THE JOURNAL OF AGRICULTURE
OF THE UNIVERSITY OF PUERTO RICO

Issued quarterly by the Agricultural Experiment Station of the University of Puerto Rico, for the publication of articles by members of its personnel, or others, dealing with any of the more technical aspects of scientific agriculture in Puerto Rico or the Caribbean Area.

Vol. LIII January 1969 No. 1

Aphid Vectors of the Papaya Mosaic Viruses in Puerto Rico

George A. Schaefers[1]

INTRODUCTION

A limiting factor in the successful cultivation of papaya (*Carica papaya* L.) in Puerto Rico and elsewhere is the occurrence of virus diseases. One or more virus diseases occur wherever this valuable fruit crop is grown. The subject of papaya viruses has been well reviewed by Jensen (*12*)[2]. Recent papers of pertinent interest include those of Capoor and Varma (*6*), Conover (*7*), Isshii and Holtzmann (*10*), Ivancheva Gabrovska, *et al.* (*11*), Martorell and Adsuar (*15*), Namba and Kawanishi (*16*), and Pontis Videla (*18*).

At present, the papaya virus diseases in Puerto Rico may be divided into two classes. These include (*Empoasca papayae* (Oman)), the leafhopper-transmitted "bunchy top" (*5*), and the aphid-transmitted mosaic viruses. This paper is concerned only with the aphid-transmitted viruses.

In 1946, Adsuar (*2*) reported the occurrence of a typical mosaic virus disease of papaya which was restricted to a small area on the South Coast of Puerto Rico. Since then, the disease has been observed elsewhere on the Island. According to Adsuar, this mechanically transmissable virus is characterized by stunting, reduction in size of internodes, leaves, and petioles, oily spots on stems and petioles, marked mottling and distortion of the leaves, free flow of latex, and dark-green to brown rings on the fruits. Laboratory-inoculated plants first developed a slight chlorosis of the top leaves. This was followed by mottling, wrinkling, puckering, and a light yellowing of the veins. Later, green spots appeared on the stems, and the leaves became filiform in structure. The latter is the most characteristic

[1] Associate Professor of Entomology, N.Y.S. Agricultural Experiment Station, Geneva, N.Y. Visiting Scientist, Agricultural Experiment Station, Mayagüez Campus, University of Puerto Rico, Río Piedras, P.R. (Oct. 1, 1967 through Mar. 31, 1968).

The author wishes to thank Director Arturo Roque, Dr. L. F. Martorell, Dr. J. Bird, and Mr. J. Adsuar for their most friendly cooperation, and for affording him the opportunity to visit the Agricultural Experiment Station at Río Piedras.

[2] Italic numbers in parentheses refer to Literature Cited, pp. 12–3.

and unique symptom of this disease. In many cases the lamina completely disappears and only a few stringlike "veins" remain (fig. 1). As noted by Adsuar (*2*), however, the distortion of the leaves in the field is not so severe as observed under laboratory conditions. Of the virus diseases of papaya reported in the literature, this disease appears identical with "Mosaico" in Venezuela (*18*), "Distortion Ringspot" in Florida (*7*), and "Tipo B Mosaico del Cotorro" in Cuba (*1*, *11*). For the purposes of this paper, this disease will be referred to as "Distortion Mosaic" or simply designated "DM".

More recently, Adsuar (unpublished) observed a second "mosaic type" of virus disease attacking papaya in Puerto Rico. The symptoms of this,

FIG.—1. Papaya seedling showing narrowing of lamina and severe distortion as caused by distortion mosaic virus. (Photo by Dr. J. Eird).

apparently related disease, resemble very closely those of "Distortion Mosaic." It is a more mild form of mosaic and it is distinguished from DM chiefly by the absence of severe leaf distortion. Symptoms are somewhat variable in inoculated plants. In some cases a slight narrowing of the lamina occurs with only a faint chlorosis, and a scattering of small dark-green islands over the surface of the leaf. More generally, in young leaves a scattering of chlorotic or clear spots appears. Later still these leaves show more extensive chlorotic areas extending along the veins (fig. 2). Finally, these form a general diffuse mosaic pattern. This disease resembles most closely "Papaya Mosaic" in Hawaii (*10*), Bombay Mosaic (*6*), and "Faint Mottle Ringspot" in Florida (*7*). For the purposes of this paper, this disease will be referred to as "Papaya Mosaic", or simply by the designation "PM".

A number of studies have been conducted on the aphid species respon-

sible for the transmission of papaya virus diseases. The aims of the present study were to support earlier findings on the vectors of DM, to investigate a number of additional potential vectors of this disease, to determine whether PM in Puerto Rico is also aphid-transmitted, to investigate potential aphid vectors of this disease, and to obtain a measure of virus-vector specificity involved in both viruses.

REVIEW OF PREVIOUS VECTOR STUDIES

Adsuar (*3*), in 1946, reported the transmission of DM in Puerto Rico by the green citrus aphid, *Aphis spiraecola* Patch. Later (*4*) he noted that the

FIG. 2.—Papaya leaf from plant infected with papaya mosaic virus (Photo by Dr. J. Bird).

virus was acquired in 15 minutes or less, and was not transmitted during a second 3-hour inoculation feeding. Following preliminary tests in 1952 (*15*), he reported transmission of the same virus with *Myzus persicae* (Sulzer), *Toxoptera aurantiae* (Boyer de Fonscolombe), and *Carolinaia cyperi* Ainslie. Pontis Videla (*18*), in Venezuela, obtained very good transmissions of a similar disease with *A. spiraecola*, *M. persicae*, and *Aphis gossypii* Glover. Conover (*7*), in Florida, transmitted "Distortion Ringspot" with *M. persicae*. Ivancheva Gabrovska *et al.* (*11*), in Cuba, reported the transmission of "mosaico" with *A. gossypii*, *Aphis craccivora* Koch, *Aphis illinoisensis* Shimmer, *Aphis nerii* Boyer de Fonscolombe, *A. spiraicola*, *M. persicae*, *Rhodobium porosum* (Sanderson), *Rhopalosiphum maidis* (Fitch), and *Acyrtosiphum pisum* (Harris). They concluded that

A. gossypii was the major summer vector, and that *M. persicae* was the major winter vector.

With reference to those diseases resembling Papaya Mosaic of Puerto Rico, Capoor, and Varma (*6*) transmitted Bombay Mosaic with *M. persicae*, *A. gossypii*, *Aphis malvae* Koch, and *A. craccivora* (as *medicaginis*). They reported weak transmission with *Macrosiphum sonchi* Linnaeus and an *Aphis* species from *Euphorbia hirta* L. Negative results were obtained by the above workers with *Pentalonia nigronervosa* Coquerel, *A. nerii*, and *Toxoptera citricidus* Kirk. Conover (*7*) reported that "Faint-Mottle Ringspot" was transmitted by *M. persicae*, but "Mild Mosaic" was not. Namba and Kawanishi (*16*) transmitted "Papaya Mosaic" in Hawaii with *M. persicae*. In their tests, the virus was acquired in 10 to 30 seconds.

According to Ishii and Holtzmann (*10*), Hawaiian "ringspot" of papaya is a virus distinct from Hawaiian "Papaya Mosaic". Jensen (*13*) obtained positive transmission of "Ringspot" with, *M. persicae*, *A. gossypii*, *A. craccivora*, *Aphis rumicis* L., *Macrosiphum euphorbiae* (Thomas (as *solanifolii*), and *Micromyzus formosanus* (Tak.). He used large numbers of aphids and found that the virus was acquired within 2 minutes, and was not retained for inoculation of a second test plant in series. Additional species tested which failed to transmit the disease were, *Hyperomyzus lactucae* (L.) (as *Amphorophora sonchi* (Oestlund), *Lipaphis* (as *Rhopalosiphum*) *pseudobrassicae* (Davis) and *R.* (as *Aphis*) *maidis*.

Transmission of the "Waialua" disease (*17*), in Hawaii, was investigated by Holdaway and Look (*8*). No transmission occurred with *M. persicae*, *M. euphorbiae* (Thomas) (as *gei* (Koch)), *A. gossypii*, *A. craccivora*, or *R. maidis*.

Reports on the occurrence of aphids on papaya would appear to be of pertinent interest, particularly with regards to the feasibility of disease control through vector control. The author has collected mature alatae on papaya with some frequency and, on two occasions, has observed a few early instar nymphs in proximity. The species collected included; *A. spiraecola*, *A. gossypii*, *A. nerii*, and *Aphis coreopsidis* (Thomas)[3], with *A. spiraecola* being by far the most commonly collected species. Successful colonization of papaya by any aphid species in Puerto Rico has not been observed by the author, however. Capoor and Varma (*6*) noted the absence of aphids on papaya in Bombay Province, India. Further, papaya has been reported to be a poor host plant for aphids in Cuba, although mature alatae of several species frequently have been observed on that host. The species observed included: *A. gossypii*, *M. persicae*, *M. euphorbiae*, *A. craccivora*, *R. maidis*, *A. spiraecola*, *T. aurantiae*, *Dactynotus ambrosiae* (Thomas),

[3] Determined by Dr. C.F. Smith, Dept. Entomology, University of North Carolina, Raleigh, N.C.

and a *Protaphis* species. *Myzus persicae* often reaches damaging proportions on papaya in Hawaii (*9,13,14,19*), but reports on the presence of this species on papaya in Puerto Rico (*22,24*) require further confirmation. In particular, information is needed on the degree of colonization. *Aphis spiraecola* has been reported to occur on papaya in Puerto Rico (*3,24,25*) and in abundance on this host in Florida (*15*). *Aphis gossypii* is of common occurrence on papaya in Hawaii (*9,13,14,19*) as well as Florida (*15*), but has not been observed to colonize this host in Puerto Rico. The species *Rhopalosiphum fitchii* (Sanderson) (as *prunifoliae*) has been observed to occur in abundance on papaya in Florida (*15*). Look and McAfee (*14*) reported the collection of two additional species from papaya in Hawaii. These included; *Aphis middletonii* Thomas, and *Aulacorthum* (as *Myzus*) *circumflexus* (Buckton).

MATERIALS AND METHODS

The virus source material used in the tests consisted of papaya seedlings infected with DM, or "Papaya Mosaic." Two varieties were used. These consisted of the highly susceptible Solo variety and a native selection designated as S-1 or P.R. 6-65 (*20*). The latter variety has expressed some field resistance to bunchy-top virus and, to a slight degree, to DM (*21*). The source materials were maintained in the greenhouse by Mr. José Adsuar, and the viruses originated from plant material collected in the Ponce and Isabela areas. Because the viruses were maintained by means of sap transmission, isolation of the DM and PM viruses was not reliably complete in all source plants used. Thus, reference to the source plant used throughout the text merely indicates the definitive symptoms expressed by the plant, and not necessarily its sole virus content. The specific virus source material presented to the aphids consisted of the youngest leaf showing symptoms. In each case, the leaf was detached immediately before the test and placed on a piece of moist filter paper in a petri dish. Although plants inoculated several months earlier were used in a number of the early tests, the material used in most cases ranged in age from 3 to 8 weeks.

All of the aphid material used was field collected from host plants other than papaya. A colony of *M. persicae* was maintained on cabbage in the greenhouse. Responsibility for the determination of the aphid species used rests with the author and was based on information concerning the host plant relationships and descriptive material provided primarily by Smith *et al.* (*23*). To prevent the incorporation of alien species in the tests, each aphid used was individually examined under the binocular microscope. Wherever possible, the aphid morph used consisted of the adult apterous viviparae.

Because of availability, the test plants used were of the P.R. 6-65 vari-

ety. The plants were grown from seed in the greenhouse and were maintained under additional screen protection. The plants used ranged in size from 5 to 14 inches in height, although plants of the same age and approximate size were used in each single test.

Aphid transfers were made with a camel's-hair brush and the tests were conducted in a laboratory isolated from other plant material. In two tests, the aphids were given individually timed acquisition feeds of 1 minute or less. In the remaining tests they were given group access to feeds for 5, 30, or 60 minutes. Where 1- or 5-minute access feeds were utilized, the aphids were given a 1- to 2-hour preacquisition starvation period in an empty vial. The aphids were placed directly on the detached leaf and those observed to wander off were returned to the leaf. Following acquisition, the aphids were transferred to healthy test plants and provided minimum inoculation feeds of 1 hour. Five or ten test plants were used in each test. The number of aphids per test plant, among the various tests, ranged from 5 to 50 per plant, 10 being the most frequently used number. After removal of the aphids, the plants were transferred to fine-mesh screen cages in the screenhouse and held until definitive symptoms developed. At least 1 check plant was used in each test. In some cases, the aphids were transferred from the host plant to the check plant and held for 2 to 3 hours. The aphids were then removed and used in the transmission tests. In most cases, however, a minimum of 15 aphids were transferred to a check-plant while a second subsample was used in the transmission study.

RESULTS AND DISCUSSION

The results obtained from the virus-transmission tests with various aphid species are summarized in table 1. The DM or PM viruses listed under "Virus source" refer to the definitive symptoms exhibited by the virus-source plant. "Age in weeks" indicates the approximate time since inoculation of the source plant. Under "Aphids/plant" are listed the numbers of aphids used per test plant. With two exceptions, as will be noted later, "Access feed" refers to the time that the aphids remained on the source leaf. The *dashes* listed under "# Test plants showing" indicate that the source plant used probably did not contain that particular virus.

Test insects of the species, *A. craccivora*, were collected from cowpea, *Vigna sinensis* L., for use in test No. 5, while those for tests Nos. 14 and 28 were collected from *Gliricidia sepium* (Jacq.). No transmission resulted from tests utilizing two different DM sources and three different PM sources. The results are somewhat unexpected, since Jensen (*13*) transmitted Hawaiian Ringspot to 19 to 42 test plants with 100 to 150 aphids per plant, using this species (as *A. medicaginis*). Similarly, Bombay Mosaic has been transmitted to 3 to 14 plants using 30 to 50 aphids per plant (*6*).

TABLE 1.—*Transmission of Distortion Mosaic and Papaya Mosaic by various aphid species in Puerto Rico*

Aphid Species	Test No.	Virus source	Age in weeks	Aphids/ plant	Access feed	Number of test plants	Number of test plants showing	
							DM	PM
Aphis craccivora Koch	14 II	DM	14	10	30 min.	5	0	—
	28 II	DM	7	25	5	5	0	—
	5	PM	32	5	60	5	—	0
	14 I	PM	3	11	30	5	—	0
	28 I	PM	10	25	5	5	—	0
Aphis nerii B. de F.	17	DM	36	20	30	5	0	—
	31 I	DM	4	10	5	5	2	—
	34 I	DM	3	10	5	5	3	—
	1	PM	28	5	60	5	—	0
	31 II	PM	4	10	5	5	—	1
	34 II	PM	3	10	5	5	—	2
Aphis gossypii Glover	6 II	DM	10	5	60	5	1	—
	16 II	DM	16	15	60	5	0	—
	6 I	PM	32	5	60	5	—	1
	6 III	PM	32	8	30	5	—	0
	8	PM	32	6	30	5	—	0
	16 I	PM	4	15	60	5	—	1
	16 III	PM (Sq.)	3	5	30	10	—	1
	16 IV	PM	4	10	30	5	—	0
	16 V	PM	4	15	180	5	—	0
Aphis illinoisensis Shimmer	11	PM	3	15	30	5	—	0
Aphis spiraecola Patch	13 II	DM	14	5	30	5	0	—
	20 I	DM	4	45–50	60	5	0	—
	20 II	DM	4	45–50	60	5	0	—
	20 III	DM	4	5	1 (or less)	10	0	1
	22[1]	DM	20	10	30	5	0	—
	29[1]	DM	4	10	5	5	0	—
	29[1]	DM	4	10 (Alate)	5	1	0	—
	32[1]	DM	5	10	5	5	1	—
	3	PM	28	5	60	5	—	0
	9	PM	32	9	30	5	—	0
	10	PM	2	5	30	10	—	0
	13 I	PM	34	5	30	5	—	0
	23[1]	PM	8	10	5	5	—	0
	30[1]	PM	4	10	5	5	—	0

TABLE 1.—*Continued*

Aphid Species	Test No.	Virus source	Age in weeks	Aphids/ plant	Access feed	# Test plants	# Test plants showing	
							DM	PM
Carolinaia cyperi Ainslie	21 I	DM	4	10	5	5	3	—
	21 II	DM	4	10	5	5	2	—
Dactynotus ambrosiae (Thomas)	26 I	DM	8	10	5	5	4	—
	26 II	PM	10	10	5	5	—	0
Hyperomyzus lactucae (L.)	27 I	DM	3	10	5	5	0	—
	27 II	PM	4	10	5	5	—	0
Myzus persicae (Sulzer)	19 II	DM	3	6	30	5	0	—
	19 III	DM	3	7	30	5	2	—
	19 IV	DM	3	5	1 (or less)	10	5	—
	19 V	DM	3	10	5	10	10	—
	21 III	DM	8	32	5	2	2	—
	22[1]	DM	20	10	5	5	0	—
	29[1]	DM	4	10	5	5	0	—
	32[1]	DM	5	10	5	5	5	—
	19 I	PM	4	20–25	30	5	—	4
	19 VI	PM	42	10	5	5	—	0
	23[1]	PM	8	10	5	5	—	2
	24	PM (*Luffa*)	10	10	5	5	—	2
	30[1]	PM	4	10	5	5	—	4
Rhopalosiphum maidis (L.)	15 II	DM	17	13	30	5	0	—
	15 I	PM	4	12	30	5	—	0
Rhopalosiphum nymphaeae (L.)	12	PM	3	12	30	5	—	0
Sipha flava (Forbes)	2	PM	30	5	60	5	—	0
Toxoptera aurantiae (B. de F.)	18 II	DM	30	15	45	5	0	—
	33 I	DM	3	10	5	5	0	—
	4	PM	30	5	60	5	—	0
	18 I	PM	16	14	30	5	—	0
	33 II	PM	3	10	5	5	—	0

[1] Same virus source leaf used for both *A. spiraecola* and *M. persicae* in tests with comparable numbers.

In the report from Cuba (*11*), however, only 1 out of 35 test plants was inoculated by this species.

A. nerii, used in test No. 1, were collected from *Calotropis procera* (Ait.), while those used in tests Nos. 17, 31, and 34 were collected from *Nerium oleander* L. Eight of the thirty test plants used became infected. These included 5 DM and 3 PM transmissions. Negative results were obtained with this species when investigated as a potential vector of Bombay mosaic (*6*), but almost 50-percent transmission was obtained with this species in Cuba (11).

A. gossypii has been found to be a fairly efficient vector of both the DM (*11,18*) and PM (*6*) type viruses. The aphids used for test No. 8 were collected from *Ixora macrothrysa* Teijsm and Binn., while those for the remaining tests were collected from *Gossypium hirsutum* L. The DM virus was transmitted to 1 to 10 test plants while the PM virus was transmitted to 3 to 40 test plants. In test No. 16 III, the source plant consisted of "Early Prolific Straight-Necked Squash". The age of the source-plants and prolonged access feeds may have contributed to the low efficiency of transmission obtained in our tests.

A single test was conducted using *A. illinoisensis* collected from *Vitis vinifera* L. The virus source contained PM virus. Fifteen aphids were transferred to each of five test-plants. No evidence of transmission was noted. Ivancheva Gabrovska *et al.* (*11*) transmitted "Mosaico" to 2 out of 20 test plants with this species. They provided no information as to methods used, however.

Numerous tests were conducted with the green citrus aphid, *A. spiraecola*. The insects used in test Nos. 3, 20, 22, and 23 were collected from various *Citrus* species, while those from the remaining tests were collected from *I. macrothrysa*. In all, nearly 1,000 aphids were transferred to 76 test plants. Transmission of PM virus occurred in only a single case (Test 20 III). In this instance, the virus was acquired and transmitted from a source-plant which exhibited DM symptoms. The transmission occurred when five aphids were observed individually under the microscope and permitted a single probe with a maximum of 60 seconds in the source plant. Transmission of DM occurred in 0 to 45 test plants. Adsuar (*3*) and Pontis Videla (*18*) have reported this species to be a fairly efficient vector of the DM-type virus. Investigators in Cuba (*11*) were able to transmit to 3 out of 46 test plants with this species.

Two tests were conducted using *C. cyperi* collected from nutgrass, *Cyperus rotundus* L. The virus source-plants used exhibited DM symptoms. Of 10 test plants which received 10 aphids each, 5 showed evidence of transmission. This species appears to be a fairly efficient vector and has previously been reported as a vector of this virus by Adsuar (*15*).

The species *D. ambrosiae*, which occurs on many different host-plant

species in Puerto Rico (*23*), was collected from *Bidens pilosa* L. Of 5 test plants which received aphids from a DM source, 4 showed evidence of transmission. Negative results occurred with the PM source-plant. This species has not previously been reported as a vector of papaya viruses.

H. lactucae, collected from *Sonchus oleraceus* L., yielded negative results when tested as a vector of both the DM and PM viruses. Jensen (*13*) tested this species (as *Amphorophora sonchi*) for the transmission of Ringspot in Hawaii and obtained similarly negative results.

The green peach aphid, *M. persicae*, has been shown to be an important vector in all reported studies where aphids were found to transmit a virus disease of papaya (*6,7,11,13,15,16,18*). On the basis of the present tests, it appears to be one of the most efficient vectors of both the DM and PM viruses in Puerto Rico. Of the 72 test plants used, 36 became infected. As indicated in test No. 19 IV, the DM virus is acquired in less than 60 seconds. In one instance, the maximum feeding time recorded for any of the 5 aphids used was 30 seconds. Five tests were designed to provide a direct comparison in transmission efficiency between the species *M. persicae* and *A. spiraecola*. These included tests Nos. 22, 23, 29, 30, and 32. In each case the same source leaflet was used for both aphid species. Neither acquired the virus from DM containing leaves in tests Nos. 22 and 29. In tests Nos. Nos. 23, 30, and 32, however, *M. persicae* infected 11 to 15 test plants, while *A. spiraecola* infected 1 to 15. The data suggest that *M. persicae* is the more efficient vector, at least in the laboratory. Two transmissions occurred with *M. persicae* when *Luffa cylindrica* (L.) Roemer, an introduced species of cucurbitae now growing spontaneously in Puerto Rico, was used as a source plant in test No. 24.

The test species, *R. maidis*, was collected from *Sorghum*. No transmissions occurred in tests using both the DM and PM virus sources. Jensen (*13*) and Holdaway and Look (*8*) reported negative results with Hawaiian ringspot and Waialua diseases, respectively, with this species. Nine out of 67 test plants were inoculated by this species in Cuban investigations (*11*).

In a single test, negative transmission was observed with the species *Rhopalosiphum nymphaeae* (L.) which was collected from *Nymphaea* species. Only the PM virus source was used.

Sipha flava (Forbes), the yellow aphid of sugarcane, was investigated in a single test using the PM virus source. No transmission occurred.

T. aurantiae was collected from *Citrus maximum* (Burm.) for use in test No. 4, and from *Calophyllum brasiliense* Camb var. *antillanum* (Britton) Standley for test Nos. 18 and 33. No evidence of virus transmission was observed. Adsuar (*15*), however, reported successful transmission of DM virus with this species in preliminary tests. Cuban workers (*11*) were unable to confirm transmission with this species.

Throughout the tests, none of the check-plants became infected. Additional tests confirmed the virus free nature of the *M. persicae* colony which was maintained in the screenhouse.

With few exceptions, the time from aphid inoculation to early symptom development was between 10 and 14 days, although extremes of 7 and 20 days were observed.

There was some indication that better transmission occurred from plants which were more recently infected. One transmission occurred from a plant which had been infected for 32 weeks, however. Namba and Kawanishii (*16*) observed optimum transmission from source plants which had been infected for 3 weeks.

The six most omnivorous aphid species in Puerto Rico (*23*) are; *A. gossypii, A. spiraecola, M. persicae, D. ambrosiae, T. aurantiae,* and *A. craccivora.* It is of interest to note that the first four species listed are shown in the present study to be vectors of at least one papaya virus. *Toxoptera aurantiae* has been previously reported to be a vector of DM (*15*), while *A. craccivora* has been reported as a vector of DM (*15*), while *A. craccivora* has been reported as a vector of Hawaiian Ringspot (*13*), Bombay Mosaic (*6*) and Mosaico in Cuba (*11*).

As is generally the case with mechanically transmitted viruses, the mosaic viruses of papaya do not demonstrate a high degree of vector specificity. In the present study, 6 out of 13 species tested were found to transmit at least 1 of the mosaic viruses of papaya. A review of the literature reveals that of 24 aphid species tested as vectors of various mosaic-type virus diseases of papaya, 18 are capable of transmitting at least 1 virus or virus strain. Continued studies would undoubtedly reveal large numbers of species capable of transmitting.

In view of the large numbers of aphid species potentially capable of transmitting the diseases the practicability of controlling the spread of mosaics in papaya by means of vector control appears very limited indeed. Practices such as isolation from the cucurbitae and diseased papaya trees, rapid roguing of diseased trees, planting on the windward corner of the Island, and maintenance of a plant-free orchard floor could markedly reduce the rate of virus introduction and spread. At present, the ideal solution to the problem would appear to be the development of new papaya varieties capable of tolerating the mosaic diseases.

SUMMARY

Two apparently related, aphid-transmitted virus diseases of papaya occur in Puerto Rico. These are the more severe, Distortion Mosaic (DM), and the more mild Papaya Mosaic (PM). Thirteen species of aphids were investigated as potential vectors of one or both viruses. The species *Aphis*

nerii B. de F., *Aphis gossypii* Glover, *Aphis spiraecola* Patch, and *Myzus persicae* (Sulzer) were found capable of transmitting both virus types. In terms of efficiency of transmission in the laboratory, *M. persicae* appeared to be the most efficient vector. In addition, the species *Carolinaia cyperi* Ainslie and *Dactynotus ambrosiae* (Thomas) were found to be efficient vectors of Distortion Mosaic virus. No transmissions occurred with *Aphis craccivora* Koch, *Toxoptera aurantiae* (B. de F.), *Aphis illinoisensis* Shimmer, or *Rhopalosiphum maidis* (Fitch) all of which have been previously reported as vectors of papaya viruses. Negative results were also obtained with *Hyperomyzus lactucae* (L.), *Rhopalosiphum nymphaeae* (L.), and *Sipha flava* (Forbes).

RESUMEN

En Puerto Rico, dos enfermedades virosas de la papaya, aparentemente relacionadas, son transmitidas por pulgones, a saber, el mosaico severo que causa la deformación de las hojas y el más atenuado mosaico de la papaya. Se investigaron 13 especies de pulgones como vectores potenciales de uno o de ambos virus. Las especies *Aphis nerii* B. de F., *Aphis gossypii* Glover, *Aphis spiraecola* Patch y *Myzus persicae* (Sulzer) fueron capaces de transmitir ambos tipos de virus. En cuanto a la eficiencia de transmisión en pruebas de laboratorio, tal parece que el *M. persicae* es el vector más eficiente. Además, las especies *Carolinaia cyperi* Ainslie y *Dactynotus ambrosiae* (Thomas) demostraron ser vectores eficientes del mosaico de la deformación. No se observó transmisión alguna con los *Aphis craccivora* Koch, *Toxoptera aurantiae* (B. de F.), *Aphis illinoisensis* Shimmer y *Rhopalosiphum maidis* (Fitch), los cuales han sido previamente informados como vectores del virus de la papaya. También se observaron resultados negativos con los *Hyperomyzus lactucae* (L.), *Rhopalosiphum nymphaeae* (L.) y *Sipha flava* (Forbes).

LITERATURE CITED

1. Acuña, J. and de Zayas, F., El mosaico y otras plagas de la fruta bomba (*Carica papaya* L.), Est. Expt. Agron., Santiago de las Vegas, Habana, Cuba, Circ. 85, 32 pp., 1946.
2. Adsuar, J., Studies on virus diseases of papaya (*Carica papaya*) in Puerto Rico, I. Transmission of papaya mosaic, Tech. Paper 1, Agr. Expt. Sta., Univ. P.R., Río Piedras, 10 pp., 1946.
3. ——, Studies on virus diseases of papaya (*Carica papaya*) in Puerto Rico, II. Transmission of papaya mosaic by the green citrus aphid (*Aphis spiraecola* Patch), Tech. Paper 2, Agr. Expt. Sta., Univ. P.R., Río Piedras, 5 pp., 1946.
4. ——, Studies on virus diseases of papaya (*Carica papaya*) in Puerto Rico, III. Property studies of papaya mosaic virus, Tech. Paper 4, Agr. Expt. Sta., Univ. P.R., 11 pp. 1946.
5. ——, Transmission of papaya bunchy top by a leafhopper of the genus *Empoasca*, *Sci. 103:* 316, 1946.

6. Capoor, S. P. and Varma, P. M., A mosaic disease of papaya in Bombay, *Ind. J. Agr. Sci. 28*(2): 225–33, 1958.
7. Conover, R. A., Virus diseases of papaya in Florida, (Abst.) *Phytopathology 52:* 6, 1962.
8. Holdaway, F. G. and Look, W. C., Possible vectors of virus disease of papaya, Ann. Rept. Univ. Hawaii Agr. Expt. for 1939, 37–8, 1940.
9. ——, Papaya production in the Hawaiian Islands, IV. Insect pests of papaya and their control, Hawaii Agr. Expt. Sta. Bull. *87:* 45–51, 1941.
10. Ishii, M. and Holtzmann, O. V., Papaya mosaic in Hawaii, *Plant Dis. Reptr. 47* (11): 947–51, 1963.
11. Ivancheva Gabrovska, T., Valdivieso, A. S., Beckquer, A., and Saenz, B., Las enfermedades virosas de la fruta bomba (*Carica papaya* L.) en Cuba, *Rev. de Agr. 1* (2): 1–21, 1967.
12. Jensen, D. D., Papaya virus diseases with special reference to papaya ringspot, *Phytopathology 39* (3): 191–211, 1949.
13. ——, Papaya ringspot virus and its insect vector relationships, *Phytopathology 39* (3): 212–20, 1949.
14. Look, W. C., and McAfee, W. L., New host records of aphids in Hawaii, *Proc. Hawaii Ent. Soc. 12:* 99–112, 1944.
15. Martorell, L. F., and Adsuar, J., Insects associated with papaya virus diseases in the Antilles and Florida, *J. Agr. Univ. P.R. 36* (4): 319–29, 1952.
16. Namba, R., and Kawanishi, C. Y., Transmission of papaya mosaic virus by the green peach aphid, *J. Econ. Ent. 59* (3): 669–71, 1966.
17. Parris, G. K., A new disease of papaya in Hawaii, *Proc. Amer. Soc. Hort. Sci. 36:* 263–5, 1938.
18. Pontis Videla, R. E., Las virosis de la lechoza (*Carica papaya* L.) en Venezuela, 1. Transmission del "Mosaico", *Agron. Trop. 2* (4): 241–51, 1953.
19. Sherman, M., and Tamashiro, M., Toxicity of insecticides and acaricides to the papaya, *Carica papaya*, Tech. Bull. 40, Hawaii Agr. Expt. Sta., 56 pp. 1959.
20. Singh Dhaliwal, T., Pérez López, A., and López García, J., Selecciones prometedoras de papaya para pruebas comerciales en Puerto Rico, Misc. Public. 57, Agr. Expt. Sta., Univ. P.R., Río Piedras, 14 pp., 1966.
21. ——, Progress in papaya breeding in Puerto Rico, Misc. Public. 58, Agr. Exp. Sta., Univ. P.R., Río Piedras, 22 pp., 1966.
22. Smith, C. F., Martorell, L. F., and Pérez Escolar, M. E., *Myzus persicae* (Sulzer) in Puerto Rico, *J. Agr. Univ. P.R. 42* (4): 263–6, 1958.
23. ——, Aphididae of Puerto Rico, Tech. Paper 37, Agr. Exp. Sta., Univ. P.R., Río Piedras, P.R., 121 pp, 1963.
24. Wolcott, G. N., The Insects of Puerto Rico, *J. Agr. Univ. P.R. 32* (1): 224 pp., 1948.
25. ——, Dispersion to the tropics of the spirea aphid, *Aphis spiraecola* Patch, *J. Agr. Univ. P.R. 39* (1): 32–40, 1955.