CITRUS GREENING AND VIRUS DISEASES IN CHINA AND SOUTH EAST ASIA

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INTRODUCTION

Citrus is native to China and much of South East Asia. Citrus still grows wild in many areas of China e.g. Poncirus trifoliata can be seen growing on the hills of North China. The Malayan citrus flora comprises on the one hand oranges and shaddocks of Chinese origin and on the other, citrons, lemons and limes imported from India. The maritime route from India to China was probably responsible for this. It is probable that quite a number of the many different varieties of lemons and limes to be found in the Malay Archipelago are the results of accidental sports and are as such indigenous to the islands (Tolkowsky, 1938).

The growing of citrus as an agricultural crop is recorded as far back in Chinese history as 2286 B.C. and the commercial industry has been well developed in China since the tenth century A.D. (Burke, 1967).

Although citrus is probably native to tropical South East Asia, it is not yet exploited commercially as a large scale plantation crop in tropical areas but is very widely grown as a dooryard and orchard crop for local consumption. The reasons for this are complex with aspects involving cultural, political and health factors as well as technological aspects (Neuther and Rico-Castano, 1969).

This paper considers citrus production in South East Asia and China, the impact of greening and virus diseases on citrus production and measures being taken to control these diseases.

PEOPLE'S REPUBLIC OF CHINA

CITRUS PRODUCTION

The total area of citrus in China in 1979 was 180,000 ha of which 67,000 ha were bearing (Shen Zhaomin pers. comm. cited in Barkley et al. 1979). Production of bearing trees was, on average, 6 tons/ha. Total production in China was 400,000 tons. The most important citrus producing provinces are: Sichuan, Guangxi, Hunan, Fujian, Hainan, Guizhou, Guangdong, Zhejiang, Jiangxi, Anhui, Hubei, Shaanxi, and Yunnan.

DISEASES

Yellow Shoot (Wang lung bing, huang lung bing)
Symptoms

Symptoms include yellowing of nearly mature shoots, leaf fall, and rotting of rootlets. Malformation of the leaves is common in sweet orange together with shortening of internodes and downwards as well as upright growth of shoots. On shoots formed later the midrib and lateral veins of the leaves turn yellow and may become enlarged, corky and split. Affected trees bloom early and profusely but bear few fruits; these may be deformed (Lin, 1956).

Nearly all species of citrus are susceptible (Lin, 1956). Rangpur lime and Satsuma mandarin are a little tolerant (Zhao, pers. comm. in Barkley et al. 1979).

Distribution and severity

Yellow shoot has seriously endangered citrus production in some areas of southern China. The disease was first recorded in 1919 but the old records of peasants claimed that yellow shoot was present in the last century or even earlier (Zhao Xue-Yuan, pers. comm. in Barkley et al. 1979). Yellow shoot is absent in northern citrus areas and at high altitudes in the southern part (Lin, 1963).

In 1975, a survey was carried out in Sichuan near the border with Yunnan to determine the effect of altitude on yellow shoot and psyllid occurrence (Zhao, pers. comm. in Barkley et al. 1979).

<table>
<thead>
<tr>
<th>Orchard</th>
<th>Altitude (m)</th>
<th>Infection Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1095 m</td>
<td>100% infection</td>
</tr>
<tr>
<td>2</td>
<td>1200 m</td>
<td>100% infection</td>
</tr>
<tr>
<td>3</td>
<td>1210 m</td>
<td>40% infection</td>
</tr>
<tr>
<td>4</td>
<td>1385 m</td>
<td>3.6% infection</td>
</tr>
<tr>
<td>5</td>
<td>1420 m</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1500 m</td>
<td>3% infection</td>
</tr>
<tr>
<td>7</td>
<td>1620 m</td>
<td></td>
</tr>
</tbody>
</table>

In the lower orchards psyllids were abundant, but they did not occur at higher altitudes.

Young trees of less than seven years are killed within 1-2 years. Nursery trees are killed more quickly and although older trees decline less rapidly they become unproductive two years after the first symptoms appear (Lin, 1956). e.g. yellow shoot appeared in 900 ha of citrus near Liuzhou in 1963 and had destroyed the orchards by 1967 (Zhao, pers. comm. in Barkley et al. 1979).

Yellow shoot disease was very serious around Liuzhou and occurred in Guangdong and Sichuan but was absent at Guilin and Chongqing and reflected populations of the vector. Perhaps the economic feasibility of growing citrus in areas where vector populations (and incidence of yellow shoot) are high, should be examined. Chemical control of the vector in these areas does not appear feasible, as even during the winter in the absence of a leaf flush, psyllids were present. In these areas the use of ultra high density plantings (up to 15,000 trees/ha) might be considered on the premise that the trees would have a short production life (5-6 years) and diseased trees removed immediately (Barkley et al. 1979).
Causal agent

Electron micrographs of the phloem tissues of the veins of leaves with yellow shoot revealed pleomorphic mycoplasma-like organisms with sizes ranging from 60-700 nm with 20 nm thick helicoidal unit membranes and nuclear strands inside the organisms (Chen et al. 1980). Bacterium-like organisms have also been seen within the salivary glands of Diaphorina citri (Dai et al. 1982).

Transmission

Graft transmission was first reported in 1956 (Lin, 1956). The best material for obtaining transmission from a Ponkan tree with citrus yellow shoot was a piece of stem with a single bud, followed by a stem without a bud. Transmission could also be obtained with a piece of leaf but was rare with stem bark. Only a few grafts transmitted the disease in May-July, more so at other times of the year (Zhao et al. 1982). Transmissibility is higher from orange and Ponkan than from Satsuma mandarin.

There may be seed transmission. In a batch of C. limonia seedlings, 14% were affected by yellow shoot (Zhao, pers. comm. in Barkley et al. 1979).

Yellow shoot is transmitted by the citrus psyllid (Diaphorina citri) (Chao et al. 1979; Dai et al. 1982). There are eight generations of D. citri per year in citrus orchards in Fujian. D. citri overwinters in the adult stage and lays eggs in very young citrus growth (Zhao, pers. comm.). In southern areas of China yellow shoot does not occur at high altitudes (Lin, 1963).

Other members of Rutaceae are hosts of D. citri, e.g., M. paniculata, Azalea sp., Coriaria, Clausena lancea. Psyllids are numerous on Murraya, but rare on Clausena.

Control measures recommended to growers (Zhao, pers. comm. in Barkley et al. 1979) include:

1. Nurseries should be removed from citrus growing areas.
2. Use only budwood from healthy mother trees and immerse seed in hot water at 55°C for 50 min. Treat budlings used for mother plants at 49°C saturated hot air for 40 min. Yellow shoot affected nursery trees of Ponkan treated with saturated hot air at 48-50°C for 31-55 min, recovered (Lin and Lo, 1965). Sometimes dipping of budwood in tetracycline hydrochloride is recommended.
3. Control the psyllids by insecticides.
4. Remove diseased trees, because they produce many new shoots during the year and psyllid populations are very high on diseased trees.
5. Tetracycline hydrochloride also causes a marked remission of symptoms when injected into trees with yellow shoot (Zhao, pers. comm. in Barkley et al. 1979; Chen et al. 1980).

Penicillin is also effective against yellow shoot as shown in a trial conducted on infected nursery trees by Zhao (cited in Barkley et al. 1979) (see Table 1).
Table 1: Effect of Two Concentrations of Tetracycline and Penicillin on Yellow Shoot in Nursery Trees

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Year</th>
<th>No. diseased plants of total treated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetracycline 1000 ppm</td>
<td>1977</td>
<td>0 of 20</td>
</tr>
<tr>
<td>Tetracycline 500 ppm</td>
<td>1977</td>
<td>1 of 33</td>
</tr>
<tr>
<td></td>
<td>1978</td>
<td></td>
</tr>
<tr>
<td>Penicillin 1000 ppm</td>
<td>1979</td>
<td>0 of 41</td>
</tr>
<tr>
<td>Penicillin 500 ppm</td>
<td>1979</td>
<td>3 of 46</td>
</tr>
<tr>
<td>Control</td>
<td>1979</td>
<td>0 of 49</td>
</tr>
<tr>
<td></td>
<td></td>
<td>38 of 49</td>
</tr>
</tbody>
</table>

Other Virus Diseases

Of 873 citrus samples from the provinces of Kwangsi, Kwangtung, Hunan, Kiangsi, Chekiang and Szechuan, 691 proved positive for citrus tristeza virus. When the infected cv. Tiang-cheng (sweet orange) was grafted onto rootstocks of six sour oranges, the cultivars Daidai, Bonkan, Shin-san and a Moroccan introduction were highly susceptible and Guo-tuo-cheng was very tolerant. The last is used as a rootstock in some Chekiang districts (Chao et al., 1979) and has great potential for use in other citrus producing countries with tristeza.

Although Poncirus trifoliata L. Raf. is native to China, exocortis is seen only in imported scions grafted onto this stock (Barkley et al., 1979).

Satsuma sudden wilt (Qing ku bing) is a serious citrus disease in Guangsi, Guangdong, Fujian and Hunan Provinces. Satsuma mandarin on Sunju (C. sunki) stock is most susceptible, and less so on Fuji (C. reticulata), Xue gan (C. sinensis) and Bai li mong (C. limonia). Satsuma on P. trifoliata is rarely affected. Nan feng miju (C. reticulata) and Ben di zao (C. reticulata) on Sunju stock are also susceptible to sudden wilt. Leaves curl and the tree wilts and the scion dies. Xylem vessels are plugged with gum. No graft transmission has been achieved.

Satsuma sudden wilt has some symptoms which are suggestive of young tree decline (or blight) which occurs in Florida. In both diseases the tree (or part of it) wilts prior to dieback and defoliation. In Florida associated symptoms (which are used for diagnosis) are: (i) a very restricted uptake of water injected into the trunk at atmospheric pressure and obstructions occur in the water-containing vessels of the xylem; (ii) relatively high levels of zinc and water-soluble phenolics in the outer layers of wood. These two points could be examined in China, along with the complete indexing of the affected Satsuma lines.

Citrus Improvement Scheme

Some selection of improved varieties was reportedly being undertaken but Barkley et al. (1979) found no evidence that a citrus improvement and multi-plication scheme was being implemented for supply of budwood to nurserymen and growers. This should be a matter of high priority. Coupled with the assessment of yield, fruit quality, juice content, absence of mutations, etc. should go freedom from viruses.
More recently the Australian Government has established a citrus aid project at Lingling in Hunan province. Selection, horticultural assessment and indexing of Wenzhou mikan is being undertaken under the supervision of Australian specialists.

**CITRUS PRODUCTION**

In Indonesia the acreage of citrus is increasing and even rice fields are being turned over to citrus. It is estimated there are 100,000 ha of citrus with 13,000 ha in West Java alone. The productive life of a citrus tree in Java is ten years, with production commencing at the fourth year. A yield of 1 kwintal (100 kg) is not unusual for a tree 5-6 years old. One kg of fruit is worth about AS40c. Based on 50 kg fruit per tree and 400 trees per hectare, one hectare of citrus will gross AS10,000. The production cost is estimated at 25% (Tirtawidjaja, pers. comm.).

**DISEASES**

Citrus vein phloem degeneration virus (CVPD)

**Symptoms**

Tirtawidjaja (1965) worked out the etiology of citrus vein phloem degeneration virus, the cause of the most serious disease of citrus in Indonesia. Macroscopic symptoms (leaf yellowing, stiff upright leaves, blotching) and microscopic symptoms (collapse of sieve tubes and companion cells and large numbers of starch granules in the ray cells) (Tirtawidjaja et al. 1965) are used for diagnosis of CVPD. No resistant species or varieties of citrus are available in Indonesia.

**Distribution and severity**

In West Java alone it was estimated that from 1960 onward, not less than three million trees were destroyed by CVPD and the destruction is still taking place (Tirtawidjaja 1980). In 1964 the disease was found widespread in several places in West Java (Bogor, Jakarta, Bandung and others) and was also found in central and southern parts of central Java (Jogyakarta, Cilacap) and in certain areas of east Java (Malang). Further surveys in recent years (Tirtawidjaja 1980) have shown that CVPD is not confined to the island of Java but is also present in several places in Sumatra. The disease was not seen in citrus areas of west Borneo, south Borneo, Sulawesi (Celebes), Madura and Lombok. Some diseased trees were seen in yards in Pontianak and Ujungpandang (Makassar).

The severity and widespread nature of the disease in Sumatra and Java is attributed to the distribution of infected citrus nursery stock from Pasarminggu (Jakarta) (Tirtawidjaja 1980). Although CVPD is widespread in Java and Sumatra, CVPD is not endemic in all citrus localities.

**Causal agent**

Electron microscopic observations indicated that in addition to viruslike particles, there were also mycoplasma-like bodies in the phloem of midveins from chlorotic CVPD-affected leaves (Tirtawidjaja, 1980).
Transmission

Inoculation trials with tissues from different parts of a CVPD-affected tree revealed that the most infective inocula were from buds of small yellow twigs and from midveins of chlorotic leaves (Tirtawidjaja, 1980). CVPD has also been successfully transmitted from inoculated rough lemon seedlings to periwinkle *Vinca rosea* by dodder (Tirtawidjaja, pers. comm.).

CVPD has been successfully transmitted from graft-inoculated seedlings of "Jeruk Siam" to small seedlings of "Jeruk Siam" mandarin (*C. reticulata*), rough lemon, Jeruk lemon (*C. amblycarpa*), Jeruk nipis (*C. aurantifolia*), and Rangpur lime by the citrus psyllid *Diaphorina citri* (Tirtawidjaja, 1983).

Control

1. Enforcement of domestic quarantine to exclude the disease from islands not yet affected i.e. Borneo, Sulawesi, Madura, Lombok, Salayar, etc. Ministry of Agriculture Regulation No. 129/Kpts/Um/3/1982 prohibits the transportation of citrus nursery stock from both Sumatra and Java to other islands. Regulation No. 377/Kpts/Um/6/1980 states that only labelled nursery stock are permitted to be sold and transported from one place to another (Tirtawidjaja, pers. comm.).

2. Private nurseries should be prohibited in endemic areas (Tirtawidjaja, 1980). There is a local regulation issued by the Governor of West Java prohibiting nurseries in endemic areas and requiring the eradication of affected trees. But due to the absence of appropriate sanctions to enforce these regulations, they are ineffective and of no practical significance in controlling CVPD.

3. Trees with CVPD should be rogued in non-endemic areas (Tirtawidjaja, 1980). 170 field workers have been instructed to date by Dr. Tirtawidjaja on procedures for detecting CVPD.

4. Citrus trees should be eradicated in endemic areas and replanting prohibited for two years after the eradication of the last trees (Tirtawidjaja, 1980).

The Central Java Agricultural Extension Service has attempted to eradicate CVPD in the endemic area of Cilacap by removal of all citrus followed by 2-3 years without citrus. Replanting has been with nursery stock issued by the Government. The oldest replant trees are now 7-8 years old but some trees have CVPD as some nursery stock was supplied from areas where CVPD is endemic.

Two other localities where roguing of affected trees has been a success are Juangko and Pulung, both in East Java. The number of affected trees was not as high as in the Garut area and the higher elevation resulted in a lowered activity of *Diaphorina citri*.

5. Injection of oxytetracycline antibiotic has caused remission of CVPD symptoms in greenhouse and field experiments and coupled with heavy fertilizer could lengthen the period of productivity of affected trees (Tirtawidjaja, pers. comm.).
Other Virus Diseases

Thrower (1959) found tristera in declining mandarin trees.

There is no bud certification programme in Indonesia apart from the regulations governing CVPD. Exocortis, xyloporosis and psorosis diseases are unimportant.

MALAYSIA

CITRUS PRODUCTION

Citrus forms at least 4% of the total fruit production in peninsular Malaysia and 6% if the production in Sabah and Sarawak is included. The breakdown of production is sweet orange 75.6%, pomelo 2.4%, mandarins 4.8%, and limes and lemons 17.1% (Weng Wah Ko, pers. comm.).

The principal varieties are:

- mandarins - Liman langkat, Liman cembol
- pomelo - Tambun
- sweet orange - Liman potang, Haji Dolah, Liman Coreng
- limes - Liman nipis, Liman kesturi

A description of these varieties is given in Santiago (1962).

In the Cameron Highlands, the citrus varieties are more varied. Some of the existing varieties originated in China; the remainder from California:

- mandarins - Ponkan, Linkan, Kwantung, Teschew, Liman longkat
- sweet orange - Washington navel, Thompson navel, Valencia, Hamlin, Lin cheng

Citrus production reached 4000 ha in 1970 after the Government's campaign to grow more fruits under the Government's Diversification Programme and with a view to saving foreign exchange. Under various state aided schemes (e.g. State Fruit Rehabilitation Schemes), citrus was distributed by the State Departments of Agriculture (e.g. 266,000 plants were distributed between 1965-1968). But production has fallen to perhaps half this value (Weng Wah Ko, pers. comm.).

DISEASES

Greening

Tanaka and Euro (1978) considered the possibility of greening disease in Malaysia. Young leaf samples were fixed and forwarded to J.M. Bove, INRA, Bordeaux, France, for electron microscopic examination (Yaakob bin Dooon, pers. comm.). No bacterium-like organisms were observed.

Much of the research on CVFD is found in reports of the Horticultural Research Institute (Tirtawidjaja 1969-1977)
Barkley (1982) observed symptoms typical of greening in grapefruit, orange and mandarins in plantings in the Cameron Highlands. Grapefruit were severely affected while lemons, limes and Dancy Tangerine appeared to have some tolerance. No bacterium-like organisms were observed in sections of young leaves.

Catling (1968) noted that *Diaphorina citri* had been recorded in Malaysia.

Barkley (1982) recommended that infected trees should be removed, that care should be taken in the movement of citrus material, and that low concentrations of insecticides should be applied to control *D. citri* whenever a leaf flush occurs.

*Tristeza and psorosis were recorded in West Malaysia in 1962* (Ling, 1962). *Tristeza* is present in all the citrus growing areas of West Malaysia (Ling Wen Poh and Arasu, 1970) and there are high populations of the citrusaphid *Toxoptera citricidus* (Kirk). Local pomeloes do not show the stempitting symptoms which occur in pomeloes in some countries. Barkley (1982) found stem-pitting symptoms in Marsh grapefruit in the Cameron Highlands.

Knorr et al. (1973) saw orchards in which most manao trees have been seriously affected by tristeza, yet in the same plantings there are scattered trees in excellent shape despite vein-clearing symptoms in the foliage.

A budwood improvement programme is being established in the Cameron Highlands of Malaysia (Weng Wah Ko, pers. comm.) and Ting Wen Poh and Arasu (1970) indicated that a rootstock trial had been established. RWI Plantations imported virus-free scions and rootstock seed from the U.S.A. for their trial plantings.

THAILAND

CITRUS PRODUCTION

The citrus production figures for Thailand in 1981-82 (Attathom, pers. comm.) are given in Table 1.
Table 1: Citrus Production in Thailand 1981-82

<table>
<thead>
<tr>
<th>Zone</th>
<th>Planting Area (Rai = 24 acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Som-Keowan</td>
</tr>
<tr>
<td>North</td>
<td>36,263</td>
</tr>
<tr>
<td>Northeastern</td>
<td>1,170</td>
</tr>
<tr>
<td>Central</td>
<td>87,101</td>
</tr>
<tr>
<td>East</td>
<td>61,434</td>
</tr>
<tr>
<td>West</td>
<td>7,544</td>
</tr>
<tr>
<td>South</td>
<td>43,190</td>
</tr>
<tr>
<td>Total</td>
<td>236,702</td>
</tr>
<tr>
<td>Yield (Kg)</td>
<td>210,692,002</td>
</tr>
</tbody>
</table>

Som-Keowan (Mandarin, C. reticulata Blanco)
Som-tra (acidless sweet orange, C. sinensis Osb.)
Som-Khaang (common sweet orange, C. sinensis Osb.)
Som-O (Pumelo, C. grandis (L.) Osbeck)
Mango (smallacid lime, C. aurantifolia (Christm.) Swingle)
Makrutt (C. hystrix)

Diseases

Greening

Symptoms: Greening was first recognised in Thailand by Schwarz et al., 1973. The most common leaf symptoms are (a) chlorotic patterns resembling zinc deficiency; (b) reduced size; (c) upright growth; (d) thickening (Bhavakul et al., 1983). The appearance and behaviour of greening does however vary among species and varieties of citrus (Schwarz et al., 1973).

Distribution and severity

The disease is widespread in Thailand. The severely affected areas are in the East (Chantaburi and Rayong Provinces 60-95%) and the North (Phetchabun, Chiangmai and Nan Provinces 70-95%). The areas with a moderate incidence of greening are in the East (Trat Province 0-40%) and in the Central (Bangkok and Pathumthani 0-40%). There is low incidence of greening in the southern part of the country. Diagnoses were based on tree symptoms and bark fluorescence tests (Bhavakul et al., 1983).

Causal agent

An 'MLO' has been found in the phloem sieve cells of affected citrus but penicillin has not been tried (M. Promminta pers. comm.).

Transmission

Presumably by vegetative propagation material from infected trees and by vectors. Diaphorini citri has been found in Thailand (Catling, 1968).
Control

Schwarz et al. (1973) suggested the following measures:

1. Prevent further spread by prevention of movement of citrus material from affected localities to those not affected.

2. Spray nursery material with dimethoate to prevent movement of citrus psyllids.

3. Spray against psyllids with the appearance of each new flush of foliage. N.B. The increased flush induced by pruning always attracts psyllids. For this reason pruning of declining orchards without simultaneous insect control will only intensify the disease.

4. In areas with a low incidence of greening, remove infected trees to prevent them becoming reservoirs of the pathogen.

5. Discourage the growing of citrus in severely affected areas such as Chanthabun, Phetchabun and Nan.

6. Injection of tetracycline HCl into the trunks of affected trees will give temporary remission of symptoms (Bhavakul et al., 1983).

Other Virus Diseases

Tristeza

Because of the widespread distribution and high population levels of the efficient vector Toxoptera citricidus in Thailand, it is likely that all citrus trees contain tristeza virus (Knorr et al., 1973). Manao (acid lime) and Makrut trees examined showed vein-clearing symptoms characteristic of tristeza and Kunagorn (1982) found long flexuous particles: (1500–2750 nm) in dip preparations and ultrathin sections of phloem cells.

Tristeza is relatively unimportant in Thailand (Knorr et al., 1973) as nearly all trees are of the tolerant variety Som-Keowan (mandarin) and are grown as airlayers. Hence tristeza-susceptible rootstocks are not used. Even infected trees of Som-0 (pomelo) in Thailand appear to tolerate the virus though some pomelo varieties elsewhere in the world are inherently susceptible. Some damage to manao (acid lime) trees does occur (Knorr et al., 1973) and mild strain protection is evident in some orchards.

Other virus and viroid diseases are at present unimportant in Thailand. However, if rootstocks are introduced particularly to overcome Phytophthora root rot, and replace the traditional airlayering, diseases such as xylem porosis, tristeza, and exocortis could become important. Ultimately a citrus improvement programme including indexing and evaluation of stock/scion combinations should be implemented to improve the local citrus industry.
PHILIPPINES

CITRUS PRODUCTION

The varieties grown commercially for local markets in the Philippines are pomelo, mandarins, principally 'Ladu' and Szinkom varieties, oranges, and Calamandarin, known locally as 'Calamansi'. The principal rootstock used is calamandarin (Wallace and Martinez, 1964).

Philippine Citrus Statistics 1982

Citrus (Summary): Area, total and bearing trees, quantity and value of production by region. Philippines CY 1982

<table>
<thead>
<tr>
<th>Region</th>
<th>Area (ha)</th>
<th>Trees ('000)</th>
<th>Production</th>
<th>Value ('000 Pesos)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>Bearing</td>
<td>Quantity MT</td>
</tr>
<tr>
<td>Philippines</td>
<td>25,440</td>
<td>8,150</td>
<td>4,036</td>
<td>131,528</td>
</tr>
<tr>
<td>Ilocos</td>
<td>2,200</td>
<td>469</td>
<td>290</td>
<td>5,622</td>
</tr>
<tr>
<td>Cagayan Valley</td>
<td>1,000</td>
<td>240</td>
<td>169</td>
<td>5,768</td>
</tr>
<tr>
<td>Central Luzon</td>
<td>510</td>
<td>155</td>
<td>121</td>
<td>3,453</td>
</tr>
<tr>
<td>Southern Tagalog</td>
<td>7,620</td>
<td>3,836</td>
<td>1,043</td>
<td>28,533</td>
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<tr>
<td>Bicol</td>
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<td>904</td>
<td>541</td>
<td>8,268</td>
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<tr>
<td>Western Visayas</td>
<td>2,200</td>
<td>645</td>
<td>518</td>
<td>6,020</td>
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<tr>
<td>Central Visayas</td>
<td>1,120</td>
<td>210</td>
<td>168</td>
<td>10,309</td>
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<tr>
<td>Eastern Visayas</td>
<td>300</td>
<td>107</td>
<td>80</td>
<td>2,661</td>
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<tr>
<td>Western Mindanao</td>
<td>1,380</td>
<td>341</td>
<td>137</td>
<td>7,136</td>
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<td>Northern Mindanao</td>
<td>730</td>
<td>209</td>
<td>150</td>
<td>9,101</td>
</tr>
<tr>
<td>Southern Mindanao</td>
<td>4,580</td>
<td>955</td>
<td>696</td>
<td>33,947</td>
</tr>
<tr>
<td>Central Mindanao</td>
<td>700</td>
<td>175</td>
<td>123</td>
<td>10,710</td>
</tr>
</tbody>
</table>

1982 Hectareage by Types/Varieties

- Calamondin: 9,970 hectares
- Mandarin: 6,610 hectares
- Oranges: 4,000 hectares
- Pomeloes: 4,060 hectares

TOTAL: 25,440 hectares

DISEASES

Leaf mottling disease

Symptoms: Leaf-mottle yellows is a disease of citrus associated with symptoms of yellowing and mottle of the leaves, which in the early stages resembles the effects of nutritional disorders, particularly zinc and manganese deficiencies. Trees in the advanced stages of decline are not unlike those affected by tristeza (Martinez and Wallace, 1967).
Symptomatology of leaf mottling is described by Martinez and Wallace (1968, 1969) and Salibe and Cortez (1966, 1968) and resembles citrus vein phloem degeneration and other diseases in the greening complex (Catling, 1968).

Distribution and severity

The leaf mottling disease was first noticed in 1957 in the Batangas Province. Since that time the flourishing citrus industry of that province and neighbouring Laguna, which together formed the largest and oldest citrus area of the Philippines has virtually collapsed (Catling, 1968). Martinez and Wallace (1967) found the disease in Laguna and in the Bicol and Mindanao regions.

Altamirano et al. (1976) believe that leaf mottling spread to other parts of the country by planting material shipped from Batangas to areas such as Bicol when their citrus areas were expanding.

In 1961, the mandarin area was 19,330 hectares and this fell to 12,010 hectares in 1965, 7,080 hectares in 1970 and 4,840 hectares in 1974. The sweet orange area was highest in 1962 at 5,750 hectares and fell to 3,470 hectares in 1974. This reduction in area was attributed to leaf mottling (Altamirano et al, 1976).

Causal agent

The cause of leaf mottling was initially attributed to a mycoplasma-like organism (Lafleche and Bove, 1970) but this was later revised by Bove et al. (1980) to a bacterium-like organism (kingdom Procaryotae, division Gracilicutes). This revision was based on the double track membrane-like cell wall in addition to its inner cytoplasmic membrane (Garnier and Bove, 1977) and its sensitivity to penicillin G which possibly indicates the presence of peptidoglycan (Bove et al, 1980).

Transmission

Leaf mottling disease is graft transmissible (Salibe & Cortez, 1966, 1968; Martinez & Wallace, 1967). Salibe and Cortez (1966) cited preliminary evidence that Diaphorina citri (citrus psyllid) is a vector of leaf mottling and this was later confirmed by Celino et al. (1969) and Martinez and Wallace (1967). See section on D. citri for further information on the vector in the Philippines.

Control

The following control measures were devised:

1. In 1969, a quarantine measure through an administrative order by the Secretary of the Department of Agriculture, was issued to prohibit entry of citrus planting materials into non-infected areas (Altamirano et al, 1976).

2. Several insecticides tested and used locally in a citrus spray programme appeared effective in controlling the vector (Celino and Molino, 1971 cited in Altamirano et al, 1976).
3. Treatment of citrus budwood with tetracycline compounds inactivated the leaf mottling pathogen (Martinez et al., 1970).

4. Gonzales et al. (1969) tested 110 citrus cultivars and found that calamondin, lime, lemon and some pomelos and mandarin hybrid trees remained mildly affected. Martinez and Wallace (1969) also found tolerance of varieties including lime, lemon and pomelo.

5. A programme for rehabilitation and development has been established (Altamirano et al., 1976): apparently disease-free trees of commercial varieties were selected and tagged as mother trees. It was hoped to eradicate all known diseased trees in Batangas province and to establish new orchards using certified material. The insect vector was to be controlled with a rigid spray programme.

It is considered that a profitable citrus industry can still be maintained in areas of the Philippines affected by leaf mottle disease (Gonzales and Vinas, 1961). Eradication of existing leaf mottle-infected trees, use of varieties and combinations with disease tolerance, replanting with healthy material, reduction of the psyllid population by judicious spraying and creation of a disease-free zone around a given citrus area has been tried. After five years the performance of replanted trees is giving promising results.

Other Virus Diseases
Tristeza and seedling yellows

Many of the calamansi trees examined by Wallace and Martinez (1964) showed symptoms of vein-clearing and wood-pitting of tristeza. Nearly all pomelo trees were stunted, defoliated and unproductive with external pits or depressions on the lower limbs of these trees. Calino et al. (1966) found that Toxoptera citricida, T. aurantii and Aphis gossypii all transmitted tristeza.

Cachexia

Wallace and Martinez (1964) found many of the trees of Ladu and Szinkom mandarins budded on calamandarin rootstock to be infected with cachexia (xyloporosis).

Psorosis

Wallace and Martinez (1964) found two trees of Szinkom mandarin with psorosis 'A' bark lesions on the trunk and leaf patterns. These authors did not establish if the other forms of psorosis were present in the Philippines but concluded that psorosis was not widely distributed.

CAUSAL AGENT OF GREENING

Under normal electron microscopy the envelope surrounding the organism associated with the various geographical forms of greening (i.e. leaf mottle, yellow shoot, likubin) is comprised of three zones. The inner membrane is the cytoplasmic membrane, the outer membrane is a cell wall and each of these two electron-dense zones can be resolved into a triple layered unit membrane 20-100Å thick (Garnier & Bove, 1977).
When first described by Lafleche and Bove (1970a) the greening organism (GO) was called 'mycoplasma-like'. Later Moll and Martin (1974) and Garnier and Bove (1977) presented evidence that the GO had a double track membrane-like cell wall in addition to its inner cytoplasmic membrane. The term 'bacterium-like organism' was proposed (Moll & Martin, 1974). A mycoplasma-like organism (e.g. stubborn) is surrounded by a simple unit membrane (Lafleche & Bove, 1970b; Saglio et al, 1971). Bove et al. found that greening (including Indian dieback, likubin, and leaf-mottling) affected sweet orange outgrow symptoms when treated with penicillin G and no organisms can be seen in the sieve tubes of new symptomless leaves but they reappear when the treatment is stopped. Penicillin G inhibits a late step (trans-peptidation) in the biosynthesis of peptidoglycan. They concluded that the greening organism probably possesses peptidoglycan and therefore belongs to the kingdom Procaryotae division Gracilicutes (Bove et al, 1980).

Diaphorina Citri Kuw. (Citrus Psyllid), the vector of greening in South East Asia

Distribution

Diaphorina citri has been recorded in many countries of Asia, namely India, Nepal, Pakistan, Burma, Malaysia, Indonesia, China, Japan, Hong Kong, Thailand and the Philippines (Catling, 1968).

Surveys

The oriental citrus psylla leaves no evidence of its feeding or breeding and thus surveys must be based on a count of live insects. Catling (1968) surveyed for the vector using two methods depending mainly on the size of the grove:

i) in most large groves 50-200 young shoots were selected haphazardly and examined. The population was expressed as a percentage of flush points infested.

ii) in small and backyard groves or where trees were semi-dormant, trees were searched for 10-20 minutes or until the vector was recovered.

Because psylla numbers are related to the number of flush points, the amount of available flush was arbitrarily (0 to 5) rated in each of the surveyed groves.

Biology

The biology of D. citri, its morphology, oviposition and duration of development are described in Catling (1968).
Hosts

All species of citrus are attacked by *D. citri*. There is some circumstantial evidence that *D. citri* has spread to citrus from indigenous host plants in some areas. The Philippine flora is rich in Rutaceae and in India and South East Asia the insect has been found on five different genera of this family. *D. citri* has been found breeding on *Murraya exotica* ("Kamuning") at Los Banos, this being an introduced species frequently used as a hedge near citrus groves. *Murraya paniculata* is a preferred host of the psyllid vector of likubin but did not show symptoms of the disease after tissue inoculation (Miyakawa, 1980).

Population dynamics

There is evidence that significant transmission of leaf mottling by *D. citri* requires fairly large populations of the vector. Prevention of high populations on the flush cycle at the start of the season may be extremely important in checking the spread of the disease (Catling, 1968).

Psyllids are known to fluctuate violently in numbers. Due to their high fecundity and short life cycle they can multiply very fast and exploit their environment when limiting factors are relaxed. Populations of *D. citri* in Batangas (Philippines) are at their lowest on the semi-dormant trees during the dry season from December to April. The main upsurge in numbers takes place on the major flush cycle in May/June which is stimulated by the first rains, with moderate populations during July and August. There are eight generations of *D. citri* per year in citrus orchards in Fujian, China (Zhao in Barkley et al, 1979). It overwinters in the adult stage and lays eggs in very young citrus growth. Pruning stimulates growth flushes which are out-of-phase with the normal rhythm of the tree and are often colonised by the vector with a consequent introduction of the causal organism. Similarly, the vigorous flushing of young trees makes them very attractive to the vector.

Control of *D. citri*

In Liuzhou, parasitism of the psyllid nymphs occurs. The percentage of parasitism varies with the year from 80-90% to almost nil. In Fujian there are two parasitic wasps: *Metapriorinitus* sp. and *Psyllaphagus* sp., *Cheilomenes quadriplagiata* Swartz, *Cneophora bicornata* Swartz, *Leiodytes Pallas*, *Symphona octmaculata* (F.), *Chrysopaboninensis okamoto*, *Chrysopa septempuncta* have been recorded preying on the psyllid (Zhao in Barkley et al, 1979).

In Reunion Island, 4,600 adults of *Tetrastichus radiatus* (originally imported from the Punjab, India, where it is an extremely effective parasite of *D. citri*) were reared in the laboratory and released against *D. citri* with good preliminary results (Stienne and Aubert, 1980).

Catling (1968) reared at least five species of chalcid parasites from *D. citri* in the Philippines. Larvae of a syrphid fly, a neuropteran nymph (probably *Chrysopa* sp.) and a coccinellid larva are apparently associated with the nymphal stages of *D. citri* (Catling, 1968).
Celino (quoted in Catling, 1968) has found a wide range of modern insecticides to be effective against D. citri in Batangas province in the Philippines. Fraser (1968) reported that three annual sprays of endrin were used to control the vector in India. In South Africa, Catling (1968) found that a concentration of dimethoate as low as .0025% active ingredient was extremely effective against the eggs and nymphs of Trioza erytreae.

Discussion

The greening diseases have dealt a severe blow to the awakening citrus industries of China and South East Asia. Assessment of the real genetic and economic potential of tropical citrus must await the advancement of agricultural research in tropical countries. There is scope for coordinated research among South East Asian countries (and including Australia) under the auspices of A.C.I.A.R. (Australia Centre for International Agricultural Research). Citrus varieties should be selected which are adapted to the tropical environment, tolerant of greening (if possible) and acceptable to Asian palates.

Among horticultural factors restraining large-scale commercial citrus culture in the tropics is the fact that the life history of the tree, the species and habits of its pests and diseases, as well as the growth, ripening and market quality of its fruits all differ in tropical as compared to subtropical climates. These differences pose many unsolved production, handling, processing and marketing problems in the tropics (Reuther and Rios-Castano, 1969).

The intensive pest control programmes in use in many citrus plantings in the Philippines (Catling, 1968) and Malaysia (Barkley, 1982) is alarming. While recognising the difficulties involved in protecting the fruit in groves which set 2-3 crops annually, severe problems are likely to arise if such spraying is continued. Not only is this a costly form of pest control (Catling, 1968) but these materials and their present method of application have caused severe mite and scale problems (Catling, 1968; Barkley, 1982). Dangerous residues on the fruit and insecticide resistance are likely to occur because of such excessive spraying (Catling, 1968).

D. citri could be regarded as the most serious citrus pest in South East Asia. Yellow shoot disease, greening, etc. are devastating in areas where D. citri is abundant. The psyllid is controlled by the foliar application of insecticides which are generally applied to control other pests, e.g. citrus leaf miner. There appears to be an urgent need for research on control methods, including changes in cultural practices, biological control of the psyllid and the use of granular formulations of soil systemics in nurseries.

The possibility of biological control of the vector should be further investigated. Dr. Zhao (Barkley et al, 1979) did indicate that parasitism of the psyllid nymphs occurs around Liuzhou (China) and in Fujian parasitids wasps attack the psyllid. This should be investigated further. In Reunion Island, for example, several thousand adults of Tetrastichus radiatus imported from the Punjab (India) and reared in the laboratory have been released against D. citri with good preliminary results (Etienne and Aubert, 1980).
Chemical control studies to determine minimal levels of selective insecticides, and the timing of such applications, for the control of *D. citri* should be undertaken, and low concentrations of safer insecticides such as metasystox, dinethoate and Thiodan should be tried to control *D. citri*, which will be less harmful to the large complex of beneficial insects in the trees (Catling, 1968).

Unless greening (likubin, leaf mottle, yellow shoot, CVPD) and its vector *D. citri* are controlled, the commercial production of citrus in South East Asia will be severely limited. More research needs to be done on possible tolerant varieties, the economics of tetracycline injections and the population dynamics of *D. citri*. If tetracycline injections for disease control are not possible, the early removal of diseased trees should be practised. Vector populations are higher on yellow shoot affected trees due to the continued production of weak new shoots.

Strategies have been worked out in Indonesia and the Philippines for limiting the spread of greening to non-endemic areas and for re-establishing citrus in endemic areas. These attempts must be commended and encouraged. If necessary, government regulations should be passed and enforced to ensure that the programmes for rehabilitation and development of citrus are not jeopardised.

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