Tristeza Susceptibility of Sweet Orange on Troyer Citrange Rootstock

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SEVERELY DECLINED trees of sweet orange on Troyer citrange rootstock were discovered near Santa Paula in Ventura County, California, in 1961, indexed, and found to be infected with tristeza virus. Numerous trees of the same combination were declining by 1964 on several properties in Orange and Ventura counties. Symptoms of the disease and preliminary evidence for its probable identity with tristeza have been published (2, 6). We report here the results of studies to determine the relationship of tristeza virus infection to the decline of sweet orange/Troyer citrange trees.

Methods

Periodic surveys were begun in 1964 to determine the incidence of decline in sweet orange/Troyer cit-

range trees in Ventura County. From 1965 through 1969 newly declined trees were plotted in several young orchards in lightly to heavily tristeza-infested localities in the Santa Clara Valley portion of the county.

The presence of tristeza virus in many declined trees in several orchards was confirmed in 1963 and 1964 by indexing on Mexican lime. We identified other diseases in most of the declined tristeza-negative trees examined. Declined tristeza-positive trees in several orchards were indexed also for exocortis, crinkly-leaf, psorosis, seedling-yellows-tristeza, stubborn, tatter-leaf-citrange stunt, and vein-enation.

Orchard A, a 20-acre block of Olinda Valencia sweet orange/Troyer citrange planted in 1961 in a moderately tristeza-infested area near Santa Paula, was surveyed annually for decline symptoms, beginning in 1964. Most of the trees in orchard A were indexed in 1966–67 and 1968–69 to confirm the correlation between decline and tristeza virus infection.

Transmission plots were established in 1964 in orchards heavily infested with tristeza but were invalidated by natural spread of tristeza virus. In April 1965, 25 Olinda Valencia trees on Troyer citrange rootstock in orchard A were inoculated from 5 tristeza-infected declined trees in the same orchard by grafting shoot pieces 5 cm long and buds from a donor tree into small branches of 1 tristeza-free 1-year-old and 4 tristeza-free 4-year-old trees; adjacent tristeza-free trees served as controls. The inoculated 4-year-old trees were located near the center of the orchard; inoculated 1-year-old trees were part of a small group of trees on the north border.

The uncertain origin of the Troyer citrange rootstock of trees in orchard A (2) and some other affected orchards led us to inoculate sweet orange trees on rootstocks from seed of Citrus Research Center Troyer citrange. Accordingly, in July 1967 a new plot was established in an isolated location at Somis, about 10 miles from orchard A. Twenty-four trees of Olinda Valencia/Troyer citrange were inoculated at planting time by grafts from one or another of 5 donor trees, including 2 declined tristeza-infected trees in orchard A, 2 tristeza-infected Frost Valencia trees at Riverside, and a screenhouse-grown seedling-line tree infected with a presumably pure, vector-transmitted strain of tristeza virus from Riverside. Sixteen noninoculated trees served as controls. Olinda Valencia trees on Carrizo citrange, Rubidoux trifoliate orange, and red rough lemon were included to determine their sensitivity to tristeza virus.

Observations and indexing were also done on some orange trees on Troyer citrange rootstock in Orange, Riverside, and Tulare counties. The effect of tristeza virus on such trees is still being studied at Riverside.

Results

SURVEYS.—Declining trees of sweet orange/Troyer citrange were found in 1964 on 29 of 337 proper-

ties in Ventura County, comprising 4,500 acres of orchards reported to have Troyer citrange rootstocks. All affected properties were in areas where some trees on sour orange rootstock were declining from tristeza. In 1966, 81 affected properties and 516 declining navel and Valencia sweet orange trees on Troyer citrange were found in the same areas. The numbers of declined trees on Troyer citrange rootstocks in 5 orchards near Santa Paula, surveyed annually for 3–5 years, are shown in Table 1. Numerous declined tristeza-infected trees were found in Orange County, and a few mild cases were located in western Riverside County, but none was seen in Tulare County or other tristeza-eradication areas.

TABLE 1. INCIDENCE OF TRISTEZA DECLINE IN SELECTED ORCHARDS OF SWEET ORANGE/TROYER CITRANGE NEAR SANTA PAULA, CALIFORNIA

Orchard	Trees evaluated (no.)	Trees declined[a]/Trees evaluated (%) 1965	1966	1967	1968	1969
A	2159	3.4	4.9	5.2[b]	10.2	15.7
B	1152		2.1	4.4	7.3	12.1
C	5895		0.6	2.8	4.2	6.6
D	4300		0.5	1.4	2.4	
E	3136		0.4	1.4	2.0	

a. Figures include trees declined in prior years.
b. Survey of March 1967.

CORRELATION BETWEEN DECLINE AND TRISTEZA.—Tristeza virus was detected in nearly all the approximately 100 declined trees but not in most normal trees indexed prior to October 1966. Vein-enation virus was frequently, though not consistently, present; exocortis, psorosis, and stubborn viruses were rarely detected in declined trees. Critical examination of declined tristeza-negative trees usually revealed other causes for the decline.

Seventy-four trees that declined in orchard A by January 1965 all indexed tristeza-positive, but none of 75 normal trees was found infected. In 1966–67, indexing showed all 38 newly declined trees and 38 of 1,122 normal-appearing trees to be infected with tristeza virus. In 1968–69, 166 of 228 trees that declined since March 1967 and 146 of 2,032 normal-appearing trees indexed positive for tristeza, with many tests in both categories incomplete.

Forty-nine per cent of the declined trees in orchard A are in 27 per cent of the area, along the south and southwest borders adjacent to older orchards moderately infested with tristeza. The distribution of declined trees in 1964 and 1965 indicated that few, if any, trees in orchard A were infected before planting in 1961 but had been infected later by means of vectors from the south and southwest.

Locations of tristeza-infected and

declined trees in 20 rows (780 trees) in the eastern portion of orchard A are mapped in Figure 1. In these rows, 37 of 41 trees that were normal in 1965 and found infected in 1966–67 have declined, as have 57 of 136 more recently infected trees. The southern third of the mapped area contains 52 per cent of the declined and 52 per cent of the tristeza-infected normal-appearing trees; the northern third contains only 20 per cent and 16 per cent, respectively, of the trees in these categories. The highest concentration of tristeza-infected and declined trees lies within 100 m, while the lowest concentration is more than 200 m from the older tristeza-infested orchard.

TRANSMISSION.—The first decline symptoms appeared on some of the inoculated 1-year-old trees in orchard A in March 1966, 11 months after inoculation. By July 1966, all 5 inoculated trees had dull green or chlorotic foliage, little vigor, and a precocious set of fruit. Sieve-tube abnormalities were found at the bud union (2). These trees have grown poorly (Table 2), declined intermittently since 1966, and now bear less fruit than the control trees, which remain vigorous and green.

Most of the 4-year-old trees in orchard A reacted slowly to tristeza infection. Mild symptoms appeared on 1 tree by 11 months and on 6 trees by 15 months after inoculation, but 19 of the 20 trees set an abnormally heavy crop of fruit in 1966. Sixteen trees were mildly and 4 moderately affected 27 months after inoculation;

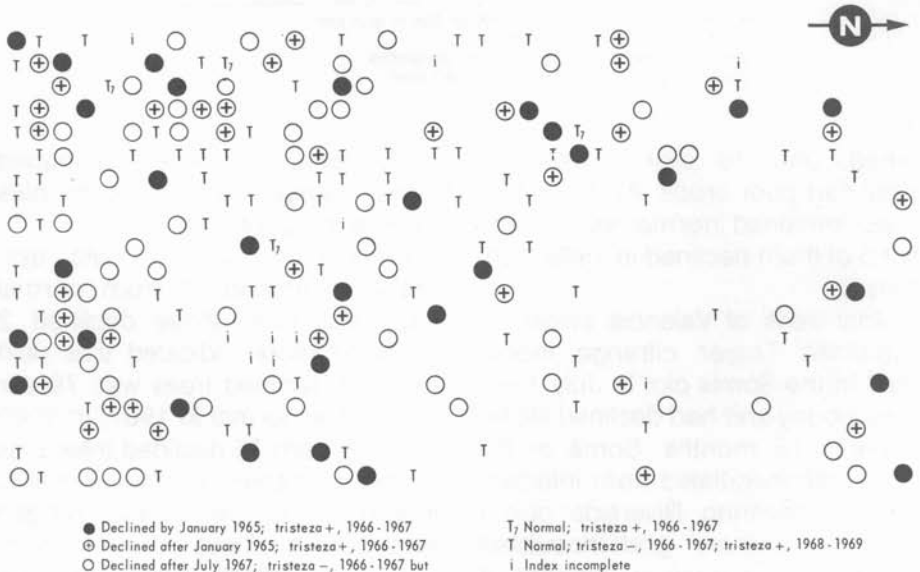

FIGURE 1. *Distribution of tristeza-infected and declined trees in 20 rows of the eastern portion of orchard A which was planted to tristeza-free trees of Valencia sweet orange on Troyer citrange rootstock in 1961. Adjacent tristeza-infested orchard on south border was important source of inoculum.*

5 were moderately and 15 severely affected 36 months after inoculation (Fig. 2). Growth of the inoculated trees has been retarded (Table 2), and production in 1969 was subnormal for most of them. Most declined trees carrying light crops had improved in appearance by 54 months after inoculation but 2 trees were severely declined, 2 moderately declined, and 16 slightly declined. Most had poor crops. All 20 control trees remained normal for 3 years but 3 of them declined in 1969 from tristeza.

Most trees of Valencia sweet orange/CRC Troyer citrange inoculated in the Somis plot in July 1967 grew poorly and had declined slightly within 15 months. Some of the trees graft-inoculated from infected, normal-appearing Riverside donor trees and others graft-inoculated from declined trees in orchard A were moderately declined by October 1969 (Fig. 2). Tristeza virus depressed trunk growth 27 per cent during the last year (Table 2). Nearly all controls remained normal. Inoculated trees on Carrizo citrange and trifoliate orange rootstocks were affected similarly to those on Troyer citrange, while those on red rough lemon appeared healthy but were slightly stunted. The preliminary results from the Somis plot indicate that tristeza virus from any of the 5 donor trees considerably damaged sweet orange/Troyer citrange trees in Ventura County.

TABLE 2. EFFECT OF TRISTEZA ON TRUNK GROWTH OF VALENCIA ORANGE TREES ON TROYER CITRANGE ROOTSTOCK IN VENTURA COUNTY, OCTOBER 1969

Orchard	Age (years)		Pairs[a] measured	Avg. growth of trunk X-section		X-section area infected/normal (%)
	Present	When inoculated		Normal (cm^2)	Infected (cm^2)	
A	8	0–5[b]	74	177	113[d]	64
A	8	4	17	192	159[d]	83
A	5	1	5	104	65[d]	62
Somis	2	0	16	11[c]	8[c,d]	73
Riverside	4	0–3	14	67	63	95

a. Normal tree less than 10 m from infected tree of each pair.
b. Trees naturally infected by vectors.
c. Based on growth the second year after inoculation.
d. Significantly less than normal at the 0.001 level.

EFFECTS ON YIELD.—Yield estimates in orchard A from normal trees and from those declined 2 years or more indicated that yield from 59 declined trees was 79 per cent below normal in 1967; in 1969 the yield from 75 declined trees was 71 per cent below normal. Yields of individual declined trees ranged from zero to about 70 per cent of normal in 1969. The yield data show that most of the trees that declined from tristeza became uneconomic about 2 years after the first symp-

FIGURE 2. *Tristeza decline in trees of Valencia sweet orange on Troyer citrange rootstock. A. Moderately declined 7-year-old tree, 3 years after graft-inoculation; healthy tree in background. B. Severely declined 6-year-old tree, naturally infected in orchard A. C. Healthy 2-year-old tree, Somis plot. D. Decline and precocious fruiting of 2-year-old tree inoculated from orchard A donor tree, Somis plot.*

toms appeared. Some stunted, slightly declined trees continue to bear substantial crops.

Discussion

Relatively mild sensitivity to tristeza was noted in 1950 by Bitters and Parker (1) in some young sweet orange trees on rootstocks of Troyer citrange and some other trifoliate orange hybrids at Baldwin Park in Los Angeles County. Later, however, sweet orange/Troyer citrange trees believed or known to be infected with tristeza virus grew satisfactorily in Riverside and other tristeza-infested locations in the Los Angeles Basin. Troyer citrange thus came to be regarded as a tristeza-tolerant rootstock without further critical comparisons between tristeza-free and tristeza-inoculated trees of various ages in different areas of southern California. The use of tristeza-free budwood by most nurserymen helped to keep most Troyer-rooted trees, except some of those used as replants in infested orchards, tristeza-free for many years because the virus spread slowly in newly infested orchards. In Ventura County, tristeza virus spread very slowly for many years after its discovery there in 1949. By 1963 it had affected only 19 per cent of the sweet orange trees on sour orange rootstocks in the two most severely infested areas. Tristeza decline appeared in trees of sweet orange on Troyer citrange rootstock within a few years after numerous trees of this combination were planted in these areas.

The increasing incidence of tristeza in mature orchards was followed by increasing incidence of decline in young trees on Troyer rootstock. This is exemplified in orchard A where decline in sweet orange/Troyer citrange trees usually followed tristeza infection by 1½ to about 3 years and closely paralleled the increasing incidence of decline in sweet orange trees on sour orange rootstocks in nearby orchards. Our data indicate that the rate of tristeza spread now occurring in some areas of Ventura County is similar to that reported earlier from Orange County (3).

The hypothesis that variant tristeza-sensitive citrange rootstocks might be primarily responsible for tristeza sensitivity of sweet orange/citrange trees in Ventura County (2, 6) seems no longer tenable despite the decline of some trees on obviously variant stocks. Most citrange rootstocks of affected trees appear to be typical Troyer citrange, and no evidence was found that decline is restricted to trees on variant rootstocks. Instead, we discovered that, in some areas, most trees on Troyer citrange rootstock decline within a few years after they are infected by tristeza virus. The severity of decline varies, but is usually much less severe than in trees on sour orange rootstock. In the area studied most, all tristeza virus strains spread by vectors apparently cause some degree of decline. Our data from the Somis plot prove that Valencia sweet orange on CRC Troyer citrange rootstock is at least moderately sensitive,

in that environment, to tristeza virus from donor trees in Riverside and Ventura counties.

Decline symptoms on most tristeza-infected trees on trifoliate orange and Carrizo citrange rootstocks at Somis indicate that these stocks are rather sensitive to tristeza virus. At Riverside, also, we have noted considerable sensitivity to tristeza infection in orange trees on rootstocks of trifoliate orange and some of its hybrids, including citremon and citrumelo. Some sweet orange trees on trifoliate orange rootstocks have declined in Argentina, possibly from tristeza (4, 5), but the decline there is apparently much more severe than in California.

Differences in the severity of reactions among trees inoculated with tristeza virus from a single donor have, to date, been greater at Somis and in orchard A near Santa Paula than the overall differences between groups of trees inoculated from different donors. Preliminary results at Somis indicate a generally more severe reaction to virus from Ventura County donors than from Riverside donors. That, plus the frequency of decline in tristeza-infected trees and the range of reactions in Mexican lime indicator plants, confirm the earlier conclusion that various tristeza strains or isolates cause decline of orange trees on citrange rootstocks (2).

The fact that tristeza decline of sweet orange/Troyer citrange trees is restricted primarily to coastal plains and valleys less than 30 miles from the ocean suggests that environmental factors are more favorable to severe disease development there than in tristeza-infested areas further inland. Although Troyer citrange possesses enough tolerance to tristeza virus for generally satisfactory performance as a rootstock for sweet orange at Riverside, and many other inland areas, it lacks sufficient tolerance to insure good performance in some localities in California.

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