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A WESTERN FIELDROT OF THE IRISH POTATO TUBER CAUSED BY FUSARIUM RADICICOLA

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INTRODUCTION

Tuber-rots of the Irish potato (*Solanum tuberosum*) which are common to the arid[1] West may be grouped into two classes: Storage-rots and field-rots. This paper is concerned only with certain rots attacking the potato tuber while growing in the field. From the tuber-rots under discussion, the fungus *Fusarium radicicola* Wollenw. was isolated. Carpenter[2] in 1915 demonstrated that *F. radicicola* could, under laboratory conditions, cause decays in potato tubers similar in every way to these rots. His experiments, however, were conducted wholly in the laboratories of the Department of Agriculture, in Washington, D. C. It was therefore thought practicable to present this paper, which gives the results of experiments performed under field conditions in the irrigated West. These experiments substantiate the results obtained by Carpenter and further establish the relationship of *F. radicicola* to the field tuber-rots under consideration.

THE DISEASE

Under the head of fieldrot are considered several types of decay occurring in potato tubers while yet in the field—a stem-end rot, a lenticel rot, and a rot proceeding from eye infections. Eye infections in the field are not as common as stem-end and lenticel infections. These types of rot are known as "stem-end rot," "field dryrot," or "blackrot." The name "blackrot" best describes them, for the decayed tissues are nearly black in color when the tubers are taken from the field. The rot may be further described as a comparatively dry rot, dark to nearly black in color, proceeding from the stem end, lenticels, and occasionally from the eyes of the tuber. The decay is first recognized by the blackened, sunken appearance of the stem end, or, in the case of lenticel and eye

[1] The observations and experiments set forth in this paper were confined principally to southern Idaho.

[2] Carpenter, C. W. Some potato tuber-rots caused by species of Fusarium. *In* Jour. Agr. Research, v. 5, no. 5, p. 183–210, pl. A–B (col.), 14–19. 1915.

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infections, by the blackened, more or less sunken spots on the surface of the tuber. Tubers collected in a commercial potato field and infected in this manner are shown in Plate XXXIV, figures 1 to 6. This black color is lost in part as the infection becomes older, the infected tissues taking on various shades from nearly black to sepia brown. In connection with the stem-end rot, the fungus often proceeds down the vascular tissue, killing and blackening the network of bundles. Figures 5 and 6 in Plate XXXIV show sections of a tuber infected in this manner. Often it is possible to break away the cortical tissues and lay bare the blackened network. Lenticel infection proceeds outward in all directions from the point of infection and may or may not extend down to the main vascular system. Very frequently in the case of eye infections the vascular strand connecting the eye with the main vascular system is blackened, but it is seldom that such infection extends far into the main vascular ring. Blackrot is confined principally to potatoes of the Idaho Rural, Pearl, and other round types.

Closely related to the blackrot of potatoes of the round types is a jelly-end rot attacking principally varieties of the Burbank group. Jelly-end-infected tubers of the Netted Gem variety are shown in Plate XXXV, figures 1 to 3. The jelly-end rot of the Burbank group differs from the blackrot of round types of potatoes in that it is a softrot, light to dark brown in color, while the blackrot is a comparatively dry rot, black or nearly black in color. Jelly-end rot may be described as a soft, wet rot of the tubers proceeding from the stem end downward through the tuber attacking all tissues but apparently advancing somewhat more rapidly through the vascular bundles. Examination of tubers infected with jelly-end rot, however, often reveals no perceptible discoloration of the vascular tissue below the line of the rot in the other tissues. As the decay becomes older, the stem end becomes somewhat shriveled and dried, often closely resembling the type of decay caused in storage by *F. trichothecioides* Wollenw.[1] Lenticel and eye infections are seldom found in connection with the jelly-end rot of the Burbank group.

Occasionally a softrot of the seed end is also found. A Netted Gem tuber infected at both the seed end and the stem end is shown in Plate XXXV, figure 1. *F. radicicola* was isolated from both ends of this tuber. There was apparently no infection in the vascular tissues connecting the two regions of decay.

At first it was thought that the jelly-end rot of the Burbank group and the blackrot of round types of potatoes were two distinct diseases, but inoculations made in 1914 into the stem ends of Netted Gem and Idaho Rural tubers with *F. radicicola* led to the belief that they might be caused by the same organism. Material collected in the field, whether jelly-end rot or blackrot, when placed in a moist chamber for a few days

[1] Jamieson, Clara O., and Wollenweber, H. W. An external dry rot of potato tubers caused by Fusarium trichothecioides, Wollenw. *In* Jour. Washington Acad. Sci., v. 2, no. 6, p. 146–152, illus. 1912.

usually showed tufts of *F. radicicola*. Infected tubers of Idaho Rural potatoes kept 10 days in a moist chamber at room temperature are shown in Plate XXXV, figures 4 and 5. Tufts of *F. radicicola* have appeared. Inoculations in 1915 left no doubt in the writer's mind that *F. radicicola* was capable of causing both types of rot.

DISTRIBUTION AND ECONOMIC IMPORTANCE

F. radicicola is apparently widely distributed. Wollenweber [1] states that its habitat is "on partly decayed tubers and roots of plants, such as *Solanum tuberosum* in Europe and America (collected by Wollenweber) and *Ipomoea batatas* in the United States of America (collected by Harter and Field)." Carpenter [2] makes the following statement as to its habitat: "On partly decayed tubers and roots of plants. Cause of potato dryrot and jelly-end rot. Identified from the following: *Ipomoea batatas* (collected by Mr. L. L. Harter); *Musa sapientum* (collected by Mr. S. F. Ashby, Jamaica, Porto Rico); *Cucumis sativus* (collected by Mr. F. V. Rand, West Haven, Conn.); soil (collected by Mr. F. C. Werkenthin, Austin, Tex.)."

The writer has isolated *F. radicicola* from the roots of poplar trees (*Populus deltoides*) at Jerome, Idaho, where he found it associated with crownrot. The fact that the fungus appears on potato tubers when disease-free seed potatoes are planted on raw desert lands suggests that it may be well distributed throughout the desert soils. Orton [3] in 1909 reported jelly-end rot of potatoes from the San Joaquin Valley, in California.

F. radicicola has been reported on potatoes from Idaho, Oregon, and California by Wollenweber [4] and from Idaho, Oregon, California, Nevada, Mississippi, New York, Virginia, and the District of Columbia by Carpenter.[5] The writer has isolated this fungus from decayed potato tubers from the following localities in Idaho: Idaho Falls, Blackfoot, Aberdeen, Rupert, Murtaugh, Twin Falls, Filer, Kimberly, Jerome, Wendell, Gooding, King Hill, and Caldwell, and has observed the rot in potato fields in many other localities in the State. The disease apparently appears at its worst under dry-land-farming conditions and in raw desert land planted to potatoes before having been in other crops. On comparing rotted tubers collected by himself in Idaho with specimens sent to the Department of Agriculture from California and Oregon he was convinced that the rots were of one and the same nature. He has also observed rots identical in outward appearance with those found in Idaho, in Portland, Oreg., Seattle, Wash., and British Columbia.

[1] Wollenweber, H. W. Identification of species of Fusarium occurring on the sweet potato, Ipomoea batatas. *In* Jour. Agr. Research, v. 2, no. 4, p. 257. 1914.

[2] Carpenter, C. W. Op cit., p. 206.

[3] Orton, W. A. Potato diseases in San Joaquin County, Cal. U. S. Dept. Agr., Bur. Plant Indus. Circ. 23, 14 p. 1909.

[4] Wollenweber, H. W. Op. cit.

[5] Carpenter, C. W. Op. cit.

In the irrigated portions of Idaho the economic importance of the disease has varied greatly from year to year. In 1913 the writer was usually able to find only an occasional rotted tuber in any one commercial field. In a few fields which had been planted on raw desert land and poorly cared for he found as high as 80 per cent of the tubers infected with stem-end blackrot and lenticel rot. The year 1914 might be called an epidemic year. In one 50-acre field of Netted Gems near Jerome, Idaho, he found as high as 40 per cent of the crop infected with jelly-end rot. Similar conditions were observed in many other fields in the irrigated portions of southern Idaho. Stem-end blackrot and lenticel rot were also found very abundant in the fields of Idaho Rurals. It is significant that in 1914 a freeze occurred in June which killed the vines to the ground, the plants coming up anew and producing a crop. Often the origin of infection could be traced from the frozen tip of the vine down through the stem to the infected tubers. Although infected tubers were found in most of the commercial fields visited in 1915, the disease this year was of slight importance.

EXPERIMENTAL WORK

PRELIMINARY EXPERIMENT IN 1914

In the fall of 1914 ten Idaho Rural tubers and ten Netted Gem tubers were disinfected by dipping in formaldehyde and were punctured at the stem end with a needle carrying spores from a culture of *F. radicicola* which had been isolated from a potato tuber infected with blackrot. After inoculation the tubers were placed in moist chambers, where they remained for something over a month. An examination of the tubers showed that infection had been produced in every tuber inoculated. The infection in the Idaho Rurals was similar in all respects to the blackrot occurring in the field. The infection in the Netted Gems was not quite so dark in color as that produced in the Idaho Rurals and resembled certain stages of jelly-end rot collected in the field. No checks were prepared.

LABORATORY EXPERIMENTS IN 1915

On August 6, young and apparently healthy potato tubers of the Netted Gem and Idaho Rural varieties were selected, carefully washed, and disinfected in a solution of formaldehyde (1:240). After disinfection the tubers were dried and inoculated with *F. radicicola*. The methods of inoculation were as follows: (1) By spraying with a spore suspension; (2) by wounding the tubers with a needle bearing spores; and (3) by dipping the broken stolon ends in a spore suspension. In method 3 the tubers were taken from the field with their stolons attached. After disinfection each stolon was broken off afresh at from 1 to 2 inches from its junction with the tuber and inoculated as stated in the foregoing.

Fifty tubers each of Idaho Rural and Netted Gem, respectively, were inoculated by methods 1 and 2, and twenty-five tubers each of Idaho Rural and Netted Gem were inoculated by method 3. Checks on each experiment were prepared in the same manner, except that in method 1 the tubers were sprayed with sterile water, in method 2 the tubers were wounded with a sterile needle, and in method 3 the broken stolon ends were dipped in sterile water. Inoculated tubers and checks were placed in moist chambers and put in the culture room of the Experiment Station laboratory. During the course of these experiments the culture-room temperature varied from a minimum of 20° to a maximum of 29° C. Temperatures were taken daily at 8.30 a. m. and 5.30 p. m. After a month the tubers were examined. Table I gives a summary of the experiments and the number of tubers found infected.

TABLE I.—*Summary and results of laboratory inoculations of Solanum tuberosum*

Method No.	Method of inoculation and parts inoculated.	Variety.	Number of tubers inoculated.	Number of tubers infected.
1	Tubers sprayed with suspension of spores	Netted Gem	50	48
		Idaho Rural	50	50
	Check. Tubers sprayed with sterile water	Netted Gem	50	0
		Idaho Rural	50	0
2	Tubers punctured with inoculated needle at stem end	Netted Gem	50	50
		Idaho Rural	50	50
	Check. Tubers; stem end punctured with sterile needle.	Netted Gem	50	0
		Idaho Rural	50	0
3	Tubers; broken stolon ends dipped in spore suspension.	Netted Gem	25	25
		Idaho Rural	25	19
	Check. Tubers; broken stolon ends dipped in sterile water.	Netted Gem	25	0
		Idaho Rural	25	0

Of the 50 Netted Gem tubers sprayed with the spore suspension, 48 showed infection. Stem-end infection was present in each of the inoculated tubers. Lenticel infections were present on most of the tubers, and eye infections were also found. Every Idaho Rural tuber sprayed with the spore suspension showed infection at the stem end. The majority showed lenticel infections and several showed eye infections. Lenticel infections, induced by spraying with the spore suspension, are shown in Plate XXXVI, figure 3. In figure 4 of Plate XXXVI is shown the same tuber after remaining several days longer in the moist chamber. Tufts of *F. radicicola* have appeared over the surface of the decayed areas.

A stem-end infection of an Idaho Rural tuber sprayed with the spore suspension is shown in Plate XXXVI, figure 5. Every tuber, whether Netted Gem or Idaho Rural, developed infection when punctured at the stem end with a needle carrying the spores of the fungus. Decays induced in this manner are shown on Plate XXXVI, figures 1 and 2. Twenty-five stem-end tuber infections resulted from the inoculation of the broken stolon ends in the Netted Gems, and 19 in the Idaho Rurals. The decay resulting from this method of inoculation was similar in every way to that produced by the other methods. A stem-end infection resulting from the inoculation of the broken stolon end under laboratory conditions is shown in Plate XXXVI, figure 6. In Plate XXXVI, figure 7, is shown an Idaho Rural tuber cut to expose the blackening of the vascular tissue which resulted from the inoculation of the tuber stolon. None of the checks were infected. The fungus was recovered from the decayed tissues each time the attempt was made.

EXPERIMENTS IN THE FIELD IN 1915

On August 11, in a plot in which disease-free Idaho Rural and Netted Gem seed potatoes had been planted, apparently healthy potato plants were selected. The soil was removed from around the plants in such a manner as to expose the tubers without disturbing their position. Three growing tubers under each plant were then inoculated with *F. radicicola*, after which the soil was replaced, care being exercised to place moist soil next to the tubers. The methods of inoculation were, respectively, as follows: (1) By spraying the tubers with a spore suspension; (2) by wounding each tuber stolon with a needle bearing spores at from 1 to 2 inches from its junction with the tuber; (3) by wounding the upper surface of each tuber with a needle bearing spores, and (4) by puncturing each tuber at the stem end with a spore-bearing needle. Ten plants each of Idaho Rural and Netted Gem potatoes were used in each experiment. As a check on each experiment, a similar number of apparently healthy Idaho Rural and Netted Gem plants were selected and a similar number of growing tubers treated in the same manner, except that in the case of experiment 1 the tubers were sprayed with sterile water, and in numbers 2, 3, and 4 a sterile needle was used in place of a spore-bearing needle.

A fifth experiment was set up in which 10 apparently healthy Idaho Rural and 10 apparently healthy Netted Gem plants, growing in the same plot with those employed in the four experiments just described, were used. In this experiment, the stem of each plant was punctured at the crown with a needle carrying spores of *F. radicicola*. Checks were prepared in the same manner, except that the stem of each plant was punctured with a sterile needle.

The soil of the plot in which these experiments were made was very dry and no irrigation water could be applied after the inoculations were made. During the course of the experiments (August 11 to September 6) the minimum soil temperature recorded was 66° and the maximum 84° F. The soil temperature was taken at a depth at which the potato tubers were found lying by burying the bulb of a soil thermograph under a potato plant. A little less than a month after making the inoculations an examination of all the plants was made. Table II gives a summary of the experiments and the results obtained from inoculating growing potato plants and tubers with *F. radicicola*.

TABLE II.—*Summary and results of inoculating growing potato plants and tubers with Fusarium radicicola*

Experiment No.	Method of inoculation.	Variety.	Number of inoculations.	Number of tubers infected.
1	Tubers sprayed with suspension of spores	Idaho Rural	30	15
		Netted Gem	30	17
	Check. Tubers sprayed with sterile water	Idaho Rural	30	0
		Netted Gem	30	0
2	Tuber stolons punctured with inoculated needle	Idaho Rural	30	27
		Netted Gem	30	23
	Check. Tuber stolons punctured with sterile needle	Idaho Rural	30	0
		Netted Gem	30	0
3	Tubers punctured with inoculated needle	Idaho Rural	30	30
		Netted Gem	30	30
	Check. Tubers punctured with sterile needle	Idaho Rural	30	0
		Netted Gem	30	0
4	Tubers punctured at stem end with inoculated needle	Idaho Rural	30	30
		Netted Gem	30	30
	Check. Tubers punctured at stem end with sterile needle	Idaho Rural	30	0
		Netted Gem	30	0
5	Stem of plant punctured at crown with inoculated needle	Idaho Rural	10	0
		Netted Gem	10	0
	Check. Plant stem punctured at crown with sterile needle	Idaho Rural	10	0
		Netted Gem	10	0

Of the 30 Idaho Rural tubers sprayed, 15 showed infection with stem-end and lenticel rot. Of the 30 Netted Gem tubers sprayed, 17 showed stem-end rot. Lenticel rot did not occur on all of the Netted Gem tubers and where it did occur the infections were very slight. The thicker skin of the Netted Gem probably renders it more resistant to fungus attacks than the Idaho Rural. The failure of a part of the sprayed tubers to develop infection can probably be attributed to the extremely dry condition of the soil. Infections resulting from spraying the growing tubers with a suspension of the spores of *F. radicicola* are shown in Plate XXXVI, figures 1 to 4. In figure 4, Plate XXXVI, is shown an eye infection which has extended down into the vascular system. *F. radicicola* was recovered from the discolored vascular tissue of this tuber. None of the checks showed any infection. Twenty-seven Idaho Rural tubers infected with stem-end rot resulted from the puncturing of the 30 tuber stolons. The three which failed to develop infection were under the same plant. Twenty-three of the Netted Gem tubers whose stolons were inoculated showed stem-end infection. Seven showed no evidence of infection in the tubers, though the stolons were black and dead up to within about one-eighth of an inch of their juncture with the tubers. Where infection in the tuber was found the line of infection could easily be traced down the stolon from the point of inoculation into the tuber.

Tuber infections resulting from the inoculation of the stolons in the field are shown in Plate XXXVII, figures 5 to 8. Both stem-end rot and vascular infection are shown. Figure 8, Plate XXXVII, represents a Netted Gem tuber with stem-end infection resulting from the inoculation of the stolon. The rot in this case was nearly black in color, soft, and resembled the earlier stages of the jelly-end rot often found in commercial fields. Vascular infection also developed in this tuber. The fungus was recovered from all infected tissues whenever the attempt was made. None of the checks were infected. Infection resulted in all cases where tubers were punctured with a needle carrying the spores of the fungus. None of the checks were infected. In the case of the checks the punctures could be seen easily but were healed over in each case. The inoculations made into the stems of potato plants failed to give very decisive results. In each case a blackening of the tissue adjacent to the puncture was observed. This blackening extended up and down from the point of puncture for from one-eighth to one-half an inch and in most cases also extended into the pith.

BLACKROT

The infections, whether at the stem end, at the lenticels, or at the eyes, produced by the artificial inoculation of Idaho Rural tubers with *F. radicicola*, could not be distinguished in any way from the infections on decayed tubers collected in the commercial fields. The infections resulting from the inoculation of growing tubers in the station plots when final examination was made were not as deep or as far advanced as many infections occurring naturally in the field, but this can easily be explained by the late date at which the inoculations were made. In fact, at the time the inoculations were made, tubers with well-advanced decay were being found in commercial fields. On the other hand, tubers with decay no farther advanced than that resulting from the inoculations have often been found in the field late in the season. In every case where an attempt was made, the fungus was recovered.

Tubers infected by inoculation in the field, by spraying with the spore suspension, by the puncture of the tuber with an inoculating needle, and by puncture of the tuber stolons, were placed in moist chambers, and in each case, after a few days, tufts of *F. radicicola* appeared. Blackrot-infected tubers in commercial fields, after being kept in a moist chamber from 3 to 10 days at temperatures ranging from 65° to 75° F., invariably threw out tufts of this fungus (Pl. XXXV, fig. 4, 5). Isolations made from the cortical and medullary tissues of blackrot-infected tubers have never yielded any fungus other than *F. radicicola*, which could be considered as the cause of the disease. Isolations made from stem-end blackrot-infected Idaho Rurals, Pearls, and other round types of potatoes have occasionally yielded *F. oxysporum*, especially when the culture was made from or near the vascular tissue. The failure to obtain *F. oxysporum* from lenticel and eye infections of tubers collected in commercial fields leads the writer to conclude that when *F. oxysporum* is found in stem-end infections it probably entered as a vascular parasite, independent of *F. radicicola*. *F. oxysporum* has never been found in connection with the stem-end blackrot of western potatoes to the exclusion of *F. radicicola*.

Fully 50 per cent of all cultures made from the decayed cortical and medullary tissues of tubers infected with stem-end and lenticel rot have remained sterile. This may have been due to improper cultural conditions, but it is believed that the discoloration of the tuber tissue often extends some distance beyond the point actually reached by the invading fungus. Stem-end blackrot-infected tubers often show a black net necrosis. Isolations made from the black network of bundles, if made some distance below the stem end, often fail to reveal any fungus. On the other hand, many such cultures have revealed *F. radicicola*, and occasionally both *F. radicicola* and *F. oxysporum*. That *F. radicicola* is capable of causing the blackened net, as well as the stem-end blackrot, is fully demonstrated by the results of artificial inoculations Pl. (XXXVI, fig. 7, and Pl. XXXVII, fig. 6, 8), though the fungus may not always be present throughout the entire length of the blackened bundle area.

JELLY-END ROT

Whenever the inoculation of Netted Gem tubers took effect at the stem end, an infection typical of certain types of jelly-end rot found in the commercial fields was produced. In the moist chamber under laboratory conditions infections at the stem end induced by puncturing the tubers, by spraying with a spore suspension, or by puncture of the stolons with an inoculating needle were fairly typical of the advanced stages of jelly-end rot, being soft and watery. Under field conditions, infections at the stem end induced by spraying the tubers with the spore suspension, by puncturing with an inoculating needle, or by the inoculation of the stolons were in no case as pronounced as the infections found occurring naturally in the field. Those induced by a puncture at the stem end were deeper than those produced by the other methods.

The failure of the inoculations in the field to develop as severe cases of infection as those occurring in nature may be attributed to the late date on which the inoculations were made and to the very dry condition of the soil. Aside from the depth of the infection at the stem end, the stem-end decays induced by artificial inoculation were very similar in appearance to infections found occurring naturally in commercial fields of Netted Gem potatoes. Wherever the attempt was made, *F. radicicola* was recovered from the stem-end infections induced by the inoculations. It is evident, therefore, that *F. radicicola* is capable of producing a jelly-end rot of the potato tuber. However, isolations made from such rotted tubers taken from the field have not always revealed *F. radicicola* to the exclusion of other fungi. *F. oxysporum* is frequently obtained.

Wollenweber[1] reports the isolation of *F. orthoceras* from jelly-end tubers and thought it the probable cause of the disease. The writer has twice isolated *F. trichothecioides* from such tubers fresh from the field.

Artificial infection of the growing tuber with *F. trichothecioides* under western conditions has never been accomplished. Under conditions of high humidity Jamieson and Wollenweber[2] were able to produce an infection in the growing tuber with this fungus, but their results are not believed to be indicative of what actually takes place in nature in the irrigated West. Tubers infected with jelly-end rot, when kept in a moist chamber for a few days, invariably threw out tufts of *F. radicicola* through the lenticels, although from these same tubers with well-advanced stem-end rot other fungi, notably *F. oxysporum*, have been isolated from the interior of the tuber. Carpenter[3] has shown that *F. oxysporum* is capable of producing a similar rot of the potato tuber, and from its frequent occurrence in connection with jelly-end-rot-infected tubers it must be considered as one of the factors involved in producing this type of rot. Other Fusarium species, either independently or in conjunction with *F. radicicola*, may be in part responsible for the disease.

STORAGE EXPERIMENTS

In the fall of 1914 two ordinary 2-bushel sacks filled with Netted Gems infected with jelly-end rot were secured. With a soft blue pencil, a line was drawn around each tuber in such a manner that the blue line separated the decayed from the healthy tissue. The tubers were then sacked and put in storage in the potato cellar of the Jerome Experiment Station, at Jerome, Idaho. Fifty tubers each of Pearls and Idaho Rurals infected with stem-end and lenticel blackrot were secured. On each tuber a blue line was drawn around the stem end at the margin of the infected and healthy tissues. Lenticel infections were marked in the same manner. The marked Pearl and Idaho Rural tubers were then sacked and placed in storage near the similarly treated Netted Gems infected with jelly-end rot.

The storage period was from November 15, 1914, to April 12, 1915. The temperature of the cellar during this period ranged from 32° to 48° F. During the last six weeks of the storage period the minimum temperature was 36°, and for the greater part of this time the temperature approached the maximum of 48°. On April 12 the tubers were removed from the sacks and examined one by one to determine whether the rot had continued to develop. In no case could any perceptible advance in the decay be found. It is apparent that neither jelly-

[1] Wollenweber, H. W. Studies on the Fusarium problem. *In* Phytopathology, v. 3, no. 1, p. 24–50. 1 fig., pl. 5. 1913.

[2] Jamieson, Clara O., and Wollenweber, H. W. An external dry rot of potato tubers caused by Fusarium trichothecioides, Wollenw. *In* Jour. Washington Acad. Sci., v. 2, no. 6, p. 146–152, illus. 1912.

[3] Carpenter, C. W. Op. cit.

end rot nor blackrot makes any progress in storage at a temperature of 48° or under.

This conclusion is further substantiated by results obtained in storing several sacks of blackrot-infected Idaho Rural and Pearl tubers for experimental use in the fall of 1913. Although the infected stock remained in the cellar until the middle of May, 1914, when the cellar temperatures had risen to something over 50° F., the tubers were apparently as sound as at the time they were put in storage. Carpenter [1] has found that when tubers were inoculated with *F. radicicola* and kept at a temperature of 12° C. (approximately 53° F.) no rot developed.

EFFECT OF PLANTING INFECTED SEED

In the spring of 1915 three plots were planted with infected seed potatoes. Plot 1 was planted with Idaho Rural potatoes every seed piece of which showed infection with *F. radicicola*, stem-end blackrot, or lenticel rot. The presence of the fungus was verified by artificial cultures. Plot 2 was planted with Pearl potatoes every seed piece of which was infected with *F. radicicola*, stem-end blackrot, or lenticel rot, the presence of the fungus being verified by artificial cultures. Plot 3 was planted with Netted Gem potatoes infected with jelly-end rot. The seed pieces were cut from the stem end, care being exercised to see that at least one healthy eye was present on each seed piece. Cultures from this seed gave a variety of fungi, including *F. radicicola* and *F. oxysporum*. Check plots were planted with the same varieties. The seed selected for the check plots was entirely free from disease and was disinfected for 1½ hours in a solution of mercuric chlorid (4 ounces of mercuric chlorid to 30 gallons of water). All of the plots were planted on alfalfa land which had never before been planted to potatoes. The soil was a heavy clay loam of lava-ash formation. Irrigation was given on July 4 and 5, July 16, July 31, and August 1. Throughout the season the plots were kept in a good state of tilth, but they suffered somewhat from lack of moisture during the latter part of August. Table III shows the percentage of disease in the harvested product.

TABLE III.—*Percentage of disease in harvested potatoes*

Plot No.	Variety.	Condition of seed.	Percentage of disease in tubers.	
			Vascular infection.	Tuber-rots.
1	Idaho Rural	Infected with blackrot	96	82
2	Pearl	do	44	40
3	Netted Gem	Infected with jelly-end rot	16	0
4	Idaho Rural	Disease-free, disinfected	40	0
5	Pearl	do	14	1
6	Netted Gem	do	10	0

[1] Carpenter, C. W. Op. cit.

The vascular infection present in plots 1 and 2 was all of the heavy black type demonstrated to be caused by *F. radicicola*. Numerous cultures from the vascular systems of tubers from these plots gave the fungus. The percentages of rot include all phases of blackrot, including stem-end, lenticel, and eye infections. Strangely enough, no tuber-rots developed in plot 3. Of the tubers from plot 3, 16 per cent showed vascular infection, of which 14 per cent were of the type usually ascribed to *F. oxysporum* and 2 per cent were of the black type caused by *F. radicicola*. Cultures made from the vascular systems of infected tubers in this plot give *F. oxysporum* in all cases of light-brown discoloration and *F. radicicola* in all cases of black vascular discoloration. In the check plots, 1 per cent of blackrot appeared in plot 5. The others were free from all tuber-rots. The vascular infection present in the check plots was for the most part of the type ascribed to *F. oxysporum*. A few tubers showing blackened vascular bundles were found, and *F. radicicola* was isolated from such tissues whenever the attempt was made.

The results clearly show that seed infected with blackrot will produce infection in the resulting product. From the fact that no jelly-end rot resulted from planting jelly-end-infected seed, the conclusion should not be drawn that such seed can not cause infection in the resulting product, but rather that it requires conditions for its development different from those required for the development of blackrot.

CONTROL OF BLACKROT

Absolute control of blackrot will be difficult. When potatoes are planted on alfalfa or grain lands blackrot is rarely found if the crop has had sufficient water to make good growth conditions possible. Plantings of disease-free seed potatoes on raw desert lands in 1915 gave as high as 11 per cent of tubers infected with blackrot in the harvested product, whereas plantings of disease-free tubers on alfalfa or grain lands were usually free from the disease, although as high as 5 per cent of infected potatoes were found in the harvested product of one plot on alfalfa land. Judging from the results of three years' observations in commercial fields, it is apparent that losses from blackrot can be reduced to a minimum by planting only on land which has been in cultivation for a number of years and by giving the growing crop the proper amount of water, care, and attention. The crop should be kept in a good growing condition until maturity or frost. Jelly-end rot, on the other hand, has been found in fields where all the conditions of growth were apparently ideal. Some adverse condition, however, is probably responsible for its development. Further research upon jelly-end rot and its cause and occurrence is highly desirable.

Both jelly-end rot and blackrot-infected tubers may be stored with safety, provided the storage cellar is fairly well ventilated and the temperature kept below 50° F.

SUMMARY

(1) *Fusarium radicicola* Wollenw. is the cause of a field blackrot of potato tubers in southern Idaho. The disease is confined principally to potatoes of the round type, such as Idaho Rural and Pearl.

(2) *F. radicicola* is capable of causing a jelly-end rot of potatoes similar to the jelly-end rot of the Burbank group found in southern Idaho, but under actual field conditions other factors are apparently in part responsible.

(3) Neither blackrot nor jelly-end rot makes any progress in storage at or below a temperature of 50° F.

(4) Seed pieces infected with blackrot will bring about infection in the following crop.

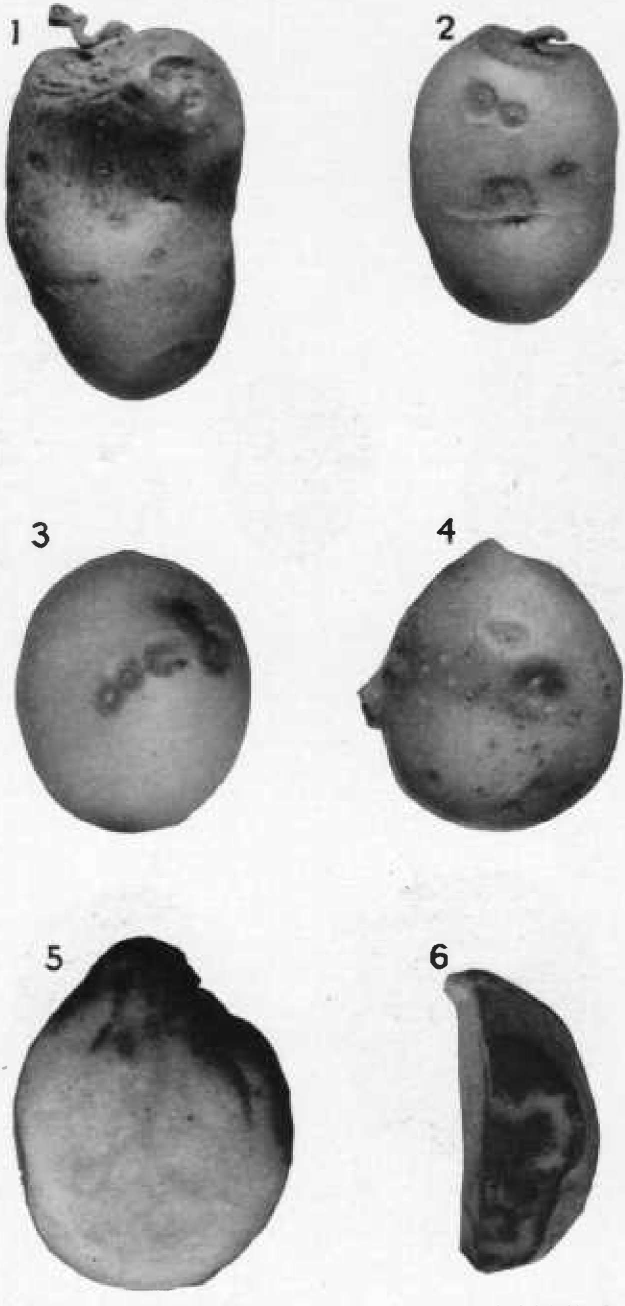
(5) *F. radicicola* is apparently well distributed throughout the desert soils.

(6) Blackrot may be controlled fairly well by planting potatoes only on lands which have been in other crops for a number of years and by providing good conditions for growth.

PLATE XXXIV

Fig. 1, 2, 3, 4.—Types of stem-end blackrot, lenticel rot, and eye rot in Idaho Rural potato tubers. Field material.

Fig. 5, 6.—Longitudinal and cross sections of an Idaho Rural tuber infected with blackrot. Note the blackened vascular system. Field material.



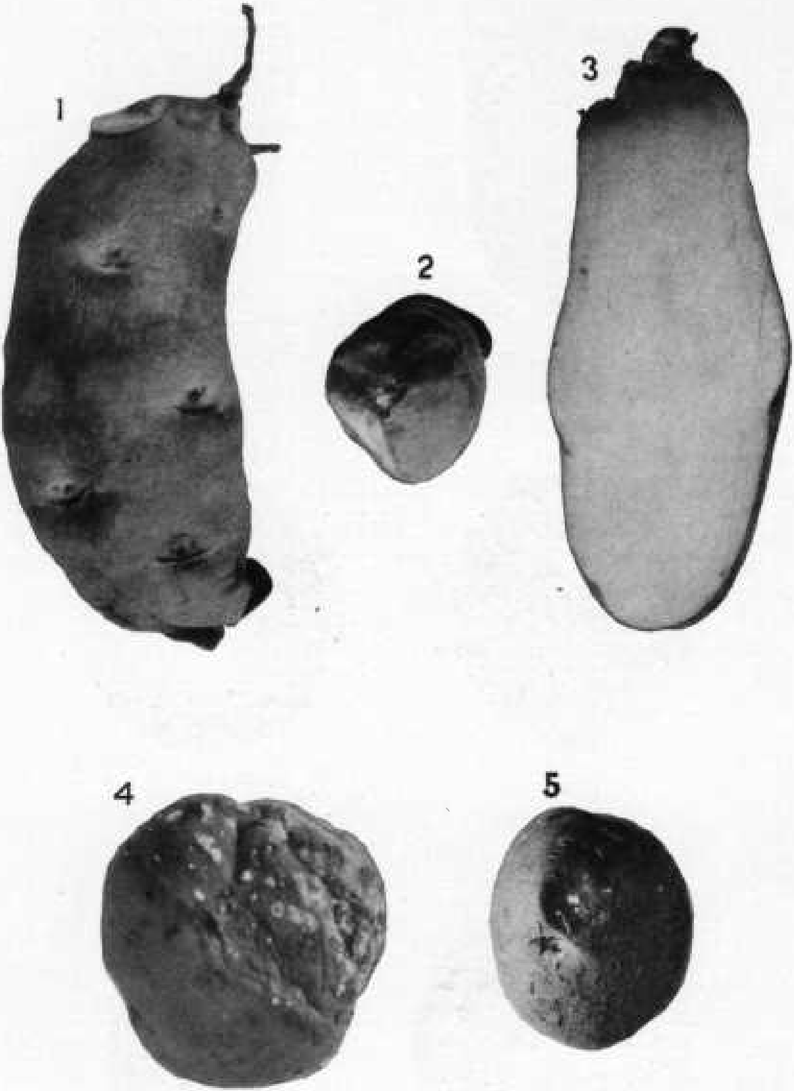

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PLATE XXXV

Fig. 1.—Netted Gem potato tuber infected with jelly-end rot. A soft bud-end infection may also be seen. Field material.

Fig. 2.—Stem-end view of a Netted Gem tuber infected with jelly-end rot. Field material.

Fig. 3.—Longitudinal section of a Netted Gem tuber infected with jelly-end rot. Field material.

Fig. 4.—Idaho Rural tuber infected with stem-end and lenticel blackrot, after having been kept 10 days in a moist chamber. Tufts of *Fusarium radicicola* have appeared. Field material.

Fig. 5.—Idaho Rural tuber infected with lenticel blackrot after having been kept in a moist chamber for 10 days. A single tuft of *F. radicicola* has appeared. Field material.

PLATE XXXVI

Fig. 1, 2.—Stem-end blackrot produced by stem-end punctures with a needle carrying *Fusarium radicicola*. Netted Gem and Idaho Rural potato tubers. Laboratory inoculations.

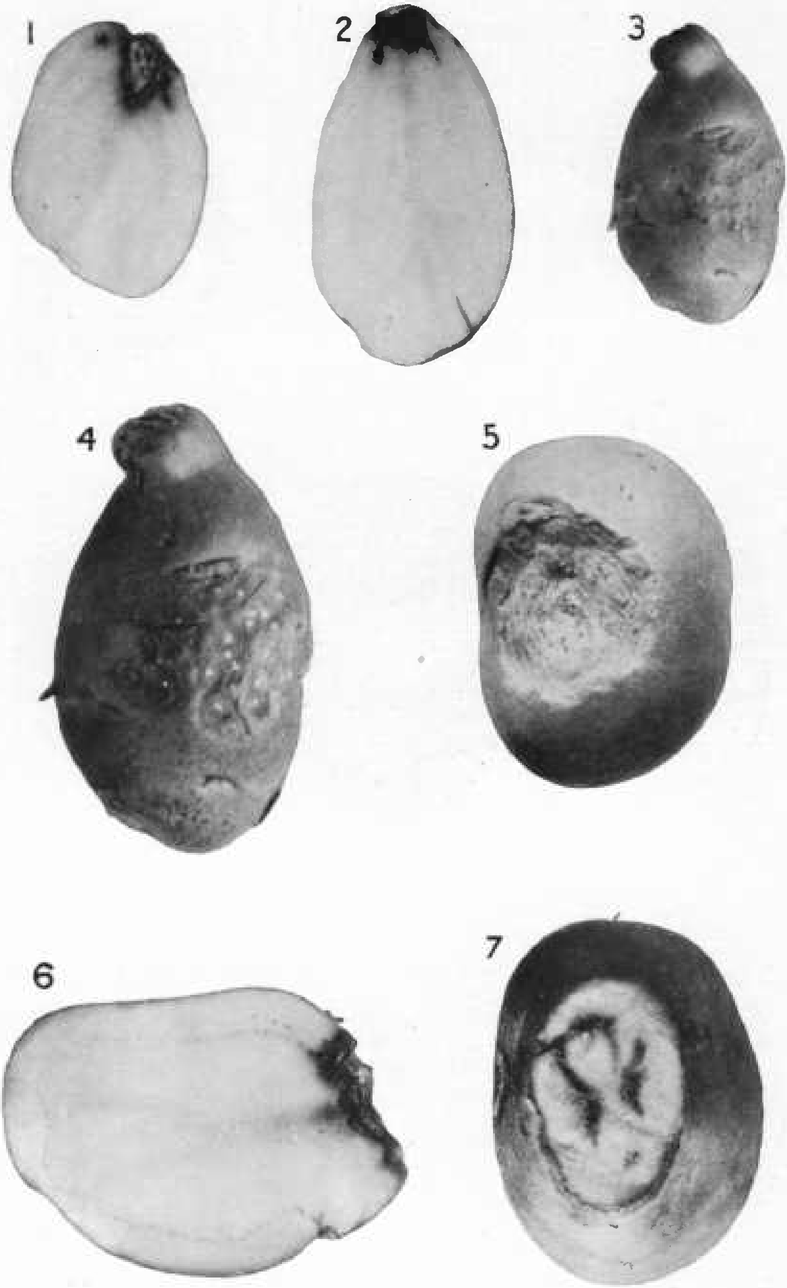
Fig. 3.—Lenticel blackrot produced by spraying the tuber with a spore suspension of *F. radicicola*. Netted Gem tuber. Laboratory inoculation.

Fig. 4.—Same tuber as shown in figure 3; after having been kept a few days longer in the moist chamber. Note the tufts of *F. radicicola* that have appeared.

Fig. 5.—Stem-end blackrot produced by spraying an Idaho Rural tuber with a spore suspension of *F. radicicola*. Laboratory inoculation.

Fig. 6.—Stem-end blackrot produced by the inoculation of the tuber stolon. Idaho Rural tuber. Laboratory inoculation.

Fig. 7.—Blackened vascular system produced by the inoculation of the tuber stolon. Idaho Rural tuber. Laboratory inoculation.



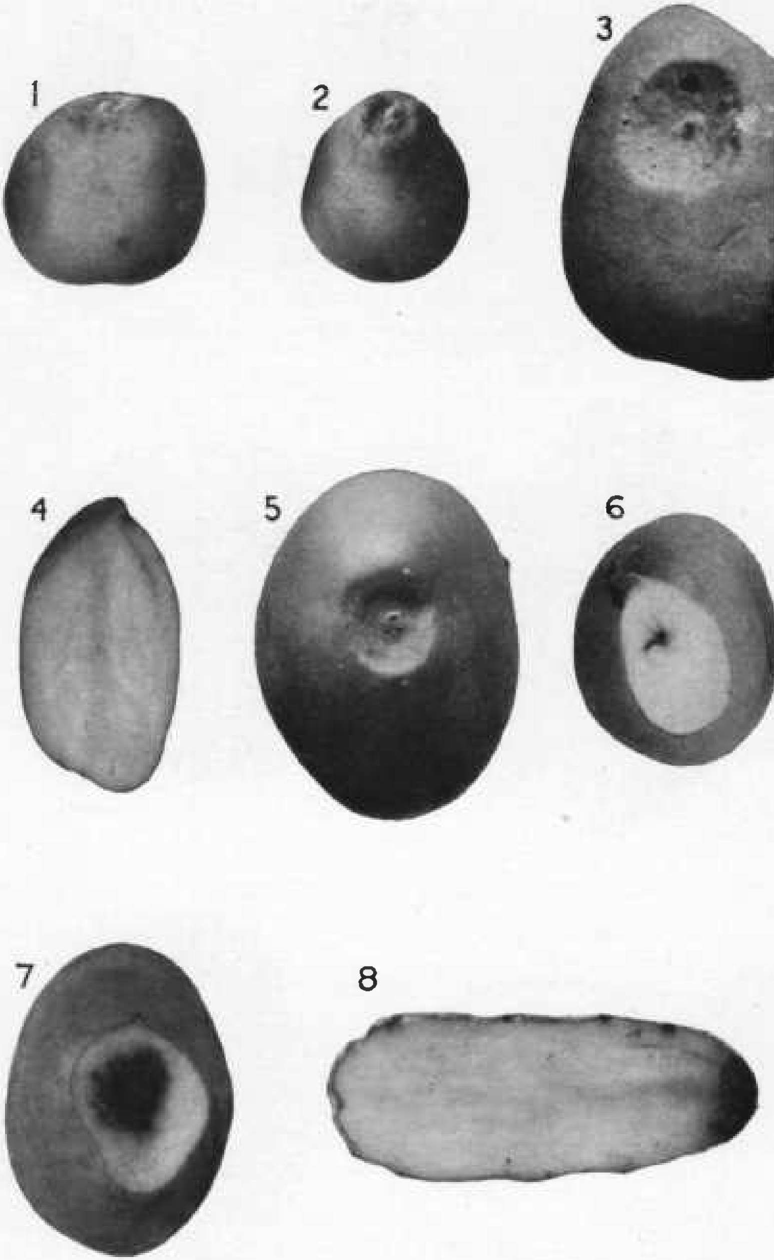

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PLATE XXXVII

Fig. 1, 2, 3.—Stem-end and lenticel blackrot produced by spraying the growing tubers with a spore suspension of *Fusarium radicicola*. Idaho Rural potato tubers. Field inoculations.

Fig. 4.—Eye infection produced by spraying the growing tuber with a spore suspension of *F. radicicola*. Netted Gem tuber. Field inoculation.

Fig. 5, 6, 7.—Stem-end blackrot produced by the inoculation of the stolons of growing Idaho Rural tuber. Field inoculation.

Fig. 8.—Stem-end rot of Netted Gem tuber produced by inoculating the stolon of the growing tuber.

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