CHAPTER 3.3

Guatemala

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Introduction

Geographical context

Of the seven countries that comprise the isthmus of Central America, Guatemala is physically and culturally the most diverse. The highlands of the southern half of Guatemala descend southward to the Pacific Coast to form the fertile "Piedmont" or "Coffee Belt" (500-1500 m above sea level) and the hot, grass- and forest-covered lowlands known as "The Coast" (0-500 m). The northern regions of Guatemala are tropical lowlands covered by rain forest and scattered savannahs, which are only sparsely populated (West and Augelli, 1977). However, it is the south-eastern region of the country ("El Oriente"), formed by low- and mid-altitude (200-1000 m) valleys, which has suffered the worst attacks from the whitefly *Bemisia tabaci* (Gennadius) and different begomoviruses transmitted by this whitefly species. This region has drastically changed its traditional agricultural environment to join the boom in export crops, thus creating complex and fragile cropping systems. Figure 1 shows the main agricultural regions affected by whitefly-transmitted begomoviruses.

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

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

The civil war in the United States in the 1860s created an increased demand for cotton (*Gossypium hirsutum* L.). Soon, cotton produced in the Pacific lowlands of the country comprised 20% of Guatemala's exports. This species was probably one of the first commercially cultivated hosts of the whitefly *B. tabaci*. A second boom of cotton production took place in the 1950s and

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1960s, and at this time the first viruses transmitted by whiteflies were observed in Guatemala and neighbouring countries (Gill, 1994).

Tobacco (*Nicotiana tabacum* L.) is another popular export crop that continues to be grown in Guatemala. The cultivation of tobacco in south-eastern Guatemala has been blamed also for increasing the population of the virus vector *B. tabaci* in the 1970s, thus provoking the first outbreaks of *Bean golden yellow mosaic virus* (BGYMV) in common bean (*Phaseolus vulgaris* L.) in that region of Guatemala (Morales, 1994).

In 1974, the Horticultural Research Division of the Instituto de Ciencia y Tecnología Agrícolas (ICTA) initiated extension work in the Zacapa Department with a view to producing export crops such as melon (*Cucumis melo* L.). At that time, the main production problems identified were outdated agronomic practices, inadequate cultivars and the poor quality of the produce, which could only meet the relatively low standards of the local markets. A similar industry to produce tomato (*Lycopersicon esculentum* Mill.) was also initiated in the late 1970s in south-eastern Guatemala (Gaytán, 1979). These crops provided better reproductive hosts for *B. tabaci* than either common bean or wild plant species. The populations of the vector soon soared and then new begomoviruses emerged to attack the new crops. The arrival of the B biotype of *B. tabaci*, a more aggressive and polyphagous variant of the original species, further aggravated yield losses, with the new whitefly acting as both a pest and a vector of damaging plant viruses (Dardón, 1992).

The first collaborative project that set out to tackle the new and growing threat of whitefly-borne viruses was the Programa Cooperativo Regional de Frijol para Centro América, México y el Caribe (PROFRIJOL), initiated by the Centro Internacional de Agricultura Tropical (CIAT) to address the bean golden yellow mosaic problem. This project, initiated in 1978 with support from the United Nations Development Programme (UNDP) and subsequently funded (from 1980) by the Swiss Development Cooperation (SDC), is credited with the development of several BGYMV-resistant (DOR) lines that have subsequently been widely adopted as commercial varieties in Mexico, Central America, the Caribbean and South America.

In Guatemala, the project began work under the auspices of ICTA in the south-eastern Monjas Valley, about 960 m above sea level. Until the 1970s, this valley had been planted to traditional crops, mainly common bean and maize (*Zea mays* L.). In the 1980s, horticultural crops such as tomato and broccoli (*Brassica oleracea* L. var. *italica* Plenck) made their appearance in the valley. Other non-traditional crops—pepper (*Capsicum* spp. L.), cucumber (*Cucumis sativus* L. var. *sativus*) and more recently watermelon (*Citrullus lanatus* [Thunb.] Matsum. & Nakai) and grape (*Vitis vinifera* L.)—have also found a niche in this valley over the latter part of the 1990s. Tobacco is a large-scale commercial crop that was first planted in the valley during the early 1970s; its production collapsed in the late 1980s, only to make a comeback in recent years.

BGYMV, appearing in the mid-1970s, was the first whitefly-transmitted virus to cause severe yield losses in the Monjas Valley (Rodríguez, 1994). Tobacco was probably the most important reproductive host of *B. tabaci*. The local common bean cultivars, Pecho Amarillo and Rabia de Gato, soon succumbed to the disease. Fortunately, the PROFRIJOL project began to show results and in due course released the first disease-resistant breeding lines: ICTA-Quetzal, ICTA-Jutiapán and ICTA-Tamazulapa (Rodríguez, 1994). The causal agent, initially believed to be *Bean golden mosaic virus* (BGMV), was characterized at the molecular level, thanks to collaborative research financed by the United States Agency for International Development and carried out at the University of Wisconsin and at CIAT. The Guatemalan virus in the early 1990s was shown to be a distinct species, different from the Brazilian isolates of BGMV (Faria et al., 1994) but with a considerable degree of homology and causing a very similar disease; it was therefore given the name *Bean golden yellow mosaic virus*. Maize is not a host of the whitefly *B. tabaci* and is not attacked by these particular begomoviruses, although maize in Africa is infected by different geminiviruses (Geminiviridae: Mastrevirus) transmitted by leafhoppers.

Advances in Biological Research

Further research, undertaken in collaboration with the University of Florida, was intended to produce monoclonal antibodies (MABs) against different isolates of BGYMV, using the Guatemalan (MAB-GA) isolate of BGYMV. At the same time, the project sought to produce a broad-spectrum monoclonal antibody (MAB-BS), capable of detecting most whitefly-transmitted begomoviruses (Cancino et al., 1995). The results shown in Table 1 indicate that these objectives were realized, in as much as MAB-BS has been able to detect all bi-partite begomoviruses encountered to date in Guatemala, but MAB-GA reacts only with the original Middle-American BGYMV isolates. The result that MAB-GA, raised against the original isolate from Monjas, does not react with isolates subsequently collected from this area suggests that some change in the antigenic properties of the virus has occurred or that a new isolate has been introduced and become established in the area. Begomoviruses are known to adapt to different host plants and vector species. It has been suggested that the changes observed in the antigenic reaction of the Monjas isolates may be associated with the displacement of the A biotype of *B. tabaci* by the B biotype, which is believed to have occurred in the 1990s.

Table 1. Antigenic properties of common bean begomoviruses from Guatemala.

Isolate	Locality	MAB-BS[a]	MAB-GA[b]
1	Monjas	+	+
2	Tecpán	+	-
3	Cuyuta	+	-
4	Monjas	+	-
5	Monjas	+	-
6	San Jerónimo	+	-
7	Quiaté	+	-

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

Characterization of whiteflies collected from sites across Guatemala confirms that the B biotype has displaced the A biotype almost completely (Table 2). This would be consistent with the hypothesis that the antigenic changes in the virus detected with the specific MAB may be related to the presence of a new vector. To explore this possibility further, the coat protein of a recent isolate of BGYMV from the locality of Monjas was partially sequenced and compared with the original isolate. Table 3 shows the comparative results obtained.

Table 2. Results of whitefly surveys in different agricultural regions of Guatemala. Data are numbers of samples that included *Bemisia tabaci* biotype A (B.t.-A), *B. tabaci* biotype B (B.t.-B) or other species of whitefly (other spp.).

Crop	Samples	Locality[a]	B.t.-A	B.t.-B	Other spp.
Melon	12	Cuyuta-Jutiapa	0	12	0
Melon	6	Río Hondo-Zacapa	0	6	0
Watermelon	10	La Fragua-Zacapa	0	10	0
Watermelon	22	L.de Retana-Jutiapa	0	2	20
Cucumber	17	Usumatlán-Zacapa	0	17	0
Cucumber	10	AMCO-Jutiapa	0	10	0
Cucumber	10	S. Agustín-Jutiapa	0	10	0
Okra	7	La Fragua-Zacapa	0	7	0
Tobacco	2	Santa Cruz-Jutiapa	0	2	0
Tomato	2	Miramar-Jutiapa	2	0	0
Tomato	1	AMCO-Jutiapa	0	1	0
Eggplant	10	San Agustín-Jutiapa	0	10	0

a. AMCO-Jutiapa, an experiment station.

Table 3. Comparative analysis of partial coat protein sequence homologies (%) among viruses associated with *Bean golden yellow mosaic virus*, comparing the isolate GA-2, collected in Guatemala during the project, with GA-1, the original isolate, and isolates from the Dominican Republic (DR), Puerto Rico (PR) and *Bean golden mosaic virus*- Brazil (BR).

Virus	GA-2	GA-1	DR	PR	BR
GA-2	100	92.7	92.3	90.0	76.0

These results show a divergence in coat protein nucleotide sequence of ca. 7.3% between the original and recent Guatemalan isolates. This difference is significant, considering that when sequences of two isolates diverge by more than 10% they are normally regarded as distinct species—as in the case of the difference observed between BGYMV-GA and BGMV-BR (see Table 3).

Table 4 shows the results of serological and other complementary diagnostic tests carried out on plant samples taken from selected crops in whitefly-affected regions in Guatemala. These results demonstrate the presence of whitefly-transmitted begomoviruses in most horticultural crops assayed, with the exception of cucumber. Tobacco is also beginning to be attacked by begomoviruses, as production of this crop increases once more. Tobacco, however, was observed to be principally affected by *Tobacco mosaic virus* (TMV) (*Tobamovirus*), a highly infectious virus that is spread by workers entering the field. A similar virus, probably *Tomato mosaic virus,* was also found infecting tomato in the south-eastern region of Guatemala, although the two viruses may be strains of TMV adapted to each crop.

The presence of *Pepper golden mosaic virus* in pepper was confirmed in samples taken from the locality of Laguna de Retana. The collaborating Plant Pathology Laboratory of the University of Wisconsin had detected this virus already in Guatemala (Douglas Maxwell, personal communication, 2003).

Socio-economic Analysis

Over half of Guatemala's total population of some 12 million people are of pure Amerindian stock. This sector of the population is concentrated

Table 4. Results of assays carried out on selected plant samples from Guatemala.

Sample	Locality	Plant	Reaction[a]		EM[b]
			MAB-BS	PTY1	
1	Zacapa	Melon	+	-	nt
2	Zacapa	Melon	-	+	nt
3	Monjas	Tobacco	+	nt	nt
4	Monjas	Tobacco	+	nt	TMV
5	El Ovejero	Tobacco	-	nt	TMV
6	L. de Retana	Tomato	+	nt	nt
7	L. de Retana	Tomato	-	-	nt
8	L. de Retana	Tomato	+	nt	nt
9	Zacapa	Tomato	-	-	nt
10	Las Conchas	Tomato	-	nt	TMV
11	Las Conchas	Tomato	-	nt	TMV
12	Las Flores	Tomato	+	nt	nt
13	L. de Retana	Tomato	+	nt	nt
14	L. de Retana	Tomato	+	nt	nt
15	Plan de la Cruz	Tomato	+	nt	nt
16	Plan de la Cruz	Tomato	+	nt	nt
17	Monjas	Tomato	+	nt	nt
18	Monjas	Tomato	+	nt	nt
19	Monjas	Tomato	+	nt	nt
20	L. de Retana	Pepper	+	nt	nt
21	L. de Retana	Pepper	-	nt	-
22	L. de Retana	Pepper	+	nt	nt
23	L. de Retana	Cucumber	-	nt	-
24	L. de Retana	Cucumber	-	nt	-

a. Positive or negative reactions to a broad spectrum monoclonal antibody used to detect bi-partite begomoviruses (MAB-BS); reactions to a potyvirus-specific monoclonal antibody (PTY1); and nt, no tests for these samples.

b. Detection of *Tobacco mosaic virus* (TMV) by electron microscopy (EM); and nt, no tests for these samples.

in the highlands, north and west of Guatemala City, as well as in the region of Petén. South-eastern Guatemala is the region with the lowest proportion of native Americans. The presence of mestizos or *ladinos* in the *Oriente* of Guatemala explains the more dynamic and complex cropping systems in these drier lowlands, including the prevalence of non-traditional export crops.

A special study was conducted in the municipality of Monjas, Jalapa Department, where Amerindians still make up over 70% of the total population. The Monjas Valley is located at an altitude of 960 m and has an average annual precipitation of 900 mm, most of which falls between May and October. The mean temperature is 23.7 °C and the mean relative humidity is 80%. Ecologically, the Monjas Valley is classified both as dry subtropical forest and temperate subtropical humid forest. Most of the agricultural land is private property, although it may have been acquired by “right” and not through a commercial transaction.

Table 5 shows the existing cropping systems in the Monjas Valley. Maize and common bean are evidently

Table 5. Cropping systems in the Monjas Valley, Jalapa, Guatemala.

Crop	Years of planting	Irrigation	Rain-fed
Common bean	>50	-	+
Maize	>50	-	+
Tobacco	25	+	+
Tomato	15	+	-
Broccoli	10	+	-
Onion	10	-	+
Pepper	7	+	+
Cucumber	5	+	-
Sweet corn	3	+	-
Grape	3	+	-

Table 6. Growers' perception of whitefly problems and growers' use of pesticides in selected cropping systems of the Monjas Valley, Jalapa.

Crop	Whitefly problem	Pesticides used (no.)
Common bean	Yes	8
Maize	No	1
Tobacco	Yes	9
Tomato	Yes	11
Broccoli	Yes	1
Onion	No	-
Pepper	Yes	5
Cucumber	Yes	10
Sweet corn	No	1
Grape	No	-

the most traditional crops in the valley. Tobacco has been planted for over 20 years as a commercial crop but almost disappeared in the late 1970s because of market problems, coming back into favour only in the late 1990s. Onion (*Allium cepa* L.) is another crop that has been planted in the valley for over 10 years but it has never become prevalent. Broccoli has been a very popular crop in the valley in the past decade and pepper has been commercially cultivated during the past 7 years. Cucumber has been planted commercially for the past 5 years and watermelon for the past 2 years, although it has been planted for local consumption for decades in the valley. Finally, sweet corn (*Zea mays* L. subsp. *mays*) and grape have been introduced in the past 3 years.

Table 5 also shows the association between commercial crops and the use of irrigation in the Monjas Valley. Subsistence crops such as maize and common bean are planted during the rainy season. The use of irrigation demonstrates the intention of local growers to minimize risk in the case of high-value crops.

Table 6 shows the perception that growers have of the whitefly *B. tabaci*, both as a pest and virus vector in the crops listed above, and the number of pesticides used in each crop. The results clearly illustrate that pesticide abuse occurs in most of the crops affected by whiteflies. In the case of tomato, only five of the 11 pesticides used are specific to the control of whitefly; the remaining six pesticides are applied as "repellents" in the belief that the "smell" of these products repels the whitefly. The low use of insecticides on broccoli is interesting and responds to demand from foreign buyers (many of whom only allow bio-pesticides to be used).

In general terms, whiteflies are the main pest on common bean, tomato, broccoli and tomato. Other pests such as white grubs and lepidopterous larvae also cause significant damage to tobacco, tomato and sweet corn. Slugs and chrysomelids are perceived as important pests of common bean in the valley. Diamond-back moth, *Plutella xylostella* (Linnaeus), is also a pest of broccoli; and the corn ear worm, *Helicoverpa zea* (Boddie) causes severe damage to maize and sweet corn. The existence of insect pests other than whiteflies in the various crops grown in the Monjas Valley hampers efforts to reduce the use of chemical pesticides against whiteflies. In fact, most growers of non-traditional export crops use “cocktails”, or “bombs”, as pesticide mixtures are locally called.

Whereas growers recognize *B. tabaci* as a pest, they do not fully understand its role as a vector of viruses. However, they readily associate the bright yellowing shown by infected common bean plants with a disease (bean golden yellow mosaic). In the case of tomato, growers call symptoms expressed by begomovirus-infected plants *acolochamiento* (curling). In the case of tobacco, growers recognize the severe malformation and stunting symptoms shown by virus-infected plants. However, they cannot distinguish between whitefly-transmitted begomoviruses and TMV.

According to most growers, whiteflies are a regular pest, year after year, particularly during the summer time because of the higher temperatures and relative humidity. Growers also perceive the complex cropping systems in the valley as a negative factor because they claim that these crops represent more food sources for the whitefly. Finally, growers blame ratoon crops for the survival of whiteflies between summer and winter seasons. Growers believe in the existence of whitefly-resistant or more generally pest- and disease-resistant crops, particularly tomato, tobacco and common bean. However, the “resistance” of tomato and tobacco seems to be associated with the implementation of more successful chemical control practices in the valley. In reality, the case of common bean is a good example of genetically controlled virus resistance obtained through a well-designed breeding programme.

A general question on the ability of growers to predict seasons of high or low whitefly incidence was generally misinterpreted. Most growers responded that they were always ready to control whiteflies in seedbeds, after transplanting and during the vegetative and early reproductive phases of the crop. In fact, some growers indirectly answered the question, associating mild winters and an abundance of alternative crops with higher whitefly populations and crop damage.

Strengthened Research Capacity

The Tropical Whitefly Integrated Pest Management (TWF-IPM) Project financed two case studies conducted by ICTA agronomists, in the departments of Jalapa, Jutiapa and Baja Verapaz. These departments used to be traditional agricultural areas, devoted to the planting of food staples such as maize and common bean. The boom in export crops, however, rapidly displaced traditional crops and drastically changed the socio-economic structure of the rural communities found in these departments. The studies conducted in these regions provided information on the positive aspects (potential higher income) and negative consequences (new biotic problems and pesticide abuse) of non-traditional export crops. The first study was conducted in 15 rural communities, located in three municipalities of the departments of Jalapa and Jutiapa. The second case study was conducted in five rural communities in the municipalities of San Jerónimo, Rabinal and San Miguel Chicaj. This study helped to develop non-chemical strategies for whitefly control and generated information of value to ICTA in its attempts to adopt suitable research policies to assist small-scale farmers.

Although training in advanced laboratory techniques was not contemplated in this preliminary phase of the project, it became apparent that a number of agricultural scientists in Central America, Mexico and the Caribbean have adequate laboratory facilities to conduct such work. These scientists are becoming increasingly reluctant to act simply as “guides” or “providers” of biological samples to foreign scientists from advanced research laboratories that often visit developing countries in search of interesting scientific materials. Although the aim of this project was to conduct research in a truly collaborative manner, in which national scientists have preferential access to the results of all research undertaken, the possibility of training national scientists in advanced molecular techniques became a need. The two research areas in which advanced techniques are being implemented in this project are in the molecular identification of whitefly biotypes and of the begomoviruses they transmit.

In Guatemala, the identification of begomoviruses is being done at the University of San Carlos with the support of the Plant Pathology Laboratory of the University of Wisconsin. The molecular characterization of *B. tabaci* biotypes is being carried out at the University of El Valle, Guatemala City, which has adequate facilities to conduct research in the area of molecular biology but did not have the technology to identify whitefly biotypes. Consequently, a research assistant from the relevant laboratory received 1 week of intensive training at CIAT on the molecular characterization of *B. tabaci* biotypes and was able to carry out this work successfully upon return to Guatemala.

Thus, the project helped national scientists to conduct surveys that improved both the biological and socio-economic knowledge base on which research and implementation of agricultural policy are founded. The research sector of Guatemala was also strengthened through the training of scientists from advanced research laboratories in the country in techniques used for the identification of whitefly biotypes and the begomoviruses that affect food and export crops of social and economic importance.

Current Status of Whitefly/Begomovirus Problems

The whitefly/begomovirus problems in Guatemala are concentrated in the south-eastern agricultural regions of the country (Figure 1). This region contains most of the country’s mid-altitude valleys (at 500 to 1000 m altitude) with an average annual rainfall below 1500 mm, and temperatures between 20 and 25 ºC; these valleys are also characterized by highly diverse cropping systems, including irrigation. All of these factors favour the reproduction of *B. tabaci*. Moreover, the concentration of non-traditional export crops in this region is associated with the intensive use of pesticides, regularly used to protect these high-value crops. Pesticide abuse is another predisposing factor for the establishment of *B. tabaci* as a pest. Any crop planted in the Pacific lowlands will be severely attacked by whitefly-transmitted begomoviruses particularly because of the higher temperatures, which increase disease severity.

The current begomovirus situation is becoming more complex as new whitefly-transmitted viruses are introduced from neighbouring countries, or evolve from the indigenous virus population, or arise through genetic recombination between the existing begomoviruses that affect the diverse crops such as common bean, tomato, pepper, squash (*Cucurbita* spp. L.), melon and tobacco that are grown in this area. Only in the case of common bean has there been a sustained effort on the part of the national program and CIAT (with Swiss funding) to develop and release virus-resistant cultivars. For the remaining crops, the emphasis has been on chemical control, although large agro-export companies have adopted some IPM packages. South-eastern Guatemala provides an ideal site to conduct a case study with small-scale farmers on the implementation of practical IPM measures to combat *B. tabaci* and the begomoviruses that this species transmits to food and industrial crops in this region.

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References

Cancino, M.; Abouzid, A. M.; Morales, F. J.; Purcifull, D. E.; Polston, J. E.; Hiebert, E. 1995. Generation and characterization of three monoclonal antibodies useful in detecting and distinguishing *Bean golden mosaic virus* isolates. Phytopathology 85:484-490.

Dardón, D. E. 1992. Las moscas blancas en Guatemala. *In*: Hilje, L.; Arboleda, O. (eds.). Las moscas blancas en América Central y el Caribe. Memorias del Taller Centroamericano y del Caribe sobre moscas blancas, Turrialba, CR. p. 38-41.

Faria, J. C.; Gilbertson, R. L.; Hanson, S. F.; Morales, F. J.; Ahlquist, P.; Loniello, A. O.; Maxwell, D. P. 1994. Bean golden mosaic geminivirus type II isolates from the Dominican Republic and Guatemala: Nucleotide sequences, infectious pseudorecombinants, and phylogenetic relationships. Phytopathology 84:321-329.

Gaytán, M. A. 1979. Proyecto de exportación de melones en el Valle de Zacapa. XXV Reunión annual Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios (PCCMCA), Tegucigalpa, HN.

Gill, A. 1994. Problemática del complejo mosca blanca-virus en algodón en Centroamérica. *In*: Mata, M.; Dardón, D. E.; Salguero, V. E. (eds.). Biología y manejo del complejo mosca blanca-virosis. Memorias III Taller Centroamericano y del Caribe sobre mosca blanca, Antigua, GM. p. 23-38.

Morales, F. J. 1994. Bean golden mosaic: Research advances. Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. 193 p.

Rodríguez, R. 1994. Situación actual del mosaico dorado del frijol en Guatemala. *In*: Morales, F. J. (ed.). Bean golden mosaic. 1994 research advances. Programa Cooperativo Regional de Frijol para Centro América, México y el Caribe (PROFRIJOL)-Swiss Development Cooperation (SDC). Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. p. 34-39.

West, R. C.; Augelli, J. P. 1977. Middle America: Its lands and peoples. Second edition. Prentice-Hall, NJ, USA. 494 p.