THE EFFECT OF CALCIUM-POTASSIUM RATIOS ON THE INCIDENCE OF POTATO SCAB

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This is to certify that the

thesis entitled

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presented by

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THE EFFECT OF CALCIUM-POTASSIUM RATIOS ON THE INCIDENCE OF POTATO SCAB

By

Philip Beaumont Turner

A THESIS

Submitted to the School of Graduate Studies of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

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Three field trials were carried out to ascertain the effect of calcium-potassium ratios upon the scabbiness and yield of potato tubers and the uptake of calcium and potassium by the plants. One field trial was conducted to determine whether application of zinc would reduce scabbing of potatoes. A greenhouse experiment was performed to test the effects of lime placement on yield and scabbing of tubers.

The field soil was Hillsdale sandy loam having originally a pH of 6.2 and an exchangeable calcium and potassium content of 3.50 and 0.80 milliequivalents per 100 grams, respectively. Katahdin, Chippewa, and Sebago potato varieties were grown.

For the greenhouse study Emmet fine sandy loam with a pH of 6.5 and five percent organic matter was chosen. Chippewa potatoes were used in this experiment.

In order to obtain descending calcium-potassium ratios, potash was supplied at rates of none to 450 pounds per acre in 50 pound increments. Zinc at rates of none, 12.5, and 25 pounds per acre was superimposed on a potash treatment series.

Lime was applied in bands at the nine inch depth and was mixed throughout the top nine inches of soil which had previously been leached with sulfuric acid to create two pH levels.

At intervals throughout the growing season leaf samples were taken from the field plots and analyzed for total calcium and potassium, while soil samples taken were analyzed for exchangeable calcium and potassium.

The harvested tubers were sorted into four classifications of scabbiness, weighed, and specific gravity of a representative sample from each plot was determined.

In 1951, as the calcium-potassium ratio approached one, there were increased yields and reduced scabbiness on Katahdin potatoes.

No general trends resulted from lowered calcium-potassium ratios in 1952. Yields increased with the first three increases in exchangeable potassium content of the soil. The picture presented by that year's data did not confirm the initial trends of the 1951 data.

The yields, percent scab, and scab index showed that Chippewa and Segabo potatoes did not respond favorably to the addition of potash in 1953. Katahdins showed trends of lowered scab index and increased yields similar to those of 1951 but of less magnitude.

Zinc did not decrease the percent of scabby tubers, the scab index, or percent heavy scab. No increase in yield resulted from the addition of zinc. The potash treatments did significantly increase yields.

The greenhouse data showed that lime placed at the nine inch depth did not reduce scabbing nor increase yield at either pH. Chippewas from Emmet fine sandy loam at pH 5.6 with 1000 pounds per acre of lime mixed throughout the top nine inches of soil were the most scab-free and largest of all the harvested tubers.

The exchangeable potassium in the soil and the total potassium in the potato leaves increased in a manner consistent with the increments of potash applied. The relationship between the calcium-potassium ratios in leaf and soil samples was evidenced by their similar curves.

The addition of as much as 450 pounds of potash per acre had no adverse effect on the cooking quality of Katahdin potatoes as measured by the specific gravity.

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INTRODUCTION

The potato, introduced into Spain during the last half of the sixteenth century (16), has had a marked influence on Occidental civilization. Its economic importance was and is considerable in that it furnishes a large portion of the carbohydrates consumed in the United States. Losses from scab have increased in major potato producing areas (25), and returns from the crop have been greatly decreased. As a result, all commercial growers are interested in control measures.

In 1890 Thaxter (20) described the causitive agent of potato scab and named it <u>Oöspora scabies</u>. Güssow renamed it <u>Actinomyces scabies</u> (8), and it is now classified as <u>Streptomyces scabies</u> as was proposed by Waksman and Henrici (2, 22). From that time numerous investigators have treated the soil and seed tubers with named and un-named compounds in an effort to conquer the disease.

In 1942 Schroeder and Albrecht (17) carried out greenhouse experiments using artificial soil in which the calcium-potassium ratios were varied. They reported that the incidence of potato scab was decreased by bringing the calcium and potassium into a 1:1 m.e. ratio. In 1926 Fellows (6) described the relationship between growth in the potato tuber and potato scabbiness as follows:

1. Potatoes are susceptible to infection during their growth period.

2. The pathogenic organism enters the host along the phellogen of the cells of the subepidermal layer by way of the middle lamella which becomes thickened and darkened.

Since it is known that calcium pectate is a component of the middle lamella (15), it is reasonable to expect, in relating the results of these two works, that an unbalanced exchangeable calcium-potassium ratio in a potato plant might allow deeper, more extensive, and more frequent invasion of the middle lamella by Streptomyces scabies.

The experiments reported in this paper were conducted to determine which of various calcium-potassium levels on a field soil in situ would decrease scabbing without adversely affecting yield.

Incidental to the main objective were

1. Appraisal of the effect of added exchangeable potassium on the potassium and calcium content of the potato leaves.
2. Evaluation of the effect of varying potassium levels on the specific gravity of the potato tubers.
3. Carrying out a greenhouse test to determine the effect on potato scab of lime concentrations at various depths.
4. Investigations of the effect of zinc on Streptomyces scabies in a field plot.

REVIEW OF LITERATURE

Previous works by Stone and Chapman (19) in Massachusetts; Wheeler, Towar, Hartwell, and Sargent (22) in Rhode Island; and Muncie, Wheeler, and Tyson (10) in Michigan, and many others were directed toward reduction of potato scabbiness by means of some inhibitor to the growth of the causal organisms. Wollenweber (24) and Wingerberg (23) reported that the etiology was not one but many species of the organism. Hence, the various soil remedies were not universally effective (9).

In 1896 Wheeler et al (22) reported that lime and wood ashes increased scab incidence on "exceedingly acid" sandy loam. Cook and Houghland's (4) results showed that fertilizers containing calcium, used over a period of years, increased the prevalence of scabby potatoes in Virginia soils with an original pH of 5.0. Generally, workers have found more scab in limed soil although Blodget and Cowan (3) found that extremely large amounts of lime applied to a soil with pH 4.48 reduced scab lesions on tubers.

Starr (18) found no significant relationship between scabbiness and the pH of the soil or its content of soluble salts, lime or available phosphorus or potassium. Nevertheless, in 1942 in a greenhouse trial Schroeder and Albrecht (17) decreased scabbing by bringing the calcium and potassium content of the soil into an equivalent balance.

The use of heavy elements for control of scab in potatoes has had many varied results. Copper sulfate gave some control in New Jersey and Michigan but failed in Vermont (9). Mercury compounds have given partial to complete control of scab in Long Island, New York, Maine, New Jersey, and foreign countries but have failed in many other places (9). KenKnight (9), in his studies on soil Actinomyces in relation to potato scab, stated, "Zinc alone and in combination with mercuric chloride as soil treatments decreased scabbing."

Nelson and Brady (11), in a 1944 greenhouse trial, showed that subsurface placement of lime in Portsmouth sandy loam increased total yield of potatoes and the amount of scab free tubers.

EXPERIMENTAL METHODS

Field

Soil. The site of the field trials was the college farm at East Lansing, Michigan. The soil type and some of its chemical properties at the beginning of the study (1951) are shown in Table 1. This soil had not been in cultivation for several years and was covered with a sod of blue grass and weeds indigenous to the area. The soil was easy to till and was well adapted to the raising of potatoes.

Field Treatments and Procedures. The soil test showed the presence of sufficient exchangeable calcium. Therefore, it was decided to add potash fertilizer at ten rates of application, the highest calculated to bring about a 1:1 calcium-potassium ratio.

The treatments were

1. 0 pounds of K_2O per acre
2. 50 pounds of K_2O per acre
3. 100 pounds of K_2O per acre
4. 150 pounds of K_2O per acre
5. 200 pounds of K_2O per acre
6. 250 pounds of K_2O per acre
7. 300 pounds of K_2O per acre
8. 350 pounds of K_2O per acre

TABLE 1

SOIL DATA

Soil Type	pH[1]	OM[2]	K[3]	Ca[3]	Na[3]	Mg[4]	Total Base Exchange Capacity[5]
		(pct.)	(milliequivalents per 100 grams)				
Hillsdale Sandy Loam	6.2	3	0.80	3.50	0.69	0.26	5.9

1 pH determined by glass electrode on a 1:1 soil-water ratio

2 Organic matter determined by dry combustion method (1)

3 Potassium, calcium, and sodium determined by use of Normal ammonium acetate extraction and flame photometer

4 Magnesium determined by colorimetric method of Drosdoff and Nearpass (5)

5 Total base exchange determined as follows:

Soak a 25-gram sample over night in distilled water. Leach with 200 ml. of 0.05 Normal HCl. Wash with two 200 ml. portions H_2O and 100 ml. of 85-90 percent ethyl alcohol. Dry in a 90° C. oven overnight. Using a 1:1.5 soil-water ratio, determine the pH. Add two grams of solid $BaCl_2$ (crystals). Determine the pH. Titrate potentiometrically with standard $Ba(OH)_2$ to pH 8.0 by adding 1 ml. increments of $Ba(OH)_2$ to pH 7.0 and then 0.5 ml. increments to pH 8.0.

9. 400 pounds of K_2O per acre

10. 450 pounds of K_2O per acre

These treatments were replicated three times in a randomized design.

The area was divided into two equal fields, designated as <u>fields A</u> and <u>B</u>. Each individual plot within these fields measured 10.5 by 30 feet and contained three rows of potatoes. There were three guard rows on the east and west borders of the entire experimental area.

On May 5, 1951, half of the potash was broadcast on each plot in <u>fields A</u> and <u>B</u>. The remainder was applied on May 19 after the soil had been plowed and fitted. Katahdin seed was then planted in <u>field A</u> without further fertilization. A blanket application of urea and phosphoric acid was made on June 9.

Samples of soil from <u>field A</u> were obtained on July 28, August 5, and November 12, 1951. Leaf samples were taken July 14, July 24, and August 4. The crop was harvested on October 4. Tubers from the center 25 feet of the middle row of each individual plot were used in this study. They were graded into four classifications of scabbiness as follows:

1. Clean - no scab
2. Light - one or two slight lesions per tuber
3. Medium - several lesions per tuber, none extremely deep
4. Heavy - many lesions per tuber, with or without deep scab

A photograph showing potatoes typical of these grades is presented in Plate IA.

To correlate yield with scabbing, tubers were weighed according to the above classifications. The specific gravity of a representative sample from each plot was ascertained at storage time.

The number two size scabby potatoes were saved for the next year's seed.

Field B was planted on May 15, 1952 without further application of potash fertilizer. Phosphoric acid and urea were applied on May 30.

Soil samples were taken from field B on July 12, and August 28. Leaf samples were taken on July 19, August 2, and August 17. On October 8 the tubers were harvested, sorted, weighed, and specific gravity determinations made as in the previous year.

In 1953 two separate field tests were carried out. Before planting, potash was added to field A for the purpose of making the exchangeable potassium content of at least three treated plots equal to or greater than the exchangeable calcium content. The following amounts were used:

1. 50 pounds of K_2O per acre
2. 55 pounds of K_2O per acre
3. 175 pounds of K_2O per acre
4. 200 pounds of K_2O per acre

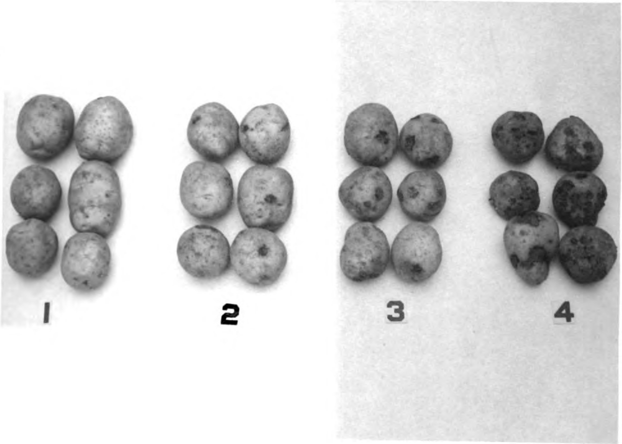


Plate IA. Potatoes typical of the scab grades used in this study

1. Clean - no scab
2. Light - one or two slight lesions per tuber
3. Medium - several lesions per tuber, none extremely deep
4. Heavy - many lesions per tuber with or without deep scabs

5. 240 pounds of K_2O per acre
6. 250 pounds of K_2O per acre
7. 270 pounds of K_2O per acre
8. 310 pounds of K_2O per acre
9. 350 pounds of K_2O per acre
10. 1,000 pounds of K_2O per acre

This field had been planted to oats, followed by rye which had been plowed down in the spring. On May 19 and 20 field A was planted so that each plot contained one row each of the Katahdin, Chippewa, and Sebago varieties.

Zinc was applied to field B so that each of the three replications in the calcium-potassium treatment series received 0, 12.5, or 25 pounds of zinc per acre. This field was planted at the same time as field A, but only Katahdin seed was used.

Soil samples were taken from field A on July 18, August 28, and November 6 and leaf samples on July 11 and August 8. Harvesting from each row and grading were done on October 23. Specific gravity was not determined.

No soil or leaf samples were removed from field B. A 25-foot section from the center row of each plot was harvested on October 23. Grading and weighing were carried out as in previous years. Specific gravity was not determined.

The methods of reporting scabbiness follow.

1. The percent scab was derived by dividing the total yield from each treatment into the total pounds of tubers which had been graded light, medium, and heavy in scabbiness and multiplying the quotient by 100.
2. The percent heavy scab refers to the percent of the total yield from each treatment which was classified as heavy in scabbiness.
3. The scab index is a weighted index which was derived for each treatment by multiplying the total pounds of tubers graded light, medium, and heavy by one, two, and three, respectively. These three products were added, and the sum was divided by the total weight of the tubers harvested from the three replications.

Yields resulting from each treatment are reported as yield index which was calculated by adding the pounds from each replication, dividing this sum by three and multiplying by 10 to remove the decimal point.

In order to indicate freedom from scabbiness, the percent U. S. No. 1 was determined by dividing the total yield from each treatment into the pounds of potatoes which had been graded clean and light. To show the correlation between percent U. S. No. 1 and yield, yield index U. S. No. 1 was determined by multiplying percent U. S. No. 1 and yield index.

Laboratory Procedures. Twenty-five grams of air dry seived soil from each sample was leached with 200 cc. of 1 Normal ammonium acetate (12). Exchangeable calcium and potassium in parts per million were determined on an aliquot of the extract by means of a Perkin-Elmer flame photometer, model 52A, using an acetylene gas flame. The internal standard method was employed. The calcium-potassium ratios were calculated from averages of milliequivalents per 100 grams found in samples taken from the three replications on different dates.

The leaves were dried at 60° C. and ground in a Wiley mill. One gram samples of the material were wet ashed (13) by means of sulfuric acid, nitric acid, and perchloric acid; made up to standard volume; and analyzed for calcium and potassium content in the flame photometer

Greenhouse

Soil. Emmet fine sandy loam having an original pH of 6.5 and containing approximately five percent organic matter was used in 1951.

Treatments and Procedures. Twelve pots were each filled with 12 kilograms of the soil. Six individual pots were leached with 150 cc. of 6 Normal sulfuric acid solution. The remaining six were leached with 185 cc. of 6 Normal sulfuric acid solution each. After being allowed to stand overnight, every pot was flushed with three quarts distilled water.

In order to apply the treatments, the above soils were repotted in the same 12 pots. Lime at the rate of 1,000 pounds per acre was placed in a band at the nine inch level in pots 1, 2, 7, and 8. One thousand pounds of lime per acre was mixed throughout the top nine inches of soil in pots 3, 4, 9, and 10. Pots 5, 6, 11, and 12 received no lime (Table 2). Soil moisture was maintained at a uniform level.

On March 13, 1951 U. S. number two Chippewa potatoes of equal size were planted and fertilized with 1000 pounds of 3-12-12 per acre. Each pot was inoculated with the same amount of a solution of S. scabies made by washing potato peels that contained scab lesions. Plants were thinned to a uniform three stalks per pot on April 4.

The crop was harvested, sorted, and stored on June 5. The classifications of scabbiness used for the field grown tubers were employed here also.

TABLE 2

LIME PLACEMENT

Lime[1]	Treated with 150 cc. 6 N H_2SO_4	Treated with 185 cc. 6 N H_2SO_4
1000 pounds per acre at 9 inch depth - band	pots 1 and 2	pots 7 and 8
1000 pounds per acre throughout top 9 inches	pots 3 and 4	pots 9 and 10
none	pots 5 and 6	pots 11 and 12

[1] CP $CaCO_3$ was used.

EXPERIMENTAL RESULTS

Field

The presentation of data is such that it is comparable between treatments and years. The reporting of percent U.S. No. 1's and the yield index were devised to express the economic aspect of the experiment, whereas the percent of scab and heavy scab are included to present the actual variations in scabbiness, disregarding amount of yield. The scab index shows the interrelationship between the three degrees of scabbing and yields under each treatment. The exchangeable calcium and potassium content of soil samples, the yield index, the scab index, the percent U. S. No. 1's, the percent scab, the calcium and potassium in leaf samples, and specific gravity of potatoes were evaluated by analyses of variance at the 5% level.

In 1951 increasing levels of potash produced a general trend of scab reduction as indicated in Table 3 and Figures 1 and 3. This trend was accompanied by increased total yield, more U. S. No. 1's, and a lowered scab index. Although there were inconsistencies from one level of potassium to the next, as in the work of Schroeder and Albrecht (17), the statistical analysis showed that the data are significant. The largest application of potash did not bring about the expected 1:1

TABLE 3

EFFECT OF CALCIUM-POTASSIUM RATIOS ON POTATO SCAB AND YIELD, 1951

Treatment Number	Ca:K in the soil	Yield Index	Percent U.S. No. 1	Yield Index U.S. No. 1	Percent Scab	Percent Heavy Scab	Scab Index
1	7.34	105	92.9	97.5	74	1.45	0.819
2	5.97	124	95.4	118.0	91	3.88	1.957
4	4.62	221	90.3	199.5	68	6.18	0.778
5	4.11	191	97.3	186.0	64	0.00	0.670
3	3.78	148	86.2	127.5	99	8.45	1.126
6	3.16	249	97.8	243.0	67	0.80	0.695
7	2.91	219	92.9	203.0	67	6.30	0.781
8	1.95	270	93.9	254.0	44	2.60	0.515
9	1.58	219	96.6	211.0	58	3.50	0.630
10	1.48	309	100.0	309.0	40	0.00	0.401
L.S.D. (0.05)		83	N.S.		152		0.40

Definitions of the above terminology may be found on page 11.

ratio but did produce the lowest scab index, the greatest yield, and the fewest scabby potatoes. From this year's results, it would appear that Schroeder and Albrecht's theory that balanced exchangeable calcium and potassium will cause a decrease of scab incidence is valid.

Potato plants grown on treatments 1, 2, and 3 showed varying degrees of potassium deficiency. Hillsdale soil is known to be low in available potassium and phosphorus. Hence, low potash applications with relatively normal applications of nitrogen and phosphorus would be expected to bring on the observed potassium deficiencies.

Table 4 and Figures 1 and 3 give the results of the 1952 trials and indicate that decreased calcium-potassium ratios had no significant effect on the total yields nor amount of U. S. No. 1's, but the percent scab showed a difference between treatment 2 and all others except treatment 8. The scab index showed no significant difference between treatments. The greatest yield and the largest quantity of U. S. No. 1's were produced in the plots which received 400 pounds of potash per acre.

It will be noted that the ratios of exchangeable calcium and potassium in the soil did not follow the treatments applied so closely as in 1951. This may be explained partly by the fact that plant roots sorb nutrients in ratios dissimilar to that of the cations on the exchange complex. Increasing the potassium available to the growing plants stimulated

TABLE 4

EFFECT OF CALCIUM-POTASSIUM RATIOS ON POTATO SCAB AND YIELD, 1952

Treatment Number	Ca:K in the Soil	Yield Index	Percent U.S. No.1	Yield Index U.S. No. 1	Percent Scab	Percent Heavy Scab	Scab Index
1	5.20	261	79.2	204	65	6.58	0.956
2	2.53	295	87.3	258	82	7.22	1.022
9	2.01	423	76.7	324	63	5.35	0.914
6	2.01	334	77.2	258	67	9.73	0.993
4	1.79	348	81.9	285	58	9.39	0.854
5	1.78	327	81.8	267	59	8.93	0.816
8	1.77	353	81.5	287	69	8.29	0.985
3	1.75	333	77.7	258	66	11.63	1.002
7	1.55	326	85.1	278	65	5.26	0.855
10	1.36	310	77.8	240	55	11.34	0.895
L.S.D. (0.05)		N.S.	N.S.		14.5		N.S.

Definitions of the above terminology may be found on page 11.

growth and could have increased the total calcium removed, thus causing the calcium-potassium ratio in the soil to fluctuate in an unpredictable manner.

The results in 1952 were inconclusive and did not corroborate the 1951 data.

Tables 5, 6, and 7 and Figures 2 and 4 present the results from the 1953 tests on field A. As the calcium-potassium ratio decreased to less than one, total yields in all three varieties were lowered with few exceptions. Under treatment 10 few of the seed potatoes germinated because of the high salt concentration in the soil. No significant trends in percent of U. S. No. 1's, percent of scabby tubers, nor in the scab index, were discerned in the Chippewas and Sebago varieties. However, the Katahdins showed a decrease in scab index (Figures 2 and 4) and were found to be significantly less scabby than the other varieties.

The 1953 yields were smaller than those of previous years. This may be explained by the facts that the seed was of lower quality and that the rainfall was inadequate (Table 8).

When this Hillsdale soil was brought to a calcium-potassium ratio of 0.42, the effect was toxic to potatoes, as is shown by Tables 5, 6, and 7.

Schroeder and Albrecht (17) indicated that excessive potassium gave more scabbiness than did excess calcium. A similar effect was seen with the two highest potassium levels of 1953, as is shown in Tables 5, 6, and 7 and Figures 2 and 4.

TABLE 5

EFFECT OF CALCIUM-POTASSIUM RATIOS ON POTATO SCAB AND YIELD, KATAHDINS, 1953

Treatment Number	Ca:K in the soil	Yield Index	Percent U.S. No. 1	Yield Index U.S. No. 1	Percent Scab	Percent Heavy Scab	Scab Index
1	8.03	44	80.3	35	34	1.1	0.635
2	5.17	155	70.4	109	51	10.8	0.935
4	2.15	201	93.4	188	15	0.7	0.219
3	1.94	93	93.6	87	15	3.2	0.247
6	1.58	119	100.0	119	8	0.0	0.075
5	1.39	148	91.4	135	16	6.1	0.298
7	1.37	120	96.9	116	2	2.5	0.219
8	1.28	135	96.5	127	8	0.8	0.120
9	0.97	119	98.6	117	14	1.4	0.164
10	0.42	38	95.6	36	27	4.41	0.177
L.S.D. (0.05)		76	N.S.		N.S.		0.48

Definitions of the above terminology may be found on page 11.

TABLE 6

EFFECT OF CALCIUM-POTASSIUM RATIOS ON POTATO SCAB AND YIELD, CHIPPEWAS, 1953

Treatment Number	Ca:K in the Soil	Yield Index	Percent U.S. No.1	Yield Index U.S. No. 1	Percent Scab	Percent Heavy Scab	Scab Index
1	8.03	69	91.3	163	32	1.93	0.425
2	5.17	206	89.6	185	29	1.70	0.419
4	2.15	151	99.0	150	27	0.00	0.278
3	1.94	123	84.6	104	38	5.16	0.608
6	1.58	134	70.0	94	42	8.70	0.805
5	1.39	135	69.5	94	50	11.10	0.924
7	1.37	66	95.5	63	14	3.52	0.221
8	1.28	144	73.0	105	51	14.60	1.175
9	0.97	80	72.6	58	46	4.97	0.785
10	0.42	39	97.0	38	35	5.94	0.525
L.S.D. (0.05)		68	N.S.		N.S.		N.S.

Definitions of the above terminology may be found on page 11.

TABLE 7

EFFECT OF CALCIUM-POTASSIUM RATIOS ON POTATO SCAB AND YIELD, SEBAGOS, 1953

Treatment Number	Ca:K in the Soil	Yield Index	Percent U.S. No.1	Yield Index U. S. No. 1	Percent Scab	Percent Heavy Scab	Scab Index
1	8.03	45	75.6	34	39	6.67	0.705
2	5.17	205	96.5	198	24	3.42	0.314
4	2.15	213	69.2	147	28	3.60	0.464
3	1.94	121	78.5	95	46	5.80	0.722
6	1.58	138	92.3	127	26	1.45	0.352
5	1.39	160	87.5	140	35	4.38	0.544
7	1.37	86	68.4	58	54	13.89	0.985
8	1.28	159	91.6	146	30	1.88	0.401
9	0.97	99	71.5	71	46	12.78	0.876
10	0.42	48	85.5	41	46	0.00	0.650
L.S.D. (0.05)		85	N.S.		N.S.		N.S.

Definitions of the above terminology may be found on page 11.

TABLE 8

RAINFALL DATA FOR THE COLLEGE FARM, EAST LANSING, MICHIGAN
(inches of rainfall)

Month	Years 1951	1952	1953	50 Year Average
April	3.15	3.18	2.71	2.58
May	3.20	4.71	2.39	3.42
June	2.96	1.30	4.09	3.51
July	2.12	2.28	2.39	3.10
August	2.66	3.51	3.22	2.82
September	2.54	1.84	0.90	2.91
Totals	16.63	16.92	15.70	18.34

Data obtained from the U.S.D.A. Hydrologic Research Station

Fig. 1. Effect of calcium-potassium ratios on scabbiness of Katahdin potatoes as measured by the scab index.

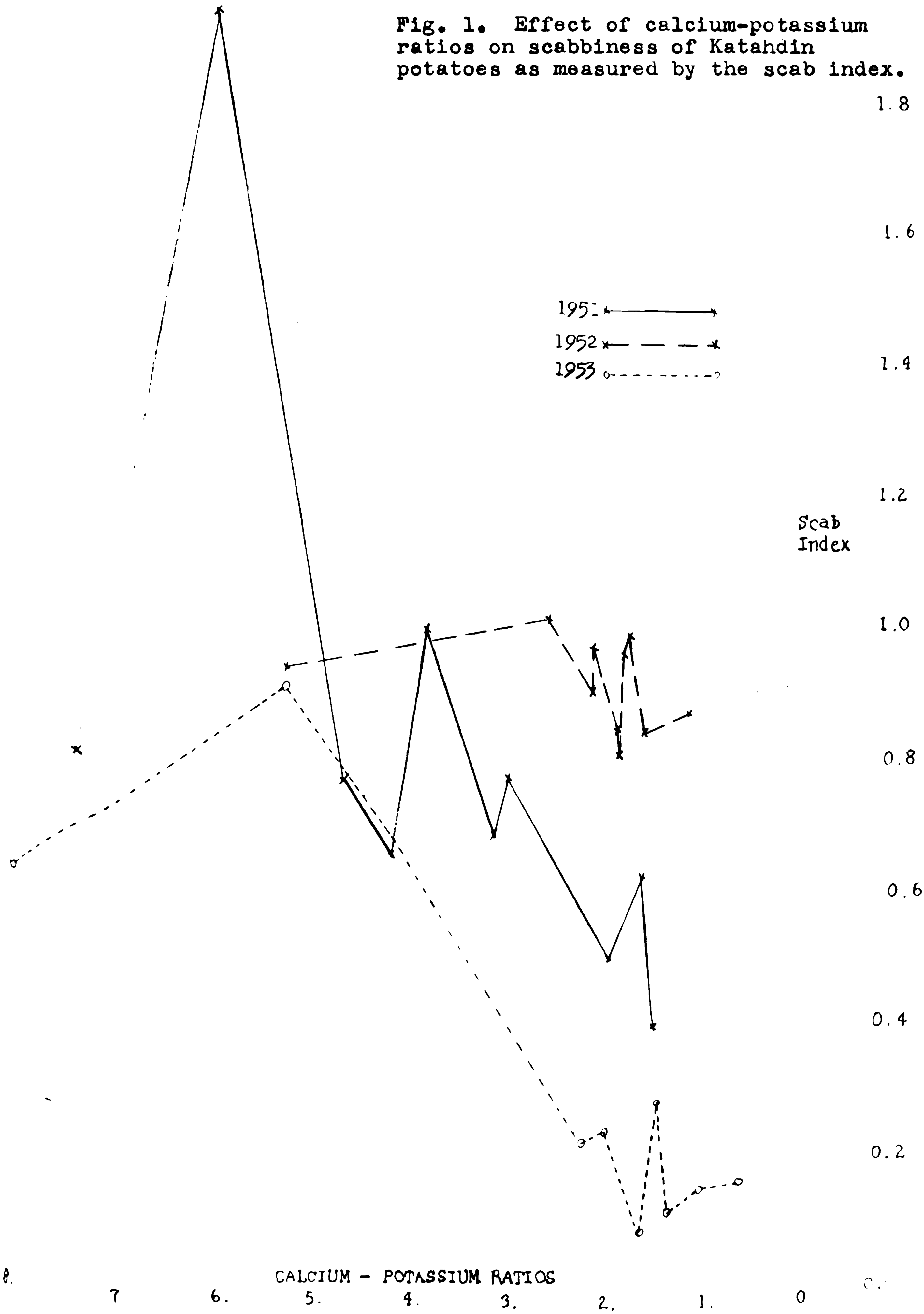


Fig. 2. Effect of calcium-potassium ratios on scabbiness of Katahdin, Chippewa, and Sebago potatoes as measured by scab index.

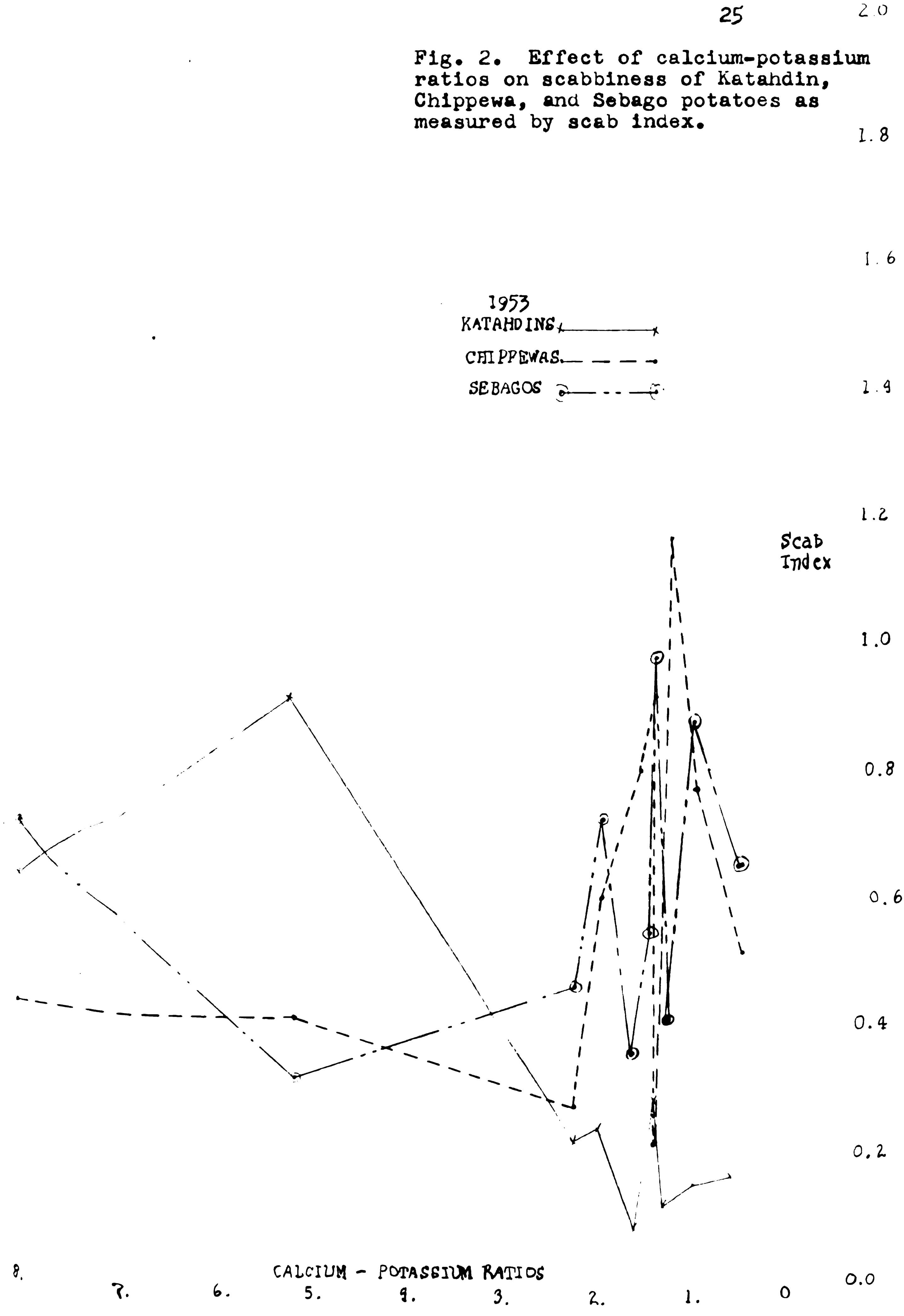


Fig. 3. Effect of calcium-potassium ratios on scabbiness of Katahdin potatoes as measured by percent scab.

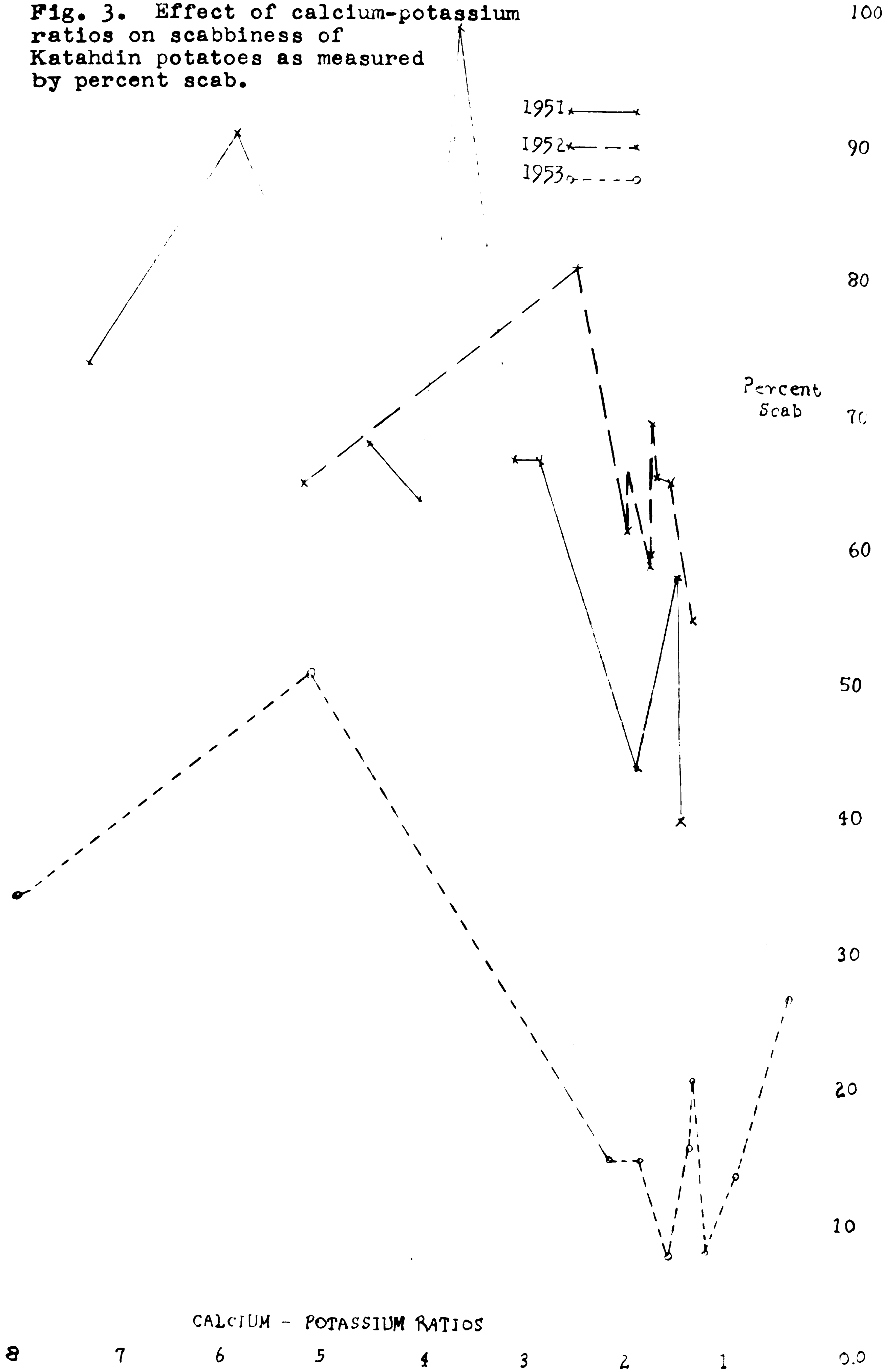
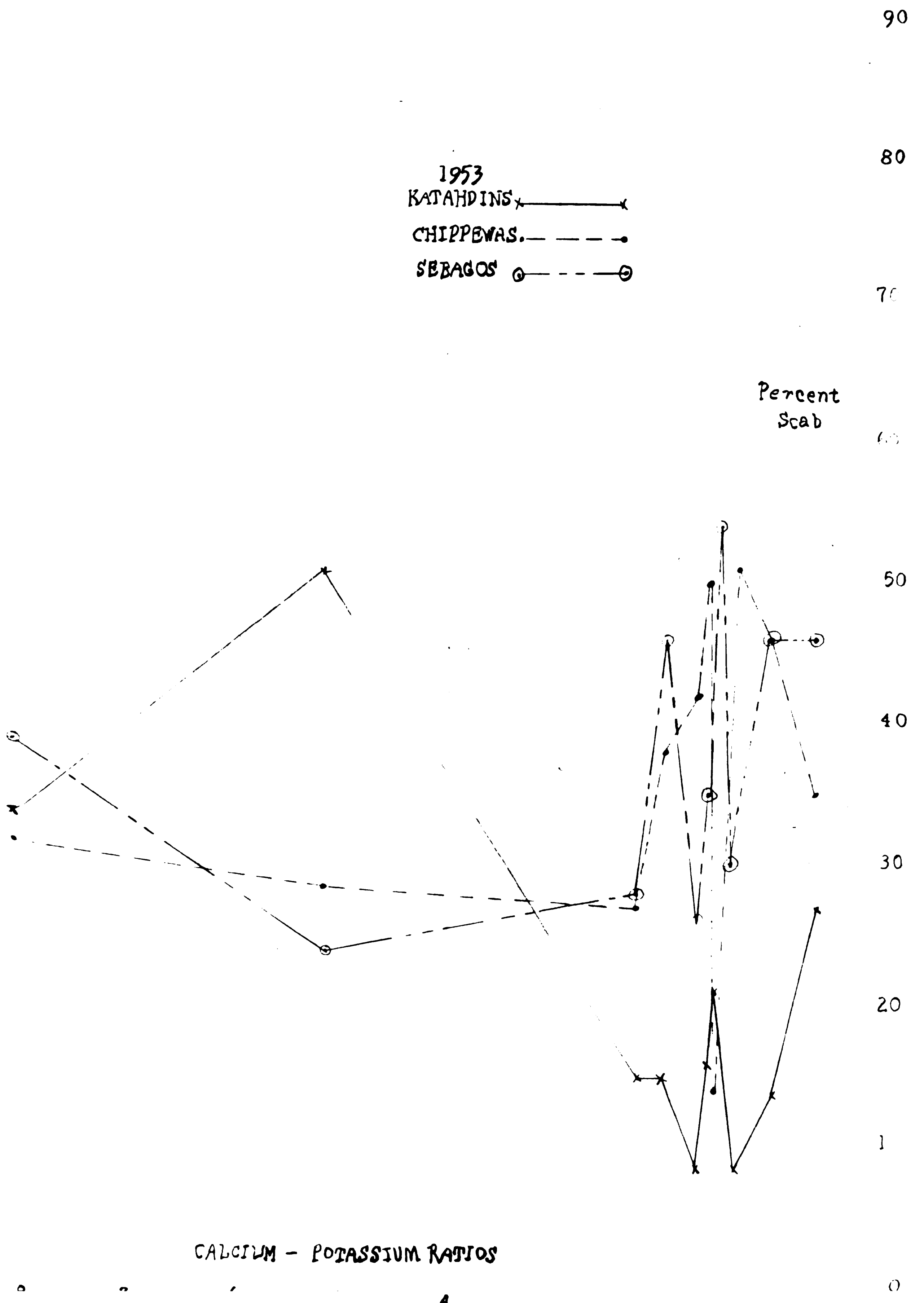


Fig. 4. Effect of calcium-potassium ratios on scabbiness of Katahdin, Chippewa, and Sebago potatoes as measured by percent scab.



The data indicate that varieties significantly influence the effect of calcium-potassium balance on scabbing of growing tubers.

It is apparent that the potatoes did not respond to potash treatment in as favorable a manner as in 1951.

The soil samples showed only a slight fluctuation in exchangeable calcium content, statistically insignificant by treatments and years (Table 9 and Figure 5). This was also true of calcium in the leaf samples (Table 10 and Figure 5). Exchangeable potassium in the soil, on the other hand, showed the effect of the increments of potash added to the soil in a logical manner. The determinable potassium in the leaf samples correlated very well with the added applications of potash. Only in 1953 was the usual Ehrenberg Ca/K reciprocal relationship demonstrated.

The exchangeable potassium content of the soil at different dates throughout the three years is shown in Table 11. Considerable variations between dates were found in all years. That the potassium was available to the plant in relationship to the potash treatments is evidenced by the potassium content of the leaves for all years (Table 10).

A graphic comparison of the calcium-potassium ratios in the soil to the ratios of those elements in the leaves shows a positive correlation (Figure 6). The curves show that adding potash to Hillsdale soil resulted in a calcium-potassium

TABLE 9

EFFECT OF INCREASING AMOUNTS OF POTASH ON THE EXCHANGEABLE CALCIUM AND POTASSIUM EXTRACTED FROM HILLSDALE SANDY LOAM

Treatment Number	Ca in Me/100 1951[a]	Ca in Me/100 1952[b]	Ca in Me/100 1953[a]	K in Me/100 1951[a]	K in Me/100 1952[b]	K in Me/100 1953[a]
1	3.45	3.64	2.65	0.47	0.70	0.33
2	3.58	3.31	2.43	0.60	1.31	0.47
3	3.33	2.83	2.23	0.88	1.62	1.15
4	3.56	3.26	2.39	0.77	1.82	1.11
5	3.54	2.07	2.18	0.86	1.66	1.57
6	3.16	3.43	2.42	1.00	1.71	1.53
7	3.67	3.14	2.43	1.26	2.02	1.77
8	3.75	3.01	2.38	1.92	1.70	1.94
9	3.54	3.32	2.48	2.24	1.65	2.55
10	4.14	3.04	2.63	2.79	2.25	6.04
L.S.D. (0.05)	N.S.	N.S.	N.S.	0.49	0.52	0.53

[a] Represents the average of samples taken from the three replications on three different dates

[b] Represents the average of samples taken from the three replications on two different dates.

TABLE 10

EFFECT OF INCREASING AMOUNTS OF POTASH ON THE COMPOSITION OF POTATO LEAVES GROWN ON HILLSDALE SANDY LOAM

Treatment Number	Ca in Me/100 1951[a]	Ca in Me/100 1952[a]	Ca in Me/100 1953[b]	K in Me/100 1951[a]	K in Me/100 1952[a]	K in Me/100 1953[b]
1	172.9	220.2	185.8	16.3	20.0	23.3
2	171.6	233.8	184.0	17.6	29.7	60.1
3	158.3	214.5	173.8	23.5	35.0	86.5
4	179.8	225.6	169.3	29.1	50.9	105.2
5	174.8	230.0	167.5	51.6	60.2	121.5
6	150.2	215.3	161.2	56.7	73.6	130.5
7	156.0	220.8	159.7	54.1	82.9	136.8
8	149.4	220.3	156.9	68.8	82.7	146.7
9	154.1	212.9	155.7	74.2	84.9	154.4
10	158.4	213.1	134.4	85.3	106.8	171.9
L.S.D. (0.05)	N.S.	N.S.	N.S.	6.3	6.0	12.9

[a] Represents the average of samples taken from the three replications on three different dates

[b] Represents the average of samples taken from the three replications on two different dates

Fig. 5. A comparison of the milliequivalents of exchangeable potassium in the soil and the milliequivalents of potassium in the potato leaves.

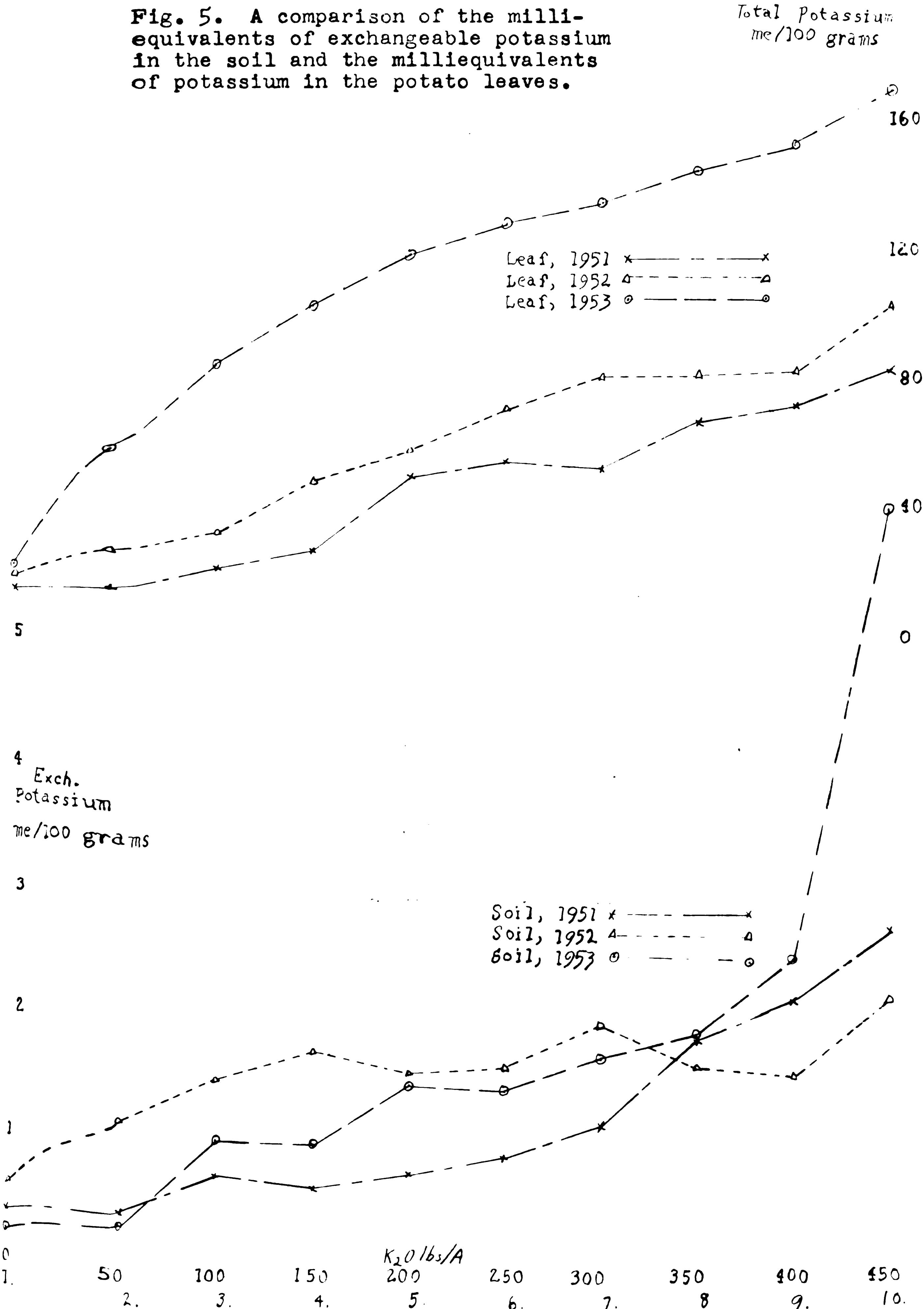


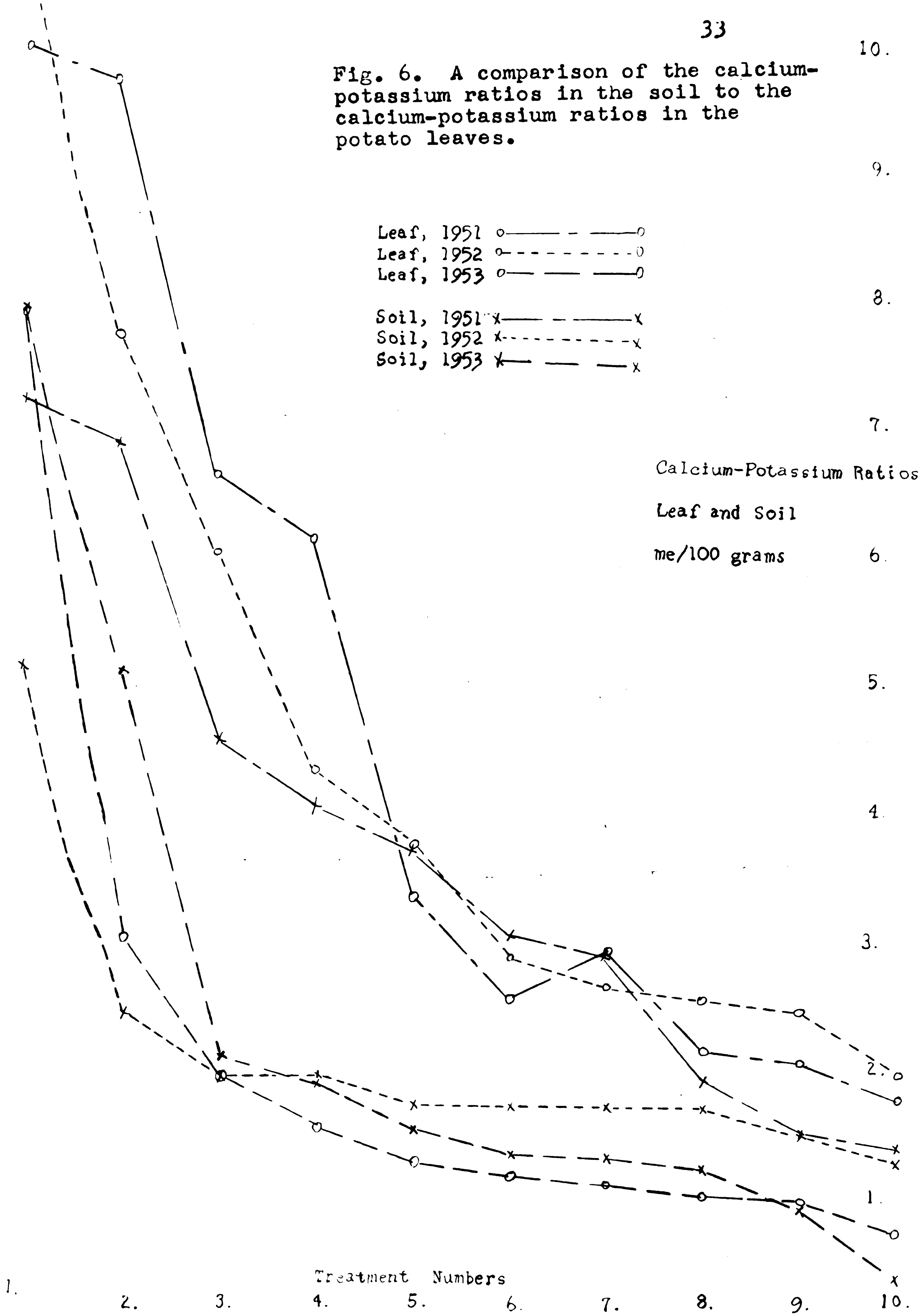
TABLE 11

EXCHANGEABLE POTASSIUM IN HILLSDALE SANDY LOAM SAMPLES TAKEN DURING 1951, 1952, AND 1953 (milliequivalents per 100 grams air dry soil)

Treatment Number	1951			1952		1953		
	7/28	8/5	11/12	7/12	11/20	7/8	8/28	11/6
1	0.46[a]	0.48	0.46	0.79	0.61	0.37	0.37	0.26
2	0.56	0.61	0.64	1.41	1.20	0.68	0.39	0.34
3	0.76	0.94	0.94	1.64	1.55	1.17	1.44	0.84
4	0.74	0.76	0.80	1.71	1.90	1.38	1.27	0.68
5	0.81	0.88	0.89	1.71	1.62	1.74	1.82	1.14
6	0.99	1.01	1.00	1.71	1.69	1.87	1.75	0.97
7	1.19	1.32	1.27	2.16	1.88	2.04	1.95	1.33
8	1.75	1.99	2.04	1.88	1.52	2.19	2.29	1.34
9	2.21	2.23	2.29	3.05	1.24	2.46	2.99	2.21
10	2.66	2.85	2.86	3.36	2.13	5.10	7.82	5.21

[a] Each figure represents the average of three replications.

Fig. 6. A comparison of the calcium-potassium ratios in the soil to the calcium-potassium ratios in the potato leaves.



ratio in potato leaves similar to the exchangeable calcium-potassium ratio in the soil.

The effect of added potash on dry matter content of the harvested tubers as measured by a hydrometer is shown in Table 12. The results of this test showed that no significant change in specific gravity was brought about by the increasing amounts of potash. These potatoes were of fair cooking quality as judged on the basis of their specific gravity (7).

The effects of applying zinc in 1953 to soil which had received the ten potash treatments in 1951 are shown in Table 13. The results show that zinc caused no significant changes in the yield nor the percent of U. S. No. 1's. The percent of U. S. No. 1's did not increase as the amount of zinc was increased nor as the amount of potash was increased. Therefore, the interaction of potash and zinc on the soil and/or the causative agent appears to have been ineffectual in reducing scabbiness. The analysis of variance shows that the potash treatments caused a significant increase in potato yields,as is seen in Table 13. The additions of zinc caused no visible effects in the vegetative plant nor in the harvested tubers.

TABLE 12

EFFECT OF VARIOUS LEVELS OF POTASH ON THE SPECIFIC GRAVITY[a] OF KATAHDIN POTATOES

Treatment: lbs. K_2O/acre	1951	1952
0	1.0737[b]	1.0657
50	1.0733	1.0640
100	1.0703	1.0680
150	1.0733	1.0683
200	1.0723	1.0690
250	1.0680	1.0660
300	1.0680	1.0683
350	1.0700	1.0663
400	1.0687	1.0670
450	1.0683	1.0627

[a] Using an 8-pound sample with a hydrometer

[b] The average of samples from all three replications

TABLE 13

EFFECT OF ZINC APPLIED TO HILLSDALE SANDY LOAM PREVIOUSLY TREATED WITH INCREASING AMOUNTS OF POTASH ON YIELD AND SCABBINESS OF POTATOES

Potash Treatments	Zinc Treatments					
	0 lbs. Zn/A		12.5 lbs. Zn/A		25 lbs. Zn/A	
	Yield Index[1]	% U.S. No. 1[2]	Yield Index	% U.S. No. 1	Yield Index	% U.S. No. 1
1	67	49.3	88	68.2	104	88.4
2	65	70.6	114	66.6	103	70.9
3	155	67.7	119	84.0	105	56.1
4	138	49.3	180	59.9	190	78.8
5	174	68.2	105	67.3	154	60.2
6	199	85.3	136	56.8	209	73.5
7	134	79.8	195	70.7	224	85.6
8	188	59.0	206	71.6	204	78.8
9	197	53.7	194	72.3	204	73.8
10	195	67.6	228	56.9	242	77.1
Zn L.S.D. (0.05)	N.S.	N.S.				
K_2O L.S.D. (0.05)	50.5	N.S.				

[1] Pounds per plot were multiplied by ten to remove the decimal point.

[2] The percent of the total yield that were graded as clean and light

Greenhouse

The addition of 1000 pounds of lime per acre throughout the top nine inches of leached Emmet fine sandy loam caused the pH to increase to some extent (Tables 14 and 15). Placing 1000 pounds of lime per acre in a band at the nine inch depth brought about no appreciable change in soil pH. These methods of lime placement caused no significant change in soil pH throughout the growing season (Table 15). Final pH values shown in Table 15 indicate that mixing lime throughout the top nine inches of soil resulted in a higher soil pH than did placing lime in a band at the nine inch depth.

Actual size photographs showing a sample representative of the tubers from each pH level and each treatment are presented. Comparing Plates I, II, and III which show tubers raised at the higher pH level (approximately 5.4), it can be seen that the largest and cleanest (See also Table 16) potatoes were produced when lime was mixed throughout the top nine inches of soil (Plate II). Tubers of inferior size were raised in the soil which received no lime (Plate III). Plate I shows that cultures with deeply placed lime produced one large tuber which had medium scabbiness and several small tubers ranging from medium to clean.

Potatoes shown in Plates IV, V, and VI were those raised at the lower pH level (approximately 4.8). These were of similar scabbiness and size and showed that the methods of applying lime had exerted no beneficial effect.

TABLE 14

pH VALUES RESULTING FROM LEACHING EMMET FINE SANDY LOAM WITH TWO DIFFERENT AMOUNTS OF 6 NORMAL SULFURIC ACID

Pot Number	Original pH[1] February 27	6 N H_2SO_4 (cc.)	pH after Leaching March 1
1	6.5	150	5.4
2	6.5	"	5.4
3	6.5	"	5.4
4	6.5	"	5.4
5	6.5	"	5.6
6	6.5	"	5.4
7	6.2	185	4.8
8	6.2	"	4.8
9	6.3	"	4.8
10	6.3	"	4.8
11	6.3	"	4.8
12	6.3	"	4.8

[1] pH was determined by use of a glass electrode and a Beckman pH meter, model H-2, using a 1:1 soil-water ratio.

TABLE 15

pH VALUES OF EMMET FINE SANDY LOAM THROUGHOUT THE GROWING SEASON

Pot Number	Lime[1] Placement	pH after Liming March 5	March 28	June 5
1	1000 lbs./A at 9 in.	5.4	5.5	5.4
2	1000 lbs./A at 9 in.	5.4	5.3	5.4
3	1000 lbs./A through top 9 in.	5.5	5.4	5.6
4	1000 lbs./A through top 9 in.	5.7	5.6	5.6
5	none	5.6	5.4	5.4
6	none	5.4	5.3	5.3
7	1000 lbs./A at 9 in.	4.7	4.6	4.6
8	1000 lbs./A at 9 in.	5.0	4.9	4.6
9	1000 lbs./A through top 9 in.	5.0	5.0	4.9
10	1000 lbs./A through top 9 in.	5.4	5.0	4.9
11	none	4.6	4.6	4.6
12	none	4.6	4.6	4.6

[1] CP calcium carbonate was used.

TABLE 16

SCABBINESS OBSERVED ON POTATOES FROM GREENHOUSE LIME PLACEMENT EXPERIMENT

Pot Number	Description of the Tubers
1[a]	Clean to lightly scabby
2[a]	Mostly clean with one tuber having medium lesions
3[b]	Clean to lightly scabby
4[b]	Clean
5[c]	Clean
6[c]	Light scab in 3 tubers
7[d]	Light scab in 2 tubers
8[d]	Medium scab in 1 tuber
9[e]	Most tubers showed medium scab; 2 with deep lesions
10[e]	Mostly medium scab; 1 clean tuber
11[f]	Medium scab in 2 tubers; others clean
12[f]	Light scab in 1 tuber; remainder clean

[a] See Plate I

[b] See Plate II

[c] See Plate III

[d] See Plate IV

[e] See Plate V

[f] See Plate VI

The effect of pH on scabbing and tuber size is shown by the fact that both methods of adding lime produced the largest potatoes which were nearly scab-free. The best potatoes were raised in soil at pH 5.6 with the addition of 1000 pounds of lime per acre mixed throughout the top nine inches of soil.

It is known that potatoes require calcium in large amounts. Thus it was theorized that subplacement of lime would supply calcium to the roots without coming in contact with the growing tubers. It is possible that the mixing of lime throughout the top nine inches of soil at pH 5.4 produced a nutritive balance favoring crop growth and in a manner thought to be beneficial by Schroeder and Albrecht (17).

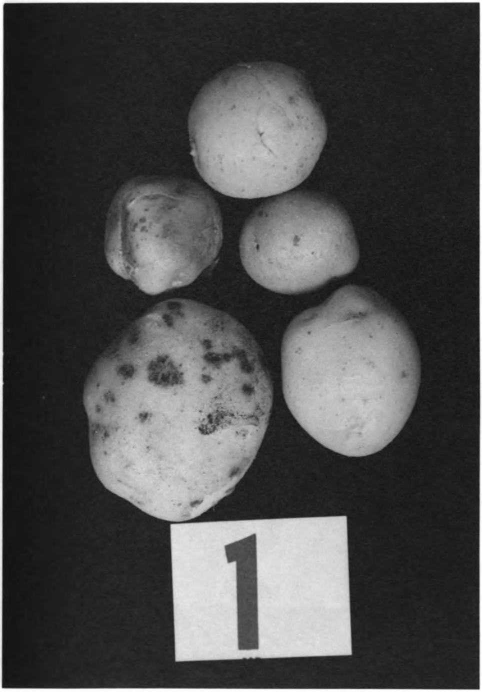


PLATE I. Response of Chippewa potatoes in Emmet fine sandy loam with a pH of 5.4 after leaching to 1000 pounds of lime per acre placed in a band at a depth of nine inches. Pots 1 and 2.

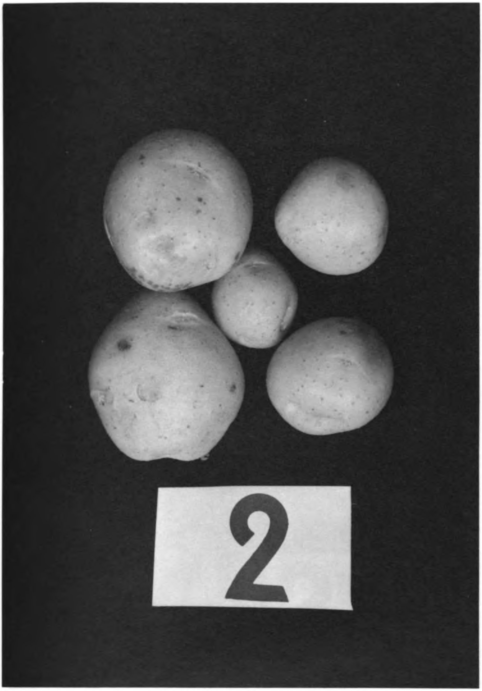


PLATE II. Response of Chippewa potatoes in Emmet fine sandy loam with a pH of 5.4 after leaching to 1000 pounds of lime per acre mixed throughout the top nine inches of soil. Pots 3 and 4.

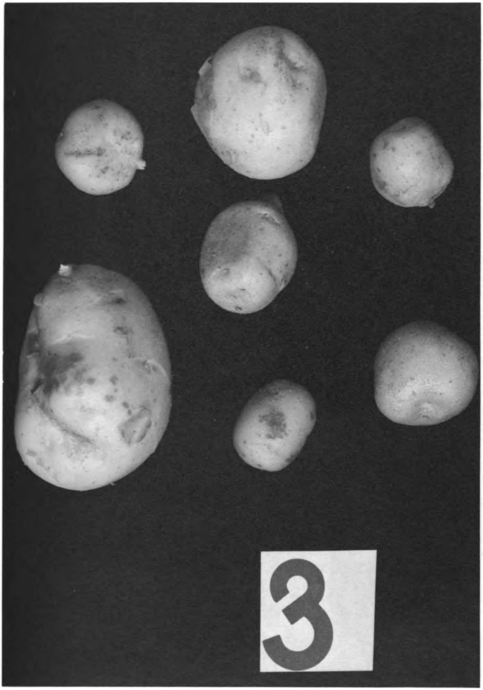


PLATE III. Response of Chippewa potatoes in Emmet fine sandy loam with a pH of 5.5 after leaching. Pots 5 and 6.

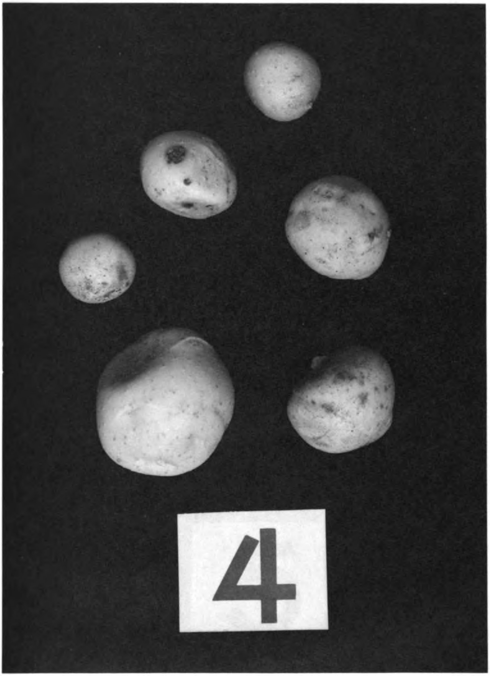


PLATE IV. Response of Chippewa potatoes in Emmet fine sandy loam with a pH of 4.8 after leaching to 1000 pounds of lime per acre placed in a band at a depth of nine inches. Pots 7 and 8.

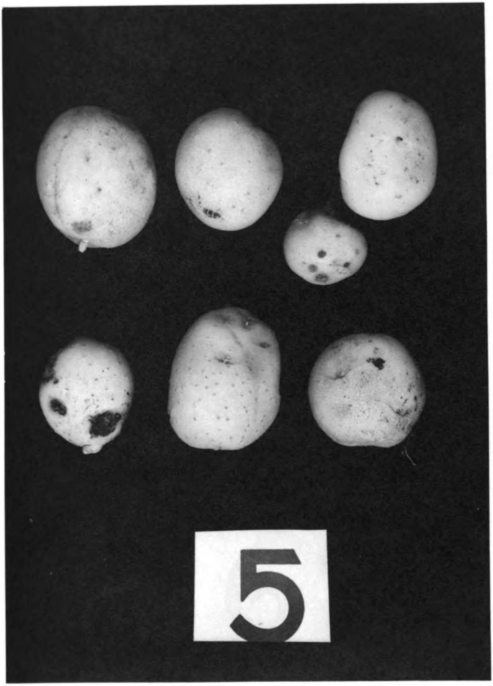


PLATE V. Response of Chippewa potatoes in Emmet fine sandy loam with a pH of 4.8 after leaching to 1000 pounds of lime per acre mixed throughout the top nine inches of soil. Pots 9 and 10.

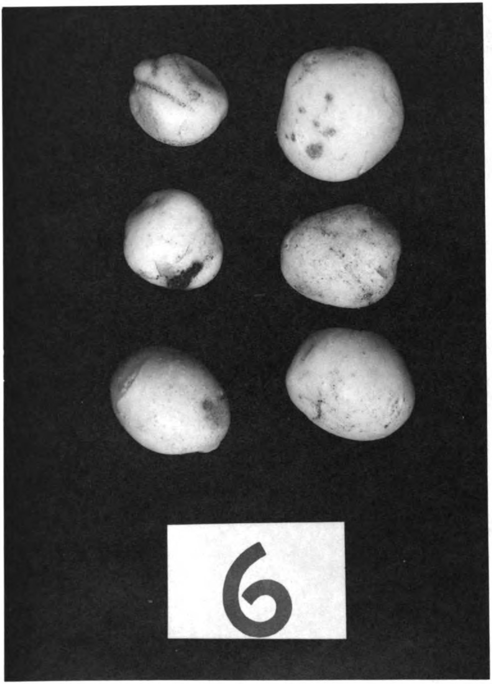


PLATE VI. Response of Chippewa potatoes in Emmet fine sandy loam with a pH of 4.8 after leaching. Pots 11 and 12.

SUMMARY AND CONCLUSIONS

Field studies on potato scab as affected by lowering calcium-potassium ratios were conducted at the college farm in East Lansing, Michigan in 1951, 1952, and 1953. Zinc treatments of the soil were included in the 1953 experiments. Lime placement trials were performed in a 1951 greenhouse study.

In 1951, in an effort to obtain a 1:1 calcium-potassium balance, 10 potash treatments were applied to two areas of Hillsdale sandy loam in two increments. Katahdin potatoes were planted on one of the areas in 1951. The resulting data show that decreasing calcium-potassium ratios led to increasing yields with a lowered scab index.

The second area was planted to Katahdins in 1952 without further potash treatment. The yields and scabbiness were not consistently affected by lowered calcium-potassium ratios.

In 1953 three varieties of potatoes, Katahdin, Chippewa, and Sebago, were grown on the original area to which had been applied additional amounts of potash in an effort to bring about a calcium-potassium ratio of 1:1. The results of this year's trials point out that Katahdins had significantly less scab with lowered calcium-potassium ratios than did Sebagos and Chippewas.

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In comparing the scab indices of the Katahdins in 1951, 1952, and 1953, it was found that there was a significant difference between years (L.S.D. 0.36). The least scab occurred in 1953.

The use of zinc as a controlling factor for reducing scab was tried on the second area in 1953. No beneficial action was exerted by the addition of 12.5 or 25 pounds of zinc per acre.

From the greenhouse study carried out in 1951 on Emmet fine sandy loam with two pH levels, limed, lime-banded, and no lime, the lower pH did not result in the least scabbiness. The best yield and the potatoes freest from scab were raised in the soil having the higher pH (5.6) in which 1000 pounds of lime per acre had been mixed throughout the top nine inches of soil. The results of this trial agree with the work of Rich (14), Starr (18), and others who have found little correlation between scab and soil pH. They do not agree with the findings of Nelson and Brady (11).

Katahdin leaf samples and soil samples were taken from all field plots, except those treated with zinc, in 1951, 1952 and 1953. There was a general trend of decreasing exchangeable calcium content in the soil from the first to the last year because no lime was added. Within years, the added potash caused no significant difference in the exchangeable calcium content of the soil. However, as would be expected, the potassium content of the leaves correlated with the addition of the potash to the soil. The calcium in the leaves and soil showed no significant differences because of treatment. There was a reciprocal relationship between calcium and potassium uptake by the leaves in 1953.

Determinations on Katahdins grown in 1951 and 1952 indicated that potash levels up to 450 pounds per acre did not significantly lower the specific gravity of the tubers. The cooked potatoes were of medium mealiness, as was indicated by the hydrometer.

From the data presented here, it can be concluded that:

1. The addition of potash did not uniformly decrease the percent of scab but generally caused a lowered scab index for Katahdin potatoes within each year.

2. Increasing the exchangeable potassium content of the soil resulted in an increased growth response.

3. There is a difference in varietal susceptibility to scab and in response to the scab decreasing effects of lowered calcium-potassium ratios.

4. Addition of lime to a soil may result in increased tuber growth without enhancing the effect of S. scabies.

5. Zinc at rates of 12.5 and 25 pounds per acre did not suppress the growth of S. scabies as measured by the percent of scabby potatoes.

6. The dry matter content of Katahdin potatoes was not adversely affected by high applications of potash in this experiment.

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