XYLOPOROSIS AND CACHEXIA — THEIR STATUS AS CITRUS VIRUS DISEASES

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INTRODUCTION

The question is whether xyloporosis and cachexia are diseases caused by the same virus or by different viruses. In other words, what is their status as virus diseases, and what is their relation to each other? It is the purpose of this paper to assemble the present information on xyloporosis and cachexia in an attempt to answer these questions. A review of the pertinent literature may lead to a better understanding of the situation and indicate whereby certain anomalies can be resolved. It is proposed to discuss references to the literature briefly in more or less chronological order and to review the salient points in detail.

LITERATURE REVIEW

In 1934, Reichert and Perlberger (*23*) described a disease of sweet lime, *Citrus limettioides* Tanaka, rootstocks and seedling trees in Palestine, characterized by pitting of the wood, gum impregnation of the bark, and other features, and named it "xyloporosis." It occurred mainly on sweet lime rootstocks of Shamouti sweet orange, *C. sinensis* (Linn.) Osbeck, and was of considerable economic importance. Xyloporosis was reported to be spreading, as indicated by the fact that 45 per cent of the trees in one three-year-old planting were affected, and three years later 75 per cent were affected. The cause was not identified, although a physiological disorder and a virus were suggested as possibilities. Wood-pitting symptoms were found on mandarin, *C. reticulata* Blanco, but not on sweet orange; sour orange, *C. aurantium* Linn.; lemon, *C. limon* (Linn.) Burm.; and grapefruit, *C. paradisi* Macf.

In 1938, Moreira (*15*) reported that xyloporosis was present on sweet lime rootstocks in Brazil and that H. S. Fawcett had identified the disease on the basis of its resemblance to xyloporosis previously seen in Palestine. Moreira concluded that xyloporosis was the result of incompatibility (disharmony) between sweet lime and Barao sweet orange, and cited Caipera and Pera sweet orange as varieties compatible with sweet lime.

In 1950, a disease resembling xyloporosis but affecting Orlando tangelo, *Citrus reticulata* X *C. paradisi*, was described from Florida (*2*) and named "cachexia" (from *kakos* = bad and *hexis* = condition, meaning malnutrition and wasting from some chronic constitutional affection). Affected Orlando tangelo trees were found on rootstocks of sour orange; sweet orange; Rough lemon, *C. jambhiri* Lushington; Rusk citrange, *C. sinensis* X *Poncirus trifoliata* (Linn.) Raf.; and Cleopatra mandarin. No symptoms were recognized on these rootstocks. Transmission experiments (*4*) demonstrated the virus nature of cachexia and that grapefruit could be a symptomless carrier of the virus. This was confirmed by Olson (*18*), who found cachexia symptoms

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on two species of mandarin; on two tangor, *C. reticulata* X *C. sinensis*, varieties; and on five tangelo varieties in Texas. Cachexia symptoms were recognized on 19 varieties and hybrids of mandarin in Florida, but not on sour orange; grapefruit; sweet orange; pummelo, *C. grandis* (Linn.) Osbeck; lemon; or *P. trifoliata* (*3*). In a later experiment, Olson and Shull (*20*) grew buds from three grapefruit sources on Orlando tangelo and sweet lime rootstocks. Cachexia symptoms developed on the Orlando tangelo stocks, and xyloporosis symptoms appeared on the sweet lime stocks. Buds from two seedling grapefruit trees induced no symptoms in Orlando tangelo or sweet lime stocks. All trees in this experiment were free of stem pitting and tristeza viruses, as indicated by indexing on West Indian lime, *C. aurantifolia* (Christm.) Swing., and on sour orange, respectively. Still later, Olson *et al.* (*19*) obtained xyloporosis-type symptoms on Leonardy grapefruit rootstocks with Valencia tops. Cachexia-type symptoms had previously been found on one Leonardy stock in Florida but at that time were discounted as resulting from an error in stock identification (*3*).

In 1952, DuCharme (*10*), in Florida, reported xyloporosis symptoms on sweet lime rootstock with tops of Jaffa, Lue Gim Gong, and Hamlin sweet orange; on Temple orange (presumed to be a chance hybrid of mandarin and sweet orange); and on Foster pink grapefruit.

Buds from the Hamlin, Temple, and Foster trees mentioned above were grown on Orlando tangelo stocks and induced cachexia symptoms in the latter (*5*). In the same experiment (*5*) buds from cachexia-affected Orlando tangelo trees induced xyloporosis symptoms in Palestine sweet lime rootstocks grown from California seed, and in Florida sweet lime rootstocks.

The studies reported above appear to indicate a positive relationship between xyloporosis and cachexia. However, other studies and interpretations have suggested that the two diseases are not the same. These points of difference deserve careful consideration. Reichert and Perlberger (*22*) originally described little-leaf disease as a separate and distinct disease, but later Reichert (*21*) associated it with xyloporosis on the basis of the many trees exhibiting symptoms of both xyloporosis and little leaf. The symptoms of little-leaf disease are misshapen, lopsided fruits, short internodes of branches, and small upright leaves. Association of xyloporosis with little leaf has not been reported in Brazil (*15*), Argentina (*9*), or Florida (*10*), where xyloporosis of sweet lime has been reported. Furthermore, little-leaf symptoms have been reported from California and Arizona (*12*), Morocco, Algeria, Lybia, Syria, and Turkey (*1*) under the name "stubborn" disease, and have been observed in Florida and Texas; but no association of stubborn with xyloporosis has been reported.

In 1954, DuCharme and Knorr (*11*) recognized a type of wood pitting in Rough lemon that was associated with the presence of California red scale, *Aonidiella aurantii* (Mask.).

In 1956, Nour-Eldin (*17*) reported phloem discoloration (gum impregnation) in seven varieties of sweet orange. The phloem discoloration did not invade the sour orange rootstocks. Two types of stem pitting were observed but they did not always accompany phloem discoloration.

Bud-union constriction with pits and pegs at the union and occasional pits on Rough lemon stock have been observed in Israel (*24*). Recently Grimm *et al.* (*14*) reported a bud-union abnormality of that type on sweet orange trees on Rough lemon rootstock in Florida. A study of trees in the Florida Citrus Budwood Program showed a high rate of association between the bud-union symptom as described by Grimm *et al.* and cachexia infection as indicated by the early results from the indexing tests on Orlando tangelo (*7*). The association was not perfect, however, and when indexing was completed it was found that an appreciable number of trees with constricted unions failed to transmit cachexia and that a number of trees found to be infected with cachexia had normal unions (*16*). None of the grapefruit trees on Rough lemon stock had constricted unions, but a large number were infected with cachexia virus, as indicated by the Orlando tangelo index test.

Observations by Grant *et al.* (*13*) on 12 trees in their rootstock plots in Brazil are of related interest. In this experiment buds from known parent trees of three sweet orange varieties were grown on Florida Rough lemon, and abnormalities of the type described by Grimm *et al.* (*14*) developed at the union. Buds from these sweet orange trees failed to induce xyloporosis symptoms on sweet lime rootstocks in 8 years. None of the three source trees was indexed on Orlando tangelo.

The relation of tristeza to xyloporosis and cachexia has been reviewed many times, with general agreement that there is little or no evidence relating these two disorders to tristeza.

The fact that Fraser's[2] stem-pitting virus, which she considers to be distinct from tristeza virus, causes pitting of sweet lime raises a question of its relationship to xyloporosis. However, this stem-pitting virus causes wood pitting of grapefruit, whereas xyloporosis virus does not. Also, stem-pitting virus does not produce pitting on Orlando tangelo, but xyloporosis virus does.

The mode of transmission frequently sheds light on the virus nature of plant diseases and their relation to other similar disorders. Reichert and Perlberger (*23*) in their original description of xyloporosis stated that unbudded seedling sweet lime trees were occasionally found with xyloporosis symptoms. In Israel, the author was shown pronounced symptoms of xyloporosis on three-year-old Shamouti orange trees on sweet lime stock (*6*) that were grown, he was told, from buds of old Shamouti orange trees on sweet lime rootstock free of xyloporosis. Transmission of the virus through the rootstock seed is indicated, because neither mechanical nor insect transmission has been implicated in transmission of the causal agent of xyloporosis. Reichert and Perlberger recognized the possibility of seed transmission and investigated this point. Their findings were inconclusive (*23*), however, probably because the possibility of coincidental bud transmission was not recognized at that time.

In 1956, evidence of seed transmission of xyloporosis in sweet lime was reported from Florida (*5*). Since then, very mild stem pitting has been found to be associated with scale infestation in the same area, and this throws some doubt on the validity of the report. The field notes on these seedling trees have been reviewed for comparison 1) with notes on adjacent uninoculated Orlando tangelo seedlings, 2) with the symptoms noted in Palestine sweet lime budded with cachexia-infected Orlando tangelo, and 3) with Orlando tangelo index plants inoculated with xyloporosis from three sources in Florida. The results of the comparison were judged to substantiate seed transmission as originally reported. However, further experiments on seed transmission are in progress. Seed transmission in Orlando tangelo seems to be extremely rare if it exists at all (*7*).

There seem to be no reports of studies or observations on insect transmission of xyloporosis. The possibility of insect transmission of cachexia has been considered in connection with transmission experiments in which numerous uninoculated check trees were present (*7*). No evidence of insect transmission of cachexia has been found in the experiments conducted to date.

DISCUSSION

It is generally recognized that citrus trees may harbor more than one virus, but it is not so widely recognized that a citrus tree with only one virus is a rare thing (*8*). Until a virus is obtained in pure culture, so to speak, it is impossible to be very certain about the cause of the various symptoms expressed. In the absence of pure cultures,

[2] Lilian Fraser; unpublished data.

there must be recourse to symptom comparisons and the safety of numbers, recognizing meanwhile the strong possibility of errors of interpretation.

In that light, xyloporosis and cachexia are discussed. That both are viruses seems scarcely worthy of contention. Certainly xyloporosis is not an instance of incompatibility, as Reichert and Perlberger's data (*23*) clearly showed. On the basis of symptom expression, both have similar host ranges. In Israel, xyloporosis symptoms were recognized on Palestine sweet lime, Florida sweet lime, mandarin, and possibly Nocatee tangelo. In Florida, buds from trees on xyloporosis-affected sweet lime rootstocks have induced cachexia symptoms when indexed on Orlando tangelo. In Florida and Texas, cachexia virus causes xyloporosis-like symptoms on many mandarin varieties, on many tangelo varieties, and on Florida, Columbian, Butwal, and Palestine varieties of sweet lime.

In Israel, xyloporosis symptoms were not found on grapefruit, lemon, sweet orange, or sour orange, if trees with little-leaf symptoms are excluded. In Florida and Texas, cachexia-virus-infected buds failed to induce symptoms when indexed on sweet orange, sour orange, lemon, and grapefruit, except for four unexplained cases on Leonardy grapefruit. On the basis of fruit characters there is reason to suspect that Leonardy is a hybrid and possibly a tangelo. Nevertheless, grapefruit is considered a symptomless carrier of cachexia in Florida and Texas. The similarity of host reactions to xyloporosis and to cachexia, as indicated above, probably constitutes the best evidence available that these two diseases result from the same virus cause.

There seems to be no good reason for relating little leaf to xyloporosis, other than the fact that they frequently occur in the same host. Association of the two is not reported from areas other than Israel, perhaps because of a paucity of observations. For purposes of clarification it is suggested that those two diseases be separated until indexing on suitable test plants indicates a common cause.

The cause of xyloporosis-like symptoms in sweet orange on sour orange rootstock, as reported by Nour-Eldin (*17*), is unknown. The fact that phloem discoloration was not found in sweet orange trees on sweet lime rootstocks, which often exhibit xyloporosis symptoms in Egypt, seems to indicate that the disease is not related to xyloporosis.

The prevalence of a bud-union disorder in sweet orange trees on Rough lemon rootstock in Florida gave rise to a report that this might be a symptom of cachexia infection in Rough lemon. However, when indexing had been completed on Orlando tangelo, the correlation of bud-union constriction with cachexia infection was inadequate. Also, a number of mature sweet orange trees on Rough lemon infected by cachexia virus had normal bud unions.

It seems generally agreed that there is little evidence relating tristeza (stunting and death of sweet orange on sour orange rootstock) to xyloporosis or to cachexia, and there is abundant evidence on which to separate them. The fact that Fraser's stem-pitting virus, which is insect-transmitted, causes pitting on grapefruit as well as on sweet lime seems to indicate its nonrelation to xyloporosis. Fraser also found that stem-pitting virus caused no wood pitting on Orlando tangelo; this could be construed as supporting evidence of their difference.

In Israel the evidence that xyloporosis virus is transmitted through the sweet lime seed is strong but circumstantial. The experimental evidence in Florida is less adequate than is desirable, and the experiments are being repeated. Nevertheless, the possibility of seed transmission can scarcely be ignored, because of its importance to any budwood certification program. At present there appears to be no evidence of insect transmission of xyloporosis or cachexia virus.

CONCLUSIONS

1) Xyloporosis, a disease first reported as affecting sweet lime trees in Israel, also affects Florida sweet lime, mandarin, and possibly Nocatee tangelo, but not sweet orange, sour orange, lemon, or grapefruit.

2) There is circumstantial evidence that the xyloporosis virus is transmitted through sweet lime seed in Israel, and experimental evidence indicative of its transmission through sweet lime seed in Florida.

3) Little-leaf disease has been confused with xyloporosis, but there is reason to believe that its cause is distinct from that of xyloporosis.

4) Cachexia, a xyloporosis-like disease, first reported on Orlando tangelo in Florida, affects mandarin and tangelo varieties and Palestine and Florida strains of sweet lime. It does not affect sweet orange, sour orange, lemon, or grapefruit, with the exception of the Leonardy variety, which may be a hybrid.

5) There is evidence that cachexia virus is rarely if ever transmitted through Orlando tangelo seed.

6) Bud-union constriction of Rough lemon rootstock with sweet orange top in Florida has been confused with cachexia, but there is reason to believe that the cause of this symptom is distinct from that of cachexia and xyloporosis.

7) The evidence in favor of the common identity of xyloporosis and cachexia rests largely on the close similarity of their host reactions. No differences in host reaction appear to exist if little-leaf (stubborn disease) symptoms are disregarded. There seems to be no good reason for relating little leaf to xyloporosis, and it is suggested that they be considered separate diseases until proved otherwise.

8) Complete proof of the identity of xyloporosis and cachexia must await indexing of xyloporosis-affected citrus, preferably sweet lime seedlings, upon Orlando tangelo seedlings in Israel, because Israel is the type locale of xyloporosis. It is an assumption that the cause of xyloporosis in other areas is the same as that in Israel.

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