CHAPTER 2.4

Tanzania

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Introduction

Geographical context

The following regions were covered in the surveys conducted during the 1997-99 period: Arusha, Babati, Arumeru, Dodoma, Kongwa, Mpwapwa, Njombe, Iringa, Mwanga, Rombo, Moshi, Hai, Same, Mkuu, Mbeya, Vwawa, Tukuyu, Morogoro, Tanga, Lushoto and Zanzibar (Figure 1). Surveys followed the methodology agreed among the project partners.

The surveyed areas can be grouped into distinct eco-climatic zones (Table 1). The northern highlands cover the Arusha and Kilimanjaro regions and Usambara Highlands in the Tanga region. The zone experiences two rainy seasons: short rains (*vuli*) from November to December and long rains (*masika*) from March to May. The main dry season is from June to September. The coastal lowlands include such areas as Muheza, Tanga, Ruvu, Dar-es-Salaam, Kibaha and Zanzibar Island. The rainfall pattern is the same as for the northern highlands but the lowlands are hotter. The Central Plateau includes Dodoma and western

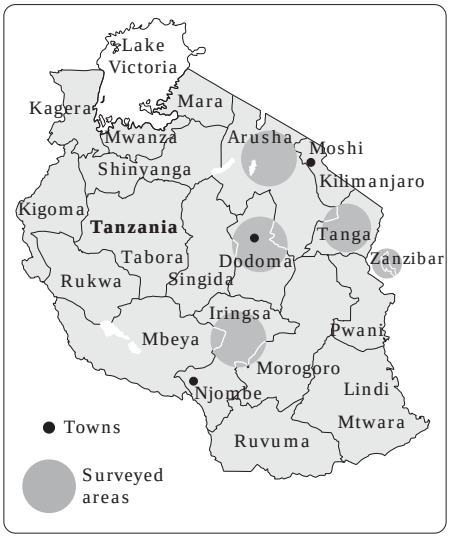

Figure 1. Regions covered in the 1997-99 survey, Tanzania.

parts of Morogoro regions, where the rainfall pattern is variable and unpredictable. The Morogoro region is transitional and receives higher rainfall than the Dodoma region. Dodoma experiences only one rainy season, around November to January, and production of vegetables in this zone is seasonal. Irrigation is common in both Morogoro and Dodoma.

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

The whitefly species *Bemisia tabaci* (Gennadius), the vector of *Tomato leaf curl virus* (ToLCV) and *Tomato yellow*

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Table 1. Mean annual temperature, precipitation and altitude range of the surveyed regions in Tanzania.

Region (Province)[a]	Mean min.-max. temperature (°C)	Mean precipitation (mm)	Altitude range (m)
Arusha	11-21	913	485-1660
Dodoma	16-29	556	329-378
Iringa	14-25	633	396-561
Kilimanjaro (Same)	14-26	1130	244-1600
Kilimanjaro (Moshi)	16-26	549	120-850
Mbeya	10-27	1132	424-536
Morogoro	19-30	854	450-900
Tanga (Lushoto)	19-30	1006	366-549
Zanzibar	21-30	1436	20-60

a. Same is on the windward side and Moshi, the leeward side, of Mt. Kilimanjaro.

leaf curl virus (TYLCV), is ranked as the most important insect pest of tomato (*Lycopersicon esculentum* Mill.) in Tanzania (Varela and Pekke, 1995). *B. tabaci* also transmits other viral diseases in common bean (*Phaseolus vulgaris* [L.]), cowpea (*Vigna unguiculata* [L.] Walp.), sweetpotato (*Ipomoea batatas* [L.] Lam.) and cassava (*Manihot esculenta* Crantz), while the woolly whitefly *Aleurothrixus floccosus* (Maskell) is widespread in citrus (*Citrus* spp. L.) growing areas. No information was available on the geographical range of whitefly species and their socio-economic significance in Tanzania prior to the country's participation in the Tropical Whitefly Integrated Pest Management (TWF-IPM) Project.

ToLCV was first reported in Tanzania in 1990 (Czosnek et al., 1990). Additional survey studies conducted by the Asian Vegetable Research and Development Centre (AVRDC)-Africa Regional Program in Tanzania from 1994-97 showed that several tomato samples with typical leaf curl symptoms did not hybridize with the Egyptian or Israeli ToLCV-DNA probes. Polymerase chain reaction (PCR) analysis performed with the above tomato samples indicated that in addition to TYLCV, a virus different from all previously characterized tomato geminiviruses of the Old World occur in Tanzania and was tentatively named *Tomato leaf curl virus-Tanzania* (TLCV-Tan; Chiang et al., 1997), now ToLCV-Tz.

Increased Biological Understanding

Characterization of begomoviruses and whitefly biotypes

During the 1997-99 period, 179 samples of whitefly adults and nymphs were collected from vegetable cropping systems in Tanzania, of which 407 nymph specimens were histologically processed and mounted on 213 slides. Identification of whiteflies conducted by the International Center of Insect Physiology and Ecology (ICIPE) revealed that *B. tabaci* was the most common whitefly species, representing 78% of the mounted specimens. *B. afer* (Priesner and Hosney) represented 8% and *Trialeurodes vaporariorum* (Westwood), 7%. Other whitefly species made up 7% of the specimens and included *Trialeurodes ricini* (Misra), *B. hirta* Bink-Moenen, *Orchamoplatus citri* (Takahashi), *Tetraleurodes andropogon* (Dozier) and *Aleurothrixus floccosus* (Maskell).

The reproductive host plants of whiteflies identified from the surveys in Tanzania belong to the following families: *Amaranthaceae*, *Asteraceae*, *Commelinaceae*, *Convolvulaceae*, *Cucurbitaceae*, *Euphorbiaceae*, *Lamiaceae*, *Leguminosae*, *Myrtaceae*, *Rutaceae*, *Solanaceae* and *Verbenaceae*. Table 2 gives the scientific names of the host plant species on which each whitefly species was found to be reproducing. Whiteflies were abundant on common bean but no whitefly-transmitted disease symptoms were observed.

ToLCV symptoms were observed in *Achyranthes aspera* L., *Euphorbia heterophylla* L. and *Nicandra physalodes* (L.) Gaertn. Nono-Womdim et al. (1996) identified TYLCV, the causative virus in these hosts. These non-cultivated host plants are widespread in the country and may serve as major reservoirs of TYLCV.

Disease incidence and symptom severity

Areas identified as "hot spots" for ToLCV incidence in Tanzania include Morogoro, Dodoma, Kilimanjaro (especially Same) and Arusha (Figure 1). Fifteen percent of the surveyed farms had 100% ToLCV incidence in their tomato crop. It should be highlighted that all surveyed farms in Morogoro (Dakawa, Kariakoo, Kipela, Kibundi, Kiruka and Bigwa) had 100% TLC incidence. Up to 100% of the crop also were reported to be affected in Kilimanjaro (Marwa, Bangalala and Same) and Dodoma (Mbalala, Chikula and Mpwapwa). Nine percent of the surveyed farms had ToLCV incidences ranging from 70% to 99%. These were in Arusha (Baraa), Kilimanjaro (Mijongomeni, Kivulini and Mkolowoni) and Dodoma (Msolota). Ten percent of the surveyed farms had ToLCV incidences ranging from 50% to 69%, while 65% of the farms had incidences ranging from 1%-19%. The lowest incidences of ToLCV symptoms, 1%-2%, were observed in the southern part of Tanzania (Iringa, Mbeya, Tukuyu and Njombe) and in Zanzibar. There were no distinct ToLCV-free zones found within the surveyed areas of Tanzania. ToLCV incidence was highest during the summer months (hot season), from December to March. Yield loss due to ToLCV depends on the susceptibility of the tomato cultivar, the crop stage at the time of infection and environmental conditions (Nono-Womdim et al., 1999).

Twenty-three tomato accessions, including progenies of crosses between *Lycopersicon chilense* Dunal LA 1969 and cultivated tomato, were field-screened for resistance to ToLCV by AVRDC (Nono-Womdin et al., 1999). Two commercial F_1 hybrids, Fiona and Tyking, had the highest level of resistance. Plants of these varieties were symptomless and they did not hybridize with Israel TYLCV-DNA probe. The varieties PSR-403511 and PSR-407111 were also resistant to ToLCV but hybridization tests showed that a few symptomless plants contained ToLCV DNA. The following progenies of crosses between *L. chilense* LA 1969 and *L. esculentum* had 30%-60% resistant plants: Chilytlc 94-1, 94-2, 94-4, 94-5, 94-6 and MultichilTLC. Tests on two commonly grown commercial tomato varieties, Moneymaker and Roma, showed 100% susceptibility.

Natural enemy species

Samples of whitefly parasitoids and predators were collected during the surveys. Preliminary identification of the sampled parasitoids showed that most were *Encarsia sophia* (Girault and Dodd), while *Eretmocerus* sp. was collected on only two occasions. A number of predators, coccinellids and predatory bugs were also collected in the vicinity of whitefly populations in the survey fields.

Table 2. Reproductive host plants of whitefly species encountered during surveys in Tanzania.

Whitefly species	Crops		Non-cultivated hosts	
	Family	Species	Family	Species
Bemisia tabaci (Gennadius)	Convolvulaceae	*Ipomoea batatas* (L.) Lam.	Amaranthaceae	*Achyranthes aspera* L.
	Euphorbiaceae	*Manihot esculenta* Crantz		*Amaranthus* sp.
	Leguminosae	*Desmodium* sp.	Asteraceae	*Ageratum conyzoides* L.
		Vigna unguiculata (L.) Walp.		*Bidens pilosa* L.
		Phaseolus vulgaris L.		*Galinsoga parviflora* Cav.
	Myrtaceae	*Psidium guajava* L.	Commelinaceae	*Commelina* sp.
	Solanaceae	*Lycopersicon esculentum* Mill.	Euphorbiaceae	*Euphorbia heterophylla* L.
		Solanum tuberosum L.	Leguminosae	*Tephrosia* sp.
			Lamiaceae	*Leonotis nepetifolia* (L.) R. Br.
			Verbenaceae	*Lantana camara* L.
Bemisia afer (Priesner and Hosney)	Euphorbiaceae	*Manihot esculenta* Crantz		
	Leguminosae	*Phaseolus vulgaris* L.		
Trialeurodes vaporariorum (Westwood)	Leguminosae	*Desmodium* sp.	Euphorbiaceae	*Euphorbia heterophylla* L.
		Vigna unguiculata (L.) Walp		
		Phaseolus vulgaris L.		
Trialeurodes ricini (Misra)	Cucurbitaceae	*Citrullus lanatus* (Thunb.) Matsum & Nakai	Amaranthaceae	*Achyranthes aspera* L.
	Euphorbiaceae	*Manihot esculenta* Crantz	Asteraceae	*Galinsoga parviflora* Cav.
	Leguminosae	*Desmodium* sp.		
		Phaseolus vulgaris L.		
Bemisia hirta Bink-Moenen			Euphorbiaceae	*Euphorbia heterophylla* L
Orchamoplatus citri (Takahashi)				Plant unidentified
Tetraleurodes andropogon (Dozier)				Plant unidentified
Aleurothrixus floccosus (Maskell)	Rutaceae	*Citrus* spp.		

Geographical range of whitefly and whitefly-transmitted virus infestation

B. tabaci was the most common whitefly species throughout the country (Table 3). *B. afer* was common in cassava in the areas of Iringa, Arusha, Mbeya and Kilimanjaro (Moshi). *T. vaporariorum* was encountered in Arusha, Dodoma, Iringa, Kilimanjaro (Same), Mbeya and Tanga (Lushoto) but not in Morogoro, Kilimanjaro (Moshi) or Zanzibar. *T. ricini* was common in Arusha, Iringa and Mbeya. *A. floccosus* was collected only from citrus. The few specimens identified as *B. hirta* require additional confirmation.

Up to 100% ToLCV incidence was found at altitudes ranging from 260 to 1060 m, while ToLCV incidence of up to 70% was encountered as high as 1460 m altitude (Table 4). *B. tabaci* was the prevalent whitefly species up to an altitude of 1260 m, while the two *Trialeurodes* species mentioned above were prevalent at higher altitudes (Table 4).

Table 3. Species composition (%) of whitefly samples collected in regions of Tanzania.

Province[a]	Species composition[b]							
	B.t.	B.a.	T.v.	T.r.	B.h.	O.c.	T.a.	A.f.
Arusha	48	18	8	14	2	0	0	10
Dodoma	90	2.5	2.5	5	0	0	0	0
Iringa	37.5	25	25	12.5	0	0	0	0
Kilimanjaro (Same)	96	2	2	0	0	0	0	0
Kilimanjaro (Moshi)	89	11	0	0	0	0	0	0
Mbeya	40	17	33	10	0	0	0	0
Morogoro	99	0	0	0	0	1	0	0
Tanga (Lushoto)	91	2	5	2	0	0	0	0
Zanzibar	83	0	0	0	0	0	17	0

a. Same is on the windward side and Moshi, the leeward side, of Mt. Kilimanjaro.
b. B.t., *Bemisia tabaci*; B.a., *B. afer*; T.v., *Trialeurodes vaporariorum*; T.r., *T. ricini*; B.h., *B. hirta*; O.c., *Orchamoplatus citri*; T.a., *Tetraleurodes andropogon*; A.f., *Aleurothrixus floccosus*.

Table 4. Maximum incidence (% of sampled plants showing disease symptoms) of tomato leaf curl (TLC) encountered and species composition (%) of whitefly samples collected at different altitudes in Tanzania.

Altitude (m)	Maximum TLC incidence	Whitefly species composition[a]							
		B.t.	T.v.	T.r.	B.a.	A.f.	B.h.	T.a.	O.c.
0-60	4	83	0	0	0	0	0	17	0
60-260	100	91	9	0	0	0	0	0	0
260-460	100	88	3	4	5	0	0	0	0
460-660	100	66	18	7	9	0	0	0	0
660-860	100	84	0	0	14	0	2	0	0
860-1060	100	44	0	0	0	56	0	0	0
1060-1260	50	75	13	12	0	0	0	0	0
1260-1460	70	0	0	100	0	0	0	0	0
1460-1660	15	14	43	0	43	0	0	0	0

a. B.t., *Bemisia tabaci*; T.v., *Trialeurodes vaporariorum*; T.r., *T. ricini*; B.a., *B. afer*; A.f., *Aleurothrixus floccosus*; B.h., *B. hirta*; T.a., *Tetraleurodes andropogon*; O.c., *Orchamoplatus citri*.

Increased Socio-economic Understanding

Farmers' assessment of whitefly-related problems

Tomato is one of the most important vegetables cultivated in Tanzania. Most (79%) of the tomato producers interviewed used their own land for production, while 17% used rented land. A vast majority of the producers (92%) were men. Almost all the producers (96%) regarded tomato as their most profitable vegetable crops and 62% of producers have been involved in vegetable farming for more than 5 years. Although tomato production has increased in the last 5 years to meet increased demand for processing and fresh markets, the average yields remain low at about 10-14 tons per hectare.

The main tomato varieties cultivated in Tanzania are Marglobe, Moneymaker and Roma VF, all of which are highly susceptible to several viral diseases. Most producers (60%) obtain planting material from the local market, 36% use their own seeds and 4% get planting material from other tomato producers. Other commonly grown vegetable crops include cowpea, pea (*Pisum sativum* L.), common bean, cabbage (*Brassica oleracea* L. var. *capitata* L.), onion (*Allium cepa* L.), Irish potato (*Solanum tuberosum* L.), eggplant (*Solanum melongena* L.), sweet pepper (*Capsicum annuum* L.), okra (*Abelmoschus esculentus* [L.] Moench), sweetpotato, *Amaranthus* spp., watermelon (*Citrullus lanatus* [Thunb.] Matsum. & Nakai), melon (*Cucumis melo* L.), cucumber (*Cucumis sativus* L. var. *sativus*) and other cucurbits. Whiteflies also attack most of these crops. The great majority (94%) of the producers interviewed practice crop rotation.

Producers ranked their pest and disease problems in tomato and associated vegetable crops in Tanzania (in order of importance) as follows: late blight (*Phytophthora infestans* [Mont.] de Bary), TLC, fruit borers (*Helicoverpa armigera* [Hübner]), whiteflies (Homoptera: Aleyrodidae), aphids (Aphididae), *Fusarium* wilt, early blight (*Alternaria solani* [Ell. and Mart.] Jones and Grout), red spider mite (*Tetranychus urticae* Koch.), diamond back moth (*Plutella xylostella* [L.]), angular leaf spot (*Pseudomonas syringae* pv. Lachrymans), bruchids (Coleoptera: Bruchidae), bacterial leaf spot (*Xanthomonas campestris* pv. *visicatoria*), leaf miner (*Lyriomyza* spp.), beanfly (*Ophiomyia* spp.), cutworm (*Spodoptera litura* [Fabricius]), powdery mildew (*Leveillula taurica*), black rot (*X. campestris* pv. *campestris*), fruit fly (*Drosophila melanogaster*), bacterial canker (*Clavibacter michiganensis*), bean rust (*Uromyces phaseoli*), *Tomato mosaic virus*, *Septoria* leaf spot (*Septoria lycopersici*), nematodes (*Meloidogyne* spp.), *Cucumber mosaic virus*, thrips (Thysanoptera: Thripidae), cabbage sawfly (*Nematus* spp.) and soft rot (*Erwinia carotovora*).

Most producers (90%) were able to recognize the whitefly and 84% also recognized ToLCV. Only 11% of the interviewed producers knew that whiteflies and ToLCV were interrelated. None of the interviewed producers from Morogoro (where the disease incidence was 100% on all surveyed farms) knew the cause of ToLCV; they did not have names for the whiteflies other than "insects", nor did they have precise names for ToLCV. Most producers (75%) believed that the whiteflies caused problems on their farms. Almost half of them (43%) believed that both whiteflies and ToLCV caused problems, whereas 30% attributed the problems to ToLCV only and 27% to whiteflies only.

Local names given to whiteflies included *chawa* (lice), *inzi weupe* (white flies), *kibanda, kifizi, kipe weupe, kipepeo* (small butterflies), *kurukury, mbuu, msubi weupe, mvumuu, ndaka, sughru* (small flying insects), *sunhuu, suru, tukorokotwa, wadudu* (insects) and *wadudu weupe* (white insects). The local names given to ToLC included *rasta* (dreadlocks), *ugonjwa wa kukunja* (curling disease), *ukoma* (leprosy), *dume* (sterile), *ghojo, kibangi, kudulala, kutu* (rust), *bondia, majani, masai, mdamango, mwanga bondia, ngofu, ngumi* (boxer), and *kibangi* and *kobe* (tortoise).

Estimation of disease incidence and yield losses

Among the surveyed farms, 99% had TLC symptoms in their tomato crop and 34% had ToLCV incidences above 25%. Common symptoms include leaf curling, yellowing, chlorosis of leaf margins, leaf distortion, reduction in leaf size, shortening of the internodes, stunting, excessive branching and flower abscission (Nono-Womdim et al., 1999). The average perceived yield loss in tomatoes due to the whitefly/ToLCV complex was 45%. Some producers (9%) reported a total yield loss, 13% reported three-quarters yield loss, 32% reported half yield loss, 42% reported one-quarter yield loss and only 5% of the producers reported no yield loss.

Most of the producers interviewed (74%) believed that they had whitefly and/or virus problems every year and 26% reported that the most severe problems occurred in 1997. Most producers (94%) also believed that there is a relationship between climate and whitefly/ToLCV occurrence. The majority (90%) believe that the problem is worst during the hot season, between December and March, while the problem is less pronounced between August and December. The producers mostly attributed the increase in severity to weather changes, particularly long dry spells. Other factors mentioned by some producers were ineffective insecticides, resistance to insecticides and old crop remains (acting as a source of infestation and virus reservoir).

Producers gave estimation of the costs involved in crop protection measures (see below). The costs were mainly incurred in the purchasing of chemical insecticides and labor for their application.

Costs estimated by producers in control of whitefly/TYLCV complex per hectare of tomato

US$	% producers
0-49	40
50-99	18
100-199	26
200-299	9
300-400	7

Pesticide use

One-third of producers (35%) received recommendations on management practices from technical advisors, 35% from other tomato producers, 3% from sales agents, 10% from others and 17% relied on their own judgement. Among those producers who applied insecticides, the decision on what insecticides to apply and when was made by the producer in 93% of the cases, while 6% relied on technical advice.

Use of pesticides was the most common option for managing the whitefly/ToLCV problem and was practiced by 76% of those interviewed. Cultural control was practiced by 11% of the producers, while 13% did not practice any control. The pesticides most commonly applied by vegetable producers in Tanzania for control of whitefly/disease problems on their

farms are profenofos, chlorpyrifos, fenitrothion, dimethoate, pirimiphos-methyl, chlorpyrifos and diazinon (organophosphates); deltamethrin, lambda-cyhalothrin and fenvalerate (pyrethoids); thiodan and endosulfan (organochlorines); and methomyl (carbamate).

Producers who made 10 insecticide applications per season to manage the whitefly/ToLCV complex accounted for 21% of those interviewed. Those who made from five to eight applications comprised 31% of interviewees and a similar percentage made from one to four applications. However, 18% reported that they did not apply insecticides. Most producers (62%) applied insecticides as a preventive measure, 26% made the application when they observed damage and 6% made the application according to the calendar.

Strengthened Research Capacity

This survey has substantially improved our understanding of the magnitude of the whitefly-associated problems in the major vegetable production areas of Tanzania. The work conducted under this first, diagnostic, phase of the TWF-IPM Project also has strengthened collaboration between the national agricultural research organization and international research institutions such as ICIPE and AVRDC.

Conclusions

TYLCV is the most important whitefly-transmitted viral disease in tomato cropping systems in Tanzania. The disease causes significant yield loss in tomato production in various parts of the country. The lowlands of Morogoro and Dodoma were identified as the principal "hot spots" for ToLCV, where incidences of symptoms of 100% were frequently encountered. Moderately high incidences were also observed in the Arumeru Highlands near Arusha and Kilimanjaro.

Commercial cultivars of tomato grown in Tanzania are susceptible to TYLCV. Some breeding lines from the African Regional Program (ARP) of AVRDC at Arusha have shown significant tolerance to TYLCV. AVRDC-ARP in collaboration with the Horticultural Research and Training Institute (HORTI-Tengeru) have begun efforts to screen a broad array of tomato germplasm and incorporate the resistance genes into cultivated tomato varieties.

Further work in Tanzania, under the second phase of the TWF-IPM Project, should focus on evaluation of germplasm for use in breeding for resistance to TYLCV and ToLCV, and development of IPM options for the management of the whitefly vector.

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