DISEASES OF APPLE IN BRITISH COLUMBIA THAT ARE CAUSED BY VIRUSES OR HAVE CHARACTERISTICS OF VIRUS DISEASES[1]

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Abstract

Recent investigations have shown that viruses occur commonly in the trees of commercial apple plantings in British Columbia. They are responsible for many types of symptoms that include modification of tree growth habit; tree decline; tree dwarfing; delayed emergence from dormancy; apparent stock-scion incompatibilities; dwarfing, mottling, chlorotic flecking, puckering and necrosis of leaves; russetting, pitting, blotching, and deformity of fruits. The various disease conditions are described. There is limited evidence for natural spread of several of the diseases.

Introduction

Until 1955, there appeared to be justification for a tacit assumption that viruses were neither commonly present nor important in British Columbia apple plantings, It is safe to broaden this comment to apply to all parts of the North American continent. Probably only to work of Hockey (9, 10) and Thomas (24, 25) portended the role that viruses now appear to play in causing abnormalities in apple.

Studies of virus occurrence in apple were begun in British Columbia, and in several Eastern and Midwestern States 6 years ago, and in other parts of the continent more recently. The findings have indicated that viruses may be as common in apple as in stone fruits, and that they 'inducevarious type of abnormalities in tree growth, and symptoms on leaves and fruits.

The object of this paper is to catalogue the disease conditions in British Columbia that have already been demonstrated experimentally to be transmissible, or that appear to be caused by viruses because of the circumstances of their occurrence.

A deliberate effort has been made to avoid unwarranted grouping of diseases, or assumption of common cause for symptoms that have common concurrence. It can be anticipated that the task of confidently establishing the identities and relationships of the causal viruses will require many years of investigation.

For previously described diseases the review of literature is not comprehensive. Rather, an attempt has been made to select several important references that provide adequate description of each disease.

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DISEASES AFFECTING TREE VIGOUR OR GROWTH HABIT

STEM PITTING

Occurrence in British Columbia: Trees showing stem pitting symptoms have been found in almost all British Columbia plantings that include susceptible varieties (11). Sample indexing on Virginia crab test trees has demonstrated that the virus occurs, commonly, but without obvious symptoms, in trees of a number of additional varieties in commercial orchards.

References: The disease has been described by Miller (15), Smith (22), Tukey et al. (26), and others. The first report of transmission was by Guengerich and Millikan (8).

Symptoms: The most reliable symptom is the presence of pits or grooves in the sapwood, matched by projections from the inner surface of the bark (Fig. 2). These are usually most apparent at the base of the trunk. Gross tree symptoms associated with stem pitting in the more severely affected varieties include dwarfing, a low-spreading and open-centre growth habit, longitudinal sunken areas on the trunks, and abundant production of suckers from the rootstock below the susceptible portion of the tree (Fig. 1B).

Host Range: Severe symptoms have been observed in Beauty crab, Columbia crab, Hyslop crab, Malus robusta No. 5, Robin crab, and Virginia crab. Additional hosts have been recorded from other regions (18, 19). Sample indexing in British Columbia has shown, so far, that the virus of stem pitting can be carried in trees of Delicious, Golden Delicious, McIntosh, Rome Beauty, Spartan, and Winesap. Mild symptoms have been found on Delicious and Golden Delicious.

Etiology: Transmission by grafting or budding has been reported by several workers, including the authors (29).

RUBBERY WOOD

Occurrence in British Columbia: Welsh and Keane (29) reported the presence of rubbery wood virus in trees of commercial plantings. Further sample indexing has provided additional evidence that the virus is present in many orchard trees, of several commercial varieties.

References: Rubbery wood has been reported and described by workers in a number of countries and several continents. Luckwill and Crowdy (13) and Prentice (20) have provided detailed descriptions of the disease. The only other known record of occurrence of the virus in North America has been provided by Brase and Gilmer (4).

Symptoms: The Lord Lambourne variety, on which rubbery wood symptoms have been described most frequently in Europe, displays strong symptoms at Summerland. These include greatly increased flexibility of smaller branches, weeping tree habit, and reduced vigour (Fig. 3). Golden Delicious, and several other varieties, have been reported to suffer dwarfing under some conditions, but so far this has not been demonstrated in British Colombia. At Summerland also, young trees of the commercial varieties Delicious, Golden Delicious, McIntosh, Rome Beauty, Spartan and Winesap,

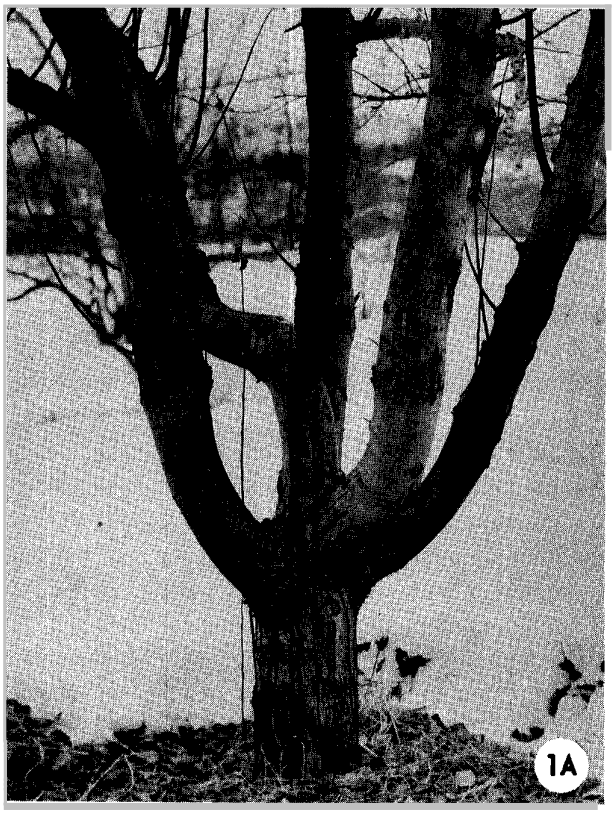


Figure 1. Stem pitting. A. Normal Virginia crab body stock (characterized by sturdy framework and strong crotch). 6. Virginia crab body stock of same age, but showing gross symptoms of stem pitting (including reduced vigour, spreading habit, and abundant suckers from rootstock beneath).

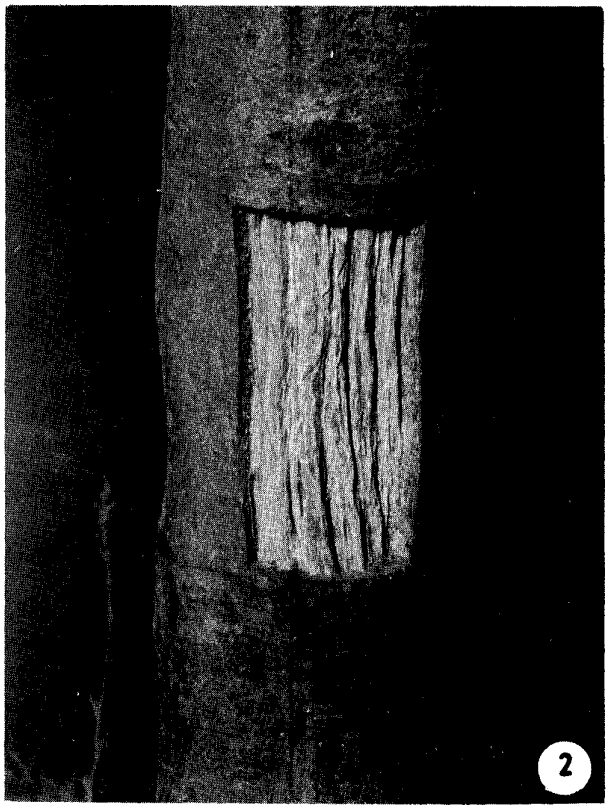


Figure 2. Stem pitting on Virginia crab body stock. Bark removed to reveal pitting and grooving of wood beneath.

and the body stock varieties Antonovka, Canada Baldwin, Charlamoff, Haralsan, Hibernal and Virginia crab have shown no obvious symptoms in 3 or more years after inoculation with a severe strain of rubbery wood virus.

Host Range: Sample indexing on Lord Lambourne has shown, so far, that trees of the varieties, Delicious, Golden Delicious, Rome Beauty, Spartan and Winesap, in B, C. plantings are carrying rubbery wood virus, None of these has shown obvious symptoms.

Etiology; Graft transmission has been reported by a number of workers, including the authors (29).

DECLINE OF VIRGINIA CRAB

Occurrence in British Columbia: This disease has been observed only in test plots on young Virginia crab trees that had received grafts or buds from several apple source clones in commercial orchards.

References: Welsh and Keane (29).

Symptoms: Young trees, in the first season after inoculation, show a reduction of vigour, pale green foliage, premature ripening of fruits, and premature defoliation (Fig, 4), In the second season a few small leaves are produced, but the tree dies before the end of the season.

Host Range: Transmission tests are in progress to determine whether the virus causing decline of Virginia crab is responsible for similar decline diseases of Hyslop crab, the U.S. D, A. rootstock Spy 227, and the Spartan and Newtown apple varieties,

Etiology: Each of the source clones that has induced decline in Virginia crab has carried both stem pitting and rubbery wood viruses, However other sources that carry stem pitting and rubbery wood viruses have not induced decline.

DECLINE OF HYSLOP CRAB

Occurrence in British Columbia: This disease has been found in one orchard in which Hyslop trees have been top-worked to Jonathan.

References: A similar decline of Hyslop crab has been reported in Michigan by Cation and Gibson (6) and by Cation (5).

Symptons: Within several years of the application of Jonathan scions, grafted and ungrafted branches of Hyslop begin a progressive decline, Terminal growth ceases and the leaves become smaller and lighter in colour, The growth from the Jonathan scions also becomes progressively less vigorous. Hyslop portions of affected trees have developed stem pitting and flute fruit symptoms.

Host Range; The similarity in symptoms of this disease, and decline diseases of Virginia crab, U.S.D.A, rootstock Spy 227, Spartan apple, and Newtown apple, has justified cross transmission experiments that are in progress.

Etiology: Stem pitting symptoms and flute fruit symptoms have been found on Hyslop trees that show no evidence of decline. It appears probable that the decline is caused by a virus distinct from those pausing the other diseases.

DELAYED FOLIATION AND DIEBACK OF SPARTAN

Occurrence in British Columbia: This disease has been seen only in test trees of the Spartan variety that had received grafts from a McIntosh tree infected with leaf pucker.

References: Welsh and Keane (28).

Symptoms: Inoculated trees remain dormant for 4-5 weeks after buds have opened on healthy trees. During the rest of the season many lateral buds fail to open, or produce only one or two small leaves. Dieback of the last 3-4 inches of the terminals is common. Blossoms have opened on inoculated trees only in the season following their inoculation, and then only on parts of the tree remote from the point of inoculation. Fruits have large dimples on the cheeks, unaccompanied by russetting. Leaves formed in the early part of the season show puckering and chlorotic flecking.

Host Range: Transmission tests are in progress to determine whether this disease is caused by the same virus or viruses as similar decline diseases in other varieties,

Etiology! So far there is no evidence to indicate whether the leaf symptoms, fruit symptoms and tree decline symptoms are caused by a single virus or by the concurrence of two or more.

FLAT LIMB

Occurrence in British Columbia: There are unpublished records of the occurrence of this disease in Okanagan Valley plantings of Gravensteins, The variety is no longer grown commercially, and affected trees have been removed. Foster (7) has recorded occurrence of the disease in coastal districts of the province.

Reference: This disease has been reported by workers in most countries where the Gravenstein variety is grown. Hockey (9, 10) has provided comprehensive information on the disease as it occurs in Eastern Canada.

Symptoms: The characteristic symptom is a flattening of the wood on restricted areas of the branches, a condition that gradually becomes more pronounced, until the branches become twisted and deformed.

Etiology: The disease has been transmitted by grafting, by Foster in' British Columbia, and workers elsewhere.

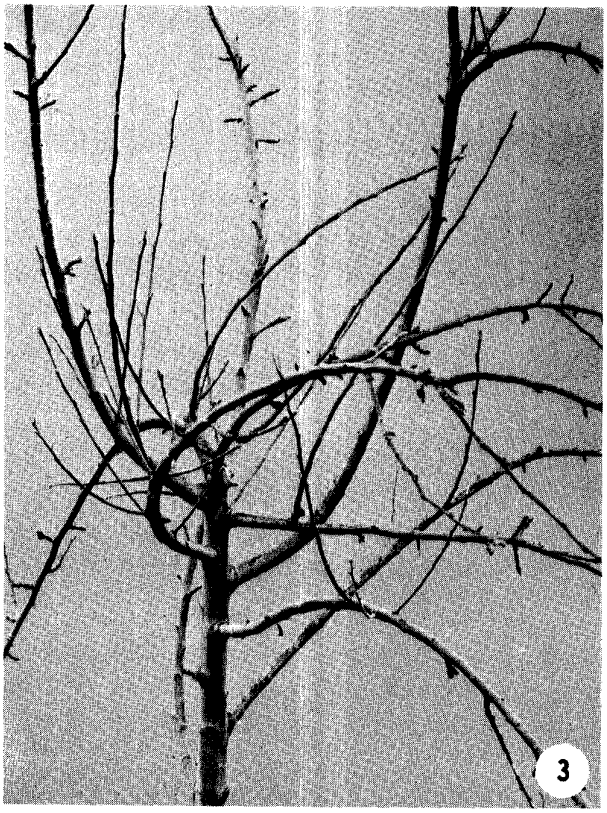
MUMPS

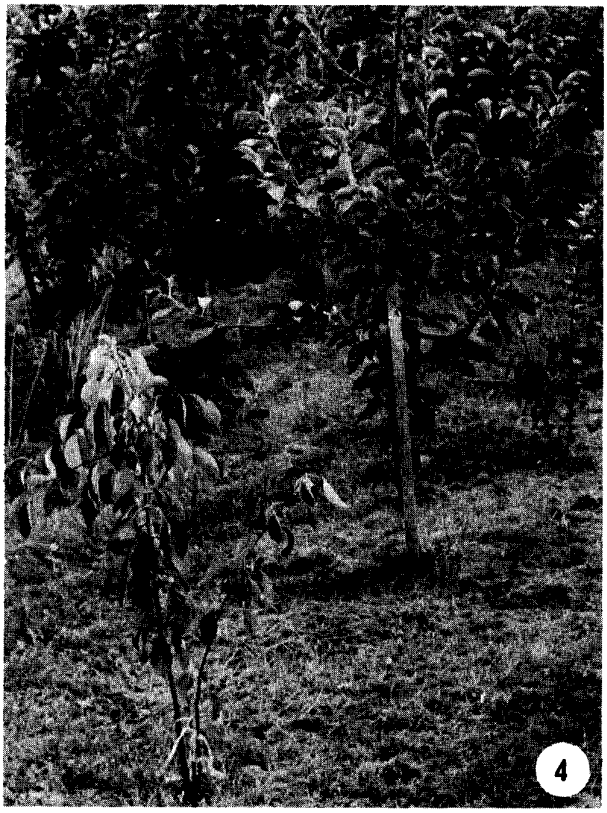
Occurrence in British Columbia: Plantings of Winesap trees in several districts are severely affected.

References: None.

Symptoms: Trees suffer a swelling of bark tissues around pruning wounds and the bases of lateral shoots (Fig. 5). This may be accompanied by linear depressions between the swellings, similar to those induced by flat limb. In severe winters the swollen tissues appear to be tender, are killed, and are transformed into limited cankers.

Host Range: Similar, but milder symptoms have been observed on branches of Golden Delicious top-worked on affected Winesap trees.





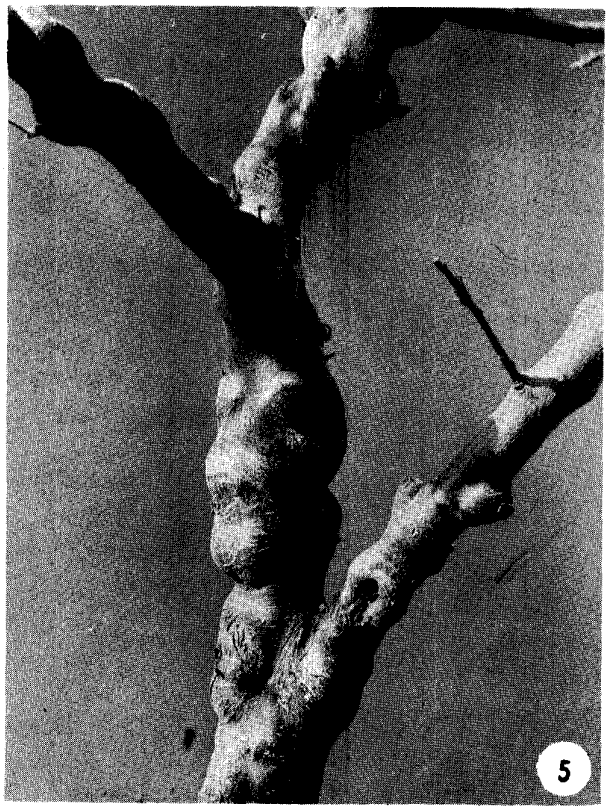


Figure 3. Rubbery wood. Lord Lambourne test tree (bud-inoculated from apparently normal Delicious).

Figure 4. Decline of Virginia crab. Tree in foreground bud-inoculated from apparently normal Rome Beauty. Tree at right is uninoculated check.

Figure 5. Mumps of Winesap, in commercial planting.

Etiology: The cause of the disease is unknown, Transmission tests are in progress to determine whether this is a virus disease, and, further, whether it may be a manifestation of flat limb in the Winesap variety.

BARK BLISTER

Occurrence in British Columbia: This has been found in one large Winesap planting. The condition is severe on several trees, entirely absent on all others.

References: None.

Symptoms: Outer layers of bark tissue on the trunk, scaffold branches, and smaller limbs to the three-year old wood, die, crack, and break into superficial scales,

Host Range: Symptoms have been found only on the Winesap variety,

Etiology: The pattern of occurrence suggests that this is a virus disease. Transmission tests are in progress.

DISEASES AFFECTING LEAVES

APPLE MOSAIC

Occurrence in British Columbia: This disease, so common in many other fruit-growing regions, has been found in British Columbia only on 5 trees, in three widely separated orchards.

References: Among many publications on this disease, full descriptions are provided by Bradford and Joley (3), Thomas (24), and Luckwill and Crowdy (13).

Symptoms: Characteristically, the leaves display irregular chlorotic areas, which are most commonly in the interveinal areas, although they have been reported to develop sometimes around veins and veinlets. These areas are creamy white in colour. Late in the summer they become necrotic, and may drop out. Leaf deformity does not characteristically accompany the chlorosis.

Host Range: Many apple varieties have been reported susceptible to this disease. In British Columbia symptoms have been observed in the varieties Delicious, McIntosh, and Granny Smith,

Etiology: There are many records of transmission by grafting, and budding; and several of juice transmission to herbaceous plants.

LEAF PUCKER

Occurrence in British Columbia: Leaf pucker symptoms have been observed in scattered trees of 6 varieties growing in 7 fruit-growing districts.

References: Occurrence of leaf pucker symptoms on Jubilee, McIntosh, Newtown, Spartan, and the Blaxtayman strain of Stayman, has been reported by Welsh and Keane (27, 28) and of similar symptoms on Golden Delicious by Reeves and Cheney (21).

Symptoms: In severe form the symptoms include irregular leaf

puckering and distortion of leaf margins, accompanied by a chlorotic vein flocking (Fig. 6). Cliaracteristically, symptoms are mild or absent on leaves formed during hot, sunny weather. Mildly affected leaves display only sparse flecking. These leaf symptoms are iisually accompanied in all varieties by fruit symptoms described elsewhere in this paper. The correlation is almost perfect, but there remains uncertainty whether leaf and fruit symptoms are caused by the same virus.

The symptoms of leaf pucker differ from those of apple mosaic in several respects. The flecking is characteristically associated with veins and veinlets. The colour is light green or dark yellow rather than creamy white. Even mild flecking is usually associated with some distortion of leaf tissues.

Host Range: The disease appears to be most widely distributed in Stayman. It has been found in a small number of McIntosh trees in 5 widely separated orchards and in several trees of each of the varieties, Delicious, Jubilee, and Newtown. It has not been found in Golden Delicious in British Columbia. Symptoms have been induced by transmission to Spartan from McIntosh, but inoculated trees of Jonathan and Winesap have shown no symptoms,

Etiology: There is experimental evidence to show that the same virus causes leaf pucker symptoms on McIntosh and Spartan. There is no evidence to indicate whether or not the same virus induces the similar symptoms on other varieties.

CRABAPPLE LEAF FLECKING AND NECROSIS

Occurrence in British Columbia: Unsatisfactory performance, and various abnormalities, have been encountered when ornamental crabapples have been propagated on E. M. II rootstocks during the course of experimental work at Summerland. Similar performance of flowering crabapples on various clonal stocks has caused serious losses in a British Columbia nursery.

References: Varieties of flowering crabapples have been reported sensitive to latent viruses commonly present in apple clones by Luckwill and Campbell (12), Millikan and Guengerich (16), Blodgett and Aichele (2) and others.

Symptoms: Symptoms vary with variety. In most varieties there is a leaf flecking symptom. On some varieties, such as Hopa and Baskatong, the flecks are purple. On others, including Echtermeyer and Makamik, the flecks are light green or yellow. On a few varieties, such as Bedford, large necrotic areas develop in the lamina of the leaf, Affected leaves are dwarfed, and usually puckered, curled, or distorted. When scions of sensitive varieties are applied to infected rootstocks, only a small proportion of the buds swell and produce leaves or shoots. Shoots that do arise remain stunted in the first season. Some varieties begin to grow satisfactorily in the second season. First formed leaves in spring are the most seriously affected; often leavee that form during the last half of the summer are normal.

Host Range: The varieties found to be affected in British Columbia now number 38. All but 6 of these varieties are in the species M. pumila niedxwetzkyana, M. purpurea lemoinei, or M, sieboldii, or are hybrids that include these species in their parentage. No information is available on parentage of the 6 other varieties.

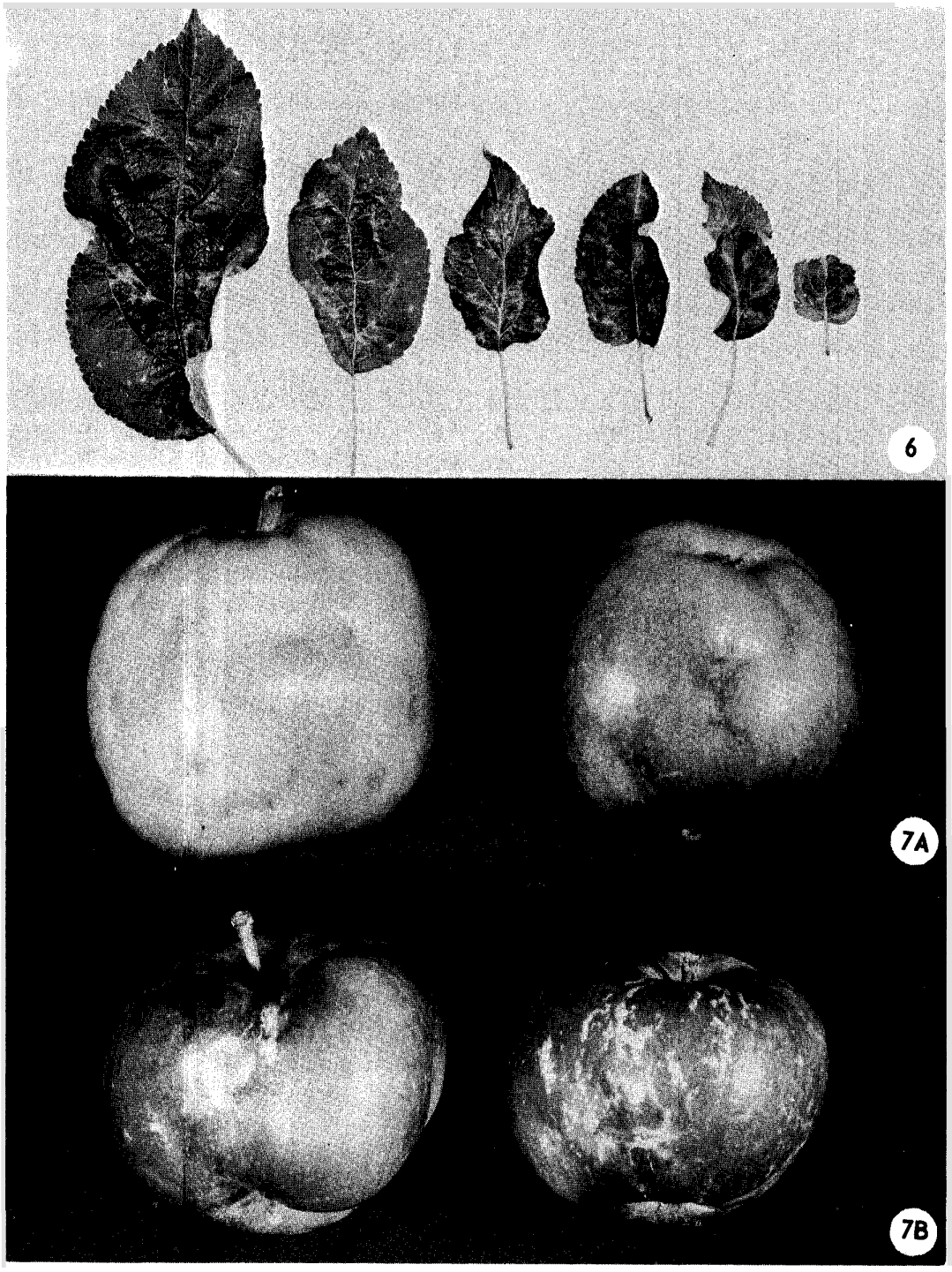


Figure 6. Leaf pucker of McIntosh.

Figure 7. McIntosh fruit pitting and russet. *A.* Pitting symptoms *B.* Russet symptoms.

Etiology: Considerable further work is needed to determine the number of viruses able to produce symptoms in these sensitive crabapple varieties, and the identities of these viruses.

CHLOROTIC LEAF SPOT

Occurrence in British Columbia: This disease name is reserved at present for the leaf symptoms shown by Russian seedling R12740-7A following tissue union with a wide range of apple clones. At Summerland this indicator variety has had only limited use. It has displayed symptoms when propagated on E. M. II rootstocks and on a clone of McIntosh apple. It has displayed no symptoms when propagated on a clone of Spartan apple.

References: The value of Russian apple seeding R12740-7A as an indexing host for latent apple viruses is reported by Mink and Shay (17).

Symptoms: Leaves of infected trees have chlorotic flecks associated with veins and vainlets. These are usually accompanied by leaf puckering and dwarfing. Symptoms are most severe on leaves that develop early in the season. When grafts of the seedling are applied to infected stocks, a large percentage produce no shoot growth, and growth that does occur is dwarfed.

Host Range: Mink and Shay have listed seedlings and crosses of R12740-7A that show symptoms of chlorotic leaf spot.

Etiology: At Summerland and elsewhere the apple sources that have induced chlorotic leaf spot in R12740-7A have caused various symptoms in ornamental crabapple varieties. Considerable further research will be needed to determine the identities of commonly-occurring viruses responsible for symptoms in these plants.

DISEASES AFFECTING FRUITS

McINTOSH FRUIT PIT AND RUSSET

Occurrence in British Columbia: Fruit symptoms have accompanied leaf pucker symptoms on McIntosh trees in all but one of the orchards in which leaf pucker has been observed.

References: Welsh and Keane (27, 28).

Symptoms: Most fruits on affected trees display a random distribution of small skin depressions, Within the depressed areas the skin often shows abnormal purple pigmentation. There is no flesh breakdown beneath, even during prolonged storage. On some fruits these symptoms are accompanied by superficial ring russetting patterns (Fig. 7). Growth of the fruit may be arrested in the russetted areas, resulting in fruit deformity. In some seasons affected trees bear much lighter crops than other trees in the same plantings. Symptoms appear to be more severe when temperatures are low in the early part of the summer.

Host Range: Spartan trees receiving grafts from affected McIntosh trees have produced fruits with large irregular dimples on the cheeks, but no russetting symptoms, Inoculated bearing Winesap and Jonathan trees have displayed no symptoms. Fruit symptoms have been found on striped and blush clones of McIntosh, but one striped clone used in test plots has displayed no

symptoms, although 10 trees of the clone have been inoculated repeatedly. This clone displays only very mild leaf pucker symptoms.

Etiology: The general similarity of fruit russetting and blotch symptoms on several varieties, and the common concurrence of leaf pucker symptoms with these fruit symptoms, suggests that the diseases on these several varieties may be caused by the same virus. Transmission tests are in progress to determine whether this is so.

The common association of leaf and fruit symptoms can be interpreted either as two effects of a single virus or as a remarkable co-occurrence of 2 viruses,

STAYMAN FRUIT BLOTCHING

Occurrence in British Columbia: This disease has been found in each of the several Stayman plantings that have been surveyed. Its presence in additional plantings has been reported by extension personnel.

References: Welsh and Keane *(28).*

Symptoms: Characteristically the fruits bear large superficial skin blotches, varying in colour from purple to brown. In 1960, for the first time since the disease was recognised in 1956, many affected fruits also suffered ring russetting, with arrested growth of russetted areas, so that the fruits were badly mis-shapen (Fig, 8): Affected trees almost invariably display leaf puckering and chlorotic flecking.

Host Range: Until transmission experiments are complete there is no evidence to indicate whether this is the disease responsible for similar fruit and foliage symptoms on other varieties.

Etiology: Transmission tests await fruiting of the test trees. In 1960 one inoculated test tree displayed leaf flecking symptoms.

In a commercial block of mature Stayman trees that has been mapped annually since 1956, symptoms have been confined to certain limbs of most affected trees. They have recurred generally in the previously affected limbs, and have appeared in a number of additional limbs, and additional trees, each season.

RING RUSSETTING OF NEWTOWN

Occurrence in British Columbia: In the seasons 1959 and 1960 this disease has been common in Newtown plantings. In sampling surveys of 23 orchards in 5 districts in the southern part of the Okanagan Valley, no orchard has been found without affected trees,

References: Welsh and Keane (28). Symptoms resemble those described by Reeves and Cheney (21) on Golden Delicious.

Symptoms: Severely affected fruits are covered with elaborate russet; patterns, basically in rings (Fig. 9). While the fruits remain on the trees the russetting is light brown. During storage it turns a dark brown and becomes much more unsightly. There is no breakdown of flesh tissues beneath. Usually all fruits on a diseased tree are affected. Scattered trees have been found on which the symptoms are very mild, with only a small proportion of the fruits bearing wisps or partial rings of russetting. In 1959 there appeared to be very

mild chlorotic flecking symptoms on the leaves of many trees that horc russetted fruits. In 1960 no leaf symptoms could be recognised. Considerable doubt exists about the correlation of leaf and fruit symptoms on this variety. Grower reports suggest that there is wide fluctuation in the severity of russetting symptoms from season to season,

Etiology; One possible transmission was recorded in 1960, with symptoms on a single fruit of a test tree. Occurrence of the disease in only some trees of each planting, and repeated occurrence in the same trees in successive seasons add to the probability that this is a virus disease.

RING RUSSETTING OF DELICIOUS

Occurrence in British Columbia: Symptoms were found on 2 trees in two Okanagan Valley districts in 1960.

References: None.

Symptoms: The fruit symptoms (Fig. 10) are identical with those of ring russetting of Newtown. Leaves on affected trees display light green flecking, or line patterns,

Host Range: One affected tree was common Delicious; the other a red strain of the variety. There is no experimental evidence to indicate whether this disease is caused by the virus or viruses responsible for similar symptoms in other varieties, However, one Newtown tree in a commercial orchard top-worked to Delicious shows ring russetting symptoms on Newtown fruits but no symptoms on Delicious fruits.

Etiology: Transmission tests are incomplete, Records of occurrence on the same trees in successive seasons, and the presence of leaf pucker symptoms, suggest that this is a virus disease.

DARK SCAR OF NEWTOWN

Occurrence in British Columbia; Trees displaying essentially similar symptoms have been found in 2 commercial orchards.

References: Welsh and Keane (28).

Symptoms; The symptoms have varied not only in severity, but in type, from season to season in one tree that was seen first in 1958. In 1958 all fruits bore large black scars over as much as half their skin surface (Fig, 11). In 1959 the fruits were dwarfed and distorted, with large purple blotches, sometimes accompanied by expanded scars. The tree was removed in 1960. In the second orchard, seen first in 1960, the symptoms on the 3 affected trees were identical with those observed in the first orchard in J 958, Severe symptoms of leaf pucker and chlorotic flecking were observed in the first orchard in 1959. The second orchard was seen too late in 1960 for observation of leaf symptoms.

Host Range: These fruit symptoms have been found only on Newtown.

Etiology: Transmission tests are incomplete. It is assumed to be a virus disease because of the recurrence-of symptoms, and the co-occurrence of leaf pucker symptoms.

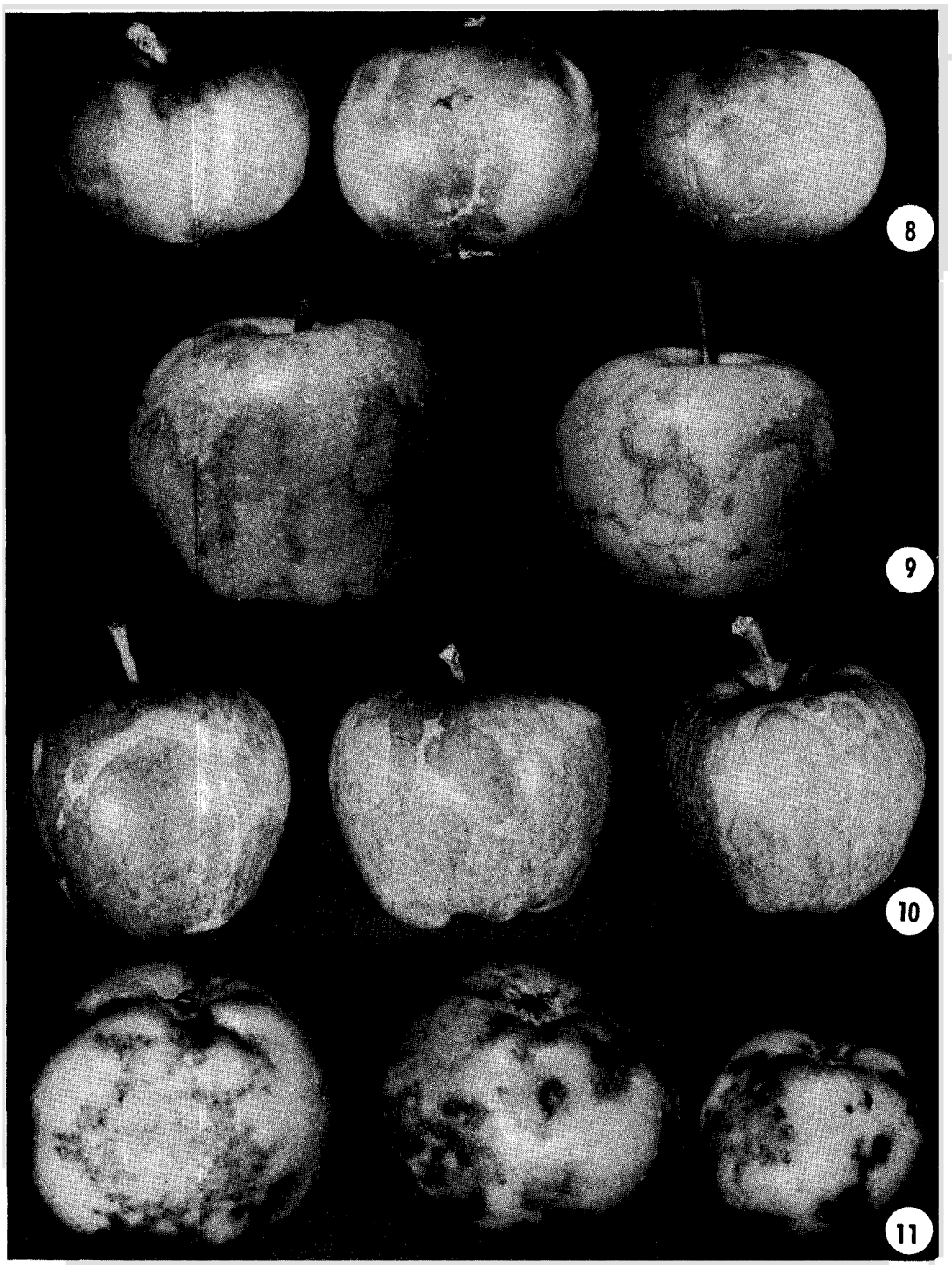


Figure 8. Stayman fruit blotching and russetting.

Figure 9. Ring russetting of Newtown.

Figure 10. Ring russetting of Delicious.

Figure 11. Dark scar of Newtown.

DAPPLE APPLE

Occurrence in British Columbia: This disease has been found in 4 trees of one block of Delicious apples.

References: New Hampshire workers (1, 23) have recorded occurrence of a disease on Cortland and McIntosh in New Hampshire, with symptoms that appear identical to those on Delicious in British Columbia.

Symptoms: Irregular patches of skin on the fruits remain green while normal pigment develops on the remainder of the fruit surface. The blotchy areas are very slightly depressed (Fig. 12).

Host Range: Symptoms have been seen only on Delicious trees growing on their own frameworks. Virginia crab interpieces are not involved, as they are reported to be in New Hampshire,

Etiology: Transmission tests are in progress, The occurrence of symptoms on all fruits of affected trees, their absence on all other trees in the block, and their recurrence on the same trees from season to season, suggest that this is a virus disease.

FLUTE FRUIT

Occurrence in British Columbia: Affected fruits have been found on crabapple trees in a number of commercial orchards, and have been borne on test trees in experimental plantings at Summerland.

References: Cation and Gibson (6) and Cation (5) have described a dwarf fruit condition on Hyslop crabapple that accompanies Hyslop decline, and that appears identical to the disease in British Columbia.

Symptoms: The fruits are reduced in size, slightly to severely. Characteristically there are deep depressions running from stem to calyx, giving the fruit a fluted appearance (Fig, 13). Sometimes there is especially severe distortionof one side of the fruit, The fruit is usually stubbier, the calyx lend-less pointed. Symptoms may be most noticeable when the fruit is half grown, become less obvious as it ripens,

Host Range: Symptoms have been observed on Virginia, Hyslop, Robin, and Almey crabapples. Indexing on Virginia crab has indicated presence of the virus in trees of a number of commercial apple varieties.

Etiology: Flute fruit is almost invariably induced in Virginia crab by its graft inoculation from apple clones that carry stem pitting virus, There is a general, but not perfect, correlation in commercial crabapple plantings of the occurrence of flute fruit and stem pitting.

SUNKEN BLOTCH

Occurrence in British Columbia: Dark sunken blotches have been observed on fruits of trees in a number of Okanagan Valley orchards. On most of the trees the symptoms recur every season, or in most seasons. There is some doubt whether this is a single disease, or several with generally similar symptoms,

References: None.

Symptoms: The characteristic symptom is a depressed area on the

cheek of the fruit. The skin within the depression is dark purple, or black. It is underlaid by a shallow pocket of brown corky flesh (Fig. 14). In one orchard the fruits on the affected trees in some seasons display large depressions or dimples, without development of dark pigment. In other seasons the dark pigment develops. No leaf symptoms have been found on affected trees.

Host Range: Symptoms have been found on trees of the varieties, Delicious, Jubilee, and Winesap.

Etiology: Restriction of symptom occurrence to certain trees, and a general pattern of recurrence on the same trees in successive seasons, have been considered justification for anticipating that viruses are responsible. Transmission tests are in progress.

EVIDENCE OF NATURAL SPREAD

Surveys have been initiated in selected orchards to determine whether the more widespread diseases have a capacity for natural spread. Very limited information is available so far.

There is strong circumstantial evidence for natural spread of stem pitting. In one large planting, the varieties Delicious and Spartan were top-worked in 1942 on Virginia crab body stocks obtained from a common source, Spartan scionwood was obtained from a single source tree that is still free from the virus. Delicious scions were obtained from a number of unidentified source trees. Of 241 trees on which Delicious was top-worked, 86% now display stem pitting symptoms. Of 118 trees top-worked to Spartan, 52% now display symptoms. Almost all of these are at the end of the Spartan block adjacent to the Delicious planting. The most plausible explanation is introduction of the virus in much of the Delicious scionwood, with natural spread from Delicious to neighbouring trees of Spartan.

Four years' surveys in a block of ninety six 20-year old Stayman trees have provided evidence of the gradual spread of fruit blotching and leaf pucker from tree to tree in the orchard. Characteristically these symptoms have occurred, usually together, in single limbs of trees in earlier seasons, and in additional limbs of these trees in subsequent years.

Survey results have provided less conclusive evidence for natural spread of ring russetting of Newtown, and leaf pucker of McIntosh. Additional years of surveying are needed to augment the limited records of apparent natural spread of these diseases.

At present there is no evidence for seed transmission of any of the viruses responsible for apple virus diseases recognised in British Columbia. Undoubtedly much of the distribution of viruses in apple can be attributed to use of infected propagating materials. Reasonably convincing proof of this has been provided by the appearance of symptoms on young trees during their first years after planting in the orchards.

ECONOMIC IMPORTANCE

Six years after initiation of apple virus investigations in British Columbia, it is apparent that several diseases are causing appreciable economic losses, that

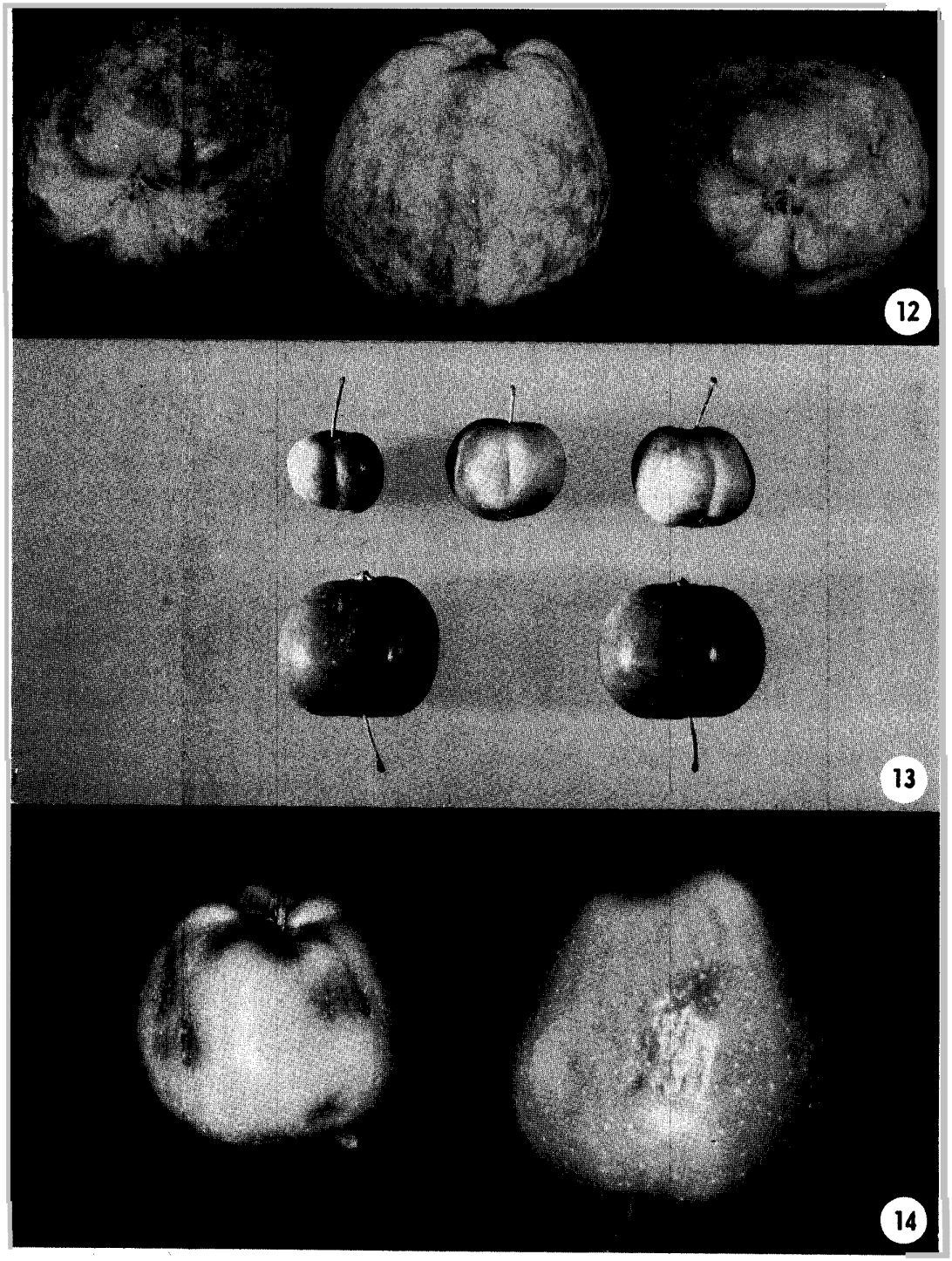


Figure 12. Dapple apple of Delicious.

Figure 13. Flute fruit of Virginia crab. Normal and affected fruits,

Figure 14. Sunken blotch of Delicious,

there are a number of other conspicuous diseases occurring in scattered trees of commercial plantings, and that there is widespread occurrence of latent viruses in orchard trees and clonal rootstocks.

Stem pitting of Virginia crab has curtailed, and finally eliminated, the use of this variety as a hardy body stock in British Columbia, as in other fruit-growing regions, This was one of the most promising materials introduced into the province to provide sturdy and hardy frameworks for tender apple varieties. It was tested by horticulturists (14), and for a few years distributed by the nurseries. The poor performance of Virginia crab when many clones of commercial apple varieties were topworked on it, probably more than any other factor, delayed widespread adoption of hardy body stocks by growers. Disastrous tree losses in northern parts of the Okanagan Valley in 1949 and 1955 winters have demonstrated that the practice of topworking tender varieties on hardy body stocks should have been adopted as rapidly as possible by growers in these districts.

Ring russetting has affected a large percentage of the Newtown trees in British Columbia in 1959 and 1960. In southern districts, where Newtown plantings are concentrated, every surveyed planting has included affected trees. Numerous reports from extension personnel, growers, packinghouse fieldmen and inspection staffs have indicated that this has been the most serious cause of disfigurement of Newtown fruits in these seasons.

Mumps has wide distribution in Winesap plantings. In several young orchards, numbers of severely affected trees have become so unthrifty that their removal has been necessary.

The common occurrence of rubbery wood and stem pitting viruses, and the apparently almost universal occurrence of the latent viruses that are indexed by flowering crab varieties, has suggested the need for investigations to determine whether vigour and productiveness of apparently tolerant commercial varieties are affected by presence of such viruses. Considerable impairment of plant performance has been amply demonstrated for latent viruses of stone fruits, small fruits, and other crops. The increasing use of clonal apple rootstocks, most of which have been shown to carry latent viruses, is providing effective means for more efficient distribution of these viruses in North American plantings.

Probably some of the diseases that have been found in small numbers of trees are, and will remain, curiosities. A few of those not already transmitted may prove to be genetic abnormalities. However the experience of the authors has been that when abnormalities are described, and shown to be virus diseases, additional reports of their occurrence are forthcoming. Many of them have been recognised by growers for years, but have been ascribed to such causes as insect injury, fungus, frost or spray damage, or simply accepted as "seasonal abnormalities". Already several that were recognised first in only a few trees have proved to have much wider distribution. Each season adds records of diseases with characteristics that indicate they are caused by viruses, At present it is impossible to assess the total number of trees in British Columbia plantings that are reduced in value because of virus infection.

DISCUSSION

This paper deals with disease conditions, known to be, or strongly, suspected to be, caused by viruses. Names that have been coined are intended to describe symptoms. The authors do not imply that each name refers to a disease caused by a single distinct virus. For some of the diseases described it is reasonable to anticipate that two or more causal viruses will be identified. It is equally probable that several of the disease conditions that are described in this paper will prove to be manifestations of the same virus in different apple varieties.

It can be anticipated that some of the described abnormalities are manifestations in local varieties of diseases reported in other varieties elsewhere. Apple varieties that are used as indicator hosts in other countries have been assembled, and are included in host range studies of the diseases found in British Columbia.

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