INFLUENCE OF GREEN MANURES AND CROP ROTATION ON COMMON SCAB OF POTATO

A. R. WEINHOLD,[1] J. W. OSWALD,[2] TULLY BOWMAN[1]
JAMES BISHOP,[3] AND DAVID WRIGHT[4]

INTRODUCTION

Common scab of potato, caused by *Streptomyces scabies*, is an important disease in many potato growing areas of the world. The persistence of this pathogen in soil and the influence of cultural practices have been the subject of many investigations. Lutman et al (7) reported a situation in which the percentage of badly scabbed tubers in a field had dropped from 100 to 3.3 during a 19-year period without a crop of potatoes. Goss and Afanasiev (3) conducted a long-term rotation experiment and found that scab was most severe in the short rotations with sugar beets and least in the long, four to six-year rotations in which alfalfa preceded potatoes. Werner et al (15) reported that scab was less severe with 3-year rotations than when potatoes were grown continuously on the same land. In addition, they observed that over a ten-year period there was no significant difference in disease incidence due to the crop preceding potatoes when the rotations were of equal length. Richardson and Heeg (12) also observed that the crop preceding potatoes had little effect on the incidence of common scab. Wheeler (16) found that 3 years of alfalfa between potato crops had little influence on scab while 2 years of sweet clover markedly increased the incidence of disease. An alternate year rotation of corn with rye planted at the last cultivation, and then turned under while green, appeared to reduce the build-up of the disease.

Hooker (4) conducted a test to determine the survival of *S. scabies* in peat soil planted to various crops. He found that scab incidence was influenced to a greater extent by the length of time between potato crops than by any of the crops tested. Hooker was unable to correlate scab incidence with the population of *Streptomyces* spp. as determined by dilution plates.

In addition to studies on the influence of crop rotations several workers have investigated the effect of incorporating cover crops into the soils as green manure. Millard (9) in 1923 found that green manure such as rye and grass cuttings, when applied to soil, inhibited scab. Millard and C. B. Taylor (10) later presented evidence that in sterilized soil *Actinomyces praecox* would depress the growth of *Actinomyces scabies* and inhibit parasitic attack. White (17) reported that scab was reduced by green manures of rye and cowpea. Rouatt and Atkinson (13) studied the decomposition of soybean, rye, and red clover in naturally infested potato scab soil and found that only soybean reduced disease incidence.

[1]Assistant Professor and Laboratory Technician III, respectively, Department of Plant Pathology, University of California, Berkeley. Accepted for publication April 22, 1964.
[2]Formerly Professor of Plant Pathology, University of California, Berkeley, now President, University of Kentucky.
[3]Associate Vegetable Crops Specialist, Department of Vegetable Crops, University of California, Davis.
[4]Agriculturist and Farm Advisor, University of California, Agricultural Extension, Kern Co., Calif.

In contrast to the above reports, however, Sanford (14) found that in a field test 50 tons of rye/acre did not reduce scab. Dippenaar (1) failed to reduce scab incidence with a green manure of green peas. In greenhouse experiments Goss (2) could not reduce scab with green manures of alfalfa or grass cuttings. He also was unable to duplicate Millard's work in *A. praecox*. In a more striking contrast KenKnight (5) found blue grass and alfalfa, as green manures, caused significant increases in scab.

It is evident from the above that there is no general agreement concerning the effects of either crop rotations or incorporation of green manures into the soil on common scab of potato. The picture with regard to soil amendments is particularly confusing because some reports are based on the use of previously sterilized soil, others with field soil. The usual approach in research of this type has been to determine the effect of these practices in reducing disease incidence. In the present study the experiment was initiated on land with a very low level of infestation. The effect of crop rotation and cover cropping with green manure incorporation on the build-up of the disease could therefore be investigated. A preliminary report of this study has been published (11).

Materials and Methods

A four-acre section of land on the U.S.D.A. Cotton Research Station, Shafter, California, was divided into 27 permanent plots. Each treatment was replicated 3 times in plots 20 x 290 ft. In 1949, the first year of the study, all 27 plots were planted with White Rose potatoes. This planting showed that there was a trace of scab uniformly distributed over the entire plot area. The investigation was terminated in 1961.

Estimation of disease severity

Scab severity was measured by determining scab index. Eight classes were established based on the percentage of tuber surface covered with scab lesions. The class ranges were 0, trace - 5, 6-15, 16-25, 26-35, 36-60, and 61-90 per cent (Fig. 1). Each tuber of a treatment sample (about 50 tubers) was examined and placed in one of the eight classes. The scab index was calculated by multiplying the number of tubers in each class by the class mean. These values for the classes were then summed and divided by the number of tubers in the sample. A scab index of 10.0 indicates that the average tuber in the sample had this percentage of its surface area covered with scab lesions.

The percentage marketable tubers was estimated by considering that all tubers with more than 5% of their surface area covered by scab lesions were not marketable.

Results and Discussion

Effect of intermittent potato cropping on build-up of potato scab

The crop rotations investigated in this phase of the study were as follows:

1. Potatoes grown every year.
2. Potatoes alternated with barley.
3. Potatoes alternated with sugar beet.

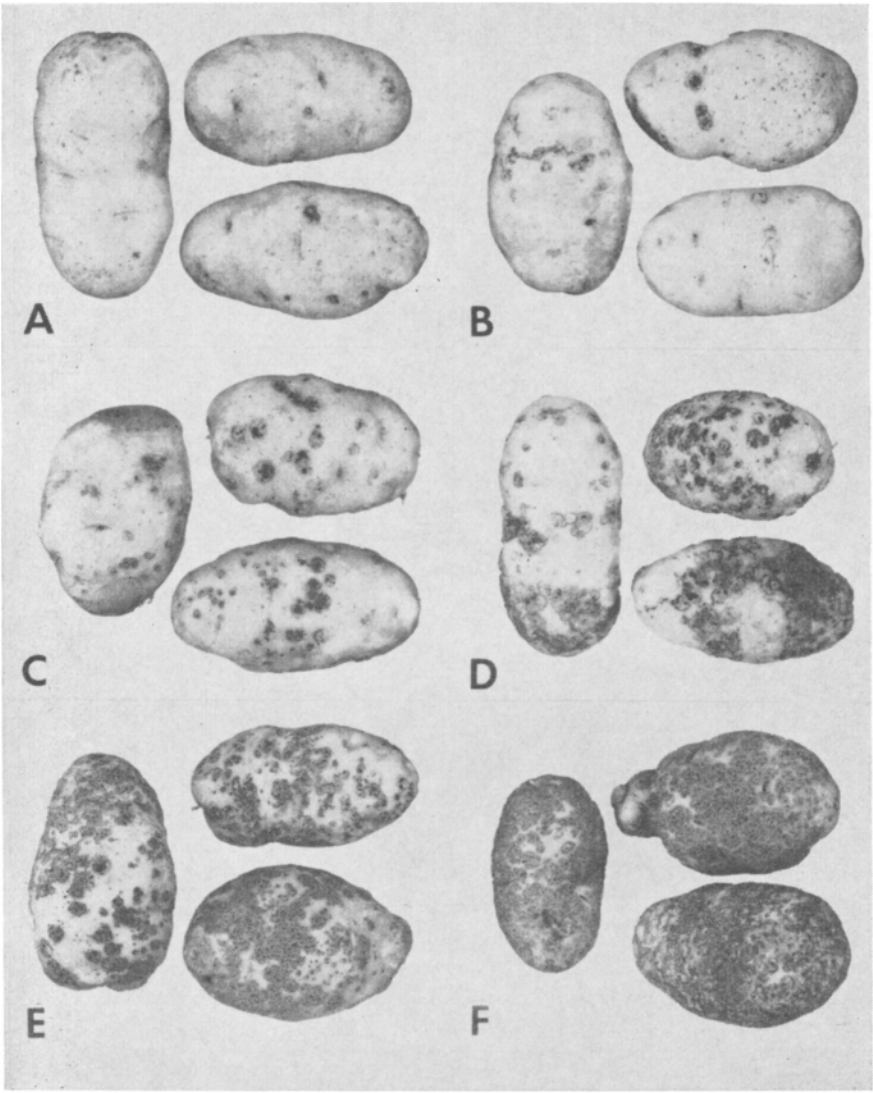

FIG. 1.—Tubers representative of classes used to determine scab index. (A) Trace - 5%; (B) 6-15%; (C) 16-25%; (D) 26-35%; (E) 36-60%; and (F) 61-90%.

4. Potatoes alternated with cotton.
5. Potatoes — cotton — sugar beets, in that order.
6. One year of potatoes alternated with 3 years of alfalfa.

Samples were taken and disease severity evaluated as described above.

In the 2-year rotations there was no difference in disease build-up between barley, cotton and sugar beets when these crops were alternated

TABLE 1.—*The effect of crop rotations on the natural build-up of common scab of potato under intermittent potato culture.*

A. Scab index[1]

Dates	Continuous[2] potatoes	Potatoes[2]-barley	Potatoes[2]-cotton	Potatoes[2]-sugar beets	Potatoes-sugar beets cotton	Potatoes 1 yr. alfalfa 3 yrs.
1949	0.17	0.17	0.25	0.18	0.30	0.19
1950	0.17					
1951	0.76	0.45	0.28	0.44		
1952	1.35				0.74	
1953	2.34	0.33	0.43	0.43		0.26
1954	6.28					
1955	11.84	0.51	1.78	1.75	2.94	
1956	15.43					
1957	5.49	2.13	3.10	2.22		0.30
1958	12.72				5.95	
1959	4.51	4.83	4.01	1.08		
1960	6.83					
1961	3.81	4.73	5.78	4.16	7.98	0.82

B. Percent marketable tubers

Dates	Continuous potatoes	Potatoes-barley	Potatoes-cotton	Potatoes-sugar beets	Potatoes-sugar beets cotton	Potatoes 1 yr. alfalfa 3 yrs.
1949	100.0	100.0	100.0	100.0	100.0	100.0
1950	100.0					
1951	99.2	100.0	100.0	100.0		
1952	97.1				99.0	
1953	86.0	98.5	97.0	97.5		100.0
1954	76.2					
1955	47.9	96.3	94.3	94.7	91.5	
1956	41.8					
1957	75.0	93.3	87.0	94.2		99.0
1958	54.7				75.3	
1959	82.0	80.4	82.8	98.6		
1960	65.8					
1961	88.8	84.3	77.9	85.4	64.9	99.6

[1]Each figure is the mean of 6 samples; 2 from each of 3 replications. Scab index = mean tuber surface area covered with scab lesions.

[2]Data from the last 4 years of the 3 alternate year rotations and corresponding years of continuous potatoes were analyzed as a combined experiment (6). The means were found to be not significantly different.

with potatoes (Table 1). In all 3 situations there was an increase in disease with each successive crop of potatoes.

For the first 5 crops of potatoes in the alternate year rotations the rate of disease increase was almost exactly parallel with the first 5 crops when potatoes were grown every year. The next 2 crops of continual potatoes showed a greater increase in disease than occurred in the alternate year rotations. Because the continuous potato plots had their

6th and 7th crops in 1954 and 1955 whereas the 6th and 7th crops were grown in the alternate rotation plots in 1959 and 1960, a direct comparison is not possible. Therefore, it is not known whether this difference is due to a beneficial influence of the rotations or to a more favorable environment for disease development in 1954 and 1955 than in 1959 and 1960 (Table 1). It appears that an increase in potato scab severity depended primarily upon the number of preceding potato crops grown in the plots. A similar observation was made by Werner (15) who reported that during a 10-year period there was no significant difference in disease incidence due to the crop preceding potatoes when the rotations were of equal length. In contrast Goss and Afanasiev (3) found in their rotation experiment that the greatest amount of scab occurred in short rotations with sugar beets.

With the 3-year rotation in which potatoes were alternated with sugar beets and cotton the incidence of scab appeared to increase with each crop of potatoes at a faster rate than in the continuous potato control or any of the 2-year rotations (Table 1).

In the plots where potatoes were rotated with 3 years of alfalfa only 4 potato crops were grown. The mean scab index for tubers from this 4th crop was 0.82. This is comparable to the scab index of 1.35 for the 4th crop from the continuous potato controls (Table 1).

Effect of cover crops and green manure incorporation on build-up of potato scab

In this phase of the study potatoes were grown every year. Cover crops were grown between potato crops and turned under as a green manure just before the seed was mature. The cover crop treatments were as follows: [1] no cover crop, control; [2] soybean, turned under in October; [3] barley turned under in December; [4] Canadian pea turned under in December. In 1956 the Canadian pea plots were changed and soybeans were substituted as the cover crop. Potatoes were planted in early February and harvest was normally between June 10th and 20th.

Each treatment was replicated 3 times. The two center rows of potatoes in each plot were harvested for record. In order to obtain better sampling, each of the plots was divided into 2 parts and a sample taken from each half. This resulted in 6 samples for each treatment. The samples consisted of approximately 35 lbs of randomly selected tubers.

For the years 1949 to 1955 records were kept on the estimated amounts of soybean, barley, and pea tissue incorporated into the soil. The estimates were made by weighing the tops grown in several 100 sq ft areas randomly selected in each plot. The average green weight of plant material turned under each year was 5-6, 5-8, and 8-10 tons/acre for soybeans, peas, and barley, respectively.

At the beginning of the experiment the scab index in all of the plots was less than one. In the control plots, which received no green manure, scab index increased steadily for the first 8 years reaching a peak value of 15.4. During the next 5 years the amount of scab fluctuated with a general trend toward decreasing incidence (Table 2, Fig. 2).

With a barley cover crop and green manure the scab level increased more rapidly and reached a maximum after 8 years which was nearly twice that of the control (Table 2, Fig. 2). The most striking result was obtained with the soybean cover crop and green manure. During the

TABLE 2.—*The effect of cover crops and green manure incorporation on the natural build-up of common scab of potato under continuous potato culture.*

A.	Scab index[1]													
Green manure crop	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	x[3]
Soybean	0.35	*0.64	0.46	0.44	0.71	1.09	0.39	0.45	0.18	0.46	0.25	0.57	0.83	0.52[a]
Canadian pea[2]	0.41	0.59	0.86	2.05	2.10	5.74	10.73	9.09	8.95	8.62	4.06	6.38	7.37	7.61[b]
Control	0.17	0.17	0.76	1.35	2.34	6.28	11.83	15.43	5.49	12.72	4.51	6.83	3.81	8.40[b]
Barley	0.14	0.58	1.28	2.74	2.89	11.39	17.56	27.89	18.92	25.85	17.41	10.81	11.31	17.64[c]

B.	Percent marketable tubers												
	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961
Soybean	100.0	*99.2	99.8	99.8	99.0	100.0	99.8	99.8	99.6	100.0	100.0	99.2	99.5
Canadian pea[2]	100.0	99.5	99.0	93.5	88.0	81.8	51.3	55.7	59.2	57.6	81.9	68.7	66.4
Control	100.0	100.0	99.2	97.1	86.0	76.2	47.9	41.8	75.0	54.7	82.0	65.8	88.8
Barley	100.0	98.9	97.3	91.1	82.0	46.3	27.2	16.8	34.7	26.5	45.5	50.4	49.85

*Cowpea used in place of soybean.
[1]Each figure is the mean of 6 samples; 2 from each of 3 replications. Scab index = mean tuber surface area covered with scab lesions.
[2]Changed to soybean in 1956.
[3]Data for last 8 years as a combined experiment following the procedure of LeClerg, Leonard and Clark (6). Mean values compared using Duncan Range Test. Means with unlike subscripts are significantly different at the 5% level.

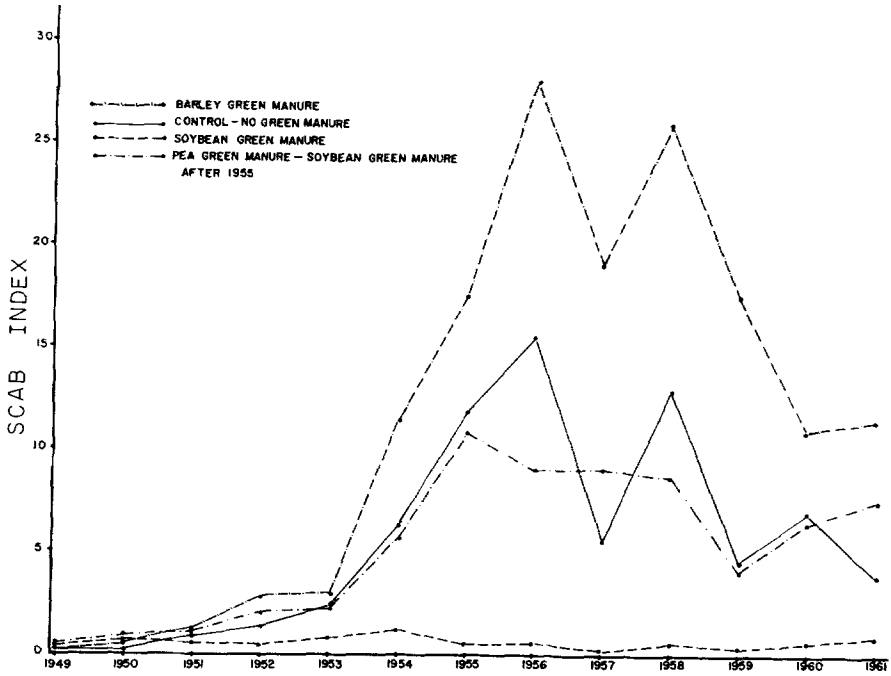

FIG. 2.—The effect of green manures on the natural build-up of common scab of potato. Soybean prevented the build-up of disease but when green pea manure was changed to soybean in 1956, disease did not decrease. This indicates that soybean green manure will not reduce potato scab when the organism is well established in soil.

entire 13-year experiment there was no build-up of scab and the scab index was never greater than 1.1 as compared to a high of 15.4 and 27.8 in control and barley plots, respectively (Table 2). The scab index of tubers from Canadian pea plots was consistently similar to that of the controls. At the end of 7 years soybeans were substituted for peas in these plots. During the remaining 6 years there was no indication that a soybean green manure had any effect in reducing incidence after the pathogen was well established in the soil (Table 2, Fig. 2).

There are many reports in the literature of studies in which green manure was used in an attempt to reduce or control potato scab. The results obtained were quite inconsistent. Several workers have reported scab control with green manure while others could not demonstrate any beneficial effect. Although the present data are based on only one test it is important to note that the primary approach was to determine the influence of green manures on disease build-up, in a field with a low initial infestation, rather than an attempt to control scab where the pathogen was well established.

From 1956 through 1961 scab incidence in the green manure plots showed considerable seasonal variation and also a general downward trend. The seasonal variation may have been due to environment. How-

ever, a comparison of temperature and rainfall records, obtained from the U. S. Cotton Research Station, for each growing season did not reveal any general relationship between these factors and disease severity. The downward trend of disease severity during the last years of the test are suggestive of the "old scab land" effect as reported by Menzies (8).

The beneficial influence of crop rotations and green manures in controlling plant diseases when the soil is heavily infested with the pathogen is well known. In such practices there may or may not be appreciable organic matter incorporated into the soil. The results of these tests have shown that with potato scab the beneficial effect of growing a suitable cover crop and incorporating the green plant material into the soil is in preventing the build-up of the disease. It should be pointed out that the effects observed in this study occurred in a sandy loam soil and under climatic conditions which permitted growing a cover crop and a potato crop each year. Whether these effects could be obtained in areas with different soil types and a more restricted growing season can only be answered by further investigations.

The influence of green manures on the build-up of diseases under continuous cropping of the affected plants has not been extensively investigated. The results of these studies suggest that this may be a useful approach to the control of certain diseases caused by soil-borne pathogens.

Summary

In this study the influence of two cultural practices on the build-up of common scab of potato was investigated. At the beginning of the test there was a low incidence of disease distributed uniformly throughout the field. The cultural practices were as follows: [1] Potatoes were grown intermittently in crop rotations; and [2] Potatoes were grown every year and between each potato crop a cover crop was grown and incorporated into the soil as green manure.

The effect of intermittent potato cropping on the build-up of potato scab can be summarized as follows:

[1] No difference was observed among alternate year rotations of barley, cotton or sugar beets and generalization can be made that an increase in potato scab severity depended primarily upon the number of preceding potato crops grown in the plots. With all 3 crops the rate of disease increase with each succeeding potato crop was relatively uniform.

[2] With a 3-year rotation of potatoes, sugar beets and cotton, potato scab appeared to increase more rapidly than would be expected in view of the data from plots planted continouusly to potatoes. Little can be concluded about the alfalfa 3-year, potato 1-year rotation because only 4 crops of potatoes were grown.

The effect of cover crops and green manure incorporation build-up of potato scab can be summarized as follows:

[1] Under continuous potato culture without any cover crop or green manure the incidence of potato scab increased steadily reaching a maximum after 8 years.

[2] A barley cover crop and green manure increased scab incidence to a level nearly twice that of the no cover crop control.

[3] A soybean cover crop and green manure completely prevented the build-up of potato scab.

[4] A Canadian pea cover crop and green manure was not appreciably different from the no cover crop control.

[5] All plots except those with a soybean cover crop reach maximum scab incidence after 8 crops of potatoes. For the remaining 5 crops disease incidence was variable with a general trend toward decreasing disease severity.

[6] Although a soybean cover crop prevented disease build-up it was completely ineffective in reducing scab incidence once the pathogen was well established.

Literature Cited

1. Dippenaar, B. J. 1933. Environmental and control studies of the common scab disease of potatoes caused by Actinomyces scabies (Thaxt.) Guss. Union of South Africa Dept. of Agr. Sci. Bull. No. 136.
2. Goss, R. W. 1937. The influence of various soil factors upon potato scab caused by Actinomyces scabies. Neb. Agr. Expt. Sta. Res. Bull. 93.
3. Goss, R. W. and M. M. Afanasiev. 1938. Influence of rotations under irrigation on potato scab, Rhizoctonia and Fusarium wilt. Neb. Agr. Expt. Sta. Bull. 317: 181.
4. Hooker, W. J. 1956. Survival of Streptomyces scabies in peat soil planted with various crops. Phytopathology 46: 677-681.
5. KenKnight, Glenn. 1941. Studies on soil Actinomycetes in relation to potato scab and its control. Michigan Agr. Expt. Sta. Bull. 178.
6. LeClerg, E. L., W. H. Leonard and A. G. Clark. 1962. Field plot technique. Burgess Pub. Co., Minneapolis, Minn. 373 p.
7. Lutman, B. F., R. J. Livingston and Alice M. Schmidt. 1936. Soil Actinomycetes and potato scab. Vt. Agr. Expt. Sta. Bull. 401.
8. Menzies, J. D. 1959. Occurrence and transfer of a biological factor in soil that suppresses potato scab. Phytopathology 49: 648-652.
9. Millard, W. A. 1923. Common scab of potatoes. Part II. Ann. Appl. Biology 10: 70-88.
10. Millard, W. A. and C. B. Taylor. 1927. Antagonism of microorganisms as the controlling factor in the inhibition of scab by green manuring. Ann. Appl. Biol. 14: 202-215.
11. Oswald, J. W. and O. A. Lorenz. 1956. Soybeans as a green manure crop for the prevention of potato scab. (Abstr.) Phytopathology 46: 22.
12. Richardson, J. K. and T. J. Heeg. 1954. Potato common scab investigations. I. A survey of disease incidence in Ontario. Canad. J. Agr. Sci. 34: 53-58 (R.A.M. 33: 623).
13. Rouatt, J. W. and R. G. Atkinson. 1950. The effect of the incorporation of certain cover crops on the microbiological balance of potato scab infested soil. Canad. J. Research, C, 28: 140-152.
14. Sanford, G. B. 1926. Some factors affecting the pathogenicity of Actinomyces scabies. Phytopathology 16: 525-547.
15. Werner, H. O., T. A. Kiesselbach and R. W. Goss. 1944. Dry-land crop rotation experiments with potatoes in northwestern Nebraska. Neb. Agr. Expt. Sta. Bull. 363, 43 p.
16. Wheeler, E. J. 1946. The residual effect of crop rotations on potato yield and the presence of potato scab. Mich. Agr. Expt. Sta. Quart. Bull. 28, p. 1-7.
17. White, E. P. 1928. Potato experiments for the control of Rhizoctonia, scab, and blackleg, 1922 to 1927. Kansas State Agr. Expt. Sta. Tech. Bull. 24: 37 p.