THE IDENTITY AND THE RELATIONSHIP OF THE VIRUSES CAUSING WESTERN X LITTLE CHERRY AND KOOTENAY LITTLE CHERRY

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JACK MORTON WILKS

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APPROVED:

[redacted]

Professor of Botany and Plant Pathology.

In Charge of Major

[redacted]

Head of Department of Botany and Plant Pathology.

[redacted]

Chairman of School Graduate Committee.

[redacted]

Dean of Graduate School.

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TABLE OF CONTENTS

THE IDENTITY AND THE RELATIONSHIP OF THE VIRUSES CAUSING WESTERN X LITTLE CHERRY AND KOOTENAY LITTLE CHERRY

INTRODUCTION

In the cherry growing regions of the Pacific Slopes of North America there occur a number of virus diseases which cause a reduction in the size of cherry fruits. These diseases are often referred to, collectively, as the "little cherry group". In addition, there is a virus disease in cherry in the Eastern United States and Canada that appears to be very closely related to this group of diseases. The application of names to the diseases in the "little cherry group" has been based partly on disease behaviour and partly on regional occurrence. In the west their distribution is as widely separated as British Columbia, California, and Utah. Due to their serious nature the assembling of these diseases in any one area for a comparative study is inadvisable. This has made the study of the relationship of these diseases difficult.

Kootenay little cherry and western X little cherry were selected for this study. Considerable information had already been accumulated on the relationship of the two diseases in certain hosts, but for the most part, comparable studies had not been carried out simultaneously. The purpose of the study was to complete these data for both diseases as well as to obtain additional data on other possible differential host reactions.

The "little cherry group" of virus diseases in sweet cherry includes those that have been named cherry buckskin, little cherry, albino disease, small bitter cherry, western X little cherry, and Utah wilt and decline. Diseases known as red leaf in chokecherry, and western X-disease, X-disease, and yellow leafroll in peach, have been shown to have the same causal virus as some of the cherry diseases in this group.

The first disease in this group to be reported was the buckskin disease in California. The occurrence of this disease and proof of its transmission by grafting were reported by Rawlins and Horne in 1930 and 1931 (22, p. 853) (23, p. 333). Three strains of the disease have been described: the Napa Valley, the Green Valley, and the Palo Alto strain (30, p. 99). Their distribution is limited to several counties in Northern California (30, p. 98). These diseases cause western X-disease in peach, red leaf in chokecherry, and wilt and decline in sweet cherry on mahaleb understock (30, p. 101).

Little cherry was reported from Willow Point in the Kootenay District of British Columbia in 1933 (6, p. 40). In 1941, Foster demonstrated the virus nature of the disease. (7, p. Y47) Observations over the next several years showed a rapid spread of this disease within orchards, and from orchard to orchard. Within a period of 12 years after

first discovery, at Willow Point, this disease spread to the east through widely scattered orchards into the Creston Valley, a distance of over 50 miles (9, p.1). This rapid spread continued, and by 1949 very few healthy cherry trees remained in the Kootenays. The known distribution of this disease is still limited to the Kootenay area. The rapid spread of the virus, and the complete loss of market value of the fruit from infected trees in certain areas has made this one of the most serious virus diseases in sweet cherry.

In 1937, the albino disease was reported from Ashland, Oregon, by Zeller, Milbrath, and Cordy (33, p.937). The local spread of this disease was very rapid, but the known distribution is still limited to the Rogue River Valley in Southern Oregon (30, p.103). The symptoms of this disease in sweet cherry on mazzard understock are very similar to the symptoms produced by the Napa strain of buckskin, and may be demonstrated to be caused by the same virus (32, p.141). In sweet cherry on mazzard understock this disease causes the formation of small colorless fruits which often drop before harvest. On mahaleb understock, a rapid wilt and decline, followed by death of the tree, is common in the year following infection (30, pp.103-104). Peach is not susceptible to the albino disease and no western X-disease has been noted in the area where albino disease occurs, either from natural infections or from

inoculations (14, p.6).

In 1940, small bitter cherry was observed in the southern districts of the Okanagan Valley of British Columbia (12, p.260). Transmission experiments were started in 1941 by Lott (13, p.444), and proof of the virus nature of this disease was obtained in 1949 from these original inoculations. The disease has been confined to the South Okanagan district of British Columbia with very little spread within the area. Western X-disease in peach is widely distributed in the same area and has been frequently found near trees infected with small bitter cherry (10, p.W84). Transmissions of small bitter cherry from sweet cherry to peach producing symptoms of western X-disease and to chokecherry producing a red leaf reaction indicate that this disease is similar to western X little cherry (5, p.23).

Since 1946, a virus disease first referred to as little cherry and later named western X little cherry, has been reported from Washington (2, pp.2-3), Oregon (34, p.56), Idaho (18, p.434), and Utah (27, p.10). Previous to this, western X-disease in peach, which has been shown to be caused by the same virus, was reported from Washington (25, p.116), Oregon (31, p.452), Idaho (1, p.216), Utah (26, p.474), Colorado (3, p.474), and the Okanagan Valley of British Columbia (4, p.35). Western X little cherry has also been shown to cause red leaf in chokecherry, and wilt

decline condition in sweet and sour cherry on mahaleb understock (28, p.19). Two types of symptom manifestation have been reported in sweet cherry (17, pp.433-34). One type occurs in Washington, Oregon, and Northern Idaho and the second one is present in Southern Idaho and Utah. The Southern Idaho and Utah type differs from the more common type in the production of a rosetted condition in the spurs and an elongation of the stipules.

In Eastern United States and Canada, a small cherry disease occurs on sour cherry (21, p.20), and has been observed in the sweet cherry variety Windsor (30, p.37). This disease has been shown to be caused by the same virus as that of X-disease in peach.

In 1951, yellow leafroll was reported from California, and the virus nature of this disease was shown by Nyland and Schlocker (19, p.33). The symptoms resemble those of western X-disease in some respects, but the two diseases can be readily distinguished from each other (29, p.40). Its relation to diseases in the "little cherry group" was demonstrated when transmission to sweet cherry on mahaleb was obtained, producing wilt and decline (20, p.942).

The possible relationships of these diseases have been discussed frequently in the literature, and these discussions have been summarized in the handbook "Virus

Diseases and Other Disorders with Viruslike Symptoms of Stone Fruits in North America "(30, pp.51-52, 104-105, 129). However, there has been little opportunity for investigation of these relationships. In California, the Napa strain of buckskin was established in Green Valley and found to maintain the symptoms of this disease observed in Napa Valley. (24, p.920) Hildebrand (11, pp.40-45) has reported the results of a comparison of eastern X disease in peach with four sources of western X-disease from California, Utah, Idaho, and Oregon. He found differences in the thermal inactivation point and symptomatology among all sources tested, but concluded that X disease, California X-disease and Utah X-disease were related strains of the same virus. Oregon X-disease and Idaho X-disease did not show such a close relationship to this group or to each other.

EXPERIMENTAL METHODS

Development of Techniques

One of the serious handicaps in the study of viruses in the "little cherry group" has been the small number of satisfactory host plants available for comparative studies. This is particularly true of Kootenay little cherry for which there are no foliage symptoms in the common commercial varieties. The only symptom is an abnormal development of the fruit during the final ripening period. This symptom can be observed only during one short season of the year and is frequently so mild that accurate diagnosis is difficult. There has been a need for an indicator host plant which would exhibit characteristic foliage symptoms following virus infection.

During the course of varietal resistance studies, some of the sweet cherry varieties and seedlings tested developed a characteristic foliage reaction when inoculated with Kootenay little cherry. In an orchard at Kootenay Bay, British Columbia, where 54 sweet cherry varieties and promising seedlings had been propagated as branches on diseased trees of standard varieties, a number of these varieties or seedlings developed leaf symptoms during the months of July and August. These symptoms included reddening of varying intensities on one or both surfaces of the

lamina of the leaf. Some of these varieties also produced prominent light green or yellow mottles, necrotic lesions and laceleaf conditions.

Twenty-two of the varieties and seedlings showing these symptoms were selected for further study and have been under observation in the Kootenay Bay orchard for a period of two to three years. They include: Bear River, Black Oxheart, Sam, Velvet, Star, S-6-7(7), S-8-4(SF), S-7-9(SF), S-7-10(SF), S-3-18(7), S-5-11(7), S-6-6(7), S-3-3(7), S-7-11(SF), S-7-1(SF), S-8-14(SF), S-9-10(SF), S-3-7(7), S-5-19(7), S-5-4(SF), S-10-14(7), and S-5-16(7). In making the observations on these varieties and seedlings three degrees of coloration were recorded: slight when only a very faint reddish color developed, moderate when the intensity was increased, and severe when the entire leaf expressed the deep red coloration on one or both surfaces.

No healthy trees of these varieties or seedlings were growing in the Kootenays. Therefore, comparative observations had to be made on the same clones grown at the Experimental Station at Summerland, British Columbia, in the summer and fall of 1949. Although these varieties and seedlings displayed unusually strong autumn coloration, they showed none of this tendency to develop the early summer red color noted when they were inoculated with

Kootenay little cherry.

A chlorotic mottle and a necrotic spotting accompanied the reddening produced in some of these clones. These symptoms are suggestive of ring spot viruses frequently found in sweet cherry sources. To determine if these ring spot viruses might also produce the red leaf reaction, Star trees were inoculated with sweet cherry sources free from little cherry, but carrying the ring spot virus. Buds from three ring spot infected Lambert trees in the Creston District were used as inoculum and were inserted into 3 Star trees located in an isolated plot in West Creston, 8 miles from the closest little cherry source in the Kootenays. These trees were observed throughout the season for the development of early red pigmentation, and the effect of ring spots alone was compared with the effect of inoculation with little cherry plus the contaminant ring spots.

For further proof of the specificity of this reaction, tests were made for the presence of ring spots in these varieties. The necrotic mottling of sweet and sour cherries has often been interpreted as a shock reaction of primary invasion of the ring spot viruses. Varieties already carrying the virus do not produce this shock effect. Therefore, as a further check on the necrotic spotting noted with the red coloration on some varieties and seedlings,

fourteen of them were indexed on Shirofugen (15, p.15-16) to determine whether they were already contaminated with ring spot. Also, if they were found to be already infected with ring spot before inoculation, and did not show the early red coloration until inoculated with little cherry, further proof would be offered that the red leaf reaction was a direct effect of the little cherry virus. The clone of Star used for all the red foliage tests was also indexed on sour cherry for the presence of ring spot and sour cherry yellows.

Star was inoculated with some of the other common stone fruit viruses to determine whether the red leaf reaction is specific for diseases in the "little cherry group", or whether it is a more general reaction to virus infection. The viruses selected for these tests were rusty mottle, mora, and ring spot plus yellows. Sixteen two-year old Star trees were established in the greenhouse in Corvallis in January, 1953. They were divided into 4 sets of 4 trees each and inoculated at bud-break using three buds in each test tree. Four trees were left uninoculated as checks. The inoculum was obtained from the plots at Corvallis maintained by the Oregon Agricultural Experiment Station.

Comparative Studies

Kootenay little cherry and western X little cherry were compared on a number of different host plants, and on host plants growing on different understocks. Other host reactions such as rate of virus movement, reduction of fruit weight, soluble solids content of mature fruit, and weight and oil content of the seed were also compared. The serious nature of these diseases and the danger of introducing them into new areas prevented a direct comparison in the same area, and made necessary the establishment of separate plots.

Studies of western X little cherry were conducted at The Dalles, Oregon, where plots are being maintained for work on this disease by the Oregon Agricultural Experiment Station. Many of the other data on western X little cherry which have been used in this study were obtained from work which is now underway at this station. Some tests were conducted during the winter months in the greenhouse of the Oregon Agricultural Experiment Station at Corvallis.

For the study of Kootenay little cherry, a plot was established in the Creston Valley at Erickson. Although this plot is not immediately adjacent to commercial plantings, it is located in an area that is now generally infected with little cherry. Where isolation from natural infection was essential, the trees were grown in screen

cages (plate 1). These cages were built of 32 x 32 mesh brass screening which was suitable for the exclusion of all suspected insect vectors. Some of the experiments were conducted in a greenhouse in Creston. Many of the tests conducted with Kootenay little cherry were designed for comparison with results which have already been obtained

Plate 1. Screen cage used when isolation from natural infection was essential. Each cage is 10 feet high and 8 feet square, and the screen roof is protected by a wooden top during the winter. Photo by M.F. Welsh.

for western X little cherry. Peach, chokecherry, and sweet and sour cherry on mazzard and mahaleb understock were established for these studies.

Sweet Cherry Foliage Indicator Varieties

The four varieties and seedlings S-5-16(7), S-7-10(SF), S-8-4(SF), and Sam which developed moderate to severe reddening reactions to Kootenay little cherry were selected for tests with western X little cherry. These varieties and seedlings were established in the plot at The Dalles, Oregon, by grafting them on the arms of two-year old mazzard seedlings which had been previously trained to four scaffold limbs. They were established in the spring of 1952 and were inoculated one year later by chip budding. Ten two-year old Star trees on mazzard understock were planted in 1951 and five of them were inoculated in the summer of 1952. All inoculations were made from a Bing tree infected with western X little cherry in the Kronberg orchard known as E10. This virus source was selected because it has consistently produced a very high percentage of diseased fruits and previous inoculations from it have yielded a high percentage of transmissions.

Lambert and Montmorency on Mazzard and Mahaleb Understock.

Ten two-year old Lambert trees on mahaleb under-

stock were established in the Erickson plot in 1951. Using the same virus source each year, every second tree was inoculated with Kootenay little cherry in 1951 and again in 1952. For all the trees, the soil was removed down to the graft to prevent secondary roots from forming on the sweet cherry stock.

Ten two-year old Lambert trees on mazzard understock were established in the Erickson plot in 1951, and four of these trees were inoculated with Kootenay little cherry in 1951 and again in 1952.

Plots similar to those for Lambert were established for Montmorency on both understocks. Experiments involving Lambert and Montmorency trees are summarized in tables 6 and 7.

The terminal growth obtained in 1952 and 1953 was measured for Lambert trees on both understocks. The trunk diameter of each tree was measured at a point one foot above the graft.

Peach Varieties

Two-year old trees of Elberta, Rochester, Vedette, and Hale peach were established in the Erickson plot in 1951. These trees were inoculated with Kootenay little cherry from various source trees in the Kootenay Bay plot in the summer of 1951 and as no symptoms had developed by

the summer of 1952, they were re-inoculated from the original source tree. The experiments involved in these studies are summarized in table 8.

Western Chokecherry, Prunus demissa (Nutt.) Walp.

Western X little cherry produces an early fall red leaf reaction in western chokecherry. To determine whether Kootenay little cherry produces the same reaction, 13 trees of P. demissa were established in 1951 in the Erickson plot and 5 of them were inoculated from Kootenay Bay source trees. The inoculations made are as follows: 3 trees inoculated from tree 31 (3 buds in 1951 and 5 in 1952), 1 tree inoculated from tree 17 (3 buds in 1951 and 5 in 1952), 1 tree inoculated from tree 29 (2 buds in 1951 and 5 buds in 1952).

Virus Effects on the Fruit.

Studies were made of the weights and soluble solids contents of comparable samples of diseased and healthy fruit from trees infected with western X little cherry at The Dalles, Oregon, and trees infected with Kootenay little cherry at Creston, British Columbia. For comparison of the weights of healthy and diseased fruits, 150 to 200 cherries were used in each test. In the tests of the soluble solids content, 15 to 20 fruits were used. Duplic-

ate samples of healthy and diseased fruit were used for all varieties tested. A Bausch and Lomb refractometer was used to measure the soluble solids content. Each test was made by cutting along the suture line of the fruit and then squeezing a small amount of juice onto the refractometer.

Weight and Oil Content of the Seed

Tests were made of the weight and oil content of seed from healthy and little cherry infected trees at Creston, British Columbia. Fifty air dried seeds were used in each oil determination. The oil extraction was made with a Soxhlet extractor. Each sample was ground up in a mortar with a small amount of ether. The material was transferred to a Soxhlet extraction thimble which was placed in the extractor above one-hundred and twenty-five mls. of ether. The extractions were made for two periods of 24 hours each. After the first extraction, the ground seed was removed and ground into a finer powder and the extraction procedure repeated. At the end of the second extraction, the ether was evaporated and the weight of the oil which remained was taken. From these data, the average weight of oil from healthy and diseased seed was calculated. Since similar experiments had already been conducted for western X little cherry by Jones, Wilks and Williams[1], this work was not

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1 Unpublished data.

duplicated in these studies.

Rate of Virus Movement

Comparative studies of the two diseases were made for rates of natural spread within orchards and of virus movement within individual trees. The rate of spread of western X little cherry within a tree following virus infection is being studied by the Oregon Agricultural Experiment Station (16). Three years of data have been obtained for 8 of the 12 trees and 2 years of data for the remaining 4 trees. The inoculations were made into a single branch of each tree and virus movement was recorded by painting infected spurs and infected branches each season when the fruit was ripe. Information on the rate of tree to tree movement of western X little cherry was obtained from survey work which has been in progress since 1947 (16).

For Kootenay little cherry, information on tree to tree spread was obtained from surveys which have been made by the provincial plant pathologist. Data on the movement of Kootenay little cherry in individual trees was obtained from inoculations made into four five-year old Star trees inoculated in 1951. In 1952, the terminals of all inoculated branches were showing symptoms. The base of each of these terminals showing symptoms was painted and

the distance the virus had moved during the two year period was measured in 1953.

EXPERIMENTAL RESULTS

Development of New Indicator Hosts For Kootenay Little Cherry

In an attempt to find sweet cherry clones resistant to Kootenay little cherry, large infected trees of Lambert were top-worked with scions of various varieties and unnamed seedlings. The first group was established in 1946, and by 1948 two of them, Star and the seedling S-6-6(7) developed a strong red pigmentation during the months of July and August. This same symptom again appeared on these branches in 1949 and has continued to be expressed every year since then. No such pigmentation was evident in the Lambert foliage or in the foliage of other varieties budded to the same trees. There were no healthy trees of Star and S-6-6(7) in the Kootenay Bay plot for direct comparison. However, the parent trees growing on the Summerland Experimental Station, although they produced the strongest red autumn coloration of all the sweet cherries in the planting, showed no tendency for early summer development of red pigments. There appeared a probability therefore that the summer reddening was caused by the little cherry virus.

In Star, the strongest symptoms developed in the basal leaves of the current season's growth, becoming

progressively less intense in the leaves towards the tip of the branch. The upper surface of severely affected leaves displayed a solid red color around the margins of the leaf which decreased in intensity towards the midrib. On less severely affected leaves, the red pigmentation was confined to the interveinal areas, with the main veins and adjacent tissue remaining a normal green and in many cases, even the veinlets remaining free from the red pigmentation. The undersurface of the leaf showed only a slight red color which often appeared as a stippling of red in the interveinal areas. (plate 2)

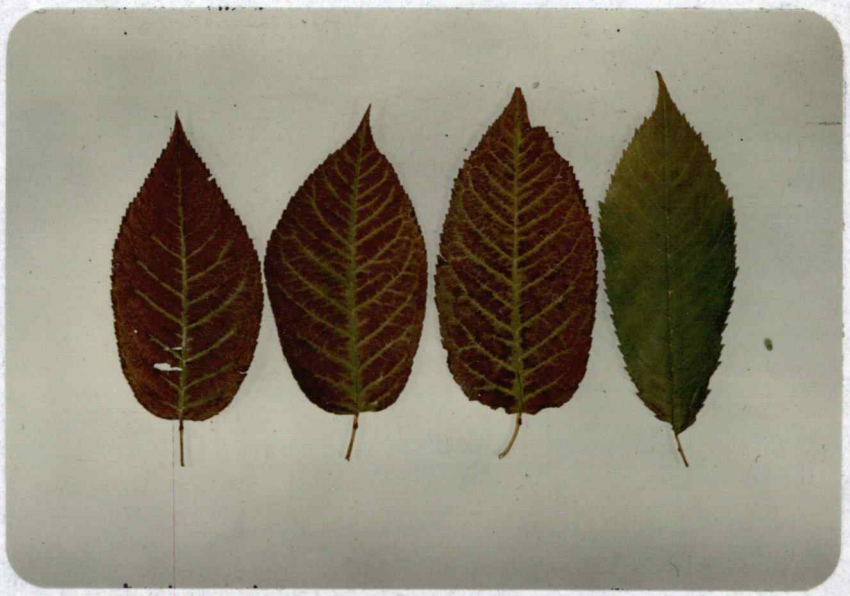

Plate 2. Leaf symptoms in Star inoculated with Kootenay little cherry. Photograph taken September 25, 1952, at season of maximum symptom expression. Leaf at right from uninoculated Star. Photo by S.R. Cannings.

In S-6-6(7), the development of the reddening was very similar to that observed for Star, but the intensity

of the color was not as strong. The reddening was first apparent on the upper surface, but later in the fall both surfaces showed equally strong symptoms. In addition to the red leaf reaction, this variety also developed strong chlorotic and necrotic lesions which later dropped out giving the leaf a shot-hole appearance.

Of the 54 varieties and seedlings established on diseased Lamberts in the Kootenay Bay plot, twenty-six displayed the red leaf symptom. The twenty-two varieties and seedlings showing the strongest coloration were selected for further study. These were observed during 1951 and 1952 to determine the date of first appearance of the red pigmentation symptoms and to follow their subsequent development. The data from these studies are summarized in table 1. The reddening usually developed on both surfaces, but the upper surface produced a stronger coloration. This was especially true of varieties that showed slight or moderate symptoms, the coloration in such varieties usually being apparent only on the upper surface. Interveinal reddening was the type most frequently observed, but in certain varieties, the color developed over the entire leaf surface including the veins. In some varieties, the reddening was confined to a narrow margin along the veins.

The first appearance of the red pigmentation varied somewhat with the season, but usually occurred about

Table 1. Kootenay little cherry: Symptoms in sweet cherry varieties producing leaf reactions.

Variety	Date of first symptoms 1951	1952	Chlorotic or necrotic mottles	Reddening	Red leaf symptoms
S-5-11(7)	Aug. 21	Aug. 18	Some chlorotic and necrotic mottle, mostly on tip leaves	Slight	Reddening present on upper surface and later in season also on lower surface. Mostly interveinal.
S-3-18(7)	Aug. 15	Aug. 18	Some chlorotic and necrotic mottle on one tree	Slight	General light red color scattered over both leaf surfaces
S-3-3(7)		July 10	None	Slight	Light red color mostly along the margins of the leaf blade and stronger on the undersurface.
S-8-14(SF)	Aug. 21	Aug. 18	None	Slight	Slight interveinal reddening, mostly on upper surface.
S-9-10(SF)	Sept. 10	Aug. 18	Some chlorotic and necrotic mottle	Slight	Light red coloration almost entirely on upper surface and developing interveinally from the margins inward

Table 1. (cont'd)

Variety	Date of first symptoms 1951	1952	Chlorotic or necrotic mottles	Reddening	Red leaf symptoms
Velvet	Sept. 7	Aug. 18	Chlorotic mottle plus some necrotic shothole	Slight	Reddening of both surfaces, interveinal and developing from margins inward
S-10-14(7)	Sept. 7		Slight chlorotic mottle on some leaves	Slight	Light red color developed mostly on upper surface and interveinal
S-3-7(7)	Sept. 7		None	Slight	Slight reddening of both surfaces, more severe on undersurface
S-6-7(7)	Aug. 21	July 10	Chlorotic plus some necrotic mottle	Moderate	Slight reddening first apparent on lower surface and later on upper surface and eventually becomes more pronounced on upper surface; interveinal
Sam	July 17	July 10	Some laceleaf and necrotic lesions on tip leaves	Moderate	Narrow red band between veins on upper surface; very slight on lower surface. Reddening more apparent at first on undersurface, and primarily basal leaves.

Table 1. (cont'd)

Variety	Date of first symptoms 1951	1952	Chlorotic or necrotic mottles	Reddening	Red leaf symptoms
S-7-1(SF)	July 31	Aug. 18	None	Moderate	Interveinal reddening general over both surfaces. Has stippled, blotchy appearance on some leaves
Bear River	July 17	July 10	None	Moderate	Marginal reddening of undersurface of leaf blade in some cases. In other cases, reddening of undersurface is general. Blotchy on upper surface; reddening usually not all interveinal
S-7-1(SF)	July 31	July 10	Necrotic and chlorotic mottle developed on basal leaves	Moderate	Interveinal reddening along margins of undersurface, occasionally breaking through to upper surface.
Black Oxheart	Aug. 20	July 10	Necrotic lesion, mostly on tip leaves	Moderate	Interveinal reddening coalescing on leaf margins and more severe on upper surface
S-5-19(7)			None	Moderate	Reddening on both surfaces interveinal, except along leaf margins

Table 1. (cont'd)

Variety	Date of first symptoms 1951	1952	Chlorotic or necrotic mottles	Reddening	Red leaf symptoms
S-5-4(SF)			None	Moderate	Interveinal reddening mostly on upper surface and along leaf margins
S-8-4(SF)	Aug. 21	Aug. 18	Chlorotic and necrotic mottle of basal leaves. In one case, only necrotic mottle	Moderate	Reddening more severe on tip growth and upper leaf surface, interveinal. Petioles red.
S-6-6(7)	July 27	Aug. 5	Strong chlorotic mottle plus some necrotic mottle	Severe	Reddening mostly interveinal; blotches ranging from light to dark red in color. First appears on upper surface, but equally distributed on both surfaces later in the season.
Star	July 17	July 10	Chlorotic mottle plus some necrotic mottle on certain trees	Severe	Leaves upcurled slightly Reddening interveinal at first but later in fall, in many cases, only the midrib remains green; rest of leaf a deep red color on upper surface. Only small blotches of red on lower surface.

Table 1. (cont'd)

Variety	Date of first symptoms 1951	1952	Chlorotic or necrotic mottles	Reddening	Red leaf symptoms
S-5-16(7)	July 17	July 10	None	Severe	Reddening more intense on undersurface and entirely interveinal. Lighter, but over entire leaf on upper surface. In some cases, there is a leaf distortion, with an accompanied increase in reddening.
S-7-9(SF)	Aug. 15	July 10	Necrotic lesions	Severe	Deep reddish purple colour solid over upper surface except for yellow green colour of veins. Only light red colour along margins on undersurface.
S-7-11(SF)	July 17	July 10	None	Severe	First apparent on lower surface; later more severe on upper. Mostly interveinal, but tends to coalesce along leaf margins to give a solid red colour.

the first of July. The color increased in intensity during the summer months and reached a maximum about the middle of September. The expression of maximum reddening appeared to be dependent upon cool weather, the date of which varied from year to year. At the time of maximum symptom expression in diseased trees at Kootenay Bay and Erickson, healthy trees of the same varieties in the Erickson plot still showed very little or no evidence of red coloration.

Young trees of Star, Sam, S-6-7(7), and S-6-6(7) were established in the Erickson plot so that young trees of these varieties could be inoculated directly with buds from trees infected with little cherry. This experiment was designed to determine whether young trees of these varieties would respond in a manner similar to those in the Kootenay Bay orchard where they had been established as branches on infected trees.

Trees of Star on mazzard understock which were inoculated in 1951 displayed leaf symptoms on the inoculated branches in 1952 and throughout the trees in 1953. Faint symptoms were evident by the middle of June and were fairly strong by mid-July, reaching full intensity after the advent of cool nights in September. Uninoculated comparable young Star trees in West Creston displayed no foliage coloration until mid-October, shortly before defoliation. Young trees of Sam, S-6-6(7), and S-6-7(7) in

the Erickson plot that were inoculated in 1952 displayed symptoms on inoculated branches in 1953. These symptoms corresponded precisely with the symptoms observed on the same clones in the Kootenay Bay plot. Their times of appearance corresponded closely with those of the symptoms in Star. Uninoculated check trees in West Creston displayed only the late October foliage coloration.

Ring spot contaminant viruses were found to be present in all the little cherry inoculum sources used. The possibility that these viruses were responsible for the red leaf reaction was tested in 2 ways as follows:(a) tests were made for the presence of ring spot viruses present in these varieties, and (b) tests were made for the reaction of these varieties to ring spot viruses from other sweet cherry sources.

Ring spot viruses already present in these varieties and seedlings would be expected to protect them from reacting to other ring spot viruses. To test for the presence of these ring spots, 14 of these varieties and seedlings were indexed on Shirofugen. These results are presented in table 2. All the clones except S-3-18(7) gave a positive reaction for ring spot. Star was also indexed on sour cherry for sour cherry yellows. The sour cherry gave a strong reaction for the presence of ring spots, but no reaction for sour cherry yellows.

Table 2. Kootenay little cherry: The indexing on Shirofugen for ring spot of varieties showing red leaf reaction.

Variety	Result	Remarks
S-3-18(7)	negative	buds alive
S-6-6(7)	positive	browning of cambium and gumming
S-9-10(SF)	positive	browning of cambium and gumming
S-3-3(7)	positive	slight gumming and severe necrosis of cambium
S-3-7(7)	positive	gumming and browning of cambium
Star	positive	gumming and browning of cambium
Sam	positive	gumming and browning of cambium
Velvet	positive	necrosis of cambium
S-7-10(SF)	1 positive 1 negative	very slight necrosis of cambium buds alive
S-5-19(7)	positive	necrosis of cambium
S-8-4(SF)	positive	necrosis of cambium and gumming
S-5-11(7)	positive	necrosis of cambium and gumming
S-6-7(7)	positive	necrosis of cambium and gumming
S-5-16(7)	positive	necrosis of cambium and gumming

To test the reaction of these varieties to ring spots alone 3 Star trees were inoculated with ring spot viruses from Lambert. Inoculations were made in 1951, and observations made over the next two years showed no development of the red leaf symptoms similar to those observed for Star trees inoculated with Kootenay little cherry.

Tests were conducted to determine whether viruses other than those in the "little cherry group" might be effective in producing this symptom in Star. These tests were carried out in the greenhouse in Corvallis in January 1953 with the mora, rusty mottle and ring spot plus sour cherry yellows virus. No symptoms developed during 1953 from any of these inoculations into Star, although similar trees inoculated with western X little cherry produced typical red leaf symptoms. These trees, when established in the greenhouse in February, 1954, produced symptoms characteristic of these diseases, but no red leaf symptoms.

Comparative Effect on Host Plant

Cherry Varieties

Red Leaf Indicator Varieties. Five of the varieties and seedlings which produced strong red leaf symptoms as a result of inoculations with Kootenay little cherry were selected for a comparable study with western

X little cherry at The Dalles, Oregon. Table 3 lists the varieties tested and their reactions to western X little cherry from observations which were made on September 25th, 1953. The data show that these varieties reacted essentially in the same manner in which they react to Kootenay little cherry, but the varieties and seedlings Sam, S-5-16(7), and S-7-10(SF), produced a strong coloration along the veins with western X little cherry whereas their characteristic symptom with Kootenay little cherry is the interveinal reddening.

Lambert on mazzard and mahaleb understock. Sweet cherry varieties have been shown to produce characteristic symptoms when inoculated with western X little cherry. On mahaleb understock, wilt and decline symptoms have been found to occur at any time during the growing season. The first symptom is the appearance of a light green or yellow color in the leaves. Later, the leaves die, with or without formation of an abscission layer. When this occurs they become reddish brown and persist on the tree throughout the summer and following winter. In Lambert on mazzard, the symptoms of western X little cherry are limited to those expressed in the fruit.

The Lambert variety was selected for studies with Kootenay little cherry because it is the variety reacting most severely to little cherry, producing very distinctive

Table 3. Western X little cherry: Reactions in sweet cherry varieties producing red leaf symptoms

Variety	Reddening	Remarks
S-5-16(7)	Slight	In contrast to Kootenay form, which is interveinal, the reddening followed the veins and veinlets almost entirely. Rest of the leaf was a yellow green color.
S-7-10(SF)	Slight to moderate	Reddening stronger on the upper surface and appears to follow the veins and margins of the leaf. In one branch, a reddish purple pattern developed. The rest of the branches had some purple colour, but it was much lighter. The same colour intensity developed on the undersurface, but it was more scattered.
Sam	Moderate	Reddish coloration over the entire leaf blade with the greatest concentration of the red pigmentation around the veins. The undersurface of the leaf was a yellow green colour except for a slight reddening of the veins.
S-8-4(SF)	Moderate	Dark red coloration similar to that produced by this variety in the Kootenays. In addition, there was some marginal reddening and leaf distortion. Rest of leaf was a yellow green colour. On the undersurface, the reddening appeared as scattered dark red blotches.
Star	Severe	Dark red interveinal reddening developed which was similar to that produced by the Kootenay form, but not quite as pronounced. The undersurface had a reduced amount of reddening as compared to the upper surface. Symptoms were limited to the inoculated branch.

fruit symptoms. When five two-year old Lambert trees on mahaleb understock and four on mazzard understock were inoculated with Kootenay little cherry, there was a reduction in vigor of all trees the first year as compared to the five trees left for checks on each understock. This became apparent by August and was characterized by reduced terminal growth and, in Lambert on mahaleb understock by a yellow green color and upcurling of the leaves. Measurements of the reduction of growth of these trees on both understocks were made in the winter of 1953 and are summarized in tables 4 and 5. In the measurements of Lambert on mahaleb, only two of the check trees could be included as 1 tree was stunted because of a root and crown rot, and 2 trees produced little cherry symptoms as a result of natural spread in the plot. For the 5 inoculated trees the average trunk diameter was 5.85 inches, compared with 7.37 inches for the two healthy trees. In 1952, the terminal growth of these trees ranged from 22 to 28 inches for the diseased trees compared with 31 to 34 inches for the check trees, while in 1953 the growth of the diseased trees ranged from 8 to 15 inches compared with 17 to 25 inches for the healthy checks.

Lambert on mazzard showed a reduction in growth similar to that displayed in Lambert on mahaleb. These results are summarized in table 5. The average trunk

Table 4. Lambert cherry on mahaleb understock: Growth measurements of healthy trees and trees infected with Kootenay little cherry.

Tree Number	Healthy or Diseased	Terminal Growth 1952 inches	Terminal Growth 1953 inches	Number of leaders	Trunk diameter
1	Diseased	30-36	5-13	2	6.25
2	Healthy	30-36	15-19	2	6.75
3	Diseased	25-36	15-22	2	7
4	Healthy	33-53	20-36	2	8
5	Diseased	20-23	8-20	2	6
6	Naturally infected	28-40	14-20	2	9.25
7	Diseased	22-24	7-14	1	5
8	Naturally infected	28-46	12-18	2	6.75
9	Diseased	15-23	4- 6	1	5
Average	Diseased	22-28	8-15		5.85
Average	Healthy	31-44	17-25		7.37

Table 5. Lambert cherry on mazzard understock: Growth measurements of healthy trees and trees infected with Kootenay little cherry.

Tree number	Healthy or Diseased	Terminal Growth 1952	1953	Number of leaders	Trunk Diameter
		inches	inches		
1	Diseased	30-50	17-23	2	6.75
2	Healthy	35-50	12-25	2.75	7
3	Diseased	28-32	9-11	1	4.25
4	Healthy	30-55	15-35	3	7.25
5	Healthy	30-46	16-25	2	6
6	Healthy	25-40	15-30	2	6
7	Diseased	20-27	10-16	2	5.75
8	Healthy	30-53	20-30	2.5	7.75
9	Diseased	20-26	7-15	1	4.5
10	Healthy	25-31	15-24	3	6.26
Average	Diseased	25-34	11-16		5.37
Average	Healthy	29-46	15-28		6.7

diameter of diseased trees was 5.37 inches compared with 6.7 inches for healthy trees. In 1952, the terminal growth of diseased trees ranged from 25 to 34 inches compared with 29 to 46 inches for healthy trees, while in 1953, the diseased trees ranged from 11 to 16 inches compared with 15 to 28 inches for the check trees.

No fruits were produced on any of the trees until 1953. At that time, all inoculated trees produced over the entire tree fruit symptoms typical of Kootenay little cherry. These symptoms which are apparent only at fruit maturity are characterized in Lambert by the production of small dull red immature fruit which never attains more than about half the size of normal fruit. The affected fruit remains hanging on the tree and retains its immature appearance far beyond the normal picking date. In addition, the fruit is more angular and pointed than normal and often has three flat sides tapering towards the distal end. It never attains the flavor of normal fruit. Plate 3 shows Kootenay little cherry symptoms in the Lambert variety.

The tests of Lambert on mazzard understock were conducted to study the performance of trees when artificially inoculated and to compare the reaction of these trees with that of similar trees established on mahaleb understock. The results of these tests are summarized in

table 6. In all cases, there were no symptoms until the second year after inoculation, when all the trees fruited. At that time, the 4 inoculated trees showed Kootenay little cherry symptoms over the entire tree while the 5 check trees produced normal fruit. These symptoms were identical with those described above for Lambert on mahaleb understock. Apart from a slight upcurling of the leaf margins, and a slight reduction in the growth of inoculated trees, there was no other symptom manifestation in this variety.

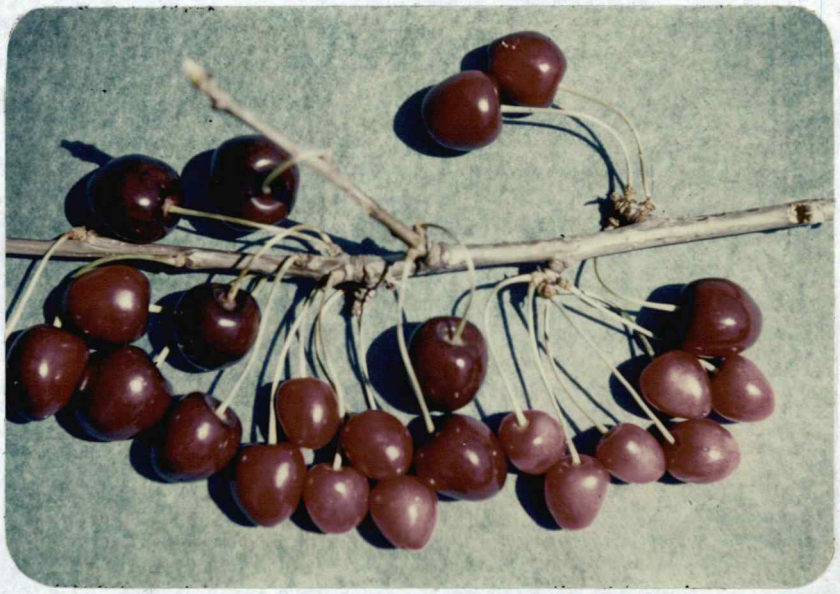

Plate 3. Symptoms of Kootenay little cherry in Lambert; specimens from tree in a commercial orchard. Note production of apparently normal fruit with the small fruit. Photograph by S.R. Cannings.

Montmorency on mazzard and mahaleb understock.

Western X little cherry produces rather distinctive

Table 6. Kootenay little cherry: Transmission studies in the Lambert variety on mahaleb and mazzard understock.

Understock	Number of trees	Inoculum source	Number of inoculum buds 1951	Number of inoculum buds 1952	Host reaction
Mahaleb	1	#44	3	5	All trees showing little cherry symptoms throughout tree and by September shoots showing reduced growth; leaves yellow-green and upcurled
Mahaleb	3	#31+#49	3	8	
Mahaleb	1	#17	3	5	
Mahaleb	5	Non-inoculated check			Trees and fruit normal except for 2 trees naturally infected.
Mazzard	2	#44	3	5	Little cherry symptoms over entire tree plus slight reduction in growth
Mazzard	1	#17	3	5	
Mazzard	1	#49	3	5	
Mazzard	6	Non-inoculated check			Trees and fruit normal.

symptoms on Montmorency sour cherry on mazzard and mahaleb understock. Montmorency on mahaleb understock manifests wilt and decline, seldom accompanied by fruit symptoms. Typical little cherry fruit symptoms are produced in this variety when it is established on mazzard understock. The Montmorency trees used in the study of Kootenay little cherry were purchased from nurseries producing ring spot-free stock. Therefore, inoculation of these trees in 1951 with Kootenay little cherry, which is normally carrying ring spot as a contaminant, resulted in a shock reaction characteristic of necrotic ring spot viruses (30, p.165).

In 1953, the trees had shown partial recovery from the ring spot reaction and all trees produced a fairly normal crop of fruit. Four of the 5 inoculated trees on mahaleb understock displayed little cherry symptoms characterized by small round fruits which developed a distinct orange color at maturity. (see plate 4) On each tree, these symptoms were produced only on the inoculated branch adjacent to the point where the sweet cherry inoculum buds had grown. In several cases, there was growth of the sweet cherry buds without any expression of little cherry symptoms in the Montmorency branch. In the inoculated trees not showing little cherry symptoms, the fruit was much smaller than fruit on the check trees,

but this could be due to the reduction of foliage from the ring spot shock. This fruit not showing little cherry symptoms developed normal shape and color. The reactions of the individual trees are outlined in table 7. During the two year period in which these trees were observed, there were no wilt and decline symptoms as reported for Montmorency on mahaleb when inoculated with western X little cherry. (28, p.11)

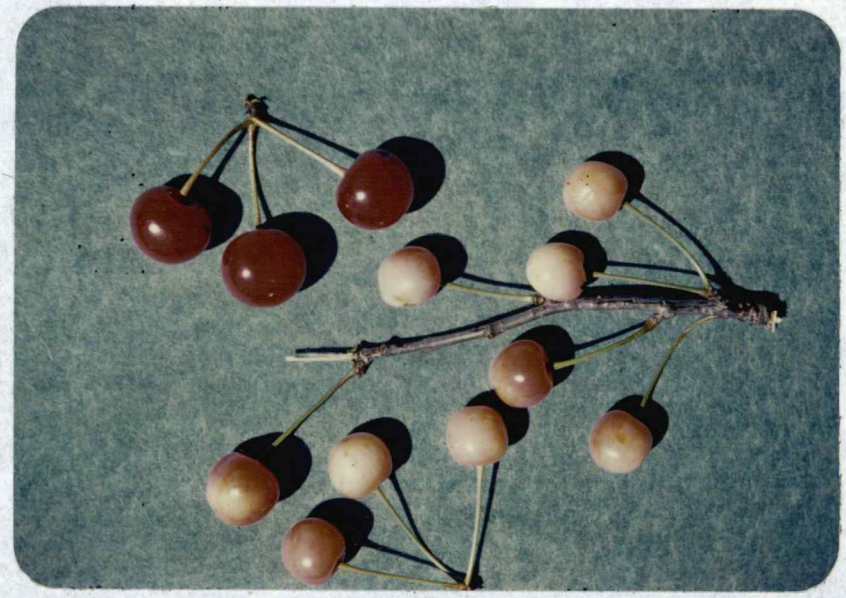

Plate 4. Little cherry symptoms in Montmorency inoculated from diseased Lambert trees. Fruits at upper left hand corner are from healthy trees.

None of the four inoculated Montmorency trees on mazzard showed any indications of little cherry symptoms when they fruited for the first time in 1953. On each of the inoculated trees one or more of the Lambert inoculum buds had grown, indicating that successful transmission

Table 7. Kootenay little cherry: Transmission studies in Montmorency on mazzard and mahaleb understock.

Understock	Number of trees	Inoculum source	Number of inoculum buds		Host reaction	
			1951	1952	Ring spot 1952	Little cherry 1953
Mahaleb	5	#44	4	5	Leaves contained necrotic lesions soon after unfolding. Later turned yellow, with or without green island remaining. All trees 60-75% defoliated by midsummer.	Several inoculated branches on 4 out of 5 trees produced small, orange appearing fruit
Mahaleb	5	Non-inoculated check			Normal growth and leaf development.	Fruit plump and matured normally on all trees.
Mazzard	3	#44	3	5	Symptoms similar to those produced in trees on mahaleb understock	Fruit colored up, but did not attain the size of fruit on healthy trees, probably due to heavy loss of leaves. No little cherry symptoms similar to those observed on Montmorency on mahaleb

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Table 7. (cont'd)

Understock	Number of trees	Inoculum source	Number of inoculum buds 1951	Number of inoculum buds 1952	Ring spot 1952	Little cherry 1953
Mazzard	1	#31	6	5	Die-back up to 18". Leaves showed ring-spot and yellows symptoms. Fruit bumpy at maturity	Fruit coloured up but did not size up normally. No little cherry symptoms similar to that observed on Montmorency on mahaleb.
Mazzard	6	Non-inoculated check			None	None

should have occurred. In 1952 and 1953, the inoculated trees displayed a ring spot shock reaction similar to that produced on Montmorency on mahaleb understock. There was a reduction of fruit size on all inoculated trees, but this was not accompanied by typical little cherry symptoms and presumable resulted from previous ring spot shock in the manner reported above for Montmorency on mahaleb understock. Table 7 lists the individual tree reactions for Montmorency on mazzard.

Peach Varieties

When seventeen young peach trees were inoculated with a total of one hundred and ninety-eight buds from sweet cherry trees infected with Kootenay little cherry, there was never any indication of western X-disease symptoms similar to those produced when peaches are inoculated with western X little cherry (34, p.710). Table 8 gives the inoculation data and the results obtained from these studies. Inoculations made into the peach trees in the summer of 1951 appeared to make good organic union, but by the spring of 1952, all the buds had died. In the spring and summer of 1952, all inoculated trees displayed a shock reaction to the ring spot viruses present in the little cherry source material. The ring spot shock reaction might have prevented satisfactory organic union

Table 8. Kootenay little cherry: Results of transmission to peach.

Variety	Number of trees	Inoculum source	Number of Buds 1951	Number of Buds 1952	Host reaction to latent viruses
Elberta	2	#49	4	6	Slight stunting plus mild ring spot
Elberta	2	#17	4	6	Severe stunting plus slight ring spot
Elberta 2	2	#31	3	6	Necrotic ring spot on all branches
Elberta	2	Non-inoculated check			
Hale	2	#17	4	6	Die-back plus severe stunting
Hale	4	#31	3	6	Strong ring spot symptoms plus die-back up to 4"
Hale		#49	4	6	Moderately severe ring spot. Severe stunting and die-back of 1" on tips
Hale	2	Non-inoculated check			
Rochester	1	#44	10	36	Gumming around buds; no dwarfing
Rochester	1	#29	10	43	Mild ring spot plus severe stunting over entire tree.
Rochester	1	Non-inoculated check			
Vedette	1	#29	10	31	Slight ringspot and mild stunting
Vedette	2	Non-inoculated check			

for entry of the more slowly moving little cherry virus. Therefore, all the peach trees were re-inoculated in 1952 from the same little cherry source trees. The 1952 sweet cherry buds made good organic union and produced active growth on seven out of the seventeen trees. By the end of the 1953 growing season, none of the trees had exhibited symptoms which might be interpreted as those of western X-disease.

Western Chokecherry Prunus demissa (Nutt.) Walp.

Chokecherry was selected as a test plant because it produces a red leaf reaction when inoculated with western X little cherry (30, p.48). Five trees of chokecherry were inoculated with Lambert buds infected with Kootenay little cherry in 1951 and all trees were re-inoculated in 1952. These inoculations resulted in some gumming around the buds the first year after inoculation and all buds died. Following the second year's inoculation sweet cherry buds grew on 2 of the 5 inoculated trees indicating good organic union. By the end of the growing season in 1953 none of these trees showed the characteristic reddening symptom which has been observed in this host when infected with western X little cherry.

Effect on Fruit Development

Size of Fruit

The most readily detected symptom of both of these diseases is a reduction in the size of the fruit. Studies were made in 1951 and in 1952 on the weight of healthy and diseased fruit infected with western X little cherry and Kootenay little cherry. Table 9 summarized the results of these studies. The average weight of fruit infected with western X little cherry was 3.6 grams compared with 8.31 grams for healthy fruit. Fruit infected with Kootenay little cherry had an average weight of 3.94 grams whereas healthy fruit averaged 7.43 grams. Fruit from trees infected with western X little cherry showed a slightly greater reduction (56.7%) in weight than fruit from trees infected with Kootenay little cherry (47.0%).

Soluble Solids Content

One of the characteristic symptoms of western X little cherry and Kootenay little cherry is the lack of flavor in the fruit at maturity. Tests were made on the soluble solids content of fruit infected with both diseases and the data from these tests are summarized in table 9. Fruit showing symptoms of western X little cherry had an average soluble solids content of 9.7% compared with 21.97%

Table 9. Western X little cherry and Kootenay little cherry: Average weight and soluble solids content of fruit showing symptoms.

Variety	Western X little cherry		Kootenay little cherry				
	Av. Wt.[1]	Av. SSC[2,3]	Av. Wt.[1]			Ab. SSC[3]	
	1952	1951	1951	1952	1953	1951	1952
	GRAMS	PERCENT	GRAMS			PERCENT	
Bing							
Healthy	10.12		7.63	7.26	7.02	20.5	19.1
Diseased	3.67		4.25	3.7	3.88	13.0	9.7
Lambert							
Healthy	9.7	24.5	7.55	7.07	7.68	19.5	17.0
Diseased	4.1	11.2	5.14	3.25	3.23	17.0	10.4
Royal Ann							
Healthy	8.49			7.8		19.0	19.7
Diseased	3.39		4.28	4.04		12.5	11.8
Black Republican							
Healthy	4.94						
Diseased	3.15						
Montmorency							
Healthy		19.4					
Diseased		8.2					
Overall Averages							
Healthy	8.31	21.9		7.43		18.8	
Diseased	3.60	9.7		3.94		10.6	

1 - based on 150-250 fruit. 2 - from E. Palm, personal contact. 3 - based on 15-20 fruit

for healthy fruit. In the Kootenays, fruit from trees infected with Kootenay little cherry had an average soluble solids content of 10.6% compared with 18.8% for healthy fruit. Western X little cherry caused a 55.7% reduction in the soluble solids content of fruit showing symptoms, whereas Kootenay little cherry caused a reduction of 43.6%.

Size of Seed

In 1952 and 1953, pits were collected from healthy and diseased Bing, Lambert and Royal Ann trees infected with Kootenay little cherry. At the time of collection, no apparent differences in the seed from healthy and diseased trees could be detected. When air dried, the seeds from healthy trees remained plump and firm while those from diseased trees shrivelled and turned brown. The data from these tests are summarized in table 10. In the studies made in 1952 and 1953, there was a 38.8% reduction in the air dry weight of seed from infected Bing trees. In the Lambert variety, there was a reduction of 26.8%. For the 2 years, the average weight of seed from diseased trees was .043 grams compared with .060 grams for seed from healthy trees. Working with western X little cherry at The Dalles, Oregon, Jones, Wilks, and Williams[1] found a reduction in the air dry weight of seed from diseased cherry

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1 Unpublished data.

Table 10. Western X little cherry and Kootenay little cherry: Average weight and oil content of seeds from fruits showing symptoms.

Variety	Western X little cherry[3]				Kootenay little cherry			
	Seed Wt.[1]		Oil content[2]		Seed Wt.[1]		Oil content[2]	
	1952	1953	1952	1953	1952	1953		1953
	grams		grams		grams			grams
Bing								
Healthy	.044	.069	.011	.025	.067	.065		.023
Diseased	.018	.027	.001	.002	.036	.046		.013
Lambert								
Healthy	.057	.085	.021	.034	.072	.056		.015
Diseased	.023	.033	.002	.004	.064	.041		.009
Royal Ann								
Healthy	.048	.065	.013	.025	.067			
Diseased	.020	.025	.002	.003	.036			
Overall Averages								
Healthy	.061		.022		.065			.019
Diseased	.024		.002		.045			.011

1 - Average of 50 seed 2 - Average of 100 seed
3 - Unpublished data: Jones, Wilks, and Williams.

trees. The average weight of seed from Bing, Lambert, and Royal Ann in 1952 and 1953 was .024 grams from fruit showing symptoms of western X little cherry and .061 grams from fruit from healthy trees, or a 60.6% reduction in the average weight of all varieties. Thus the seed from fruit showing symptoms of western X little cherry showed a much greater reduction in weight than that from Kootenay little cherry fruits. Plates 5 and 6 illustrate the appearance of air dried seed from fruit showing symptoms of western X little cherry and Kootenay little cherry.

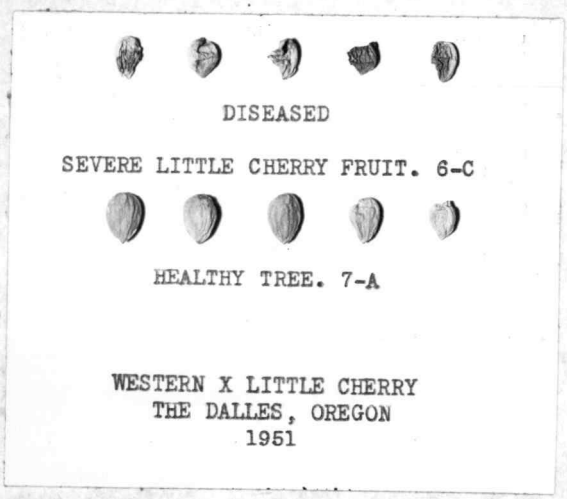

Plate 5. Air-dried seed from healthy and diseased Bing trees. Photograph by Dr. Leo Jones.

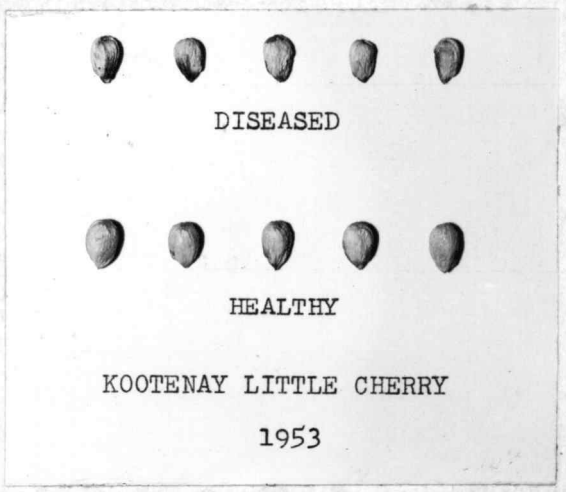

Plate 6. Air-dried seed from healthy and diseased Bing trees. Photograph by S.R. Cannings.

Effect on Oil Content of Seed

Working with western X little cherry at The Dalles, Oregon, a reduction was found in the oil content

of seed from diseased trees (Jones, Wilks and Williams[1]). The results of studies made on the oil content of seed from fruit showing symptoms of western X little cherry and Kootenay little cherry are summarized in table 10. For Kootenay little cherry the average oil content of seed from fruit showing symptoms was .011 grams as compared with .019 grams for healthy seed. The average oil content of seed from Bing, Lambert, and Royal Ann fruit showing symptoms of western X little cherry was .002 grams compared to .022 for comparable seed from healthy trees. Extraction methods differed for the determination of the oil content of western X little cherry and Kootenay little cherry, so the total oil content for healthy and diseased seed of the 2 diseases cannot be compared. However, the oil content of diseased seed taken as a percentage of the oil content of healthy seed provides a basis for comparison of the two diseases. Western X little cherry caused a 90.0% reduction in the oil content compared with a 42.1% reduction for Kootenay little cherry.

Rate of Virus Spread

Natural Spread in Orchards

Information on the rate of tree to tree movement

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1 Unpublished data.

of these 2 diseases was obtained from data which have been accumulated for the past 5 years by the Oregon Agricultural Experiment Station for western X little cherry (16), and from data which were accumulated for a period of 2 years for Kootenay little cherry (8, p.91). These data are summarized in tables 11 and 12. They indicate a much higher rate of spread for Kootenay little cherry. Surveys of 5 orchards in the Creston district showed an increase in number of trees infected from 155 in 1946 to 723 in 1947, or a percentage increase of 367% within a 2 year period. In surveys of 785 trees for western X little cherry the number of new infections observed over a 4 year period from 1949 to 1953 increased from 102 trees to 171 trees or a percentage increase of 67.6% for the four years.

Table 12. Kootenay little cherry: Tree to tree spread for the years 1946 and 1947. (8, p.91)

Orchard	Number of infections.	
	1946	1947
A	7	33
B	63	330
C	54	216
D	0	56
E	31	88
Total:	155	723

Movement in Individual Trees

Studies on the movement of western X little cherry in individual trees were made from information which has

been accumulated at the Experimental Station at The Dalles, Oregon, over the past 2 to 3 years (16). The results of these studies are reported in table 13. For the 12 trees for which these records were made, movement of the virus was found to vary from those trees in which only spurs adjacent to the point of inoculation were showing symptoms to trees in which scattered spurs a distance of 4 - 6 feet from the point of inoculation were showing symptoms. The average annual movement of the virus was about 15 to 20 inches. There did not appear to be any increase in the rate of spread of the virus the second and third years after infection.

Studies on the movement of Kootenay little cherry were made on four five-year old Star trees in the Erickson plot in 1952 and 1953. The results of these tests are summarized in table 14. These trees were inoculated in 1951, and by 1952, spread of the virus was found to vary from 35 to 38 inches into the tips of each inoculated branch. In 1953, the virus had spread throughout the remaining healthy branches in the tree. The rapid spread of this disease has been previously noted many times in field observations. This rapid spread of the virus has never been noted for western X little cherry in which the virus gradually moves through a branch, and eventually spreads throughout the rest of the tree.

Table 11. Western X little cherry: Tree to tree spread from 1949 to 1953, at The Dalles, Oregon.[1]

Orchard	Total number of trees checked	Number of trees infected. 1949	Percentage of total	1951	Percentage of total	1952	Percentage of total	1953	Percentage of total
Weston Meyer	111	15	13.5	15	13.5	17	15.3	19	17.1
Don Bailey Plot 1	288	18	6.2	28	9.7	42	14.6	44	15.0
Don Bailey Plot 2	267	49	18.4	55	20.6	64	24.0	76	28.5
Kaster-Kronberg	119	20	16.8	25	21.0	27	22.7	32	26.9
Overall Average	785	102	13.0	123	15.7	150	19.3	171	21.8
Percentage increase in infection each year					20.6		21.9		14.0

1 - Personal contact: J.A. Milbrath.

Table 13. Western X little cherry: Progress of symptoms in individual trees, at The Dalles, Oregon.

Tree number	Virus movement through tree[1]		
	1951	1952	1953
24	6-10"; 93 spurs	very slight increase; moved into several spurs missed in 1951; 101 new spurs	
45	6 directions of movement of 12-30"; 261 spurs	12-20"; 49 new spurs	
46	spread 14-48";41 spurs	12-18"; 83 new spurs	
61	6-10"; 34 spurs	12-20"; 147 new spurs	
114	only spurs adjacent to buds infected; 8 spurs	12-18"; 10 new spurs	10-18"; and one branch 6' long
115	spurs adjacent to buds	8-12"	12-20"; scattered spurs
117	24" down branch; 12-18" up branch; 33 spurs	6-10"; 17 new spurs	5' on 1 branch; another 6' branch showing scattered infection

1 - Limit of spread was determined by progressive symptom expression outward from the point of inoculation

Table 13. (cont'd)

Tree number	Virus movement through tree		
	1951	1952	1953
118		18-24"; scattered spurs on 6' branch infected	24" into tips; movement of 4' into upper branch
120	scattered near points of inoculation; 7 spurs	15-20" up branch; 120 new spurs	upward 10"; downward 36"
121	on spurs adjacent to buds; 5 spurs	8-10"; 15 new spurs	
122	adjacent to buds and scattered; 2 spurs	very slight; 14 new spurs	downward 24-26" and into other branches up to 6' away
132	localized about 6"	6-12"	14-26"; movement of 40" into one branch

Table 14. Kootenay little cherry: Progress of virus spread in individual trees

Tree number	Virus movement.[1] 1952 inches	1953
B1	40-47	Spread into 3 remaining scaffold branches
B6	35-38	Spread into 4 remaining scaffold branches
N1 Branch 1	40-50	Moved into 2 remaining non-inoculated branches
Branch 2	45-52	
Branch 3	55-58	
N2 2 branches	45-50	Moved into 4 remaining non-inoculated branches

1 Limit of spread was determined by progressive symptom expression outward from the point of inoculation.

DISCUSSION

Western X little cherry, Green Valley buckskin, small bitter cherry, Utah wilt and decline, Napa Valley buckskin, Albino cherry and Kootenay little cherry, are virus diseases which are collectively referred to as the "little cherry group". The research here reported has dealt only with a comparison of Kootenay little cherry with western X little cherry. These have been reported as two distinct diseases in the handbook (30, pp.43-52; pp.126-120) although the fruit symptoms manifested by the two diseases in their respective districts are similar, varying only in degree of severity. Establishment of the identities and the relationship of these two diseases is required as a basis for future studies of varietal resistance, vector transmission and control, and for framing policies to control movement of propagation material. At the present time, much effort and expense is entailed in the attempts to keep these diseases confined to their respective districts. If the diseases are distinct, this phase of the work becomes important, but if they are the same disease, this would be wasted effort.

The red leaf reaction that occurs when certain sweet cherry varieties and seedlings are inoculated with Kootenay little cherry has not been previously reported as

a reaction to any other stone fruit virus in sweet cherry. However, the red leaf condition in chokecherry when infected with X-disease and western X little cherry resembles this reaction.

Preliminary studies indicated that the red leaf reaction in certain sweet cherry varieties and seedlings was correlated with little cherry virus infection. The latent ring spot viruses in sweet cherry have been shown to be common contaminants in all little cherry inoculum sources and therefore were suspect as the cause of the red leaf reaction. However, when the Star variety was inoculated with Lambert infected only with ring spot, no red foliage developed. On the other hand, Star has produced the red foliage reaction whenever exposed to little cherry plus ring spot, either as branches on old infected Lamberts or in young infected trees. Further evidence that the ring spot viruses do not cause the red leaf reaction was obtained when original clones of most of the test varieties were shown, by Shirofugen indexing, to carry a ring spot virus. This combined evidence of the presence of ring spots in the original clones that have never manifested the summer reddening, and the failure to produce reddening by further inoculation with ring spot cultures, demonstrates conclusively that the reddening symptomsis not induced by contaminant ring spot viruses.

Some of the varieties and seedlings showing this red leaf reaction to little cherry virus also produced chlorotic and necrotic lesions. This type of symptom suggested the action of contaminant ring spots. However, since these varieties have been shown to carry the ring spot virus without symptoms previous to inoculation with little cherry, the subsequent development of this symptom has to be interpreted as a part of the little cherry reaction, or reaction to some other contaminant virus.

Five of these sweet cherry varieties and seedlings were inoculated with western X little cherry at The Dalles, Oregon. The symptoms produced from these inoculations were very similar to those produced by Kootenay little cherry, but the intensity of symptoms expression was not as severe. This may be due to the lack of cool weather which is necessary before the leaves produce full expression of the red pigments, or to the strong winds which occur in the area and which blow the leaves off as soon as the abscission layer starts to form, preventing full symptom expression. In most cases, the basal leaves had fallen on all inoculated trees. In the Kootenays, these basal leaves have been the first to show symptoms and usually develop the strongest color.

In all the clones inoculated with western X little cherry, there was a certain amount of distortion of

the lamina of the leaf, and the leaves felt quite leathery. Both symptoms can probably be attributed to accumulation of starch in the tissues. There were no necrotic or chlorotic mottles similar to those produced by Kootenay little cherry on any of the varieties tested with western X little cherry.

These varieties will prove valuable as indicator hosts for western X little cherry and Kootenay little cherry, as bearing trees are not required to read symptoms. They can be used in the research work on western X little cherry by grafting them onto the arms of mahaleb. As this understock is immune to western X little cherry each arm could be used for a different experiment, and be removed when it becomes infected. This would save considerable time and space in the study of vector relationships and in the testing of varieties which do not show symptoms, to determine if they are latent carriers of the virus. In areas where protection from natural infection is essential, a large number of small trees can be established in screen cages as the trees need not be maintained for more than 2 to 3 years. In seed transmission studies, these varieties can be established on the young seedlings and several years would be saved as there would be no necessity to wait for fruit symptoms or to index on some other host. In the Kootenays, these clones are being established on young Lambert trees which are to be used in spray tests for

insect vector control. Each young tree will contain a branch of Star, and records of the spread of the virus should thus be obtained several years before sufficient fruit is produced to read fruit symptoms. The use of these varieties as indicators offers as additional advantages the display of foliage symptoms that persist through a longer season than those produced in fruits, and the fact that these foliage symptoms can be diagnosed more accurately.

The range of symptoms expressed by these two diseases in sweet cherry on mazzard understock is so similar that no attempt has been made to separate them. For both diseases, the symptoms are confined to the fruit, with the production of small immature cherries which never reach proper maturity even if left on the tree long after the normal picking date. Tests made of the weight and soluble solids content showed that both diseases cause a 40% or greater reduction in the weight and soluble solids content of fruit showing symptoms. The effect of western X little cherry was found to be slightly more severe than that of Kootenay little cherry.

In the Kootenays, Lambert trees infected with little cherry show a wide variation in the severity of symptoms expressed each year. In some areas, severe symptoms are produced every year, while in other areas, in some seasons the fruit attains normal size and color.

However, such fruits usually lack flavor, and are altered in shape, with 3 flat sides tapering toward the distal end. In the Bing variety, severe little cherry symptoms are produced the first year after infection occurs. In ensuing seasons in some districts, the fruit develops normal size and shape (plate 7), although full flavour is lacking. In the West Kootenay, and in several orchards in the Creston district Bing trees have continued to produce little cherry symptoms after the first year of infection.

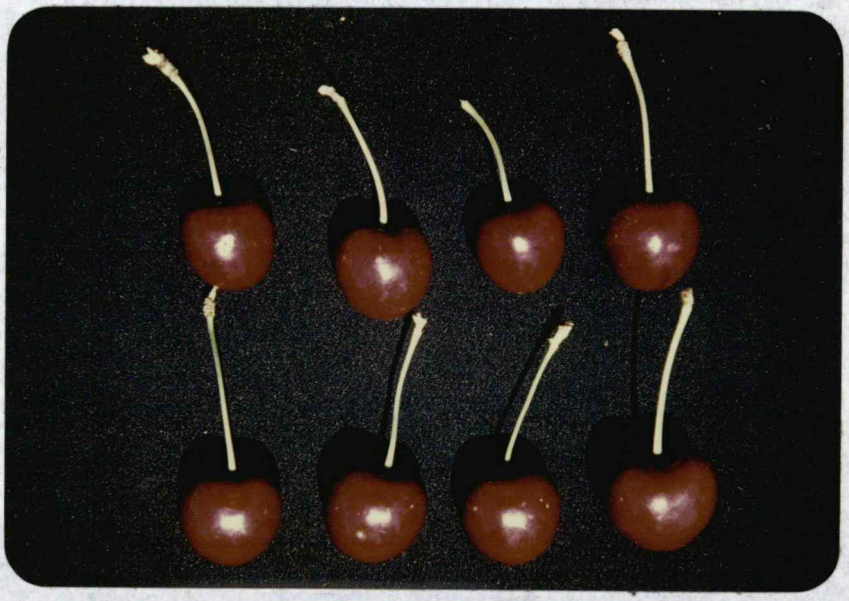

Plate 7. Kootenay little cherry in Bing; fruits from trees which have undergone the shock reaction and have recovered.
Upper row: fruits infected with little cherry.
Lower row: normal fruits. Photo by Dr. J.A. Milbrath.

The severity of fruit symptoms in trees infected with western X little cherry varies from year to year depending on climatic conditions. The occurrence of a shock

reaction followed by recovery which has been noted in Bing, and to a lesser extent in Lambert when infected with Kootenay little cherry, has never been observed in these varieties infected with western X little cherry. (plate 8)

Plate 8. Bing fruits from tree infected with western X little cherry for several years. Three fruits in upper part of picture are from healthy tree. Note the lack of recovery in western X little cherry, and compare with Kootenay little cherry in plate 7. Photo by Dr. J.A. Milbrath.

In the Royal Ann variety, the symptoms of western X little cherry show a much wider variation in severity than is found in infected Bing and Lambert varieties. In seasons when the symptoms of western X little cherry in Bing and Lambert are mild, branches of trees of Royal Ann which have been previously marked as diseased often produce fruit of normal size, but with reduced red color. This fruit meets the standards set for cannery and processing purposes.

Working with western X little cherry at The Dalles, Oregon, Jones, Wilks and Williams[1] found that there was a reduction in the weight and oil content of seed from diseased trees. Similar studies made with Kootenay little cherry, showed that this disease caused a 30% or better reduction in the weight and oil content of the seed from fruit showing symptoms. This was found to be true of all varieties tested except the samples of Lambert collected in 1952 in which there were no differences between the weight of healthy and diseased seed. The reason for this discrepancy is not known. By comparison western X little cherry caused a 60% reduction in seed weight and a 90% reduction in oil content; in each case a much greater reduction than that caused by Kootenay little cherry.

The spread of Kootenay little cherry has been exceedingly rapid. The alarming rate at which the disease spread throughout the Kootenays has always provided a serious threat to other cherry growing districts. Within a period of 15 years after the first report of the disease, practically all the cherry trees in the Kootenay District of British Columbia had become infected. The spread of little cherry in individual trees was also found to be very rapid. Tests showed that once little cherry was introduced into a tree, by budding, spread throughout the tree was

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1 Unpublished data.

complete within a period of 2 years (see table 14). This rapid spread in individual trees has also been observed many times in surveys which have been made in commercial plantings.

Records of the movement of western X little cherry both from tree to tree and within individual trees show that this disease moves at a much slower rate. Once it is established in a branch, symptoms of the disease gradually appear over the rest of the tree. Depending on the size of the branch and the vigor of the tree, it may take several years to move out of an infected branch into the rest of the tree. This virus also appears to move much more slowly in older trees and in trees which are low in vigor and producing very little growth.

Differences in the rate of tree to tree spread may be explained by the activity of the vector which carries each disease. The vector for Kootenay little cherry may be more active and move over greater distances with more frequent stops than the one for western X little cherry. However, movement of the virus in individual trees is more dependent on the host relationships of the virus, and these differences in the rate of movement of the two viruses provide strong evidence that they are distinct.

In peach, symptoms of western X-disease have been repeatedly produced when this host is inoculated with

western X little cherry (30, p.50). In the Kootenays, inoculations made over a 2 year period into 17 peach trees have not produced any symptoms other than those attributable to the latent ring spot viruses in sweet cherry. As many as 40-50 buds containing Kootenay little cherry were put into each of certain peach trees over a 2 year period without any indication of transmission. Western X-disease has never been observed in any commercial plantings of peach grown adjacent to sweet cherry trees infected with Kootenay little cherry. The results in peach suggest that the two diseases are caused by 2 different viruses.

Western chokecherry produces a red leaf reaction which has been demonstrated to be caused by the causal virus of western X-disease in peach and western X little cherry in cherry (15, p.19). In the Kootenays, no such symptoms developed on any of the 5 chokecherry trees inoculated with Kootenay little cherry. Moreover, this red leaf reaction has never been observed in the abundant native Prunus demissa trees occurring in the area. On this host the two diseases appear to be caused by 2 distinct viruses. This provides additional evidence that the causal viruses are not the same.

One of the most striking differences between western X little cherry and Kootenay little cherry is their reaction on sweet and sour cherry established on mahaleb

understock. In these hosts western X little cherry produces wilt and decline and death of young trees within 1-2 years after inoculation. During this period of decline, there are no western X little cherry symptoms manifested in the fruit. The reaction of Kootenay little cherry was distinct from that of western X little cherry in that symptoms typical of those produced on mazzard understock were produced on all 5 inoculated Lambert trees on mahaleb understock. Over the 2 year period in which these studies were made, the symptoms in inoculated trees were limited to a reduction in terminal growth and a slight upcurl of the leaves of Lambert trees which became apparent about August. There were no symptoms of wilt and decline similar to those reported for western X little cherry.

Practically all the sweet cherry varieties in the Kootenays are established on mazzard understock. A Lambert tree budded high on mahaleb, so that it was entirely on mahaleb roots, was found in one commercial orchard. This tree produced little cherry symptoms similar to those produced by the rest of the trees in the orchard and similar to those induced by the inoculations made into Lambert on mahaleb, in the Erickson plot.

Montmorency trees on mahaleb understock treated with Kootenay little cherry in 1951 produced fruit symptoms in 1953, but only on inoculated branches. This differed

from the result in Lambert in which the symptoms were apparent throughout each tree 2 years after inoculation. However, as in Lambert, there were no symptoms of wilt and decline similar to those reported for western X little cherry on any of the trees inoculated.

CONCLUSION

These studies indicate that western X little cherry and Kootenay little cherry are caused by distinct strains of the same virus. Both diseases produce small fruit symptoms which vary from year to year in degree of severity. In most seasons difficulty would be encountered in separating these two diseases on fruit symptoms alone, even though the symptoms of western X little cherry are more persistent, especially in Bing and Lambert where recovery similar to that observed with Kootenay little cherry seldom, if ever, occurs. When Star, Sam, and 3 unnamed seedlings, which had given a strong red leaf reaction to Kootenay little cherry, were inoculated with western X little cherry, the leaf reactions obtained were similar. Both diseases caused a reduction in the weight and soluble solids content of mature fruit. Likewise, both diseases caused a reduction in the weight and oil content of seed from fruit showing symptoms.

Despite these similarities, a number of rather distinct reactions have been obtained on certain hosts. When western X little cherry is inoculated into sweet and sour cherry on mazzard understock, the reaction differs from the reaction of the same varieties on mahaleb understock. Kootenay little cherry produces the same type of

fruit symptom when inoculated into sweet and sour cherry, whether they are propagated on mazzard or mahaleb understock. The failure of Kootenay little cherry to produce western X-disease in peach is also a significant difference between the two diseases. Similar evidence is provided by the failure of Kootenay little cherry to produce red leaf in Prunus demissa.

On the basis of their performance in sweet cherry these two diseases would be difficult to differentiate. However, the two diseases have given sufficiently distinct reactions on other hosts to indicate that they cannot be produced by the same causal agent. Presumably two distinct strains of the same virus are involved.

SUMMARY

1. Kootenay little cherry and western X little cherry have a similar range of symptoms in commonly grown sweet cherry varieties on mazzard understocks. For each disease the effect is limited to a failure of the fruit to reach proper maturity.

2. Both diseases cause a reduction in the weight and soluble solids content of fruit showing symptoms.

3. Both diseases cause a reduction in the weight and oil content of seed from fruit showing symptoms.

4. A number of varieties and unnamed seedlings developed by the Dominion Experimental Station at Summerland British Columbia, produce a red leaf reaction when inoculated with Kootenay little cherry. Similar symptoms were induced when some of these varieties were inoculated with western X little cherry.

5. The ring spot viruses have occurred as common contaminants in all the little cherry source material used. The possibility that these viruses are responsible for the red leaf symptoms has been eliminated by (a) the demonstration that this reaction does not result from inoculation of Star with Lambert sources carrying ring spot, but not little cherry; (b) indexing on Shirofugen which indicated the presence of ring spot viruses in original clones of all

these varieties tested except one.

6. No reddening was produced in Star when inoculated with viruses other than those in the little cherry group. Viruses used in this study included those of sour cherry yellows, the mora disease, rusty mottle, and the commonly occurring ring spots.

7. In sweet and sour cherry on mahaleb understock, western X little cherry produces wilt and decline and death of the tree. In these hosts, Kootenay little cherry produces fruit symptoms similar to those induced in cherry on mazzard understock, but no tree symptoms.

8. Peach reacts to western X little cherry with the production of western X-disease symptoms. No symptoms of western X-disease have been produced in peach trees inoculated with Kootenay little cherry.

9. Western chokecherry, P. demissa gives a red leaf reaction when inoculated with western X little cherry. Kootenay little cherry produces no symptoms in this host.

10. The spread of Kootenay little cherry in 5 year old Star trees is complete within a period of 2 years. Observations on the movement of western X little cherry have indicated a much slower spread. Following the expression of symptoms, the spread of the virus has averaged 15 to 20 inches a year.

11. The natural spread of Kootenay little cherry in

commercial orchards is much more rapid than the spread of western X little cherry.

12. There is a wide variation in the severity of symptom expression of Kootenay little cherry from year to year in the Bing and Lambert varieties. In some districts, symptoms in the Bing variety are apparent only in the first year after infection occurs. Although these varieties infected with western X little cherry show a variation in symptom severity from year to year, recovery similar to that observed for Kootenay little cherry has never been observed.

13. On the basis of the similarities and differences found between these two diseases, they are considered to be separate strains of the same virus.

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