CHAPTER 3.2

Mexico

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Introduction

Geographical context

Mexico is the largest country in Middle America, with an area of 1,958,201 km^2. The country can be divided into different regions, the largest being the Central Plateau, which extends from the United States border in the north to the Isthmus of Tehuantepec in the south. At its northern end, the plateau is about 1320 m above sea level, rising to more than 2650 m south of Mexico City, the country's capital. This Central Plateau is divided into two parts—the Mesa del Norte extends from the United States border to near San Luis Potosí, and the Mesa Central from San Luis Potosí to just south of Mexico City. The Mesa Central is a less arid, higher and flatter plateau than the Mesa del Norte. Although the Central Plateau contains many agricultural basins and valleys, the altitude limits the survival and activity of the whitefly *Bemisia tabaci* (Gennadius). Instead, other whiteflies such as *Trialeurodes vaporariorum* (Westwood) predominate. The latter species can become a major pest on some crops, including common bean (*Phaseolus vulgaris* L.), tomato (*Lycopersicon esculentum* Mill.), potato (*Solanum tuberosum* L.) and other horticultural crops grown above 900 m altitude; but it is not a vector of begomoviruses. Figure 1 shows the main agricultural regions affected by whitefly-transmitted begomoviruses.

The Central Plateau is flanked by the Sierra Madre, two mountain ranges running west and east of the plateau. To the south is the Balsas Depression, a hot, dry and broken area with numerous small basins. Further south is the Mesa del Sur, with small isolated valleys, 1300 m to 1650 m above sea level. The Valley of Oaxaca is the largest and most densely populated of these valleys. The Southern Highlands consist of a series of mountain ranges and plateaux, including the Sierra Madre del Sur. The Isthmus of Tehuantepec is a narrow stretch of lowland (up to about 330 m altitude) with a hilly central area. The presence of *B. tabaci* south of the Central Plateau has not been well documented and it seems that *T. vaporariorum* may predominate as a pest of agricultural significance. The Chiapas Highlands are an extension of the mountain ranges of Central America. The Sierra de Soconusco runs along the Pacific Coast. The Grijalva river valley leads

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

northwest into the Tabasco Plain, an extension of the Yucatán Peninsula, bordering the Gulf of Mexico. This peninsula consists of flat, limestone terrain, seldom exceeding 160 m above sea level. The northernmost coastal area of the Yucatán Peninsula is an important horticultural area and has been affected by *B. tabaci* and different begomoviruses transmitted by this vector.

The main horticultural areas of Mexico affected by *B. tabaci* are the coastal lowlands that lie east and west of the Central Plateau. The Gulf Coastal Plain extends some 1400 km from the Texas border to the Yucatán Peninsula. The triangular northern portion is more than 160 km wide near the US border, narrowing southwards until it encounters the Sierra Madre Oriental close to the sea, north of Tampico. This is a swampy area with several lagoons and is called the Zona Lagunera. South of this constriction, the Gulf Coastal Plain runs, narrow and irregular, all the way to the Yucatán Peninsula. The narrower Pacific coastal lowlands begin near the Mexicali Valley in the north and end, also some 1400 km to the south, near Tepic, Nayarit. Parts of these arid regions have been irrigated since the 1930s and support intensive cropping systems of traditional and non-traditional (export) crops. Finally, Baja California is an isolated strip of arid land, about 1280 km long and 160 km wide. Most of the eastern side of this peninsula is mountainous, reaching elevations of almost 3000 m and sloping downwards towards the west.

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

The first report of *B. tabaci* as a vector of plant viruses in Mexico, in the early 1950s, is linked to the production of cotton (*Gossypium hirsutum* L.) in the Valley of Mexicali, Baja California (Cárdenas et al., 1996). The disease observed was probably "cotton leaf crumple", caused by a begomovirus transmitted by *B. tabaci*, previously observed in the United States near the Colorado River Valley (Brown, 1994). Around that time, *B. tabaci* was also associated with a disease of tomato (*Lycopersicon esculentum* Mill.), called 'chino del tomate', in the Valley of

Culiacán, Sinaloa, in north-western Mexico (Gallegos, 1978). In 1962, *B. tabaci* was observed attacking cotton in the Soconusco region of the southern state of Chiapas (Cardenas et al., 1996).

In 1978, *B. tabaci* caused considerable damage to horticultural crops in the Huasteca region, including parts of the states of Hidalgo, Tamaulipas, San Luis Potosí and Veracruz, where the Gulf Coastal Plain tapers to form a narrow strip that reaches all the way to the northernmost point of the Yucatán Peninsula. A disease believed to be *Bean golden yellow mosaic virus* (BGYMV) was observed for the first time in the north-western state of Sinaloa, in 1974 (López, 1974). When this disease occurred later (1990) in the state of Sonora, it was shown to be caused not by BGYMV but by a distinct virus, *Bean calico mosaic virus* (BCaMV) (Brown et al., 1990). BCaMV induces more striking golden mosaic symptoms, which eventually resemble a bleaching effect. The virus is not closely related to BGYMV but rather to *Squash leaf curl virus* (SLCV), a virus previously described attacking cucurbits in California (Flock and Mayhew, 1981). BGYMV emerged on the Gulf Coast of Veracruz in 1977. In 1979, it affected common bean plantings in Las Huastecas and in 1980 affected the same crop in the state of Chiapas (López-Salinas, 1994). Finally, in 1980, *B. tabaci* reached the Yucatán Peninsula, particularly the state of Yucatán, where it caused severe yield losses to horticultural crops as a pest and virus vector (Díaz-Plaza et al., 1996).

Most of the subsequent dissemination of whitefly-transmitted begomoviruses in Mexico has been associated with the boom in horticultural and other export crops that took place in the 1980s. The cultivation of melon (*Cucumis melo* L.), soybean (*Glycine max* [L.] Merr.), tomato and peppers (*Capsicum* spp. L.), has created conditions favourable for the reproduction of *B. tabaci* away from its traditional hosts such as cotton. These non-traditional export crops are currently planted in *B. tabaci*-affected regions such as the north-west, Las Huastecas and Yucatán. Among the most important viruses affecting horticultural crops in Mexico may be mentioned: Tomato chino (leaf crumple) virus, described in Sinaloa in 1970 (Gallegos, 1978); Serrano golden mosaic virus, in north-eastern Mexico (Sánchez et al., 1996) and Texas pepper virus (Stenger et al., 1990), both of which are regarded as *Pepper golden mosaic virus* (PepGMV); (Brown et al., 1993); *Pepper Huasteco yellow vein virus* (PHYVV) in pepper and tomato in Las Huastecas and Sinaloa (Hou et al., 1996); and “El Tigre” virus of pepper in Tamaulipas (Brown, 1989). In Yucatán, chilli pepper (*Capsicum* spp.), tomato, squash (*Cucurbita* spp. L.), melon, and watermelon (*Citrullus lanatus* [Thunb.] Matsum. & Nakai) have been attacked since the 1980s by *B. tabaci* and the begomoviruses this whitefly species transmits (Díaz-Plaza et al., 1996).

More recently, *Tomato mottle virus* (ToMoV), a begomovirus originally described from Florida, United States, was detected in the Yucatán Peninsula, also affecting tomato (Garrido and Gilbertson, 1998). In addition, PHYVV was found in Habanero varieties of chilli pepper and in pepper, and PepGMV was found in Habanero. PHYVV had already been detected infecting Jalapeño varieties of chilli pepper in the neighbouring state of Quintana Roo (Díaz-Plaza et al., 1996). Meanwhile, an Old World begomovirus, *Tomato yellow leaf curl virus* (TYLCV) has made its appearance in the Yucatán Peninsula (Ascencio-Ibáñez et al., 1999). This virus has caused yield losses in the

Caribbean estimated at millions of US dollars and thus poses an evident threat to agriculture in Mexico.

Advances in Biological Research

The participation of Mexican researchers in Sub-project 2 of the Tropical Whitefly Integrated Pest Management (TWF-IPM) Project provided an opportunity to gain an updated and more systematic view of the status of whitefly-borne viruses in the country. The Centro de Investigaciones y Estudios Avanzados (CINVESTAV), located at Irapuato, Guanajuato, was selected as the lead institution in Mexico. This Centre conducts research on begomoviruses affecting horticultural crops in Mexico. Dr. Rafael Rivera-Bustamante conducted surveys in collaboration with Dr. Irineo Torres-Pacheco, co-ordinator of the horticulture program of the Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP) at that time.

In the course of this project, samples were taken from crop plants showing begomovirus-like symptoms at a range of sites in major horticultural production areas of Mexico (Table 1) and assayed using monoclonal antibodies (Cancino et al., 1995). In addition, a wide-ranging survey was conducted of viruses affecting tomato and chilli in Mexico (Table 2). The results obtained demonstrate that begomoviruses can attack the main

Table 1. Analyses of plants affected by begomovirus-like diseases in Mexico.

Location	Plant (year)	Begomovirus[a]		Other viruses
		MAB-BS	MAB-GA	
Los Mochis, Sinaloa	Common bean (93)	+	-	-
Los Mochis, Sinaloa	Common bean (93)	+	-	-
J. Rosas, Guanajuato	Tomato	+	-	-
Dzemul, Yucatán	Squash	+	-	-
Dzemul, Yucatán	Chilli	-	-	-
Dzemul, Yucatán	Chilli	-	-	-
Dzemul, Yucatán	Chilli	+	-	-
Los Mochis, Sinaloa	Common bean	+	-	-
Los Mochis, Sinaloa	Common bean	+	-	-
Los Mochis, Sinaloa	Common bean	+	-	-
Los Mochis, Sinaloa	Squash	+	na	-
Los Mochis, Sinaloa	Squash	+	na	-
Los Mochis, Sinaloa	Squash	+	na	-
Culiacán, Sinaloa	Common bean	+	na	-
Culiacán, Sinaloa	Common bean	+	na	-
Culiacán, Sinaloa	Common bean	+	-	-
Culiacán, Sinaloa	Common bean	+	-	-
Culiacán, Sinaloa	Soybean	+	na	-
Culiacán, Sinaloa	Soybean	+	na	-
Culiacán, Sinaloa	Squash	+	na	-
Culiacán, Sinaloa	Squash	-	na	-
Etchojoa, Son.	Common bean	+	-	-

a. 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; and na, not analysed.

Table 2. Virus survey of tomato and chilli fields in 22 states of Mexico.

Sample	Plant	Locality[a]	State	N	W	V1[b]	V2[b]	V3
1	Sida	Chetumal	Q. Roo	18 30	88 15	TMV	TEV	-
2	Chilli	Chetumal	Q. Roo	18 30	88 15	PHYVV	TPV	-
3	Malvaceae	Campeche	Campeche	19 50	90 26	TMV	TEV	-
4	Weed	Uxmal	Yucatán	20 25	89 42	TMV	-	-
5	Chilli	Campeche	Campeche	19 50	90 26	PHYVV	-	-
6	Chilli	Sayula	Jalisco	19 50	103 30	TPV	-	-
7	Chilli	Sayula	Jalisco	19 50	103 30	TEV	-	-
8	Tomato	Sayula	Jalisco	19 50	103 30	TMV	PHYVV	-
9	Squash	Sayula	Jalisco	19 50	103 30	PHYVV	-	-
10	Euphorbia	Sayula	Jalisco	19 50	103 30	TPV	-	-
11	Sida	Sayula	Jalisco	19 50	103 30	PHYVV	-	-
12	Chilli	Tecomán	Colima	19 01	103 55	TMV	PHYVV	-
13	Chilli	Tecomán	Colima	19 01	103 55	TMV	-	-
14	Chilli	Tecomán	Colima	19 01	103 55	PHYVV	-	-
15	Chilli	Tecomán	Colima	19 01	103 55	TPV	-	-
16	Weed	Tecomán	Colima	19 01	103 55	TPV	-	-
17	Chilli	S. Ixcuintla	Nayarit	21 50	105 10	PHYVV	-	-
18	Chilli	S. Ixcuintla	Nayarit	21 50	105 10	TPV	-	-
19	Tomato	S. Ixcuintla	Nayarit	21 50	105 10	TPV	-	-
20	Chilli	Apaseo Alto	Guanajuato	20 35	100 25	PHYVV	-	-
21	Weed	Celaya	Guanajuato	20 32	100 49	TMV	-	-
22	Malvaceae	Los Angeles	R. Lagunera	25 32	103 30	TMV	-	-
23	Common bean	Los Angeles	R. Lagunera	25 32	103 30	TMV	-	-
24	Tomate	CIAN	R. Lagunera	25 32	103 30	TMV	-	-
25	Melon	CELALA	R. Lagunera	25 32	103 30	TMV	-	-
26	Tomate	CELALA	R. Lagunera	25 32	103 30	TMV	-	-
27	Chilli	Ciudad Isla	Veracruz	18 5.1	95 36	TPV	-	-
28	Chilli	Martinez dlt	Veracruz	20 5.0	97 5.0	PHYVV	TPV	-
29	Chilli	Papantla	Veracruz	20 30	97 12	PHYVV	-	-
30	Chilli	Papantla	Veracruz	20 30	97 12	PHYVV	TPV	-
31	Chilli	Poza Rica	Veracruz	20 33	97 26	PHYVV	-	-
32	Melampodium	Veracruz	Veracruz	19 9.5	96 6.4	TMV	CMV	TEV/TPV
33	Chilli	Guegovela	Oaxaca	16 46	96 49	TEV	-	-
34	Datura	S.L.Cacaote	Oaxaca	17 7.9	96 47	TPV	-	-
35	Tomato	Guegovela	Oaxaca	16 46	96 49	TEV	-	-
36	Chilli	Pabellón	Aguascal.	21 55	102 15	CMV	-	-
37	Chilli	Jalpa	Aguascal.	21 55	102 15	TEV	-	-
38	Malvaceae	Jalpa	Aguascal.	21 55	102 15	TEV	-	-
39	Chilli	Jaral Progr.	Aguascal.	20 30	101 6	TEV	TMV	CMV
40	Chilli	Jaral Progr.	Aguascal.	20 30	101 6	TEV	TMV	-
41	Chilli	Jaral Progr.	Aguascal.	20 30	101 6	TEV	CMV	-
42	Chilli	Paracuaro	Guanajuato	20 15	100 48	TEV	CMV	-
43	Chilli	Paracuaro	Guanajuato	20 15	100 48	TEV	CMV	-
44	Malvaceae	S. Luis Paz	Guanajuato	21 33	100 32	TMV	-	-
45	Malvaceae	S. Luis Paz	Guanajuato	21 33	100 32	TEV	-	-
46	Tomato	Yautepec	Morelos	18 50	99 11	PHYVV	-	-
47	Physalis	Yautepec	Morelos	18 50	99 11	PHYVV	-	-
48	Chilli	Yautepec	Morelos	18 50	99 11	PHYVV	TPV	-
49	Tomato	Metztitlán	Hidalgo	20 38	98 39	PHYVV	TPV	-
50	Chilli	Metztitlán	Hidalgo	20 38	98 39	PHYVV	-	-
51	Chilli	Salitral	S.L. Potosí	22 53	102 02	PHYVV	TPV	-
52	Tomato	Salitral	S.L. Potosí	22 53	102 02	PHYVV	-	-
53	Sida	Salitral	S.L. Potosí	22 53	102 02	PHYVV	-	-
54	Chilli	Apaseo	Querétaro	20 35	100 25	PHYVV	-	-

a. CIAN and CELALA are experiment stations in the Lagunera region of Mexico.
b. TMV, *Tobacco mosaic virus*; TEV, *Tobacco etch virus*; PHYVV, *Pepper Huasteco yellow vein virus*; TPV, *Texas pepper virus* (= *Pepper golden mosaic virus*); CMV, *Cucumber mosaic virus*.

horticultural crops grown in the country: common bean, tomato, chilli and squash. Additionally, a begomovirus was detected in soybean plants in Sinaloa State. Soybean is a host for *B. tabaci* in South America but its role in Mesoamerica as a reproductive host for this whitefly seems to have been secondary to that of other crops such as cotton and some horticultural crops. Nevertheless, *B. tabaci* reportedly destroyed over 5000 ha of soybean in the Valle del Fuerte, Sinaloa, in 1994 (INIFAP, 1995).

As noted above, golden mosaic symptoms in common bean in northern Mexico are caused by BCaMV, which is related to SLCV, a cucurbit virus originally recorded from the United States. In this project, we surveyed three key locations in the north-western region of Mexico—Etchojoa in Sonora, and Los Mochis and Culiacán in Sinaloa state—and took samples of common bean plants affected by symptoms of the disease. A partial molecular characterization of the viral isolates collected (Table 3) shows that BCaMV is still present in common bean plantings in north-western Mexico, specifically in Los Mochis. This isolate is still closely related to an isolate of BCaMV collected in the same locality in 1986. The sample from Culiacán represents a begomovirus closely related to BCaMV but already evolving into a new species (as indicated by a sequence homology of less than 90%). Perhaps of even greater interest is that the common bean begomovirus from Sonora is still identifiable as an isolate of the original SLCV, constituting the first direct evidence of the evolution of this virus.

Selected whitefly samples were also collected on different crops in north-western Mexico. Table 4 presents the

Table 3. Comparative sequence homologies (%) of common bean begomoviruses from north-western Mexico (Sonora and Sinaloa) and other whitefly-transmitted begomoviruses.

Virus isolate	ORF[a]	Common bean begomoviruses[b]				
		BGYMV-GA	BCaMV	SLCV	BCaMV-MO	BDMV
Etchojoa, Sonora	*AC1*	57.0	77.2	96.0	76.8	61.0
	AV1	72.2	75.4	97.8	74.9	74.2
Los Mochis, Sinaloa	*AC1*	69.8	89.7	70.5	88.3	68.8
	AV1	74.4	92.2	76.1	92.2	73.9
Culiacán, Sinaloa	*AC1*	74.3	83.0	69.1	81.8	74.6
	AV1	73.0	86.1	79.2	85.7	74.2

a ORF, open reading frame; *AC1*, replicase; and *AV1*, capsid protein.
b BGYMV-GA, *Bean golden yellow mosaic virus*-Guatemala; BCaMV, *Bean calico mosaic virus*; SLCV, *Squash leaf curl virus*; MO, Mochis; BDMV, *Bean dwarf mosaic virus*.

Table 4. Identification of *Bemisia tabaci* biotypes from Sinaloa, northern Mexico.

Locality	Crop	Biotype A	Biotype B
Los Mochis	Common bean	X	-
Los Mochis	Common bean	X	-
Los Mochis	Common bean	-	X
Los Mochis	Common bean	-	X
Los Mochis	Common bean	-	X
Culiacán	Eggplant	X	-
Culiacán	Eggplant	X	-
Culiacán	Eggplant	X	-
Culiacán	Eggplant	X	-
Culiacán	Eggplant	X	-

results of the molecular biotyping of the whiteflies collected. As can be observed, there is a mixed population of biotypes A and B of *B. tabaci*.

Finally, the project supported work conducted by INIFAP researcher, Genovevo Ramírez-Jaramillo, based in Mérida, Yucatán, on “the bio-ecology of the whitefly *B. tabaci* in the Yucatán Peninsula.” This work—which also included the Government of the State of Yucatán, the Secretary of Agriculture, Livestock and Rural Development, the Regional Research Centre for the South-east and the Fundación Produce de Yucatán—involved developing a geographical information system (GIS)-based model to predict the probability of whitefly and begomovirus attack.

According to the classification of Toledo (1989), Mexico can be divided into five major ecological zones. Interestingly, the northernmost portion of the Yucatán Peninsula belongs to the Dry Tropics (*Trópico Seco*), the same ecological zone as the northern Pacific Plains, where the *B. tabaci* thrives. In this dry zone, the annual precipitation ranges between 600 and 1500 mm and the mean annual temperature is over 20 °C. Although Yucatán is not one of the country’s main horticultural regions, in 1992 this peninsula cultivated over 11,000 ha of Habanero and Jalapeño chilli pepper, watermelon and tomato (listed in declining order of production area). However, the agriculture of the peninsula includes a diversity of other crops, including species that can act as reproductive hosts of *B. tabaci* such as soybean and cotton of which over 500 ha of each are grown.

The GIS-based model for whitefly and virus outbreaks drew on three components of a database developed by INIFAP: (1) a digital elevation model, (2) a climate database and (3) a soils database. For the biological parameters, a mean monthly temperature of 23-27 °C and annual rainfall of less than 50 mm were chosen as defining areas with a high probability of *B. tabaci* infestation. Whitefly population dynamics in Yucatán were influenced to a large extent by the amount of rainfall but only minimally by the temperature, which remains within a range that is favourable for whitefly development (Figure 1). Thus, the peak populations of *B. tabaci* occurred in the months of May and June, following 4-5 months (December-April) of low precipitation (0-18 mm/month). Based on all of these parameters, risk assessment maps for the Yucatán Peninsula were produced. The assessments will allow recommendations to be issued regarding the most appropriate planting dates for those crops most likely to be affected by *B. tabaci*, both as a pest and vector of plant viruses.

Socio-economic Analysis

The results of the biological surveys conducted during the course of the project show that whitefly-transmitted viruses and *B. tabaci* affect several crops of social and economic importance throughout Mexico, with the exception of the Central Highlands, where other whitefly species predominate.

In the Mexicali Valley, Baja California and the San Luis Río Colorado region of Sonora, *B. tabaci* attacked fields of cotton (damaging some 14,000 ha), summer melon (causing the loss of 1500 ha) and sesame (*Sesamum indicum* L.) (damaging 7500 ha) in the 1991-92 season, causing nearly US$10,000,000 in production losses (López, 1996). Some 3000 ha of Serrano chilli and tomato crops were lost between 1992 and 1995 in the central region of San Luis Potosí State, because of damage by *B. tabaci* and begomoviruses. Other crops colonized by *B. tabaci* in this region were common bean, cotton, *tomatillo* (*Physalis ixocarpa* B.), squash, melon, watermelon, cucumber (*Cucumis sativus* L. var. *sativus*), sweetpotato (*Ipomoea batatas* [L.] Lam.) and sunflower (*Helianthus annuus* L.) (Hernández et al., 1996).

B. tabaci caused severe yield losses to various horticultural crops, especially melon, in the Comarca Lagunera, Durango, in 1993 (Morales et al., 1996). *B. tabaci* attacked melon, chilli and cotton in the state of Coahuila, northern Mexico. The investigation that was conducted at the time showed that melon was an excellent host, cotton was a good host and chilli did not adequately support the reproduction of *B. tabaci* (Nava and Riley, 1996). Sonora has been one of the states in northern Mexico most affected by infestations of *B. tabaci* on various crops. An epidemiological study in the Valley of the Yaqui indicated that one of the main reproductive hosts of the whitefly in the valley was soybean (Pacheco, 1996). The incidence of whitefly-transmitted begomoviruses in common bean plantings in the valley of El Fuerte, Sinaloa, caused yield losses estimated at 20%-30% in the entire region, between February and June 1994 (Salinas et al., 1996). *B. tabaci* has been increasing its populations on cucumber in the valley of Culiacán, Sinaloa, since 1993, causing significant yield losses in over 9000 ha of this crop (Avilés and Valenzuela, 1996).

In the state of Nayarit, the fall-winter cropping cycle has been reduced by 50% because of the direct and indirect damage caused by *B. tabaci* as a pest and vector of viruses in tomato, common bean, chilli and eggplant (*Solanum melongena* L.) (Ortíz et al., 1996). Viruses transmitted by *B. tabaci* have severely affected tomato plantings in the state of Guerrero. In order to harvest tomato, farmers have resorted to treating their fields twice a week with insecticides (Barajas, 1996). And in the state of Yucatán, *B. tabaci* and whitefly-borne begomoviruses have affected horticultural crops such as hot peppers, tomato, squash, melon and watermelon since the 1980s (Díaz-Plaza et al., 1996).

The social and economic impact of these pest and disease outbreaks must be enormous. In the mid-1990s, horticultural and fruit crops occupied over 1 million hectares in Mexico. About 7 million tons of produce, mainly tomato, melon and watermelon were exported (principally to the United States, Canada, Japan and Brazil). The rest, some 35 million tons of squash, melon, pepper, tomato, potato, eggplant and chillis, was absorbed by the national market for local consumption, underlining the importance of these crops to the domestic economy. The production of horticultural crops demands considerable human labour. For instance, tomato requires 271 work-days per cropping cycle as compared with only 24 for maize (*Zea mays* L.). Production costs for maize were US$430 per hectare compared with US$3800 per hectare for tomato in 1990. The marketing of horticultural products is difficult because of their perishable nature and price instability. In 1988, over 50% of the farmers producing horticultural products in Mexico had less than 5 ha of land (FIRA, 1997). Overall, the incidence of whitefly-transmitted viruses affects a large portion of Mexico's rural population, many of whom can be considered small-scale farmers.

Strengthened Research Capacity

In addition to its research activities, CINVESTAV offers training to visiting scientists from developing countries. During the course of this project, two Cuban scientists conducted research on *Taino tomato mottle virus* (TToMoV), a whitefly-transmitted begomovirus affecting tomato in Cuba (Ramos et al., 1997). The project also contributed limited funds for research on viruses of economic importance in horticultural crops to the Horticulture Program of INIFAP, and paved the way for continuing collaboration between INIFAP and the current Tropical Whitefly Project. (The state of Yucatán is the main target area for the current Phase II of the project.)

Current Status of Whitefly/Begomovirus Problems

The whitefly/begomovirus situation in Mexico is rather complex because of the size and diversity of the country—and because of the introduction or emergence of different whitefly-transmitted viruses in both the north and the south. In the north, the intensive cropping systems for non-traditional export crops share not only a common border but also common whitefly/begomovirus problems with the equally intensive agricultural systems of the south-western United States. In the south, commercial and small-scale subsistence agriculture co-exist as an extension of the cropping systems found in Central America. Thus, it is not surprising to find some North American begomoviruses in northern Mexico and some Central American begomoviruses in southern Mexico.

Whereas the begomovirus situation on common bean has been partially controlled through the use of resistant cultivars, the situation of other horticultural crops affected by whitefly-transmitted begomoviruses such as tomato, pepper, chilli and melon is not yet resolved in most regions. Nevertheless, Mexico has made considerable progress in implementing integrated pest management (IPM) measures such as biological control, physical barriers (micro-tunnels) and other relevant cultural practices, and in developing the necessary knowledge base, including, for instance, virus characterization. Mexico is also at the forefront in using GIS technology for more effective management of agricultural resources.

More research is needed to study the epidemiology of *B. tabaci* biotypes and other whitefly species in agricultural regions with altitudes above 1000 m, including those in the states of Oaxaca, Guerrero, Morelos, Mexico, San Luis Potosí, Guanajuato and Durango. Suitable IPM measures should be rapidly implemented and evaluated to reduce dependence on chemical insecticides for whitefly control.

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