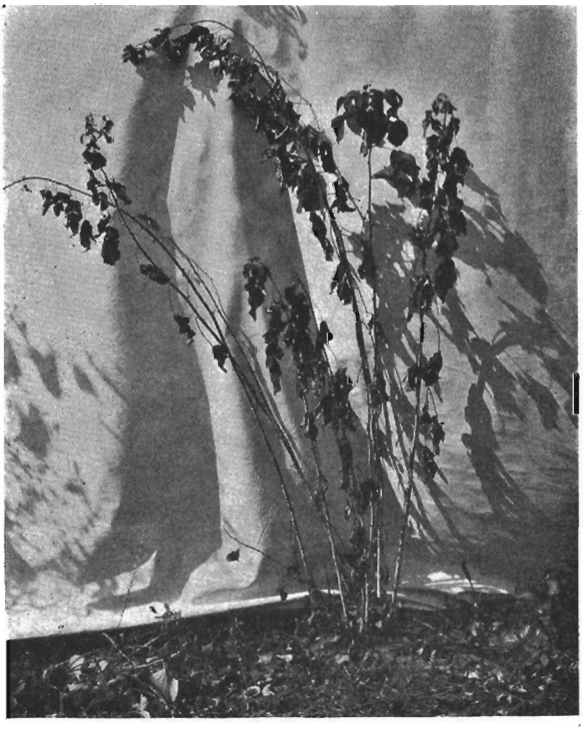
STATION BULLETIN 344 JUNE 1936

Verticillium Wilt of Cane Fruits

S. M. ZELLER



Agricultural Experiment Station
Oregon State Agricultural College
CORVALLIS

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Illustration on cover—

Figure 1. Typical symptoms of a black raspberry plant affected with verticillium wilt.

SUMMARY

1. Verticillium wilt of brambles is an important disease in Western Oregon. It doubtless has been the primary factor in causing certain districts to discontinue the growing of black raspberries, and is the chief factor limiting the yields of black raspberries to about one-third of their theoretical amounts. In severe cases where black raspberries have followed a potato or similarly susceptible crop, 50 per cent or more of the plants have been infected. It is perhaps safe to say that there are few, if any, black raspberry plantings in Western Oregon that are not in some degree infected.

2. SYMPTOMS—The disease may be recognized by the general wilting of the plant in late stages, but in earlier stages the lower leaves of the canes yellow and drop prematurely. The entire plant is somewhat stunted, or bluish stripes or ribbons of infected tissue may extend up the canes from the ground. See text for detailed description.

3. Infection usually takes place through the small roots and thus remains in the soil following an infected crop. The more common crops and weeds that may be regarded as carriers are potatoes, tomatoes, eggplant, pigweed, and groundsel or Old-man-of-spring. In nurseries maples and barberry have been found infected.

4. Experimental work was planned and carried out so as to study (a) the behavior of the verticillium wilt in inoculated plantings of black raspberry, and (b) to determine the influence of crop rotations of various lengths on the amount of verticillium infection to be expected from infected soil.

There were two plantings, one continuing for three years and one for four years. Equal numbers of the Cumberland, Munger, and Plum Farmer varieties were used, uninoculated and inoculated with strains of *Verticillium albo-atrum* from black raspberry canes and from potato tubers.

5. To inoculate a plant an ample culture of Verticillium growing on sweet clover stems was placed in the soil at planting time so that the roots of the tip plant were in contact with the fungus.

6. Determination of infection was accomplished by cultures from discolored wood. Of the total inoculated plants, 55.1 per cent were infected when one year old; 31.1 per cent when two years old; 12.4 per cent when three years old; and 1.4 per cent when four years old. Of the 1877 inoculated plants, 86.5 per cent were infected sometime during the experiment, while 52.3 per cent of the check plants became infected. Two thirds of the infection in the check rows took place, however, in the third year. No check plants were infected at the end of the first year after planting, but at the end of the second year, 6.7 per cent of the checks and 54.8 per cent of the inoculated plants were infected. Of the infected plants, 1.8 per cent recovered.

7. There were 37.3 per cent of inoculated and 10.3 per cent of check plants killed by Verticillium.

8. Out of a possible 723 plants, only 274, or 37.9 per cent, attained four years of age.

9. The percentages of infection by Verticillium correlate well with the minimum temperatures and the number of days each winter having temperatures below freezing.

10. Low temperatures and continuous cold weather seem also to increase the number of plants killed by Verticillium.

11. Verticillium from black raspberry infected 64.3 per cent of inoculated black raspberry plants while 60.2 per cent were infected by wilt from potato.

12. METHOD OF SPREAD—Verticillium spreads from one plant to another in the row. When planted 30 inches apart, 8.3 per cent of the plants as far as fourth from inoculated plants became infected in the third year. This shows the possibility that infection may travel 10 feet from plant to plant in three years. In the second year, 6.7 per cent were infected at 9-foot distances without intervening plants.

13. SUSCEPTIBILITY—All varieties of black and purple raspberries tested were found susceptible to verticillium wilt, although some of them live for several years after infection.

14. The Cuthbert red raspberry was found to be very resistant, while considerable infection was observed in the Ranere, Chief, Herbert, Red Antwerp, Latham, and Sunbeam. The Lloyd George, although not tested experimentally, is known to be susceptible to the Oregon strain of Verticillium.

15. Among varieties of blackberries, some infection was noted in the Cory Thornless, Kittatinny, Logan, Lucretia, Mammouth, Phenomenal, Snyder, and Stuart. The Evergreen, Himalaya, Lawton, and wild Northwestern Trailing (*Rubus macropetalus*) seem to show high resistance.

16. Some of the Asiatic varieties show very high resistance to Verticillium and others, although somewhat infected, continue growing vigorously.

17. Roguing to eliminate field infection should not be practiced except where infection is below at least 5 per cent; then indications are that productive longevity of the planting is increased.

18. Tests on the viability of *Verticillium albo-atrum* on raspberry canes in the soil show the fungus to live over from one fall (October 25, 1927) to the next (October 30, 1928) but not to continue much longer (February 25, 1929) on dead plant tissues.

19. Crop rotation trials indicate that three- or four-year rotations with two to three non-susceptible intervening crops, between infected raspberries and raspberries again on the same soil, were effective in eliminating the fungus from the soil.

20. SUGGESTIONS FOR CONTROL—There are three suggestions for the control of verticillium wilt; namely:

a. Rogue infected plants to eliminate spread of wilt where the disease is less than about 5 per cent.
b. Rotate crops to rid the soil of wilt contamination.
c. Use planting stock from nurseries or other plantings that are free of wilt.

Verticillium Wilt on Cane Fruits

By

S. M. ZELLER,
Plant Pathologist

INTRODUCTION

VERTICILLIUM WILT has been severe in northwestern districts wherever there has been an extensive production of black raspberries. By 1910 a flourishing black raspberry industry in the Puyallup Valley of Western Washington had been practically discontinued. In the Newberg-Springbrook district, Yamhill County, Oregon, where until about ten years ago black raspberries were the one leading cane fruit, there are practically none grown now as a result of this disease. Damage by this disease and the small returns from black raspberry plantings under Western Oregon conditions were the primary reasons for an investigation of the disease in commercial and experimental fields.

The disease has been intensively studied in many crops such as the potato,[1] okra, cherry, apricot, etc. The general history and literature pertaining to the disease in various other crop plants are treated adequately, however, by Rudolph[2] and van der Meer.[3] Although there have been scattered notes concerning this disease and its effect on raspberry and various types of blackberry, no intensive study of the trouble on Rubus has been reported. Lawrence[4] gave a few field notes concerning the disease in the Puyallup Valley but directed most of his attention to a study of the causal organism. In 1925, Harris[5] described the disease on several English varieties of red raspberry (*Rubus idaeus*). The following year Berkeley and Jackson[6] described a very closely related (or the same) disease of American red raspberry varieties (*Rubus strigosus*) growing in the Niagara-Ontario district.

Rudolph,[2] however, has ably covered the more recent literature concerning this disease and its effect on Rubus.

LOSSES DUE TO THE DISEASE

To show the destruction of the disease in the Springbrook district of Yamhill County reference will be made to a case cited by the writer in 1925.[8] One acre of 3-year old Plum Farmer black raspberries on land planted the previous year to potatoes had about 52 per cent of the plants dead or dying during the late fall of 1923. The Munger variety on the same

[1]McKay, M. B. Further Studies of Potato Wilt Caused by Verticillium *albo-atrum*. Journ. Agr. Res. 32:437-470. illus. 1936.

[2]Rudolph, B. A. Verticillium *hadromycosis*. Hilgardia 5:197-353. 1931.

[3]van der Meer, J. H. H. Verticillium Wilt of Herbaceous and Woody Plants. Med. Landbouwhoogesch (Wageningen) 28:1-82. illus. 1925.

[4]Lawrence, W. H. Bluestem of the Black Raspberry. Wash. Agr. Exp. Station Bul. 108. 1-30. illus. 1912.

[5]Harris, Ralph V. The Blue Stripe Wilt of the Raspberry. East Malling Res. Sta. (Kent), Ann. Rept. 1924:126-133. illus. 1925.

[6]Berkeley, G .H. and A. B. Jackson. Verticillium Wilt of the Red Raspberry. Sci. Agr. 6: 261-270. illus. 1926.

[7]Zeller, S. M. A Case of Verticillium Wilt of Black Raspberries in Oregon. Phytopathology 15: 125-126. 1925.

soil, not planted previously to potatoes, was doing well after five years. Cultures of a strain of *Verticillium albo-atrum* were obtained from 49 out of 51 of the affected Plum Farmer plants.

In the same district three acres of potatoes that had been severely infected with verticillium wilt were followed by black raspberries. These proved a total loss during their first year. Many similar cases have been observed where black raspberries have followed potatoes or other susceptible crops. There are probably few, if any, plantings of black caps in Western Oregon that are not somewhat infected.

SYMPTOMS OF THE DISEASE

In black raspberries. The appearance of the disease above ground in black raspberries may vary according to the distribution of infection in the roots. In case the infection is throughout the root system involving many of the secondary and tertiary rootlets, there is accordingly a general dwarfing of the entire plant accompanied by pale, yellowish, irregular areas appearing between the principal veins of the leaves. Usually these symptoms occur on the lower leaves early in the summer, spreading farther up the plant later in the season. Occasional diagnosis is difficult in such cases except by comparison with a healthy plant. The canes also do not make the usual growth.

In cases where infection is localized in one-, two-, or three-lateral primary roots, it is the usual experience to find canes on the same side of the plant showing discoloration. This discoloration in extreme cases is of an intense purplish or bluish-black involving either the whole cane from the collar or merely appearing as a dark longitudinal band or ribbon on one side of the cane. On canes of the current season's growth the infected area shows a strong contrast to the healthy green tissue. Superficial evidence of the disease spreads upward in the canes at variable rates of 2⅛ to 8⅝ inches per day, according to controlling factors of temperature and moisture. The affected wood beneath the discolored surface also becomes discolored probably due to byproducts of the infested wood and causal fungus which invades the pith and sap-conducting vessels of the wood.

Another very common type of verticillium infection takes place through small secondary roots produced directly from the main crown of the plant. In such cases very definite and characteristic verticillium symptoms are produced above the surface of the ground. The entire crown soon becomes involved, and the plant may die out during the season. Usually, however, the central part of the plant dies but the fungus seemingly does not readily progress downward in the primary lateral roots. The latter, therefore, frequently remain alive and each produces a small raspberry plant from an adventitious bud. This results in many weak canes appearing around the old dead crown.

It is not unusual during the winter to find aerial infection taking place through pruning cuts or broken canes. In such cases only the extreme top of the main cane is infected including usually one or more laterials.

In red raspberries. Experience with verticillium wilt in varieties of red raspberries has been extremely limited in Oregon except in experiments

where the varieties have been inoculated. The common commercial red variety, Cuthbert, is seldom affected. The very susceptible varieties, Lloyd George and Ranere (St. Regis), have not come into common use in the state.

Harris[1] has described fully the verticillium-wilt disease of the Lloyd George variety in England. The disease is frequent in the limited plantings of this variety in Oregon, and doubtless will be one of the limiting factors in its production. Harris used the term "blue stripe wilt" to designate the disease in this variety because of the tendency of the disease to produce the longitudinal blue bands of infection in the canes.

In the Lloyd George the leaf symptoms are characteristic under Oregon conditions, producing a beautiful "calico" effect of yellow leaf tissue between the green veins. The lower leaves are affected first and in serious cases, the leaves of the entire plant may be involved. In many cases the infection may be entirely under the ground, no "blue stripes" appearing on the canes. Fruiting canes thus affected may die before maturity or usually will yield small tasteless fruit. In the Ranere the symptoms are much the same, except that under Oregon conditions the disease progresses more rapidly and the canes usually "purple" and wilt early. Frequently in this variety the new canes wilt before they reach 12 or 15 inches in height.

In the red raspberry more than in the black raspberry varieties characteristic superficial discoloration of the canes may not be continuous at various heights. Examination of sections of such canes at various levels, however, reveals that the fungus *is* continuous from the crown, sometimes through the pith only, and sometimes in the pith and adjacent wood but not producing visible superficial symptoms except where near the surface of the cane.

In blackberries. In blackberries the symptoms are not sufficiently different from those described for raspberries to justify repetition of the discussion.

SOURCES OF INFECTION

So many different kinds of plants are susceptible to the disease that it would be difficult to determine the source of soil infection for all cases. In Oregon, however, it is noted that black raspberries are not profitable following potatoes. The two common weeds, pigweed and groundsel or Old-man-of-spring, frequently are found infected and have been proved to be carry-over agencies in contaminated soils. Tomatoes and eggplants are commonly infected crops. Several species of maples and barberry in nurseries have been found to sustain heavy losses. Any of these and many other susceptible plants, therefore, may be considered common sources of infection in cultivated land.

CAUSAL ORGANISM

The strains of the organism used in the experimental work were isolated from potato and black raspberry. The former was the same as that used by McKay.[1] The Verticillium from the two hosts was considered

[1]Loc. cit.

to be specifically identical since they agree in morphological characters. Sclerotia were present in all isolations and were maintained during repeated transfers on sweet clover stems. Saltations without sclerotia were sometimes noted when cultures were transferred to potato-dextrose agar. The same type of organism has been isolated from the following additional hosts in Oregon.

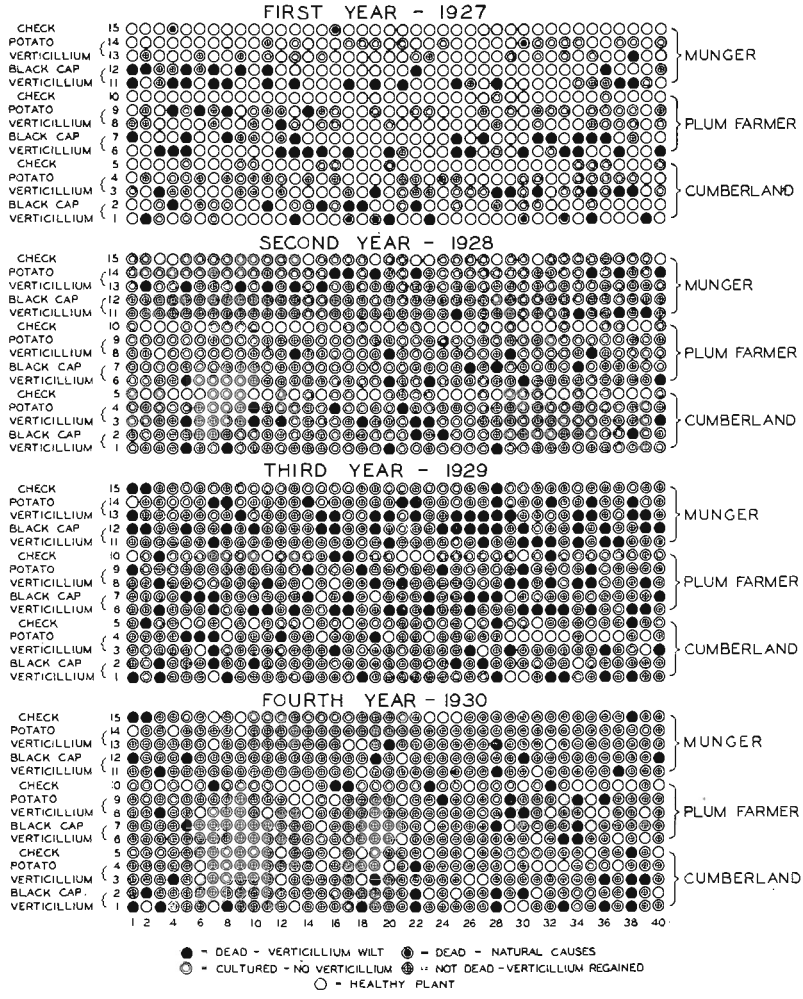

Figure 2. Plan of the 1927-planting of 15 rows, 40 plants each, of the black raspberries, Cumberland, Munger, and Plum Farmer, as indicated. The condition of each plant at the end of each of 4 years is indicated by symbols. There are five rows of each variety, including one check or uninoculated row, two rows inoculated with Verticilliunt from black raspberry and two rows inoculated with the same from potato.

Barberry (*Berberis thunbergii*), blackberry, including the Mammoth, Snyder, and nursery stock of the youngberry; eggplant; ginseng; maple (several species of nursery stock); Michaelmas dairy (*Aster sp.*); red raspberry, including Lloyd George and Ranere (as well as several recoveries of inoculation reported elsewhere in this bulletin); tomato; and three weeds, the common white field daisy (*Chrysanthemum leucanthe-*

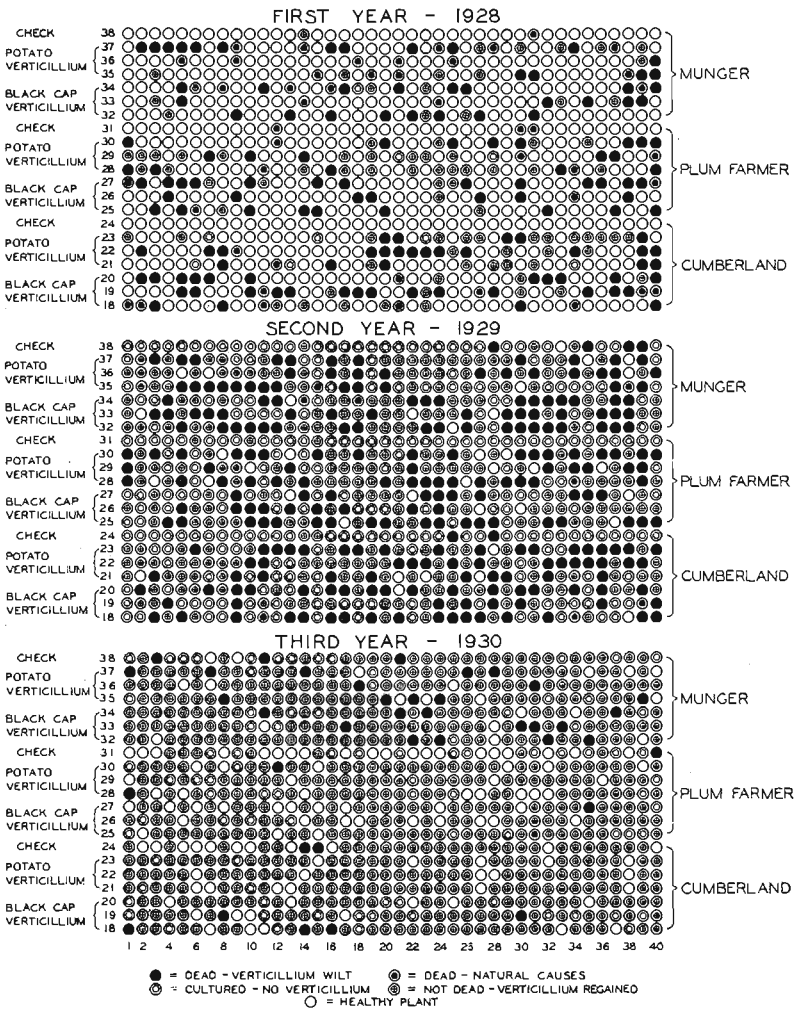

Figure 3. Plan of the 1928-planting of 21 rows, 40 plants each, of the black raspberries, Cumberland, Munger, and Plum Farmer, as indicated. The condition of each plant at the end of each of 3 years is indicated by symbols. There are seven rows of each variety, including one check or uninoculated row, three rows inoculated with Verticillium from black raspberry and three rows inoculated with the same from potato.

mum), groundsel or Old-man-of-spring (*Senecio vulgaris*) and pigweed (*Amaranthus sp.*).

The fungus has been considered as being identical with the potato wilt organism described by Reinke and Berthold as *Verticillium albo-atrum*. Several variations have been observed which doubtless are within reasonable varietal limits of the species.

PLAN OF EXPERIMENTAL WORK

The experimental work included (1) a study of the behavior of the verticillium wilt disease in inoculated plantings of black raspberry, (2) the testing of the possible elimination of the fungus from such inoculated soil by crop rotation.

EXPERIMENTAL PLANTINGS

Plan of planting. There were two plots each of the three commercially important Oregon-grown black raspberries—Cumberland, Munger, and Plum Farmer. The plants were set 9 feet apart in rows of 9-foot spacing. In one plot planted in March, 1927, there were five rows each of the three varieties, 40 plants to the row.

One row was an uninoculated check, two were inoculated with Verticillium isolated from potato tubers, and two rows were inoculated with Verticillium isolated from black raspberry canes.

These 15 rows were supplemented in March, 1928, by 21 rows of 40 plants each. In this planting there were seven rows each of the three varieties, one uninoculated check row, three inoculated with Verticillium from potato, and three with Verticillium from black raspberry. All of the plants were grubbed out in 1931, allowing 4-year records on the first plot and 3-year records on the 1928 planting.

A separate record sheet was kept for each plant throughout its life of 1 to 4 years. Data presented includes records on 1-, 2-, 3-, and 4-year-old plants. When a plant died during its first year, it was classed as a 1-year-old plant, and so on through the series. When a plant died from any cause, it was replaced by another young tip the following spring. Replants in inoculated rows were reinoculated at time of replanting. In the 36 rows of 40 plants each, therefore, there were records on a total of 2,139 plants instead of the original 1,440. In other words, there were 699 replants during the 4-year experiment.

Method of inoculation. A quantity of pure culture of *Verticillium albo-atrum* was grown on sweet clover stems in quart jars. The sweet clover stems were gathered in late summer while green and dried. For use as a culture medium they were cut into about 2 to 2.5 inch lengths and sterilized in jars or tubes containing enough water to allow a little free water after sterilization. The young rooted blackraspberry tips were planted directly upon a liberal inoculum of Verticillium growing on sweet clover stems so that the roots came in contact with the fungous culture.

Determination of infection. Infected plants usually could not be diagnosed prior to the first winter or late fall after planting, and therefore the month of February was the arbitrary annual period chosen to examine each

plant thoroughly for any evidence of infection. Cultures were attempted in duplicate (usually in March) from canes of dead plants, and living plants that showed discolored wood to any extent. Experience showed that if there were no abnormal symptoms during the summer and no discolored wood above ground during the following February, the plant could be counted as healthy for that year.

Isolation from infected tissues. If the verticillium organism was not recovered in culture from totally dead plants, they were recorded as "dead from natural cause," which may have been from any cause except verticillium wilt, although Verticillium may have contributed to the death of some of these plants. Verticillium has been found to be more readily isolated from the margins of infected areas than from totally dead wood. Most of the 65 plants that died from "other causes" succumbed during the first summer after planting. The spring of 1928 was especially dry for successful planting. There were no root borers nor weevils found in the experimental plots during the four years, except a few borers when the 4-year old plants were grubbed out.

Content of cultures. Although *Verticillium albo-atrum* was the organism usually reisolated from inoculated black raspberry canes, there were many other secondary fungi occasionally obtained in the cultures. Among these were:

> *Acrostalagmus cinnabarinus* and *Fusarium* spp. when cultures were from the crown or low down in the canes; *Ascospora rubi* (Westend.) Zeller, *Cylindrocarpon didyma* (Hart.) Wr., *C. obtusispora* (Cke. & Harkn.) Wr., *Didymella applanata* (Niessl) Sacc., *Graphium eumorphum* Sacc., *Leptosphaeria coniothyrium* Sacc., *Pestalozzia truncata* Lev. var. *Rubi* Karst., and *Pezizella Lythri* (Desm.) Shear & Dodge (*Hainesia*) from the canes. Of these *Pestalozzia* and *Ascospora* were more frequent except *Verticillium.*

RESULTS OF INOCULATION

The data from the three- and four-year plots are presented for the most part in Table 1. Field observations that cannot be presented in tabular form will be included in a discussion of the results.

The various types of verticillium infection that were observed have been presented under the discussion of symptoms. The general stunting of inoculated plants was outstanding, especially in the second year of both plantings. At that time few plants in the uninoculated check rows were infected; in fact, there were but 16 plants out of 240 or 6.7 per cent of the uninoculated checks that showed any infection. The general contrast between the growth of check rows and the stunting and lack of vigor of the inoculated rows was very marked, 657 plants out of 1,200 inoculated plants becoming infected.

According to the method used by the Agricultural Experiment Station many of the inoculated plants not infected were noticeably stunted in comparison to healthy plants of the uninoculated checks. There were 223 inoculated plants that showed no visible infection but 70 per cent of these (156 plants) were noticeably stunted or lacking in vigor. In the checks such stunting became more apparent during the third and fourth years. At the

Table 1. GENERAL DATA ACCUMULATED DURING PERIOD 1927-31 FROM EXPERIMENTAL PLOTS OF BLACK RASPBERRIES INOCULATED WITH VERTICILLIUM FROM RASPBERRY STEMS AND POTATO TUBERS

Row number	Total number of plants		Plants not infected				1-year-old plants	2-year-old plants	3-year-old plants	4-year-old plants	Number of plants infected								Total plants infected	
			Robust		Stunted						First year		Second year		Third year		Fourth year			
	Inoculated	Checks	Inoculated	Checks	Inoculated	Checks					Inoculated	Checks	Inoculated	Checks	Inoculated	Checks	Inoculated	Checks	Inoculated	Checks
1	62	....	2	....	7	....	22	6	13	21	26	....	16	....	10	....	1	....	53	....
2	54	....	2	....	2	....	12	5	10	27	21	....	14	....	14	....	1	....	50	....
3	61	....	1	....	3	....	15	14	11	21	34	....	9	....	11	....	3	....	57	....
4	48	....	5	....	5	....	5	6	5	32	17	....	7	....	11	....	3	....	38	....
5	....	43	....	3	....	11	3	0	3	37	....	3	....	1	....	17	....	8	....	29
6	79	....	3	....	1	....	41	8	17	13	52	....	10	....	12	....	1	....	75	....
7	61	....	1	....	2	....	21	5	14	21	35	....	6	....	16	....	1	....	58	....
8	55	....	4	....	2	....	13	6	9	27	18	....	11	....	18	....	2	....	49	....
9	50	....	2	....	6	....	10	1	8	31	18	....	7	....	16	....	1	....	42	....
10	....	44	....	9	....	22	4	0	4	36	....	3	....	0	....	7	....	1	....	11
11	67	....	1	....	1	....	27	5	17	18	42	....	19	....	4	....	0	....	65	....
12	66	....	0	....	1	....	26	4	18	18	38	....	19	....	7	....	1	....	65	....
13	63	....	0	....	2	....	19	11	13	20	28	....	18	....	11	....	4	....	61	....
14	57	....	1	....	4	....	12	12	8	25	17	....	14	....	17	....	4	....	52	....
15	....	45	....	1	....	15	5	0	5	35	....	3	....	2	....	19	....	5	....	29
18	68	....	2	....	12	....	33	18	17	....	31	....	20	....	3	....	....	....	54	....
19	68	....	1	....	19	....	33	18	17	....	29	....	17	....	2	....	....	....	48	....
20	69	....	2	....	9	....	33	21	15	....	38	....	19	....	1	....	....	....	58	....
21	56	....	3	....	5	....	17	14	25	....	25	....	18	....	5	....	....	....	48	....
22	69	....	2	....	1	....	34	18	17	....	44	....	18	....	4	....	....	....	66	....
23	64	....	3	....	5	....	26	20	18	....	39	....	14	....	3	....	....	....	56	....
24	....	42	....	1	....	10	2	2	38	....	....	2	....	4	....	25	....	....	....	31
25	69	....	2	....	8	....	35	17	17	....	35	....	23	....	1	....	....	....	59	....
26	56	....	5	....	9	....	17	15	24	....	13	....	26	....	3	....	....	....	42	....
27	64	....	2	....	11	....	27	20	17	....	29	....	20	....	2	....	....	....	51	....
28	64	....	6	....	10	....	26	20	18	....	28	....	19	....	1	....	....	....	48	....
29	56	....	4	....	8	....	17	14	25	....	23	....	16	....	5	....	....	....	44	....
30	67	....	5	....	5	....	32	17	18	....	32	....	20	....	5	....	....	....	57	....
31	....	43	....	0	....	35	3	3	37	....	....	0	....	4	....	4	....	....	....	8
32	67	....	0	....	4	....	30	21	16	....	38	....	24	....	1	....	....	....	63	....
33	63	....	3	....	4	....	24	21	18	....	30	....	22	....	4	....	....	....	56	....
34	67	....	4	....	9	....	30	21	16	....	33	....	16	....	5	....	....	....	54	....
35	63	....	2	....	10	....	26	17	20	....	25	....	21	....	5	....	....	....	51	....
36	57	....	2	....	7	....	19	13	25	....	17	....	29	....	2	....	....	....	48	....
37	67	....	3	....	8	....	33	15	19	....	40	....	13	....	3	....	....	....	56	....
38	....	45	....	4	....	12	5	5	35	....	....	5	....	5	....	19	....	....	....	29
Totals	1,877	262	73	18	178	105	737	413	607	382	895	16	505	16	202	91	22	14	1,624	137

Table 1. GENERAL DATA ACCUMULATED DURING PERIOD 1927-31 FROM EXPERIMENTAL PLOTS OF BLACK RASPBERRIES INOCULATED WITH VERTICILLIUM FROM RASPBERRY STEMS AND POTATO TUBERS—*Continued*

Row number	Plants recovering		Plants killed by Verticillium								Plants dying of natural causes		Plants infected each year							
			1-year-old plants		2-year-old plants		3-year-old plants		4-year-old plants				1927-28		1928-29		1929-30		1930-31	
	Inoculated	Checks	Inoculated	Checks	Inoculated	Checks	Inoculated	Checks	Inoculated	Checks	Inoculated	Checks	Inoculated	Checks	Inoculated	Checks	Inoculated	Checks	Inoculated	Checks
1	2	....	17	....	4	....	6	....	1	....	4	....	6	....	22	....	15	....	10	....
2	2	....	7	....	4	....	5	....	4	....	0	....	8	....	20	....	17	....	3	....
3	2	....	10	....	8	....	6	....	2	....	0	....	16	....	16	....	16	....	7	....
4	3	....	0	....	3	....	5	....	1	....	0	....	11	....	8	....	14	....	7	....
5	....	0	....	0	....	0	....	3	....	0	....	1	....	0	....	1	....	16	....	11
6	2	....	24	....	6	....	11	....	0	....	0	....	17	....	26	....	17	....	15	....
7	0	....	16	....	5	....	6	....	0	....	0	....	15	....	15	....	19	....	10	....
8	3	....	5	....	4	....	8	....	0	....	0	....	7	....	12	....	20	....	8	....
9	3	....	5	....	1	....	5	....	3	....	0	....	13	....	6	....	18	....	5	....
10	....	0	....	0	....	0	....	4	....	2	....	3	....	0	....	0	....	7	....	4
11	1	....	19	....	3	....	7	....	1	....	0	....	18	....	32	....	7	....	9	....
12	0	....	13	....	4	....	14	....	0	....	0	....	12	....	27	....	7	....	19	....
13	2	....	5	....	7	....	13	....	0	....	0	....	5	....	19	....	16	....	20	....
14	0	....	2	....	7	....	7	....	0	....	1	....	1	....	13	....	24	....	13	....
15	....	0	....	2	....	0	....	3	....	1	....	2	....	0	....	1	....	20	....	8
18	1	....	9	....	15	....	0	....	....	....	7	....	....	....	9	....	20	....	25	....
19	0	....	17	....	6	....	1	....	....	....	6	....	....	....	18	....	16	....	14	....
20	0	....	15	....	13	....	0	....	....	....	1	....	....	....	14	....	30	....	14	....
21	1	....	6	....	9	....	0	....	....	....	1	....	....	....	10	....	24	....	16	....
22	3	....	18	....	9	....	0	....	....	....	1	....	....	....	17	....	32	....	16	....
23	1	....	7	....	16	....	0	....	....	....	1	....	....	....	25	....	14	....	19	....
24	....	0	....	0	....	2	....	2	....	....	....	0	....	....	....	0	....	4	....	26
25	0	....	15	....	13	....	0	....	....	....	1	....	....	....	11	....	31	....	16	....
26	0	....	8	....	8	....	0	....	....	....	1	....	....	....	8	....	25	....	10	....
27	0	....	16	....	8	....	0	....	....	....	2	....	....	....	17	....	20	....	15	....
28	1	....	7	....	15	....	0	....	....	....	3	....	....	....	17	....	21	....	10	....
29	0	....	6	....	8	....	0	....	....	....	2	....	....	....	15	....	18	....	12	....
30	0	....	13	....	14	....	0	....	....	....	1	....	....	....	12	....	27	....	19	....
31	....	0	....	0	....	0	....	1	....	....	....	3	....	....	....	0	....	3	....	5
32	0	....	13	....	17	....	1	....	....	....	0	....	....	....	11	....	32	....	20	....
33	0	....	9	....	15	....	1	....	....	....	2	....	....	....	10	....	27	....	21	....
34	0	....	13	....	12	....	0	....	....	....	5	....	....	....	11	....	26	....	17	....
35	1	....	8	....	12	....	2	....	....	....	6	....	....	....	8	....	20	....	22	....
36	0	....	5	....	9	....	0	....	....	....	5	....	....	....	2	....	33	....	13	....
37	0	....	17	....	7	....	3	....	....	....	5	....	....	....	16	....	25	....	14	....
38	....	0	....	0	....	4	....	3	....	....	....	1	....	....	....	0	....	7	....	23
Totals	29	0	325	2	262	6	101	16	12	3	55	10	129	0	449	2	630	57	419	77

end of the experiment 106 out of 121 plants (87.6 per cent) showed this stunting or lack of vigor. This will be mentioned later under SPREAD OF THE DISEASE FROM PLANT TO PLANT IN ROW.

Of the total of 1,877 inoculated plants, 1,624 or 86.5 per cent became infected with Verticillium, 895 or 55.1 per cent when one year old; 505 or 31.1 per cent when two years old; 202 or 12.4 per cent when three years old; and 22 or 1.4 per cent when 4 years old.

There were 137 or 52.3 per cent of the 262 uninoculated checks that became infected.

The infection in the check rows, however, was much delayed, two-thirds of it taking place the third year after planting. This perhaps was aided by the intermingling of roots of the inoculated plants with those of the check plants and may have been partly the result of cross cultivation.

Out of the 1,624 infections resulting from inoculations, 29 or 1.8 per cent recovered practically normal vigor and showed no indication of infection at the close of the experiment.

There were 700 or 37.3 per cent inoculated; and 27 or 10.3 per cent check plants killed by Verticillium. From a possible 723 plants only 274 or 37.9 per cent attained four years of age.

RELATION OF INFECTION AND DEATH TO LOW TEMPERATURES

There was a high peak of infection the second year in both plots, after which there was a slight decline. The respective percentages of infection for the 1927 and 1928 plantings were as follows:

	1927	*1928*	*1929*	*1930*
1927	26.9	45.0	39.6	26.3
1928	.....	32.4	61.1	58.2

Perhaps the higher percentage of infection in the latter was influenced by initial vigor contingent upon the unfavorable dry conditions for planting in the spring of 1928. The total percentages of infection for the two plots for the first, second, third, and fourth years after planting were 30.2, 54.7, 24.4, and 26.3 per cent, respectively. This latter observation, however, means little due to the fact that temperatures were so distinctly different each of the four winters. The percentages of infection, however, seem to correlate well with the minimum temperatures and the number of days each winter having temperatures below freezing (Figure 4).

During the winter of 1927-28, there were four days in December when the temperature went below freezing, reaching a minimum of 19° F. In January there were seven days below freezing with a minimum of 20° F., and seven days in February with 24° F. as a minimum. The next winter was a little more severe, there being 15 days below freezing, and the temperature ranged as low as 18° F. in January, and 16° F. in February. There were 13 days below freezing during February.

During the winter of 1929-30, there were the lowest temperatures and the most continuous cold weather of the four years. In November, 1929, there were four days when the temperature went below freezing and reached a minimum of 25° F.; in December, two days with a low of 26° F.; January, the most severe, with 25 days below freezing with a minimum of 2° F. It was during this winter that a marked increase of infection was apparent over that for the other years.

The winter of 1930-31 was very mild. There were eight days below freezing in November, January and March each having three such days. The minimum temperature of 24° F. was in December. The plants showing infection after the winter of 1929-30 held over the infection to the following year, making impossible any correlation between infection and low temperatures during 1930-31.

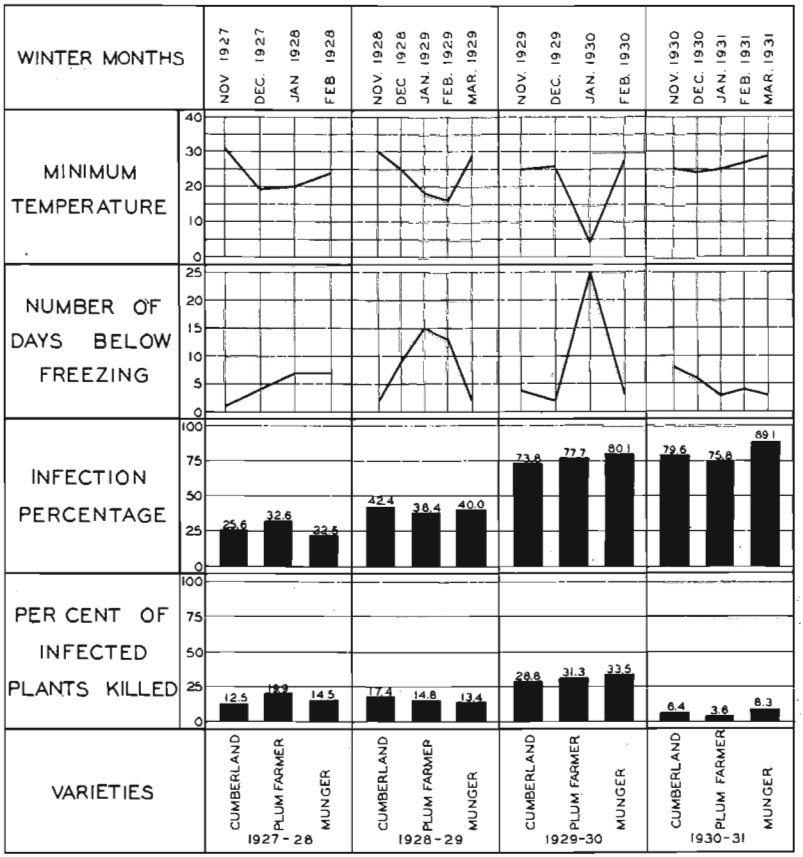

Figure 4. Graphic summary of minimum temperatures and number of days below 32° F. during the winter months of 1927-31 correlated with percentage of infection and infected plants killed by Verticillium.

Table 2. PERCENTAGE OF PLANTS INFECTED AND KILLED BY VERTICILLIUM EACH WINTER FROM 1927 TO 1931, AS INDICATED BY CULTURES MADE ANNUALLY IN THE MONTH OF MARCH, 1928 TO 1931.

Variety	1927-28			1928-29				1929-30				1930-31			
	Number of plants	Plants infected or killed		Number of plants	Plants infected or killed			Number of plants	Plants infected or killed			Number of plants	Plants infected or killed		
		Plants	*Per cent*		*Plants*	*Per cent*	*Per cent*		*Plants*	*Per cent*	*Per cent*		*Plants*	*Per cent*	*Per cent*
Plants infected															
Cumberland	160	41	25.6	160	84	52.5	.....	160	123	76.9	.....	160	130	81.3	.....
	.....	.....	.....	240	86	35.8	42.5	240	172	71.7	73.8	240	188	78.3	79.5
Plum Farmer	160	52	32.5	160	75	46.9	.....	160	136	85.0	.....	160	126	78.8	.....
	.....	.....	.....	240	79	32.9	38.5	240	175	72.9	77.8	240	177	73.7	75.8
Munger	160	36	22.5	160	104	65.0	.....	160	140	87.5	.....	160	149	93.1	.....
	.....	.....	.....	240	56	23.3	40.0	240	182	75.8	80.5	240	207	86.2	89.0
Totals	480	129	26.9	1,200	484	.....	40.3	1,200	928	.....	77.3	1,200	977	.....	81.4
Plants killed															
Cumberland	160	20	12.5	160	17	10.6	.....	160	27	16.9	.....	160	21	13.1	.....
	.....	.....	.....	240	52	21.7	17.3	240	84	35.0	27.8	240	5	2.1	6.5
Plum Farmer	160	32	20.0	160	12	7.5	.....	160	44	35.0	.....	160	12	7.5	.....
	.....	.....	.....	240	47	19.6	14.8	240	81	23.5	31.3	240	3	1.2	3.8
Munger	160	23	14.4	240	17	10.6	.....	160	51	31.9	.....	160	10	6.3	.....
	.....	.....	.....	.....	37	15.4	13.5	240	83	34.5	33.5	240	24	10.0	8.5
Totals	480	75	15.6	1,200	182	.....	15.2	1,200	370	.....	30.8	1,200	75	.....	6.25

Low temperatures and continuous cold weather seem to increase the number of plants killed by Verticillium, leading to the conclusion that infected plants are more susceptible to winter injury than normal plants. Figure 4 suggests a correlation between killing of verticillium-infected plants and temperatures ranging below 20° F. When temperatures ranged below 10° F. there was a marked increase both of infection and death of plants. The infection increment may have been related to the age of the plants, but the record for 1930-31 indicates that the death of plants was not related to the age factor.

BLACK RASPBERRY AND POTATO VERTICILLIUM INFECTIVITY

The strain of Verticillium from black raspberry stems was slightly more infective to black raspberry than that isolated from potato tubers. Over the entire period of the experiments reported in this bulletin, 60.2 per cent of the black raspberry plants inoculated with Verticillium from potato became infected, compared with 64.3 per cent of those inoculated with Verticillium from black raspberry stems.

During the same period there was a mortality of 14.2 per cent of the plants inoculated with the potato fungus and 19.5 per cent of those inoculated with the black raspberry fungus. These differences are slight when considering possible experimental error under field conditions where perennial plants are used.

SPREAD OF DISEASE FROM PLANT TO PLANT IN THE ROW

In the experimental plantings the plants were set on a 9-foot square. This spacing was greater than in commercial plantings so as to prevent the possibility of too much transfer of the disease from plant to plant. The uninoculated check rows of plants gave an opportunity to observe the facility with which the disease spreads from plant to plant when nine feet apart.

Table 3. SHOWING INFECTION SPREAD FROM PLANT TO PLANT BY VERTICILLIUM ALBO-ATRUM WHERE BLACK RASPBERRY PLANTS ARE SET AT DISTANCES OF 18 AND 30 INCHES IN THE ROW. Data taken at the end of one, two, and three years.

Distance of infection spread in the row from inoculated plant	Percentages of black raspberry plants infected by *Verticillium albo-atrum*		
	First year	Second year	Third year
Inches			
18	84.6	96.7	100.0
30	68.2	100.0	100.0
36	11.5	75.0	93.3
54	7.7	42.9	83.3
60	4.5	45.5	79.2
72	0.0	10.7	43.3
90	0.0	9.1	37.5
*108	0.0	6.7	40.4
120	0.0	0.0	8.3

*The uninoculated check plants in the two regular plots were nine feet from the inoculated plants.

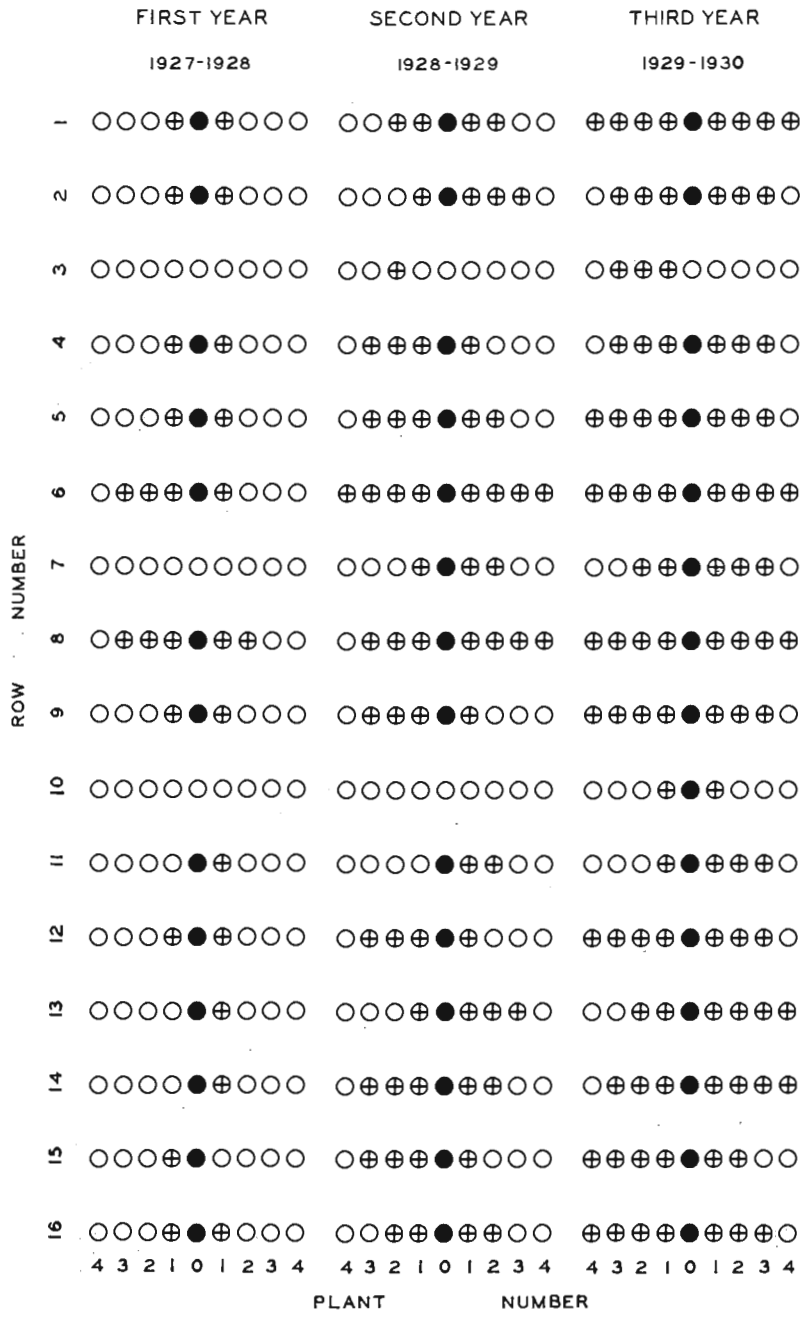

Figure 5. Graphic representation of a 3-year experiment showing the spread of Verticillium from plant to plant in a black raspberry planting where the plants were 18 inches apart in the row. The solid black circles (●) indicate inoculated plants, circles with the plus sign (⊕) indicate infected plants, and clear circles (O) indicate healthy plants.

Rate of spread. At the end of the first year, no check plants showed infection. At the end of the second year, 6.7 per cent of the check plants were infected; 40.4 per cent the third; and 59.6 per cent the fourth. By the third year many other plants in these rows also showed stunting and lack of vigor even though infection could not be proved.

In a row of black raspberry plants of the Plum Farmer variety set 18 inches apart, every ninth plant was inoculated with *Verticillium albo-atrum* isolated from black raspberry canes, leaving eight uninoculated plants in the row on each side of an inoculated plant. Sixteen such plants were inoculated. In a row of plants set 30 inches apart, the same arrangement was followed, 12 plants being inoculated.

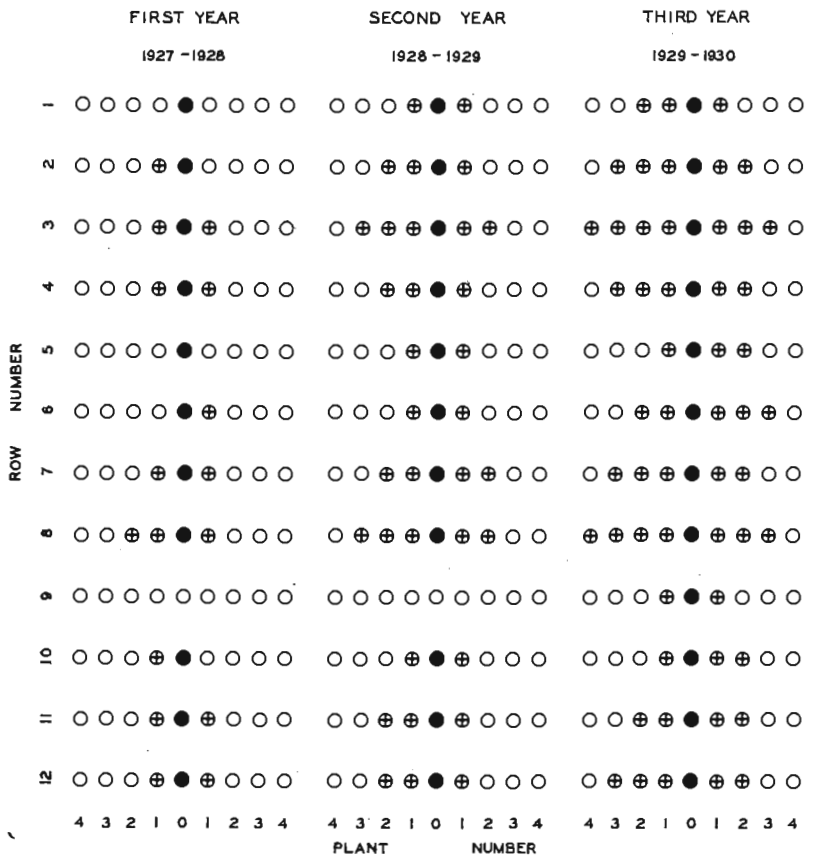

Figure 6. Graphic representation of a 3-year experiment showing the spread of Verticillium from plant to plant in a black raspberry planting where the plants were 30 inches apart in the row. The solid black circles (●) indicate inoculated plants, circles with plus sign (⊕) indicate infected plants, and clear circles (O) indicate healthy plants.

The plan of planting followed was patterned somewhat after that discussed by McKay[1] where potatoes were planted "at regular intervals of 15 inches in the row." McKay has presented a fine discussion of the spread of this disease in an annual crop and the State College experiments were conducted to learn whether the spread of the disease in a perennial crop would be comparable. Figures 5 and 6 present the results of these two trials for spread of the disease from plant to plant. During the first year the disease infection was in 84.6 per cent of the plants that were 18 inches from inoculated plants; 68.2 per cent at 30 inches; 11.5 per cent at 36 inches; and 4.5 per cent set 60 inches from the inoculated plants.

At the end of the second year all of these percentages had increased. Additional infections of 10.7 and 9.1 per cent were noted in plants set 90 and 120 inches respectively from the originally inoculated plants. At the end of the third year all of the percentages had increased, where possible, over those of the second year. These results concerning spread of infection from plant to plant through the soil are comparable to the infection of the uninoculated check rows that were nine feet (108 inches) from inoculated plants.

Value of roguing. This feature of the experimental work bears directly on the probable control of the disease by the elimination of infected plants in commercial plantings having a rather low percentage of disease. Growers who have consistently rogued out all black raspberry plants showing any yellowing, stunting, or wilting, claim they prolong the fruitful life of their acreages. The results of these experiments indicate that this condition quite obviously is true. Plants could be spaced so closely together that roguing would be impractical, but doubtless this is not the case in a great majority of commercial plantings. (See ROGUING TO ELIMINATE INFECTION, page 22.)

SUSCEPTIBILITY OF VARIETIES

Field observations and results of inoculation indicate that practically all commercial varieties of black raspberry (*Rubus occidentalis*) are subject to verticillium wilt. Most purple cane varieties, which are crosses of black and red raspberries, seem to possess the susceptibility factor of the black parent. Most of the red varieties are more resistant to Verticillium than the black raspberries. There are, however, several red varieties, such as Ranere (St. Regis), Chief, Herbert, Latham, and Sunbeam, which according to inoculation tests prove to be susceptible in the order named. In Table 4 are presented the results of inoculations on several varieties and species of Rubus.

Cuthbert highly resistant. Owing to the fact that Cuthbert is the leading commercial canning variety in Oregon it was given more attention than other red varieties. With 84 inoculations in this variety no cases of infection were apparent. The Cuthbert evidently is highly resistant but reports of its infection by other strains or isolations of Verticillium in California indicate that it is not entirely immune.

Another indication of the high resistance of the Cuthbert to Verticillium in the Willamette Valley was noted in 1931. A grower in 1928 had planted the Cuthbert on land where black raspberries following potatoes

[1]Loc. cit. (see pp. 440-444)

had failed almost completely in one year due to verticillium infection. Upon first observation this Cuthbert planting had many volunteers of the black raspberries. Nine rows through the middle of the patch were staked off for careful observation. In this area there were 1,980 Cuthbert plants and 121 volunteer black raspberries. By culturing out the fungus, 97 or 80.2 per cent of the 121 black raspberry plants proved to be infected. There were 67 Cuthbert plants in the area that did not appear entirely healthly but one would not suspect more than three of these to have verticillium infections. All of the 67 were cultured, however, and only the three proved to be infected, 0.15 per cent of the 1,980 Cuthbert plants in the entire planting.

Black raspberry varieties susceptible. Even though the black raspberries and purple canes are highly susceptible to infection, they persist for several years. Among the purple canes the Potomac, U.S.D.A. No. 231,

Table 4. VARIETIES AND SPECIES OF RUBUS INOCULATED IN THE YEARS 1927, 1928, AND 1929 WITH VERTICILLIUM ALBO-ATRUM ISOLATED FROM BLACK RASPBERRY CANES.
The records below are totals of the inoculations for the three years and their results.

Variety or species of Rubus	Total plants inoculated	Total plants showing infection	Percentage infection
Red raspberries			
Cayuga	18	0	0.0
Chief	30	7	23.3
Cuthbert	84	0	0.0
Herbert	9	2	22.2
Latham	30	5	16.6
Marlboro	9	1	11.1
Ohta	9	0	0.0
Owasco	18	0	0.0
Ranere (St. Regis)*	36	34	94.4
Red Antwerp	9	2	22.2
Seneca	18	0	0.0
Sunbeam	9	1	11.1
Purple canes			
Potomac	18	10	55.6
Webster	9	3	33.3
U. S. D. A. No. 231	18	8	44.4
U. S. D. A. No. 326	18	11	61.1
Black raspberries			
Western Wild (*Rubus leucodermis*)	12	7	58.3
Winfield	12	12	100.0
Blackberries			
Cory Thornless	9	1	11.1
Evergreen (*Rubus laciniatus*)	30	0	0.0
Himalaya	18	0	0.0
Kittatinny	30	1	3.3
Lawton	9	0	0.0
Logan	18	1	5.6
Lucretia	12	2	16.6
Mammouth	9	1	11.1
Northern trailing wild (*Rubus macropetalus*)	9	0	0.0
Phenomenal	9	1	11.1
Snyder	9	2	22.2
Stuart	9	1	11.1
Miscellaneous			
Golden Queen	12	1	8.3
Salmon berry (*Rubus spectabilis*)	10	0	0.0
Thimble berry (*R. parviflorus*)	10	0	0.0

*Thirteen of these plants died the first year after inoculation.

U.S.D.A. No. 326, and the black variety, Winfield, have been under observation for six years. Although during this period most of the plants were infected they maintained a nominal fruitage. Usually black raspberry crops in western Oregon are extremely meagre, limited to one or two thousand-pound yields per acre. Undoubtedly these low yields are due as much to verticillium wilt as to any one other cause, including insect pests.

The western wild black raspberry (*Rubus leucodermis*) is rather hardy and persists even though quite susceptible to Verticillium. Plants that were infected have been watched for six years and each has persisted but during certain seasons the yield has been practically nil. Under cultivation, the plants are extremely vigorous but gradually weaken after becoming infected by Verticillium.

Some blackberries immune. Among the blackberries used commercially in Oregon the Evergreen (*Rubus laciniatus*) and Himalaya seem to be immune to verticillium wilt while Loganberry and Mammoth are comparatively resistant.

The Youngberry and Lloyd George red raspberry were not available for observation during the years when other varieties were tested for susceptibility to verticillium wilt. The *Youngberry is susceptible when young* and has been reported as rather susceptible in California. Wilt has not proved to be a limiting factor in production for commercial plantings of the Youngberry in Oregon. More recently the *Lloyd George variety* of red raspberry has been found to be *very susceptible* and in some small plantings in Oregon the disease has taken a toll of 2- and 3-year-old plants. Roguing in some cases has greatly aided in wilt control.

Hybrids of Asiastics studied. Eighteen distinct hybrids of Asiastic species of Rubus have been under observation for seven years. They represent the *Coreanus*, *Lasiostylus*, and *Triflorus* types. Although many of these hybrids have proved by culture isolations of the fungus to be infected with Verticillium, the plants maintain an extraordinary vigor and remarkable resistance to the disease. Many of the infections remain localized to lateral branches low on the canes or to short discolored bands on the main canes.

CONTROL

The control of verticillium wilt consists mainly in prevention of infection in the future planting rather than effecting a cure in the established planting. Since the fungus is root- or soil-borne, there are but three practicable preventive measures to suggest, (1) roguing out diseased plants, (2) rotating crops, and (3) securing planting stock from clean soil.

ROGUING TO ELIMINATE FIELD INFECTION

When it is realized that Verticillium does spread commonly from plant to plant in the row as shown experimentally, it is natural to suppose the removal of affected plants as soon as they are observed will aid in the prevention of such spread. No experiments were conducted to test the feasibility of roguing black raspberries for wilt control, but grow-

ers who have consistently practiced roguing are of the opinion that longevity of commercial production is greatly increased by this practice.

McKay[1] found in potatoes that the spread of verticillium wilt might even be increased rather than decreased by roguing only the infected plants. He says: "It seems reasonable to suppose that where diseased plants are rogued, the roots of adjoining plants would grow more freely into the area formerly occupied by the diseased plant, and since in roguing diseased plants, many Verticillium-invaded roots would be broken off and left in the ground, the chances of spread might be increased."

He found, however, that when a diseased plant and the one on either side of it in the row were rogued out (the three-plant method of roguing) practical results were obtained. The three-plant method of roguing was suggested for all potatoes grown for seed purposes. Surely roguing of black raspberries or other brambles would be impracticable in land thoroughly infected with the disease, owing to the fact that they would be following such infected crops as potatoes, tomatoes, etc. Rotation of crops is the only practical method of eliminating wilt in such cases.

CROP ROTATION

Fungus viable in dead tissues for short period. *Verticillium albo-atrum* will not remain viable much longer than one year on dead plant tissues in the soil. Ten-inch sections of infected canes of black raspberry were buried at a depth of six inches in sandy loam soil exposed to natural outdoor conditions (October 25, 1927). When they were examined in February and May, 1928, and cultures made from the discolored tissues, Verticillium was obtained in every case in February and 12 out of 15 cultures in May returned Verticillium. On October 30, 1928, 15 of the buried canes were cultured and Verticillium was obtained from six of them. By February 25, 1929, cultures showed the Verticillium to have entirely died out. These results could have been expected because of the experience of McKay who used old potato stalks, and also from the fact that Verticillium does not persist for long in dead woody tissues of infected cherry trees.[2]

This would indicate that on land kept in clean cultivated summer fallow for two seasons all Verticillium would die out, providing living roots of susceptible weeds and crops are not allowed to grow.

Experimental rotation. A series of field plots was planned on land where inoculated black raspberry plants were grubbed out in the spring of 1931 (page 10). Trials were conducted on these plots to determine the results that could be expected in eliminating this disease by crop rotations of different length.

The field of about four acres was divided into plots, each of which accommodated 240 black raspberry plants set on a 9-foot square. The Plum Farmer variety was used throughout these rotation trials. In March, 1931, plot No. 1 was planted to black raspberries and plot No. 2 to potatoes. The balance of the land was left to summer fallow and then planted to a cover crop of vetch and oats in the fall of 1931. Plots No. 2 and 3 were planted to black raspberries in 1932 and the balance of the land to barley which was

[1]McKay, M. B. Loc. cit.

[2]van der Meer, J. H. H. Verticillium wilt of herbaceous and woody plants. Med. Landbouwhoogesch. (Wageningen) 28: 1-82. 1925. (See pp. 40 and 43.)

plowed under as a green manure crop. Plot No. 4 was planted to black raspberries in 1933 and the balance of the land left to summer fallow. Plot No. 5 was planted to black raspberries in 1934. The plan of rotation is presented in Figure 7.

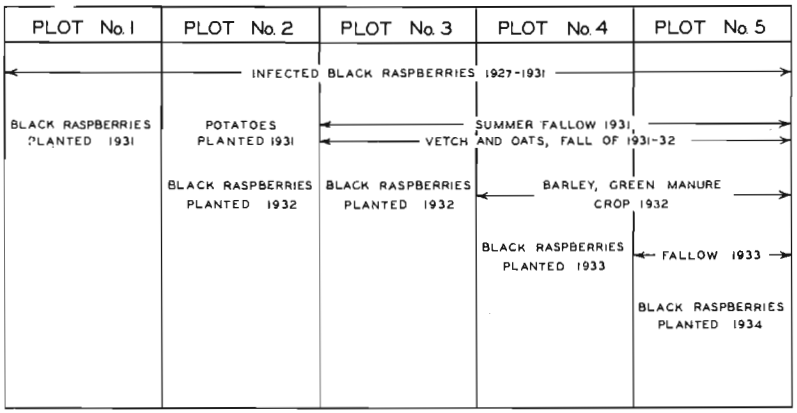

Figure 7. Diagram showing the sequence of crop rotation following infected black raspberries.

Results of experiment. Plot No. 1, black raspberries following infected black raspberries, gave 37.9 per cent infection at the end of the first year and 49 per cent at the end of the second year. Plot No. 2, potatoes following infected black raspberries, proved to be an almost worthless potato crop. The next year black raspberries following the potatoes were 33 per cent infected. Where oats and vetch was the one-year intervening crop (Plot No. 3) there was 21 per cent infection the first year and 34 per cent the second year.

The three-year rotation (Plot No. 4) gave satisfactory control with 2.5 per cent of the plants infected, demonstrating that two intervening crops between infected raspberries and the next successful planting of raspberries is necessary.

Table 5. RESULTS OBTAINED FROM EXPERIMENT TO DETERMINE THE INFLUENCE OF ROTATION OF CROPS OF DIFFERENT LENGTH ON THE PERCENTAGE OF VERTICILLIUM INFECTION THROUGH THE SOIL; 1931-35, CORVALLIS, OREGON.

Length of rotation	Plot number	Year infected black raspberries were grubbed from contaminated soil	Year test black raspberries were planted	Plants infected by *Verticillium albo-atrum*			
				1932	1933	1934	1935
Years				*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	1	1931	1931	37.9	49.0	.....	.....
2[1]	2	1931	1932	.....	33.0	.....	.....
2[2]	3	1931	1932	.....	21.0	34.0	.....
3[3]	4	1931	1933	.....	.....	2.5	2.6
4[4]	5	1931	1934	.....	.....	.....	1.03

[1]The first 2-year rotation was potatoes—black raspberries.
[2]The second 2-year rotation was oats and vetch—black raspberries.
[3]The 3-year rotation was oats and vetch, barley—black raspberries.
[4]The 4-year rotation was oats and vetch, barley, fallow—black raspberries.

The four-year rotation (Plot No. 5) shows results within experimental error of Plot No. 4 and furnishes an additional illustration of the effectiveness of two or more intervening crops in the rotation to avoid infection from the soil.

Results of the rotation are shown in tabular form in Table 5.

CLEAN PLANTING STOCK

At times black raspberry plantings are found where rather high percentages of wilt noticeable the first year after planting cannot be explained on the basis of previously infected crops in that particular land. In such cases there is no explanation for this infection except that the planting stock carried infection from the field where it was grown. It is recommended, therefore, that to avoid this source of contamination the grower be sure of the source of planting stock for his prospective planting.

To be relatively certain that black raspberry planting stock is *free of wilt* it would be necessary to know that (1) the land where it had been grown had had at least two non-susceptible crops previous to the raspberries, and that (2) the mother plants had maintained vigorous growth for at least two years.

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