fall and spring and grown in field plats on the farm of H. V. Cochran, Silver Lake. A similar experiment was conducted on the farm of James Trant, Edwardsville, in 1925, and on Mr. C. V. Cachran's farm in 1926. The results in 1924 and 1925 are given in Tables XIX and XX, and the results in 1926 in Table XIII.

TABLE XIX.—EFFECT OF FALL AND SPRING TREATMENT ON YIELD OF POTATOES.
Farm of H. V. Cochran, Silver Lake, 1924.

TREATMENT.	Yield per acre.	Increase per acre.
	Bus.	*Bus.*
Mercuric chloride, fall	143	15
Hot formaldehyde, fall	131	3
Mercuric chloride, spring	140	12
Hot formaldehyde, spring	135	7
Untreated	128	....

TABLE XX.—EFFECT OF FALL AND SPRING SEED TREATMENT ON THE YIELD OF POTATOES.
Farm of James Trant, Edwardsville, 1925.

TREATMENT.	Total yield per acre.	Yield U. S. No. 1.	Increase U. S. No. 1.
	Bus.	*Bus.*	*Bus.*
Hot formaldehyde, 3 minutes 124° to 126° F. Fall	286	186	+82
Hot formaldehyde. Fall and spring	267	186	+82
Hot formaldehyde. Spring	254	163	+59
Mercuric chloride, 90 minutes. Spring	305	156	+52
Untreated	169	104	....

The hot-formaldehyde treatment in 1924 did not control Rhizoctonia and hence failed to equal the corrosive sublimate treatment in yield per acre.

Treatments both in the fall and spring failed to give any larger yields than a single treatment in the fall, but did produce a smaller total yield than the fall treatment, probably because of the delay in germination caused by the spring treatment. In the latter comparison, however, there was no difference in the yield of U. S. No. 1 grade. Fall treatment controls Rhizoctonia satisfactorily, and causes no delay in growth in the spring.

The experiment was again repeated in 1926 on the farm of Mr. C. V. Cochran, of Topeka, with similar results. See Table XIII.

Spring treatments shortly before planting will control Rhizoctonia and will therefore result, in increased yields, provided other factors do not counteract the beneficial results of tuber disinfection. Seed treatment in the spring, however, throws the tubers back into their dormant period, causing a delay in sprout emergence. This delay, especially in dry seasons, causes retarded growth and lower yields, provided other factors do not enter. These two factors, disease control and induced dormancy, oppose each other in practical seed treatment, one tending to increase yields due to disease control, the other tending to decrease yields due to a delayed growth in the spring. In some seasons (1922,1923,1924) the former overbalances the latter, while in others (1925 and 1926) the latter may nullify the beneficial effects resulting from the former,

SPROUTED VERSUS UNSPROUTED SEED

Considerable has been written about the advisability of treating sprouted seed. It has been claimed that if badly sprouted seed is treated the sprouts will be killed and the plant retarded in growth. It appears, however, that this argument may not be valid since sprouts of any considerable length will be broken off in handling or in planting and nothing is gained by failure to treat.

However, the delay in germination due to treatment of sprouted seed is greater than the delay caused by treating seed just emerging from its dormant period. Why this is true has not been investigated. Preliminary experiments have been conducted using treated sprouted and unsprouted seed of the same seed stock as well as treated and untreated sprouted seed stock.

Two experiments have been conducted to determine the effect of treating sprouted seed. One was on the farm of Mr. Geo. Plummer, of Perry, Kan., in 1925. Treated sprouted seed yielded at the rate of 224 bushels per acre while the treated unsprouted seed yielded at the rate of 226 bushels per acre.

The second was on the farm of Mr. Chas. Speaker, of Turner, Kan. Sprouted seed was treated with mercuric chloride for 90 minutes and yielded 210 bushels per acre. When treated for 4 minutes in hot formaldehyde at 124° to 126° F. the yield was 249 bushels per acre. Untreated sprouted seed yielded 272 bushels per acre. In this case, however, the plats were all carefully hand planted and care was taken not to break pff the sprouts which had started and which were over one-half inch long at the time of planting. Both methods of seed treatment caused injury to the sprouts, and also brought about induced dormancy. In commercial plantings the majority of these sprouts would have been broke off in handling and the yields would in all probability have been quite different.

INFLUENCE OF TREATMENTS ON TUBER SET

Little information relating to the effect of treatment on the set of the tubers is available, but what there is indicates that seed treatments do not decrease the set of tubers per plant.

In the 1926 experiment on the farm of Mr. C. V. Cochran, of Topeka, the average set was determined by counting the tubers per plant of four one-rod rows in each plat. This included from 50 to 60 hills, depending upon the stand. Further information upon this matter was obtained from the field plats at Manhattan in 1926, when the same procedure was followed as above. The data obtained appear in Table XXI.

TABLE XXI.—INFLUENCE OF TREATING UPON SET OF TUBERS, 1926.

TREATMENT.	Average number of tubers per hill.	
	Topeka.	Manhattan.
Untreated	6.02	4.62
Mercuric chloride, 90 minutes	....	3.92
Hot formadehyde, 2 minutes	6.09	5.26
Hot formaldehyde, 3 minutes	....	5.71
Hot formaldehyde, 4 minutes	6.69	5.21
Hot formaldehyde, 5 minutes	....	5.64
Hot formadehyde, 6 minutes	6.69	4.63
Hot formaldehyde, 3 minutes, February	6.79	....
Hot formaldehyde, 3 minutes, fall	7.40	....

As is evident from Table XXI even the most severe treatment used, namely, hot formaldehyde for 6 minutes, failed to cause any reduction in the number of tubers per hill, when compared to untreated seed stock. Seed treated in the fall with hot formaldehyde set the largest number of tubers per hill.

HOT CORROSIVE SUBLIMATE TREATMENTS

Hot corrosive sublimate solutions are being used for the control of Rhizoctonia in some potato-growing sections. The author has had some experience with such solutions (1-1,000) at 126° F. for varying lengths of time in the control of Rhizoctonia. As with the formaldehyde solutions, the effectiveness of the treatment increases as the period of immersion increases. However, the induced dormancy is greater than with the hot formaldehyde solutions, and seed injury as measured by stand is also greater. Like the cold corrosive sublimate solutions, it weakens with use and is more corrosive to metals. There seems to be, therefore no advantage in using the hot corrosive sublimate treatment.

This conclusion is confirmed by the results of an experiment in which hot formaldehyde (1-120) was compared with hot corrosive subclimate (1-1,000) The data are given in Table XXII

TABLE XXII.—COMPARISONS OF HOT FORMALDEHYDE AND HOT CORROSIVE SUBLIMATE SOLUTIONS UPON RHIZOCTONIA CONTROL.

Early Ohio seed. Manhattan, 1925.

TREATMENT.	Per cent of stand.	Sprouts per plant.	Per cent of Rhizoctonia infected plants.	Remarks.
Untreated	91	1.9	87	———
Hot formaldehyde, 3 minutes 126° F.	92	1.8	57	———
Hot formaldehyde, 6 minutes 126° F.	92	1.6	32	———
Hot formaldehyde, 12 minutes 126° F.	85	1.1	7	Some plants stunted and weak.
Hot formaldehyde, 18 minutes 126° F.	65	0.9	0	Stunted plants.
Untreated	83	1.8	84	———
Corrosive sublimate, 3 minutes 126° F.	95	1.2	70	———
Corrosive sublimate, 6 minutes 126° F.	87	1.2	35	———
Corrosive sublimate, 12 minutes 126° F.	80	1.0	2	———
Corrosive sublimate, 18 minutes 126° F.	45	0.5	0	Stunted plants.
Untreated	80	1.7	81	———

THE INFLUENCE OF SULPHUR UPON SOIL ACIDITY AND SCAB CONTROL

Potato scab, caused by *Actinomyces scabies* (Thax) Güssow had been a source of minor trouble to the Kansas potato growers prior to the season of 1924, when a severe epiphytotic of this disease occurred. Since then potato scab has become a major problem to the potato growers of this state.

Experiments upon the control of the disease were initiated immediately after the 1924 crop was harvested. Two lines of experimentation were chosen, based upon the previous experience in other states. Controls were attempted by the use of green manures and sulphur, alone and in combination. The applications of sulphur to potato soils is intended to increase the soil acidity to a point where the organism causing potato scab can no longer cause infection. The use of green manures is supposed to supply the potato scab organism with a preferential food, upon which it will live, instead of attacking the growing tubers.

Uniform plats of land were selected which had produced an extremely scabby crop in 1924. The type of soil was a sandy loam, which had been in potatoes for at least three years previously, followed, in most instances, by a nonleguminous cover crop, rye being the most common green-manure crop used up to that time.

The sulphur used in the experiments was supplied by the Texas Gulf Sulphur Company. Both inoculated and uninoculated sulphur was used, and was broadcast by hand on the soil a week to ten days before the crop was planted, and immediately worked into the soil. Soil samples were taken from all plats before the application of sulphur, and later samples were taken at intervals throughout the growing season.

Acidity determinations were upon all samples not later than one day after being brought to the laboratory. 411 determinations were made by the electrometric method.

Clean seed treated with either corrosive sublimate 1-1,000 for 90 minutes or hot formaldehyde 1-120 for 3 minutes at 124° to 126° F. was used for planting.

Four field experiments were made during the season of 1925. Complete acidity determinations of the soil for the entire growing season are available for three of the experiments and per cent of scab on the harvested crop was determined on all four. The data obtained appear in Tables XXIII and XXIV.

TABLE XXIII.—SOIL ACIDITY DETERMINATIONS ON EXPERIMENTAL PLATS.

Farm of J. H. Skinner & Co., Topeka, 1925.

Cover crop.	SOIL TREATMENT.	Soil acidity determinations expressed as PH on—				
		3/10(a).	3/27.	4/30.	5/28.	6/11.
Rye	200 lbs. inoc. sulphur per acre	7.3	6.16	5.12	5.02	5.51
	Check, no sulphur	6.8	7.38	6.86	5.40	5.30
	400 lbs. inoc. sulphur per acre	7.2	5.44	5.02	4.53	5.57
None	200 lbs. inoc. sulphur per acre	5.7	7.03	5.85	4.92	5.92
	Check, no sulphur	5.85	6.89	6.30	5.61	5.57
	400 lbs. inoc. sulphur per acre	6.00	5.30	4.53	4.88	5.64
Cowpeas	200 lbs. inoc. sulphur per acre	6.5	7.34	6.54	5.44	5.37
	Check, no sulphur	6.4	6.93	7.10	6.86	5.16
	400 lbs. inoc. sulphur per acre	6.6	4.92	5.57	4.40	5.02

(a) Samples taken previous to sulphur application.

HISTORY OF LAND:
Crops on land in 1922: potatoes; rye-vetch cover crop.
Crops on land in 1923: potatoes; rye cover crop.
Crops on land in 1924: potatoes; no cover crop.

TABLE XXIV.—INFLUENCE OF SULPHUR APPLICATIONS TO SOIL AND COVER CROPS ON PER CENT OF SCAB.

Farm of J. H. Skinner & Co., Topeka, 1925.

Cover crop.	TREATMENT: Pounds of sulphur per acre.	Yield per acre.	Per cent of scab.		
			Clean.	Slight.	Bad.
		Bus.			
Rye	200 lbs. inoculated	84.7	24.7	42.0	33.3
	None	115.7	35.7	40.8	23.5
	400 lbs. inoculated	82.4	62.3	32.7	5.0
None	200 lbs. inoculated	145.2	23.9	33.2	42.9
	None	120.7	11.8	35.3	52.9
	400 lbs. inoculated	147.1	29.1	39.4	31.5
Cowpeas	200 lbs. inoculated	151.3	37.5	35.5	27.0
	None	180.2	18.4	40.4	41.2
	400 lbs. inoculated	164.5	35.2	33.1	31.7

Clean—no scab spots.
Slight—1 to 2 scab spots (salable).
Bad—3 or more scab spots (unsalable).

Several interesting facts are to be noted from these experiments. From Table XXIII it is readily noticed that 200 pounds of inoculated sulphur was not sufficient to appreciably change the soil acidity where no cover crop had been used the previous year, or where cow-peas had been plowed under. It did cause an appreciable increase in soil acidity on the plats which had grown a green manure crop of rye. On the other hand 400 pounds of inoculated sulphur caused a decided increase in acidity on all three series.

From Table XXIV it appears that in considering yields alone, sulphur applications to soils without green manures the previous season are beneficial, since the two plats that had received sulphur outyielded the one that received none by 25 and 27 bushels per acre, respectively. On the other hand, sulphur applications to soils higher in humus content, in other words those that did have a green-manure crop plowed under, caused a decrease in total yield. Plats with rye or cowpeas alone outyielded the adjoining plats which had in addition sulphur applications to the soil.

By examining the scab data of Table XXIV it is apparent that 200 pounds of inoculated sulphur gave an increase in per cent of clean tubers in two out of the three cases where it was used, namely, on those plats where no cover crop had been used and where cowpeas had been plowed under the previous season. Four hundred pounds of inoculated sulphur increased the per cent of clean tubers in all three cases where it was used, giving the largest increase on the rye plat, where it increased the per cent of clean tubers from 35.7 per cent on the plat with rye alone, to 62.3 per cent where rye and 400 pounds of inoculated sulphur were combined, and decreasing the per cent of badly scabbed from 23.5 to 5 per cent.

It is also evident from these data that sulphur alone or green manures alone are not as efficient, in general, in reducing scab due to soil infection, as combinations of the two. Furthermore, it is indicated that of the two cover crops used, rye, or the nonleguminous cover crop which is plowed under in early spring, is more effective in reducing scab than cowpeas alone, a leguminous cover crop plowed under the previous fall. The reason for this may be due to the fact that rye plowed under in the spring furnishes more decomposing organic matter at the time tubers are setting and infection with scab is taking place than cowpeas which had been plowed under the previous fall. Judging from Millard's results *(8)* with green manures in England this is probably the correct explanation of these results.

A second experiment, comparing inoculated with uninoculated sulphur, was conducted on the farm of Mr. Floyd Cochran. The piece of land chosen for these experiments had been in potatoes for three successive years previous to 1925, and rye as a green-manure crop had been turned under in 1922 and 1923, but no green-manure crop had been used in 1924.

The sulphur was applied at the rate of 300 pounds per acre, being broadcast and worked into the soil a week previous to planting. The three plats were each one-third of an acre in size.

The soil acidity determinations of these plats are given in Table XXV. The yield and per cent of scab data appear in Table XXVI.

TABLE XXV.—SOIL ACIDITY DETERMINATIONS ON EXPERIMENTAL PLATS.
Farm of Floyd Cochran, Topeka, 1925.

SOIL TREATMENT.	Soil acidity determinations expressed as PH on—				
	3/10 (a).	3/28.	4/30.	5/28.	6/11.
300 lbs. inoculated sulphur per acre	5.0	5.40	5.78	6.86	6.00
Check, no sulphur	5.0	6.27	6.37	6.23	6.61
300 lbs. uninoculated sulphur per acre	5.0	5.75	5.19	6.34	4.71

(a) Samples taken previous to sulphur application.
HISTORY OF LAND:
Crops on land in 1922: potatoes; rye cover crop.
Crops on land in 1923: potatoes; rye cover crop.
Crops on land in 1924: potatoes; no cover crop.

TABLE XXVI.—INFLUENCE OF INOCULATED AND UNINOCULATED SULPHUR ON YIELD AND SCAB CONTROL.
Farm of Floyd Cochran, Topeka, 1925.

SOIL TREATMENT.	Yield per acre.	Per cent of scab.		
		Clean.	Slight.	Bad.
	Bus.			
300 lbs. inoculated sulphur per acre	110.4	9.0	32.1	58.9
Check	53.4	13.4	42.0	44.6
300 lbs. uninoculated sulphur per acre	62.4	8.7	42.9	48.4

Clean—no scab spot.
Slight—1 to 2 scab spots (salable).
Bad—more than 3 spots, usually several (unsalable).

The plats of this experiment produced a uniformly badly scabbed crop. In 1924 the crop harvested was practically worthless, and the soil was very heavily infested with the scab organism. Neither inoculated nor uninoculated sulphur, at the rate used, caused any increase in soil acidity at the critical time for infection (the last of May or the first of June) and no appreciable differences resulted in the per cent of clean tubers in the resulting crop.

The rate of sulphur application on these plats was evidently too low to produce appreciable increase in soil acidity that extended over a sufficient period to cause any reduction in scab infection. Furthermore, there was no difference observable between the inoculated and the uninoculated sulphur.

A second experiment, identical to the above, was conducted on the farm of Mr. Harry Stover. The soil acidity determinations appear in Table XXVII. The yield and per cent of scab data appear in Table XXVIII.

TABLE XXVII.—SOIL ACIDITY DETERMINATIONS ON EXPERIMENTAL PLATS.
Farm of Harry Stover, Topeka, 1925.

SOIL TREATMENT.	Soil acidity determinations expressed as PH on—				
	3/10 (a).	3/27.	4/30.	5/28.	6/11.
300 lbs. inoculated sulphur per acre	5.0	7.65	5.82	6.51	5.88
Check, no sulphur	5.0	6.54	6.75	7.48	6.27
300 lbs. uninoculated sulphur per acre	5.0	4.53	5.82	(b)	5.23

(a) Samples taken previous to sulphur applications.
(b) Sample contaminated with H_2O in H-ion machine.

HISTORY OF LAND:
Crops on land in 1922: potatoes; no cover crop.
Crops on land in 1923: potatoes; rye cover crop.
Crops on land in 1924: potatoes; turnips cover crop.

TABLE XXVIII.—INFLUENCE OF INOCULATED AND UNINOCULATED SULPHUR ON YIELD AND SCAB CONTROL.
Farm of Harry Stover, Topeka, 1925.

SOIL TREATMENT.	Yield per acre.	Per cent of scab.		
		Clean.	Slight.	Bad.
	Bus.			
300 lbs. inoculated sulphur per acre	96.8	38.4	37.8	23.8
Check	79.2	25.4	38.4	36.2
300 lbs. uninoculated sulphur per acre	70.4	29.1	43.2	27.7

Clean—no scab spots.
Slight—1 to 2 scab spots (salable).
Bad—3 or more scab spots (unsalable).

The land on which these plats were located had been in potatoes for three years previously, with rye as a green-manure crop in 1922 and 1923, and turnips as a green-manure crop in 1924. Sulphur was broadcast at the rate of 300 pounds per acre and worked into the soil a week previous to planting.

From Table XXVII it is evident that neither the inoculated nor the uninoculated sulphur, at the rate used, caused an appreciable increase in soil acidity, and from Table XXVIII no great increase in per cent of clean tubers resulted from either application, although slight, increases in per cent of clean tubers were recorded. Little, if any, difference can be observed between the plats receiving inoculated or uninoculated sulphur.

A third replication of the above experiments was made on the farm of Mr. John Taylor, Edwardsville. No soil acidity determinations were made of soil in these plats. The yield and per cent of scab data appear in Table XXIX.

From Table XXIX it is again evident that the sulphur at the rate used failed to increase the per cent of clean tubers. The sulphur applications did result in increased yields, however, so actually more clean tubers were harvested from these plats than from the plat which had not received sulphur.

TABLE XXIX.—INFLUENCE OF INOCULATED AND UNINOCULATED SULPHUR ON YIELD AND SCAB CONTROL.

Farm of John Taylor, Edwardsville, 1925.

SOIL TREATMENT.	Yield per acre.		Per cent of scab.	
	Total.	U. S. No. 1.	Clean.	Scabby (a).
	Bus.	*Bus.*		
300 lbs. inoculated sulphur per acre	154.0	109.5	71.9	28.1
Check, no sulphur	141.0	95.8	68.7	31.3
300 lbs. uninoculated sulphur per acre	161.0	123.1	66.1	33.9

(a) Scabby—1 to 3 scab spots (salable).

The work thus far conducted on potato scab in Kansas indicated that some control can be obtained on heavily infested soil by the use of green-manure crops. The indications point toward those green-manure crops that can be plowed under in the spring as being more efficient in this respect. Sulphur applications in combination with green manures have also given a higher per cent of clean tubers in the following crop of potatoes. Sulphur applications alone, at the rates used, have given little if any beneficial results. The continued use of sulphur on potato ground for the control of scab, or single large applications, may lead to decreases in yield, not only of the current season's crop of potatoes, but to subsequent crops. This point should be further investigated.

The continued use of heavy green-manure crops that can be plowed under in the spring, shortly before planting time, is at the present the best recommendation that can be made for the control of potato scab, on heavily infested soils. Seed treatment, by the recommended methods, will effectively control tuber-borne scab, and should be practiced consistently,

THE USE OF TREATED SEED IN THE KAW VALLEY

Since the original experiments were conducted with the hot-formaldehyde method of potato-seed treatment by Melhus and his associates in Iowa *(3, 4, 5, 6, 7)* many states have conducted experiments with this method and 13 states are now recommending it *(1)* It has been the means by which a much larger per cent of the total acreage in the state of Kansas has been planted with treated seed. This is brought out by Table XXX, which shows the total acreage in the Kaw valley of Kansas for several years, the acreage treated by the two recommended methods, and the per cent of the total acreage treated.

TABLE XXX.—ACREAGE OF POTATOES IN THE KAW VALLEY AND THE USE OF TREATED SEED.

YEAR.	Total acreage.	Acres treated.			
		Hot formaldehyde.	Corrosive sublimate.	Total.	Per cent.
1921	17,500	0	2,200	2,200	13
1922	18,000	0	3,000	3,000	17
1923	16,000	500	4,000	4,500	28
1924	18,000	700	6,000	6,700	37
1925	16,000	9,265	1,809	11,074	69
1926 (*a*)	14,500	9,288	2,575	11,863	81

(*a*) Includes a small acreage in the Arkansas valley.

It will be noted that with the advent of the hot-formaldehyde method, supported by the recommendation of the Agricultural Experiment Station in 1925, the per cent of the total acreage that was treated increased from 37 to 69. This may be partially due to the accumulative effects of a vigorous seed-treatment campaign which had been in force for a number of years. However, this supposition is less tenable, when the acreage treated with each of the treatments in 1925 is noted. There was a distinct and sharp tendency to discard the corrosive sublimate method in favor of the hot formaldehyde. This was due largely to the time-saving factor which went with the latter method, although the necessary constant renewal of corrosive sublimate solutions had been a serious drawback to the latter.

There is a tendency at present to revert to the corrosive sublimate method or to discard seed treatment entirely. The disturbing factor has been the delay in emergence from the soil of sprouts arising from seed treated with either of the two methods, which is most pronounced with the hot-formaldehyde method.

During the past two years the untreated seed has almost equaled or in some cases surpassed in yield the treated seed. This condition has not been general in the Kaw valley, but the exceptions always receive more attention than the normal in such cases.

GENERAL DISCUSSION AND RECOMMENDATIONS

Both the corrosive sublimate and hot-formaldehyde methods of seed treatment are recommended for Kansas potato growers. It is felt that for the small grower the expense of equipment for the hot-formaldehyde method is more than the extra time saved is worth. However, growers are quick to eliminate expensive and complicated apparatus, and to devise simple means for reaching the desired end. For example, an ordinary hog-scalding tank with a tin bottom will handle two sacks of potatoes at a time very easily. Such tanks are in use in Kansas, the heat being supplied by a wood fire built directly beneath the tank. Such apparatus is within the reach of any farmer, and very satisfactory results in maintaining the desired temperature have been obtained. Where gas is available a small tank similar to the above, accommodating two to six sacks, can be heated satisfactorily by a regulated gas burner. Watering tanks holding large quantities of solution are satisfactorily heated only by steam.

There are several commercial treating outfits on the market which serve the purpose well, handling one or two sacks at a time. Heat is supplied in these machines by pressure oil burners. On the whole these have proved satisfactory, although they may have certain disadvantages, other than expense.

The recommended treatment for the hot-formaldehyde method is as follows: The solution is made up of 2 pints of 40 per cent formaldehyde to 30 gallons of water. The temperature should be maintained between 124° and 126° F. The length of dip should be between 3 and 4 minutes, depending upon the temperature of the solution at the time of dipping.

The cold corrosive sublimate treatment should be carried out as follows: The strength of the solution should be 4 ounces of corrosive sublimate to 30 gallons of water. The potatoes should be immersed in this solution for 1½ hours. Shorter periods have not in general given satisfaction or good control of Rhizoctonia.[5]

It is recommended that whenever possible potato seed treatment by either method be done in the fall or at least a month before planting. This eliminates the delay in germination due to spring treatments, eliminates the rush at time of planting, and causes less

5. For more detailed directions write to the Agricultural Experiment Station, Manhattan, Kan.

shrinkage in storage. If fall treatment is practiced the tubers should be thoroughly dry before storing, and for this reason the hot formaldehyde method is more highly recommended at this time of the year. Formaldehyde, being a gas dissolved in water, readily evaporates from the surface of the tuber, and no danger of injury from this cause can be expected. It has been observed that potatoes treated in hot solutions dry more readily than those treated in cold solutions. It will probably be more convenient, to use the hot method in the fall, due to its rapidity. A car of seed potatoes can be treated, dried, and stored in a day, thus eliminating any danger of frost injury that might result, if the potatoes had to be left standing over night out of the storage cellar.

In seasons of late frosts the plants from treated seed are at a further disadvantage. Plants free from stem cankers of Rhizoctonia grow more rapidly than plants with disease lesions upon them. Although treated plants are likely to be smaller at the time of the frost they are more succulent and are invariably injured to a greater degree.

This fact was forcibly illustrated in 1925. In this year a heavy frost on May 24 severely injured a large number of seed-treatment experiments. The treated plats were just approaching the untreated in amount of top growth, although some had been delayed ten days in emerging from the soil. The freeze injured the treated plats much more severely than the untreated, and a smaller yield was harvested from the treated plats in every instance.

As previously suggested "induced dormancy" may be eliminated by fall or winter treating. Injury to the sprouts is also avoided. Furthermore, tubers showing bruises and cuts will store better, if treated in the fall, due to a decreased shrinkage caused by dry rot, and other storage diseases.

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