CHAPTER 10

Incidence and Spread of Citrus Viruses: Control Methods and Programs

Production of Virus-Free Budwood in Citrus—Past, Present, and Future

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A REVIEW of programs for the control of virus diseases necessarily begins with the budwood selection scheme started in California in 1937—a scheme designed to control a single virus, psorosis. In the original California regulations, the need for indexing was left to the discretion of the inspector. One important procedure of this first program, the indexing of symptomless parent trees on suitable indicator plants, became a basic part of later programs.

In 1943, Texas undertook a psorosis control program which required that *all* parent trees be indexed for psorosis and that test plants be kept under observation for a period of two years. Unfortunately, severe damage to the Texas citrus industry, resulting from the freeze of 1951, obscured the benefits of the program.

Shortly after the start of the Texas program, other virus diseases of citrus were discovered. Tristeza, the cause of heavy losses in South America, South Africa, Australia, and California, was shown to be a virus disease by Meneghini (10). Confirmation was provided by Bennett and Costa (1) in Brazil, Fernandez Valiela (7) and DuCharme (5) in Argentina, Oberholzer in South Africa (11), and many others. Indexing procedures were worked out subsequently by Schneider *et al.* (14) and

Wallace and Drake (15). At about the same time, exocortis was described by Fawcett and Klotz (6), and the disease was shown by Benton *et al.* (2) in Australia to be transmissible. Xyloporosis, first described by Reichert and Perlberger (13) in Palestine in 1934, was shown to be a virus disease by Childs (3) in Florida in 1952.

Thus, by 1952, when Florida was planning a citrus budwood program of its own, there were four viruses to be considered, compared with only one under the California and Texas programs. Florida decided to undertake a maximum program, one that would provide protection against three viruses: psorosis, xyloporosis, and exocortis. Tristeza was added later when its presence in Florida was established by Grant and Schneider (8) in 1953.

The distribution of viruses in old-line trees was poorly understood when the Florida program was planned. Orchards were known in which 75 per cent or more of the trees were affected by psorosis; however, the majority of commercial trees were thought to be free of viruses. Consequently, it seemed at the time that indexing old-line trees and eliminating the virus-infected ones would result in a plentiful supply of virus-free budwood. The utilization of nucellar seedlings was considered too time-consuming and too expensive. Consequently, nucellar clones were ignored in the original program, but were included later when the hopelessness of finding virus-free old-line Dancy mandarin trees by indexing became apparent.

Indexing for psorosis, xyloporosis, and tristeza was begun in 1953. Exocortis indexing on trifoliate orange was started two years later. In 1958, the budwood committee voted to use Childs' color test for preliminary screening of exocortis. When the impossibility of controlling a vector-disseminated disease through indexing was fully realized, the tristeza portion of the program was dropped.

As the demand for registered budwood grew, it became evident that the amount of budwood from the program would not satisfy needs of the Florida industry. To remedy the situation, plans were adopted in 1958 to establish a foundation planting (9). Indexed candidate trees of each commercially important variety of citrus were selected and propagated on five different stocks in a special nursery. The purpose of the foundation planting was twofold: to provide nurserymen with enough registered budwood to give them a start with indexed budwood of any variety of citrus they might require, and to provide a continuing index test of the sources selected.

When it became apparent that most old-line varieties were infected with viruses, more attention was given to nucellar lines, especially of Valencia orange. Thus, the program eventually acquired a sizeable collection of nucellar material.

Present

By most standards, the Florida program can be considered very successful. Psorosis-free and tristeza-free budwood has been available since 1956. In 1961, the State Plant Board was in a position to prohibit further sale of psorosis-infected nursery stock. Budwood free of xyloporosis (as well as psorosis and tristeza) has been available since 1958, but registered exocortis-free budwood of old-line clones is still not ready for release. By 1962, 70 per cent of the nursery trees sold in the state were the progeny of registered trees.

Though designed at a time when little was known about the number or the distribution of citrus viruses, the Florida program made great strides in disease control. The ravages of psorosis were checked. Use was made of highly desirable rootstocks that once were rejected because of susceptibility to xyloporosis and exocortis. And, the program also contributed to a solution of the tristeza problem, permitting substitution of trifoliate orange and citrange rootstocks for the tristeza-susceptible sour orange.

The full impact of the Florida program is still to be felt. Another 20 years may be required before the program's role in augmenting yields is fully appreciated.

Problems resulting from the indexing of old-line trees.—Valuable information, much of it startling and unexpected, emerged from the Florida program. For example, index tests of old-line citrus trees revealed that less than 1 per cent of the old-line orchard trees examined finally proved acceptable. Seventy-two per cent were found to be infected with xyloporosis virus, 6.8 per cent with psorosis, and 5.5 per cent with tristeza. Preliminary indexing with the color test indicated that approximately 50 per cent of the candidate trees tested were also infected with exocortis. Bark scaling of trifoliate test stocks six years later showed that 55 per cent actually carried exocortis virus. Because of these percentages, which proved to be so much higher than anticipated, the program as set up in 1952 falls short of present-day needs.

What are present-day needs? Budwood free of psorosis, xyloporosis, and exocortis is unquestionably better than budwood derived from old-line sources, but is that enough? Basically, the citrus industry today requires budwood that is free of *all* non-insect-transmitted viruses, not just four. More than a dozen virus disorders are now recognized by citrus virologists, but indexing old-line trees for 12 or more viruses is a task of enormous proportions. Furthermore, some assurance is required that all this indexing will not have to be repeated whenever a new virus is discovered or whenever a previously discovered virus suddenly becomes important. This is especially true if full use is to be made of the different rootstocks that are needed to replace tristeza-intolerant sour orange.

Cost is another serious consideration. Programs based on finding acceptable sources of budwood from among old-line trees are necessarily expensive. The annual budget of the Florida program five years after its inception amounted to 30 thousand dollars, and by 1961, the program had become a 100 thousand dollar-a-year operation. Where citrus is one of the principal sources of income, as in Florida, and where annually it returns to growers approximately 350 million dollars, this outlay may be warranted. However, a program of this magnitude can scarcely by justified by most citrus-growing countries. Of the 13 nations that produce 93 per cent of the world's citrus, ten grow citrus only as a secondary crop. If benefits of budwood improvement programs are to accrue to the majority of citrus-growing nations, a more economical approach must be found.

Future

To judge from results of the Florida program since 1952, we feel that the next advance in procurement of virus-free budwood must come through nucellar selection.

Budwood from nucellar seedlings is superior to old-line budwood in many respects: 1) it is far more certain to be free of viruses, both those known and those not yet recognized; 2) it requires little, if any, additional time to produce compared with complete indexing of old-line sources for all known viruses; 3) it is less expensive to produce; and 4) its production is more dependable in the hands of personnel not trained in pathology.

Actually, there is nothing new about obtaining virus-free budwood from nucellar seedlings. The apomictic mechanism in citrus was first described in 1878, and many later workers noted the superior vigor of nucellar seedlings. Years ago, Frost in California and Moreira in Brazil set out to produce nucellar lines of commercially important citrus varieties, with the result that growers in California and Brazil now have many clones of nucellar budwood that can be used safely on any rootstock tolerant to insect-transmitted viruses. To a limited extent this is true also for Florida.

The nucellar approach, however, is not without its own problems. These include the identification of seedlings as nucellars and the waiting period required for juvenility to run its course. Also, there is the tendency to rely on the false generalization that no citrus viruses are seed transmitted.

Identification of nucellar seedlings is not the serious problem it has been made out to be. The trifoliate pollination method is always available. In addition, techniques have been developed by Pieringer and Edwards (12), at the Florida Citrus Experiment Station, for separating nucellar and sexual seedlings on the basis of infrared spectroscopic analyses of citrus leaf oils.

Waiting for juvenility to run its course may take years, as many as 20 in the case of Valencias. Other varieties, however, like lemons and most mandarins, usually fruit within three to five years. Moreover, long waiting periods can often be circumvented by finding and testing seedling trees of bearing age that occur scattered in most citrus-growing areas.

The recent discovery of seed transmission of psorosis virus requires a reconsideration of the often-repeated generalization that citrus viruses are not seed transmited. Childs and Johnson (4) have shown that in one clone of Carrizo citrange, psorosis virus was transmitted through as many as 31 per cent of the seeds from affected parent trees. This occurrence suggests that citrus viruses may be seed transmitted in certain species and varieties and not in others, and that until each is tested, it cannot be assumed that seed transmission is inoperative. Also, there are the possibilities of root grafting and accidental infection. These problems illustrate the need of routine indexing, even in programs based on selection of nucellar lines.

Other viruses may prove to be seed transmitted; nevertheless, nucellar selection continues to provide the most certain and efficient way of obtaining virus-free budwood. Furthermore, there is an excellent probability that other viruses, as yet undescribed or for which index tests are lacking, are likewise not transmitted through the seed. In short, by using either nucellars or sexual seedling sources of budwood, there is a strong likelihood that most viruses, both known and unknown, can be eliminated at a single stroke.

The essence of this situation can be stated briefly as follows. Anyone willing to guarantee delivery of ten old-line varieties of citrus in virus-free condition would be either very optimistic or very poorly informed. To deliver ten virus-free nucellar clones of the same ten old-line varieties, on the other hand, would be relatively simple. A large number of plants would be required in a few instances, but the mechanics of the operation are easily managed and quite routine.

Considerable information on the relative incidence of viruses in old-line sources and nucellar lines has emerged from the Florida program; for example, it was found 1) that the number of old-line trees free of four viruses was extremely small, less than 0.5 per cent; 2) that the expense of finding old-line trees free of four viruses was extremely large, this being due to time and money spent indexing trees that failed to pass; 3) that the possibility of old-line trees free of four viruses being free of all other viruses was close to nil; and 4) that the majority of trees found free of four viruses were either seedlings or recent seedlings.

Because of the foregoing considerations, we conclude that it is more economical of time, effort, and money to develop virus-free lines of commercially important varieties by testing nucellar seedlings than by indexing old-line trees.

In the past, indexing programs have served us well. In the future, we expect that further progress toward virus-free citrus will be made through nucellar selection.

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