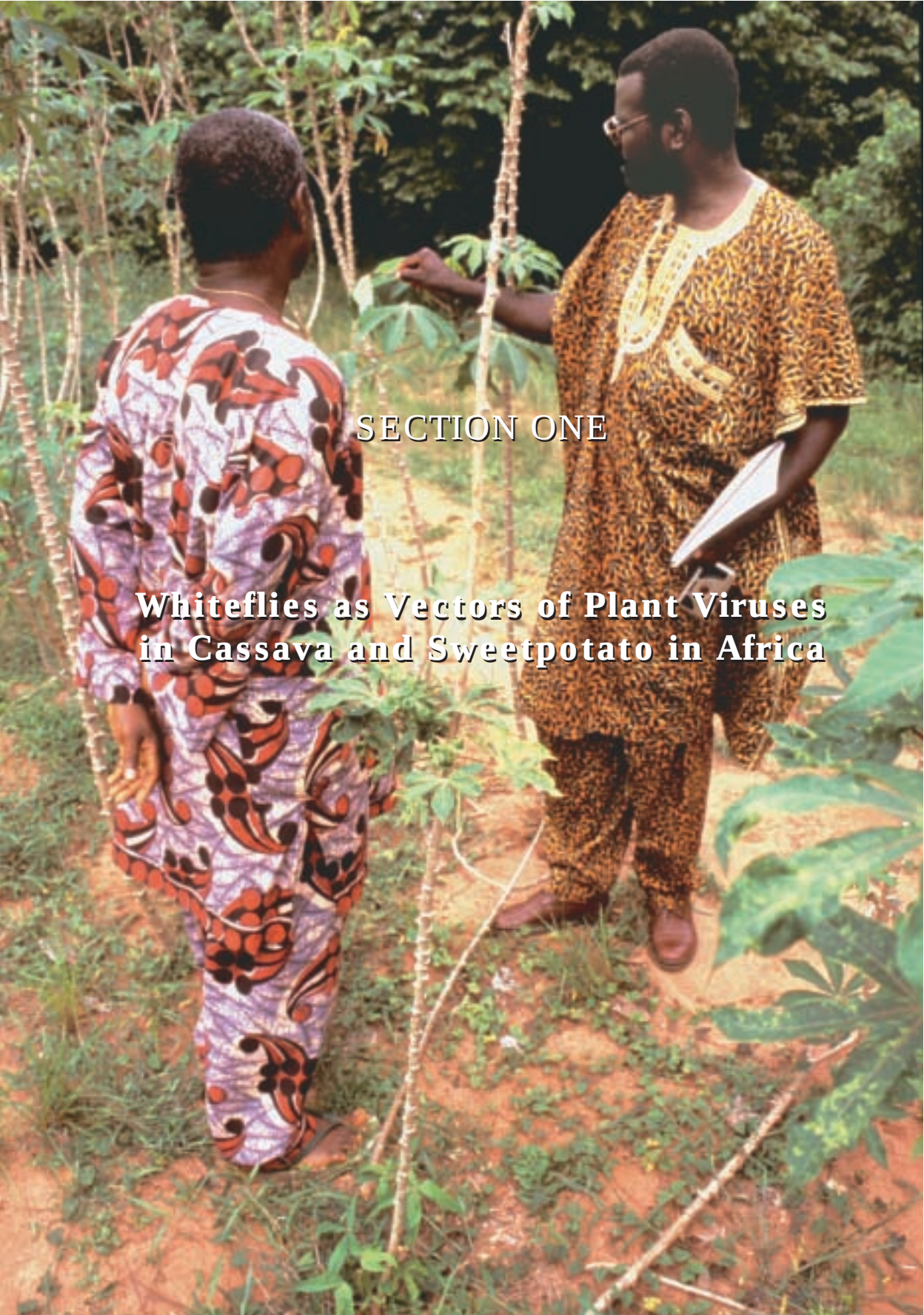

SECTION ONE

Whiteflies as Vectors of Plant Viruses in Cassava and Sweetpotato in Africa

BLANCA 14

CHAPTER 1.1

Introduction

*James Legg**

More than 1200 species of whitefly (Homoptera: Aleyrodidae) have been described worldwide, of which roughly one quarter occurs in Africa (Mound and Halsey, 1978). Of these diverse whitefly species, only a few are of significant economic importance. These include: *Aleurocanthus spiniferus* (Quaintance), *Aleurocanthus woglumi* Ashby, *Aleurodicus dispersus* Russell, *Aleurothrixus floccosus* (Maskell), *Aleyrodes proletella* (Linnaeus), *Bemisia tabaci* (Gennadius), *Dialeurodes citri* (Ashmead), *Parabemisia myricae* (Kuwana), *Siphoninus phillyreae* (Haliday), *Trialeurodes vaporariorum* (Westwood) and *Vasdavidius indicus* (David and Subramaniam) Russell. Principal among these, however, is *B. tabaci*, which is a pest on a wide range of field crops throughout the continent.

B. tabaci was first described from tobacco (*Nicotiana tabacum* L.) in Greece and is thought to have originated from the Old World (Frohlich et al., 1996). It has been recognized as an important agricultural pest in Africa since at least the 1930s, with several of the earliest reports relating to damage in cotton (*Gossypium hirsutum* L.) (Kirkpatrick, 1931) and cassava (*Manihot esculenta* Crantz) (Kufferath and Ghesquière, 1932; Storey and Nichols, 1938). By the 1950s, *B. tabaci* was reported causing major losses in cotton as a result of population resurgence of this species when it developed resistance to pesticides applied against other pests (Joyce, 1955). And, by the 1980s, *B. tabaci* had been associated with a major pandemic of cassava mosaic disease (CMD) in East Africa (Otim-Nape et al., 1997; Legg, 1999).

Cassava and Sweetpotato in Sub-Saharan Africa

According to international production statistics (FAO, 2004), Africa produces almost half of the world's crop of cassava and East Africa is one of the world's most important areas for growing sweetpotato (*Ipomoea batatas* [L.] Lam). Nigeria is the world's leading producer of cassava, while Uganda ranks third, worldwide, in total sweetpotato production. These two crops are of major importance to sub-Saharan Africa and play vital roles in sustaining food security, particularly in view of their ability to provide reasonable yields even under conditions of poor soil fertility or drought (Jennings, 1970).

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Cassava was brought to Africa in the sixteenth century by Portuguese seafarers and, perhaps because of this relatively recent introduction, has few major pests and diseases. This is in contrast to the wide diversity of pests and diseases that affect this crop in its native South America (Bellotti et al., 1994). The two most important arthropod pests of cassava in Africa, the cassava mealybug (*Phenacoccus manihoti* Matile-Ferrero) and the cassava green mite (*Mononychellus tanajoa* [Bondar]) were both introduced from South America in the early 1970s (Yaninek and Herren, 1988; Neuenschwander, 1994). They spread rapidly to all cassava-producing zones of mainland Africa during the 1980s and 1990s but both have been controlled successfully through the implementation of continent-wide biological control programs (Herren and Neuenschwander, 1991; Yaninek et al., 1993).

The principal diseases of cassava in Africa are CMD and cassava bacterial blight. The latter, like the two arthropod pests described above, was introduced into Africa in the 1970s and spread rapidly to all cassava-growing areas (Boher and Verdier, 1994). The disease is caused by the bacterium *Xanthomonas axonopodis* pv. *manihotis* (Xam). Although, under certain circumstances, damage may be very severe and result in total crop loss, outbreaks with serious effects are usually localized. Cassava bacterial blight is therefore less economically important than CMD.

CMD was first described more than a century ago (Warburg, 1894) from what is modern-day Tanzania. It was assumed from the early years of the twentieth century that the disease was caused by a virus, since no pathogens were visible on affected plants and the condition was shown to be graft transmissible (Zimmerman, 1906). It was not until the 1970s, however, that the viral etiology was confirmed (Bock and Woods, 1983). CMD is caused by begomoviruses (Bock and Woods, 1983; Hong et al., 1993), which are transmitted by *B. tabaci* (Storey and Nichols, 1938; Chant, 1958; Dubern, 1979). Cassava mosaic begomoviruses occurring in Africa are thought to be indigenous to that continent; it is assumed that they moved into cassava from wild host plants following the introduction of cassava from South America (Swanson and Harrison, 1994).

Cassava was subsidiary in importance to other staple crops until the early part of the twentieth century but promotion of the crop as a famine reserve by colonial authorities in the 1920s and 1930s rapidly led to it being more widely grown and consumed (Hillocks, 2002). It appears that this increase in cultivation area and intensity, coupled possibly with the unrestricted movement of germplasm between countries, catalyzed the continent-wide spread of CMD. New occurrences as well as the increasing importance of CMD were reported from numerous countries in East and West Africa, including Sierra Leone (Deighton, 1926), Uganda (Hall, 1928), Ghana (Dade, 1930), Nigeria (Golding, 1936) and Madagascar (François, 1937). Losses due to CMD in Africa have been estimated at between 12 and 23 million tons annually, equivalent to between US$1200 and US$2300 million (Thresh et al., 1997). Following the success of biological control in reducing losses caused by cassava mealy bug and cassava green mite, CMD generally is regarded as the most important biotic constraint on cassava production in Africa.

Sweetpotato in Africa is attacked by a greater diversity of pests and

diseases than is cassava, although, as with cassava, few are of major economic importance. The most important pests include the sweetpotato weevil (*Cylas* spp.), the striped sweetpotato weevil (*Alcidodes dentipes* [Oliver]), the sweetpotato butterfly (*Acraea acerata* Hewitson), leaf blight (*Alternaria* spp.) and sweetpotato virus disease (SPVD). The latter has been ranked as the single most important constraint to sweetpotato production in the East African region and is the most important disease throughout Africa (Geddes, 1990). It results from co-infection of sweetpotato plants with the aphid-borne *Sweetpotato feathery mottle virus* (SPFMV) and the *B. tabaci*-borne *Sweetpotato chlorotic stunt virus* (SPCSV) (Schaefers and Terry, 1976; Gibson et al., 1998).

Status of CMD and SPVD Research

Since its description more than a century ago, CMD has received significant research attention. Fauquet and Fargette (1990) and Thresh et al. (1994; 1998) have reviewed a wide range of studies on the biological and molecular characterization, etiology, epidemiology, yield loss and control of these viruses. Fishpool and Burban (1994) and Legg (1994) have reviewed studies on *B. tabaci* as the vector of cassava mosaic geminiviruses, including work on biotype characterization, population dynamics, virus transmission and movement within cassava fields. The emergence of a severe form of CMD in the 1990s (Otim-Nape et al., 1997; Legg and Ogwal, 1998; Legg, 1999) has had a devastating effect on cassava cultivation across a large area of East and Central Africa. Rapid expansion of the pandemic has been associated with a new, more virulent, cassava mosaic begomovirus (Deng et al., 1997; Zhou et al., 1997). Super-abundant *B. tabaci* populations associated with the pandemic also have been shown to result from a synergistic interaction with severely CMD-diseased cassava plants, in which the diseased plants appear to promote *B. tabaci* population increase, possibly through the disease improving the food quality of the plant for *B. tabaci* (Colvin et al., 1999). However, evidence has been presented for a link between a distinct *B. tabaci* genotype cluster and the pandemic in Uganda (Legg et al., 2002).

In contrast to CMD, knowledge of SPVD and the role of *B. tabaci* in the ecology of the disease is extremely limited. Studies have been restricted largely to virus characterization, etiology and transmission, virus-virus interactions, and yield loss assessments (Schaefers and Terry, 1976; Hahn, 1979; Gibson et al., 1997; 1998). Although the disease is known to occur widely in sub-Saharan Africa, virtually nothing is known about its prevalence in the major sweetpotato cultivation areas and at the inception of this study published incidence data were available only for Uganda (Aritua et al., 1998).

Although significant progress had been made previously in characterizing whitefly-transmitted viruses and whiteflies associated with CMD and SPVD, at the time of launching the present study, significant gaps in understanding remained (Table 1). This was most apparent for *B. tabaci*, where very little research other than one-time assessments of abundance and limited population dynamics studies had been done outside Uganda and the Ivory Coast.

Table 1. Scope of published work in sub-Saharan Africa for key fields of cassava mosaic disease (CMD) and sweetpotato virus disease (SPVD) research at time of starting present study in Project target countries of sub-Saharan Africa.

Disease	Country	Research topic[a]							
		Virus characterisation	*Bemisia tabaci* characterisation	CMD/SPVD prevalence	*B. tabaci* abundance	CMD/SPVD epidemiology	CMD/SPVD yield losses	Farmer perceptions	Natural enemies of *B. tabaci*
CMD	Uganda	(+)	(+)	+	+	+	+	(+)	(+)
	Kenya	(+)	-	(+)	(+)	+	+	-	-
	Tanzania	(+)	-	+	+	(+)	-	-	-
	Malawi	(+)	-	-	-	-	-	-	-
	Madagascar	(+)	-	-	-	-	-	-	-
	Ghana	(+)	-	+	+	-	-	(+)	-
	Benin	(+)	-	+	+	-	-	(+)	-
	Nigeria	(+)	-	+	+	+	+	(+)	-
	Cameroon	(+)	-	+	+	+	+	(+)	-
SPVD	Uganda	+	-	+	-	(+)	+	-	-
	Kenya	+	-	+	-	-	-	-	-
	Tanzania	(+)	-	-	-	-	-	-	-
	Malawi	-	-	-	-	-	-	-	-
	Madagascar	-	-	-	-	-	-	-	-

a. + Published literature available; (+) Limited study published; - No published literature available.

Sub-project on Whiteflies as Vectors of Viruses of Cassava and Sweetpotato in Sub-Saharan Africa

Within the framework of the Tropical Whitefly Integrated Pest Management (TWF-IPM) Project, the purpose of the diagnostic phase of the sub-project was to gather, generate and analyse baseline data relevant to the diagnosis and characterization of whitefly problems and whitefly-transmitted virus problems in cassava and sweetpotato. The rationale behind the diagnostic phase was therefore to provide essential baseline information on CMD, SPVD and whiteflies on cassava and sweetpotato, to serve as the basis for the development and implementation of targeted and appropriate IPM strategies in subsequent phases of the project.

The sub-project involved collaboration among three international agricultural research centres, one national agricultural research organization in each of nine African countries, and three other research institutions outside Africa (Table 2). The inclusion of nine countries at this stage of the project and the use of a standardized protocol provided a unique opportunity to obtain data that could be compared from country to country and region to region. The scope of the study also facilitated the first systematic collection and characterization of whitefly-transmitted viruses, whitefly and whitefly natural enemy specimens from cassava and sweetpotato in sub-Saharan Africa.

Collaboration and selection of target areas

Countries were identified for participation in the sub-project primarily on the basis of the importance of cassava and/or sweetpotato cultivation to their farmers, although security concerns precluded the participation of some of the major producers of each crop. The nine African countries that were extensively surveyed—Ghana, Benin, Nigeria, Cameroon, Uganda, Tanzania, Kenya, Malawi and Madagascar—together represented 62% of cassava and 56% of sweetpotato production in Africa (FAO, 1999). Zambia was involved in the project only to a limited extent, implementing a sweetpotato virus diagnostic survey in collaboration with the Natural Resources Institute, UK. Sweetpotato work was carried out only in eastern and southern Africa, because the crop is not grown widely in West Africa. Table 2 summarizes the roles of each of the partners involved in the diagnostic phase.

Implementation of the work plan, results and analysis

Diagnostic surveys were conducted according to protocols set out in the standardized methodology agreed among the project partners. In each country, three or four target areas were identified for the survey. The criteria for selection of these areas were that they should be major root crop-producing zones and preferably should have contrasting agro-ecological characteristics. In each ecozone, the sites were selected at about 20-km intervals along roads. Where no cassava farms were encountered at the 20-km point, the next suitable site thereafter was selected. Field data and biological specimens were collected from 3-6 month-old cassava plantings on surveyed farms and producers were interviewed using the standardized project questionnaires.

Between 10 and 42 locations were used for sampling in each target area, and at each location a single set of samples and data was collected. The data set comprised: (1) a producer questionnaire relating to perceptions

Table 2. Partners involved in the diagnostic phase of the sub-project on Whiteflies as Vectors of Viruses of Cassava and Sweetpotato in sub-Saharan Africa and their roles.

Institution	Country	Role[a]
International agricultural research centres:		
International Institute of Tropical Agriculture (IITA)	Uganda/Benin	Co-ordination
Centro Internacional de la Papa (CIP)	Uganda	SPVD epidemiology
International Centre of Insect Physiology and Ecology (ICIPE)	Kenya	Whitefly and natural enemy species identification
National agricultural research organizations/institutes:		
Plant Protection and Regulatory Services Directorate (PPRSD)	Ghana	Diagnostic survey
Institut National de Recherche Agronomique du Bénin (INRAB)	Benin	Diagnostic survey
National Root Crops Research Institute (NRCRI)	Nigeria	Diagnostic survey
Institut de Recherche Agronomique (IRA)	Cameroon	Diagnostic survey
National Agricultural Research Organisation (NARO)	Uganda	Diagnostic survey
Tanzania Root and Tuber Crops Programme (TRTCP)	Tanzania	Diagnostic survey
Kenya Agricultural Research Institute (KARI)	Kenya	Diagnostic survey
Chitedze Research Station (CRS)	Malawi	Diagnostic survey
Centre National de Recherche Appliquée au Développement Rural (FOFIFA)	Madagascar	Diagnostic survey
Mount Makulu Research Station	Zambia	Diagnostic survey (SPVD only)
Specialized research organizations:		
Natural Resources Institute (NRI)	United Kingdom	Epidemiology of CMD and SPVD
Biologische Bundesanstalt für Land und Fortwirtschaft (BBA)	Germany	Sweetpotato virus diagnostics
John Innes Centre (JIC)	United Kingdom	Molecular diagnostics of cassava viruses and whiteflies

a. CMD, cassava mosaic disease; SPVD, sweetpotato virus disease.

and management of whiteflies and whitefly-transmitted virus problems; (2) biological samples of whiteflies, virus-diseased leaf and stem tissues, and whitefly natural enemies; and (3) field assessments of disease incidence, virus symptoms and whitefly abundance. Before carrying out the survey, lead scientists in each country were trained in survey methods. Surveys were conducted between November 1997 and September 1998. The results are reported in the subsequent country chapters in this section. Data from the producer questionnaires for all countries were entered into a single database from which they could be summarized and queried. Field data from all countries were summarized and integrated to develop maps (Chapter 1.14, this volume). Studies conducted in partnership with research institutions outside Africa were initiated in early 1998 and completed by mid-1999; results are reported later in this section (Chapters 1.11, 1.12 and 1.13) or in Section 5 (Chapter 5.3).

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