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Manzer, F.E., G.A. McIntyre, and D.C. Merriam. 1977. A new potato scab problem in Maine. Life Sciences and Agriculture Experiment Station Technical Bulletin 85.

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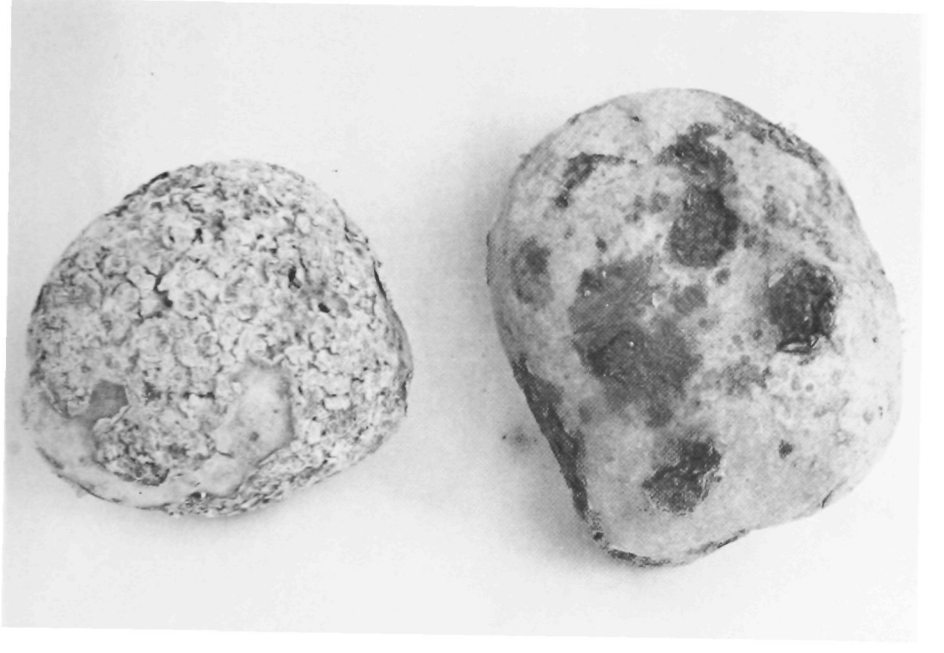
A NEW POTATO SCAB PROBLEM IN MAINE

F.E. Manzer, G.A. McIntyre and D.C. Merriam



LIFE SCIENCES AND AGRICULTURE EXPERIMENT STATION
UNIVERSITY OF MAINE AT ORONO

JUNE 1977

ACKNOWLEDGMENTS

The authors gratefully acknowledge the cooperation of many Maine growers who supplied seed samples. Special thanks are due to Treston and Ivan Bubar of Littleton for providing test plots on their farm. Appreciation is also expressed to Dr. D.C. McGee, Department of Botany and Plant Pathology, University of Maine, Orono, and Dr. R.C. Cetas, Department of Plant Pathology, Cornell University for their critical review of the manuscript. This work was supported in part by Hatch funds.

CONTENTS

A New Potato Scab Problem in Maine

F.E. Manzer, G.A. McIntyre,[1] and D.C. Merriam[2]

INTRODUCTION

The scientific literature is filled with conflicting reports on the development of the common scab disease of potatoes and its causal organism. Some recent publications have reviewed this situation (1, 2, 7, 24) but most of the questions and inconsistencies remain unresolved. One such question is soil reaction, once thought to be the answer in controlling this disease. Scientific studies and practical experience over a long period had shown that acid soils having a pH of approximately 5.3 or below usually did not support common scab development, though sporadic and unexplained reports of disease occurrence in these soils were observed. In the late 1950's however, such reports became more frequent in Maine and before the mid 1960's, losses related to scabby potatoes growing in acid soils were common (14). Throughout this period overall crop losses from the disease were minimal even though individual growers sometimes lost a large part of their crop. During the dry 1970 growing season, however, a disease survey estimated that up to 5% of the Maine crop was scabby (unpublished). Studies of this new form of scab and observations on its development within the State are reported herein.

EARLY HISTORY

In 1953 a few growers encountered problems with scab on acid soils involving a seed source of the Chippewa variety obtained from the midwest. This was the first notable indication that the disease could be a problem in Maine when soils were maintained below a pH of 5.3 to 5.5. Previous isolated instances of its occurrence were attributed either to freakish weather, soil testing errors or were simply ignored. All affected lots of this seed were discarded and the problem did not reoccur until 1957 when it was again traceable to a seed source of the Chippewa variety. Despite the presumed elimination of all affected lots the disease was reported in succeeding years with the 1960 crop showing the highest

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incidence. In that year a survey showed that 68 out of 74 fields, where scab was a problem, had pH levels below 5.0 (Mosher, P.N., personal communication). Seed source was again implicated but by this time several potato varieties were involved. The name "uncommon" scab was first coined to describe this disease since its occurrence in acid soils was contrary to traditional experiences with common scab in Maine. We now propose the name "acid scab" as being more descriptive of the disease.

In 1961, an experiment was designed to test the apparent association of seed source with this acid scab problem. Four seed sources of the Chippewa variety and one of the Katahdin variety were compared with two seed sources of Chippewas infected with scab, but not associated with the acid scab problem. The Chippewa variety was used because of its previous association with the problem and because it is known to be highly susceptible to common scab. Both scabby and scab-lesion-free seed pieces of each source were planted in replicated trials at two locations on Aroostook Farm (Life Sciences and Agriculture Experiment Station, Presque Isle, Maine) and at one location in Littleton, Maine. The latter farm was selected because the grower had encountered the acid scab problem the previous year. The results (Appendix, Table 1) show that at all three locations scabby seed from problem lots produced a high incidence of the disease whereas scabby seed of the controls produced potatoes having very little scab. Furthermore, scab-lesion-free seed from the problem sources also produced a high incidence of scab whereas scab-lesion-free seed from the controls produced mostly scab-free potatoes. These results confirmed past observations that the disease was associated with seed source, not high pH.

A trial similar to the one described above was conducted in 1962 using 10 different Katahdin seed sources, two of Rushmore and three of Chippewa planted at two locations. Of the Chippewa lots, one was known to have been associated with acid scab, one was questionable and one was assumed to have common scab only. The results of this test (Appendix, Table 2) were consistent with those of the previous year.

SEED TREATMENT

A preliminary trial in 1962 showed that acid scab incidence resulting from infected or infested seed could be reduced from 60% to about 5% by the use of a standard organo-mercury (Semesan Bel) seed treatment. A more extensive test conducted the following year demonstrated the value of treating scab-free seed selected from seed lots affected by acid scab (Appendix, Table 3). Some seed transmission of scab assumed from past history to be of the common type was also obtained in this test.

Seed treatment controlled the disease in these lots as well. Since these tests showed conclusively that seed treatment with organo-mercury was an effective control measure, screening trials were begun in 1964 (12) to find other equally effective treatment materials. These tests have been continued annually except for years when too few candidate materials were available. It should be noted here that the use of organo-mercury seed treatments was outlawed around 1970.

In addition to the search for seed treatment chemicals, efforts have been made to develop simple and efficient methods of applying chemicals to the seed potatoes. During the period when wet treatments were used, a planter-mounted sprayer was developed which treated the seed on the planter. The system worked well and was used by many growers but effectiveness of the chemical was reduced when compared to a five-minute dip (13). When dust treatments became available a treater was designed and built which gave good coverage of the seed potatoes while reducing the operator's exposure to the dust (20).

PERSISTENCE IN SOIL

Fields which had grown one or more crops affected by acid scab have been observed over several years. When scab-free treated seed from a non-scabby source is used on these fields a virtually scab-lesion-free crop is produced. This is true even when no rotation crop intervenes. Where no rotation is practiced, however, the crop should not be used as seed since it may produce scabby potatoes. This indicates that the incitant of acid scab does survive winters in Maine soils and can thereby infect or infest a potato crop, but no evidence has yet been obtained to suggest that populations of the pathogen are increasing. Seed growers who had a scab problem and who followed a three-year rotation had no subsequent outbreaks of the disease. Test plantings over the past dozen years at Aroostook Farm, have shown no indication of marked build up of the organism causing acid scab.

LIMING AND FERTILIZATION

Studies showed that acid scab incidence at harvest may be reduced in acid soils by additions of up to 2 tons of ground limestone at planting. However results of liming tests have been inconsistent as shown in Appendix, Table 4. Similar studies by P.N. Mosher (personal communication) likewise showed inconsistent results. Growers also have found that soil pH and liming appeared to have no direct relationship to the acid scab problem.

A fertilizer rate study conducted at two locations in cooperation with Prof. H.J. Murphy, Department of Plant and Soil Sciences, showed

that increasing rates of 10-10-10-1½ grade of fertilizer in 200 lb increments from 1000 lbs/A to 2000 lbs/A had no effect on scab incidence. Surveys and observations of grower experience are consistent with these findings.

VARIETAL SUSCEPTIBILITY

Many named and numbered potato varieties have been subjected to field inoculation with the organism causing acid scab. Inoculum is prepared by mincing scab lesions peeled from infected tubers and adding water to make a slurry. Fresh cut seed pieces are dipped in the slurry, placed in the furrow and covered immediately. Results of several years of testing show that some varieties are much less susceptible than Katahdin (Appendix, Table 5). Most varieties having resistance to common scab also exhibited resistance to the acid tolerant type.

IDENTIFICATION OF THE PATHOGEN

Bonde and McIntyre (2) showed that the acid scab pathogen (*Streptomyces* sp.) was physiologically different from *Streptomyces scabies*, the generally accepted incitant of common scab. They felt that the two pathogens were different species, citing the coiled sporophores of *S. scabies* and the straight sporophores of *Streptomyces* sp. as an additional basis for separation. McCrum and Manzer (15, 16) have shown serological differences between the two organisms (Figure 1). Hughes, McCrum and Manzer (9) studied protein and esterase electrophoretic patterns and also found differences. All of the differences found by these investigations plus the initially recognized variance in response to soil pH suggest that the two organisms could be designated as different species.

Physiological Tests

Since the work of Bonde and McIntyre (2), considerable progress has been made in developing standard morphological and physiological tests for the identification of *Streptomyces* species. These tests, which have become generally accepted, rely on specific, standardized media upon which cultures are grown for observations of sporophore morphology, pigment production, color of aerial and substrate mycelium, and carbon utilization (3, 21). The development of the scanning electron microscope (SEM) has greatly aided observation of sporophore and spore morphology (25). The availability of these procedures and the need to identify the causal agent of potato scab in low pH soils in Maine led to the initiation of this phase of research.

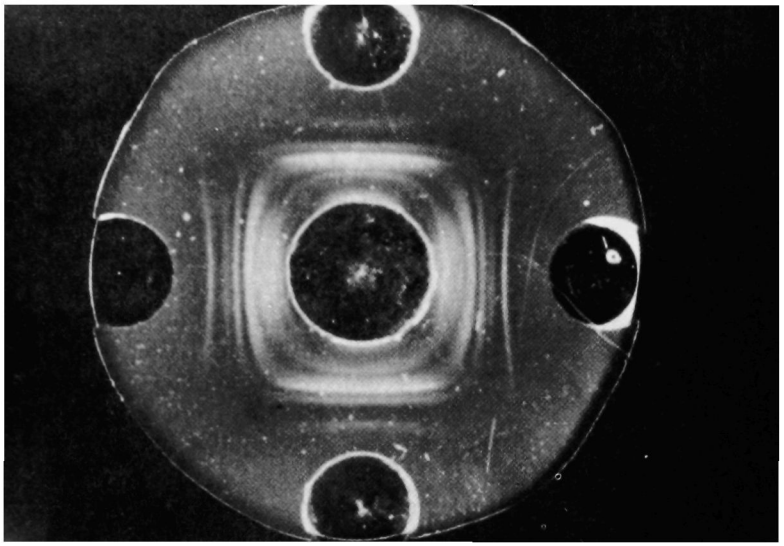

Figure 1. When mycelium of the acid scab organism is placed in the center well of an agar double diffusion plate, several antigenic components are seen to be common to both acid scab antiserum (left and right) and common scab antiserum (top and bottom). Lines not common to both antisera indicate differences.

An isolate of *Streptomyces* sp. (U30) was obtained from scabby potatoes grown in a field with a pH below 5.2 at Aroostook Farm in Presque Isle, Maine. This isolate had been used in other studies and was known to cause scab on Chippewa tubers grown in soils with a pH below 5.2. A known pathogenic isolate of *S. scabies* (CB) obtained from the Department of Botany and Plant Pathology, University of Maine, Orono, culture collection was used for comparison. This isolate had been used in other studies and was known to cause scab to develop only on tubers grown in soil with a pH above 5.2. The following cultures were obtained from the American Type Culture Collection for additional morphological and physiological comparisons: *S. scabies* (ATCC #15485), *S. scabies* (*griseus*) (ATCC #10246) (4), *S. scabies* (*griseus*) (ATCC #3352), *S. griseus* (ATCC #10137), *S. globisporus* (ATCC #'s 19906 and 15864). All cultures were maintained on potato dextrose agar (PDA) at 15°C until used. Characterization media used in these studies were prepared according to procedures outlined by Shirling and Gottlieb (21).

Morphological Observations

Observations of all strains were made on PDA, yeast extract-malt agar (YMA), oatmeal agar (OA), inorganic salts-starch agar (ISSA), and glycerol-asparagine agar (GAA). Six plates containing 25 ml of each medium were inoculated aseptically with the individual isolates (21). Cultures were incubated at 25-28°C in the dark, and two plates of each medium for each culture were observed 7, 14 and 21 days after inoculation.

All observations of spore-bearing hyphae and spore chains were made by direct microscopic examination of the culture surface after removal of the petri dish lid (21). At least 10 observations per plate were made at magnifications of 100 to 450X. Numbers of spores occurring at the ends of mature hyphae were recorded by the method of Shirling and Gottlieb (21) and the forms of the spore chain and of the spore-bearing hyphae were recorded and compared to the morphological groups of Pridham and Lyons (18).

Hyphae of all strains observed bore smooth walled spores usually in chains of 10 or more spores after three weeks' incubation (Appendix, Table 6). Only strains CB, *S. scabies* (ATCC #15485) and *S. scabies* (ATCC #3352) bore spore-chains which could be termed spiral (Spira) by the definition of Pridham and Lyons (18), and the number of spiral spore-chains observed on the latter was well under 5% of the total observations for this strain. All other cultures bore spore-chains which tended to be long and straight (Rectus) to flexed (Flexibilis) using the scheme porposed by Pridham and Lyons (19). It is interesting to note that cultures of *S. griseus* (ATCC #10246) also contained a number of spore-chains which had open loops and hooks. This strain was originally described as *S. scabies*, but later renamed *S. griseus* by Ettlinger *et al* (6).

While spore size varied considerably within the individual strains as well as from strain to strain, it was not felt that this characteristic was particularly helpful in ascertaining the relationship of U30 to the other isolates tested.

Color Determinations

The mass color of mature sporulating hyphae, of substrate mycelium as viewed from the reverse side, and of diffusible, soluble pigments was determined for all cultures after 7, 14, 21 days incubation in YWA, OA, ISSA, and GAA. Colors were determined by comparisons with the Tresner-Backus color series (11, 23) under the same artificial light system.

Observations of aerial mycelium color were made only on mature cultures with a heavy spore mass surface. The aerial spore mass of U30

was usually white; however, some cultures appeared yellow with occasional cultures appearing grey or red (Appendix, Table 8). This variation depended upon the medium and age of the culture with more variation occurring after 21 than after 7 days. Both isolates of *S. scabies* (CB and ATCC #15485) produced grey aerial spore masses, while isolates of *S. griseus* varied from grey (ATCC #3352) to white to yellow (ATCC #'s 10246 and 10137). Both isolates of *S. globisporus* produced yellow aerial spore masses (Appendix, Table 7).

Substrate mycelium color was determined by removing aseptically a plug of typical, mature mycelial growth with a cork borer and depositing the plug in an inverted position on filter paper. Excess medium was removed with a razor blade and the reverse surface color observed (21). The excess medium was saved for observation of diffusible pigment production. The substrate mycelium of U30 appeared yellow although an orange to red cast occasionally occurred after 21 days' incubation. All other strains also had a yellow substrate mycelium with the exception of *S. scabies* (ATCC #15485) which had a dark brown to almost black substrate mycelium (Appendix, Table 7).

Soluble Pigment Production

Presence of soluble pigments was observed on media plugs obtained by procedures described earlier. The four media listed at the beginning of the section on color determinations were used in this test. Observations were made and recorded at 7, 14, and 21 days. A summary of results for the 21 day observations is reported (Appendix, Table 7). All isolates tested produced diffusible pigments in the 4 test media. U30 produced a deep yellow to orange pigment while all other isolates produced a light yellow pigment. The color of the pigment produced by CB was partially obscured by the production of a second dark brown melanin pigment on the test media. No pH reaction was observed when a drop of either 0.05 N HCL or NaOH was placed on the medium containing the pigment.

Carbon Utilization

All isolates were tested for utilization of D-glucose, L-arabinose, sucrose, D-xylose, I-inositol, D-mannitol, D-fructose, rhamnose, and raffinose (3, 21). Observations were made after 16 days' incubation at room temperature. While trace amounts of growth occurred for all strains in the absence of a carbon source, the growth was so slight that it may have resulted from utilization of carbon introduced in the inocula-

tion procedure. U30 grew well on all carbon sources except raffinose where growth was marginal and again may have been due to carbon contamination during the inoculation procedure. Similar growth was observed for *S. griseus* (ATCC #3352); however, questionable growth occurred on both I-inositol and raffinose. The known isolate of *S. scabies* grew well on all carbon sources except glucose while the *S. scabies* isolate provided by the ATCC grew poorly on all carbon sources except L-xylose, L-arabinose, and glucose. Similar results with minor exceptions were observed for the other strains tested (Appendix, Table 8).

Observations were also made on the production of melanoid pigments after growth for 16 days on the carbon utilization medium with glucose as a carbon source (Appendix, Table 8). *S. scabies* (CB) produced a melanin pigment as expected; however, pigment production was not observed in other isolates.

Scanning Electron Microscopy

All isolates were examined with a Cambridge Stereoscan S4 scanning electron microscope. Each strain was inoculated onto the surface of coverslips embedded at a 45° angle, in oatmeal agar (21, 25). Plates were then incubated at 25° for 5-10 days. Coverslips with aerial mycelium were examined in both fixed and unfixed states. Coverslips with unfixed material were mounted on the SEM specimen stubs with Duco cement and coated with either gold or aluminum in a Denton Vacuum evaporator, DV 515, equipped with a variable tilt, rotary specimen support. Aerial mycelium on other coverslips was fixed for 2 hours at room temperature in a 1% solution of osmium tetroxide in either phosphate buffer (pH 7.0) or sodium cacodylate buffer (pH 6.5). Coverslips were then washed 3 times in distilled water and dehydrated in a graded ethanol series — 50% and 70% ethanol, 30 min each, and absolute ethanol, 60 min (26). Subsequent handling was the same as for the unfixed material.

In all instances the SEM observations showed that all spores were smooth walled with no indication of surface markings (Appendix, Table 6 and Figs. 2 to 5). While these observations were expected, they confirmed that the isolates fit in the smooth walled species which are found in *Streptomyces* located in the white, yellow, cream, and buff color series (8).

DISCUSSION

Through the first years of work with this problem the indisputable evidence of seed transmission strongly suggested that the acid scab

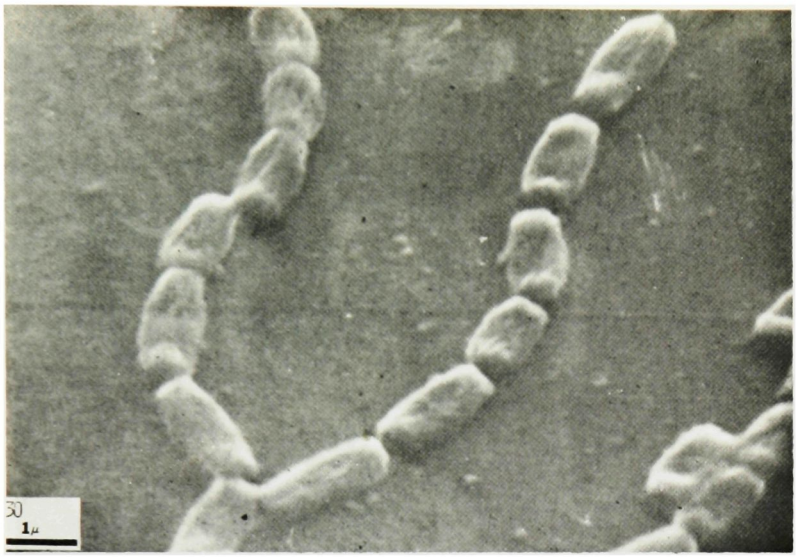

Figure 2. U30, 10,000X fixed for 2 hrs in a 1% solution of Osmium tetroxide and coated with ~ 150Å Au.

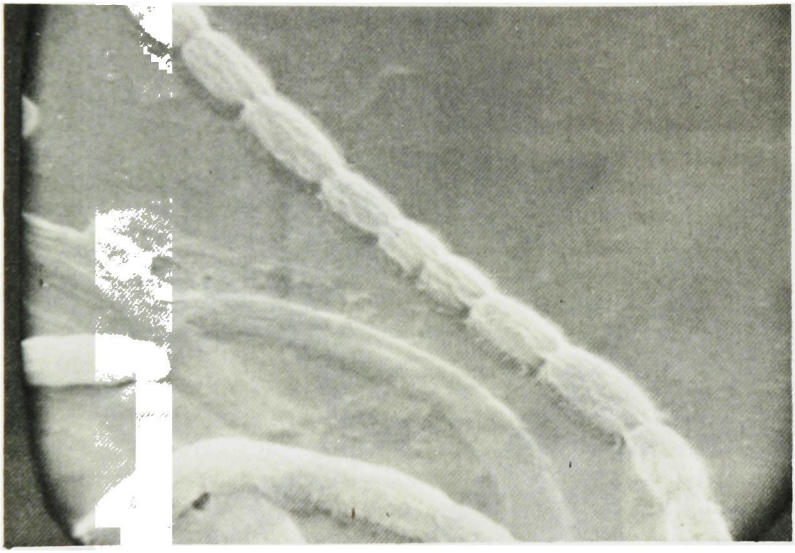

Figure 3. CB, 10,000X, fixed for 2 hrs in a 1% solution of Osmium tetroxide and coated with ~ 70Å Au.

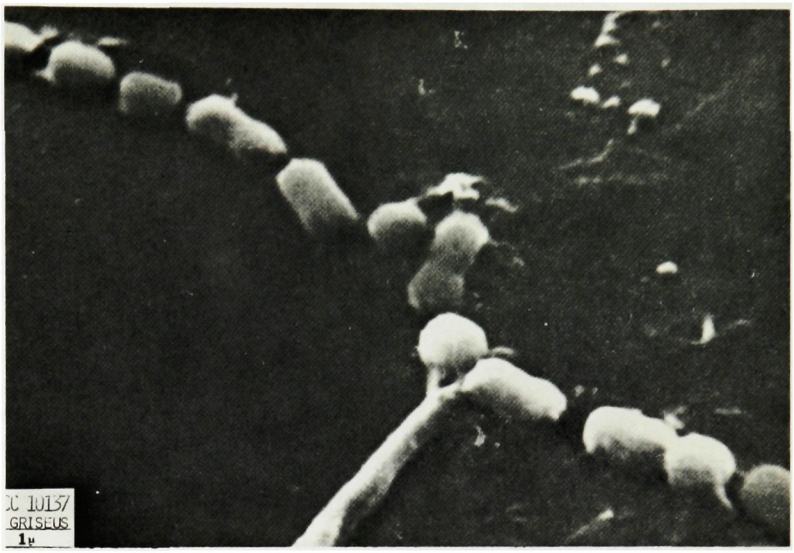

Figure 4. S. griseus (ATCC 10137) 10,500X, fixed for 2 hrs in a 1% solution of Osmium tetroxide and coated with ~ 70Å Au.

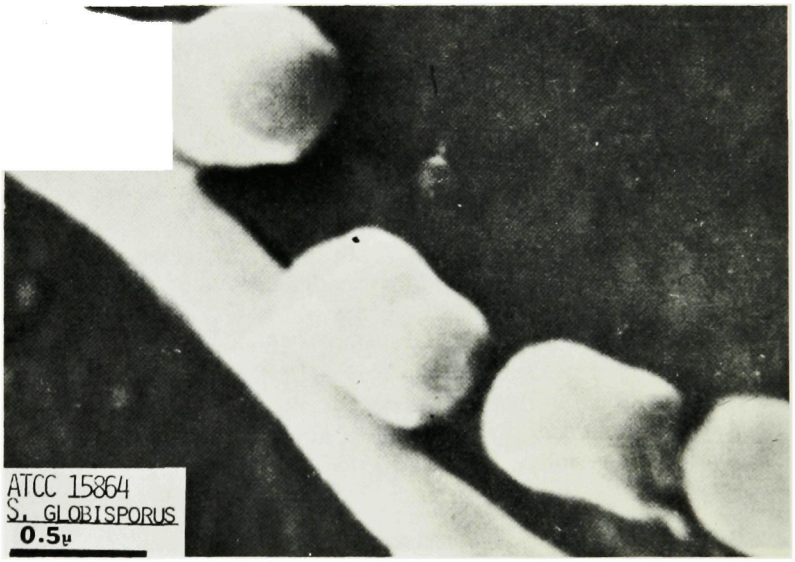

Figure 5. S. globisporus (ATCC 15864) 24,000X, fixed for 2 hrs in a 1% solution of Osmium tetroxide and coated with ~ 70Å Au.

organism had been introduced into Maine. Many of the early reports of scab were linked with one particular seed source of the Chippewa variety originating from outside Maine. This variety is very susceptible to scab and was implicated in scab problems in Maine before the present outbreak. Furthermore, similar scab problems involving Chippewa were reported from New Jersey and Wisconsin. When the disease was found in the Katahdin and other varieties it was logical to assume that the organism had spread from infected Chippewas.

The re-introduction of the Russet Burbank variety to Maine in the early 1950's was another possible source of the organism causing acid scab. This variety has a high level of resistance to both types of scab in Maine and could have carried the organism even though scab lesions were absent or inconspicuous. Though many different seed sources of several varieties were brought here over the years, none has been as widely grown in Maine as has the Russet Burbank.

One cannot discount the many opportunities for importation of the acid scab organism during and just prior to the outbreaks of the disease. However, it is logical to assume that the organism could have been imported much earlier but failed to cause a problem because of unfavorable environmental factors. Thus, the implications of changing production practices, soil erosion and the like must be considered. Such changes could also encourage the development of endemic *Streptomyces* spp. which were not previously pathogenic or which could not build up in sufficient numbers to cause disease problems. The list of changes in production practices over the past 15 or 20 years is long and includes such things as: use of high analysis fertilizers with various compounds supplying the nutrients; a switch from inorganic copper fungicides to the zinc and manganese containing carbamates; the introduction of many different insecticides including the systemics; use of a host of new weed and vine killers; changing, shortening or discontinuance of crop rotation; and soil compaction caused by heavier machinery. Any one of these factors or combinations of them could conceivably have altered the environment sufficiently to allow a previously unimportant microorganism to flourish as a pathogen.

Some instances of scab development during these years have been inexplicable based solely on seed source. For example, scab-free crops were grown on some farms using a seed source which produced scabby crops on other farms. Likewise, a seed source which produces virtually a completely scabby crop at Aroostook Farm each year gives only about a 20-30% scab incidence on Long Island (4) and no scab at all when planted on the Maine Department of Agriculture's seed potato testing farm in South Florida. Furthermore, a Katahdin seed source known to have been grown exclusively for more than 20 years on one farm developed into a scab-producing source. The grower insists that there was

no opportunity for the acid scab organism to have been introduced on this farm.

One other production practice change which should be considered separately is the practice of seed treatment. Until the late 1940's, most good growers, particularly seed growers, treated their seed with strong, broad spectrum materials such as corrosive sublimate or formaldehyde. In addition, these same growers usually followed a recommended three-year rotation such as oats, clover and potatoes. The combination of seed treatment and rotation undoubtedly kept many potential soil-borne plant pathogens under control. It seems logical to expect therefore, that the acid scab pathogen could have increased in the absence of these controls because replanting scabby seed has been a common practice for many years. Since seed treatment and rotation were not discontinued abruptly it could be expected that pathogenic microorganisms would build up slowly over several years. Thus, this third possible explanation for the appearance of the present scab problem must be evaluated. Though the question may never be resolved, the authors suggest that this latter hypothesis best fits the evidence. Some growers have had scab problems where there was no recognized opportunity for introduction of a causal organism. Also, many growers have avoided a scab problem despite the introduction of various seed lots and use of most of the production practices followed by those who have had a scab problem. Most importantly, however, we have observed that seed treatment can greatly reduce or eliminate the scab problem in an infected seed lot.

Since Thaxter's (22) early report it has been generally accepted that *Streptomyces scabies* (Thaxter), Waksman and Henrici is either the only incitant of the disease or at least primary causal agent. There are however, several reports that implicate other species of *Streptomyces* as causal agents (5, 7, 17). Results of the current study further enhance the observation that the causal agents represented by the U30 group are not *S. scabies* and must be considered a new pathogenic group of as yet uncertain taxonomic position. Bergey's Manual of Determinative Bacteriology (3) establishes the criteria for classification of *Streptomyces*, and these criteria were used primarily in determining the status of the U30 group. Unfortunately, the type strain of *S. scabies* is no longer extant and many taxonomically different reference strains are available. Consequently *S. scabies*, as a species, occupies the dubious position of *species incertae sedis* (3).

In no instance was there sufficient similarity to consider U30 to be an isolate either of *S. scabies* or of the ATCC cultures of *S. globisporus* and *S. griseus* used in the comparative studies. Sufficient similarities exist, however, to speculate strongly that U30 may be a variety of either *S. globisporus* or *S. griseus* or a subspecies thereof. This view is not as

awkward as would initially appear because *S. griseus* and *S. globisporus*, while treated as separate species in the eighth edition of Bergey (3), are considered as synonymous by both Pridham and Lyons (19) and Hutter (10) and classified as *S. griseus*. This is particularly significant in light of earlier studies in which certain *Streptomyces* species, originally identified as *S. scabies*, were reclassified *S. griseus* (6) and the evidence that certain isolates of *S. griseus* are pathogenic to potatoes (5, 8, 17). Therefore, while the conclusion that U30 and similar isolates are closely allied to *S. griseus* may be valid, the current state of taxonomy of this group is such that the definite designation as to variety or subspecies awaits further clarification.

CONCLUSIONS AND CONTROL MEASURES

The new scab disease which Maine potato growers have encountered over the last 15 years is a threat to the entire industry and of special concern to seed growers. The accepted common scab control practice of keeping the soil at a pH below 5.3 to 5.5 does not control the acid scab disease. There is no practical, quick method for distinguishing between scab lesions caused by the acid sensitive pathogen and the new acid tolerant one. Furthermore, both types may be present in a given seed lot. The acid scab organism can be carried on lesion-free tubers of an infected seed lot. To date, this pathogen has not been proven to be a new species of *Streptomyces*, though considerable evidence suggests this possibility. Concrete evidence relating to the introduction of acid scab in Maine is lacking. Both research and observation suggest that the pathogen may not be a new import to Maine.

Though much remains to be learned about this new disease the following control measures are known to be effective:

1. Scab-infected tubers should never be used as seed. Seed lots known to have produced scabby crops should be avoided even though scabby tubers have been removed.
2. All seed should be treated with a chemical known to be effective in controlling this disease. Mancozeb 8% dust and Polyram 7% dust are recommended.
3. Accepted crop rotations should be practiced especially in fields where scab has been a problem.
4. All vine refuse should be removed from the field or burned after harvest to prevent carry-over of the pathogen on infested or infected plant material.
5. Where accepted crop rotations cannot be practiced, disease-resistant varieties should be used.
6. Potato handling equipment and storages should be disinfested.

SUMMARY

A new form of potato scab which can develop in acid soils has become a problem in Maine. First recognized in the mid 1950's, the disease now called "acid scab" was not of economic concern until 1960. In that year and those following, losses were minimal until the dry 1970 growing season when a survey showed that up to 5% of the Maine crop was scabby. Research and observation during the last 15 years have shown that the causal organism can be transmitted on seed and also persists in the soil. Most evidence seems to suggest that this pathogen may be a new species of *Streptomyces* rather than a variant of *S. scabies*. Concrete evidence of importation to Maine is lacking though ample opportunities are known prior to the period when the disease was first recognized. Several hypotheses are advanced to explain the relatively sudden appearance of the disease and its widespread distribution in Maine. The most plausible of these seems to be that the organism was endemic but unknowingly kept under control until the discontinuance of seed treatment and adequate crop rotation. Seed treatment, which was shown by the authors to be effective in controlling the disease, was not practiced widely by the late 1940's and crop rotations also were becoming shortened or eliminated at that time. Both of these practices are strongly recommended for control of this disease. Other control measures include the avoidance of scabby or contaminated seed, use of resistant varieties and the burning or elimination of plant refuse.

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APPENDIX TABLE 1

Percentage of total yield showing moderate to severe scab from seven seed sources at three locations. 1961.

Seed Source[1]	Aroostook Farm Plot 1		Aroostook Farm Plot 2		Littleton, Maine	
	Scabby Seed	Scab-free Seed	Scabby Seed	Scab-free Seed	Scabby Seed	Scab-free Seed
Acid Scab						
Chippewa A	36	11	39	6	9	1
Chippewa C	24	0	19	1	7	1
Chippewa D	41	8	54	20	13	2
Chippewa E	42	8	34	3	14	8
Katahdin G	33	1	46	0	8	1
Common Scab						
Chippewa B	0	0	0	0	0	4
Chippewa F	5	2	2	0	2	2

[1] Scabby and scab-lesion-free tubers were selected from each lot and planted separately. Plots were single rows, 20 feet long and each percentage is an average of five replications. Soils were at or below pH 5.0.

APPENDIX TABLE 2

Scab incidence in per cent of total yield from scab-free and scabby seed of three varieties planted at two locations. 1962.

Seed Source[1]	Aroostook Farm[2]			Littleton, Maine		
	Light	Heavy	Scab-free	Light	Heavy	Scab-free
Acid Scab						
Katahdin:						
Scab-free	20	1	79	19	1	80
Scabby	55	10	35	55	7	38
Rushmore:						
Scab-free	14	1	85	12	1	86
Scabby	53	10	37	61	5	34
Chippewa B:						
Scab-free	9	0	91	13	0	87
Scabby	40	8	52	64	12	25
Common Scab						
Chippewa A:						
Scab-free	13	0	87	15	0	85
Scabby	29	0	70	38	0	62
History Unknown						
Chippewa C:						
Scab-free	4	0	95	5	0	95
Scabby	8	0	92	21	0	79

[1] Ten different seed lots of the Katahdin variety, and two of Rushmore were included, all of which were associated with the acid scab problem. The Chippewas are single lots. Soils were at or below pH 5.0.

[2] The percentages are averages based on total weight of tubers in each category from five 20-foot plots of each lot within each variety.

Light=Scab Lesions on up to 20% of the tuber surface but no severe pitting.

Heavy=Scab Lesions on 20-100% of the tuber surface or severe pitting.

APPENDIX TABLE 3

Resultant disease incidence in per cent of total yield from 11 acid scab seed lots having scab or being scab-free treated or untreated, as compared with two control lots. 1963.

Seed Source[1]	Averages[2]		
	Light	Heavy	Scab-free
Acid Scab lots			
Scab-free	12	2	86
Scab-free — treated	1	0	99
Light Scab	42	22	35
Heavy Scab	44	38	18
Common Scab lots			
Scab-free	2	0	98
Scab-free — treated	1	0	99
Light scab	3	0	97
Heavy scab	7	0	93

[1] Eight of the acid scab lots were of Katahdin, one of Chippewa and two of Rushmore. Two additional Katahdin sources had no known history of acid scab. Treated lots were immersed in Semesan Bel (1 lb. in 7½ gallons of water) then allowed to dry partially before planting.

[2] Based on total weight of tubers in each category from five 10-foot plots per seed lot. Light=scab lesions on up to 20% of the tuber surface but no severe pitting. Heavy=scab lesions on 20-100% of the tuber surface or severe pitting.

APPENDIX TABLE 4

Resultant acid scab incidence in percent of total yield following four rates of lime applications at planting of scab-free and scabby seed of the same seed lot in two locations.[1] 1962.

	Littleton, Maine[2]					
Lime	Scab-free Seed			Scabby Seed		
lb/Acre	Light	Heavy	Scab-free	Light	Heavy	Scab-free
0	40	2	58	49	4	47
1000	38	1	61	56	7	37
2000	42	4	54	57	7	36
3000	44	3	53	62	12	26
4000	58	4	38	64	10	26
	Aroostook Farm[3]					
0	33	2	65	66	11	23
1000	36	1	63	78	9	13
2000	35	1	64	72	7	21
3000	43	1	52	73	8	19
4000	31	1	68	67	4	29

[1] This study was conducted cooperatively with Prof. Hugh J. Murphy, Department of Plant and Soil Sciences, University of Maine.

[2] Average of five replications of 10-foot single-row plots planted on May 30 and harvested on October 1, 1962. Fertilization was with 1300 lbs. per acre of a 10-10-10-1½ ratio and soil tests showed a pH of 5.4 with P, K and Ca at medium-high levels. Light = scab lesions on up to 20% of the tuber surface but no severe pitting. Heavy = scab lesions on 20-100% of the tuber surface or severe pitting.

[3] All conditions were the same as at the Littleton location except that plots were harvested on September 28.

APPENDIX TABLE 5

Named and numbered varieties showing resistance to acid scab equal to the standard, Russet Burbank, in inoculation tests conducted over several years.[1]

Named Varieties	Numbered Varieties
Early Gem	B 3726-6
Huron	B 5412-10
Menominee	B 5458-6
Norchip	B 6116-18
Norgold Russet	B 6138-3
Ontario	
Plymouth	
Russet Burbank	
Russet Rural	
Superior	

[1] Many named and numbered varieties were involved in these tests conducted over several years. Five replications of 10-hills of each variety were inoculated by dipping seed pieces into a slurry of minced scab lesions. About 15 varieties were tested each year, some of which were retested in succeeding years.

APPENDIX TABLE 6

SUMMARY OF CHARACTERIZATION OF STREPTOMYCES SPECIES
Morphological Observations-Spore Chain and Spores

Culture & ATCC NO.	Spore Wall Ornamentation[1]	Approximate Spore Size	Production Week Spore Count	Spore Chain Shape[2]
U30	SM	0.8−1.3μ × 0.4−0.7μ	1. 0→10+ 2. 10+ 3. 10+ (1 to 50+)	RF
S. scabies 15485	SM	1.0μ × 0.5μ	1. − 2. 10+ 3. (30+ to 50+)	F 50%; RA 30%; S 20%
CB *S. scabies*	SM	1.3μ × 0.9μ	1. 10+ 2. 10+ 3. 10+ (1 to 50+)	All simple shapes found R, F. RA & S
S. scabies (*griseus*) 10246	SM	0.9μ × 0.5μ	1. − 2. 10+ 3. (3+ to 10+)	F 60% R 30% RA 10%
S. scabies (*griseus*) 3352	SM	1.0μ × 0.6μ	1. − 2. 10+ 3. (0 to 10+)	All simple shapes found as in CB
S. griseus 10137	SM	0.8μ × 0.5μ	1. 0 2. 3+→10+ 3. 10+ (1 to 10+)	R & F
S. globisporus 15864	SM	0.7−1.0μ × 0.5−.6μ	1. 0→10+ 2. 10+ 3. 10+ (3+ to 50+)	Most F; others R
S. globisporus 19906	SM	0.9μ × 0.6μ	1. 10+ 2. 10+ 3. 10+ (1 to 50)	Most F; R

[1] Spore wall ornamentation − SM = smooth

[2] Spore chain Shape − Straight = Rectus (R); Flexible = Flexibilis (F); Open Loops = Retinuculum-Apertum (RA); Spirals = Spira (S)

APPENDIX TABLE 7

SUMMARY OF CHARACTERIZATION OF STREPTOMYCES SPECIES
Color Determination

Culture & ATCC No.	Aerial Spore Mass[1]	Reverse Substrate[1] Color	Soluble Pigment[1]
U30	Color varied each week depending on media 7 days: 4W, 1Y 14 days: 3W, 1Y, 1R 21 days: 2W, 1Y, 1G, 1R	Y-R on 3 wk plates	O
S. scabies 15485	7 days: – 14 days: GY 21 days: GY	B (almost black on some media)	Y-B
CB *S. scabies*	7 days: GY 14 days: GY 21 days: GY	Y-G on 3 wk plates	Y
S. scabies (*griseus*)	7 days: – 14 days: poor growth W to Y 21 Days: poor growth	W or Y	Y
S. scabies (*griseus*) 3352	7 days: – 14 days: GY 21 days: GY	Y-dark G (blk)	Y
S. griseus 10137	7 days: Y 14 days: Y 21 days: Y	Y	Y
S. globisporus 15864	7 days: Y 14 days: Y 21 days: Y	Y	Y not on all media
S. globisporus 19906	7 days: Y 14 days: Y 21 days: Y	Y	Y

[1] Y=yellow, W=white, O=orange, B=brown, G=green, GY=grey, R=red: observations were made 7, 14, and 21 days after inoculation of the test media.
Note: No color change was observed upon addition of 0.05N HCI or NaOH to the substrate mycelium.

APPENDIX TABLE 8

SUMMARY OF CHARACTERIZATION OF STREPTOMYCES SPECIES

Carbon Utilization

Culture & ATCC No.	Melanoid Pigment	Sucrose	I-inosital	Raffinose	Rhamnose	L-xylose	L-arabinose	Glucose	No Carbon Source
U30	−	+	+	±	+	+	+	+	Trace
S. scabies 15485	−	−	−	−	−	+	+	+	Trace
CB *S. scabies*	+	+	+	+	+	+	+	±	Trace
S. scabies (*griseus*) 10246	−	+	−	−	−	+	+	+	Trace
S. scabies (*griseus*) 3352	−	+	±	±	+	+	+	+	Trace
S. griseus 10137	−	−	−	−	−	+	±	+	Trace
S. globisporus 15864	−	−	−	−	+	+	+	+	Trace
S. globisporus 19906	−	−	−	−	−	−	+	+	Trace