
BEHAVIOR OF VARIOUS CITRUS ROOTSTOCK-SCION COMBINATIONS FOLLOWING INOCULATION WITH MILD AND SEVERE STRAINS OF TRISTEZA VIRUS

A. S. Costa,1 Theodore J. Grant,2 and Sylvio Moreira3

The discovery of a mild strain of tristeza virus of citrus was described in a previous publication (8). Initial evidence was presented indicating that plants of sweet orange on sour orange rootstock when infected with a mild virus strain did not develop severe tristeza symptoms even when they were re-inoculated several times with large numbers of the aphid vector that had fed on plants carrying severe strains. It seemed desirable to carry out additional tests to determine whether sweet orange and other citrus species budded on tolerant as well as non-tolerant rootstocks and inoculated with mild strains of the virus would be protected against subsequent invasion by severe strains.

Tests were started in 1950 for the purpose of making field comparisons of various rootstock-scion combinations following separate inoculation with a severe and with mild strains of tristeza virus from several sources. By carrying out these tests in Brazil, where an efficient vector is responsible for the natural spread of the disease, and where the ordinary tristeza virus complex includes severe strains, it was thought that any benefit resulting from protection conferred by the mild strains in the plants could be measured. In addition, periodic tests on sour orange rootstock using buds from plants originally infected by the mild strains and buds infected by the severe strain would indicate whether the former were still carrying the mild form of the virus.

MATERIAL AND METHODS

Uniform seedlings of sweet orange and sour orange to be used as rootstock were set out in nursery beds, 5 plants per row and 10 rows per bed.

In the first test series, the citrus scion tops were established on the rootstocks in the nursery beds by using buds from virus-free, nuclear seedlings of the desired variety that had been maintained in a screenhouse. The virus strain inoculations were carried out by inserting an infected bud 10 centimeters below the scion bud. In addition to nine rows of inoculated trees in each nursery bed, one row of plants was budded with virus-free buds of the same variety. Eight sources of mild tristeza virus and a single source of a severe strain were employed. Each source plant that supplied virus-carrying buds was studied under test conditions to determine, insofar as was possible, its freedom from any psorosis virus mixture.

1 Pathologist, Instituto Agronomico, Campinas, Brazil, and collaborator, United States Department of Agriculture.
2 Principal Pathologist, Horticultural Crops Research Branch, Agricultural Research Service, United States Department of Agriculture, Orlando, Florida.
3 Head of Division of Horticulture, Instituto Agronomico, Campinas, Brazil.
In a second test series, the effects of mild and severe strains of tristeza virus were compared by establishing variety tops directly on both sweet and sour orange stocks by using buds from nucellar seedlings previously inoculated with these strains by means of aphids. Control plants were prepared by using buds from comparable healthy nucellar seedlings.

All budding operations were carried out in March and April 1951. After the scion and infected buds had united, the tops of the seedling rootstocks were cut back and the scion tops allowed to develop.

The scion varieties included in the tests were Barao, Valencia, Florida sweet seedlings, Pera, and Hamlin sweet oranges; Tangerina Cravo tangerine; Ruby Red, Red Blush, and Red Mexican grapefruits; and Galego and Key limes.

Records on growth and tristeza symptoms of all plants were taken periodically. The records on growth were based on a general classification using an arbitrary scale of 0 to 5: 0 representing dead trees, 1 very poor growth, and 5 very good growth. This arbitrary scale was used in order to obtain comparable data on the growth of the different citrus variety tops on sweet orange and sour orange rootstocks.

**Results**

The preliminary results reported in this paper concern mainly the growth made by the various scions on the two types of rootstock up to February 1954, that is, three years after budding. Although there was some variation in plant growth, these variations did not alter the general trends. Thus, for purpose of presentation, the data from both series of tests were combined and the average growth by classes of the various rootstock-scion combinations is presented in Fig. 1.

It is evident in Fig. 1 that all varieties on non-tolerant sour orange rootstock inoculated with the severe strain of tristeza virus had an average rating below class 1, which means that the plants were dead or in an extremely poor state of growth. These same variety tops on the same non-tolerant rootstocks but infected with mild strains had growth class averages of 2.5 to 3.6. The sweet orange and tangerine tops on tristeza-tolerant sweet orange rootstocks had growth class averages 4 and 5, which represent very good growth. This occurred regardless of whether the severe or the mild strains of the tristeza virus were used. A photograph of sweet orange trees on sweet orange rootstock, taken approximately 3 years from date of budding and inoculation, is shown in Fig. 2. The information given on growth responses and the photograph illustrate the desirability of using a tristeza-tolerant rootstock for sweet orange and tangerines, to insure against possible losses from tristeza.

It was previously reported (5, 9) that the tristeza virus has some detrimental effects on grapefruit tops even when they are grown on tristeza-tolerant rootstocks. In Fig. 1 it can be seen that the grapefruit grown on tolerant sweet orange rootstock and inoculated with the severe virus strain had a growth rating of only 3; whereas, those inoculated with the mild strains had average growth of 4.1.

Grapefruit plants on non-tolerant sour orange rootstock when infected with the severe virus strain had a growth average of 0.7; whereas, when infected with the mild virus strains had average growth of 3.6. A photograph of the Ruby Red grapefruit on sour orange rootstock is shown in Fig. 3. It is evident that the mild tristeza virus strains caused considerably less damage to the grapefruit plants than did the severe strain.

**Fig. 1—Average growth class of various scion-rootstock combinations three years after inoculation with severe and mild strains of tristeza virus and non-inoculated controls subject to natural infection under field conditions in Brazil. Growth class: 0, dead; 1, very poor growth; 5, very good growth.**
The growth reactions of the lime plants in the tests, as shown in Fig. 1, were similar to those of the grapefruit plants.

During the test period of approximately 3 years the non-inoculated plants in the nursery were exposed to natural infection and no attempt was made to control the Oriental brown citrus aphid, *Aphis citricidus* Kirk., which was relatively abundant in the area. These non-inoculated plants could thus be used as a measure of natural spread of tristeza in the nursery planting, and as an indicator of the degree to which the inoculated plants could have become reinoculated. During this period, 100% of the non-inoculated lime plants, 76% of the sweet orange, and 60% of the tangerine plants became infected, while only 20% of the non-inoculated grapefruit became infected with the tristeza virus.

It can be noted in Fig. 1 that the growth of all the non-inoculated scions on sweet orange rootstocks was very good. In contrast, the average growth of the non-inoculated sweet orange and lime scions on sour orange rootstock was somewhat poorer. Symptoms shown by the naturally infected plants of these combinations were usually of the severe type. Under the field nursery conditions it was evident that the plants naturally infected in the early stages of these tests were severely stunted, while those that had escaped infection were growing very well.

The slightly higher growth class of the non-inoculated tangerine scions on sour orange rootstock, as compared with that of tangerine on sweet orange rootstock is not considered important. Records of presence of tristeza symptoms showed that the non-inoculated tangerine tops on sour orange rootstock had until recently escaped infection.

**Discussion**

The reactions of the non-inoculated plants in these tests paralleled the observed trends of tristeza spread in commercial citrus varieties in field plantings. Among the citrus species grown on sour orange rootstock in Brazil, the sweet oranges were the first to show symptoms. The tangerines or mandarins were infected later, and the grapefruits were the last to become diseased.

The mild tristeza virus strains caused considerably less damage to grapefruit tops than did the severe strains. This fact might explain the observations made in some Florida and California groves (1), where it was noted that sweet orange tops on sour orange rootstock had declined, while adjacent trees of sweet orange on grapefruit rootstock survived. This reaction can now be more readily explained on the basis of the existence of a mild rather than a severe tristeza virus complex in these areas, assuming that the mild strains would not be very detrimental to the grapefruit rootstocks, as they were not in the present tests in the grapefruit scions.

Grapefruit and lime scions grown on a tolerant rootstock made better growth when infected with a mild strain than when infected with a severe strain. This fact is an indication that the use of a tolerant rootstock, budded with scions already invaded by an ade-
quate mild strain of the virus, might be the most promising means of continuation of production of both grapefruit and lime in areas where severe strains of the tristeza virus are present. These results might also explain, in part, the observation made in Africa (12) that the propagation of grapefruit trees that showed mild symptoms of stem-pitting gave origin to trees that showed only mild symptoms.

The three-year period of these tests is not adequate to judge accurately the ability of the mild virus strain to protect the infected plants from showing severe disease symptoms, particularly in case of grapefruit and lime scions on tolerant rootstocks. On the other hand, the results obtained on the behavior of grapefruit, lime, and tangerine scions infected by mild strains and grown on the non-tolerant sour orange rootstock are similar to those described previously for sweet orange on the same rootstock (8). In order to obtain further information on the comparative behavior of the various rootstock-scion combinations infected with the severe and mild strains, selected plant material has been transplanted from the nursery beds to a field planting.

From the standpoint of practical citrus culture, it should be apparent that healthy uninfected plants are certainly the most desirable. At the same time the Florida grower is faced with the fact (2, 4) that a mild strain of the tristeza virus is present in some citrus trees widely scattered throughout the citrus areas of the state. The Texas citrus grower is also now aware that tristeza virus has been found in some Meyer lemon and in Satsuma trees in the Rio Grande Valley (13, 14). The present study has shown that in a 3-year period the mild virus strains caused appreciably less damage to infected trees of citrus varieties on sour orange rootstock than did the severe strain. The fact that only 20% of the grapefruit tops of the non-inoculated plants became infected should be of special interest to the grapefruit growers in areas such as Indian River in Florida and the Rio Grande Valley of Texas, where the grapefruit is grown on sour orange rootstock. The results of the present study are believed to be of particular significance, inasmuch as they were obtained in Brazil, where the Oriental brown citrus aphid, *Aphis citricidus*, is present and is recognized as a relatively efficient agent for the spread of the virus from tree to tree (6).

*Aphis citricidus* is not known to exist in the United States. Studies of insect vectors of tristeza, or quick decline, virus in California (7) showed the melon aphid, *A. gossypii* Glov., to be an inefficient vector. A report of the preliminary work in Florida (11) showed that the common green citrus aphid, *A. spireaecola* Patch, and the melon aphid, *A. gossypii*, could transmit the mild strain of tristeza virus present in Florida, but these vectors were judged to be much less efficient than *A. citricidus*. It was also noted that infected Temple orange appeared to be a better source of tristeza virus than did infected Valencia orange or Key lime plants.

It seems plausible that the relative inefficiency of the insect vectors, their feeding habits, and the differences in growth characteristics of the citrus varieties, combined with the presence of a mild rather than a severe strain complex of tristeza virus, may be important reasons why tristeza disease in Florida has not in the past caused the widespread damage that it has in Argentina (10) and Brazil (8). It should be equally evident that the introduction or occurrence of a severe virus strain and of a more efficient vector of the virus in Florida could result in more rapid spread and greater losses from tristeza.

**Summary**

The present experiments were designed to study the ability of mild strains of the tristeza virus to confer protection in infected plants against subsequent invasion by severe strains and also to study their influence on scion behavior on tristeza-tolerant rootstocks.

Five sweet orange, 3 grapefruit, 2 lime, and 1 tangerine variety were used as scions on sweet orange and sour orange rootstocks, and inoculated separately with eight sources of mild strains and with one source of a severe strain. The results obtained 3 years after budding are as follows:

1) The growth made by the four types of scions on non-tolerant sour orange rootstock was very poor when they were inoculated with the severe strain. Growth of these scions on the same rootstock was less adversely affected by mild strains.

2) There was no visible difference in the good growth of sweet orange or tangerine tops infected with mild or severe tristeza virus strains, when these varieties were grown on tristeza-tolerant sweet orange rootstock. Grapefruit and lime tops on sweet orange rootstock infected with the mild strains grew...
slightly better than when infected with the severe strain. These differences, however, were of a lesser degree than those found by comparing growth of the same scions infected with mild and severe strain on sour orange rootstock.

3) During the period covered by the present observations, uninoculated control plants that had been subject to natural infection, became infected in the following proportion: lime plants, 100%; sweet oranges, 76%; tangerine plants, 60%; and grapefruit plants, 20%.

4) It was noticed that the symptoms shown by plants infected naturally tended to be of the severe type, indicating that severe strains were present in the natural tristeza virus complex in the area.

LITERATURE CITED


ROOT DISTRIBUTION IN RELATION TO THE WATER TABLE

Harry W. Ford
Florida Citrus Experiment Station
Lake Alfred

The citrus root system is capable of rapid and deep growth in sandy soils but will not grow into or exist long in a soil saturated with water. Thus, when the water table is within a few feet of the surface the roots are confined to a shallow zone. Fluctuating water levels have a pronounced effect on the root system. Water damage to citrus trees—a major problem in the Indian River area—also occurs on the West Coast and in many Central Florida groves.

To further study water table influence, observations have been made during the past year in a citrus grove at Largo, Florida that is equipped with an extensive drainage system. The soil in this grove varies between Blanton and Leon fine sand and has an organic hardpan present at depths from two to five feet. Mr. W. D. Owens, the owner, designed and installed the drainage system in his 80 acre grove in 1950. Six-inch drain tile were laid six feet deep with elaborate manholes and valves at intervals for observation, control of water level, and ease of cleaning the lines. The tile drainage system consisted of one central drain line with four alternating lateral drains laid perpendicular to the central line. Thus several blocks of trees were tile drained on two and three sides. The central drain line began at a manhole 750 feet from the west side of the grove so that a large block of trees was located beyond the western boundary of the drain field. An open ditch, 18 feet wide and nine feet deep, had been dug on the west side of the grove in 1948.

The distribution of feeder roots of 54 mature trees was studied under three drainage-control conditions in the Owens grove in June 1954; namely, grapefruit trees tile drained on two sides (Fig. 1), orange trees located beyond the end of a drain line (Fig. 2), and grapefruit trees in the vicinity of an open drainage ditch. The tree plots were further subdivided according to the distance from the ditch or drain tile.