UNIVERSITY OF IDAHO
College of Agriculture

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IDAHO Agricultural Experiment Station

Bulletin 260
June 1956

Department of Plant Pathology

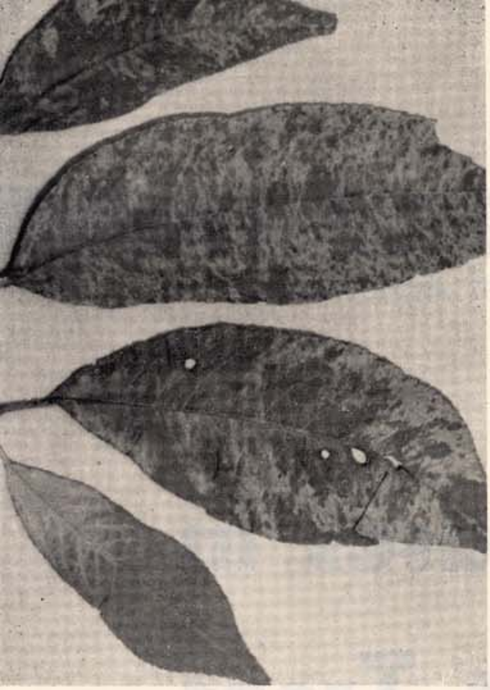


Figure 1.—Symptoms of calico virus in peach leaves.

Figure 2.—Upper: Peach leaves showing the variegation condition. Lower: Chlorosis in peach leaves due to iron deficiency.

Figure 3. — Upper: Montmorency sour cherry leaves showing symptoms of sour-cherry-yellows. Lower: Green-ring-mottle symptoms in leaves of Late Duke.

Latent Viruses in Stone Fruit Trees

A. W. HELTON*

Latent viruses generally do not produce visible symptoms. Because of this peculiarity, locating and identifying them has become one of the most difficult problems confronting the practical pathologist. Detection of such viruses and observation of their effects has been virtually impossible for the average grower.

Fortunately, these viruses do cause the development of symptoms in certain host plants under certain conditions. One of the favorite activities of the research virologist has been transmission studies in which many kinds of budwood have been placed on many kinds of rootstocks or on other variety trees. During such tests the presence of the so-called latent viruses was discovered.

Some of the latents are so widespread that locating virus-free sources from which nurseries might propagate clean trees has been extremely difficult. Only recently have virus-free stocks of a few varieties been available so that actual effects of latent viruses could be investigated. Such work now is underway in various parts of the country and is slowly accumulating evidence that yield loss and reduction of growth rate and vigor are significant.

Symptomatology

Several of the stone fruit varieties are considered to be universally infected with latent virus. In most cases recognizable symptoms are produced only at the time of initial infection. Such symptoms may be very mild or they may be extremely severe. They may be very fleeting or they may persist for several seasons. They vary from hardly detectable yellowish foliar discolorations in the form of lines, spots, blotches or circles to severe necrotic spotting, shot-holing and even death of the tree.

After preliminary "shock" symptoms have developed in the tree, the foliage in succeeding seasons generally appears to be normal. Occasionally, however, viruses or virus strains considered to be related to latent groups cause symptom development year after year. Such viruses are said to be "recurrent" since their symptoms recur annually. This characteristic hardly justifies their being called latents, but they are tentatively grouped with the latents because of their symptomatologyical appearance and intervarietal behavior.

Several other known viruses produce symptoms annually under certain types of environmental conditions but fail to do so under others. For example, a virus may be recognizable every year in

*Assistant Plant Pathologist, Idaho Agricultural Experiment Station, Moscow orchards in the southernmost parts of the country and seldom if ever develop symptoms in the northern part. As far as Idaho orchard problems are concerned, therefore, such viruses are latent—despite the fact that they simply are "masked," or hidden because of some factor in the environment.

Calico of Peach

Calico is a virus disease of peaches which sometimes shows prominent symptoms and sometimes does not. Generally it behaves much like other commonly latent viruses in that its most important symptoms develop soon after infection. There may be no recognizable symptoms during succeeding years.

Symptoms of **calico** consist of blotchy yellow mottles and streaks (Figure 1). The yellow may be pale or very bright. The veins turn yellow as readily as other portions of the leaf, which distinguishes **calico** from the common iron deficiency **chlorosis** (Figure 2, lower). The virus disease is more often confused with **variegation,** which is a genetic and therefore non-infectious condition (Figure 2, upper). However, **variegation** almost always shows evidence of three distinct shades of color in the leaf surface, which **calico** does not. These are normal green, bright yellow and a shade of yellow-green between the two.

Thus far, **calico** is not a disease of economic importance in Idaho. Nevertheless, infected trees should be destroyed when found to prevent build-up of the virus in the orchard. Since the symptoms will disappear, the tree should be marked when found.

Yellows of Sour Cherry

Sour-cherry-yellows generally does not produce recognizable "yellows" symptoms on varieties of stone fruits other than sour cherry. However, the virus or viruses that cause **yellows** can be carried in other varieties.

Symptoms of **yellows** show much more often and clearly in warmer climates. There, symptoms develop each spring, whereas in northern parts of the country the symptoms may or may not be produced in the spring. Where symptoms develop the leaves turn yellow, with islands of green color remaining scattered over the leaf surface (Figure 3, upper). Affected leaves drop off shortly after symptom development. Leaves produced later in the season generally do not show symptoms.

Yellows is thought to be the most important virus infecting sour cherries with the possible exception of members of the **ring-spot** complex—to which **yellows** appears to be closely related. The virus is widespread throughout the country, resulting in considerable economic loss.

Sometimes a symptom is found which appears to be a cross between the **yellows** and **ring-spot** symptoms. This disease is known as **green-ring-mottle** (Figure 3, lower). It is like **yellows** in that the symptom consists of green islands on a yellow leaf. It is like **ring-spot** in that the islands are not solid spots but are green rings. It is like the **rusty-mottle** viruses found in cherries in that **rusty-mottle** can cause development of green rings in sweet cherry leaves under certain conditions. Ring formation is a symptom associated with several other virus diseases, e. g. in raspberries, tobacco, and some others.

Green-ring-mottle symptoms are not as common as those of **yellows** and the effect on the tree does not appear to be as severe.

V-Leaf of Sweet Cherry

In Idaho there occurs a peculiar symptom which may or may not prove to be due to virus infection. It is commonly found in sweet cherry orchards and often is associated with other virus-like symptoms not yet fully investigated. The condition tentatively is labeled **V-leaf** because of the unique nature of the smyptom.

Affected leaves develop V-like lines of very pale yellow to white color and of very ragged design. The base of the "V" points toward the tip of the leaf, but each lateral vein on both sides of the mid-rib has its own "V" with the base of the "V" pointing toward the edge of the leaf (Figure 4). **V-leaf** symptoms do not recur with any consistency. Occasionally, **line-pattern** or ring symptoms develop on leaves showing symptoms of **V-leaf** (Figure 4, leaves upper left and right center).

These are orchard observations only and definite relationships to known viruses other than symptomatic occurrence have not yet been established. Thus far **V-leaf** is considered to be of minor importance in Idaho.

Line-Pattern of Sweet Cherry

The **line-pattern** symptoms found in sweet cherry orchards in Idaho do not appear to be due to the virus that causes the **line-pattern** disease in plums. The cherry **line-pattern** condition is common throughout the state, is virus-like in its appearance, and behaves as a virus would be expected to in individual trees. Some trees have been observed

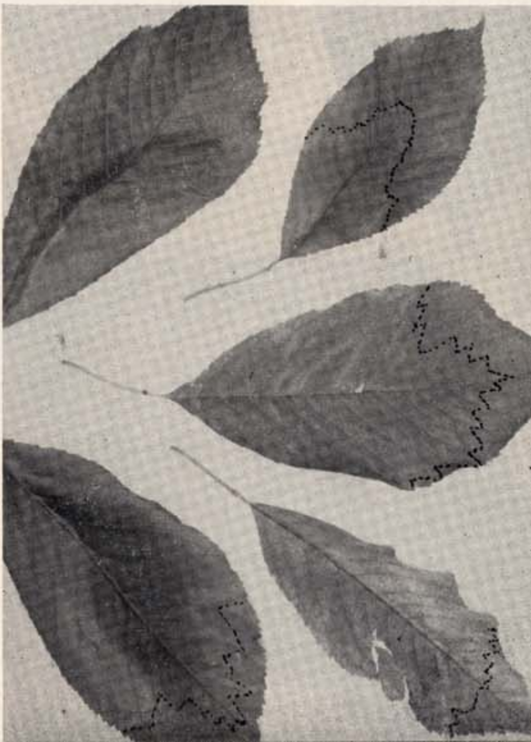


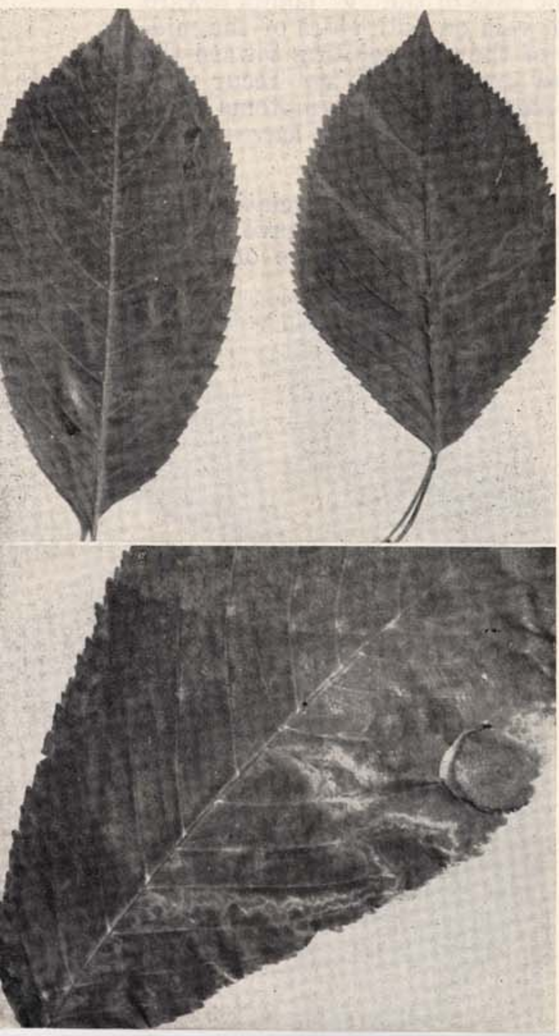
Figure 4.—Leaves of Bing cherry showing the faint symptoms of the unidentified V-leaf condition. The dotted lines are drawn just terminal to the major symptom lines to make them stand out.

for several years and found to show the symptom in various parts annually. Some trees show the symptom one year and not the next. Transmission studies designed to discover relationships of the casual factor with known viruses are underway.

Line-pattern varies considerably in its symptomatic development, from faint irregular lines similar in intensity to those of V-leaf (Figure 5, upper) to prominent ragged lines of bright yellow (Figure 5, lower). Occasionally both types seem to form single or concentric circles (Figure 5) reminiscent of some of the **chlorotic-ring-spot** symptoms.

Irregular line patterns reminiscent of the cherry **line-pattern** symptom have been observed in raspberries and rose leaves infested with leaf miners.

Thus far, although **line-pattern** symptoms are widespread in Idaho, no data are available on which to base estimated effects on yield or tree vigor.



Ring-Spot of Sweet and Sour Cherry

This is a group of viruses which normally are not seen in the orchard because of their predominantly latent nature. Some produce symptoms annually, yet their appearance is so like that of the typically latent ones, that separating them into two distinct groups has not been considered expedient.

Ring-spot symptoms vary from extremely fine and pale circles and lines, through severe yellow blotches and circles, to necrotic (brown) rings, spots and leaf tattering. The appearance of these diseases in the orchard and the experimental data thus far collected throughout the country suggest that **ring-spot** viruses constitute a virus complex that includes many strains, known and unknown. Their effects probably vary as widely as their appearance.

Figure 5.—Line-pattern symptoms in Bing leaves. Upper: An unaffected leaf to the left of one showing faint circles and line suggestive of V-leaf. Lower: Roughly parallel lines of bright yellow hue.

The mildest ring symptom type in orchard trees is the **chlorortic-ring-spot** in which there is a tendency to develop irregular lines similar to the **line-pattern** symptom, single circles, and concentric circles of a bulls-eye appearance (Figure 6, upper). There are more prominent types of **chlorortic-ring-spot** in which the yellow rings tend to be hidden in blotches of yellow color on the leaf surface (Figure 6, lower).

Some symptoms occupy an intermediate position between the **chlorotic-ring-spots** and the **necrotic-ring-spots** in that the chlorotic rings appear but tend to develop necrosis in the rings themselves, usually as necrotic flecks (Figure 7).

Necrotic - ring - spot symptoms, in which there are definite and well-formed rings, develop occasionally in Idaho but rarely are widespread during a single season. The symptom is found in both sweet and sour cherry orchards. Several types are involved and each type appears in some relationship with other symptoms.

Necrotic - ring - spot sometimes develops in sour cherry orchards throughout the state. During the spring of 1955, symptoms appeared in alarming proportions in some orchards. Leaves of affected trees were thickly covered with small necrotic rings. This graded into severe tattering of the leaves—

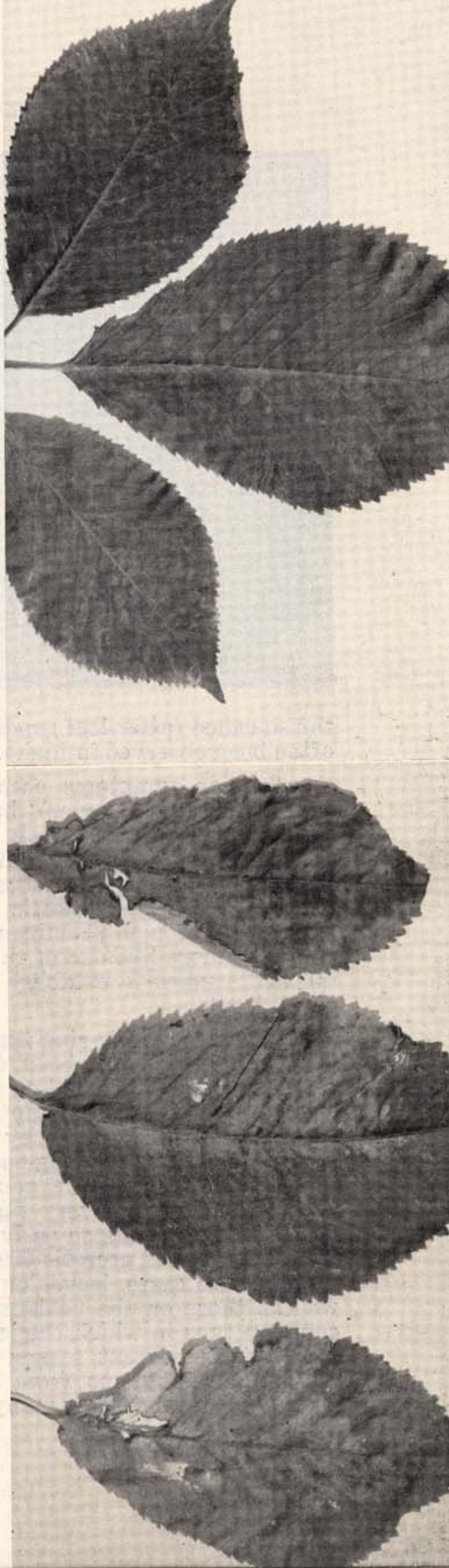


Figure 6.—Symptoms of Chlorotic-ring-spot in Bing cherry leaves. Upper: Single and concentric circles and irregular lines suggestive of the line-pattern condition. Lower: Bright and severe yellow blotches almost obscure all the chlorortic rings, though some are still visible in the uppermost leaf.

Figure 7.—Chlorotic-ring-spot in a Bing leaf, with minute necrotic flecks developing in the yellow lines.

the so-called **tatter-leaf** condition (Figure 8). Such tattering has not often been observed in Idaho.

Similar symptoms occasionally develop in sweet cherry orchards (Figure 9, upper), but there the symptom generally disappears before the following season. Sometimes the necrotic rings are large and the leaf tissue surrounding the rings pale in color (Figure 9, lower). The virus responsible for this symptom may be related to the **rusty-mottle** group of chronic symptom producers, since without such prominent and well-defined rings the symptoms would be more like one of the rusty-mottles than **ring-spot.** Transmission studies to establish any such relationships have not been carried out.

Where **necrotic-ring-spot** ends and the so-called **tatter-leaf** condition begins has been difficult to establish in Idaho. **Tatter-leaf** symptoms are found on trees that show no **ring-spot** symptoms as such, on trees with symptoms of **chlorotic-ring-spot** and on trees that are affected either by transient or recurrent **necrotic-ring-spot.** Severe **necrotic-ring-spot** sometimes develops without tattering (Figure 10, left), but generally speaking the necrotic areas tend to drop out leaving very ragged leaves (Figure 10, right). Often the tattering begins so early and is so severe that by harvest time little evidence of necrotic tissue remains (Figure 11, left). In these more severe cases, leaves on current season twigs are shredded as well as those on the year-old twigs. This contrasts with the more common type in which the leaf tattering takes place on older wood rather than current season growth (Figure 11, right). This exclusion of symptoms from leaves on current season twigs is a characteristic shared by many stone fruit virus diseases.

Figure 8.—A group of necrotic-ring-spot infected leaves of Montmorency sour cherry. The rings are small, spread thickly over the leaves and graded into a tatter-leaf condition.

Sometimes **chlorotic-ring-spot** and extremely **severe tatter-leaf** symptoms develop at the same time on the same parts of the affected tree. In Idaho, this is found most often in trees of the Black Tartarian variety (Figure 12, lower). However, the tattering symptom, without any production of rings, frequently is found in sweet cherry orchards (Figure 12, upper). This condition has not been sufficiently investigated but is believed to be a combined effect of zinc deficiency and certain viruses such as strains of **ring-spot** or **tatter-leaf,** or of **rusty-mottle.**

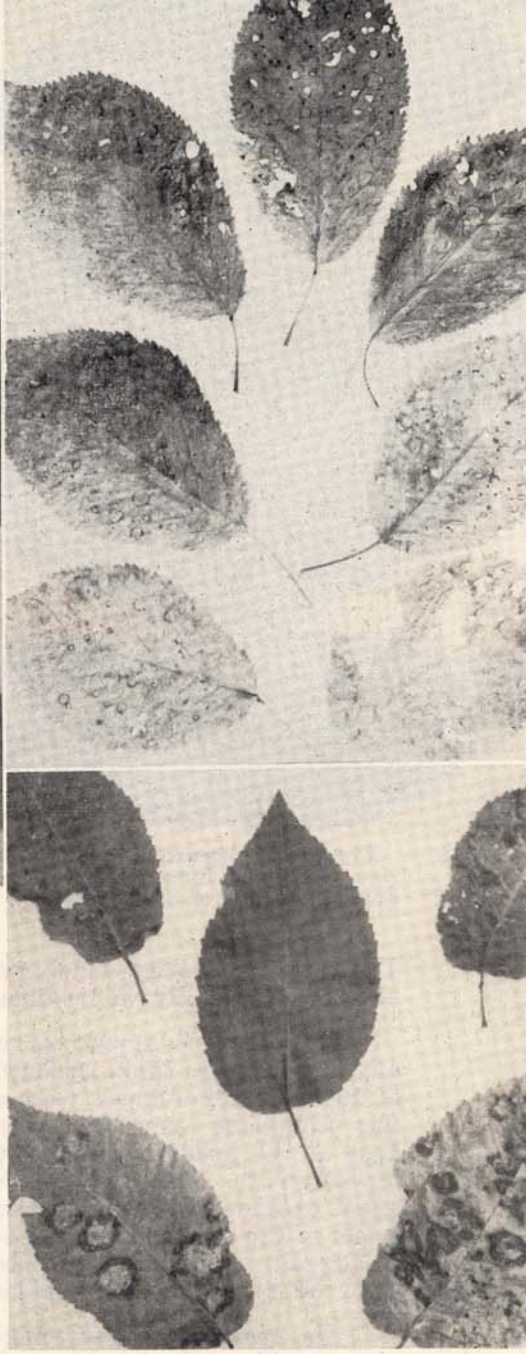


Figure 9.—Upper: A non-recurrent type of necrotic-ring-spot in Bing leaves. Lower: A severe necrotic symptom in Bing in which the large brown rings develop on pale green to yellowish leaves reminiscent of the leaf condition in some cases of rusty-mottle infection.

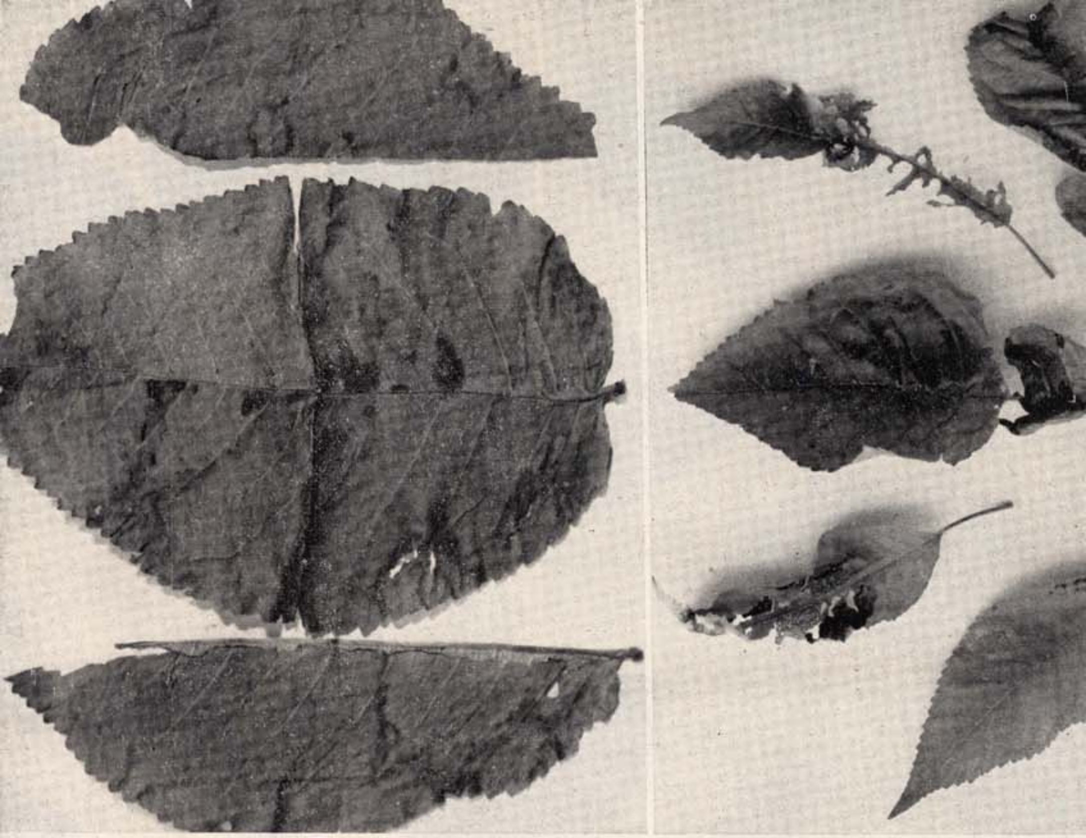


Figure 10.—Recurrent types of necrotic-ring-spot in leaves of Black Tartarian (left) and Bing (right). Note that the Bing leaves show a tatter-leaf condition instead of ring symptoms.

The symptom varies widely with season both in distribution and severity. Generally the terminals are most affected.

Extremes of damage by **ring-spot** and, or, **tatter-leaf** occasionally are found in Idaho orchards. For example, during the summer of 1955 several orchards were examined in which a few trees showing prominent symptoms of **ring-spot** or **tatter-leaf** were dying back at the terminals. Where the symptoms were most severe the leaves on the spurs were drying up and dying (Figure 13). This effect extended for some distance down the twigs until as much as 3 feet of the terminal growth were dead. Both young and old growth in affected terminals were killed. No cause for this reaction other than the virus infection could be found in the orchard.

The **ring-spot** virus complex is the most widespread of the virus problems in the stone fruit orchards of Idaho. Almost all orchard trees in production are infected. Relative effects on yield have not been determined but are thought to be substantial. Certainly tree vigor is adversely affected. There is little that can be recommended thus far other than use of clean stock in planting new orchards. This leads to the complicated procedures involved in certification of nursery stock as to virus-freedom.

Figure 11.—Sweet cherry tatter-leaf symptoms in which new terminal growth is as severely tattered as leaves on older growth generally are (left), and in which the new terminal growth shows no symptoms (right).

Dwarf of Prune

Prune-dwarf is a virus disease of prunes which produces recognizable symptoms in prune varieties year after year. However, the virus responsible for the disease can be carried in other varieties in a latent condition. For example, a preliminary test indicated that the virus, or viruses, responsible for the **chlorotic-ring-spot** symptoms in Bing Cherry leaves illustrated in Figure 6 (lower) — or another virus carried along in that condition — caused the development of **prune-dwarf** symptoms (Figure 14, upper) and a tattered leaf condition (Figure 14, lower) when transferred to Italian prune. Thus, as far as the cherry was concerned **prune-dwarf** virus appears to have been present in a latent condition.

Dwarf has been considered a minor virus problem in Idaho in the past. Such a view cannot long be maintained if future investigations reveal that the virus is widespread in other varieties in a latent condition.

Figure 12.—Upper: A Bing twig showing necrotic spotting and tattering possibly due both to virus infection and zinc deficiency. Lower: A Black Tartarian twig severely affected by tatter-leaf, so much so that accompanying chlorotic ring-spot symptoms are pretty well obscured. It is doubtful that different viruses cause the two conditions.

Figure 13.—Terminal die-back of leaves, spurs and twigs on Bing branches severely affected by tatter-leaf. The center twig is unaffected. The lower one shows tattering above terminal to which the die-back takes place. The die-back is illustrated by the upper twig.

Detecting Latent Viruses

Comparative growth rates of virus-free and virus-infected trees clearly shows that in most cases there is pronounced growth reduction when the viruses are present. Needless to say, this comparison was not possible prior to development of methods for detecting latent infection.

In some cases, where the latent virus causes obvious symptoms during the first year or so of infection, it can be re-discovered simply by transferring budwood from the infected tree to a healthy tree of the same variety. **Calico** behaves in this way in peach trees, and complicated detection procedures are not necessary.

Sometimes a change in the environment is all that is required to "unmask" a hidden virus and cause it to develop symptoms in the host tree. For example, young sour cherry trees carrying latent **yellows** often can be induced to develop symptoms by moving them into a greenhouse operated at a higher temperature.

Differences in susceptibility among common commercial varities often holds the key to easy detection. Such is the case where cherry budwood carrying **prune-dwarf** in a latent condition causes typical symptoms when placed on a variety like Italian.

However, in most cases of true latency the virus will only be detected soon after infected budwood is placed on a clean tree (or on one not infected with a closely related virus). The effect on a clean tree generally is sudden and severe, i. e. a "shock" response develops. This shock effect eventually disappears, as is well demonstrated by the **ring-spot** and **line-pattern** types.

Detection by the shock method presupposes either that there is sufficient difference in virus strains in the donor and test tree to allow for such a reaction, or that the test tree is clean, or virus-free. An unfortunate complication arises in that so many of the mild **ring-spot** strains are essentially universal in nature and therefore the shock reaction is not produced in routine budding among common stock of the same or closely related varieties.

The most recent and most generally accepted methods of detecting latent viruses are based on effects produced on different varieties or different species. For example, cherry budwood can be tested for latent virus on peach, prune, flowering cherry varities, and several others.

Healthy appearing budwood is tested for latent virus in Idaho by first placing it on trees of Shirofugen flowering cherry for detection of **ring-spot** types. The budwood is tested on other test hosts if negative reactions result from the Shirofugen test. In searching for virus-free propagation sources, no budwood is tested unless it comes from vigorous trees that show no evidence of a systemic disease.

In accomplishing such a test, the buds first are placed in a line along the Shirofugen branches in the ordinary nursery propagation manner of T-budding. The buds that callus-in normally are considered likely to be healthy, whereas those that develop brown, necrotic tissue below the bud shields and die are considered to be infected (Figure 15).

Most of the severe **ring-spot** strains produce such a local reaction on Shirofugen. If all the buds placed on the Shirofugen tree are from the same source tree and there is no chance of confusing the result, the budded branches are left on the tree for observation of any delayed symptom development.

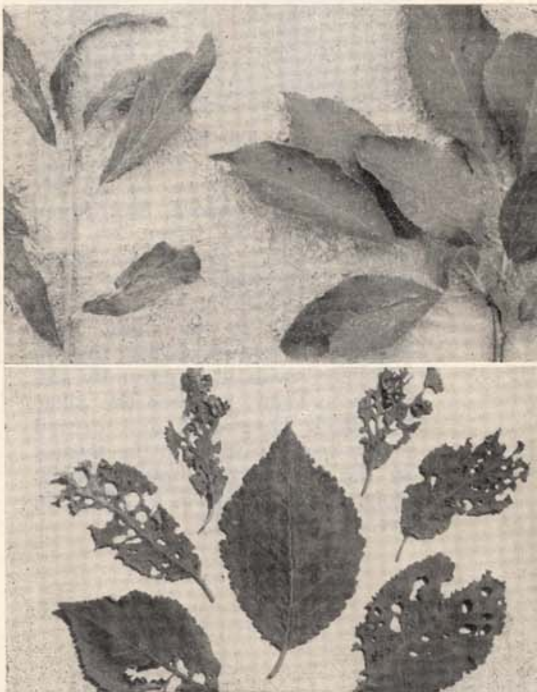


Figure 14.—Upper: A healthy Italian twig to the right of one severely affected by the prune-dwarf virus. Lower: A healhty Italian leaf surrounded by severely tattered leaves. Both the prune-dwarf and tatter-leaf symptoms developed when budwood from the tree showing the symptoms illustrated in lower Figure 6 was transferred to Italian prune from cherry.

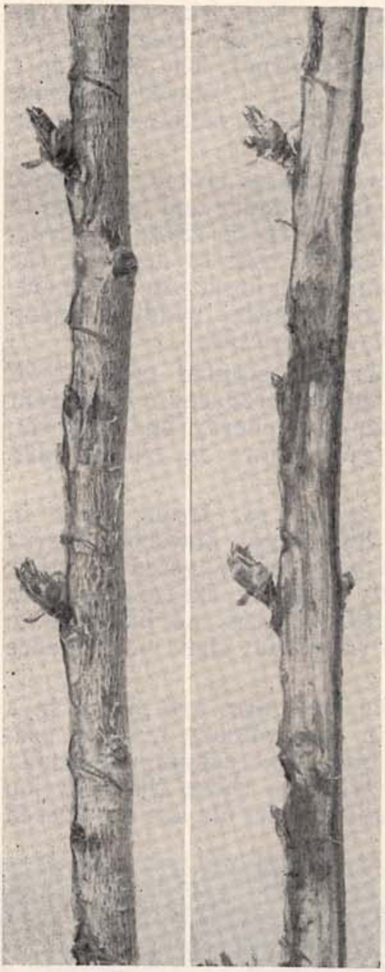


Figure 15.—The Shirofugen local necrosis reaction to buds carrying latent ring-spot virus. To the left is shown the budded Shirofugen branch before the tissue has been shaved away to reveal the brown pockets of necrosis under the infected buds—which is shown in the shaved photo to the right. Note that the top and third-from-the-top buds have callused in normally and begun to grow, whereas the other two buds have died and caused brown spots to form in the tissues of the Shirofugen branch below them. (Courtesy Dr. J. A. Milbrath, Ore. Agr. Exp. Sta.)

Figure 16.—A Kwanzan tree showing the systemic reaction to latent ring-spot virus in which the leaves become severely distorted. Defoliation and death follows. Note that the two lowest branches appear to be healthy. They grew out of the sweet cherry buds that were budded into the trunk of the Kwanzan tree and which carried the virus in latent form.

This is done because some virus strains will not cause local necrosis under the bud shield on Shirofugen, but will become systemic later on and cause obvious distortion of the leaves. The local reaction may require only two or three weeks, whereas the systemic reaction may require a whole growing season.

If more than one suspected source of budwood has been placed on the first Shirofugen and some of the buds appear to be clean, additional buds from that source are placed on other Shirofugen trees for detection of the same sort of systemic reaction (Figure 16) that would have shown up later in the first (or screening test) Shirofugen. Kwanzan trees also can be used for the systemic reaction test.

If a vigorous orchard tree has survived the Shirofugen test without producing a positive reaction, some of the other test hosts are employed to make sure that viruses common in other varieties but non-reactive on Shirofugen are not being carried in a latent condition. Only after all these tests have been completed with negative results is a source considered virus-free and suitable for propagation.

Thus far every clean tree located in Idaho could be traced to a nursery engaged in the propagation of one of the few virus-free selections now available.

Control Measures

Generally speaking, a tree found to have a virus disease should be destroyed to prevent spread of the virus by natural means to other trees nearby. Obviously such a practice can have little value where the virus does not betray itself through symptom expression or where it is so widespread that most or all of the trees in the orchard already are infected. In such cases the orchardist has little choice but to live with the disease in the most profitable manner that he can.

Prune-dwarf virus in prunes is easy to locate and such trees can readily be removed. **Calico** in peach orchards also can be detected visually if the grower is observant while carrying out his routine orchard duties. The problem is more difficult where **ring-spots, line-patterns** and perhaps other latents as yet unidentified are concerned. The **ring-spot** group, at least, is so widespread that even if infection caused chronic and obvious symptoms, tree removal would hardly be a practical answer.

With the knowledge now available, the only logical approach to control lies in elaborate preventive programs of inspection, testing and certification of nursery stock as to virus-freedom. This does nothing to alleviate conditions presently existing in stone fruit orchards, but it does hold promise for the future.

Selection of the healthiest and best trees of popular varities has been going on for many years, and these selections occasionally have proved to be virus-free when tested on indicator or detector varities such as Shirofugen. Only recently, however, have nurseries begun to propagate such sources in a diligent effort to produce clean stock for the grower.

Nursery inspection programs are in operation in most states producing fruit stocks, but such inspection without the necessary testing on indicator varieties does little to reduce further distribution of latent viruses. Some states now are modifying their programs to provide measures designed to prevent such distribution through propagation from infected source trees.

Where the infectious agent is widely distributed, disease resistance or tolerance often proves to be the most effective and practical as well as the quickest means of bringing the problem under control. Unfortunately such resistance among stone fruits is difficult to find. Breeding it into the stock is equally difficult because of the great number of years required to gain resistance without loss of quality of the fruit.

Such modern methods as those involved in chemotherapy and physicotherapy may evolve workable methods in a shorter period of time, but thus far they are only in the exploratory stage. Certain viruses in trees and other plants reputedly have been destroyed in the living plant by application of heat or of certain chemical compounds. In no sense is such work on the verge of developing an effective orchard program for destroying viruses similar to those for fungi, bacteria, insects, etc. It does hold good promise if it can be used to develop virus-free trees for propagation purposes, or to re-establish such virus-free sources after they have been contaminated.

One of the most pressing problems at the moment is concerned merely with protecting virus-free sources so that the propagator will continue to have virus-free scion wood available. Only in this way can clean trees continue to be made available to the grower.