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CITRUS VIRUSES, THEIR ECONOMIC IMPORTANCE AND THEIR MODERN METHODS OF TRAVEL

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INTRODUCTION

The purpose of this paper is to introduce the subject of citrus viruses, the many technical phases of which will be discussed by research leaders from the important citrus-growing regions of the world in sessions of this conference that are to follow. Citrus production is on the increase in nearly every area suitable for citrus culture; such increase, as is usual, is accompanied by an increase in pest-control problems. Diseases caused by viruses have become a major factor in citrus production and research. Unless adequate measures are taken to control these diseases or eliminate their causal viruses from propagation sources, they will continue to be distributed and will add to the cost and difficulty of profitable citrus production.

Despite the fact that citrus is one of the oldest crop plants and has been widely distributed throughout the world, no virus had been proved to affect it until Fawcett (*5*), in 1933, demonstrated the virus nature of psorosis. Since then more than ten citrus diseases have been shown to belong in the virus category. In addition to psorosis, the list of "Common Names of Plant Virus Diseases used in the *Review of Applied Mycology*" (*4*) includes infectious mottling (*7*), stubborn (*6*), tristeza (*1*), Satsuma dwarf (*15*), vein enation (*13*), xyloporosis (*3*), and exocortis (*9*). Since publication of this list, vein banding of limequat (*14*) has been shown to be transmissible. Calavan, Wallace, and Weathers (*2*) have shown that the factor which reduces vigor in old-line citrus clones, and which is eliminated in nucellar lines of Eureka lemon, is transmissible and is therefore probably a virus. Fraser (*8*), in 1952, reported a virus in the tristeza complex which caused yellows on Eureka lemon seedlings and which she thought to be distinct from tristeza virus. Later studies (reported in this volume) have led her to conclude that the so-called stem-pitting virus is unrelated to tristeza virus, and that tristeza (quick decline) is caused by the virus of seedling yellows or a mixture of this virus and the stem-pitting virus. A number of other virus-candidate citrus disorders are waiting to have their etiology determined.

ECONOMIC IMPORTANCE

Little data that would aid in formulation of specific figures on the amount of damage caused by virus diseases to citrus production is available. A catastrophic example of damage is that caused by tristeza in South America, where the disease spread very rapidly and where most of the trees were of the combination of sweet orange on sour orange rootstock, which is severely affected. In the State of São Paulo, Brazil, tristeza spread in about twelve years to all the citrus-growing areas, destroying upwards of

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6 million trees (*1*), or about 75 per cent of all the trees in the state. Similar spread has occurred in other states of Brazil and in other South American countries. Spread was rapid in the western part of southern California, but is less rapid in inland areas away from the coastal climate. The tristeza virus was established early in the culture of citrus in South Africa and has made the use of sour orange rootstock impracticable for that area. Tristeza has also caused severe losses in Australia, and it is feared in other important citrus-growing areas of the world. The causal virus is probably indigenous to the Orient but does little damage there because most of the trees are grown from seed and are therefore on their own roots. Since tristeza affects trees grown on sour orange rootstock, many of the trees in the Orient are probably infected without expressing symptoms.

Psorosis virus, so far as is known, has no natural vector to spread it in orchards but has been unwittingly carried in budwood by man to all the major citrus-growing areas of the world. In many of these areas it is the number-one cause of tree decline. In southern California many orchards have high percentages of diseased trees. Surveys of 6,000 trees in plantings of one of the large citrus estates showed that 14 per cent of the trees were affected and producing reduced yields and that 6.5 per cent were in a state of unprofitable production (*11*).

The stubborn disease, as it has become more clearly characterized, has given evidence of being much more widespread than had been known and may be the cause of poor production and inferior fruits in many areas of the world. Some evidence indicates that all of certain clones of citrus may be affected and correspondingly reduced in vigor and yield.

Psorosis and stubborn diseases affect horticultural varieties grown on any rootstock; damage from tristeza, exocortis, and xyloporosis is restricted to trees on certain rootstocks. All the citrus viruses are somewhat insidious in that they can exist in trees at some stages or under certain conditions without readily recognizable symptoms. Such viruses have been distributed widely in propagating stocks, and in some areas high percentages of orchard trees of many horticultural varieties are carriers of one or more of these viruses.

In Florida an extensive indexing program has been carried on in connection with the bud-certification program (*10*). In this program only trees free of visible symptoms of disease, in a good state of vigor, and old enough to show symptoms of psorosis are considered. Of 1,047 trees indexed in 1953 for psorosis and xyloporosis, only 115 remained in the program in 1957. A sizable number of the 115 are of nucellar seedling origin and would not be expected to be virus-infected. Undoubtedly most of the remainder of the 115, other than the nucellars, will be eliminated when exocortis index tests are completed.

IMPORTANCE IN RESEARCH PROGRAMS

It is obvious that any studies on reaction of rootstocks, nutrition, soil management, and related subjects involving yield records will give misleading results if some of the trees are virus-infected and the others are not. Rootstock studies may be particularly affected. If tristeza is present, sweet orange, mandarin, and grapefruit trees on sour orange will be affected. If exocortis virus is in the top variety, trees on trifoliate orange, some citranges, and possibly Rangpur lime will be affected. If xyloporosis is present, trees on sweet lime and possibly those on certain varieties of mandarins and mandarin hybrids will be affected.

The presence of viruses such as tristeza, which, given time, will be found in all citrus varieties in some areas, has changed the rootstock problem for orchards in such areas. Sour orange has been widely used because of its resistance to foot rot and root rot caused by *Phytophthora* spp. On sour orange in many of the important citrus-growing areas of the world, trees attain moderate size and produce moderate to good yields of good-quality fruit. In areas where the tristeza virus is present and spreads in orchards, sour orange cannot be used. There is much concern in other areas where sour orange rootstock has been widely used lest the tristeza virus be introduced. In Florida, trees of much of the citrus acreage in the deep, sandy soils of the ridge section are on Rough lemon rootstock. Such trees are vigorous and large, but they produce fruits which are low in total solids and hence less desirable for frozen concentrate; thus new, more satisfactory stocks are needed. New, tolerant rootstocks seem to be a promising approach to the ever-increasing nematode problem. The choice of such rootstocks will be affected by their reaction to viruses present in the top scion varieties.

Hybrids involving trifoliate orange parentage have shown the most promise, but some of these have shown severe reactions where the scion variety was carrying exocortis virus. Correspondingly, hybrids with mandarin heritage have shown reaction where the scion variety contained xyloporosis virus. It is therefore very difficult to produce a rootstock both tolerant to the viruses and satisfactory from a horticultural standpoint. It would seem much easier to use budwood free of viruses and thus produce virus-free trees. Fortunately, citrus viruses other than tristeza do not appear to spread naturally in orchards in North America. Satsuma dwarf (*15*) is reported to be spread by an insect in Japan. There is no evidence of seed transmission of citrus viruses, except of xyloporosis in sweet lime, which needs confirmation, and in rare instances, the psorosis virus. In any case, it should be relatively easy to obtain seeds from indexed virus-free seed-source trees.

BUDWOOD CERTIFICATION PROGRAM

The details of budwood certification in relation to virus diseases will be discussed by others at this conference, but the present paper would not be complete if the complexity of the problem were not mentioned. It is true that certain standards and index procedure have taken us a long way on the road to virus-free budwood, but much more work is needed. No entirely satisfactory index plants are available for stubborn disease. Much difficulty is experienced where strains of such viruses as tristeza, exocortis, and even psorosis are involved. Many workers are turning, when possible, to the use and development of nucellar lines as sources of virus-free clones.

METHODS OF DISTRIBUTION AND INCREASE

Man is and has been the principal agent in both the dissemination and the increase of citrus viruses. Citrus was distributed widely over the world before virus diseases were known, and no doubt some of the viruses that affect citrus were present in trees and propagative material introduced from one country to another. Quarantines set up to prevent the introduction of fungus and bacterial diseases and insect pests failed to exclude viruses. Even after the threat of virus diseases was recognized, quarantine procedures were at best only partially successful. Since viruses generally are not evident in budsticks and may be present in certain plant hosts without causing symptoms, ordinary quarantine examination failed to disclose them. It is not surprising, then, that the principal citrus viruses are found in nearly all the major citrus-growing areas of the world.

How do viruses get into stocks originally? For those having insect vectors, the answer to this question is self-evident. Some which appear to have no vectors in the areas where they were first recognized may have had vectors in the areas of their origin. The most common means of contamination of stock is the top-working of old, virus-infected trees. New varieties brought from other countries or newly developed hybrid varieties have commonly been propagated on old trees to increase the available budwood or to obtain early fruiting. New growth from such propagations is usually vigorous and may not show symptoms of the virus or viruses present. However, the new growth will carry the viruses present in the old tree, and budwood from these sources will carry these viruses to progeny trees. It seems safe to conclude that, with the exception of the aphid-transmitted tristeza, citrus virus diseases have been distributed and increased almost exclusively by man through the use of infected propagative material. As our knowledge of citrus virus diseases increases and methods of diagnosis and detection are discovered, the costly mistakes of the past will be avoided. The fortunate fact that the majority of viruses that affect citrus are not spread naturally provides the hope and expectation that in the not-too-distant future the new plantings of citrus throughout the world will remain free of most of the virus diseases which have plagued them up to the present time.

Viruses often come into areas in plant hosts other than the plants on which they cause serious damage. Pierce's disease of grape has a host range of over 111 species in 41 families, and presumably could be introduced into new areas in plants or propagative parts of any one of these. The little cherry disease of sweet cherry, which has been so devastating in the Kootenay Lake area of British Columbia, was apparently introduced from Japan in symptomless ornamental flowering cherries. Indexing of such flowering cherries now growing in many of the arboretums and parks of the United States has shown them to be carrying the virus (*12*). In the Kootenay Lake area infected flowering cherry trees came in contact with a vector capable of carrying the virus to sweet cherries. Numerous other examples of such virus introductions could be cited, but none are more pertinent to the subject than tristeza in Meyer lemon from China and in various mandarins from the Orient. These serve to indicate the need for thorough screening of foreign introductions and for fundamental information which will aid in recognition of citrus viruses before they are transported into areas where they do not yet occur.

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