today than twenty-nine years ago. This has been brought about by several factors, but one of the most important has been the tremendous increase in yields obtained by using higher rates of nitrogen per acre. The fertilizer materials in use today, from which the citrus fertilizer is made, are generally of a higher analysis, and this has tended to keep the per unit cost of plant food stable. Better and faster methods of mixing, handling, and distributing fertilizer has kept the costs of actually putting the fertilizer on the ground from getting too high.

Table 3 would indicate that the primary reason has been the increase in yields obtained with the higher rates of nitrogen application. The first ten years shown in Table 3 averaged $23.19 per acre for fertilizer, with a per-box cost of 16 cents. The last ten years of record averaged $73.12 per acre, but with a per-box cost of only 14.2 cents. The per-box costs of fertilizer have remained rather stable because of increased yields. As fertilizer costs increased slightly more than three times as much per acre, yields also increased by more than three times. If the deflation of the dollar since 1931 is taken into account, it is quickly apparent that by accepting improved fertilizer practices the grower has made it possible to realize a greater return from his investment in fertilizer.

**Summary**

Fertilizer and yield records were compiled for twenty-three years on a Valencia Orange Grove and for twenty-nine years on a group of mixed varieties of citrus. These records are believed to show typical fertilizer programs that were used during the period covered. The fertilizer ratios were found to change from low nitrogen, high potash to about equal amounts of each. The total poundage of nitrogen applied per acre increased from approximately 62 pounds to 180 pounds per acre. During this time potash rates remained fairly constant. Minor elements were first added to the fertilizer in 1938. Yields increased from 131 boxes per acre to 487 boxes per acre. The large increase in yields was associated with increasing nitrogen rates.

The cost of fertilizer decreased from an average of 16 cents per box to an average of 14.2 cents per box during the twenty-nine year period. In this same period per-acre costs of fertilizer increased from $23.19 to $73.12. The decreased box cost was due mainly to increased yields.

---

**REPORT ON GENERAL ASPECT OF TRISTEZA AND STEM PITTING IN CITRUS VARIETIES IN SAO PAULO, BRAZIL**

**T. J. Grant**, S. Moreira, and **Ary A. Salibe**

Sao Paulo produces more citrus than any other state in Brazil. A 1960 (15) estimate indicated that there were 160,000 acres in citrus, two-thirds orange trees and the others tangerine, lime, lemon, and grapefruit trees in Sao Paulo. There are about 14 million trees, of which one-third are not yet producing fruit. In 1959 approximately 15 million boxes (90 lbs. each) were produced. The production per tree varied from 1 to 10 field boxes and the producing trees were 5 to 12 years old.

The groves are young because in 1939-49 tristeza killed about 9 of 11 million trees. Exports of citrus dropped from about 2.8 million boxes (75 lbs. each) in 1939 to 100,000 in 1952. From 1955 to 1959, as a result of the use of tristeza-tolerant rootstocks, exports rose from 500,000 to over 3 million boxes (9).

These figures show that oranges are being produced in Brazil in spite of tristeza. The use of tristeza-tolerant rootstocks for oranges solved this problem, at least temporarily, for orange production. Grapefruit and West Indian lime trees, however, are directly injured by the tristeza virus regardless of the tolerance of the rootstock employed. Symptoms of tristeza on West Indian lime and grapefruit are stem pitting on the trunk and branches.
stunting, and small fruit and leaves with signs of nutrient deficiency. Some of these symptoms were recently observed on Pera sweet orange in Brazil (10) and on Valencia orange in the African Congo.*

The fact that some sweet oranges were apparently showing serious adverse effects even when grown on tristeza-tolerant rootstocks led to a recent trip to Brazil of the senior author. This report, based on the observations and with the cooperative efforts of all the authors, summarizes the general aspects of the problem of tristeza and stem pitting.

**Observations**

Citrus groves in the vicinity of the important producing areas around Limeira, Ararquara, Bebedouro, Pitanguiras, and Sao Martinho were surveyed. Particular attention was given to stem pitting and growth of West Indian limes, grapefruit, Pera, Baianinha, Hamlin and Valencia oranges.

**West Indian limes** (Key limes) are locally known as Limao Galego. This variety is particularly sensitive to tristeza virus and shows marked stem pitting when infected by the severe strain. Many trees have stem-pitted and stunted branches and yellowing and mineral-deficiency symptoms in the leaves. An outstanding grove with few tristeza virus symptoms was found at Pitanguiras. The owners had made a series of selections from surviving trees in three earlier plantings. Although no specific tests had been made, the success of this planting may have been due to the selection of surviving trees that were infected by a mild rather than a severe virus strain. This lime planting in Pitangueiras was a distinct contrast to the one made at the Limeira Citrus Experiment Station where the trees had been inoculated with the severe tristeza virus strain by aphids when the trees were in the nursery (1). The trees in this latter planting were affected with branch die-back and stem pitting and were extremely stunted.

**Grapefruit plantings** were composed largely of the Marsh seedless variety. In the groves stem pits ranged from very few to many deep trunk and branch pits. According to the grove owners and operators, the grapefruit trees show seasonal deficiency symptoms on the leaves and the trees were judged to be considerably smaller than they would have been in the absence of virus infection.

A high proportion of fruits were small, very acid, and thick-skinned. In general, the trees in groves receiving heavy fertilizer applications were in better condition than unfertilized trees, but fruit quality was relatively poor.

The experimental field plantings of Foster and Duncan grapefruit at Limeira, where the plants had been inoculated in the nursery with the severe tristeza virus strain, exhibited many trunk and stem pits and were very small with compact bunchy tops. These plantings produced no fruits of commercial value.

**Pera orange** is the late variety most commonly exported from Brazil. The oblong or pear-shaped fruit has the advantage of holding well on the tree, which is particularly important in Brazil, where storage facilities are limited. In recent years this variety has been subject to stem pits similar to those observed on the West Indian limes and grapefruit trees. This stem pitting has been accompanied by production of small fruit and stunting of the infected branches, and when trunk pits are evident the entire tree produces small fruits. Severely infected young groves, fertilized heavily in the first few years, have produced normal-sized fruits, but there is no evidence that they will be able to continue production for long periods.

The largest numbers of groves with badly pitted Pera orange trees 4 to 8 years old were in the vicinity of Limeira. However, all plantings in this area were not uniformly infected, which indicated that in some cases the budwood may have been from trees infected with the severe tristeza virus strain and that in such cases trunk pitting started at the bud union of the Pera top and the rootstock. It was estimated that in some groves 10 to 20 percent of the trees were from buds carrying the severe strain of tristeza virus by aphids when the trees were in the nursery (1). The trees in this latter planting were affected with branch die-back and stem pitting and were extremely stunted.

**Grapefruit plantings** were composed largely of the Marsh seedless variety. In the groves stem pits ranged from very few to many deep trunk and branch pits. According to the grove owners and operators, the grapefruit trees show seasonal deficiency symptoms on the leaves and the trees were judged to be considerably smaller than they would have been in the absence of virus infection.

A high proportion of fruits were small, very acid, and thick-skinned. In general, the trees in groves receiving heavy fertilizer applications were in better condition than unfertilized trees, but fruit quality was relatively poor.

The experimental field plantings of Foster and Duncan grapefruit at Limeira, where the plants had been inoculated in the nursery with the severe tristeza virus strain, exhibited many trunk and stem pits and were very small with compact bunchy tops. These plantings produced no fruits of commercial value.

**Pera orange** is the late variety most commonly exported from Brazil. The oblong or pear-shaped fruit has the advantage of holding well on the tree, which is particularly important in Brazil, where storage facilities are limited. In recent years this variety has been subject to stem pits similar to those observed on the West Indian limes and grapefruit trees. This stem pitting has been accompanied by production of small fruit and stunting of the infected branches, and when trunk pits are evident the entire tree produces small fruits. Severely infected young groves, fertilized heavily in the first few years, have produced normal-sized fruits, but there is no evidence that they will be able to continue production for long periods.

The largest numbers of groves with badly pitted Pera orange trees 4 to 8 years old were in the vicinity of Limeira. However, all plantings in this area were not uniformly infected, which indicated that in some cases the budwood may have been from trees infected with the severe tristeza virus strain and that in such cases trunk pitting started at the bud union of the Pera top and the rootstock. It was estimated that in some groves 10 to 20 percent of the trees were from buds carrying the severe strain. The remaining trees showed varying degrees of infection ranging from no pits to trees with one or more branches with stem pits and small fruits. These latter cases seemed to be the result of spread of the severe strain by aphids.

In the Bebedouro area one grower, who had maintained detailed records, indicated that 200 of 22,000 budded trees had shown trunk pitting 3 years after budding. These trees were scattered through his field planting.
and seemingly aphids had spread the virus to adjacent trees. These more recently infected trees showed no trunk pits but individual branches had stem pits and small fruits. The remaining branches were producing fruits of normal size.

From the observations, it seems evident that Pera orange budwood, free of tristeza virus or with only a mild strain of it, should be selected.

At the Experiment Station in Limeira, Pera orange has been used both as a top and as a rootstock. Evidently the Pera orange holds an intermediate position of tristeza tolerance. As a rootstock it is more tolerant to severe tristeza virus than sour orange or grapefruit, but as a top it is less tolerant than other sweet oranges tested.

Sweet oranges, Baianinha, Hamlin, and Valencia, were observed in many field plantings. No trunk or branch pitting could be observed without removal of the bark. Upon removal of the bark, however, varying numbers of small pits could be observed on all varieties. In general growth of these sweet orange varieties was relatively very good even in plantings adjacent to Pera orange groves that showed deep stem pits.

Eureka lemon has been recognized as a variety that could be top-worked on sweet orange on sour orange rootstock and would continue to grow and produce lemon fruits even in areas such as at the Limeira Citrus Experiment Station where tristeza virus is prevalent. The tristeza virus does not readily multiply in Eureka lemon. In 1957 one of 135 Eureka lemon trees that had been inoculated with tristeza virus by aphids 7 years earlier when they were young plants showed very strong trunk pitting symptoms. This unusual trunk pitted Eureka lemon was thought to be a potential source of a stem-pitting virus. Therefore, in 1957 Moreira took buds from this tree and propagated them on seedlings of 3 different lemon varieties, Villa Franca, Genova, and Sicilian. Three years after grafting of the Eureka lemon propagated tops and the lemon rootstocks no pitting was evident and the plants are growing vigorously in the field. It is evident that the stem or trunk pitting on the Eureka lemon tree was not transmitted to the lemon rootstocks nor was it perpetuated in the Eureka lemon tops. One is forced to conclude that the stem pitting on this Eureka lemon behaved exactly as if it were caused by the tristeza virus and not due to a separate stem pitting virus.

**Discussion**

In 1949 Oberholzer, Mathews, and Stiemie (14) used the term "stem pitting" to designate a specific disease of grapefruit. They characterized the stem pitting as having corrugations or longitudinal pits on the outer surfaces of trunks of infected trees. These infected trees become stunted and bushy giving rise to the name "stunt bush." In 1950 Costa, Grant, and Moreira (2) pointed out the possible relation between tristeza and the stem-pitting disease of grapefruit in Africa. Also, in the same year, McClean (11) proved the disease to be infectious and to be transmissible by grafting and by means of the aphid *Toxoptera citricidus* which also transmits the tristeza virus.

In 1952 Fraser (3) found that very young seedlings of Eureka lemon, sour orange, and grapefruit, when grafted with material from sweet orange and mandarin trees, caused symptoms she referred to as "seedling yellows," but seedling test plants of these same seedling varieties grafted with material from field trees of grapefruit, Eureka lemon, and sour orange had only occasional vein fleckings in the spring growth. Fraser at first considered "seedling yellows" to be caused by a virus distinct from tristeza. McClean and van der Plank (12) suggested the tristeza virus complex has two components, a stem-pitting component and a seedling yellows component. In 1956 Knorr and Price (8) discussed grapefruit stem pitting and hypothesized that tristeza, stem pitting, seedling yellows, and the Gold Coast's lime die-back are caused by a single virus that exists in the form of numerous strains. In 1957 Grant and Higgins (7) demonstrated the occurrence of mixtures of tristeza virus strains. In 1959 Fraser (4) considered seedling yellows as a reaction to the tristeza virus and stem pitting as caused by a distinct virus. She was unable, however, to obtain the seedling yellows or tristeza virus free of the stem-pitting virus. The same year Grant (5) reported the occurrence of varying proportional mixtures of different strains of tristeza virus as demonstrated by subcultures from plants with experimentally induced mixtures and from plants subjected to heat treatment. In 1959 also Grant (6) described tristeza virus strains in relation to different citrus
species used as test plants. He obtained the yellowing reaction on Eureka lemon seedlings with the T$_8$ severe tristeza virus strain and the deep stem-pitting symptoms on grapefruit seedlings with the same inoculum source.

In summary, it may be stated that yellowing, stem pitting, leaf cupping, die-back, stunting and wilting are merely different symptoms. Whether one wishes to consider each symptom, or combination of symptoms, to be caused by a distinct virus or by strains or combination of strains of a single virus is purely a technical matter. For all practical purposes, the citrus grower has to deal with the tristeza virus complex that is aphid-transmitted in various combinations under field conditions.

In Brazil the West Indian lime (Key lime) plants that had been inoculated 10 years ago as young nursery plants with the common or severe strain of tristeza virus by means of repeated aphid infestations (1) are now either dead or show stunting and stem pitting. Duncan and Foster grapefruit plants similarly inoculated all show deep trunk and branch pits and compact “stunt bush” symptoms similar to those described by Oberholzer, et al (14).

The current observations of some other lime and grapefruit plantings in Brazil show that where budwood has been selected from surviving lime and grapefruit plants in the field, the propagations of these have in many cases survived and do not show marked trunk pitting symptoms. They may, however, show some stem pits on the branches. Some vein clearing of lime leaves can also be found. These observations would indicate that, in spite of the general prevalence of tristeza virus, budwood should be selected from trees that show the most desirable growth and survival characteristics.

From the limited records available on field plantings of Pera orange and their budwood sources, it also was apparent that budwood from apparently healthy rather than pitted trees might have had an important influence in the presence or absence of trunk pitting and the general severity of branch pitting and stunting. These observations suggested that certain field trees had a protective mechanism that might be related to the presence of a mild strain of the virus or virus strain complex.

In 1956 Knorr and Price (8) discussed the question — “Is stem pitting of grapefruit a threat to the Florida grower?” They believed that it is a threat but one that should not be taken too seriously so long as an efficient vector of tristeza like Toxoptera citricidus is kept out of Florida.

Since 1956 stem pitting has been found to occur, not only on grapefruit and limes, but also on Valencia orange in the Congo and Pera orange in Brazil, and more recently it has been observed on Mediterranean sweet orange in Argentina. In all cases, these above mentioned varieties have shown stem pitting even though they were grown on tristeza-tolerant rootstocks.

It would thus seem desirable for the Florida citrus grower to take an active interest in methods that might be employed to minimize the effects of stem pitting. There is no guarantee that Toxoptera citricidus will not enter the state nor is there any certainty that some lines of the present aphid populations may not become more efficient vectors (13).

At present the most desirable place to carry out research work is in Brazil, where stem pitting is a specific problem on grapefruit, lime, and Pera orange and where Toxoptera citricidus exists.

The authors have drawn up a proposed plan of research that would include the following:

1. Determine the importance of budwood sources in relation to trunk and stem pitting.
2. Test Hamlin and Valencia orange varieties that presently do not show deep stem pits by top-working them on badly pitted lime, grapefruit, and Pera orange trees.
3. Try interplanting with Hamlin and Valencia oranges in groves of badly pitted Pera orange to determine whether such a procedure is practical for rehabilitating groves.
4. Determine the effects of fertilizer and pruning practices on stem pitting and fruit production.
5. Test for the presence of mild virus strains in outstanding trees that have survived and show little or no stem pitting in the field.

Communication from J. L. Foguet, Tucuman, Argentina.
6. Select mild strains for studies to determine whether grapefruits, limes, and Pera orange inoculated with these mild strains can survive and produce good fruit under field conditions.

A project of this magnitude requires funds that are not now available locally in Brazil. The results of such a study would be of interest and value to citrus growers in the United States. Thus such a project could qualify for consideration for the use of funds under U. S. Public Law 480. These funds result from the sale of our surplus agricultural products in foreign countries. The project as outlined above has been submitted for consideration.

LITERATURE CITED