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DISEASES AND THEIR CONTROL

CHAIRPERSON: PATRICIA BROADBENT

RECOGNITION AND CONTROL OF CITRUS VIRUS DISEASES IN AUSTRALIA

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Abstract. **Eight diseases of citrus trees, known or suspected of being caused by viruses, one by a suspected mycoplasma-like organism, and a bud transmissible factor causing crop enhancement in nucellar navel orange on** Poncirus trifoliata **stock are described. Symptoms and control measures are discussed.**

Citrus trees have been grown in Australia since the time of the first white settlement in 1788. Captain Phillip on the way from England with the First Fleet called at Rio de Janeiro on the long voyage to Sydney Cove, and there he took aboard propagative material of crop plants likely to be suited to the climate of Sydney, including fruit and seed and young trees of orange, lime and lemon. These were planted in the Governor's garden at Sydney where they grew and provided cuttings for further plantings. Citrus proved to be suited to the climate and its culture increased. Subsequently citrus varieties were imported from all parts of the citrus-growing world, often as fruit and seed, but also as budded trees and budwood (1). These importations inevitably brought with them, unnoticed and unrecognised, diseases of all kinds including most of the bud-transmitted diseases which are the subject of this paper. The recognition and identification of these have been slow and control, at least in one case, preceded recognition and identification. Recognition in most cases has largely depended on information from overseas countries where research had clarified and defined symptoms and causes of the various classes of disease. Eight diseases known or suspected of being caused by viruses and one by a suspected mycoplasma-like organism, are considered in this survey. Two are accepted as endemic to Australia (5).

Much of the material discussed has resulted from the work of the Citrus Improvement Committee (CIC) of the New South Wales Department of Agriculture in pursuit of solutions to problems of the expanding citrus industry. This committee was set up in 1942, as the Trifoliata Improvement Committee, with instructions to solve problems attending the use of *Poncirus trifoliata* as a citrus rootstock. The scope of its investigations was expanding over the years to include identification and control of other disease conditions as necessity arose. The Committee initially comprised a plant pathologist and two horticultural officers, one a research officer and one an experienced field officer. It has grown somewhat over the years, personnel has changed and its activities expanded to cover other production problems of citrus. This combination of research-trained personnel with field officers of wide industry experience is the ideal one for early recognition of abnormalities in the field and for the broadly based attack necessary in most cases for the solution of such problems and the practical application of the solutions found.

The emergency which led to the formation of the CIC was an outbreak of Phytophthora root rot which caused very heavy losses of citrus trees on rough lemon stock in the Murrumbidgee Irrigation Areas following a series of seasons of above average rainfall in the 1930's and 1940's. As well as destroying established orchards this disease made impossible the replanting of infested soil with trees on the currently used stocks, rough lemon and sweet orange. The location of a reliable root rot resistant citrus stock was therefore imperative. The traditional stock for this purpose overseas was the sour orange, but this had for many years proved a failure in New South Wales, as it had also in South Africa, because of the presence, unrecognised, of the tristeza virus.

Exocortis/Gummy Pitting

Poncirus trifoliata was found to be unaffected by tristeza and highly resistant to *Phytophthora* spp. However, it had a world-wide reputation as an unreliable stock, producing trees of variable size, often severely dwarfed. It had long been used as a minor stock, particularly in coastal New South Wales and for such varieties as Unshiu mandarin and Ellendale tangor which could not be grown successfully on rough lemon stock. The task of the CIC was to find the cause of this variable behaviour and to develop a means of overcoming it. Trials were designed to explore all possibilities and experimental trees were planted at Narara and Somersby Research Stations in the central coast of New South wales and later at Yanco and Dareton in the western part of the State.

It was well known that not all trees on *P. trifoliata* stock were dwarfed. Fortunately for the CIC there were numbers of small blocks of mature trees on this stock in the central coast citrus growing areas of New South Wales. Surveys of these blocks in the 1940's showed that some of these trees were dwarfed in varying degree and others were of size approaching that of trees on rough lemon or sweet orange stock. The most severely dwarfed trees showed rough scaling of the stock below the bud union ('the exocortis' disease). Trees of sizes intermediate between the scaling and apparently normal trees showed a variety of growth abnormalities of the stock such as flaky scales or corky pustules in groups or horizontal rows, or combinations of these symptoms and some were strongly benched at the bud union. These trees showed a second symptom—gummy pits originating in the cambium, which were persistent or intermittently active, and varied from few and scattered to strongly developed, grouped and persistent. The scaling, gummy pitting and dwarfing symptoms were shown, in a wide range of field trials, to be bud-transmitted, and the presence of a virus, symptomlessly, in the scion was inferred. In 1968 Semancik and colleagues in California (7) extracted and purified the causal organism of exocortis which proved to be a viroid. The relationships between the scaling disease—exocortis—and the gummy pitting/dwarfing components and the identity of the agent causing gummy pitting have not been clarified. Many strains of the dwarfing/gummy pitting complex and of exocortis exist and these are variously combined in the field trees and unevenly distributed to progeny trees.

Control of the field disease was simple and effective—the use of budwood from trees certified free of exocortis and the dwarfing component. Rapid indexing methods developed in California have made it possible to select source trees free of exocortis without the delay incurred in waiting for symptoms to develop in the trees themselves, a period which might be eight years or longer. It is therefore not now necessary to rely on mature trees on *P. trifoliata* for propagation material.

The exocortis/gummy pitting complex is quite widespread but there is no evidence of activity of insect vectors in Australia. Mechanical transmission has not yet proved a problem in New South Wales as it has in California. The disease is symptomless in combinations other than with *P. trifoliata*, Rangpur lime, sweet lime and some citranges.

Tristeza

The second virus disease to be discussed is *tristeza*, the aphid-transmitted disease which is lethal to orange trees on sour orange stock but is carried symptomlessly in orange, mandarin, rough lemon and many other varieties (5). The causal organism is a long flexuous rod found in the phloem of affected trees. Its most efficient vector, the aphid *Toxoptera citricidus*, is distributed throughout the country. In New South Wales published comment by experienced growers and nurserymen point to the presence of this disease and its vector well before 1890 and probably earlier than 1870. In the mid 1860's Phytophthora root rot, brought on by several seasons of unusual rains, destroyed the previously flourishing citrus industry around Ryde on the Parramatta River near Sydney. A committee of enquiry set up to examine the problem recommended, amongst other measures, the use of sour orange as a stock, because of its outstanding performances in Spain under similar circumstances, but there is no record that this advice was successfully followed up and it is likely that the presence of tristeza at that time had made this impossible. The identification of the cause of failure of sweet orange on sour orange stock in New South Wales and Victoria had to await the elucidation of the disease in South America and California where its introduction in the late 1920's and 1930's to areas where sour orange was the major stock sparked off an epidemic which has killed millions of trees.

The establishment of tristeza and its vector in the Sydney district when the citrus industry was in its infancy ensured that sour orange was not used as a stock—though not recognised as a disease, tristeza had been controlled by avoidance of susceptible stock-scion combinations. Tolerant rootstocks—rough lemon, sweet orange and later *P. trifoliata* and Troyer and Carrizo citrange were used.

The tristeza complex in Australia, as in South Africa and South America, has a component which causes a disease of grapefruit, West Indian lime, smooth sour orange and *Citrus macrophylla*—stem pitting. This is readily recognisable in the field by its symptoms, pitting of trunk and limbs and distortion and size reduction of fruit. It has prevented the commercial growing of West Indian limes and the use of *C. macrophylla* as a rootstock in New South Wales. Its most serious effect has been on grapefruit and in the 1940's it seemed that stem pitting disease might spell the end of grapefruit growing, particularly in coastal New South Wales. However, variation in symptoms of disease in mature grapefruit trees, from nil to severe, indicated the existence of many strains and this was confirmed by indexing. It was postulated that since symptomless trees had remained in a stable state and apparently healthy for a number of years under conditions of high aphid activity, the strains of stem pitting which they carried must have a high level of protective value against the establishment of strains of greater severity brought in by aphids, and that this could be exploited. Trials were set up at Research Stations at Somersby, Narara and Dareton using grapefruit trees preimmunised with selected mild strains. An acceptable degree of protection has been obtained in long term trials. This has been more complete at Dareton than in the coastal stations. Two factors contribute to the better performance at Dareton—(1) the higher average temperatures which have a modifying effect on virus symptom expression, and (2) aphid activity is curbed somewhat by the aridity and heat of the climate, compared with the more equable coastal climate.

All commercial grapefruit trees produced in New South Wales now carry approved mild strains of the virus, and their performance has proved generally reliable. Research is continuing to locate more efficient protective strains.

Australian Citrus Dieback

This disease has come into prominence only since the early 1970's but it has been recognised on the basis of field symptoms since 1952, as a condition distinct from other known diseases of citrus in Australia (2). These symptoms, blotchy leaf markings and pseudo-deficiency patterns, with increasing debility and dieback of trees, suggest its relationship to the group of psyllid-transmitted diseases caused by mycoplasma-like organisms—greening in South Africa and dieback in India, yellow branch and mottle-leaf in Indonesia and South East Asia. These two recalcitrant and very important diseases were clarified sufficiently by 1970 to permit comparisons to be drawn with the Australian disease and for the methods found successful in their study to be applied to the Australian problem. Some evidence has been obtained that a native insect related to psyllids could be the vector of Australian citrus dieback.

The very wide but sporadic distribution of Australian citrus dieback, its appearance in isolated orchards, sometimes in remote areas surrounded by native vegetation, and in trees of mature age and previous good record or known budline, suggest that this is an endemic disease with a native vector which until recently has visited citrus rather infrequently. Several psyllid-transmitted diseases of vegetable and field crops in this category are known in Australia, particularly in arid and semi-arid districts where crops grown under irrigation can provide an alternative food source when native plant growth becomes mature and unattractive.

Dieback is distributed throughout the citrus-growing areas of the State and its incidence is variable—from a few scattered trees to pockets of infection approaching 100 per cent. A considerable increase in dieback incidence in widely separate parts of the State in the years from 1972 to 1976 was coincidental with a sequence of seasons of above-average rainfall which encouraged growth of native shrubs and weeds and a build-up in populations of native insects. There had also been a trend towards reliance on biological control of red scale, and consequent decreasing use of insecticides, during this period.

The disease is most severe in its effects on grapefruit and sour orange which deteriorate to an unproductive state within four to seven years of infection taking place. Orange trees, particularly those of mature age at the time of infection, can be kept in a productive condition for up to fifteen years after infection occurs. Good management, with periodic pruning and timely application of fertiliser is important, and foliar nutrient sprays appear to be of particular value. The disease is slow moving within the tree and it is possible that removal of limbs showing early symptoms could be of value.

The status of varieties which are symptomless in the field, Rangpur lime, rough lemon and commercial lemon varieties, is not known.

It may be that the disease will prove to be a cyclic one, linked to weather patterns. High temperatures reduce intensity of disease expression over the summer months and following unusually hot summers in 1976-77 and 1977-78 there has been a degree of remission of symptoms. This improvement, enhanced by good cultural treatment, gives some hope that the disease will prove less devastating than Indian dieback, but no real control measures are in sight.

Psorosis

This bud-transmitted disease, the first virus disease of citrus trees to be recognised, was described by Fawcett in California in 1934 (4). No insect vector is known and control is by the use of certified virus-free budwood. Six different diseases have been grouped in the psorosis complex and each of these appears to have a number of strains differing in intensity of symptoms and age of the tree at time of their onset. Two sets of symptoms are shown by several of these diseases, patterns in the young leaves and bark scaling or trunk pitting associated with gumming in the wood. Five diseases of the psorosis group are recorded in New South Wales—crinkly leaf, infectious variegation, psorosis A, concave gum and blind pocket. Strains of several of these are usually variously combined in psorosis-affected field trees, which makes for a considerable range of disease expression. Identification is by indexing on a standard range of seedling varieties, but the sorting out of component substrains can offer problems. Some sub-strains are so mild that they cause no noticeable effect on tree vigour and the onset of bark symptoms may be delayed until old age, or perhaps may never develop. In Australia psorosis is now of no commercial significance and is seen only in old trees.

Two types of virus particles have been associated, spherical particles with crinkly leaf and infectious variegation and long rods with psorosis A.

Xyloporosis

This bud-transmitted disease was described as causing serious deterioration of sweet lime stocks in Israel in 1934 (6) and later under the name cachexia, as a disease of Orlando tangelo in Florida. Several mandarin varieties are susceptible as well as sweet lime and *Citrus macrophylla*, but most citrus species can carry the disease symptomlessly. The symptoms are pitting of xylem with corresponding pegs in the bark and gum impregnation of bark, associated with deteriorating vigour.

In New South Wales two clones of the Ellendale tangor have shown field symptoms of the disease and it has been detected in indexing programmes in one grapefruit and two Washington navel orange clones.

No insect vector is known and the disease is therefore controlled by the use of certified budwood. As with psorosis, tristeza and exocortis/gummy pitting, field variation in disease expression suggest that numerous strains occur, varying in severity of the symptoms developing in susceptible varieties. Variation in transmission also occurs—progeny trees from a single source of Ellendale tangor have produced trees showing a range of symptoms from deterioration and death at 3-4 years to no observable reduction in size of tree and only traces of gum production in the bark of the trunk at the bud union, at maturity. Detection of mild strains on indicators poses problems.

Vein-enation/Woody Gall

This aphid-transmitted virus disease is present in most citrus-growing countries and is of no commercial significance. It is carried symptomlessly in most species but in rough lemon it causes symptoms of two kinds—enations on the under-surface of leaves, associated with veins, and woody galls which are formed on trunks and branches. These vary from small and inconspicuous simple rounded structures to large cauliflower-like growths. The disease is most often seen as galls on the rough lemon stocks of orange, grapefruit or other varieties or on seedling rough lemon trees. There is evidence that many strains exist, differing in the numbers and size of galls produced. No control measures have been considered necessary, though mild-strain protection could be worth exploring. Woody gall is thought to be endemic in New South Wales, possibly in non-citrus native species.

A property of this virus of possible significance is that its presence has been shown to enhance symptom production of yellow vein virus, under experimental conditions in California (8).

Bud Union Corky Ring

An abnormal rough bud union between sweet orange scion and rough lemon rootstock was first reported from Israel in 1937 and subsequently from other Mediterranean countries, South America, Florida, South Africa and India. In affected trees periodic gumming at the bud union is associated with development of a ring of corky bark. It is transmissible by budding and is not seen in combinations other than sweet orange and rough lemon. A virus is therefore suspected. In New South Wales it has been identified only in a clone of Joppa orange and in single trees of two old clones, Shamouti and Golden Nugget, now no longer grown. Trees of the affected Joppa budline are noticeably dwarfed but appear healthy, bear good crops of normal sized fruit and are precocious in cropping. No spread of the disease has been observed in New South Wales. It is controlled by bud certification.

Tatter Leaf

This condition was described in California in 1962, where it occurred in Meyer lemon, in combination with another virus-citrange stunt. Only the citrange stunt component of this mixture has been picked up in indexing programmes in New South Wales and this only in one clone of Meyer lemon. No symptoms are shown by the infected Meyer lemon. It is controlled by bud certification.

The Crop Enhancement Factor

Nucellar navel oranges on *P. trifoliata* rootstocks inoculated by budding in the nursery with buds of a selection of Ellendale tangor have shown enhanced cropping. Trees of the same nucellar navel orange clone, now 13-years-old, inoculated in the nursery with budwood from four selections of Unshiu mandarin have outyielded the uninoculated control trees during the last 6 years. The nature of this crop enhancement factor has not been identified. No relationship to known virus conditions has been found as yet, but, as it is bud-transmissible, a virus relationship is inferred. The response has so far only been observed in trees on *P. trifoliata* rootstocks and trials with other rootstocks may throw some light on its identity.

Discussion

In 1957 Childs (3), discussing viruses and the perennial host, commented—"It is now generally realized that citrus trees may harbour more than one virus, but it is not so widely recognized that a citrus tree with only one virus is a rare thing." The situation is different now. With the widespread operation of budwood testing and certification schemes the use of nucellar budlines and of budlines cleared of virus by heat therapy or meristem culture techniques, freedom from all but insect transmitted diseases is assured. With the exception of psorosis total freedom is not really essential since tolerant and symptomless stock/scion combinations are available.

Though perennial crop plants cannot be protected completely against infection by insect-borne diseases, there is evidence from several countries that an acceptable degree of protection against the severer forms of the stem pitting component of tristeza, by preimmunization with mild strains, can be achieved. Continued research is needed to find protective strains of better performance and reliability. The problem remains of the occasional appearance of mutants, affecting varieties tolerant to the general virus strains, as demonstrated by the emergence in California and South America of strains of stem pitting which cause damaging symptoms on varieties not so affected—yet—in Australia.

There is no reason to hope that the insect-borne disease, dieback, can be controlled by mild-strain protection, and amelioration of symptoms by nutritional amendments seems to be the only avenue of attack. Research on the mode of operation of this disease which, among other things, disrupts minor element metabolism should prove valuable.

There is evidence that all the diseases discussed, with the exception of dieback, exist as complexes of strains, which vary in the intensity of the symptoms induced in field trees and in indicator seedlings. With tristeza, the exocortis/gummy pitting complex and psorosis, variation in the symptom-type also occurs. Some strains may be so mild as to be difficult or perhaps impossible to pick up on inoculated indicators.

Is it justified to accept that all these different infectious agencies—and there could be strains of five or six of them multiplying and spreading with the growth of the tree and influencing the growth processes in their various ways—are independent of each other within the host? Weathers (8) has demonstrated enhancement of symptoms of yellow vein when combined with vein enation virus: this phenomenon has no commercial significance, but it indicates the possibility of other such interactions. For example, there is a suggestion from one of our trials that strains of the exocortis/gummy pitting complex may ameliorate the symptoms caused by the tristeza virus. When more is known of this interaction it may be possible to use it to give added protection to grapefruit in the field against stem pitting.

Dwarfing straits of exocortis/gummy pitting have shown some promise for the production of small trees planted at high density, which give improved performance in their early years. Establishment costs are high but lower maintenance costs make for increased profit margins. Reliable strains or strain mixtures which do not show an unacceptable level of variation in transmission are required for the commercial application of this technique.

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STRAINS OF EXOCORTIS AND GUMMY PITTING: SYMPTOMS IN PONCIRUS TRIFOLIATA AND CITRUS SPP.

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Additional index words. Shellbark, Rangpur lime, Etrog citron, 'dwarfing' budlines.

Abstract. **Varietal reactions to strains of exocortis and gummy pitting range from nil to very severe. Symptomless varieties include sweet orange, mandarin, rough lemon, grapefruit, acid lime, cumquat, calamondin, some citranges and tangelo. Of the varieties showing overt symptoms,** Poncirus trifoliata **reacts with bark and wood symptoms to both exocortis and gummy pitting; Rangpur lime shows mild bark symptoms of exocortis; some sour oranges, lemons, citron and shaddock exhibit shellbark symptoms (presumed to be related to exocortis infection). Etrog citron is used as a glasshouse indicator of exocortis because of its rapid epinasty and leaf curling reaction. The butt characteristics of** Poncirus trifoliata **when used as a stock for scions carrying exocortis and/or gummy pitting include: (a) persistent scaling (exocortis); (b) transient, recurrent or pustular scaling and gummy pitting of the xylem; and (c) no external symptoms and mild gummy pitting. The stock/scion reaction includes a reduction in tree size, and tree shape modification. Yield may or may not be reduced per unit canopy area depending on severity of the exocortis or gummy pitting strains. Field trees, bud-inoculated with 'dwarfing' budlines derived from trees with mild gummy pitting, show an initial growth stimulus followed by a reduction in growth rate. Symptom intensity and time of symptom appearance are influenced by temperature.**

The exocortis/gummy pitting disease complex affects *Poncirus trifoliata* (L.) Raf. and to a lesser extent Rangpur lime (*Citrus limonia* Osbeck), sweet lime (*C. limettioides*

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The second virus disease to be discussed is *tristeza*, the aphid-transmitted disease which is lethal to orange trees on sour orange stock but is carried symptomlessly in orange, mandarin, rough lemon and many other varieties (5). The causal organism is a long flexuous rod found in the phloem of affected trees. Its most efficient vector, the aphid *Toxoptera citricidus*, is distributed throughout the country. In New South Wales published comment by experienced growers and nurserymen point to the presence of this disease and its vector well before 1890 and probably earlier than 1870. In the mid 1860's Phytophthora root rot, brought on by several seasons of unusual rains, destroyed the previously flourishing citrus industry around Ryde on the Parramatta River near Sydney. A committee of enquiry set up to examine the problem recommended, amongst other measures, the use of sour orange as a stock, because of its outstanding performances in Spain under similar circumstances, but there is no record that this advice was successfully followed up and it is likely that the presence of tristeza at that time had made this impossible. The identification of the cause of failure of sweet orange on sour orange stock in New South Wales and Victoria had to await the elucidation of the disease in South America and California where its introduction in the late 1920's and 1930's to areas where sour orange was the major stock sparked off an epidemic which has killed millions of trees.

The establishment of tristeza and its vector in the Sydney district when the citrus industry was in its infancy ensured that sour orange was not used as a stock—though not recognised as a disease, tristeza had been controlled by avoidance of susceptible stock-scion combinations. Tolerant rootstocks—rough lemon, sweet orange and later *P. trifoliata* and Troyer and Carrizo citrange were used.

The tristeza complex in Australia, as in South Africa and South America, has a component which causes a disease of grapefruit, West Indian lime, smooth sour orange and *Citrus macrophylla*—stem pitting. This is readily recognisable in the field by its symptoms, pitting of trunk and limbs and distortion and size reduction of fruit. It has prevented the commercial growing of West Indian limes and the use of *C. macrophylla* as a rootstock in New South Wales. Its most serious effect has been on grapefruit and in the 1940's it seemed that stem pitting disease might spell the end of grapefruit growing, particularly in coastal New South Wales. However, variation in symptoms of disease in mature grapefruit trees, from nil to severe, indicated the existence of many strains and this was confirmed by indexing. It was postulated that since symptomless trees had remained in a stable state and apparently healthy for a number of years under conditions of high aphid activity, the strains of stem pitting which they carried must have a high level of protective value against the establishment of strains of greater severity brought in by aphids, and that this could be exploited. Trials were set up at Research Stations at Somersby, Narara and Dareton using grapefruit trees preimmunised with selected mild strains. An acceptable degree of protection has been obtained in long term trials. This has been more complete at Dareton than in the coastal stations. Two factors contribute to the better performance at Dareton—(1) the higher average temperatures which have a modifying effect on virus symptom expression, and (2) aphid activity is curbed somewhat by the aridity and heat of the climate, compared with the more equable coastal climate.

All commercial grapefruit trees produced in New South Wales now carry approved mild strains of the virus, and their performance has proved generally reliable. Research is continuing to locate more efficient protective strains.

Australian Citrus Dieback

This disease has come into prominence only since the early 1970's but it has been recognised on the basis of field symptoms since 1952, as a condition distinct from other known diseases of citrus in Australia (2). These symptoms, blotchy leaf markings and pseudo-deficiency patterns, with increasing debility and dieback of trees, suggest its relationship to the group of psyllid-transmitted diseases caused by mycoplasma-like organisms—greening in South Africa and dieback in India, yellow branch and mottle-leaf in Indonesia and South East Asia. These two recalcitrant and very important diseases were clarified sufficiently by 1970 to permit comparisons to be drawn with the Australian disease and for the methods found successful in their study to be applied to the Australian problem. Some evidence has been obtained that a native insect related to psyllids could be the vector of Australian citrus dieback.

The very wide but sporadic distribution of Australian citrus dieback, its appearance in isolated orchards, sometimes in remote areas surrounded by native vegetation, and in trees of mature age and previous good record or known budline, suggest that this is an endemic disease with a native vector which until recently has visited citrus rather infrequently. Several psyllid-transmitted diseases of vegetable and field crops in this category are known in Australia, particularly in arid and semi-arid districts where crops grown under irrigation can provide an alternative food source when native plant growth becomes mature and unattractive.

Dieback is distributed throughout the citrus-growing areas of the State and its incidence is variable—from a few scattered trees to pockets of infection approaching 100 per cent. A considerable increase in dieback incidence in widely separate parts of the State in the years from 1972 to 1976 was coincidental with a sequence of seasons of above-average rainfall which encouraged growth of native shrubs and weeds and a build-up in populations of native insects. There had also been a trend towards reliance on biological control of red scale, and consequent decreasing use of insecticides, during this period.

The disease is most severe in its effects on grapefruit and sour orange which deteriorate to an unproductive state within four to seven years of infection taking place. Orange trees, particularly those of mature age at the time of infection, can be kept in a productive condition for up to fifteen years after infection occurs. Good management, with periodic pruning and timely application of fertiliser is important, and foliar nutrient sprays appear to be of particular value. The disease is slow moving within the tree and it is possible that removal of limbs showing early symptoms could be of value.

The status of varieties which are symptomless in the field, Rangpur lime, rough lemon and commercial lemon varieties, is not known.

It may be that the disease will prove to be a cyclic one, linked to weather patterns. High temperatures reduce intensity of disease expression over the summer months and following unusually hot summers in 1976-77 and 1977-78 there has been a degree of remission of symptoms. This improvement, enhanced by good cultural treatment, gives some hope that the disease will prove less devastating than Indian dieback, but no real control measures are in sight.

Psorosis

This bud-transmitted disease, the first virus disease of citrus trees to be recognised, was described by Fawcett in California in 1934 (4). No insect vector is known and control is by the use of certified virus-free budwood. Six different diseases have been grouped in the psorosis complex and each of these appears to have a number of strains differing in intensity of symptoms and age of the tree at time of their onset. Two sets of symptoms are shown by several of these diseases, patterns in the young leaves and bark scaling or trunk pitting associated with gumming in the wood. Five diseases of the psorosis group are recorded in New South Wales—crinkly leaf, infectious variegation, psorosis A, concave gum and blind pocket. Strains of several of these are usually variously combined in psorosis-affected field trees, which makes for a considerable range of disease expression. Identification is by indexing on a standard range of seedling varieties, but the sorting out of component substrains can offer problems. Some sub-strains are so mild that they cause no noticeable effect on tree vigour and the onset of bark symptoms may be delayed until old age, or perhaps may never develop. In Australia psorosis is now of no commercial significance and is seen only in old trees.

Two types of virus particles have been associated, spherical particles with crinkly leaf and infectious variegation and long rods with psorosis A.

Xyloporosis

This bud-transmitted disease was described as causing serious deterioration of sweet lime stocks in Israel in 1934 (6) and later under the name cachexia, as a disease of Orlando tangelo in Florida. Several mandarin varieties are susceptible as well as sweet lime and *Citrus macrophylla*, but most citrus species can carry the disease symptomlessly. The symptoms are pitting of xylem with corresponding pegs in the bark and gum impregnation of bark, associated with deteriorating vigour.

In New South Wales two clones of the Ellendale tangor have shown field symptoms of the disease and it has been detected in indexing programmes in one grapefruit and two Washington navel orange clones.

No insect vector is known and the disease is therefore controlled by the use of certified budwood. As with psorosis, tristeza and exocortis/gummy pitting, field variation in disease expression suggest that numerous strains occur, varying in severity of the symptoms developing in susceptible varieties. Variation in transmission also occurs—progeny trees from a single source of Ellendale tangor have produced trees showing a range of symptoms from deterioration and death at 3-4 years to no observable reduction in size of tree and only traces of gum production in the bark of the trunk at the bud union, at maturity. Detection of mild strains on indicators poses problems.

Vein-enation/Woody Gall

This aphid-transmitted virus disease is present in most citrus-growing countries and is of no commercial significance. It is carried symptomlessly in most species but in rough lemon it causes symptoms of two kinds—enations on the under-surface of leaves, associated with veins, and woody galls which are formed on trunks and branches. These vary from small and inconspicuous simple rounded structures to large cauliflower-like growths. The disease is most often seen as galls on the rough lemon stocks of orange, grapefruit or other varieties or on seedling rough lemon trees. There is evidence that many strains exist, differing in the numbers and size of galls produced. No control measures have been considered necessary, though mild-strain protection could be worth exploring. Woody gall is thought to be endemic in New South Wales, possibly in non-citrus native species.

A property of this virus of possible significance is that its presence has been shown to enhance symptom production of yellow vein virus, under experimental conditions in California (8).

Bud Union Corky Ring

An abnormal rough bud union between sweet orange scion and rough lemon rootstock was first reported from Israel in 1937 and subsequently from other Mediterranean countries, South America, Florida, South Africa and India. In affected trees periodic gumming at the bud union is associated with development of a ring of corky bark. It is transmissible by budding and is not seen in combinations other than sweet orange and rough lemon. A virus is therefore suspected. In New South Wales it has been identified only in a clone of Joppa orange and in single trees of two old clones, Shamouti and Golden Nugget, now no longer grown. Trees of the affected Joppa budline are noticeably dwarfed but appear healthy, bear good crops of normal sized fruit and are precocious in cropping. No spread of the disease has been observed in New South Wales. It is controlled by bud certification.

Tatter Leaf

This condition was described in California in 1962, where it occurred in Meyer lemon, in combination with another virus-citrange stunt. Only the citrange stunt component of this mixture has been picked up in indexing programmes in New South Wales and this only in one clone of Meyer lemon. No symptoms are shown by the infected Meyer lemon. It is controlled by bud certification.

The Crop Enhancement Factor

Nucellar navel oranges on *P. trifoliata* rootstocks inoculated by budding in the nursery with buds of a selection of Ellendale tangor have shown enhanced cropping. Trees of the same nucellar navel orange clone, now 13-years-old, inoculated in the nursery with budwood from four selections of Unshiu mandarin have outyielded the uninoculated control trees during the last 6 years. The nature of this crop enhancement factor has not been identified. No relationship to known virus conditions has been found as yet, but, as it is bud-transmissible, a virus relationship is inferred. The response has so far only been observed in trees on *P. trifoliata* rootstocks and trials with other rootstocks may throw some light on its identity.

Discussion

In 1957 Childs (3), discussing viruses and the perennial host, commented—"It is now generally realized that citrus trees may harbour more than one virus, but it is not so widely recognized that a citrus tree with only one virus is a rare thing." The situation is different now. With the widespread operation of budwood testing and certification schemes the use of nucellar budlines and of budlines cleared of virus by heat therapy or meristem culture techniques, freedom from all but insect transmitted diseases is assured. With the exception of psorosis total freedom is not really essential since tolerant and symptomless stock/scion combinations are available.

Though perennial crop plants cannot be protected completely against infection by insect-borne diseases, there is evidence from several countries that an acceptable degree of protection against the severer forms of the stem pitting component of tristeza, by preimmunization with mild strains, can be achieved. Continued research is needed to find protective strains of better performance and reliability. The problem remains of the occasional appearance of mutants, affecting varieties tolerant to the general virus strains, as demonstrated by the emergence in California and South America of strains of stem pitting which cause damaging symptoms on varieties not so affected—yet—in Australia.

There is no reason to hope that the insect-borne disease, dieback, can be controlled by mild-strain protection, and amelioration of symptoms by nutritional amendments seems to be the only avenue of attack. Research on the mode of operation of this disease which, among other things, disrupts minor element metabolism should prove valuable.

There is evidence that all the diseases discussed, with the exception of dieback, exist as complexes of strains, which vary in the intensity of the symptoms induced in field trees and in indicator seedlings. With tristeza, the exocortis/gummy pitting complex and psorosis, variation in the symptom-type also occurs. Some strains may be so mild as to be difficult or perhaps impossible to pick up on inoculated indicators.

Is it justified to accept that all these different infectious agencies—and there could be strains of five or six of them multiplying and spreading with the growth of the tree and influencing the growth processes in their various ways—are independent of each other within the host? Weathers (8) has demonstrated enhancement of symptoms of yellow vein when combined with vein enation virus: this phenomenon has no commercial significance, but it indicates the possibility of other such interactions. For example, there is a suggestion from one of our trials that strains of the exocortis/gummy pitting complex may ameliorate the symptoms caused by the tristeza virus. When more is known of this interaction it may be possible to use it to give added protection to grapefruit in the field against stem pitting.

Dwarfing straits of exocortis/gummy pitting have shown some promise for the production of small trees planted at high density, which give improved performance in their early years. Establishment costs are high but lower maintenance costs make for increased profit margins. Reliable strains or strain mixtures which do not show an unacceptable level of variation in transmission are required for the commercial application of this technique.

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STRAINS OF EXOCORTIS AND GUMMY PITTING: SYMPTOMS IN PONCIRUS TRIFOLIATA AND CITRUS SPP.

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Abstract. **Varietal reactions to strains of exocortis and gummy pitting range from nil to very severe. Symptomless varieties include sweet orange, mandarin, rough lemon, grapefruit, acid lime, cumquat, calamondin, some citranges and tangelo. Of the varieties showing overt symptoms,** Poncirus trifoliata **reacts with bark and wood symptoms to both exocortis and gummy pitting; Rangpur lime shows mild bark symptoms of exocortis; some sour oranges, lemons, citron and shaddock exhibit shellbark symptoms (presumed to be related to exocortis infection). Etrog citron is used as a glasshouse indicator of exocortis because of its rapid epinasty and leaf curling reaction. The butt characteristics of** Poncirus trifoliata **when used as a stock for scions carrying exocortis and/or gummy pitting include: (a) persistent scaling (exocortis); (b) transient, recurrent or pustular scaling and gummy pitting of the xylem; and (c) no external symptoms and mild gummy pitting. The stock/scion reaction includes a reduction in tree size, and tree shape modification. Yield may or may not be reduced per unit canopy area depending on severity of the exocortis or gummy pitting strains. Field trees, bud-inoculated with 'dwarfing' budlines derived from trees with mild gummy pitting, show an initial growth stimulus followed by a reduction in growth rate. Symptom intensity and time of symptom appearance are influenced by temperature.**

The exocortis/gummy pitting disease complex affects *Poncirus trifoliata* (L.) Raf. and to a lesser extent Rangpur lime (*Citrus limonia* Osbeck), sweet lime (*C. limettioides*