three metals. None of these elements reduced the iron concentrations in roots. In these respects the effects are similar regardless of which metal is involved. On the other hand differences were evident. The higher level of iron, which prevented chlorosis, improved growth in the excess-manganese cultures (compare numbers 20 and 17; 21 and 18) without necessarily lowering the manganese concentration in the tissues (compare 17 and 21). Within a few days after the start of the experiment chlorosis was prominent in the plants of treatment 17 and was so pronounced that even the buds were chlorotic. Root growth was reduced, but stubby roots did not develop. These observations suggest that it is also possible to induce iron chlorosis of citrus (and consequent stunting) with sub-toxic levels of manganese. The importance of iron-manganese ratios in other plants has been indicated by numerous workers. The work of Hopkins et al. (2) is outstanding in this regard.

Copper, however, appears to function in a different manner even though the end result may appear to be the same as that of manganese toxicity. It has been repeatedly observed that excess copper, in soil, sand, vermiculite and solution cultures, causes chlorosis (if at all) mostly after stunting of growth has been evident for some time. Plants of treatment 2 showed no chlorosis for several weeks and then only the 1 or 2 youngest leaves were affected out of an average of 19 leaves per plant (3). Toxicity to roots (manifested by stubby, malformed laterals) was evident from the beginning of the culture period. Furthermore, little or no improvement in growth resulted at any copper level when chlorosis was prevented by 5 p.p.m. of iron. Thus, the possibility exists that toxicity to roots is the initial effect of excess copper and not chlorosis as with manganese. Iron chlorosis thus may be a secondary response, just like the disturbed base-element nutrition which appears to accompany a debilitation of the root system. If so, it may be somewhat comparable to iron chlorosis induced by poor aeration or water damage.

This distinction between the effects of mild excesses of copper and manganese may not be borne out by more critical experiments but, from data now available, it appears unlikely that excesses of all heavy metals depress growth through exactly the same mechanism.

Summary

Chemical analyses were made for 12 elements in Valencia orange seedlings grown in solution culture with excessive quantities of copper, zinc or manganese. These strengthen previous observations in regard to the toxic effect of these metals.

The relative tolerance of the plant for these metals is reflected by the concentrations of the metals in the roots and tops. Thus, copper, which is the most toxic of the three, occurs in the lowest concentrations in the plant. Manganese, the least toxic, shows the highest concentrations in the plant parts.

Large excesses of all three metals lowered the absorption of the base elements. All three metals lowered the iron concentration in the tops but not in the roots. Adequate chelated iron maintained a normal supply of iron in the foliage, which parallels its prevention of chlorosis.

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PRELIMINARY STUDIES OF APHID TRANSMISSION OF TRISTEZA VIRUS IN FLORIDA

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The tristeza, or quick-decline, virus of citrus can be transmitted by budding or grafting (1, 6), or by insect vectors (3, 9). Searches for probable insect vectors had been carried on in South America (1, 3), Africa (8), and California (5) for a number of years before the mild form of the disease was discovered in Florida (7), where it now has been reported in all the citrus-producing counties (2).

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In all places where the disease has been found, the only insects that have repeatedly proved to be vectors are aphids.[2] Transmission of tristeza virus by means of *Aphis citricidus* (Kirk.) has been demonstrated in Brazil (3, 9), Argentina (10) and South Africa (8). This aphid species is not known to exist in the United States. In California, Dickson *et al.* (5) carried out a large number of tests and reported transmission of this virus by *Aphis gossypii* Glover (the melon aphid) to only 13 test trees and an additional 3 test trees where this species was present in mixtures with other insects. On the basis of published results it appears that *citricidus* is a highly efficient vector of the tristeza virus, and that *gossypii* is a relatively inefficient one.

Transmission by *Aphis spiraecola*.—In the writer's studies in Florida, the first attempts to secure insect transmission of tristeza virus were made in March 1952, when potted Key lime seedlings were placed in the vicinity of infected trees. One of these seedlings developed vein-clearing and stem-pitting symptoms, indicating transmission of a mild strain of the tristeza virus (7). The presence of large numbers of *Aphis spiraecola* Patch, the species commonly known here as the green citrus aphid, on or near the test plants suggested the desirability of a study of this species as a possible vector of the tristeza virus, and studies were begun in November 1952.

The sources of virus inoculum available for use included citrus trees known to be carrying the mild strain of the tristeza virus found in Florida and the Key lime plants that had been inoculated under controlled screenhouse conditions by scion wood grafts from infected field trees. It is realized that all the virus sources, such as stunted trees or those in a state of decline in the field, could be carrying more than one virus or causal agent of disease. The proof of insect transmission of the tristeza virus therefore has been based on the production of characteristic vein-clearing and stem-pitting symptoms on the inoculated Key lime plants.

The aphids were obtained from field collections of isolated and apparently unmixed colonies of *spiraecola*. These aphids were placed on the known virus source plant and were allowed to feed (acquisition feeding) for 24 hours or longer. They were then transferred to Key lime plants in fine-mesh screen cages and allowed to feed (transmission feeding) for varying periods. At the end of this time they were removed with a brush and sent to a specialist[3] for positive identification. The number of aphids and the transmission feeding time were recorded for each Key lime plant. Each Key lime plant was considered an individual transmission test.

The first evidence of successful transmission of the virus was the occurrence of vein-clearing symptoms on the Key lime test plants. In all cases further confirmation of the presence of the tristeza virus in each Key lime plant was obtained by bottle-grafting twigs of these plants to healthy Key lime seedlings.

Of 160 tests to transmit the virus by means of *spiraecola* from infected Valencia orange field trees and from infected Key lime test plants, none were successful. However, in 128 tests with a stunted Temple orange field tree on a red lime (Rangpur type) rootstock as a source of the virus, there was transmission to 9 Key lime plants. These plants developed

[2]/Since preparation of this manuscript an article by W. A. Hughes and C. A. Lister has come to the attention of the writers. This report is entitled, "Lime dieback in the Gold Coast, a virus disease of the lime, **Citrus aurantifolia** (Christmann) Swingle. Jour. Hort. Sci. 28: (2) 131-140, 1953. In this article Hughes and Lister point out similarities of the lime dieback and tristeza and report transmission of the causal virus, viruses, or virus strains, not only by means of **A. citricidus** (Kirk.) but also by mealybugs, **Ferrisia virigata** (Cockerell).

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TABLE 1

Transmissions by Aphis spiraecola of the mild tristeza virus from an infected Temple orange field tree to 9 Key lime plants in 128 tests

Plant No.	Number of aphids	Acquisition-feeding time, hours	Transmission-feeding time, hours	Re-transmission by grafts to Key limes
329	75	168	1	+
334	70	116	1.5	+
343	60	118	2	+
341	35	118	2	+
206	70	116	20	+
216	65	116	21	+
221	35	116	21	+
234	30	117	23	+
297	25	118	43	+

typical vein-clearing symptoms and some stem pits. The first symptoms were observed 4 to 9 weeks after inoculation. Most of these plants grew out of symptom expression during the summer months, but after being cut back in late August their new growth again showed typical vein-clearing symptoms. This behavior of the test plants indicates that a mild rather than a severe strain of the tristeza virus was transmitted.

The data for the 9 Key lime plants that showed symptoms of tristeza virus transmission are given in table 1.

It is evident that transmission occurred in 4 plants when the transmission-feeding time was as short as 1 to 2 hours and it also occurred in feeding periods of 20 to 43 hours. The fact that successful transmission was obtained in only 9 of 128 plants indicates that *spiraecola* is not a very efficient vector of the mild tristeza virus present in Florida, but that it nevertheless can be a vector.

In 8 of these successful virus transmissions the transmission-feeding period was less than 24 hours. In one case 75 aphids transmitted the virus in 1 hour and in another case a group of 35 aphids transmitted the virus in 2 hours. This information indicates that a 24-hour transmission-feeding period is sufficient, and to extend the feeding time would merely increase the possibility of injury to the plants from aphid feeding.

It is recognized that the larger the aphid population the greater are the chances of virus transmission (3). However, the small size of the test plants and the limited supply of aphids had to be given consideration in the present studies.

Transmission by *Aphis gossypii*.—To date (October 1, 1953) 26 tests have been carried out with *gossypii* as a possible vector of the tristeza virus in Florida. In one of these tests positive transmission was obtained, when 25 aphids collected from watermelon plants were fed for 41 hours on a virus-infected Temple orange branch that had been grafted to a Key lime test plant. A few of the aphids may also have fed on the Key lime branches. After feeding to acquire the virus, the aphids were transferred to a healthy Key lime plant, where they fed for 28 hours. This plant subsequently developed vein-clearing symptoms characteristic of tristeza virus infection. When bottle-graft transmissions were made from this plant to 5 other healthy Key limes, all subsequently developed typical vein-clearing symptoms of tristeza.

The fact that this aphid was not found to be a vector in Brazil (1, 3) may be due to the limited number of tests. However, it should also be kept in mind that the tests in Florida were made with the mild form of the tristeza virus whereas those in Brazil were made with the common tristeza virus, which causes much more severe disease symptoms. The possibility that there might be some differences in aphid species and their ability to transmit various forms of tristeza virus needs further investigation.

Discussion.—In investigations of *Aphis citricidus* as a vector of the tristeza virus in Brazil, it was found that the percentage of transmission was greater when a good source of inoculum, such as a virus-infected sweet orange on a tolerant rootstock, was established (3). It was also found that the percentage of transmission obtained following the inoculation by viruliferous aphids varied among citrus varieties (4). For example, in one test 70 percent of the Barao sweet orange, 50 percent of the Valencia orange, 47 percent of the Leonardy grapefruit, and 31 percent of the Duncan grapefruit plants were infected after the first inoculation, whereas only 15 percent of the sour orange plants became infected even after three inoculations. Thus it seems evident that there are differences between citrus varieties in relation to tristeza virus entry, multiplication, and distribution within a plant. It is also possible that aphid species may differ in their ability to acquire the virus from some citrus varieties or to infect some varieties.

It is well known that in Florida the Temple orange has more succulent growth than most other citrus varieties and that it is a favored host for aphids. Some of the first places where the tristeza disease in Florida was detected were in Temple orange groves. Furthermore, in the present tests the successful transmissions with both *spiraecola* and *gossypii* have been from Temple orange.

The relatively low efficiency of *spiraecola* and *gossypii* as vectors of the tristeza virus, as well as their distribution and abundance, should be given consideration when any estimate is made of future spread of the disease in Florida citrus groves.

Summary.—A preliminary study of aphid vectors of the mild tristeza virus in Florida shows that two kinds of aphids may transmit

the virus, *Aphis, spiraecola* Patch and *gossypii* Glov. The low percentages of successful experimental transmissions indicate that they are less efficient vectors than *citricidus* (Kirk.), the vector of the tristeza virus studied in Brazil.

Tristeza-virus infected Temple orange appeared to be a more satisfactory source of virus than did the infected Valencia orange or the Key lime plants used.

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Vegetable Section

A PRELIMINARY REPORT ON THE USE OF NUTRITIONAL SPRAYS CONTAINING N, P AND K IN TOMATO PRODUCTION

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Introduction.—The use of foliar nutrient sprays as a means of supplying the major elements to vegetable crops has attracted considerable attention during the past few years. In some instances only nitrogen has been included, but more recently all three major elements have been applied as foliar sprays. Vegetable producers may purchase commercial formulations containing soluble nitrogen, phosphorus and potash along with other elements which may be deficient in some soils. Producers of tomatoes have shown a great deal of interest in these nutrient sprays, and have made many inquiries pertaining to their use. The value of sprays containing minor elements such as manganese, zinc, iron, boron and copper has been well established where these elements are lacking or are unavailable in the soil. The effectiveness of the major elements as foliar sprays has not been established, however. Some investigators have concluded that tomato plants can utilize one or more of the major elements when applied as sprays, but that this method is no better than soil applications. Since soil applications are generally more economical than the spray formulations, these investigators have not recommended the use of foliar sprays.

In working with tomatoes at the Indian River Field Laboratory it soon became evident that a shortage of nitrogen was responsible for many poor yields and premature deterioration of the plants, especially during periods of heavy rainfall. The problem seemed to be that of insuring a constant supply of nitrogen proportionate to the requirements of the plants. With this problem in mind, and due to the interest in the use of the major elements in foliar sprays, investigations were begun to evaluate the use of these nutrient sprays on tomatoes.

Figure 1 is a diagrammatic sketch which is included to illustrate the cultural methods used by producers of unstaked tomatoes in the

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