# CHAPTER 2.2

# Sudan

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## Introduction

### *Geographical context*

Diagnostic surveys were conducted during 1997-99 following the methodology agreed among project partners, and covering Gezira, Butana, Dindir, Hasaheisa, Kamlin, Managil, Umulgra, White Nile, El Jabalain, Um Rawaba, Er Rahad, Dongola, Merewe, Gedaref and Nahr el Rahad in central, eastern, northern and western Sudan (Figure 1). Most of the surveyed sites are low lying (< 500 m above sea level). The climate is hot and dry for most of the year, with temperatures in summer reaching more than 40 °C and relative humidity less than 10%, and irrigation is commonly used. The driest of the survey areas are Dongola and Merewe in the Northern State. Gedaref region and some areas in Kordufan Province are at a somewhat higher altitude (> 500 m above sea level) and receive enough rainfall for rain-fed vegetable production.


Figure 1. Areas surveyed for whitefly incidence in the Sudan.

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

The whitefly species *Bemisia tabaci* (Gennadius) is considered to be the economically most important crop pest in the Sudan (Eveleens, 1983; Ahmed et al., 1987). In addition to the direct damage this whitefly causes through feeding, it disseminates a number of viruses that affect fibre and vegetable crops grown in the country.

Research on *B. tabaci* and whitefly-transmitted viruses (WTVs) in Sudan started in the late1920s, when recurrent outbreaks of C*otton leaf curl virus* (CLCuV), transmitted by *B. tabaci*, threatened to end cultivation of cotton (*Gossypium hirsutum* L.) in the Gezira (Kirkpatrick, 1931). Since then, a considerable research effort has been focused on *B. tabaci* and WTVs in

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cotton, leading to the introduction of CLCuV-resistant varieties in the Gezira in the late 1960s. However, research on whitefly-related problems in vegetable crops has been limited. Vegetables are severely affected by WTVs and the incidence of WTVs in a given season constitutes the major factor determining the success or failure of tomato (*Lycopersicon esculentum* Mill.), cucurbits, okra (*Abelmoschus esculentus* [L.] Moench), pepper (*Capsicum annuum* L.) and common bean (*Phaseolus vulgaris* L.) in that season. It is estimated that, on average, 75% of the fruit yield of tomato, watermelon (*Citrullus lanatus* [Thunb.] Matsum. & Nakai), musk melon (*Cucumis melo* L.) and okra is lost each year to WTVs.

Yassin and Nour (1965) first reported *Tomato leaf curl virus*, transmitted by *B. tabaci*. Later investigations showed that the virus from Sudan is similar to *Tomato yellow leaf curl virus* (TYLCV) from the East Mediterranean region. In recent years, severe yellowing symptoms were observed in watermelon and melon grown in many parts of the country, similar to those described for the *B. tabaci*-transmitted *Watermelon chlorotic stunt virus* (WmCSV) in Yemen. CLCuV not only affects cotton but also has been reported by many workers to cause heavy damage in okra in most parts of the country. Both cotton and okra belong to the mallow family. According to some workers (cited by Dafalla and Sidig, 1997) the whitefly-transmitted African cassava mosaic disease is still the most destructive in cassava in Western Equatoria Province in southern Sudan.

At producer level, research efforts have not been reflected sufficiently in the successful management of *B. tabaci* and WTVs, especially in vegetables. In the absence of such management strategies, the problem has become more complicated and has defied vegetable producers' efforts to overcome it and secure a return for their efforts. The need to design viable integrated control strategies, based on a strong scientific foundation and knowledge of the field situation, has emerged as a major challenge for research.

Little information was available on the whitefly-related problems of vegetable production in Sudan prior to the commencement of the Tropical Whitefly Integrated Pest Management (TWF-IPM) Project. Many findings from the survey conducted in the first, diagnostic phase of the project are new and add substantially to our knowledge base on biological and socio-economic aspects of the whitefly and WTV problems of vegetable cropping systems in Sudan.

## Increased Biological Understanding

### *Characterization of begomoviruses and whitefly biotypes*

Samples of whitefly adults and nymphs were collected mostly from tomato, with a few from lablab (*Lablab purpureus* [L] Sweet) and Nalta jute (*Corchorus olitorius* L.), on 80 farms. One hundred and fifty specimens were processed and mounted on 76 slides and sent to the International Center of Insect Physiology and Ecology (ICIPE) for identification. All the mounted nymph specimens were identified as *B. tabaci*.

In an experimental field at the University of Gezira, severe silver leaf symptoms were noticed on squash (*Cucurbita pepo* L.), heavily infested with whiteflies. These symptoms have been associated elsewhere with the

*B. tabaci* B-biotype (Shapiro, 1995) but molecular characterization of these whitefly specimens is still pending. In general, some variability has been noticed in the patterns of behaviour and efficiency in virus transmission, which also may be circumstantial evidence of the existence of different *Bemisia* biotypes.

Host plants on which whiteflies were found to reproduce, identified in the course of surveys in Sudan, belonged to the following families: *Amaranthaceae*, *Asclepiadaceae*, *Asteraceae*, *Brassicaceae*, *Commelinaceae*, *Convolvulaceae*, *Cucurbitaceae*, *Euphorbiaceae*, *Lamiaceae*, *Leguminosae*, *Malvaceae*, *Solanaceae*, *Tiliaceae* and *Verbenaceae* (Table 1).

Many of the WTVs in vegetables in Sudan have been well characterized but more information on the inter-seasonal variation of virus incidence and on the distribution and economic importance of various WTVs in the different regions is needed. The field surveys revealed that TYLCV, WmCSV, *Okra leaf curl virus* and *Pepper leaf curl virus* are the most widespread and economically important WTVs in Sudan. Tomato, watermelon, melon, okra, pepper and common bean were among the most affected crops.

Other viruses detected include Tomato vein thickening virus, which causes another important disease of tomato in Sudan and *Bean mild mosaic virus* (BMMV). *Cucumber vein yellowing virus* (CVYV) and a virus inducing potyvirus-like yellowing have been observed in cucurbits but the latter is yet to be identified. In legumes, a geminivirus and a *Closterovirus* that affect cowpea (*Vigna unguiculata* [L.] Walp.) and common bean have been observed and are yet to be identified. Symptoms of another putative WTV, whose identity is yet to be established, were also noticed on pepper.

Some weeds, *Acalypha indica* L., *Datura stramonium* L. and *Solanum coagulans* Forskål, were identified as TYLCV reservoirs. Many other non-cultivated host plants of *B. tabaci* may act as WTV reservoirs. Continuous cultivation of tomato and other solanaceous vegetables, coupled with the abundance of alternative hosts for vector and viruses, is very likely to contribute to the build up of disease problems.

## *Disease incidence and symptom severity*

The Gezira Irrigation Scheme is the area with the most severe and persistent WTV disease problems in the country. Incidences of 80-100% were frequently recorded in Gezira, Hasaheisa, Managil, Umelgura, Dindir and Butana. In half of the tomato fields in the Gezira Province, 100% TYLCV incidence was recorded. *B. tabaci* was found to be more abundant in the southern part of Gezira that receives less rainfall than the northern region. High whitefly populations and TYLCV incidence were observed in Central Sudan, significantly lower populations and TYLCV incidences (1%-9%) were observed in Nahr el Rahad (Eastern State), Dongola and Merewe (Northern State), and in Umm Rawaba and Er Rahad (Western State). No TYLCV symptoms were observed in Gedaref Province (Babiker, Khor-Garab, El Ramla, Basunda, Doka) and the Abu Habil Basin. Vegetable gardens along the Blue Nile River were once the sole suppliers of tomato outside the period suitable for rain-fed cultivation. This is no longer the case because of severe TYLCV epidemics in recent years.

The overall impression provided by the surveys is that *B. tabaci* does not

Table 1. Reproductive host plants of *Bemisia tabaci* (Gennadius) in the Sudan.

| Family | Species | Common name |
|---|---|---|
| Crops | | |
| Brassicaceae | *Raphanus sativus* L. | Radish |
| Cucurbitaceae | *Citrullus lanatus* (Thunb.) Matsum & Nakai | Watermelon |
| | *Cucumis melo* L. | Melon |
| | *Cucumis sativus* L. | Cucumber |
| | *Cucurbita pepo* L. | Squash |
| Euphorbiaceae | *Manihot esculenta* Crantz | Cassava |
| Leguminosae | *Cajanus cajan* (L.) Millsp. | Pigeon pea |
| | *Cassia alexandrina* Mill. | Senna |
| | *Lablab purpureus* (L.) Sweet | Lablab |
| | *Lens culinaris* Medik. subsp. *culinaris* | Lentil |
| | *Phaseolus vulgaris* L. | Common bean |
| | *Vicia faba* L. | Broad bean |
| Lamiaceae | *Ocimum basilicum* L. | Basil |
| Malvaceae | *Abelmoschus esculentus* (L.) Moench | Okra |
| | *Gossypium hirsutum* L. | Cotton |
| | *Hibiscus cannabinus* L. | Kenaf |
| Solanaceae | *Capsicum annuum* L. | Pepper |
| | *Lycopersicon esculentum* Mill. | Tomato |
| Tiliaceae | *Corchorus olitorius* L. | Nalta jute |
| Non-cultivated hosts | | |
| Amaranthaceae | *Achyranthes aspera* L. | |
| | *Amaranthus tricolor* L. | |
| Asclepiadaceae | *Leptadenia* sp. | |
| Asteraceae | *Ageratum conyzoides* L. | |
| | *Bidens pilosa* L. | |
| | *Sonchus* sp. | |
| Commelinaceae | *Commelina benghalensis* L. | |
| Convolvulaceae | *Ipomoea cordofana* Choisy | |
| Euphorbiaceae | *Acalypha indica* L. | |
| | *Euphorbia aegyptiaca* Boiss. | |
| | *Euphorbia heterophylla* L. | |
| Leguminosae | *Rhynchosia hirta* (Andrews) Meikle & Verdc. | |
| Malvaceae | *Abutilon pannosum* (G. Foster) Schltdl. | |
| Solanaceae | *Datura stramonium* L. | |
| | *Solanum incancum* L. | |
| | *Solanum nigrum* L. | |
| Verbenaceae | *Lantana camara* L. | |

cause major problems outside of areas where cotton is cultivated. For example, in the Abu Habil Basin, where no cotton is grown, tomato is typically produced without whitefly infestation. Similarly, OLCV is present in many parts of the country where cotton is grown, whereas WmCSV is present in almost all melon production areas.

## *Natural enemy species*

Seventeen collections of whitefly parasitoids and predators were made

and preliminary identification made. The most common parasitoids of *B. tabaci* were found to be *Encarsia lutea* (Masi) and *Eretmocerus mundus* Mercet. The following natural enemies that were found in the vegetable-based systems in the country also could be involved in regulating *B. tabaci* populations: the coccinellids *Coccinella undecimpunctata* L., *Hippodamia variegata* (Goeze), *Cheilomenes sulphurea* (Olivier) and *Scymnus* sp.; the lacewings *Chrysoperla pudica* (Navás) and *Chrysoperla* spp.; pirate bugs, *Orius* sp.; other predatory true bugs *Campylomma* sp. and spiders.

## Increased Socio-economic Understanding

### *Farmers' assessment of whitefly-related problems*

More than 95% of vegetable production in the surveyed areas is carried out on small-scale holdings of 2 to 5 ha. Among tomato producers in Sudan, 40% farmed their own land, 38% used rented land, while 22% were squatters. Virtually all farmers interviewed (99%) were men. Almost all the producers interviewed (94%) regarded tomato as the most profitable of the horticultural crops they could grow and most (74%) have cultivated tomato for more than 5 years. The varieties of tomato most widely grown in Sudan were Moneymaker, Strain B, Peto 86, Pearson, Early pack and Ace. Most producers (65%) bought their tomato seed from the local market, while 28% used their own seed and 7% imported seed from other countries. Other commonly grown vegetable crops include cucurbits (especially melon and cucumber), okra, common bean, pepper, eggplant (*Solanum melongena* L.), sweetpotato (*Ipomoea batatas* [L.] Lam.), radish (*Raphanus sativus* L.), onion (*Allium cepa* L.), carrot (*Daucus carota* L. subsp. *sativus* [Hoffm.] Arcang. var. *sativus* Hoffm.) and leafy vegetables. Most producers (82%) practised crop rotation.

Whiteflies and/or WTVs were found to be the greatest cause of concern to most tomato producers in the survey. Other destructive pests reported were *Helicoverpa armigera* (Hübner), *Liriomyza sativae* Blanchard, *Scrobipalpa* sp. and *Keiferia lycopersicella* (Walshingham).

Most tomato producers in Sudan (75% overall, including all those in Central Sudan) were able to recognize whiteflies and even more (89%) recognized TYLCV. However, 65% of them did not know that TYLCV and *B. tabaci* were inter-related. The majority (84%) believed that whiteflies and/or TYLCV were serious production constraints in their farms. Whereas 65% of the producers reported that TYLCV was a problem, only 35% reported that both the whitefly and the disease were problematic, and none reported a problem with whitefly alone. In contrast, most producers in Gedaref, Northern and North Kordufan Provinces, where TYLCV incidence was very low (0%-9%), could not recognize whiteflies or TYLCV nor did they have local names for them.

All producers who recognized whiteflies and TYLCV had names for both and in most cases the producers gave very specific names for the problems they cause. Local names for whiteflies include *asala*, *biadah*, *dubbana*, *dubbana beida*, *zubaba* and *zubaba beida*. These literally mean "flies" or "white flies", except *asala*, which refers to the honeydew that the insects secrete. Names given to the TYLC include *hurug* (burning), *saratan* (cancer) and *karmata*, *karmasha* or *kurmut* (all of which allude to leaf deformation).

Historically, Sudan has been regarded as one of the countries worst hit by whitefly problems, especially in the cotton production system. This scenario has changed recently and the whitefly problem in cotton seems to have become less acute. Highly effective insecticide treatments, often containing insect growth regulators, have reduced the breeding success of whiteflies on cotton. Nonetheless, the whitefly has maintained its status as a highly injurious pest of tomato, cucurbits, pepper, okra and common bean, and the numbers of producers who have abandoned tomato cultivation because of TYLCV are on the increase.

Farmers' perceived yield loss to whitefly and/or TYLCV in tomato was on average 62%. According to the survey, 26% of producers, mainly in Gezira, reported total yield loss, 38% reported losing three-quarters of their yield, 10% reported losing half, 10% reported losing one-quarter of their yield and 16%, mainly from Gedaref and North Kordufan, reported no loss. Of the producers interviewed, 34% (most of them in Gezira State) reported abandoning their tomato crops in at least 1 year because of whitefly/TYLVC problems and most reported that this occurred in 1997. The perceived losses can be compared usefully with the recorded incidence of TYLCV symptoms. Among all surveyed tomato producers, 92% had some virus symptoms in their tomato crop and 50% had more than 25% incidence. It should be emphasized that 31% of the tomato producers had an 80% TYLC incidence in their tomato crops and these outbreaks were mainly confined to the greater Gezira. TYLC was significantly less severe (1%-9%) in western, northern and eastern states, and absent in Gedaref and the Abu Habil Basin. Most tomato producers (65%) believe that they have whitefly/TYLCV problems every year. The majority of producers (86%) believe that there is a direct relationship between the climate and the incidence of whiteflies and/or whitefly-transmitted disease, with 63% of producers associating high incidence with hot and dry seasons, while only 9% believe that they have the problem all year round.

### *Estimation of disease incidence and yield losses*

The damage associated with *B. tabaci* and WTVs is always more serious in summer crops, especially during the hot season from March to August (during which there are three planting periods: "early summer" in March, "late summer" in May and the "main planting season" in July) and total failure of the tomato crop due to TYLCV is common. This is despite the lower prevalence of the vector in the summer season. Whitefly populations build up during the winter (October-January) and peak in December-January. Up to 100% infection by TYLCV can occur during a mild winter but less yield depression is associated with these winter infections.

In 1998, tomato grown during the May-July season suffered severe attack by TYLCV and this crop failed completely. Watermelon likewise suffered severe losses from WmCSV. An exceptionally heavy rainy season from mid-August to mid-October, however, seemed to alter the whitefly situation later in the year, with population levels dropping sharply and tomato crops grown during October-November being comparatively less affected by TYLCV. A field experiment conducted at the University of Gezira revealed that early infection by TYLCV reduced the total number of flowers per plant, percent fruit setting and the quality of fruits. The infection resulted in 67% reduction in the number of

mature fruits and 84% reduction in the weight of marketable fruits per plant. Severe infection resulted in 86% reduction in the number of green mature fruits, 87% reduction in the number of ripe fruits and 93% reduction in the weight of marketable fruits per plant. Flower bud initiation substantially decreased as the infection became more severe or when infection occurred early in the plant's growth cycle but the proportion of flower abortion and fruit setting was not significantly affected. Affected plants had reduced foliage cover and fruits were exposed to direct sunlight, which caused white blotches (sunscald) and reduced their market value. The results show that TYLCV infection can affect all yield components, from flower production through to the quantity and quality of fruits.

WmCSV is less important economically than TYLCV but is considered to be the most important single cause of high yield loss of cucurbits in eastern and central Sudan and has affected the country's melon exports seriously in recent years. Crops affected include watermelon, musk melon and, to a lesser extent, snake melon (*Cucumis melo* L. subsp. *melo* var. *flexuosus* [L.] Naudin) and squash. Melon producers incur a 64% loss in revenue because of WmCSV. The virus is prevalent in Gezira, Upper Atbara River and southern Sinnar, where fresh market varieties such as Charleston Grey, Congo Red and Sugar Baby are grown. Watermelon in large areas of Southern Blue Nile, Shuwak and Dinder inland delta were totally devastated by WmCSV in1998-99, and up to 80% yield losses occurred in Galia melon (a variety of musk melon) grown for export in Khartoum and Gezira States. However, this virus is only sporadically important in Kordufan and western Sudan where local strains of watermelon are grown for seed production and water storage. WmCSV incidence of 82% was observed on Galia melon grown for commercial purposes at the Gezira University farm in 1997. Complete absence of "netting" on the fruit surface was evident in some severely affected plants, while the healthy ones produced fruits entirely covered with netting (an important quality that correlates positively with sweetness of the fruit). The severely affected plants gave 1.3 fruits per plant, while healthy plants gave 2.1 fruits per plant. The average incidence of WmCSV in Galia melon from eight sites in the Selait Irrigation Scheme (Kordufan Province) was 70% and data from these sites indicated a positive correlation between the level of virus incidence and yield loss.

OLCV restricts okra production in Sudan. Symptoms of the virus appeared to be more severe during the late winter and early summer growing seasons, with Gezira being the worst hit area. The virus had less effect on local varieties of okra. BMMV may constitute a potential hazard, especially in the newly established export-oriented vegetable production area in Khartoum State. This virus is less important and is considered a late season disease in northern Sudan.

### *Pesticide use*

The cost of controlling whiteflies and WTVs accounts for more than 30% of the total production costs of tomato in Sudan. A small proportion of producers (4%) spent as much as US$300-400 per hectare on pesticide treatment. Other producers estimated their pest control costs at US$200-299 per hectare (14% of producers), US$100-199 per hectare (21% of producers), US$50-99 per hectare (27% of producers) and US$0-49 per hectare (34% of producers). The costs of chemicals and their application vary greatly among sites.

Only 10% of producers reported receiving technical advice or information regarding the management of pest and disease problems. Forty percent of producers received advice from other vegetable producers or neighbours, 30% from commercial sales agents, while 20% had not received any advice but applied insecticides according to their own judgement. The absence of an effective extension service has left the farmers to make their own decisions on whitefly/WTV management. The constraints on farmers' knowledge of whitefly management can be summarized as:

(1) Low level of education and limited knowledge of modern techniques of vegetable production;

(2) Poor ability to choose the right crop and a suitable variety of that crop;

(3) Poor knowledge on pesticide usage and related hazards; and

(4) Inability to monitor market trends as a basis for deciding what to grow and when to grow it.

Because of the lack of extension services in vegetable farming, chemical control of the whitefly remains the principal pest management strategy. The great majority of tomato producers in the country (80%) used insecticides, mostly pyrethroids and organophosphates, to combat the whitefly/TYLCV problem on their farms. The most popular pesticides applied by the producers were fenpropathrin, fenvalerate and cypermethrin (pyrethroids), omethoate, malathion, dimethoate and chlorpyriphos (organophosphates), methomyl and carbaryl (carbamates), and endosulfan (organochlorine).

Most producers believed that the pesticides were indispensable in tomato farming. A significant proportion of producers (30%) made more than 10 insecticide applications per season, 26% made 9 or 10 applications, and a few producers applied pesticides as many as 24 to 30 times per season. Ten percent of producers practiced crop rotation to combat the problem. A few farmers used cultural control methods such as burying of infected plants and inter-cropping with repellent crops such as coriander (*Coriandrum sativum* L.) and fenugreek (*Trigonella foenum-graecum* L.). Others claimed that directly sown tomato, that is, without transplanting, was less affected by TYLCV. Ten percent of producers, mainly in Gedaref, Western State and Northern State did not practice any sort of management of the problem.

Lack of knowledge of the proper use of pesticides was evident in all areas surveyed. Farmers were found to be ignorant of the judicious use of pesticides and alternative whitefly control methods. Some tomato growers overused chemicals, while others did not spray until symptoms of damage were observed, and subsequent intensive chemical application failed to save the crop. Producers were ignorant of the interval required between the last spraying and harvest, and some even used the taste or smell of the pesticides to judge their effectiveness. Lack of protective clothing and equipment exposed the farmers to serious health hazards. Inappropriate chemicals such as fungicides (propiconzale) and others without any labels were being used in an attempt to control the whitefly and WTV problem. Recommended dosages were not followed and virtually all vegetable producers mixed one tomato sauce tin, containing about 50 mL, of any insecticide, irrespective of its formulation or active ingredient, with 4 gallons (18 L) of water. A few

producers used twigs to apply pesticide, instead of a knapsack sprayer, resulting in poor coverage and greater loss of pesticides. Most producers (67%) applied insecticides as a preventive measure, 17% applied insecticides when they observed whitefly/TYLCV damage, while 8% applied insecticides according to calendar.

Vegetable growers in Gezira and Rahad illegally obtain part of their supply of chemicals from the stocks of cotton schemes. These include highly toxic "cocktails" of insecticide, exclusively recommended for use on cotton. Their experience of severe whitefly outbreaks in previous seasons leads most of them to use excessive quantities of these chemicals. As a result, environmental contamination, occupational health hazards and production costs are on the increase. In addition, the overuse of chemicals to control whitefly seemed to have resulted in the build-up of previously secondary pests such as *H. armigera*, *L. sativae* and *Scrobipalpa* sp. Nevertheless, several producers suffered complete loss of even the treated crop.

Several researchers (e.g., Ahmed et al., 1987; Dittrich et al., 1990) have documented the resistance status of *B. tabaci* in cotton to various insecticides in the Sudan. They reported that *B. tabaci* showed high levels of resistance to many organophosphates and synthetic pyrethroids and moderate resistance to carbamates and organochlorines. The specific levels of resistance reported vary depending on the source of the samples, the history of insecticide application in that area, the time of the year when bioassays were done and the sensitivity of the whitefly population used. However, the reports were primarily based on dose responses of whiteflies in the cotton monoculture system. Pesticide resistance of whiteflies in the mixed vegetable cropping systems in the Sudan has not been documented.

Sudan is the only country in East Africa that has adopted IPM as its official crop protection policy. The government's position is well defined in a recent publication entitled "Sudan Country Strategy Note, 1997-2001: Partnership towards Sustainable Human Development". The document emphasizes that the government of the Sudan is pursuing an integrated program for environmentally sustainable development. However, implementation of the policy is minimal, particularly, in the case of vegetable farming, because of farmers' ignorance of alternatives to chemical control, which in turn is mainly attributed to the lack of effective extension services in this sector. In the absence of alternatives, chemical control of the whitefly therefore remains the principal strategy for managing WTVs.

## Strengthened Research Capacity

Sudan's participation in the diagnostic phase of the TWF-IPM Project has provided a substantial body of knowledge covering various aspects, biological and socio-economic, of the whitefly/WTV problems in vegetable-based cropping systems in the country. Sudan's participation in the planning workshop in April 1997 and the co-ordination meeting in June 1998 provided national researchers with a chance to learn from, and share ideas and experiences with, scientists from other countries. A Ph.D. project on "Distribution of whitefly species (and biotypes) and their natural enemies in vegetable-based cropping systems in Sudan" was undertaken in collaboration with the University of Gezira under the auspices of the project.

## Conclusions

The work conducted during the diagnostic phase of the TWF-IPM Project has provided, for the first time, a biological and socio-economic characterization of the problems linked to *B. tabaci* in the vegetable cropping systems of Sudan. The studies have provided a better understanding of the biology of this important vector, the distribution of its natural enemies, the epidemiology of the viruses it transmits and the socio-economic implications of virus disease problems for producers.

Farmers viewed the *B. tabaci*/TYLCV problem as the most important constraint on tomato production. The areas identified as hot spots for TYLCV include Gezira, Managil, Umelgura and Hasaheisa Provinces, all of which are characterized by irrigated production and are within cotton production areas. The main problems associated with *B. tabaci* in vegetable production systems in Sudan are:

(1) Tomato: transmission of TYLCV and TVTV, and direct feeding by *B. tabaci* during early crop stages;

(2) Watermelon and musk melon: transmission of WmCSV, CVYV, and a virus inducing potyvirus-like yellowing symptoms;

(3) Okra: transmission of OLCV, sooty mould induced by secretion of honeydew by *B. tabaci*, and direct feeding damage;

(4) Peppers: transmission of TYLCV; and

(5) Vegetable legumes: symptoms of a begomovirus and closterovirus observed on cowpea and common bean but transmission by *B. tabaci* is not yet confirmed.

The surveys documented alarming misuse of pesticides on vegetables. The information gained can help to sensitize policy makers in Sudan to the alarming magnitude of the whitefly and WTV problems and to the dangers inherent in the associated misuse of pesticides. The knowledge gained has provided a sound foundation for developing a future research agenda. The following priorities are recommended:

(1) Research should be conducted on the following IPM components:

   (a) Evaluation of available TYLCV-resistant or -tolerant tomato varieties for immediate incorporation into IPM plans;

   (b) Screening of exotic tomato varieties for resistance to *B. tabaci* and/or TYLCV;

   (c) Breeding for resistance against *B. tabaci* and WTVs, while utilizing resistant strains of crops;

   (d) Evaluation of alternative and novel pest and disease management methods, including the use of botanicals, biological control and cultural methods; and

   (e) Investigation of the efficiency of natural enemies in vector control.

(2) Available IPM options should be tested and refined, with the close participation of producers, under on-farm conditions; participatory research should be complemented with intensive training of producers and other stakeholders.

(3) Resistance of whiteflies to insecticides commonly used in vegetable farming should be

monitored, using a standardized methodology in Sudan and elsewhere to enable valid comparisons to be made.

(4) Appropriate techniques to evaluate insecticide residues in fruits and vegetables should be developed and applied.

(5) The whiteflies observed inducing silverleaf in Gezira for the first time in 1998 should be characterized using molecular techniques and biological assays.

The recommended research will provide a platform for the development and adoption of sustainable production practices for vegetables in Sudan, leading to improved well-being for producers and consumers.

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