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The Present Status of Citrus Virus and Virus-Like Diseases in China

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Abstract: Citrus yellow shoot (Huanglongbing), exocortis and tristeza have been found in several provinces of the mainland of China. Psorosis and xyloporosis have also been reported in Taiwan Province (6, 9). Satsuma sudden wilt and yellow ring of sweet orange on trifoliate orange which are similar to virus diseases in symptomatology, also occur in China (22, 25).

Citrus Yellow Shoot (Huanglongbing)

Citrus yellow shoot (CYS) is the most serious disease in Chinese citriculture, and is prevalent in the southern citrus-producing area of China. Likubin in Taiwan Province is probably the same disease (2).

The recorded history of CYS in Guangdong Province began in 1919. In areas where the disease is prevalent, a citrus orchard isolated from existing diseased orchards may be seriously damaged 8-9 years after planting. New plantings near orchards with CYS incidence often are fatally damaged before bearing.

Almost all citrus species and scion-stock combinations are susceptible to CYS; however, trifoliate orange (*Poncirus trifoliata* (L.) Raf.) does not show strong symptoms after infection.

Yellow shoot in the primary stage of the disease and leaf mottling yellows are characteristic symptoms.

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Initially, a few shoots with yellowing leaves appear in the green canopy, and this is the typical yellow shoot symptom. In general, yellow shoot appears first in the top of the tree. There are three types of leaf yellowing for CYS, i.e., mottling yellows, uniform yellowing, and yellowing similar to zinc deficiency symptoms. Leaf mottling yellows usually appears after the leaf matures. The yellowing starts near the midrib, the lateral veins and the petiole, and as yellowing spreads the leaf shows a mottled pattern. Ultimately the whole leaf may turn yellow. If leaf yellowing occurs before the leaf matures, the entire leaf will be yellow.

Leaf mottling yellows appears in every citrus cultivar and in different stages of the disease, and it can be used as the main basis for diagnosis.

The graft transmissibility of CYS was described and its virus nature was proposed in the 1950's (1). In the 1960's, disputes arose on whether or not tristeza infection was the cause of CYS. Indexing revealed that most trees affected with CYS were infected with tristeza, but negative results were obtained from some young seedlings with typical CYS symptoms in the field and, also, from seedlings infected by psyllid inoculation. These results confirmed that tristeza usually co-infected plants with CYS, but was not the cause of CYS (17). In the 1970's, pleopmorphic organisms with envelopes more than 20 nm in thickness were found associated with the phloem tissue of CYS-infected plants, and the sensitivity of the causal agent to tetracycline and penicillin was also described (7, 15, 18, 19, 21, 26, 28). Therefore, the causal agent of CYS apparently is a rickettsia-like organism (RLO) or bacterial-like organism (BLO).

Diseased seedlings recovered and showed normal growth after treatment with saturated hot air (49°C for 50 min), and other results indicating heat sensitivity were also described (3, 4, 27).

The graft transmissibility of CYS is high when buds or a piece of stem are used as inoculum, but when stem bark alone is used as inoculum, transmission rates are much lower or transmission may not occur. If the budstocks are collected from a diseased tree and propagated between October and April, the progeny plants usually show a high incidence of CYS. However, if the plants are propagated from the same tree, between May and July, only a small proportion of them show symptoms.

Vectors studies indicate that the citrus psyllid (*Diaphorina citri* Kuw). is responsible for the spread of CYS in the field (10, 11, 20).

A survey in Guangxi has shown that there is no natural spread of CYS in the northern part of the province where the psyllid has not been found. In the southern part, where CYS is epidemic, there is usually a high population of psyllids (14, 20). A survey of Ningnan County, Sichuan Province, revealed that psyllids were absent in citrus orchards at high altitude which had a very low incidence of CYS, while a high psyllid population was associated with high CYS incidence at lower altitudes (13). An orchard in a mountain valley in Wuzhou, Guangxi, was surveyed in 1978. Citrus psyllid was not found there and the damage caused by CYS was slight. In addition to possible environmental influence on the CYS-psyllid status, CYS spreads much slower in orchards where psyllids are controlled by frequent insecticidal sprays (20). In addition to the observations on the different CYS-psyllid status in the orchards with different environmental conditions, CYS spreads much slower in commercial orchards in CYS areas where psyllids are controlled by frequent insecticide sprays. The above observations have given us important inspirations for CYS control.

In addition to quarantines, the following control measures are recommended: (1) Nurseries should be established at sites at least 2 km away from citrus plantings. Seeds and budwood should be collected from healthy trees in CYS-free areas or in bearing orchards where CYS damage is slight. Seeds, budwood, and mother seedlings should be heat treated. In commercial nurseries where a large amount of budwood must be treated, tetracycline treatment is also recommended. (2) New plantings should be isolated from established orchards affected with CYS. (3) Citrus psyllid should be rigidly controlled by insecticides. (4) Diseased trees should be removed promptly.

Cure of diseased trees by pressure injection of tetracycline has been successful, but it has not been used on a commercial scale.

Exocortis

Most citrus cultivars introduced from the U.S.A., Morocco, etc., before 1960 and individual native cultivars such as 'Anliucheng' (*Citrus sinensis* (L.) Osbeck) show scaly butt symptoms of exocortis in the field when grafted onto trifoliate orange or *C. limonia* (23, 24).

Exocortis infection of most imported plants of grapefruit (*C. paradisi* Macf.) and 'Eureka' lemon (*C. limon* Burm. f.), and a few plants of natives cultivars was revealed by indexing in Taiwan Province. Exocortis infection of 'Liucheng,' also, has been found there (6, 9).

Between May 1980 and July 1981, 179 trees of 47 cultivars of old-line citrus with or without exocortis symptoms were indexed on Etrog citron (*C. medica* L.) (Arizona 861-S-1 or Arizona 861) in Luizhou, Guangxi. Nine cultivars imported from the U.S.A. before the 1950's were all infected, and 28 out of 31 trees of these cultivars indexed positive. Four satsuma trees (*C. reticulata* Blanco) from a Japanese source were free from exocortis. Eight out of 10 cultivars introduced in the 1960's from Morocco, Cuba, etc., were infected, and 15 out of 27 trees of these cultivars indexed positive. Indexing of 117 trees of 27 native cultivars revealed exocortis infection of 35 plants of 6 cultivars. Among the native citrus, 30 out of 32 plants of 'Anliucheng' collected from 6 localities and 'Xinhuicheng' from 3 localities were infected. 'Anliucheng' and 'Xinhuicheng' are predominant sweet orange varieties in south China.

These preliminary indexing results indicate that exocortis is present in most imported citrus varieties and a small proportion of native cultivars.

Since the highly susceptible trifoliate orange and *C. limonia* are commonly used as rootstocks in several important citrus areas, and extensive spread of exocortis could cause serious losses to the Chinese citrus industry, the control of exocortis should be emphasized. In recent years, shoot-tip grafting of citrus has been conducted in some laboratories with the main objective of excluding exocortis.

Tristeza

Tristeza and its efficient vector, the citrus aphid (*Toxoptera citricida* Kirk.), are widely distributed in Chinese citrus areas. Chen et al. (1965) described indexing with 'Mexican' lime (*C. aurantifolia* (Christm.) Swing.) and *C. hystrix*, and reported that 9 citrus cultivars collected from 5 provinces were infected with different strains of tristeza (5). In 1964-1967 and 1974-1976, Zhao et al. (1979) indexed 864 citrus trees from 6 provinces using 'Eureka' lemon and grapefruit seedlings for indicators, and found seedling yellows-tristeza infection in 691 trees (16).

Since the tristeza-tolerant rootstocks, trifoliate orange, *C. sunki*, *C. tangerina* and *C. limonia*, are commonly used, tristeza is not an important problem in most areas. But in certain dis-

tricts where citron and some sour oranges (*C. aurantium* L.) are being used, tristeza damage is apparent.

'Jincheng' (*C. sinensis*) infected with seedling yellow-tristeza has been grafted onto 6 varieties of sour orange to test the tristeza susceptibility of the sour orange rootstocks. The budlings with Daidai, Shinsan sour orange, a sour orange from Morocco and Bankan rootstocks show yellowing and significant dwarfing. The budlings with Shauhungcheng rootstocks show slight yellowing and dwarfing, while the combination of 'Jincheng' on Guotuocheng grows normally. Tristeza tolerance and salinity tolerance of Guotuocheng as a rootstock in Huangyan County, Zhejiang Province (16).

The current practice of using tolerant rootstocks plays an important role in controlling tristeza in Chinese citrus cultivation. The possible appearance of more virulent strains of tristeza virus may cause serious losses in the future; therefore, studies on tristeza should also be noticed in China.

Satsuma Sudden Wilt

Since the 1960's, satsuma sudden wilt has been an important problem for satsuma production in Guangxi, Hunan, and some other provinces. Studies on the symptomatology, on incidence in different citrus varieties and different rootstocks, on graft transmissibility, and on control measures were conducted by Guangxi Citrus Research Institute and Hunan Horticultural Research Institute in the 1970's (8, 12).

Satsuma is the cultivar mainly affected, but some other mandarins such as 'Bendizau' and 'Nanfengmiju' are affected in some cases. Middle- and late-ripening cultivars of satsuma are damaged more seriously than early cultivars. The incidence of the disease is much higher in satsuma on Sunki rootstock than in satsuma on trifoliate orange rootstock. Normal satsuma seedling trees have been observed in orchards abandoned because of sudden wilt. When satsuma and sweet orange were grafted to the same rootstock, the sweet orange grew vigorously, although the neighboring satsuma decline.

The initial symptom usually appears between October (after harvesting) and the following June. In the initial stage, the leaves on the top of the tree wilt and curl, and after 6-7 days the symptoms appear on the entire tree. Sometimes the symptoms only appear in a part of the tree. Leaves usually drop soon after wilting, but in some cases the withered leaves hang on the tree for a long time. After the leaves wilt, the twigs begin to dieback, and the scion part of the tree may die if not pruned in time. In some diseased trees, the leaves show water stress symptoms, without rapid leaf drop, the spring flush is suppressed or delayed, and the mature leaves drop progressively.

When the bark of the trunk is peeled, a yellow-brown stain of the wood shows above the bud union. Cross sections of the diseased trunk show that some of the xylem vessels are plugged with gum-like materials. The wood below the bud union remains normal in color, but in some cases a few of the xylem vessels of the rootstock are also plugged.

After heavy pruning, most diseased trees recover and grow normally for 2-3 years and then wilt suddenly. Graft transmission has not been described yet. Control measures include the use of trifoliate rootstock, the development of early-ripening cultivars of satsuma, heavy pruning of the diseased tree, and top working with sweet orange or 'Ponkan' mandarin.

Yellow Ring of Sweet Orange on Trifoliate Orange Stock

In Guangxi, Guangdong, Fujian, Hunan, and Jiangxi provinces, some cultivars of sweet orange grafted on trifoliate rootstock show yellowing and dwarfing in the nursery or after

planting. The incidence of affected plants may be as high as 80%.

Budlings graft-propagated in February usually yellow by July or August. Mature leaves on the lower part of the budling show midvein yellowing much like the yellowing caused by girdling, and leaves on the upper part of the budling show zinc deficiency-like symptoms.

A yellow ring around the bud union is clearly visible after the bark is peeled and, apparently, it is responsible for the leaf yellowing. When observed in September the wood at the yellow ring shows small, honeycomb-like holes. Yellowed leaves drop in autumn and winter, and in severe cases, the defoliation causes dieback of the budling. Some mildly yellowed budlings recover and show normal growth after planting.

A survey by Hunan Horticultural Research Institute revealed that sweet orange cultivars with low fruit acidity such as 'Bingtangcheng' may show yellow ring, but that cultivars with high fruit acidity such as 'Dahongcheng' are not affected.

The yellow ring reaction of two types of trifoliate orange has been tested. The large-leaf trifoliate orange Jiangjin-4 and small-leaf trifoliate orange Zaoyang were sown in spring 1976 in Liuzhou, and grafted with 'Xinhuicheng' by single-bud grafts in January 1978. The incidence of yellowing in 342 plants with Jiangjin-4 rootstock in December 1978 and December 1979 were 7.9% and 14.7% respectively. The plants of this combination which did not show leaf yellowing showed yellow ring, but in general the yellow color was light. On the other hand, the 84 plants with Zoayang rootstocks grew normally in 1978-1979, and did not show yellow ring after the bark was peeled.

Etiological studies should be conducted to determine whether yellow ring is caused by the incompatibility of scion-stock or caused by a pathogenic infection. Further studies might be conducted also on the yellow ring of different trifoliate types when combined with different cultivars of sweet oranges.

In Hunan Province, bearing trees of sweet orange on trifoliate rootstock showed leaf yellowing like the yellowing caused by gridling, and the trees usually broke at the bud union just like a dislocation. It is deduced that this disorder is the same as yellow ring.

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