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CRANBERRY DISEASE INVESTIGATIONS ON THE PACIFIC COAST

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INTRODUCTION

Although the diseases of the cultivated cranberry (*Vaccinium macrocarpon*) have been studied rather intensively since 1901, most of the work prior to 1922 was done in New Jersey, Massachusetts, and Wisconsin. This bulletin summarizes the results of a four-year study of cranberry diseases in the States of Oregon and Washington. The climate of the Pacific coast region is so different from that of the older cranberry-growing sections that important modifications in cultural practices have been found necessary. Since cultural methods have a very important relation to the pathological problems considered in this work, it seems essential to outline briefly the general methods at present followed in this region, with particular reference to the points in which these methods differ from those of the older cranberry sections.

GENERAL CONSIDERATIONS

Cranberry growing on the Pacific coast is a comparatively recent industry, its extensive development having been started in 1912 to 1915 (*4*).[1] The problem of determining the most successful varieties

[1] The serial numbers (*italic*) in parentheses refer to "Literature cited," p. 28.

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and sometimes distorted in shape. The hypertrophied zone may extend several centimeters along the stem, but the latter often continues its normal growth beyond the lesion. The disappearance of red stem lesions later in the season, consistently followed by the appearance of black stem spot in the same vines, leads to the belief that the fungus causing the latter disease often invades the red spots and produces its fruiting bodies in the same lesions. Much more frequently the black-spot fungus gains entrance through the red spots on the leaves and proceeds to attack the stem, through the petiole, without the appearance of any symptoms of reddening and swelling associated with Exobasidium In this case the stem lesions are black from the beginning, and immature perithecia appear early. The infected leaves are entirely killed, shrivel rapidly, and drop off easily, a result that Exobasidium apparently does not cause when acting alone. The minute immature perithecia are frequently borne on the petioles of infected leaves and have occasionally been found on leaves. Ascospores are produced the following spring.

The latter type of infection is the rule in severe attacks of the disease. The first indication is always an epidemic of red leaf spot. If weather conditions continue favorable for any length of time the leaves are completely killed by the invasion of the black-spot organism and turn brown in a manner similar to severe fireworm injury. Close observation at this time will show numerous black stem lesions, usually centering around leaf scars, on both runners and uprights. The lesions generally encircle the stem entirely, though they may be confined to the side on which infection occurred. In severe cases most of the uprights may be killed by the black-spot fungus.

Control.—Red leaf spot and black stem spot are very dependent upon weather conditions. The disease may appear during a period of rainy or misty and cloudy weather at any time after vine growth has started. It is more severe in shaded portions of a bog and in sheltered places where air drainage is poor. The disease is rarely severe in large plantings of producing vines and consequently rarely warrants control measures other than cutting back the surrounding brush and trees to give better air drainage and light. That it may be controlled by Bordeaux mixture was demonstrated on the Fieselman bog, at Columbia Beach, Oreg., in 1923. A portion of this bog was so severely attacked late in July that all the uprights were killed. Beginning about the 1st of August, several applications of 3–3–50 Bordeaux mixture were made at frequent intervals. New uprights which grew from below the old dead ones were kept free from the disease and matured normal fruit buds the same season.

ROSE-BLOOM

Rose-bloom, caused by *Exobasidium oxycocci* Rost., is occasionally found in Washington and Oregon. Shear (*6*, *8*) has noted that this fungus is erratic in making its appearance in all the regions where it occurs. The disease was fairly prevalent in 1922, but could scarcely be found in any of the other three years of these observations. It apparently causes no appreciable injury in this section, since the bog most severely affected in 1922 yielded a crop of berries larger than the average of producing bogs that year, and the crop was also good the following year. The disease appears soon after the vines start growing. "The axillary leaf buds, which usually remain dormant, are attacked by the disease and produce short shoots with rather close, enlarged, swollen, and distorted leaves which are pink or light rose colored" (*6*). No particular control measures have been found necessary, although it is possible that the systematic spraying with Bordeaux mixture practiced within recent years may be partly responsible for its rarity.

FALSE-BLOSSOM

The false-blossom disease of the cranberry (*7, 14*) is present to some extent in practically all Pacific coast bogs planted with Wisconsin vines and has been found on the Bennett Jumbo, Searls, and Prolific varieties. The writer has not found it on any Cape Cod or New Jersey varieties, even when the latter were planted adjacent to affected Wisconsin vines. The form of disease usually met with here is the characteristic witches'-broom growth with flowers upright and dark red in color, receptacle enlarged and petals dwarfed, but no proliferation of floral organs. Berries frequently mature on affected plants, though they are dwarfed in size. Careful observation disclosed no evidence that the disease spreads under the conditions prevailing on the Pacific coast.

False-blossom is demanding a great deal of attention in eastern cranberry districts, and evidence is accumulating that the disease is infectious. The behavior of the disease on the Pacific coast is therefore of unusual interest. Several newly planted bogs of the Bennett Jumbo variety came under the observation of the writer and an opportunity was thus offered to watch the development of the disease. By the end of the second growing season diseased plants could be easily located by their upright witches'-broom appearance. Such plants were scattered at random over the bog wherever cuttings from diseased plants happened to have been planted. A year or two later, however, when the bog had become thoroughly vined over, it was exceedingly difficult to locate these diseased plants. Despite the fact that numerous sources of infection were originally scattered throughout the bog, the disease evidently did not increase in abundance, but, on the contrary, actually appeared to decrease as the affected vines became inconspicuous in the tangle of healthy vines. Obviously, cuttings from such a bog will carry a certain number of diseased vines to new plantings; and since practically all new plantings for several years past have been made from cuttings produced locally, it is not surprising that the disease is so universally present among affected varieties. The disease is no more prevalent on the whole in the oldest affected bogs in the region, however, than in those planted very recently, a fact that would be difficult to explain if the disease spread actively. Under Pacific coast conditions this disease at present exerts no appreciable influence on the yield.

RUST

No evidence has been discovered that rust, caused by *Pucciniastrum myrtilli* (Schum.) Arth., is of economic importance. Infected leaves may be found here and there in numerous bogs, but never in abundance. Usually the only evidence of the presence of this fungus is the appearance of a few yellowish uredinial pustules on the lower surface of a leaf.

VENTURIA LEAF SPOT

A disease that is prevalent at times and alarms some growers is the Venturia leaf spot. It is characterized by conspicuous black spots on the lower surfaces of leaves. The black color is due to closely packed superficial perithecia of the causal organism. There is no definitely outlined diseased area in the leaf, which in many cases shows no symptoms whatever of the presence of the fungus other than the perithecia above referred to; in other cases slight discoloration may be noticed on the upper leaf surface.

Venturia is confined to leaves, so far as known, and is of little economic importance.

SCLEROTINIA TIP-BLIGHT

Sclerotinia oxycocci Wor. causes both a tip-blight disease of the plant and a rot of the fruit. Since the tip-blight is of relatively slight importance compared with the rot, this disease will be described under the latter heading.

DISEASES OF BERRIES IN THE FIELD

Field rots are of comparatively little importance in the Pacific coast region. Species of Botrytis often rot berries which have been injured by fireworms or otherwise, and a few berries rotted by Phomopsis may sometimes be found at picking time. Black spot of the berry may occur in isolated patches. The only rot that ever becomes serious in the field, however, is the Sclerotinia hard rot or "cotton ball."

SCLEROTINIA HARD ROT (COTTON BALL) AND TIP-BLIGHT

The symptoms of Sclerotinia hard rot or cotton ball in the berry are easily recognized. At harvest time the diseased berries fail to ripen normally, rarely showing any red color. Soon yellowish brown areas appear in broad bands running lengthwise of the berry and rapidly spread until the whole berry is uniformly yellowish brown in color. The interior of diseased berries is filled with the cottony white mycelium of the fungus, this condition giving rise to the local name for the disease.

Sclerotinia is usually most abundant in young bogs or in those which are made up largely of young growth following heavy pruning and resanding. The prevalence of cotton ball during any given season depends to a large extent upon favorable weather conditions occurring at critical times in the life history of the fungus. The total annual loss from the disease probably never is large, but occasionally it becomes epidemic in areas of from 1 to a few acres and may affect 90 per cent or more of the berries in these areas. Berries rotted by this fungus have to be sorted by hand, necessarily an expensive operation.

The life history of the fungus (*Sclerotinia oxycocci* Wor.) causing hard rot and tip-blight will be given somewhat in detail, since there is no published account of the disease based upon continuous observation in the field. Mature apothecia were first found under natural bog conditions on May 16 in 1923 (others evidently had matured earlier than this), on April 1 in 1924, and on April 18, 1925. It may be stated, then, that the apothecia mature as a rule in April and early in May, especially during the prolonged rainy periods which are likely to occur at this time of year. Mature apothecia are 1 centimeter or less in diameter and are borne on slender stalks that vary from about 1 to about 5 centimeters in length. Numerous apothecia sometimes arise from a single sclerotium. Sclerotia wholly or partly buried in the fallen leaves and trash beneath the vines seem to produce apothecia more freely than those in other situations. They are infrequently found in piles of rotten berries containing numerous mummies and are very difficult to force artificially.

Little is known concerning the infection of the vines by ascospores. The latter are produced before or just as vines begin growing and infect the new growth, usually the uprights. No macroscopic evidence of infection is visible until the sudden wilting of uprights occurs about the time the bog is coming into bloom. The infected uprights, now nearly full grown, collapse a short distance back of their tips, become brown and shriveled, and soon the dead stems are covered with the grayish white powdery masses of conidia. Conidia are borne chiefly on the curved portion of the stem formed where the upright has collapsed. Flowers, pedicels, and leafstalks are also occasionally attacked, and the characteristic grayish masses of conidia are produced along the bent and curved parts of these organs.

The tip-blight stage of this disease rarely affects a sufficient proportion of uprights to cause noticeable injury to the vines or to the crop. Diseased tips are rather hard to find even when relatively numerous, because they are so inconspicuous among the erect healthy uprights. The first tip-blight observed in 1923 was on June 12, in 1924 on May 21, and in 1925 on May 22.

The time of conidial production of this fungus coincides closely with the blooming period of the cranberry. Conidiospores unquestionably are carried over to and infect the berries during the blossoming period. Infected berries continue their normal increase in size all summer without showing any external evidence of infection. The fungus may easily be seen, however, upon cutting open an infected fruit any time after it has set, the seeds being invested with the cottony mycelium. This relation between fungus and berry is maintained until the latter reaches mature size—such berries frequently average somewhat larger than uninfected ones—when the fungus suddenly becomes very active and rapidly invades all the surrounding tissues, and the whole interior of the berry becomes filled with the cottony mycelium. The further development of the fungus takes place rather rapidly if other contaminating rots do not overrun the Sclerotinia. The flesh of the diseased berry becomes filled with hyphæ, which eventually develop into a hard, compact, black sclerotium. The interior of the berry and some of the tissue midway between the four walls of the seed cavity rot away entirely, so that the sclerotium as finally formed consists of circular plates of sclerotial tissue at either end of the berry, connected by four riblike formations of the same tissue which have replaced the fruit pulp at its junction with the four seed-cavity walls. The fruit epidermis usually remains intact over this sclerotium throughout the winter, the whole forming the characteristic mummy. These mummies sometimes remain attached to the uprights all winter. The following spring they produce apothecia and start the life cycle over again.

Control.—The disease is most abundant when three conditions prevail, namely, prolonged wet periods during the time the apothecia mature, rainy periods during blossoming time, and a plentiful supply of mummied berries to start the tip-blight infection. As already noted, hard rot rarely is troublesome on older bogs. This may be partly because these bogs are picked clean regularly and very few mummied berries are left to carry the disease over winter. Clean picking is recommended as an important control measure. Some evidence has been obtained that in the "hook" stage of the vines (just as they begin to bloom) Bordeaux spray helps to reduce berry infection, and it is believed that a thorough application of Bordeaux mixture to the vines just before ascospore discharge occurs will help to prevent tip-blight and thus reduce the possibility of berry infection; but all attempts to prove this experimentally have failed because of the impossibility of locating in advance a place where the disease was going to be epidemic.

BLACK SPOT OF THE FRUIT

Under favorable weather conditions the fungus causing black stem spot sometimes attacks berries, producing conspicuous black sunken spots that vary in size from very small spots to lesions that involve more than half of the berry. The entire spot is filled with innumerable young fruiting bodies of the fungus. Berries affected by this spot are found only in sections of the bog heavily diseased with stem spot, but are rarely noticed prior to harvesting. Black spot is readily distinguished from the black rot of the fruit caused by *Ceuthospora lunata* by the fact that it develops before harvest and is strictly a spotting disease, with spots decidedly sunken. When no secondary fungi follow the black-spot organism, the healthy portion of the berry remains perfectly sound and normal, whereas black rot involves the entire berry.

Mature perithecia of the black-spot fungus were not found on the berry. Although the immature perithecia are present in large numbers in all spots, the berries become so overrun with other fungi before spring (the normal time for the ascospores to develop) that it is impossible to find fruiting material of the fungus.

Control measures for black fruit spot are the same as for black stem spot.

MINOR FIELD ROTS

Botrytis, as noted above, rots berries which have been injured in the field. Such berries become softened and yellowish in color. The fungus often fruits around the edges of wounds made by the fireworm.

Phomopsis rot sometimes develops shortly before harvest. Berries rotted by this fungus are rather firm and leathery and are likely to be yellowish to reddish yellow in color at this season of the year. Phomopsis is better known as a storage rot, but numerous cultures showed that this early developing rot is due almost exclusively to this fungus.

Exobasidium vaccinii infrequently attacks the fruit also, producing somewhat raised circular red spots upon green berries. Curiously enough, this fungus produces its spores in the interior of the fruit, upon the wall lining the seed cavity, which is known to have stomata.

DISEASES OF BERRIES IN STORAGE

Increasing attention has been given within recent years to the losses of cranberries in storage resulting from fungous diseases and other causes (*1, 5, 9, 10*). In the Pacific coast region the problem is predominantly one of storage rots. From the point of view of the grower there are two periods of storage losses, the first including decays developing in the warehouse before berries are shipped and the second those occurring in the markets.

It is now well known that the development of fungous diseases can be materially reduced by care in harvesting and handling the crop and by storing the berries in cool, well-ventilated warehouses. With the best of attention to these details a certain degree of deterioration, varying from season to season, always takes place before the berries are milled and shipped to the markets. This loss is taken directly by the grower, the spoiled berries being removed in the processes of milling and sorting. The magnitude of the loss suffered prior to shipping often is not fully realized. It was found by actual count of representative samples of berries to vary from 5 per cent to more than 20 per cent in the storage experiments of 1924, these tests including three varieties from different bogs, and representing various spraying schedules. (See Table 8, p. 14.)

Rots develop much more rapidly after berries have been milled, packed, and subjected to the adverse conditions of shipping and handling in the markets. Given a sufficient extent of fungus infection to begin with, a shipment of berries leaving the grower in excellent condition may be absolutely unsalable in the markets a short time later. The effect which a series of such shipments will have on the good will of the trade should be evident (*3*). Where experience has shown that, despite all possible care in harvesting and handling, an excessive percentage of storage and market rot develops in frequent years, the only recourse available to the producer is to prevent the initial infection of berries by putrefactive fungi. This condition may be said to exist in a general way in the entire Pacific coast region.

Storage rots are caused by a number of different fungi. The symptoms produced by most of them, however, are so nearly identical that it is practically impossible to determine by inspection alone the fungus responsible for the rotting of a particular berry. Again, these fungi are similiar, in that they infect berries in the field before harvest. Since the effect on the berry, the time of infection, and the control methods are so much alike, these fungi will be here treated as a class, and the specific organisms involved will be reserved for future consideration. The major part of the experimental work described in this bulletin was concerned with controlling storage rots.

EXPERIMENTAL WORK

METHODS

Bordeaux mixture[2] has always proved to be the most effective fungicide for cranberries and therefore was used throughout these experiments, except for a few tests conducted with lime-copper dust.

[2] For descriptions of the methods of spraying cranberry bogs, the reader is referred to publications by C. L. Shear (*8*) and H. K. Plank (*4*). The commercial Bordeaux preparation used in 1924 and 1925, which gave practically as good results as the freshly prepared mixture, consisted of pulverized bluestone and lime in separate containers.

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The standard procedure followed in making the test was as follows: Early in the season plots were marked off of sufficient size to insure an adequate quantity of berries for the storage tests. Spray was applied to these plots as noted in the various tables. One plot (in some cases two or more) was held as a check and received no spray throughout the season. The berries from the different plots were harvested by experienced pickers, care being taken to avoid berries from the fringe area at the junction of plots. The samples, properly labeled, were hauled to the warehouse and stored with the remainder of the crop until ready for shipment. They were then milled and sorted in the usual manner by experienced employees and packed in standard shipping boxes. In the earlier tests a full box was used for each unit, but later three and four samples, respectively, were put in ⅓-barrel and half-barrel boxes. Usually three units were taken from each sprayed plot, in order to allow three successive examinations to be made without handling any sample more than once. The boxed berries were then shipped to some market and held in storage for varying lengths of time, usually in a commercial fruit warehouse. In 1922 the storage tests were conducted in San Francisco, Calif., in 1923 and 1924 in Portland, Oreg., and in 1925 in Washington, D. C. This form of procedure was followed in order to give the experimentally sprayed berries the same kind and degree of handling that commercial berries receive.

Franklin's 7-sample method was used throughout the experiments to determine the percentage of rot (*2*). Seven cups of berries were taken from each lot to be examined, two from near the top of the box, three from the center, and two near the bottom, the samples being spaced equidistantly with reference to one another. Rotten berries were carefully sorted out of these samples, and both decayed and sound berries were then counted. The percentage of spoiled berries thus found was considered to be representative of the amount of rot in the box as a whole.

PRELIMINARY EXPERIMENTS

The spraying experiments outlined for the first season (1922) were based directly upon the schedules recommended for eastern cranberry bogs (*8*). This program calls for three, or in some cases four, applications of Bordeaux mixture—(1) at the hook stage, (2) after blossoming, (3) two weeks later, and (4) not later than August 15. In addition to these an earlier application of spray was to be made to control the Sclerotinia disease. The tests were made on a section of the Howes variety on the Dellinger bogs at Clatsop, Oreg. It soon became evident that difficulties would be encountered in fitting this schedule to the bog selected for the tests. The Sclerotinia spray was applied on May 27 when new uprights were just starting to grow. After this time the development of the vines was exceedingly irregular, no definite hook-stage period ever appearing. The spray scheduled for this time was finally applied on June 22, after some bloom had appeared all over the bog, but most of the uprights were in the hook stage or an even earlier state of development. Blooming continued general over the bog for more than six weeks. The after-blossom spray was applied on August 6, despite the fact that many flowers were still in full bloom. Meanwhile the earlier berries had almost matured, and it was considered inadvisable to make any further applications of spray.

The above account is given in some detail because subsequent experience proved that irregularity of growth and blooming is typical of cranberries in this section. Some varieties begin blooming earlier than others, and the blossoming period is always comparatively long drawn out, even in bogs with a single variety of uniform age and growth.

The results of storage experiments with berries from these plots are shown in Table 1.

TABLE 1.—*Percentage of rot developing in storage in cranberries from experimentally sprayed plots in 1922*

[Berries were scooped Oct. 9 to 15, screened Oct. 15, and shipped to San Francisco, Calif., Nov. 1. The first spray was applied May 27, when new vine growth was starting, the second (hook stage) June 22, and the third (after blossom) Aug. 6]

Date of examination of storage material	Check lot, not sprayed	Sprayed with homemade Bordeaux mixture, 4-4-50, with fish-oil-soap spreader, 2-50		Check lot, not sprayed	Sprayed with homemade Bordeaux mixture, 4-4-50, with casein spreader, ¾-100		Sprayed with commercial Bordeaux mixture, 4-4-50, no spreader	
		Second and third sprays	First, second, and third sprays		Second and third sprays	First, second, and third sprays	Second and third sprays	First, second, and third sprays
Nov. 7	6	3	2	1	3	8	----------	4
Nov. 20	8	6	3	7	5	8	----------	10
Dec. 2	9	7	4	13	8	8	13	10

This series of tests was inconclusive because the checks exhibited excellent keeping qualities. Some other storage experiments, however, brought out more valuable facts. In a test comparing the keeping qualities of cranberries from bogs (1) sprayed regularly with Bordeaux mixture, including two applications in 1922, (2) reflowed for fireworm but never sprayed, and (3) neither sprayed nor reflowed, the results shown in Table 2 were obtained.

TABLE 2.—*Percentage of rot developing in storage in cranberries from sprayed, reflowed, and untreated bogs in 1922*

Date of examination of storage material	Bog regularly sprayed with Bordeaux mixture		Bog reflowed in 2 successive years; no Bordeaux mixture		Check, neither reflowed nor sprayed with Bordeaux mixture	
	Howes variety	Searls variety	Howes variety	Searls variety	Howes variety	Searls variety
Nov. 6	6	----------	16	23	18	20
Nov. 20	7	----------	34	----------	36	42
Dec. 1	13	----------	52	60	40	52

Table 2 shows that both unsprayed bogs produced very poor berries, suggesting that continuous spraying greatly improves the keeping quality of the fruit while reflowing tends to increase the development of rot. At the same time, however, it is to be noted that the three bogs represented in this test being widely separated were not exactly comparable.

In another experiment in 1922, berries of the Bennett Jumbo variety from a bog not sprayed in previous years were used. One plot received two applications of Bordeaux mixture (hook stage and after blossom) and the other was not sprayed. The results of the storage tests are given in Table 3.

TABLE 3.—*Percentage of rot developing in storage in Bennett Jumbo cranberries in 1922 from bog not sprayed in previous years*

Date of examination of storage material	Sprayed with Bordeaux mixture June 15 and July 20	Check, not sprayed
Nov. 7	17	18
Dec. 1	30	38.1

Table 3 shows that a bog that was not sprayed year after year produced berries of poor keeping quality. The applications of Bordeaux mixture as made in 1922 served to improve the keeping quality to some extent, but the results were not entirely satisfactory.

The year 1922 was on the whole a good keeping year for commercial berries. Observation showed that more trouble developed in such varieties as Searls and Bennett than in McFarlin and Howes, suggesting that under the local conditions there may be considerable variation in the susceptibility of different varieties to fungous rots.

As a result of the experiments and observations of the first season it seemed apparent that spraying with Bordeaux mixture as a rule reduced storage losses. Bogs sprayed year after year with Bordeaux mixture produced berries this season which kept well, while those from some bogs not sprayed in past years developed a much greater degree of rot. Certain varieties exhibited keeping qualities superior to others. It became clear that future studies should be along the lines of determining the necessary number of applications of Bordeaux mixture, the proper times to make these applications, and more intensive control work with varieties appearing to be most susceptible to rot-producing fungi.

EXPERIMENTS TO DETERMINE TIME AND NUMBER OF APPLICATIONS OF BORDEAUX MIXTURE

The results obtained in an extensive series of tests with various combinations in the time of spraying are given in Tables 4 to 9, inclusive.

TABLE 4.—*Percentage of rot developing in storage in cranberries from West bog, West, Oreg., in 1923*

Berries were screened Nov. 5 and shipped to Portland, Oreg., Nov. 6. The first spray was applied June 20 (hook stage), the second on July 10 (after blossom), and the third Aug. 1, when berries were one-half to three-fourths grown]

Variety and date of examination of storage material	Sprayed with Bordeaux mixture, 4-4-50			Check, not sprayed
	First, second, and third sprays	Second and third sprays	Third spray	
Searls:				
Dec. 1	21			38
Jan. 1	45			61
Feb. 1	36			73
Howes:				
Dec. 1	8	10		26
Jan. 1	11	15	23	30
Feb. 1	20	21	35	52

TABLE 5.—*Percentage of rot developing in storage in cranberries from Poole bog, Carnahan, Oreg., in 1923*

[Berries were picked Oct. 20 to 30, screened Nov. 5, and shipped to Portland, Oreg., Nov. 6. The first spray was applied June 5 (hook stage), the second July 9 (after blossom), and the third July 31, when berries were about three-fourths grown]

Variety	Date of examination of storage material	Sprayed with Bordeaux mixture, 4-4-50		Check, not sprayed
		First and second sprays	First, second, and third sprays	
Searls	January 1	42	40	75
Bennett	do		33	67

TABLE 6.—*Percentage of rot developing in storage in Bennett Jumbo cranberries from Pilkington bog, Clatsop, Oreg., in 1923*

[Berries were hand picked Oct. 1 to 5, screened Nov. 5, and shipped to Portland, Oreg., Nov. 6. The first spray was applied May 18, when new vine growth was starting; the second June 6 and 7 (hook stage); the third July 12 (after blossom); the fourth July 26 and 27, when berries were one-half to three-fourths grown]

Date of examination of storage material	Sprayed with homemade Bordeaux mixture 4-4-50, with fish-oil-soap spreader			Sprayed with homemade Bordeaux mixture, 4-4-50, with casein spreader		Check, not sprayed
	First, second, third, and fourth sprays	Second, third, and fourth sprays	Third and fourth sprays	Second, third, and fourth sprays	Fourth spray	
Dec. 1	9	10	13	11	21	19
Jan. 1	6	19	23	20		30
Feb. 6	21	27	30	26	52	42

In the experiment shown in Table 6, duplicate series of sprays were applied on a bog infected with Sclerotinia the preceding year, in the hope that one of them at least would cover a concurrent outbreak of the disease. The plots extended entirely across the bog. The vines on the higher side of the bog bloomed two weeks in advance of those on the lower side, interfering greatly with the problem of applying the spray at given stages in the development of the plants. No Sclerotinia appeared. The average of rot in two samples is given in each case.

Another unsuccessful attempt was made to catch an outbreak of Sclerotinia in the experiment shown in Table 7.

TABLE 7.—*Percentage of rot developing in storage in Bennett Jumbo cranberries from Fieselman bog, Columbia Beach, Oreg., in 1923*

[Berries were hand picked early in October, screened Nov. 5, and shipped to Portland, Oreg., Nov. 6. The first spray was applied May 3, when new vine growth was starting, the second June 1 (hook stage), the third July 1 (after blossom), and the fourth July 20, when berries were one-half to three-fourths grown. Homemade Bordeaux mixture 4-4-50 with fish-oil-soap spreader 2-50 was used]

Date of examination of storage material	Sprayed	Check not sprayed	Sprayed	Check not sprayed
Jan. 1	21	46	7	26

Analysis of the preceding tables shows that spraying with Bordeaux mixture reduced the percentage of storage rot in all instances except those in which the first spray was put on after the blossoming period. In the latter case the keeping quality was sometimes improved to a lesser extent, but very little benefit was derived from the final spray alone. The percentage of rot was reduced approximately one-half in all plots receiving the spray at the hook stage.

TABLE 8.—*Percentage of rot developing in storage in cranberries experimentally sprayed in 1924*

[Berries were screened Nov. 10 and 11 and shipped to Portland, Oreg., Nov. 20]

Variety, bog, and date of examination of storage material	Sprayed with Bordeaux mixture						Check, Not sprayed
	First spray	First and second sprays	First, second, and third sprays	Second spray	Second and third sprays	Third spray	
McFarlin, Pilkington bog: [1]							
Nov. 10 (before screening)	8	5	8	12	10	9	10
Dec. 2 (after storage)	7	4	6	9	11	12	13
Bennett, Schimpff bog: [2]							
Nov. 10 (before screening)	--------	6	5	16	18	26	21
Dec. 2 (after storage)	14	7	6	25	22	31	30
Searls, West bog: [3]							
Nov. 10 (before screening)	12	9	--------	--------	--------	--------	18
Dec. 2 (after storage)	25	18	--------	--------	--------	--------	29

[1] First spray applied June 12 at hook stage; commercial Bordeaux mixture, 4-4-50. Second spray applied July 29, after blossom; homemade Bordeaux mixture, 4-4-50; soap, 2-50. Third spray applied Aug. 25; berries nearly grown; homemade Bordeaux mixture, 4-4-50; soap, 2-50. Hand picked Oct. 11 to 16.

[2] First spray applied June 11 at hook stage; commercial Bordeaux mixture, 4-4-50. Second spray applied July 30; some blossom, some berries one-half grown; commercial Bordeaux mixture, 4-4-50. Third spray applied Aug. 22; berries one-half to three-fourths grown; commercial Bordeaux mixture 4-4-50. Scooped Oct. 17 and 18.

[3] First spray applied June 11 at hook stage; homemade Bordeaux mixture, 4-4-50. Second spray applied Aug. 1, after blossom. Scooped early in October.

The final Bordeaux spray, applied on most of the bogs in this section about the first of August in 1923, remained adherent to the vines and berries so persistently that in many cases pickers objected to harvesting them. This fact, in conjunction with the observation that the final spray in itself apparently had little value, led to an alteration in the subsequent recommendations given the growers. The new program called for only two applications of Bordeaux mixture, one at the hook stage, the other immediately after blossoming.

Meanwhile further experiments were performed to procure additional data on the adequacy of the schedule recommended, with the results shown in Tables 8 and 9.

The tests in both 1924 and 1925 clearly demonstrated that the new schedule was justified. There was a sharp increase in the percentage of rot developing in berries from plots not receiving the hook-stage spray compared with those from all plots which had received it, this being more striking in 1924 than in 1925. Berries receiving both preblossom and after-blossom applications uniformly held up in storage practically as well as those receiving the additional third spray. Every lot which had received two applications of Bordeaux mixture in 1924 was in good marketable condition after three weeks of storage, with the possible exception of the Searls variety. In the 1925 tests the berries were in transit for 3½ weeks, during which time the twice-sprayed lots developed from 2 to 6 per cent of rot, while the berries from plots not receiving the hook-stage spray showed a higher percentage, ranging up to 14 per cent in Bennett plots. After an additional storage period of one month 11 per cent was the highest proportion of rot found in any standard-sprayed lot, whereas many of the lots originating from plots receiving no hook-stage spray had more than 20 per cent of rotted berries. The superior keeping quality of the former group became even more pronounced as the storage period was increased. In other words, the hook-stage and after-blossom applications of Bordeaux mixture controlled storage rots satisfactorily under conditions as severe as commercial berries are ever subjected to in a well-regulated marketing system, whereas in many cases berries produced and handled under conditions identical in all respects except that of being differently sprayed rotted so badly as to be unmarketable.

DISCUSSION OF SPRAYING EXPERIMENTS

Before drawing definite conclusions from this series of spraying experiments it may be well to point out certain factors which may have some bearing upon the results.

In the first place, it is not to be expected that the proportion of infected berries will be equally and uniformly present throughout any considerable bog area, as is well illustrated in the extreme case of Sclerotinia rot. This disease usually appears in isolated spots in a bog where most of the berries may be infected, while it is entirely absent over the remainder of the area. A similar condition, though less marked, undoubtedly holds true of other rots. Local influences also must play an important part in determining the number of berries infected, such as depth of vine and elevation of the bog above the water table. For example, in the McFarlin tests of 1925 (Table 9) the last two plots recorded in the last two columns were located on low, wet ground on either side of a cross ditch, and the berries from these two plots developed considerably more rot than the unsprayed check a short distance away on higher and drier ground. Since the relative proportion of infection is likely to vary to some extent, it is not surprising to find that contradictory results were sometimes obtained even on the small, comparatively uniform areas used for the experimental plots.

In the second place, it is impossible to establish and maintain complete coverage of all the fruits in a sprayed area. The quantity of spray applied per acre, the care with which the spray is applied, and the depth of vines through which the spray must penetrate in order to reach the berries are three very important factors in determining the proportionate number of berries which receive the protective covering of spray. It is evident that thoroughness of application is of great importance in obtaining successful results from spraying.

It should also be emphasized that berries in the late-storage tests were screened early in the season and were then kept boxed until sampled. The proportion of rot present in such a case is not an index of the percentage which would be found in commercial berries in the market at the same time of year, because the latter would have been screened much later and all early-developed rot removed.

CONCLUSIONS FROM SPRAYING AND STORAGE TESTS

Storage tests conducted over a period of four years lead to the following conclusions:

Some years an excessive percentage of storage rot develops in most of the unsprayed cranberries produced in the Pacific coast region.

Each year an excessive percentage of rot develops in certain bogs and apparently in particular varieties, if uncontrolled.

Two applications of Bordeaux mixture—the first made in the hook stage or just as the bog begins to bloom, the second in the after-blossom stage, as the vines go out of bloom—control the development of storage rots satisfactorily, provided the berries are harvested and handled with sufficient care.

Of the two applications, that at the hook stage is the more essential.

DUSTING EXPERIMENTS

In the 1925 spraying tests a parallel series of plots was treated with a commercial preparation of lime-copper dust for the purpose of getting comparative data on spraying and dusting as control methods for cranberry rots. The dust used in the test contained 25 per cent by weight of monohydrated copper sulphate and 75 per cent of hydrated lime. It was applied by means of a hand-blower dust gun fitted with two nozzles, a method which is not very satisfactory on cranberry vines, because of the habit of vine growth. At first it was attempted to apply the dust at a definite rate per acre, but this was abandoned after a few trials, and thereafter an excessive quantity was used to insure some dust reaching all the vines. Winds, which blow almost constantly over the bogs in this region, often carried away most of the dust before it could settle into the vines.

The results of the dusting tests are given in Table 9. It is seen that the dust failed to give as consistently good control as did the spray, although in a few instances it proved equal to the Bordeaux mixture. This inconsistency of results was expected, when so much difficulty was encountered in the attempt to spread the dust uniformly over all the vines. Apparently, commercial dusting of cranberries will not prove satisfactory on the Pacific coast until some superior method of applying the dust is developed.

TABLE 9.—*Percentage of rot developing in storage in cranberries experimentally sprayed and dusted in 1925*

[Berries were screened Oct. 13 and 14 and shipped to Washington, D. C., Oct. 16, arriving Nov. 9]

Variety, bog, and date of examination of storage material	Sprayed with homemade Bordeaux mixture					Check, not treated	Dusted with lime-copper dust					Check, not treated	Sprayed with commercial Bordeaux mixture				
	First spray	First and second sprays	First, second, and third sprays	Second and third sprays	Third spray		Third application	Second and third applications	First, second, and third applications	First and second applications	First application		First spray	First and second sprays	First, second, and third sprays	Second and third sprays	Third spray
McFarlin, Pilkington bog:[1]																	
Nov. 10	3	2	2	3	5	8	4	5	3	4	10	6	6	2	4	11	9
Dec. 6	6	6	7	10	7	15	11	10	8	10	20	14	13	5	11	25	12
Jan 4	10	11	10	15	19	30	22	17	12	15	23	19	16	8	15	32	23
Bennett, Schimpff bog:[2]																	
Nov. 10	2	4	4	11	10	14	8	8	11	7	11	11	8	4	3	7	6
Dec. 6	19	11	14	25	28	27	33	31	25	18	32	21	11	11	11	25	23
Jan. 4	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Searls, Schimpff bog:[3]																	
Nov. 10	9	6	4	8	8	8	7	3	5	5	11	8	6	5	7	7	8
Dec. 6	11	10	8	12	15	16	10	11	6	12	16	20	11	10	9	16	25
Jan. 4	22	15	10	18	19	18	18	16	10	15	24	32	15	18	14	19	25

[1] First application June 5 at hook stage; Bordeaux mixture, 4-4-50, with 2-50 soap in homemade, no additional spreader in commercial. Second application July 13, after blossom. Third application Aug. 7; berries one-half to three-fourths grown. Hand picked Sept. 17 to 21.

[2] First application June 15 at hook stage; sprays same as in 1. Second application July 21, after blossom. Third application Aug. 8; berries one-half to three-fourths grown. Scooped Oct. 6.

[3] Sprayed as in 2. Scooped Sept. 22 and 23.

COLD-STORAGE EXPERIMENTS

The question has been raised among the growers as to whether cold storage of the fruit might not be substituted for spraying in the control of storage rots. The plan was proposed on the following grounds: No decay is found when cranberries are picked. If the entire crop is screened and shipped immediately, the grower will suffer no warehouse loss in the first place. Pacific coast berries at present are consumed in an area lying wholly within a radius of three or four days' haul from the bogs, and very little rot should be expected to develop in a shipment of such short duration so early in the season. Consequently the berries would reach the distributing markets in perfect condition very soon after being harvested. They could be immediately placed in cold storage and held until a market demand arose and would then be consumed before any rots developed, if such storage was found to be satisfactory. Furthermore, it might be possible to prolong the marketing season of cranberries by holding them in cold storage for later distribution.

The following data were obtained on cold storage: In 1922 a box of Howes berries from the Wills bog at Long Beach, Wash., was shipped to Washington, D. C. On arrival two samples of sound berries, consisting of about 1 peck each, were sorted out and put in ventilated boxes, one of which was placed in the cold-storage plant at the Arlington Experiment Farm, Rosslyn, Va., at a uniform temperature of 32° F., while the other was kept in a greenhouse as a check. The berries were held from November 13, 1922, to January 20, 1923, when the percentage of rot was determined. The berries kept in cold storage showed 3 per cent and those in the greenhouse 10 per cent of rot. The berries used in this test, as the check showed, were of good keeping quality.

A box of McFarlin cranberries grown at Long Beach, Wash., and placed in a commercial cold-storage house in Los Angeles, Calif., by H. S. Gane in the fall of 1921 was examined by the writer in November, 1922. It was not learned at what temperature this house was kept, and nothing is known of the condition of the berries when placed in storage. The berries were practically 100 per cent rotted when examined and were overgrown with molds, Penicillium and Fusicoccum being very much in evidence.

In 1923 cold storage was tried experimentally on a scale large enough to give an indication of what might be expected from it commercially. The end-rot fungus is known to grow slightly even at 32° F., so the temperature would have to be kept low to prevent the development of this organism. On the other hand, it would be difficult to find commercial storehouses in which the temperature is held consistently at or near 32° F. Bearing these two facts in mind, the cold-storage plant selected as furnishing the most favorable temperature conditions among the several which were kindly placed at the disposal of the writer was the meat storage house of Swift & Co., in Astoria, Oreg. The temperature in this warehouse is held at an average of 32° to 34° F.[3]

Table 10.—*Percentage of rot developing in cranberries in cold-storage test in 1923*

[All samples were screened Oct. 26 to 31. Check lots were kept in unheated warehouse at Clatsop, Oreg., and other lots placed in cold storage Nov. 1]

Date examined	McFarlin, Bloomer bog, not sprayed		McFarlin, Morse bog, sprayed		Bennett, Pilkington bog, sprayed		Cape Cod Beauty, Pugh bog, sprayed		Centennial, Pugh bog, sprayed	
	Cold storage	Check	Cold storage	Check	Cold storage	Check	Cold storage	Check	Cold storage	Check
January 14, 1924	16	25	4	7	8	18	13	24	16	21
April 26, 1924	67	78	--------	--------	33	--------	30	58	45	64
August 8, 1924	87	--------	31	64	62	75	--------	--------	--------	--------

For these tests, McFarlin cranberries were selected from sprayed and unsprayed bogs and Bennett Jumbo, Cape Cod Beauty, and Centennial from sprayed bogs, the latter three being considered comparatively poor keeping varieties. Two standard shipping boxes (in the case of Bennett and unsprayed McFarlin three boxes) of each were kept in cold storage, while an equal number of boxes of each were held as checks in a cranberry warehouse at Clatsop, Oreg. The berries were screened and boxed by the growers October 26 to 31 and were placed in cold storage November 1. The condition of these berries when removed at successive intervals is shown in Table 10.

[3] The variations (daily maximum and minimum) as determined by a thermograph record for one week (Nov. 14–20) were as follows: 34–27, 33–24, 36–30, 35–31, 34–30, 32–29, 38–34° F. The average daily temperature for this particular week was 32.2° F. The extreme daily averages were 28.5° and 36° F., respectively, and the extreme temperatures 24° and 38° F.

On January 14, 1924, when the first lot was taken out of storage, all the samples were sound enough to be sold without remilling, although Cape Cod Beauty, Centennial, and unsprayed McFarlin were beginning to decay rather badly. On the other hand, the checks were not in decidedly poorer condition, showing only from 3 per cent to 11 per cent more rot than the cold-storage berries. Three months later none of the lots withdrawn were salable, while the margin between cold-storage samples and their checks varied from 11 per cent in the unsprayed McFarlin to 28 per cent in the Cape Cod Beauty. At the end of nine months the cold-storage sample of sprayed McFarlin was still in fair condition, as were the check berries of this lot, considering the length of time they had been held. The check lot of Bennett was almost as good, but the cold-storage lot was not much better than its check.

Under the temperature conditions prevailing in the test, rot developed so badly even in two or three months that poor-keeping berries would require remilling before being marketed. To be effective the temperature would have to be kept lower than was the case here, but whether or not a lower temperature would prove entirely satisfactory remains to be determined.

RELATION OF WEATHER TO KEEPING QUALITY

In the foregoing discussion of field diseases emphasis is frequently placed upon the relation of favorable weather conditions to the prevalence of the disease under consideration. Later it was pointed out that infection by storage-rot fungi takes place in the field. It is natural to infer, then, that the degree of infection in the latter case is likewise dependent to some degree upon the weather and that cranberries will consequently develop more storage rot in some seasons than in others. That this is actually the case has been abundantly proved in the older cranberry areas, and it is becoming more and more apparent in the Pacific coast region as the production there increases. The problem of evaluating all the various factors controlling storage-rot infection is so complicated that many years of careful work will be required before our knowledge of these relations becomes very exact (*11*, *12*). On one phase of the problem, however, there are definite and convincing data, namely, the effect of storing berries wet upon the subsequent development of rot.

The importance of this relation in the Pacific coast region is apparent when the seasonal nature of the climate is considered. During the summer months there is very little rainfall, while the autumns and winters are rainy. Fall rains sometimes begin before cranberry harvesting is finished, and it appears to be in such years that the greatest trouble with rots is encountered. To give a clearer picture of the relation of picking to rainfall, notes on the weather prevailing in September of the last four seasons and in October of the last three seasons are presented in Table 11. "Rainy" days as recorded include those in which rain fell all or part of the day, the vines and berries remaining wet in the latter case.

TABLE 11.—*Weather conditions on cranberry bogs in Clatsop County, Oreg., during the months of September and October in the years shown*

Day of month	September				October		
	1922[1]	1923	1924	1925	1923	1924	1925
1	Rain	Partly cloudy	Clear	Clear	Clear	Rain	Clear
2		Rain	do	do	do	do	Do.
3		Clear	Partly cloudy	do	Rain	do	Do.
4	Rain	do	Cloudy	Cloudy	Partly cloudy	Clear	Do.
5		do	Clear	Cloudy, wet	Rain	do	Do.
6	Rain	do	Foggy	do	Clear	do	Cloudy
7		do	do	do	do	Cloudy	
8		Cloudy	Partly cloudy	Cloudy	Rain	Rain	
9		do	Clear	do	Clear	do	
10		do	do	Clear	Cloudy	Clear	
11		do	do	Cloudy	Clear	do	
12		do	do	Clear	do	Rain	
13		Clear	Cloudy	do	Partly cloudy	do	
14	Partly cloudy.	do	Partly cloudy	do	Cloudy, then rain.	do	
15	Cloudy	Partly cloudy	Cloudy	Rain	Rain	do	
16		Clear	do	Clear	do	Clear	
17		Partly cloudy	do	do	do	do	
18	Misty	Misty	Rain	Rain	Clear	do	
19	do	Rain	Clear	Clear	do	do	
20		Clear	Cloudy	do	do	Partly cloudy.	
21	Rain	do	Rain	do	Rain	Rain	
22		do	do	do	do	Clear	
23		Partly rainy	do	do	Clear	Rain	
24		Rain	do	Cloudy	do	do	
25	Rain	Clear	Partly cloudy	do	do	do	
26	do	do	Clear	Clear	do	do	
27	do	do	do	do	do	do	
28	Clear	do	do	Rain	do	do	
29	Rain	do	Cloudy	do	Partly cloudy	do	
30		do	Rain	Clear	Misty	Cloudy	
31					Clear	Rain	

[1] When condition of weather is not shown the bogs were dry.

The harvesting of early varieties usually begins soon after September 1, but picking does not become general before the 15th or sometimes still later. As a rule the harvest season extends well into October. The year 1924 furnished an illustration of a rainy picking season. Berries were late maturing, picking being started on a large scale after September 20. Reference to Table 11 shows that on the average not more than two days a week were classed as dry after this date; that is, a considerable portion of the crop had to be picked in the rain, and it was very difficult to dry the berries before storing them in the warehouse. In addition, from 1 to 10 per cent of the unharvested berries were frozen on October 10. As a result of these two factors the 1924 crop kept poorly. Berries picked before the rains kept unusually well, this being especially noticeable with the Searls variety, which often rots badly, and with Bennett when picked early. Table 8 shows that the Bennett in the experimentally sprayed plots also kept satisfactorily, although they were picked after the rains started. The entire bog on which these plots were located was very carefully sprayed twice with Bordeaux mixture, yet some shipments of this variety from the same bog rotted badly, the only difference in handling being that the experimental plots were picked on one of the few dry days while some of the crop had to be stored wet. Storing berries wet invariably causes a decided increase in the development of rot.

With the danger of early fall rains always present, it is essential for the harvesting period to be reduced to a minimum in the Pacific coast region. Each grower must learn by close observation how early his crop may be picked and still color up sufficiently by marketing time. Rapidity of harvesting, once the berries are colored well enough to pick, can not be too strongly emphasized.

Care should be exercised to see that all berries stacked in the warehouse are thoroughly dry. Spreading the berries thinly in crates in moving air will often accomplish this result, but eventually some of the larger bog owners will probably find it profitable to install some type of drying machine similar to those in use on a few of the eastern cranberry bogs. Though it is far preferable to pick only dry berries, the writer recognizes that this is often impossible; hence the emphasis placed upon the importance of thoroughly drying before storing.

CULTURE WORK WITH CRANBERRY ROT FUNGI

MATURE BERRIES

Most of the fungi which cause rot in mature cranberries produce symptoms so nearly identical that the causal organism can be determined with certainty only by means of cultures from the decayed berries. Therefore nearly one thousand cultures were made each year, to obtain an idea of the fungi responsible for the decay. The material for these cultures was usually taken from storage experiments, but the latter represented the most important varieties and a sufficient number of bogs to give a fair indication of the relative prevalence of the different fungi during the year. Cultures were made each time storage lots were examined, in order to include both early and late decay-producing fungi (*5*). A more comprehensive study of the succession of rots which develop in storage is planned for the 1926 season, including berries from each of the important commercial areas.

Berries were surface sterilized five minutes in a 1-to-1,000 solution of mercuric chloride in 70 per cent alcohol, and bits of the decayed pulp were transplanted into test tubes of corn-meal agar. A single culture was made from each berry. Tables 12 to 16 show the fungi that developed in these cultures year by year and Table 17 gives a summary of all cultures made in the series of years.

TABLE 12.—*Fungi developing in cultures made from rotted cranberries in fall and winter of 1922–23*

Fungus	Gibbs bog, Hauser, Oreg.	Oregon experimental berries	Wills bog, Long Beach, Wash.	Washington experimental berries	Total
Acanthorhyncus vaccinii		2		4	6
Botrytis sp		3	11		14
Ceuthospora lunata		10			10
Fusicoccum putrefaciens	28	248	80	47	403
Glomerella rufomaculans vaccinii		2			2
Guignardia vaccinii		6		4	10
Penicillium sp		14	26	1	41
Pestalozzia guepini vaccinii		1			1
Pezizella lythri		1			1
Phomopsis sp	12	43		2	57
Sporonema oxycocci	4	46		14	64
Sterile	8	112	101	20	241
Not identified	5	45	28	14	92
Total number of cultures	56	534	246	106	942

TABLE 13.—*Fungi developing in cultures made from rotted cranberries in fall and winter of 1923-24*

Fungus	Dellinger bog, Bennett variety	Fieselman bog, Bennett variety	West bog, Searls variety	Bloomer bog, McFarlin variety	Hill bog, McFarlin variety	Poole bog, Searls variety	Pugh bog, Pacific Beauty variety	Total
Acanthorhyncus vaccinii		2					4	6
Botrytis sp.			1				1	2
Ceuthospora lunata			8	1		1		10
Fusicoccum putrefaciens	69	124	104	60	30	90	41	518
Guignardia vaccinii			1					1
Penicillium sp.	1	2	3		1	3	5	15
Pestalozzia guepini vaccinii		5						5
Phomopsis sp.	18	3	22	9	6	23	5	86
Pleospora sp.			1			1		2
Sporonema oxycocci				8	4	1		13
Sterile	7	12	8	12	9	10	27	85
Not identified	5	2	2	10		6	18	43
Total number of cultures	100	150	150	100	50	135	101	786

TABLE 14.—*Fungi developing in cultures made from rotted cranberries in fall and winter of 1924–25*

Fungus	Schimpff bog, Searls variety	Schimpff bog, Bennett variety	West bog, Howes variety	West bog, Searls variety	Dellinger bog, McFarlin variety	Poole bog, Bennett variety	Dellinger bog, rotten pile	Taylor bog, rotten pile	Total
Botrytis sp.	[1]4	2						2	8
Ceuthospora lunata	4	1		[1]14	[1]4	1	[1]11	1	36
Fusicoccum putrefaciens	[1]22	43	33	[1]66	[1]72	43	[1]38	[1]23	340
Gloeosporium sp								4	4
Penicillium sp	2	1			1	1	[1]12	[1]13	30
Pestalozzia guepini vaccinii					1			4	5
Phomopsis sp		1	1	2	6	1	4	2	17
Rhizopus sp							2		2
Sporonema oxycocci					1		[1]5	[1]18	24
Sterile	15	1	16	20	14	1	9	19	95
Not identified	4	1			2	3	20	19	49
Total number of cultures	50	50	50	100	100	50	100	100	600

[1] Two fungi in one culture.

TABLE 15.—*Fungi developing in cultures from cranberries rotten at harvest time*

Fungus	Dellinger bog, Bennett variety	Poole bog, Searls and Bennett varieties	Poole and Dellinger bogs, Searls, Bennett, Centennial, and other varieties	Fieselman bog, Bennett variety	Total
Botrytis sp.			1		1
Fusicoccum putrefaciens	2		1		3
Phomopsis sp	70	53	24	25	172
Sporonema oxycocci			1		1
Sterile		7	3		10
Total number of cultures	72	60	30	25	187

TABLE 16.—*Fungi developing in cultures made from rotted cranberries in fall and winter of 1925–26*

Fungus	Schimpff bog, Searls variety	Schimpff bog, Bennett variety	Dellinger bog, McFarlin variety	Total number of times each fungus occurred
Botrytis sp	[1]3	1	3	7
Ceuthospora lunata	----------	5	10	15
Fusicoccum putrefaciens	[1]140	[1]202	[1]129	471
Penicillium sp	[1]54	10	[1]37	101
Phomopsis sp	[1]13	[1]5	10	28
Sporonema oxycocci	4	1	5	10
Sporonema pulvinatum	----------	1	----------	1
Sterile	24	6	15	45
Not identified	57	15	44	116
Total number of cultures	266	237	239	742

[1] Two fungi in one culture.

TABLE 17.—*Complete summary of fungi developing in cultures made from rotted cranberries on the Pacific coast in years shown*

Fungus	1922	1923	1924	1925	Total number of times each fungus occurred	Percentage of total cultures
Acanthorhyncus vaccinii	6	6	----------	----------	12	----------
Botrytis sp.	14	2	9	7	32	1
Ceuthospora lunata	10	10	36	15	71	2
Fusicoccum putrefaciens	403	518	341	471	1,733	53
Gloeosporium sp.	----------	----------	4	----------	4	----------
Glomerella rufomaculans vaccinii	2	----------	----------	----------	2	----------
Guignardia vaccinii	10	1	----------	----------	11	----------
Penicillium sp.	41	15	30	101	187	6
Pestalozzia guepini vaccinii	1	5	5	----------	11	----------
Pezizella lythri	1	----------	----------	----------	1	----------
Phomopsis sp.	57	156	102	28	343	10
Pleospora sp.	----------	2	----------	----------	2	----------
Rhizopus sp.	----------	----------	2	----------	2	----------
Sporonema oxycocci	64	13	25	10	112	3
Sporonema pulvinatum	----------	----------	----------	1	1	----------
Sterile	241	85	105	45	476	15
Not identified	92	45	49	116	302	9
Total number of cultures	919	856	715	742	3,232	----------

End rot, caused by *Fusicoccum putrefaciens* Shear, was found to be by far the most important rot in the Pacific coast region. This fungus appeared in more than 60 per cent of the total cultures which developed any fungus growth. The remaining species of fungi varied somewhat in abundance from season to season. The five species occurring most often were, in the order of their importance, *Fusicoccum putrefaciens* (end rot), *Phomopsis* sp., *Penicillium* sp. (soft rot), *Sporonema oxycocci* (ripe rot), and *Ceuthospora lunata* (black rot). The total list, however, includes nearly all of the fungi which are known to rot cranberries in eastern cranberry districts, as well as a few others of minor importance, such as Botrytis and Pleospora, which have not been found in the eastern sections. Perhaps the most striking feature disclosed by these cultures is the almost total absence of the early-rot and bitter-rot organisms (*Guignardia vaccinii* and *Glomerella cingulata vaccinii*, respectively), one or both of which are generally among the five most important fungi found in comparable studies of eastern cranberries.

Two rots are found in storage which may be determined by symptoms alone, hard rot (cotton ball) and black rot (caused by *Ceuthospora lunata* Shear). Hard rot has been described above. Black-rot berries are, as the name implies, black or bluish black in color and are usually rather firm in texture, whereas the majority of other rots are of the soft or watery type. The proportion of black rot is somewhat higher than that indicated in the tables, because berries obviously rotted by this organism were not often cultured.

Proportionately, all varieties appear to be affected about equally by the different fungi, with the exception of Bennett, which has a higher percentage of end rot as a rule, and Searls, which often shows more black rot and Phomopsis than the average. Since the storage experiments showed that unsprayed Bennett and Searls berries invariably rotted worse than all other varieties tested, it is logical to conclude that these two varieties are more susceptible to these fungi. Sporonema was rarely found on any variety except McFarlin.

Table 15 gives the results of cultures made from berries that rotted early—that is, just preceding or following harvest. It was previously pointed out that this early-developing rot is largely due to Phomopsis.

TABLE 18.—*Fungi developing in cultures from green Howes cranberries from West bog, West, Oreg., in 1923*

Fungus	June 26, flowers open or just fallen			July 3, bloom gone, berries well set			July 11, berries 1/16 to 1/8 inch diameter			July 16, berries nearly half-grown			July 25			Aug. 2, berries about three-fourths grown			Aug. 9, berries large			Aug. 22, berries beginning to ripen		
	W[1]	B[2]	S[3]	W	B	S	W	B	S	W	B	S	W	B	S	W	B	S	W	B	S	W	B	S
Acanthorhyncus vaccinii	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---
Botrytis sp.	---	---	---	---	---	---	---	2	---	3	---	---	---	1	---	2	1	---	---	---	---	1	1	---
Ceuthospora lunata	---	---	---	---	---	1	2	---	---	1	1	---	---	1	---	---	---	---	---	---	---	---	---	---
Cladosporium sp.	---	1	---	1	---	---	---	---	---	1	---	---	---	---	---	1	---	---	---	1	---	---	1	---
Fusarium sp.	---	---	---	1	---	---	1	---	---	---	---	---	1	---	---	---	---	---	---	---	---	1	---	---
Fusicoccum putrefaciens	---	---	---	---	---	---	2	---	---	---	1	---	1	---	---	---	---	---	---	---	---	[4]5	4	1
Guignardia vaccinii	---	---	---	---	---	---	1	---	---	---	1	---	---	1	---	---	---	---	1	---	1	1	---	1
Penicillium sp.	---	---	---	---	1	---	---	---	---	---	---	---	---	1	1	---	1	2	---	---	---	---	---	---
Phomopsis sp.	---	1	---	---	---	---	---	---	---	---	---	---	1	---	---	2	---	---	---	2	---	[4]1	---	---
Pleospora sp.	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---
Sterile	3	7	6	6	1	4	---	1	7	1	2	6	2	1	3	2	7	8	9	5	9	3	1	8
Not identified	[5]7	1	[5]4	2	[5]8	-	[5]4	[5]7	3	4	5	4	4	4	[5]6	3	1	---	---	2	---	1	[5]3	---
Total number of cultures	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	[4]10	10	10

1 W indicates that the whole berry was used for culture.
2 B indicates that blossom-end half of berry was used for culture.
3 S indicates that stem-end half of berry was used for culture.
4 Two fungi in one culture.
5 Many unidentified fungi were contaminations, especially frequent in the earlier cultures made before a culture chamber was available.

TABLE 19.—*Fungi developing in cultures from green Searls cranberries from West bog, West, Oreg., in 1924*

Fungus	July 3, flowers half open, half in bud	July 10, flowers mostly dropped, but some still present	July 19, bloom nearly gone, some berries fairly large			July 24, some bloom, some berries half grown			July 31, berries half grown on average			Aug. 9, berries large			Aug. 16			Aug. 25, berries beginning to ripen			Sept. 8, berries ripening		
			W[1]	B[2]	S[3]	W	B	S	W	B	S	W	B	S	W	B	S	W	B	S	W	B	S
Alternaria sp	---	---	---	---	---	---	---	---	1	---	---	---	1	---	---	---	---	---	---	---	---	---	---
Botrytis sp	---	1	---	---	---	2	---	---	1	1	---	---	2	---	---	---	---	1	1	---	2	2	---
Cladosporium sp	---	5	---	---	---	---	1	---	---	---	---	1	3	---	2	---	---	1	---	---	1	---	---
Fusicoccum putrefaciens	---	4	1	1	---	1	---	---	3	5	---	2	---	---	1	1	---	3	2	2	3	2	[4]1
Guignardia vaccinii	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	[4]2
Penicillium sp	---	---	---	1	1	1	---	1	2	1	1	2	---	3	1	2	3	---	---	---	---	---	---
Phomopsis sp	---	1	---	---	---	---	1	---	---	---	---	---	---	---	2	---	---	---	1	---	---	1	1
Pleospora sp	---	2	1	---	---	---	1	---	---	---	---	1	---	---	---	---	---	---	2	---	1	---	1
Sclerotinia oxycocci	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Sterile	30	8	5	6	7	2	2	6	2	3	7	3	4	6	4	4	6	---	---	7	1	4	6
Not identified	---	7	3	2	2	4	5	3	1	---	2	1	---	1	---	3	1	5	4	1	2	---	---
Total number of cultures	30	30	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

[1] W indicates that whole berry was used for culture.
[2] B indicates that blossom-end half of berry was used for culture.
[3] S indicates that stem-end half of berry was used for culture.
[4] Two fungi in one culture.

TABLE 20.—*Fungi developing in cultures from green Bennett Jumbo cranberries from Gratke bog, Clatsop, Oreg., in 1925*

Fungus	June 27, midbloom, some buds	July 7	July 14	July 20, bloom about gone, berries one-quarter grown			July 27			Aug. 4			Aug. 11			Aug. 18, berries almost grown			Sept. 3			Sept. 10		
				W[1]	B[2]	S[3]	W	B	S	W	B	S	W	B	S	W	B	S	W	B	S	W	B	S
Botrytis sp	---	---	3	---	---	---	1	1	---	---	---	---	1	---	---	1	4	---	3	1	---	2	1	---
Cladosporium sp	---	---	---	---	---	---	2	4	---	---	---	---	---	---	---	2	1	---	---	---	---	---	---	---
Ceuthospora lunata	---	---	---	---	---	---	2	1	---	---	1	---	[4]1	6	---	1	---	---	---	---	---	1	1	---
Fusicoccum putrefaciens	---	---	1	---	---	---	2	1	---	2	---	---	[4]4	3	1	6	3	1	3	7	2	6	[4]2	1
Guignardia vaccinii	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	[4]2	5
Gloeosporium sp	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Lophodermium oxycoccus (Fr.)	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Penicillium sp	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---
Phomopsis sp	---	---	2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Pleospora sp	6	---	---	---	1	---	1	---	---	2	1	---	3	---	---	---	---	---	---	---	---	---	---	---
Sterile	30	50	25	19	14	15	6	3	15	12	12	15	5	1	13	7	4	14	8	4	13	9	6	9
Not identified	4	---	18	1	---	---	6	4	---	4	1	---	7	4	1	3	3	---	5	3	---	2	5	---
Total number of cultures	40	50	50	20	15	15	20	15	15	20	15	15	20	15	15	20	15	15	20	15	15	20	15	15

[1] W indicates that whole berry was used for culture.
[2] B indicates that blossom-end half of berry was used for culture.
[3] S indicates that stem-end half of berry was used for culture.
[4] Two fungi in one culture.

GREEN BERRIES

The Office of Fruit Diseases of the Bureau of Plant Industry has for several years been making cultures from green cranberries at intervals during the growing season in an effort to clear up the problem of infection by storage-rot fungi (*13*). As part of this program similar series of cultures were made in the Pacific coast region. Beginning about blooming time, green berries were collected at weekly intervals, surface sterilized for five minutes in a 1-to-1,000 solution of mercuric chloride in 70 per cent alcohol, and planted in test tubes of corn-meal agar. As soon as the berries became large enough to be conveniently cut in half, cultures were made from blossom and stem ends as well as from entire berries. The results of these cultures are given in Tables 18, 19, and 20.

The results of these cultures agreed with the results obtained in eastern cranberry districts, namely, that storage fungi infect berries in the field rather early in the season. Usually the cultures made just after blossoming developed almost as high a percentage of storage-rot fungi as those made later in the season. The high percentage of sterile cultures from the stem-end half of the berry indicates that infection takes place largely at the blossom end. Guignardia alone occurred more frequently in stem-end cultures than in those from the blossom end. Fusicoccum appeared much more frequently than any other fungus. Botrytis ranked next in importance, and Pleospora, rarely found in mature-berry cultures, was sometimes common in the earlier part of the season. In all, 1,000 cultures were made from half and whole berries, and storage-rot fungi appeared in 222 of these.

It is perhaps needless to point out the relation between these green-berry culture results and the results obtained in the spraying experiments. In the latter it was found that hook-stage and after-blossom applications of Bordeaux mixture invariably improved the keeping quality of the berries; the former showed that storage-rot infection had largely occurred some time during or soon after bloom.

SUMMARY

Four years' study of cranberry-disease problems in the Pacific coast region led to certain conclusions which are summarized below:

Six diseases of vines and leaves are described and control measures for the more important of these are suggested.

Field rots of berries are of comparatively little economic importance. Hard rot, caused by *Sclerotinia oxycocci* Wor., sometimes causes loss in local areas. The life history of the fungus causing this disease is presented and control measures are suggested.

Storage rots, caused by various fungi, are a very serious cause of loss, both in quantities of berries and in effect on the good will of the trade.

A series of spraying experiments followed by storage tests demonstrated that two applications of Bordeaux mixture, the first just before blossom and the second immediately following blossom, will control the development of storage rots satisfactorily.

Dusting with a lime-copper mixture, in less extensive experiments, failed to give as consistently good control of storage rots as spraying.

Cold storage at an average temperature of 32° to 34° F. failed to prevent the development of rots, particularly over a period of several months.

Wet weather at picking time, and especially storing berries while still wet, increased the percentage of storage rot.

In more than 3,200 cultures from individual rotted cranberries, end rot, caused by *Fusicoccum putrefaciens* Shear, was found to be decidedly the most important rot. Practically all fungi known to rot cranberries elsewhere were found in cultures made from Pacific coast berries.

At intervals during the growing season 1,000 cultures were made from green berries. Infection by storage-rotting fungi was found to take place chiefly during or immediately following the blossoming period. Infection usually occurred on the blossom-end half of the berry.

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