

# Insects Associated with Papaya Virus Diseases in the Antilles and Florida

LUIS F. MARTORELL<sup>1</sup> and JOSE ADSUAR,<sup>2</sup> *Agr. Expt. Station Río Piedras, Puerto Rico*

Papaya (*Carica papaya* L.) is native to the American Tropics, its point of origin being as yet unknown. Facts tend to demonstrate that the southern part of Mexico is the original home of this fruit. Nowadays this plant is distributed throughout the tropical and semi-tropical areas of the World.

Botanically, *Carica papaya* L., is the type species of the Family Caricaceae, within the Order Passiflorales. According to Britton and Wilson, the family is composed of two genera: *Carica* and *Jacaratia*. *Carica* is native to the American Tropics and semi-tropics from Mexico to Paraguay, while *Jacaratia* occurs not only in America but also in Africa. According to Harms (1925) the Caricaceae is divided into four genera as follows:

- |                   |                        |
|-------------------|------------------------|
| 1. <i>Carica</i>  | 3. <i>Jacaratia</i>    |
| 2. <i>Mocinna</i> | 4. <i>Cylicomorpha</i> |

The first three genera belong to tropical America, particularly Mexico, and *Cylicomorpha* has its original habitat in Africa.

Within the past few years papaya cultivation has made a great progress among farmers in the Antilles and Florida, because of the versatile character of the fruit. Papaya is not only a source of food but has many uses in industries and in medicine. Wolfe & Lynch (1950) discussed the uses of papaya in a recent publication.

Papayas are good sources of vitamins A, B, C, G. The fruit can be used for salads, pies, jams, and preserves. The green fruit yields a digestive enzyme: papain, which is a commercial product. The latex of the fruit is used as meat tenderizer and the pulp as an ingredient for cosmetic products.

The Agricultural Experiment Station of the University of Puerto Rico has been interested in papaya culture for many years. Studies with this crop were initiated about 20 years ago. More interest was taken when the virus diseases were first observed in the field and became limiting factors for papaya production in the island.

HISTORY OF PAPAYA VIRUS DISEASES IN THE ANTILLES.—The first report of a virus disease in papaya was made by the

government microbiologist at Jamaica, Mr. F. E. V. Smith (1928–32). He reported as follows:

“Throughout the island, papaws are subject to a disease but this trouble is most noticeable on the Liguanea Plain. The plants are attacked at all ages, but more often the symptoms do not appear until the tree is about reaching the bearing stage. The terminal leaves as they emerge from the bud are yellow and frequently mottled while their size gradually becomes reduced until nothing but a pencil point is left. By the time this stage is reached the larger leaves hang down and gradual death is the result. Usually some adventitious buds lower on the stem start into growth, but the majority of these suffer the same fate, and strong growth is never regained. While root attack is suggested by the symptoms, it has not been possible to associate the symptoms with unhealthy root system and failure to find any organism in the tissues coupled with the mottling suggest that it is a virus disease. It has not been found that the disease is carried in the seed and other methods of transmission of a possible virus are being investigated.”

Smith (1932) in 1930 mentioned once more that this disease had been a limiting factor to commercial papaya growing in Jamaica. In the same year, 1930, Ciferri (1930) discovered a mosaic disease of papaya in the Dominican Republic. A year later, 1931, Cook (1931) reported another virus disease of papaya in Puerto Rico, the first report of a virus disease of papaya recorded from the Island. Cook wrote as follows:

“What appears to be a virus disease of *Carica papaya* L. attacked the plants in the Station grounds a few years ago but the gardener destroyed the plants before the writer could make a study of them. This or a similar disease was later described by Dr. R. Ciferri of Santo Domingo as ‘curly leaf’ but he was uncertain as to the cause. My histological studies indicate that it is a virus disease. The young leaves become more or less curled

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paya. In 6 months of constant work collecting insects from the lowlands to the highlands it was concluded that *Empoasca papayae* has a single host plant: *Carica papaya*. Collections of *Empoasca papayae* were made once at lights in Río Piedras. In 1950, the junior writer made a preliminary study (1950) on the host range of papaya mosaic in which 49 species of plants representing 21 families were tested. Of these, the wild cucumber or "pepinito," *Melothria guadalupensis* was found susceptible to the papaya mosaic virus. *Melothria* proved to be a symptomless carrier and the virus could not be recovered after 2 months. In 1950 Bird and Adsuar (1952), also cooperated in these investigations, particularly on the bunchy top. Bird's investigations can be summarized as follows:

"Previous studies gave indications as to the viral nature of papaya bunchy top, but the evidence was inconclusive. Evidence obtained in present studies through the use of the leafhopper, *Empoasca papayae* Oman, associated with the transmission of the disease, was limited by the inability to secure non-viruliferous insect stock cultures. A single leafhopper was capable of transmitting the viral agent. After feeding on healthy plants for a period of one day the disease appeared one and a half months later. Evidence that the causal agent is capable of reproducing within the host plant was demonstrated by transmission of the causal agent in series through one plant after another by grafting. Latex failure to flow, as determined by pricking, shortly follows penetration of downward spread. Affected plants can be cured by cutting back the stem below the infected portion."

Because of discrepancies in the reports of different investigators, particularly in the Antillean area, it was very difficult to ascertain which disease or diseases of papaya were present in the Antillean Islands. The symptoms described were rather confused and sometimes those of more importance in describing the disease were not discussed. Because of this difference in opinion the writers began a series of trips throughout the Antillean region including Florida. It was the purpose of this investigation not only to determine the status of the existing virus diseases of papaya in the Caribbean Area, but to

establish the relation of the possible insect vectors to the virus diseases under study.

STATUS OF THE VIRUS DISEASES OF PAPAYA AND THEIR INSECT VECTORS.—*Puerto Rico*.—Two virus diseases of papaya are known to occur in Puerto Rico. These will be referred to hereafter as: "bunchy top" and "papaya mosaic." Bunchy top virus is transmitted exclusively by the leafhopper *Empoasca papayae* Oman, while the papaya mosaic virus is transmitted by aphids or plant lice. The disease of papaya previously reported in literature (1946) as "die-back," is nothing but a form of bunchy top characterized by high virulence on susceptible papaya plants.

Bunchy top is the common papaya disease in Puerto Rico and is found everywhere in the island from the lowlands to the middle altitudes up to 2000 ft. high. Papaya mosaic is limited to a small area around the city of Ponce and the vicinity of Guánica. Why this disease is so limited in distribution is unknown. Both Ponce and Guánica are located on the south coast of Puerto Rico. The authors have never seen papaya mosaic in any areas other than the ones mentioned above.

*Empoasca papayae* Oman is the sole vector of bunchy top disease of papaya in Puerto Rico. The plant aphid, *Aphis spiraeicola* is one of the proven vectors of papaya mosaic in the Island. In preliminary tests the junior writer has transmitted the papaya mosaic by the use of the aphid: *Carolinaia cyperi* Ainslie, *Myzus persicae* Sulzer and *Toxoptera aurantii* Fonscolombe.

Surveys made in Puerto Rico collecting insects on papaya since 1945 to date have demonstrated that *Empoasca papayae* Oman is the only leafhopper breeding on papaya in the Island. Not even by chance have any other leafhoppers been found breeding on this plant. During the spring of 1947 and the winter of 1948 the following insects (Caldwell and Martorell 1950) were collected from weeds and grasses growing under the shade of papaya plantations:

*Cicadellidae:*

- Poeciloscarta laticeps* Metcalf & Bruner
- Hortensia similis* (Walker)
- Carniocephala sagittifera* (Uhler)
- Agallia albidula* (Uhler)
- Deltocephalus sonoratus* Ball
- Deltocephalus flavicosta* Sål
- Deltocephalus maculellus* Osborn

and in severe cases this curling persists throughout the life of the plant. The lower leaves become yellow and fall. One or both symptoms may appear on the plants. Sometimes all the older leaves fall, leaving a cluster or rosette of leaves at the apex. In severe cases the fruits are reduced in number and size."

These reports were followed by additional information on the Jamaica virus published by Edwards (1933), Larter (1934-38), and Martyn (1933-38).

Reports by Stell (1937) followed by those of Baker (1936), concerned the presence of a papaya virus ravaging the papaya plantations of Trinidad.

In 1940, Acuña & Zayas (1940) described two papaya diseases in Cuba, both apparently caused by a virus. Reports on papaya diseases have been recorded from different parts of the World by many investigators, however, we shall discuss only the status of these diseases in the Antilles and Florida.

**PAPAYA VIRUS DISEASE INVESTIGATIONS IN PUERTO RICO.**—After Cook's first report on the presence of a virus disease of papaya in Puerto Rico during 1931 no immediate attempt was made to study the disease.

Jensen (1949) in 1937 and 1938, while working at the Puerto Rico Agricultural Experiment Station at Mayagüez, studied the "bunchy top" disease, described its symptoms, and made unsuccessful attempts to transmit the virus by mechanical means, budding and grafting. Tests to transmit the disease by means of the lacewing bug, *Corythucha gossypii* (L.), the stink bug, *Nezara viridula* (L.), the leafhoppers, *Agalliopsis pepino* (DeLong & Wolcott), and *Nesosteles incisa* (Matsumura) did not succeed. Jensen found a new species of leafhopper breeding on papaya, later named by Oman (1937) *Empoasca papayae*. Although Jensen worked with this leafhopper, his experiments were never completed and did not establish the relationship between the insect and the virus.

Alvarez (1941) initiated studies on the papaya virus diseases in 1940. He reported the following:

"Experiments were conducted in an attempt to transmit the disease mechanically and with the aid of possible insect vectors. The possibility of the disease being seed borne was considered. Several

imported varieties of papayas were tested for resistance."

"During the last few years the papaya growing enterprise in Puerto Rico suffered to a considerable extent of the mosaic disease. This disease is considered a limiting factor in production has been impossible to determine the nature of the malady. All attempts to transmit the disease have been unsuccessful. Inoculated and check plants as well as trees grown from diseased fruit seed remained symptomless while in the laboratory. However, these plants became infected when taken to the field. The possibility of an insect vector is apparent. Papayas brought from Panama, Honduras, and Guatemala were found to be as susceptible as our varieties."

Simultaneously with these first investigations Cook & Asenjo (1941) were studying the chemistry of virus-infested papaya plants as well as the relations between total content of protein and papain in papaya. For some reason these investigations were not continued until 1945, when the junior writer initiated a new project to study the virus diseases of papaya in Puerto Rico.

In 1945, Adsuar (1950) was working simultaneously with bunchy top and papaya mosaic. He described the mosaic and verified its transmission by the green citrus aphid, *Aphis spiraeicola* Patch. In 1946, Adsuar (1946-1950) found that *Empoasca papayae* was the insect vector responsible for the transmission of the bunchy top virus. In 1947, Sein (1947) confirmed this. At the same time the writers (Adsuar & Martorell 1950) were investigating the control of *Empoasca papayae* as well as of *Aphis spiraeicola*. It was demonstrated that the *Empoasca papayae* is easily controlled by the application of Agricultural Grade DDT to papaya plantations every 15 or 20 days, starting with the first spraying on the papaya seedbed and continuing this spraying on schedule for the entire life of the trees. Experiments to control aphids responsible for the transmission of the mosaic by the use of modern insecticides including DDT, BHC and toxaphene gave negative results. During the autumn of 1947 and the winter of 1948, J. S. Caldwell & Martorell (1950) made a survey in Puerto Rico and nearby Islands to determine whether *Empoasca papayae* had a plant host other than P.

*Sanctanus fasciatus* (Osborn)  
*Graminella colonus* (Uhler)  
*Chlorolettix tethys* Van Duzee  
*Chlorolettix minimus* Baker  
*Macrosteles divisus* Uhler  
*Dikraneura delicata* Osborn  
*Typhocybella minima* Baker  
*Empoasca plebeia* DeLong and Davidson

*Fulgoridae:*

*Bothriocera undata* (Fabricius)  
*Delphacodes propinqua* (Fieber)  
*Delphacodes vaccina* Caldwell  
*Melorminis antillarum* (Kirkaldy)

It is interesting to note that, although breeding abundantly on the underbrush in papaya plantations, these insects were never collected on papaya foliage, not even while resting there. The only insects except *Empoasca papayae*, that have been collected on papaya foliage in Puerto Rico, though they were never found breeding on the papaya themselves, are: The leafhopper *Poeciloscarta laticeps* Metcalf and Bruner, and the fulgorids, *Oliarus complectus* Ball and *Omolicna puertana* Caldwell.<sup>1</sup> *O. puertana* is the most common fulgorid found on papaya in Puerto Rico. Whether it breeds there has never been verified.

In October 1946, Martorell & Francisco Seín visited Vieques Island and made a thorough survey of the insects affecting papaya there. During a 4-day survey only the leafhopper *Empoasca insularis* Oman was collected. No virus disease of papaya was found in Vieques Island. Papayas were perfectly healthy except for a serious outbreak of the disease known as *phytophthora* rot, which ravaged the papaya plants during that time.

Vieques Island was visited once more by Martorell and Caldwell and a thorough search was made from October 22 to 25, 1947. The only insects collected on papaya foliage at that time were: The fulgorids *Oliarus complectus* Ball and *Sanctanus fasciatus* Osborn and one male adult of the leafhopper, *Empoasca canavalia* DeLong, which was collected from a small plant in a papaya seedbed. At this time no virus disease of papaya was seen in this locality.

*Virgin Islands.*—During December 16 to 19, 1946, the writers visited the islands of St. Thomas and St. Croix and collected extensively throughout them. No virus disease of papaya was recorded during this survey. The only insects collected from papaya foliage in St. Thomas were the following:

*Empoasca fabae* (Harris)

*Empoasca dilitara* DeLong & Davidson  
*Empoasca* sp.  
*Dikraneura* sp.  
*Ormenis quadripunctata* (Fabricius)  
*Aphis spiraeicola* Patch

Only one species of *Empoasca*, apparently a new one, was found breeding in the Island of St. Croix. The senior writer once more visited St. Thomas on June 1949, and later on during September 1951. The status of the papaya diseases in this Island remained the same: No virus disease of papaya was present.

*Santo Domingo.*—On September 1950, the senior writer visited the Dominican Republic, staying at San Pedro de Macorís through the kind hospitality of Mr. Jorge Serrallés. The writer had an opportunity to make a 3-day survey on papaya plantations around San Pedro de Macorís and vicinity. In Hacienda Las Cabullas, on the property of Mr. Serrallés, 60 per cent of the papaya plants in a 2 acre plantation were infested by bunchy top disease. Leafhoppers were breeding profusely on papaya trees and, after collection and identification, were found to be the common *Empoasca papayae* Oman. No mosaic disease was noted in the area at this time.

During November 1950 the writers once more visited the Dominican Republic and made a thorough survey around Ciudad Trujillo, Villa Duarte, Boca Chica, Haina, and San Cristobal. Leafhoppers were collected in all this area. Every single specimen was identified as *Empoasca papayae* Oman. The only disease present in this area was bunchy top showing exactly the same symptoms as the bunchy top found in Puerto Rico.

*Haiti.*—The trip was continued to Port-Au-Prince, Haiti. A survey was made around papaya plantations in the vicinity of Port-Au-Prince, Damien, Petionville, Tcholand, Leogane, Grand-Goave and Petit-Goave. The only insect found breeding on papaya during this survey was the leafhopper, *Empoasca papayae*. The only virus disease of papaya observed in Haiti, was bunchy top.

*Cuba.*—From Haiti the authors went to Camaguey, Cuba, on November 18, 1950. Around the Camaguey airport and in the city of Camaguey proper leafhoppers were collected from papayas and at the same time, the presence of the bunchy top disease was observed. The leafhoppers

were the common *Empoasca papayae*. Later in the afternoon the writers went to Havana, Cuba. On Monday, November 20 the Experimental Agronomic Station at Santiago de las Vegas was visited. During the trip a very large papaya plantation of around 30 acres was visited, (Hacienda Bijirita) and proved to be 100 per cent infested by the papaya mosaic. Leafhoppers, were collected there, while breeding abundantly on the papaya trees. They were identified as *Empoasca dilitara*. During this stay collections were made at Santiago de las Vegas, Bauta, Artemisa, Baracoa, Guanajay, and Porvenir. Except for Hacienda La Bijirita, where the papaya mosaic was very abundant, only the papaya bunchy top was observed. Leafhoppers collected at Baracoa and Bauta and the other localities mentioned above were identified as *Empoasca papayae*. These collections were made from bunchy top-diseased trees as well as from healthy trees near diseased ones. During October 1949 the senior writer had visited Cuba previously and collected leafhoppers from papaya at Guanabacoa near Havana. These were identified as *Empoasca papayae* and *Empoasca dilitara*. The insects were collected from apparently healthy trees. Bunchy top was noticed at Guanabacoa, but no leafhoppers were breeding on those trees at that time. No mosaic was observed in this area, although Guanabacoa is close to El Cotorro where the mosaic disease of papaya was reported for first time in Cuba. *Empoasca fabae* (Harris) had been reported by Bruner *et al.* (1945), and later by Acuña & Zayas (1939-40), as breeding on *Carica papaya* in Cuba. The authors did not find this species breeding on papaya in collections in Cuba. Although this is the most common species of leafhopper in Puerto Rico, and has been recorded from 15 or 20 host plants, it has not been found on papaya foliage in the Island during 6 years of constant search for papaya insects.

The work of Acuña & Zayas (1946) is among the best published in the Antilles regarding the papaya virus diseases. The authors knew very well indeed the difference between the papaya mosaic and our common bunchy top. They called the bunchy top, mosaic of the Type "A," and our common mosaic was identified by them under the name "Mosaico del Co-

scriptions of the diseases in this work are very accurate and the present writers consider this publication as basic on papaya virus diseases. However, at that time the vectors of these diseases were not determined and Acuña & Zayas apparently were not sure of the identity of the vectors of these virus diseases.

*Florida.*—From Cuba the authors continued to Florida and between November 23 and 27, made a survey around Miami and vicinity, Homestead, Hollywood, West Palm Beach, and Vero Beach. Leafhoppers were collected from papaya trees in Miami University Campus, Miami, and Hollywood. These were identified as *Empoasca dilitara* DeLong and Davidson. Aphids were abundant on papaya throughout the area. Collections were made in the above-mentioned places and the aphids were identified as: *Aphis spiraeicola* Patch, *Aphis gossypii* Glover and *Rhopalosiphum prunifoliae* (Fieber).

The only disease of papaya observed in Florida was the common papaya mosaic. No bunchy top was observed in the localities visited. Near West Palm Beach a leafhopper was collected from a tree showing symptoms like bunchy top, but not quite typical of the disease. The insect was identified as *Idona* sp.

*Empoasca papayae* has never been recorded from Florida. Poos & Wheeler (1943) have recorded *Empoasca plebeia* DeLong & Davidson<sup>1</sup> and *Empoasca dilitara* DeLong & Davidson from nymphs collected from papaya foliage in Florida. *Empoasca solana* DeLong and *Empoasca fabae* (Harris) were also recorded from papaya foliage, but the origin of the papaya plants is not mentioned by the authors.

Dr. John S. Caldwell, Circleville, Ohio, reported *Empoasca dilitara* from papaya growing spontaneously along the shores on Boca Chica Key, Vaca Key, and Grassy Key. All these collections were made in the Florida Keys during January and February, 1951. *Empoasca plebeia* was also collected on papaya at Vaca Key. No papaya mosaic was recorded by Dr. Caldwell while collecting throughout the Keys at that time.

*Jamaica, B.W.I.*—During December 1951, the senior author accompanied by Mr. Julio Bird, made a 3-day survey on

<sup>1</sup> For the original description of *Empoasca plebeia dilitara*,

Jamaica to investigate the status of the virus diseases of papaya in that territory. The southern coast of Jamaica from Port Royal, Kingston, Hope, Spanish Town, Indian Village, Old Harbor, Porus, and Mandeville was studied and collections of leafhopper were made at different places. This trip was made possible by the courtesy of Mr. Robert Buhrer, General Manager of Shell Co., West Indies Ltd. of Jamaica. We were accompanied by Mr. Michael Fawcus, in Charge of Agricultural Products of the Shell Co. Bunchy top was the only virus disease of papaya observed under study. All the leafhopper material collected at the different localities visited was identified by Dr. David Young of the U. S. National Museum, as *Empoasca papayae* Oman.

We noticed a scarcity of papaya trees on the area surveyed. No doubt bunchy top has considerably diminished papaya growing in this area of Jamaica. Only one winged aphid specimen was collected during our survey. This was at the Mandeville Hotel. The insect was identified as *Aphis spiraeicola* Patch, by Miss Louise

Russell of the U. S. National Museum.

CONCLUSIONS AND SUMMARY.—The bunchy top disease of papaya is found wherever its insect vector, *Empoasca papayae*, occurs: Puerto Rico, Santo Domingo, Haiti, Jamaica and Cuba. The Virgin Islands (St. Thomas and St. Croix), Vieques, and Florida, are so far free from this disease.

The role of *Empoasca dilitara* as a vector of the bunchy top should be studied in Cuba, since it occurs there in combination with *E. papayae*. *E. dilitara* is common in Puerto Rico, but has never been collected from papaya.

Papaya mosaic is found in Puerto Rico, Cuba, and Florida. This disease is transmitted by various species of plant aphids. The symptoms of the disease are similar in all the areas studied, but whether the same virus occurs in all three places must be determined by further investigations. *Aphis spiraeicola* Patch is a potent vector of the papaya mosaic in Puerto Rico. The role of the aphids found in papaya in Cuba and Florida should be further investigated.

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## Continuous Vaporization of Insecticides with Special Reference to DDT

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Vaporization of insecticides by heat has been employed since insecticide-bearing materials such as ground pyrethrum flowers or tobacco juice were placed on fires or hot surfaces. Later, heaters were developed for the vaporization of such materials as naphthalene for control of greenhouse red spiders. Such methods were used intermittently and each treatment was of relatively short duration. One of the war-born devices for producing screening smokes for military purposes was adapted for civilian use and is now called the thermal aerosol fog generator. It is especially useful for space fogging open areas for the control of flying insects (Glasgow 1948). This process, too, is employed intermittently and makes the

atmosphere lethal to insects for comparatively short periods of time. During World War II, English workers developed a technique for continuously dispersing bactericides by heat. Subsequently, DDT and certain other newer insecticides were found capable of continuous vaporization by heat. Beginning in 1947 investigations have been conducted at the University of Massachusetts on both fundamental and practical aspects of production and use of continuously vaporized insecticides. Toxicity studies regarding vaporized DDT were conducted at other laboratories.

VAPORIZATION RATES AND THEIR CONTROL.—Vaporizers are marketed for insect control in stores, theaters, restau-