CHAPTER 3.4

El Salvador

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Introduction

Geographical context

El Salvador lies entirely within a volcanic region but most of its territory is formed by mid to low altitude valleys (up to 1000 m). About 40% of El Salvador consists of agricultural land—the highest proportion in Latin America, where it is the smallest country but the most densely populated. Given the shortage of land, the higher slopes are dedicated to crops such as coffee (*Coffea arabica* L.). Farmers make up over 50% of the population, primarily producing subsistence crops such as maize (*Zea mays* L.) and common bean (*Phaseolus vulgaris* L.).

Cotton (*Gossypium hirsutum* L.), undoubtedly the second most important commercial crop in El Salvador in past decades (for export to Japan), is mostly found in the Pacific lowlands. Sugarcane (*Saccharum officinarum* L.) became an important cash crop at the turn of the century and a third of the sugar produced is exported to the United States. Rice (*Oryza sativa* L.) is another important crop as well as some cucurbits such as watermelon (*Citrullus lanatus* [Thunb.] Matsum. & Nakai) (Pastor, 1988). More recently, the production of melon (*Cucumis melo* L.), pepper (*Capsicum* spp. L.) and tomato (*Lycopersicon esculentum* Mill.) has greatly increased because of their relatively high market value; even so, some of these products continue to be imported because the local market absorbs most of the country's produce. Common bean is widely grown in El Salvador, occupying about 75,000 ha (1995). However, total common bean production does not satisfy internal demand and, in 1994-95, El Salvador imported 14,600 tons of common bean (Parada and Pérez, 1996).

Because of the relatively small size of the country, there are few ecologically distinct areas other than those defined by altitude, where the whitefly *Bemisia tabaci* (Gennadius) cannot thrive. Hence, the whitefly/begomovirus problem is distributed fairly evenly throughout the country. Figure 1 shows the main agricultural regions affected by whitefly-transmitted begomoviruses.

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Figure 1. The main agricultural regions affected by whitefly-transmitted begomoviruses, El Salvador.

The emergence of Bemisia tabaci *as a pest and virus vector*

Granillo and co-workers (1974) first reported *B. tabaci* as a vector of plant viruses in El Salvador. The first virus and whitefly outbreaks occurred in the Pacific coastal area, affecting cotton, kenaf (*Hibiscus cannabinus* L.) and common bean. As in the case of Guatemala, we find here a close association between cotton and the whitefly *B. tabaci*. Among the biotic problems that limit common bean production in the country, the main pest and disease problems are *B. tabaci* and *Bean golden yellow mosaic virus* (BGYMV). Zaumeyer and Smith (1964) first reported this virus in El Salvador. BGYMV was more commonly observed in the Pacific lowlands, reaching up to 100% incidence in most affected common bean plantings in the departments of La Libertad, La Paz, San Vicente and Usulutan. BGYMV has reached most of the adjacent mid-altitude valleys in the departments of La Libertad and Ahuchapan, and it can be found now wherever common bean is grown in the country. The introduction of new crops, particularly horticultural crops, further complicated the dynamics of whitefly populations in El Salvador. The Zapotitán Valley (La Libertad) is a good example of a traditional agricultural area where crops such as maize and common bean were largely displaced by high-value horticultural crops (e.g., tomato, pepper and cucurbits). However, these vegetable crops have been eliminated gradually from the valley because of the damage caused by whitefly-transmitted viruses.

Advances in Biological Research

The first generation of black-seeded, BGYMV-resistant common bean varieties produced in Guatemala in the late 1970s made no impact on the control of BGYMV in El Salvador, because Salvadorans prefer bright red-coloured beans. It was not until 1992, when the first red-seeded bean varieties were developed and released, that bean could be cultivated again in these mid-altitude valleys. The BGYMV isolates from El Salvador are very invasive in susceptible common bean cultivars such as Rojo de Seda, the preferred common bean cultivar in the country. Nevertheless, the BGYMV isolates from El Salvador were shown to be closely related to the Middle American BGYMV isolates from Guatemala and Puerto Rico (Table 1).

Table 1. Serological reactions of selected begomoviruses from El Salvador.

BGYMV[a] isolate	Year collected	MAB-BS[b]	MAB-GA[c]
Guatemala	1992	+	+
El Salvador	1992	+	+
Puerto Rico	1992	+	+
El Salvador	1998	+	-
El Salvador	1999	+	-
El Salvador	1999	+	-

a. BGYMV, *Bean golden yellow mosaic virus*.
b. MAB-BS, a broad spectrum monoclonal antibody used to detect bi-partite begomoviruses.
c. MAB-GA, a monoclonal antibody used to detect the original Middle American isolates of BGYMV-Guatemala.

During the course of this project, individual virus samples were collected from common bean plants showing typical BGYMV symptoms. Table 1 shows the results of the serological tests, with the broad spectrum and specific (Guatemalan) monoclonal antibodies developed for BGYMV, for BGYMV isolates collected in 1992, 1998 and 1999. The results show that, as of 1998, there have been changes in the coat protein composition of BGYMV isolates in El Salvador (no reaction with the specific MAB-GA antiserum).

In order to determine the current composition of whitefly species/biotypes in El Salvador, a collection of immature whiteflies found on economically important crops affected by begomoviruses and/or *B. tabaci* was undertaken in selected agricultural departments of the country. The results obtained (Table 2) show an interesting situation of mixed populations of biotype A and B of *B. tabaci*, biotype B being predominantly associated with cucurbits.

The next step was to investigate the proportion of whitefly-transmitted viruses in the different crops grown in whitefly-affected agricultural regions. Table 3 shows the results from this investigation. Basically, it is evident that whiteflies are not the only group of vectors transmitting viruses to horticultural crops in El Salvador. Many of the samples tested also contained potyviruses transmitted by aphids. It is interesting to note that the cucurbit locally called *pipián* (*Cucurbita argyrosperma* C. Huber subsp. *argyosperma*) had not been recorded previously in Central America as a host of whitefly-transmitted viruses. For the four cucurbit species assayed in the above survey, aphid-transmitted potyviruses appear as the main viral problem, with the exception of *pipián*. For common bean, BGYMV was present but the relatively low number of samples collected probably reflects the displacement of this food legume from areas traditionally growing common bean. The results obtained for tomato and pepper suggest a complex

Table 2. Results of whitefly biotype surveys in different agricultural regions of El Salvador.

Crop[a]	Sample	Department	B.t.-A[b]	B.t.-B[b]	Other
Tomato	1	Chalatenango	9	-	1
Chilli	2	Chalatenango	4	5	1
Watermelon	3	La Libertad	7	-	3
Loroco	4	La Libertad	-	3	7
Chilli	5	La Libertad	7	-	3
Ayote	6	Santa Ana	6	-	4
Watermelon	7	La Paz	8	1	1
Melon	8	La Paz	2	7	1
Pipián	9	La Paz	4	-	6
Tomato	10	Chalatenango	5	-	5
Tomato	11	Chalatenango	18	-	2
Watermelon	12	Santa Ana	9	-	1
Tomato	13	Ahuachapán	8	-	2
Cucumber	14	Ahuachapán	4	3	3
Ayote	15	Ahuachapán	4	4	2
Watermelon	16	Santa Ana	2	6	2

a. *Loroco* (*Fernaldia pandurata* [A. DC.] Woodson), *ayote* (*Cucurbita moschata* Duchesne), *pipián* (*Cucurbita argyrosperma* C. Huber subsp. *argyrosperma*).
b. *Bemisia tabaci* A and B biotypes.

Table 3. Serological analyses of plants showing virus-like symptoms associated with the presence of whiteflies in El Salvador.

Samples	Plant[a]	Begomovirus	Potyvirus	Other	None
45	*Pipián*	25	11	0	9
9	Watermelon	0	9	1	-
11	Cucumber	0	7	0	4
6	*Ayote*	1	2	0	3
6	Common bean	2	0	0	4
38	Tomato	0	2	2	36
19	Pepper	0	4	0	0
1	Okra	0	0	0	0
1	*Loroco*	0	1	CMV[b]	0
1	*Chilipuca* (lima bean)	1	0	0	0

a. *Pipián* (*Cucurbita argyrosperma* C. Huber subsp. *argyrosperma*), *ayote* (*Cucurbita moschata* Duchesne), *loroco* (*Fernaldia pandurata* [A. DC.] Woodson), *chilipuca* (*Phaseolus lunatus* L. var. *lunatus*).
b. CMV, cucumovirus.

virus problem in these crops. In past tests, one pepper sample and one tomato sample collected earlier in the Zapotitán Valley had tested positive for the presence of begomoviruses.

A BGYMV isolate from San Andrés, El Salvador, was selected for partial sequencing to determine the degree of molecular divergence with respect to BGYMV isolates characterized in the early 1990s. Table 4 shows the comparative results obtained with two partial regions of the BGYMV genome: the viral replicase (*AC1*) and the coat protein (*AV1*). As can be observed, the Salvadoran BGYMV-ES isolate has not changed drastically over the past decade and it can still be considered an isolate of the Middle American BGYMV species (sequence homologies above 90%). The differences observed at the coat protein level (*AV1*) probably reflect minor changes in certain aminoacids as a result of the introduction of a new whitefly biotype. Differences at the replicase level (*AC1*) may represent an evolutionary trend. The significant differences between the Middle American BGYMV species and the Brazilian BGMV species reflect their different origins or divergent evolutionary paths.

A visit to one of the most traditional agricultural areas of El Salvador, the Zapotitán Valley, showed the profound changes that have occurred in the cropping systems of this country. This irrigation district, thanks to its proximity to the capital, San Salvador, was the breadbasket of El Salvador, producing most of the basic food crops demanded by the local

Table 4. Partial sequence homology (%) between a *Bean golden yellow mosaic virus* (BGYMV) isolate from El Salvador (ES) and related BGYMV/*Bean golden mosaic virus* (BGMV) isolates characterized in the early 1990s.

ORF[a]	Isolates[b]				
	BGYMV-DR	BGYMV-PR	BGYMV-GA	BGMV-BR	BGYMV-ES
AC1	90.5	88.8	91.7	69.4	100
AV1	94.3	91.5	93.8	78.2	100

a. ORF, open reading frame; *AC1*, viral replicase gene; and *AV1*, coat protein gene.
b. DR, Dominican Republic; PR, Puerto Rico; GA, Guatemala; and BR, Brazil.

markets: common bean, maize, etc. In the past decade, this valley has experienced drastic changes in its agriculture to meet the increasing demand for higher value crops, particularly horticultural crops such as tomato, pepper and cucurbits. A recent survey of the Zapotitán Valley revealed the predominance of horticultural crops and the high incidence of viral diseases affecting them. Eight samples (Table 5) were taken selectively from different fields visited in the valley, all from plants showing symptoms usually associated with whitefly-borne viruses.

This preliminary survey, conducted in order to define priorities in Phase II of the Tropical Whitefly Project, shows that other viruses are present in the valley, besides whitefly-transmitted begomoviruses. The viruses detected by electron microscopy and with the use of the monoclonal antibody PTY1 are potyviruses transmitted by aphids and predominantly were found affecting pepper and cucumber (*Cucumis sativus* L. var. *sativus*) in this valley.

Socio-economic Analysis

A case study was conducted in El Salvador, in the San Vicente Department. The study was entitled "Farmers' perception of the whitefly *B. tabaci* as an agricultural pest: management and environmental factors affecting the incidence of the whitefly in the department of San Vicente". This department has an agricultural area of 55,340 ha, including 20,346 ha planted to basic grains—maize, sorghum (*Sorghum bicolor* [L.] Moench), common bean, sesame (*Sesamum indicum* L.) and soybean (*Glycine max* [L.] Merr.)—4015 ha are cultivated to coffee, 2844 ha are in sugarcane and the rest in horticultural and fruit crops. Among the horticultural crops grown here, *ayote* (*Cucurbita moschata* Duchesne), *pipián*, sweet pepper (*Capsicum annuum* L. var. *annuum*), hot pepper (*Capsicum* spp. L.), tomato, cucumber, melon and watermelon are the most important.

About 50% of the farmers interviewed were over 40 years old and

Table 5. Results of the analyses practiced on selected samples of horticultural crops affected by viral diseases in the Zapotitán Valley, El Salvador.

Sample	Crop	Analyses[a]					
		EM	MAB-BS	MAB-GA	PTY1	CMV	PCR
1	Pepper	+	-	-	+	nt	nt
2	Pepper	+	-	-	+	nt	nt
3	Tomato	-	+/-	-	-	nt	nt
4	Tomato	-	-	-	-	-	nt
5	Pepper	+	-	-	+	nt	nt
6	Cucumber	+	-	-	+	-	nt
7	Pepper	-	+	-	-	nt	nt
8	Tomato	-	-	-	-	nt	nt

a. EM, electron microscopy; MAB-BS, a broad spectrum monoclonal antibody used to detect bi-partite begomoviruses; MAB-GA, a monoclonal antibody used to detect the original Middle American isolates of *Bean golden yellow mosaic virus*-Guatemala; PTY1, monoclonal antibodies to detect potyviruses; CMV, monoclonal against cucumovirus; PCR, polymerase chain reaction; and nt, not tested.

40% were between 25-40 years of age. Only 25% of the farmers interviewed had secondary (high school) education and 41% had received technical assistance in the selection of pesticides to control the whitefly problem. Pesticide salesmen are highly influential in the selection and use of insecticides for all crops. Most farmers (54%) apply insecticides with a frequency between 10-15 times per crop cycle. A significant proportion (16%) of the farmers interviewed apply pesticides more than 20 times in a single crop cycle. One hundred and forty-seven different commercial pesticides were mentioned during this survey. Sixty-two percent of the farmers interviewed mentioned preventive pesticide applications as a risk-averting practice.

Of the farmers interviewed, about 97% recognizes the whitefly problem but only 36% associates this pest with viral diseases. Farmers believe that whitefly-related problems are more severe during the dry months of the year but they cannot predict the incidence of whiteflies and viral diseases based on climatic factors. Over 60% of the respondent farmers considered that yield losses in susceptible crops range from 25%-50% because of the whitefly/ begomovirus problems.

Strengthened Research Capacity

El Salvador was undoubtedly the country where this project established more collaborative activities with different agricultural research institutions. The local coordinating entity was the national agricultural research institution, CENTA, under the co-ordination of Dr. Priscila Henríquez (biotechnology) and Ing. Carlos A. Pérez (Coordinator of Programa Cooperativo Regional de Frijol para Centro América, México y el Caribe [PROFRIJOL] activities in El Salvador). A major collaborator in this project has been the University of El Salvador, under the guidance of Prof. Leopoldo Serrano. The University has generated and collected a considerable amount of grey literature on whitefly-related production problems in El Salvador and has offered students to conduct thesis research on whitefly-transmitted viruses affecting crops of socio-economic importance in the country. The University of El Salvador covered the San Vicente Valley, another important agricultural area. A second institution of higher learning collaborating in this project was the Universidad Técnica Latinoamericana (UTLA), which also conducted some studies in the Zapotitán Valley. The Plant Health Division of the Dirección General de Salud Ambiental (DIGESA) also participated in this collaborative effort, covering the departments of Santa Ana, Ahuachapán and Sonsonate. Finally, a nongovernmental organization, the Programa Regional de Manejo Integrado de Plagas en América Central (PROMIPAC), devoted to the production of non-traditional crops, also joined the project by providing support to the various activities undertaken by the different groups. The creation of a national network was unique for Central America and represented a major local effort to address the important problem of whitefly-transmitted begomoviruses in El Salvador.

All of these institutions were provided with technical guidelines for the collection and processing of biological samples related to the whitefly problem affecting crops of socio-economic importance.

Current Status of Whitefly/Begomovirus Problems

The whitefly/begomovirus problems in El Salvador are widely dispersed in the main agricultural areas of the country. However, the incidence of these pests is higher in the plains and mid-altitude valleys. These agro-ecosystems range in altitude, from sea level to 1000 m, with average temperatures of 27 ºC and about 1600 mm of rainfall; all of these being conditions that favour the biology and reproduction of *B. tabaci*.

The displacement of traditional agriculture (e.g., maize and common bean) with non-traditional export crops (e.g., tomato, pepper and cucurbits) has aggravated the whitefly/begomovirus problem because of the availability of new reproductive hosts for *B. tabaci* and the intensive use of pesticides to protect the new high-value crops against begomoviruses.

The current situation of the whitefly/begomovirus problems in El Salvador merits an effort to implement integrated pest management strategies in the main horticultural areas of the country, mainly in the departments of San Vicente, San Salvador, La Libertad, Sonsonate and Santa Ana.

The use of virus-resistant common bean cultivars has attenuated the problem in this food crop but genetic resistance is not available in any of the other crops affected by begomoviruses in El Salvador.

References

Granillo, C. R.; Díaz, A.; Anaya, M. A.; Bermúdez, L. A. 1974. Enfermedades transmitidas por *Bemisia tabaci* en El Salvador. Resumen de trabajo, seminario de leguminosas de grano, Río Piedras, PR. 2 p.

Parada, M. E.; Pérez, C. A. 1996. Situación actual del cultivo del frijol común en El Salvador con énfasis en bacteriosis común. Informe Técnico, Taller de bacteriosis, Mayagüez, PR. 12 p.

Pastor, R. 1988. Historia de Centroamérica. Editorial Piedra Santa, GT. 272 p.

Zaumeyer, W. J.; Smith, F. F. 1964. Report of a bean disease and insect survey in El Salvador. Technical Report, Agency for International Development (AID). Technical Assistance Agreement, Agricultural Research Service, United States Department of Agriculture (USDA), Beltsville, MD, USA.