Transmission of Tristeza by Aphids Prevalent on Citrus, and Operation of the Tristeza Suppression Programme in Israel*

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Natural spread of citrus tristeza virus (CTV) in Israel was first observed in 1970 in the Hibbat Ziyyon area (Bar-Joseph *et al.* 1972). The disease had been found as early as 1956, mainly in introduction plots, but without any indication of natural spread (Reichert and Bental, 1960). Subsequently, it was shown that the tristeza strain VT, from the area in the Sharon Plain where natural spread was observed, is efficiently transmitted by *Aphis gossypii* Glov. (Bar-Joseph and Loebenstein, 1973). Transmission rates averaging 40% (with 100 aphids in each test) were obtained, compared with less than 5% with two other isolates, CT and ST. The high rate of transmission with VT was considerably more than that reported for transmissions with *A. gossypii* in California (Dickson *et al.*, 1956) and Florida (Norman *et al.*, 1968), and approached that known for *Toxoptera citricidus* (Kirk.) (Costa and Grant, 1951). The high transmission rate by *A. gossypii* seems to be an intrinsic property of this strain.

In this paper we report some features of VT transmission by *A. gossypii*, vectorial ability of several other aphid species prevalent in citrus groves, as well as recent developments in the tristeza suppression scheme operating in the Hibbat Ziyyon area.

MATERIALS AND METHODS

Six CTV isolates were studied, of which three—VT, CT, and ST—were described previously (Bar-Joseph and Loebenstein, 1973); in addition BT, from Shamouti trees in Bet Dagan; AT, originating from grapefruit budwood brought from the United States; and HT, from Kefar Hayyim, are described here. HT and BT cause a severe vein-clearing reaction on Egyptian lime, while AT induces a very mild reaction on only a few minor veins.

Aphid cultures were kept in screened cages. *A. gossypii* was reared on cucumbers and *Myzus persicae* (Sulzer) on Chinese cabbage; *T. aurantii* (B.d.F.) and *A. spiraecola* (Patch) were collected from citrus trees.

For transmission tests with 100 aphids per test, plastic cages and four to five old Egyptian sour lime seedlings were used as described previously (Bar-Joseph and Loebenstein, 1973). When smaller numbers of aphids were used, hand-picked aphids were transferred with the aid of a camel's-hair brush from infected Madam Vinous sweet orange plants, serving for acquisition, to one- to two-months-old Egyptian sour lime seedlings 5 cm in height. Each seedling was covered with a plastic cylinder, the upper part of which was covered with dense gauze. Generally, three to five seedlings were grown in one 12-cm pot. After periods of infection feeding, plants were sprayed with an aphicide and screened for symptoms over a period of four months.

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RESULTS AND DISCUSSION

Vector Transmission. Whereas previous transmission tests were done with 100 aphids per seedling, subsequent studies showed that high transmission rates of the VT isolate were obtained even with 10 apterous aphids per test. Thus, 35 seedlings out of 96 inoculated became infected (36 per cent). In comparable experiments with 100 aphids, 69 seedlings out of 118 inoculated became infected (58 per cent). Acquisition- and infection-feeding periods of less than four to six hours gave only low transmission rates, although some transmissions were obtained even at durations of one half to one hour (table 1). *Toxoptera citricidus*

TABLE 1
EFFECT OF DURATION OF ACQUISITION AND INFECTION FEEDINGS ON TRANSMISSION OF VT TRISTEZA VIRUS ISOLATE BY *A. GOSSYPII*

Duration* (hours)			Transmission
Acquisition	Infection	Transmission†	per cent
½	24	1/24	5
6	24	6/30	20
24	1	1/33	3
24	4	4/37	11
24	24	9/31	29

*10 aphids per test.
†Numerator = number of plants infected; denominator of plants inoculated.

needs only seconds to transmit tristeza virus (Retuerma and Price, 1972), as is typical for stylet-borne viruses, whereas transmission by *A. gossypii* of VT, as well as of other strains (Norman *et al.*, 1968), requires much longer periods for acquisition and infection (one half to one hour), which is characteristic for a semipersistent mode of transmission.

Viruliferous melon aphids retained their infectivity when kept for more than three hours in a glass tube.

Other aphids prevalent in citrus groves were tested for their ability to transmit various tristeza virus isolates. *Myzus persicae*, *T. citricidus* and *A. spiraecola* did not transmit CT, ST and VT (the last mentioned being highly transmissible by *A. gossypii*) (table 2). The AT isolate was transmitted at a low rate by *A. spiraecola*

TABLE 2
TRANSMISSION* OF TRISTEZA VIRUS ISOLATES BY DIFFERENT APHIDS†

	Tristeza strain					
Aphid species	VT	HT	AT	CT	ST	BT
A. gossypii	69/118	14/35	3/50	2/57	2/68	0/50
A. spiraecola	0/100	—	1/23	0/37	0/37	—
M. persicae	0/100	—	—	—	0/35	—
T. aurantii	0/100	—	—	—	0/51	—

*Numerator = number of plants infected; denominator = number of plants inoculated.
†Fifty to 100 aphids; 24-hour acquisition; 24-hour infection feeding.

(1/23) and by *A. gossypii* (3/50). The BT isolate was not transmitted by *A. gossypii*, whereas the HT isolate was highly transmissible (14/35). It is evident, therefore, that aphids other than *A. gossypii* are presently of minor importance, whereas the combination VT-*A. gossypii* has a major potential in spreading tristeza virus in Israel. The ability of *A. gossypii* to transmit this isolate brings the efficiency of its transmission to a level approaching that of *T. citricidus*.

Tristeza Suppression Programme. The scheme was started in 1971 in the Hibbat Ziyyon area, where natural spread occurs. Using the combined "indicator-EM" method (Bar-Joseph *et al.*, 1974) with budwood from 6 to 10 source trees per lime seedling, and examining the sources by EM if any indicator reacted positively, a substantial saving of indicator seedlings was achieved. The VT strain, which predominates in this area, causes a conspicuous lime reaction even during the summer, which facilitates year-round indexing. The total number of trees indexed over the last four years in the Hibbat Ziyyon area (trees in some groves have already been indexed eight times), and those found to be infected, are summarized in table 3. In the first half of 1975, 30 additional infected trees were located, brining the total to 523, from more than 190,000 indexes.

When the ratio of infected to indexed trees was evaluated for the central locus (16.5 ha) in Hibbat Ziyyon, a gradual decrease was observed (table 4). The ratio decreased from 1.04 and 1.23% in 1970 and 1971, respectively, to less than 0.1% in 1974. So far, however, a perimeter without any infected trees has not been reached.

TABLE 3
TOTAL NUMBERS OF TRISTEZA-INFECTED AND OF INDEXED TREES IN THE HIBBAT ZIYYON AREA

Year	Tristeza-infected trees	No. of trees indexed
1971	106	28,000
1972	160	60,500
1973	135	47,600
1974	92	36,500

TABLE 4
NUMBERS OF TRISTEZA-INFECTED TREES AND OF INDEXINGS IN THE CENTRAL LOCUS AT HIBBAT ZIYYON

Year	Tristeza-infected trees	No. of indexings	Ratio per cent
1970	35	3,353	1.04
1971	91	7,346	1.23
1972	42	10,023	0.41
1973	24	9,617	0.24
1974	5	5,413	0.09

LITERATURE CITED

BAR-JOSEPH, M. and G. LOEBENSTEIN
1973. Effects of strain, source plant, and temperature on the transmissibility of citrus tristeza virus by the melon aphid. Phytopathology 63: 716-20.

BAR-JOSEPH, M., G. LOEBENSTEIN, and Y. OREN
1972. [New Cases of tristeza in Israel] Hassadeh 52: 569-72. (in Hebrew).

BAR-JOSEPH, M., G. LOEBENSTEIN, and Y. OREN
1974. Use of electron microscopy in eradication of tristeza sources recently found in Israel, p. 83-85. *In* L.G. Weathers and M. Cohen, (eds.), Proc. 6th Conf. Intern. Organization Citrus Virol. Univ. of California Div. Agr. Sci., Berkeley.

COSTA, A.S., and T.J. GRANT
1951. Studies on transmission of the tristeza virus by the vector, *Aphis citricidus*. Phytopathology 41: 105-13.

DICKSON, R.C., M.M. JOHNSON, R.A. FLOCK, and E.F. LAIRD, Jr.
1956. Flying aphid populations in southern California citrus groves and their relation to the transmission of the tristeza virus. Phytopathology 46: 204-10.

NORMAN, P.A., R.A. SUTTON, and A.K. BURDITT
1968. Factors affecting transmission of tristeza virus by melon aphids. J. Econ. Entomol. 61: 1205-07.

REICHERT, I., and A. BENTAL
1960. Citrus varieties in Israel infected with tristeza. Ktavim 10:53-58.

RETUERMA, M.L., and W.C. PRICE
1972. Evidence that tristeza virus is stylet borne. F.A.O. Pl. Prot. Bul. 20: 111-14