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TECHNICAL BROCHURE

WHITEFLY MANAGEMENT STRATEGY DOSSIER FOR THE CONTROL BODIES

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1. BACKGROUND INFORMATION

EU REGULATIONS CONTEXT

The European Union (EU) has overhauled its plant health (phytosanitary) regulations. On 14 December 2019, the new Plant Health Regulation (EU) 2016/2031 came into operation bringing rigorous new rules to prevent the introduction and spread of pests and diseases into the EU. More details on specific pests and requirements are given in a new Implementing Regulation (EU) 2019/2072 issued on 28 November 2019.

Whitefly species are found on a wide variety of host plants and can be a serious problem for crops causing direct damage as well as acting as a vector of plant viruses. Some species are listed under the EU regulations as quarantine pests including *Aleurocanthus citriperdus*, *Aleurocanthus woglumi*, and *Bemisia tabaci* (non-European populations). Consignments of imported produce that are found to contain *B. tabaci* or other quarantine pest will be intercepted and detained at EU border controls. It is therefore essential to monitor and avoid their presence and all other harmful organisms in export crops.

This document has been developed as a cross-cutting strategy to give a comprehensive overview of whitefly management along the supply chain from the field to point of shipment to ensure that no pests are present in plant commodities exported to the EU. The strategy includes a monitoring, inspection and certification system as a guide to the control bodies to elaborate their national action plans to control presence of whiteflies. In addition, the strategy provides an overview of practical integrated pest management (IPM) approaches that producers in the ACP countries can integrate along all the supply chain to control whiteflies.

This whitefly management strategy dossier for the control bodies is a part of a series of 4 brochures for the whiteflies management:

1. Whitefly strategy management dossier for the control bodies
2. Whitefly inspection and identification brochure for inspectors and extension workers in ACP countries
3. Whitefly field management brochure for growers in Togo
4. Whitefly packhouse management brochure for packhouse managers in ACP countries

These are all available on COLEAD e-library here

1.1 Introduction

Whitefly is a small, white, fly-like insect, found mostly on the underside of leaves. The adult stage is about 1-2mm long. Whiteflies are a serious pest of cultivated crops in tropical and subtropical areas including Africa, Asia, Central America, South America and the West Indies (CABI, 2021). Whiteflies feed by piercing and sucking sap from the phloem. Persistent feeding with increased population causes leaf chlorosis, leaf withering, premature dropping of leaves and plant death. Whiteflies also release honeydew secretions that make leaves sticky and shiny. Honeydew leads to the growth of ugly grey sooty mold, which reduces photosynthetic ability of the host plant and its aesthetic value. Whitefly species i.e. the sweet potato whitefly (*Bemisia tabaci*) are vectors to a number of disease causing viruses that are of quarantine importance. Whiteflies are difficult to control by conventional pesticide programmes. Some of the reasons attributed to this are:

- Whitefly adults and nymphs are found mostly on the underside of leaf surface, often escaping contact with sprays;
- The egg and the pupae are very well protected against pesticides as they are covered by waxy layers and do not feed;

- All stages of the life cycle are present in any crop, therefore targeting the adults or the scales does not reduce the impact of the populations as much as is required; and
- The life cycle is relatively short and reproduction rates are fast.

1.2 Countries facing interceptions due to the presence of whiteflies

The EU directive 2072/2019, Annex II, part A lists whitefly species *Aleurocanthus citriperdus*, *Aleurocanthus woglumi* and *Bemisia tabaci* as pests not known to occur in the union territory.

In 2020, 90 interceptions on *leafy vegetables (41), vegetables (33), edible/infusion flowers (15), leafy fruits (1) in Togo (46), Nigeria (12), Cameroon (8), Suriname (8), Sierra Leone (5), RDC (4), Kenya (3), Congo (1), Gambia (1).*

A total of 92 interceptions within the EU territory have been recorded between January and May 2021 from 25 countries due to presence of whitefly species in various plant commodities (Table 1).

Table 1: List of countries with interceptions due to whitefly species (January-May 2021)

Period	Country	Commodity	Plant spp	Harmful organism	No. of interceptions
Jan. 2021	Cote D'Ivoire	Cuttings intended for planting	*Echinodorus*	*B. tabaci*	2
			Hygrophila	*B. tabaci*	1
			Pogostemon stellatus	*Aleyrodidae*	1
		Seedlings intended for planting	*Alternanthera*	*B. tabaci*	1
			Bacopa	*B. tabaci*	1
			Hemigraphis	*B. tabaci*	1
	Israel	Plants intended for planting	*Mixed plant spp*	*B. tabaci*	1
		Living plants with cut branches	*Amaranthus*	*B. tabaci*	1
	Suriname	Fruits and vegetables	*Cestrum latifolium*	*B. tabaci*	1
	Togo	leaves	*Adansonia*	*B. tabaci*	1
			Corchorus	*B. tabaci*	1
			Hibiscus	*B. tabaci*	1
			Ipomoea	*B. tabaci*	2
			Ocimum basilicum	*B. tabaci*	1
			Solanum macrocarpon	*B. tabaci*	2

Feb 2021	Brazil	Vegetable	*Ocimum basilicum*	*B. tabaci*	2
	China	Plants intended for planting	*Euphorbia*	*B. tabaci*	1
	Israel	Cut flower	*Lisianthus*	*B. tabaci*	1
		Fruits	*Capsicum*	*B. tabaci*	1
	Lao People's Democratic Republic	Leafy vegetables	*Ocimum tenuiflorum*	*B. tabaci*	1
		Leaves	*Ocimum tenuiflorum*	*B. tabaci*	2
	Nigeria	Leafy vegetables	*Vernonia amygdalina*	*B. tabaci*	1
	Suriname	Fruits and vegetables	*Cestrum latifolium*	*B. tabaci*	1
		Leafy vegetables	*Cestrum latifolium*	*B. tabaci*	1
	Togo	Leafy Vegetables	*Ipomoea*	*B. tabaci*	1
			Solanum macrocarpon	*B. tabaci*	2
		leaves	*Hibiscus*	*B. tabaci*	1
			Ipomoea	*B. tabaci*	2
			Solanum macrocarpon	*B. tabaci*	1
	Zambia	Cut flower	*Solidago*	*B. tabaci*	1
March 2021	Cameroon	Aquatic plants intended for planting	*Anubias*	*B. tabaci*	1
	Congo, Democratic Republic of (Was Zaire)	Leaves	*Hibiscus*	*B. tabaci*	1
			Ipomoea	*B. tabaci*	1
	Costa Rica	Cut flower	*Veronica longifolia*	*B. tabaci*	1
	Egypt	Cut flower	*Viburnum*	*B. tabaci*	1
		Vegetable	*Ipomoea batatas*	*B. tabaci*	1
	Israel	Cut flower	*Trachelium*		
	Lao People's Democratic Republic	Leaves	*Eryngium foetidum*	*Aleyrodidae*	1
	Malaysia	Vegetables	*Eryngium foetidum*	*B. tabaci*	1
			Ocimum tenuiflorum	*B. tabaci*	2
	Nigeria	Leafy vegetables	*Pentaclethra macrophylla*	*B. tabaci*	1
			Pterocarpus soyauxii	*B. tabaci*	1
		Leaves	*Telfairia*	*B. tabaci*	1
	South Africa	Fruits and vegetables	*Capsicum frutescens*	*B. tabaci*	1
	Suriname	Fruits and vegetables	*Cestrum latifolium*	*B. tabaci*	2
	Thailand	Aquatic plants intended for planting	*Hygrophila*	*B. tabaci*	1
		Fruits and vegetables	*Eryngium foetidum*	*B. tabaci*	1
			Ocimum tenuiflorum	*B. tabaci*	1
			Polygonum	*B. tabaci*	1
	Zambia	Cut flower	*solidago*	*B. tabaci*	3

April 2021	Bangladesh	Fruits and vegetables	*Corchorus*	*B. tabaci*	1
	China	Living plants	*Pachira*	*B. tabaci*	1
	Congo, Democratic Republic of (Was Zaire)	Leaves	*Rumex acetosa*	*B. tabaci*	1
	Guinea	Leafy vegetables	*Manihot esculenta*	*B. tabaci*	1
	India	Plant intended for planting	*Psidium guajava*	*Aleurothrixus sp. (Aleyrodidae)*	1
	Kenya	Leafy vegetablle	*Ocimum basilicum*	*B. tabaci*	1
	Nigeria	Leafy vegetable	*Telfairia*	*B. tabaci*	1
			Vernonia amygdalina	*B. tabaci*	1
	Singapore	Aquatic plants for planting	*Echinodorus*	*B. tabaci*	2
	Sri Lanka	Leaves	*Alternanthera*	*B. tabaci*	1
May 2021	Cote D'Ivoire	Cuttings intended for planting	*Nomaphila*	*B. tabaci*	1
	Egypt	Fruits and vegetables	*Capsicum*	*B. tabaci*	1
	Guinea	Leafy vegetables	*Manihot esculenta*	*B. tabaci*	1
	Israel	Cutflower	*Eustoma*	*B. tabaci*	1
			Lisianthus	*B. tabaci*	1
			Solidago	*B. tabaci*	1
	Kenya	Cut flower	*Hypericum*	*Aleyrodidae*	1
	Malaysia	Fruit and vegetables	*Eryngium foetidum*	*B. tabaci*	1
	Morocco	Aquatic plants intended for planting	*Alternanthera*	*B. tabaci*	1
	Singapore	Aquatic plants for planting	*Echinodorus*	*B. tabaci*	2
	Thailand	Fruits and vegetables	*Eryngium foetidum*	*B. tabaci*	1
			vegetable plant	*B. tabaci*	1
		Leafy vegetables	*Manihot*	*B. tabaci*	1
	Togo	Fruits and vegetables	*Solanum macrocarpon*	*B. tabaci*	1
		Leaves	*Hibiscus*	*B. tabaci*	1
			Hibiscus sabdariffa	*B. tabaci*	1
			Ipomoea	*B. tabaci*	1
			vegetable plants	*B. tabaci*	1
	Viet Nam	Cuttings for planting	*Hibiscus rosa-sinensis*	*B. tabaci*	1
	Zimbabwe	Cut flower	*Aster*	*B. tabaci*	1
Grand Total					**92**

Source:https://ec.europa.eu/food/plants/plant-health-and-biosecurity/european-union-notification-system-plant-health-interceptions-2_en

2. OVERVIEW OF WORLD DISTRIBUTION AND HOST RANGE OF WHITEFLIES

2.1 World distribution of whitefly species

A total of 1556-whitefly species occur in the world with *B. tabaci* being the most economically important. Moreover, *Aleurocanthus* species are widespread in tropical and subtropical countries of Africa, America, Asia and Oceania (EPPO, 2021).

Major species occurring widely in Africa include the greenhouse whitefly (*Trialeurodes vaporariorum*), sweet potato whitefly (*B. tabaci),* spiraling whitefly (*Aleurodicus dispersus*), citrus woolly whitefly (*Aleurothrixus floccosus*) and the cabbage whitefly (*Aleyrodes proletella).* Spiraling whitefly (*A. dispersus*) is native to the Caribbean islands and Central America but has since spread to North America, South America, Asia, Africa, Australia and several Pacific islands (CABI, 2021).

2.2 Common whitefly species affecting fruits and vegetables

There are eleven (11) economically important whitefly species affecting fruits and vegetables. Table 2 describes their global distribution, preferred host range and key distinguishing features.

Table 2: Distribution, preferred host range and distinguishing characteristics of economically important whitefly species.

Greenhouse whitefly *(Trialeurodes vaporariorum)*	
 ©University of California	**Host plants:** Attacks approximately 859 species, belonging to 469 genera in 121 families of ornamental and horticultural crops. May also occur on avocado, fuchsia, gardenia, lantana and redbud (CABI, 2021). **Characteristics:** Adults have white wings and a yellow surface or substrate. Fourth-instar nymphs have very long waxy filaments and a marginal fringe. **Distribution:** Widely distributed but not native to Europe. Occurs in some countries in Africa, Asia, Europe and North America.

Sweet potato whitefly (*Bemisia tabaci*)	
 ©Public Domain - Released by the USDA-ARS/original image by Stephen Ausmus	**Host plants:** Has broad host range including herbaceous and woody plants. Common hosts include cotton, cucurbits, tomatoes, brinjals, peppers, lantana, roses, solidago, hibiscus, okra, potato and tobacco (Khan, 2015). **Characteristics:** Adults have white wings and yellow body. They hold their wings slightly tilted to the surface or substrate. Fourth-instar nymphs have no waxy filaments or marginal fringe. **Distribution:** *B. tabaci* is widely distributed globally. However, certain areas within Europe are still free from *B. tabaci*, e.g. Finland, Sweden, Republic of Ireland and the UK (Cuthbertson and Vänninen, 2015).
Citrus blackfly *(Aleurocanthus woglumi)*	
 ©Florida Division of Plant Industry/Florida Department of Agriculture & Consumer Services/Bugwood.org	**Host plants:** Is a highly invasive and polyphagous species with a strong preference for citrus and mango. It infests over more than 300 host plant species belonging to 69 families (CABI, 2021). **Characteristics:** Wings appear to form a band across the insect. The body is orange to red initially. The thorax is dark-grey in color. The limbs are whitish with pale-yellow markings. **Distribution:** Occurs in some countries in Africa, widely in Asia, some countries in Europe and North America.
Ash whitefly (*Siphoninus phillyreae*)	
 ©University of California	**Host plants:** Prefers broadleaved trees and shrubs including ash, citrus, Bradford pear and other flowering fruit trees, pomegranate, redbud and toyon. **Characteristics:** Adults are white. Fourth-instar nymphs have a very thick band of wax down the back and a fringe of tiny tubes, each with a liquid droplet at the end. **Distribution:** widely distributed in Europe, the Middle East, North and Central Africa and the Indian subcontinent. Introduction has also been introduced into America and the Australia (CABI, 2021).

Banded winged whitefly (*Trialeurodes abutilonea*)

©The Food and Environment Research Agency (Fera), 2010.

Host plants: Very broad including cotton, cucurbits, other vegetables. Commercially important ornamental host for Acacia, Aster, Bidens, Citrus, Eucalyptus, Euphorbia, Fuchsia, Hibiscus, Impatiens, Pelargonium, Petunia, Solidago and Veronica.

Characteristics: Adults have brownish bands across the wings, and their body is gray. Fourth-instar nymphs have short, waxy filaments around their edges.

Distribution: Occurs naturally in North, South and Central America and the Caribbean (CABI, 2021).

Citrus whitefly *(Dialeurodes citri)*

©Lyle J. Buss/University of Florida/Bugwood.org

Host plants: Has been reported on 80 plant species, belonging to more than 50 genera and 30 families. It is an important pest of Citrus, coffee, Diospyros kaki, gardenia, ash, ficus, pomegranate and various ornamentals.

Characteristics: Adults are white. Fourth-instar nymphs have no fringe around their edges but have a distinctive Y-shape on their backs.

Distribution: It has a cosmopolitan distribution in southeastern Asia, the Middle East, the Mediterranean Region, USA, Central and South America (CABI, 2021).

Iris whitefly (*Aleyrodes spiraeoides*)

©University of California

Host plants: Preferred host plants are Iris, Gladiolus, various vegetable crops, cotton and other herbaceous plants.

Characteristics: Fourth-instar nymphs have no fringe or waxy filaments but are located near distinctive circles of wax where egg laying took place. Adults have a dot on each wing and are quite waxy.

Distribution: Occurs mainly in North America.

(CABI, 2021)

Mulberry whitefly (*Pealius mori*)

©2008 Dan Leeder, https://bugguide.net

Host plants: Most preferred hosts are avocado, citrus, mulberry and other trees.

Characteristics: Adults have reddish to gray wing markings. Nymphs have blackish, oval bodies with white, waxy fringe.

Distribution: Occurs in Africa (Egypt), Europe (Greece) and Asia (China and Thailand.

Crown whitefly (*Aleuroplatus coronata*)

Pupae on Live Oak leaf. Wood Canyon, Aliso Viejo, Orange County, CA. 1-2-10. © Peter J. Bryant. http://nathistoc.bio.uci.edu

Host plants: Restricted to oak, chinquapin trees and chestnut.

Characteristics: Identified most easily by the pupa. Adults are white. Fourth-instar nymphs are black with large amounts of white wax arranged in a crown like pattern

Distribution: It is Native to the southern U.S. and Mexico.

(CABI, 2021)

Giant whitefly *(Aleurodicus dugesii)*

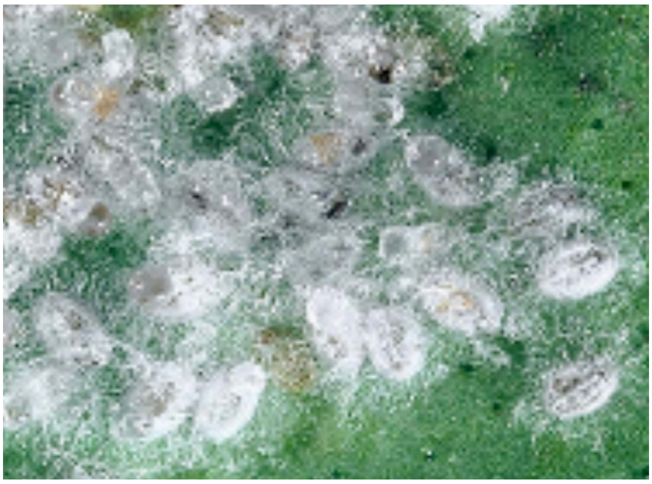
© University of California

Host plants: Avocado, begonia, hibiscus, giant bird of paradise, lilies, citrus, orchid tree, banana, mulberry, vegetables, and various ornamentals.

Characteristics: Adults are up to 0.19-inch long. They leave spirals of wax on leaves. Nymphs have long filaments of wax that can be up to 2 inches long and give leaves a bearded appearance.

Distribution: Occurs in some countries in Asia (Pakistan, Indonesia) North America and South America (Venezuela)

(CABI, 2021)

Woolly whitefly (*Aleurothrixus floccosus*)	
 ©University of California	**Host plants:** It a polyphagous whitefly species. It has been recorded on more than 20 different plant genera of various families. Common hosts include citrus and Eugenia. **Characteristics:** Nymphs are covered with fluffy, waxy filaments. Adults are white. **Distribution:** It is widely distributed in South America. It occurs in Africa, a number of countries in Asia, Europe and North America. (CABI, 2021)

2.3 The importance of whitefly as virus vectors

Whiteflies are indirect pests as vectors of viral diseases. *B. tabaci* is a more efficient transmitter of viral diseases, transmitting more than 200 plant viruses with majority of the viruses belonging to the genera Begomovirus, Carlavirus, Crinivirus, Ipomovirus, and Torradovirus (Jones, 2003). Some of the most vulnerable crops to these viruses include cassava, cotton, cowpea, cucurbits, crucifers, eggplants, tobacco, tomato, potato, soybean, sweet potato, okra, lettuce, pea, bean, pepper, poinsettia, and chrysanthemums (Kedar et al., 2014). Amongst the viruses transmitted by *B. tabaci*, begomoviruses are the leading cause of yield losses in crops, ranging from 20–100% and losses worth millions of US dollars (Gangwar and Charu, 2018).

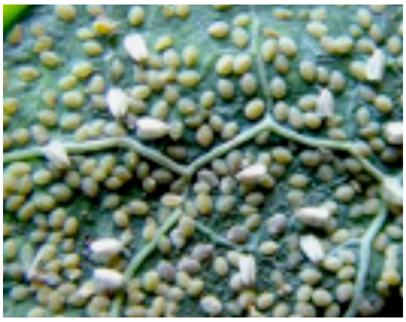
Begomovirus species such as Cotton leaf curl Burewala virus (CLCuBuV), Cotton leaf curl Multan virus (ClCuMuV), and Cotton leaf curl Kokhran virus (CLCuKoV), cause cotton leaf curl disease complex in cotton. Cotton leaf curl disease complex is one of the most devastating disease of cotton globally causing losses amounting to millions of US dollars annually throughout the world (Iqbal et al., 2014). In Africa, Cassava mosaic and cassava brown streak are destructive viral diseases of cassava spread by *B. tabaci*. The diseases affect approximately half of cassava plants in the continent, with annual yield losses of more than 1 billion USD (Legg et al., 2014).

Tomato production is severely affected by Tomato yellow leaf curl virus (TYLCV) transmitted by begomoviruses species (Liu et al., 2013). *B. tabaci* transmits the Sweet Potato Chlorotic Stunt virus, which together with the aphid-transmitted Sweet potato Feathery Mottle Virus causes the Sweet potato virus Disease. Sweet potato virus disease is a major constraint to sweet potato production in Sub-Saharan Africa (Legg et al., 2014). *B. tabaci* is quarantine to the EU because of its importance in vectoring viruses such as the Cowpea mild mottle virus (CPMMV) that are not known to occur in the EU territory.

3. SYMPTOMS OF WHITEFLY DAMAGE

Whiteflies use their stylets in sucking sap from the phloem of plant stems and leaves. High populations of whiteflies cause leaves to turn yellow, appear dry, distorted, discolored, or fall off. Whiteflies also excrete honeydew (sugary liquid). Leaves get sticky and covered with black sooty mold that grows on honeydew as a result (Biovision, 2021a). Honeydew attracts ants, which may interfere with the activities of natural enemies that control whiteflies and other pests (Perring et al., 2018). Table 3 presents pictorial symptoms of whitefly damage.

Table 3: Signs and symptoms of whitefly damage on various host plants

 Eggs of spiralling whitefly (*Aleurodicus dispersus*) © A.M.Varela, ICIPE	 Adults and immature stages of the cabbage whitefly (*Aleyrodes proletella*). © A. M. Varela, ICIPE	 Whiteflies *(Bemisia tabaci)* on French Beans © A.M. Varela, icipe
 Whiteflies on chilli leaf. © B. Nyambo, A. A. Seif, ICIPE	 Cabbage whiteflies © A.M. Varela, ICIPE	 Adults and eggs of the cabbage whitefly *(Aleyrodes proletella).* © A. M. Varela, ICIPE
 Citrus woolly whitefly Immature stages of the citrus woolly whitefly *(Aleurothrixus floccosus)* © B. Loehr, ICIPE	 Typical yellow leaf curl symptom on tomato (var. seeda) infected with TYLCV in Thailand © Supat Attathom	 Cotton plant infected with cotton leaf curl disease showing typical leaf curl symptoms © Rob W. Briddon, NIBGE, Pakistan, PaDIL.gov.au

4. INTEGRATED PEST MANAGEMENT STRATEGIES IN THE FIELD FOR WHITEFLY MANAGEMENT

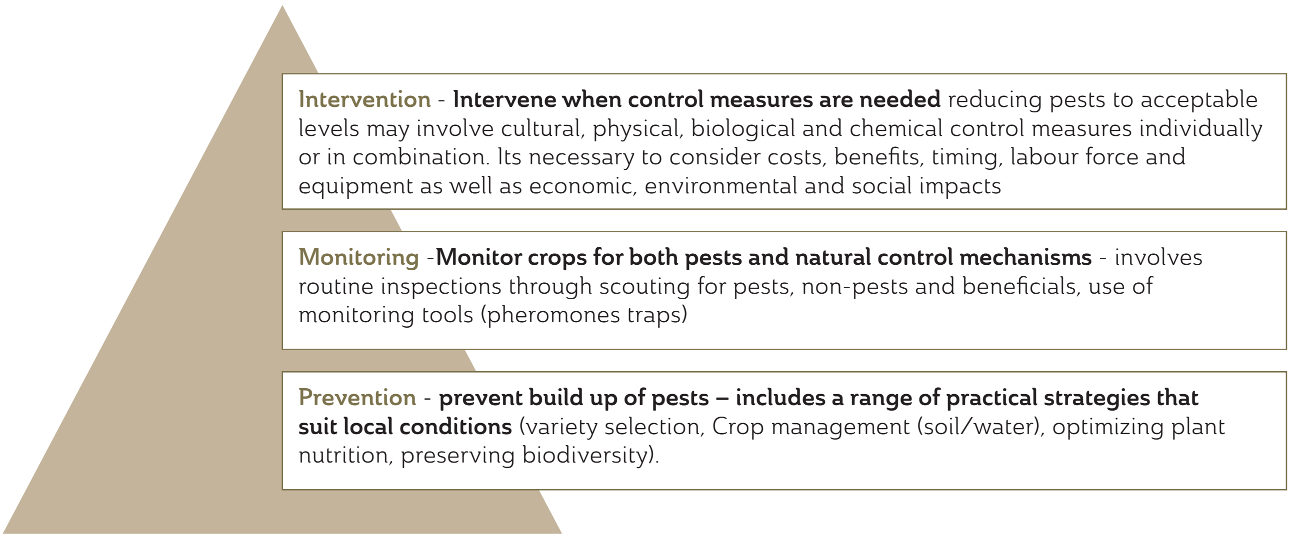
Over the years, the use of insecticides has been the main whitefly population management approaches. However, the practice has been greatly restricted due to the environmental concerns and the widespread insecticide resistance to most of the insecticides in use (Kumar et al., 2017; Horowitz et al., 2011). To overcome these challenges, it is essential that management of whiteflies along the commodity supply chain takes into account a systems approach as detailed in the International Standard for Phytosanitary Measures (ISPM) 14 (*The use of integrated measures in a systems approach for pest risk management*). A systems approach includes a combination of measures applied in places of production, during post-harvest, at the pack house, during exit point inspections and certification or during shipment to ensure pest free commodities to the importing country. This strategy defines use of an integrated approach taking into account use of good agricultural practices (GAPs) while incorporating integrated pest management (IPM) in the ACP countries in order to reduce whitefly populations and resulting crop damage for commodities destined for the EU market.

GAPs provide a basis for observing best practices during on-farm production, harvesting and post-harvest handling of farm produce (fresh fruits and vegetables) aimed to reduce contamination and ensure the safety of consumer and the environment. To ensure adequate protection of crops against attack by whiteflies, it is essential to provide adequate growing conditions such as good soil, adequate water supply, adequate spacing and proper nutrition. These will favour establishment and ensure vigorous growth of plants; healthy plants are able to withstand or tolerate pest infestation; however, weak plants are more susceptible to pest damage at lower pest populations (Crop Life International, 2014).

IPM is an effective and environmentally system that, in the context of the associated environment and the population dynamics of the pest species, integrates all suitable techniques in a compatible and the most economical manner. IPM aims to maintain the pest populations below the economic threshold, while protecting human health and the environment. The strategy proposes an IPM program, which is a combination of good agricultural practices, use of cultural, physical/mechanical, biological, routine monitoring and surveillance of fields for trouble spots, and use of chemical measures with selective pesticides only when necessary. The strategy incorporates various IPM strategies that have practically proven their potential towards whitefly management while allowing flexibility for farmers to use all relevant control tactics and methods that make good use of local resources, latest research, technology, knowledge and experience

IPM Components: The strategy takes into consideration that IPM requires competence in three areas: Prevention, Monitoring and Intervention (Figure 1).

Figure 1: IPM competency areas (Adopted from Crop life IPM guide)



4.1 Crop management

Water and fertility management play important roles as cultural tactics in whitefly management. To optimize soil health, mineral and organic amendments should be applied at the right time and in the correct amounts. Over use of both water and nitrogen fertilizer can greatly exacerbate damage from *B. tabaci* infestations by increasing whitefly numbers and honeydew production. Proper nutrition is essential hence; high doses of nitrogen fertilizers that favor development and survival of whiteflies should be avoided. Use of clean planting material is recommended. Inspection of seedlings for the presence of whiteflies before transplanting can help prevent or delay whitefly infestation on the field. Appropriate or recommended plant spacing should be adopted to allow air movement; this reduces ideal conditions for whiteflies to develop and increases the ease of detection. Protection of natural habitats near farmlands is recommended as it helps conserve biodiversity including many natural enemies (Biovision, 2021a; Crop Life International, 2014).

4.2 Physical control

Physical control of whiteflies includes the use of methods that lead to exclusion or trapping of whiteflies using physical barriers and mechanisms. The physical methods that have proven to be effective in whitefly management include use of sticky traps, use of plastic covers and reflective mulches and covering.

4.2.1 Use of yellow sticky traps

Monitoring whitefly populations is an important part of an IPM program. Yellow sticky traps attract adult whiteflies hence used to monitor and detect presence of whiteflies, for timely interventions. Although traps will not eliminate damaging populations but may reduce them somewhat serves as an important component of an IPM relying on multiple tactics. The traps have also been used to control low density infestations especially in enclosed environments such as green houses and shade nets. Traps (100-300cm^2) spaced at 1 per 6m^2 will assist in control of up to 50-60 percent of the pests. Since whiteflies are poor flies, the best catches are on traps hung at 30 cm from the ground (Legg et al., 2003; Biovision, 2021a).

4.2.2 Use of plastic covers, reflective mulches and nets

Preventing physical contact of the whiteflies with the plant can prevent the transmission of viral diseases. Some of the means that have shown to reduce whitefly damage include reflective plastic mulches (silver, yellow, and white/black) and plastic mulches. The whiteflies are attracted by the color of the plastic mulch, while the heat of the plastic kills the whiteflies. This is effective if the plants are young and do not cover the mulch; the protection can last for 10 to 20 days after transplanting and about 30 days after direct seeding. However, when using plastic covers, care should be taken to avoid sunscald and before putting the reflective mulch it is advisable to remove all weeds. The mulch should be placed on the plant beds and the edges buried with soil to hold them down. Cut 3- to 4-inch diameter holes and plant several seeds or single transplants in each hole. If a coated construction paper or other porous mulch that can tolerate sprinkling is used, the beds can be irrigated using furrow or sprinkle while on the other hand, plastic mulches require drip irrigation (Horowitz et al., 2011; Biovision, 2021a).

4.2.3 Covering

If the plants require to be established in a seedbed and later transplanted, it is critical to protect the seedlings under a properly closed fine-meshed insect netting or nylon nets until they are ready for transplanting to avoid infestations. It is also advisable to use tunnels for 3 to 5 weeks in order to protect seedlings from whiteflies infestation. To prevent whiteflies from entering production sites such as the greenhouse, openings should be sealed or screened with appropriate screening material. Whiteflies are small, so screens with a hole size of 0.27 x 0.82 mm are recommended. Use of these methods has reported reduced transmission of the Tomato Yellow Leaf Curl Virus in several countries (Biovision, 2021a).

4.2.4 Limiting movement in the infested areas

Movement of infested plants into areas known to be free from whiteflies should be restricted. This is to avoid spread of whiteflies from infested areas by humans, plants and clothing. It is important to wear protective clothing before entry, and these must be left or removed before leaving the infested areas.

4.3 Cultural control

4.3.1 Use of clean planting material

Growers should obtain planting material from certified sources to avoid introducing whiteflies in growing sites. If producing own planting material/seedlings, good nursery management should be undertaken to get crops that are healthy and vigorous. New planting material should be examined carefully, particularly host plant species that are prone to regular infestation with whiteflies.

4.3.2 Proper crop sanitation/hygiene

Weeds play an important role in harboring whiteflies between cropping seasons. They also often harbor whitefly-transmitted viruses. Growers should clear weeds early in advance before planting to reduce overwintering of whitefly stages. During active crop growth, the plant fields should be maintained weed free. Control of weed species that harbor *B. tabaci* in non-crop areas including head rows and fallow fields may also be helpful. Old crops with high levels of whitefly represent a threat to newly planted crops hence crop residues should be destroyed promptly after harvest, and the time between harvest and planting of subsequent host crops should be maximized. Good sanitation practices are also key components for establishment of host-free periods and for reducing whitefly adult intercrop migration.

4.3.3 Use of trap crops

Certain plants, such as tobacco, brinjal and okra are particularly attractive to whitefly. These could be used as "trap plants" in organic agriculture, to be destroyed before pupation occurs, or used as "banker plants" for the breeding of parasitic wasps.

4.3.4 Use of resistant varieties

Plant host resistance is the ability of a plant to resist or tolerate infestation by a pest. Growing resistant varieties is useful for the management of viral diseases transmitted by whiteflies, *B. tabac*i. Certain crop varieties have resistance and tolerance that is either natural or through selective breeding. For example, many varieties of cassava in East Africa have been bred particularly for resistance to cassava mosaic virus (CMV).

4.3.5 Early or delayed planting

Growers should plan planting dates to avoid the dry season when whiteflies are most prevalent. Whiteflies multiply rapidly in warm climate/conditions, quickly growing to overwhelming numbers that can cause severe damage to plants. Adjusting planting and harvest dates to avoid the heaviest migration periods and crop overlap has been a successful strategy and a also a key component in establishment of a host-free period for management of *B. tabaci* and its vectored virus pathogens. Geographic manipulation of crops has been used to avoid heavy periods of *B. tabaci* migrations. Adjusted planting and harvest dates are a key.

4.3.6 Crop rotation

Crop rotation is a practice of growing different crops (crops in different families or groups) on the same land in a regular recurring sequence. One of the main important reasons for crop rotation is to hinder development of weeds, insect pests and soil-borne diseases by reducing their population levels. Farmers should practice planting crops from different families in each season in order to break the lifecycle of whiteflies hence prevent them from multiplying. Developing a rotation plan involves dividing the farm for instance into 4 plots and allocating a crop per season for each plot. The crops are rotated on the plots making sure the same family of crop is not planted repeatedly on the same plot (Biovision, 2021b). Table 4 lists crop families and their common names that farmers can consider for integration into a crop rotation program.

Table 4: Crop families for consideration in a crop rotation program

Family	Common names
Allium	Chive, garlic, leek, onion, shallot
Cucurbit (Gourd family)	Bitter gourd, bottle gourd, chayote cucumber, ivy gourd, luffa gourd, melons pumpkins, snake gourd, squash, wax gourd
Crucifer (Brassica)	Bok choy (petchay), broccoli, brussels sprouts, cabbage, Chinese cabbage, cauliflower, collard, kale, kohlrabi, mustard, radish, turnip, watercress
Legume	Common beans, black bean, broad bean (Fava), clover, cowpea, garbanzo, hyacinth bean, kidney bean, Lima bean, lintel, mungbean, peanut, pigeon pea, pinto bean, runner bean, snap pea, snow pea, soybean, string bean, white bean
Aster	Lettuce, artichoke
Solanaceous (Nightshade family)	Potato, tomato, pepper, eggplant
Grains and cereals	Corn, rice, sorghum, wheat, oat, barley, millet
Carrot family	Carrot, celery, dill, parsnip, parsley
Root crops	Cassava, sweet potato, taro, yam, water chestnut
Mallow family	Cotton, okra

Source: Biovision, 2021b

4.3.7 Use of intercropping

Intercropping is an effective means of managing whitefly populations. Inter-planting tomatoes with capsicum or cucumber reduces whiteflies numbers when compared with tomatoes alone or tomatoes planted with eggplant or okra. Planting of border rows with coriander and fenugreek (which are not hosts of *B. tabaci*) favor establishment of natural enemies and as well as repelling whiteflies. Planting African marigolds around the boundary of the field has proven to repel whiteflies. Susceptible crops such as lettuce and Brassica spp. should not be sown near infestation sources such as cotton or melon, which themselves should not be sown near each other (Biovision, 2021a).

4.3.8 Use of oils, soap and starch

Spraying with soap and water has proven effective against whiteflies. Soaps work by partially removing the waxy layer from the scales and causing them to desiccate and die. Liquid soap sprayed at rate of 3 tablespoons per litre of water is recommended for control of *B. tabaci* on tomatoes. Spraying 10 tablespoons of liquid soap per 10 litres of water weekly is recommended for control whiteflies on cabbage. Oils and starch when sprayed onto scales of whitefly can act as suffocants. Various products marketed around the world are based on these ingredients (Biovision, 2021c).

4.4 Biological control

Biological control of whitefly constitutes use of natural enemies (parasitoids and predators), use of products derived from plant extracts (neem, pyrethrum etc.) and microorganisms which include fungi which are the only disease-causing organisms currently known to attack whiteflies. Biological control products are usually only efficient at low pest intensities and other interventions are often required. A key precaution to take into account is that biological beneficial have a very short life expectancy and therefore introduction to the crop should be done as soon as possible after receipt. Use of bio-controls provides an option for growers to replace use of chemical applications by 50% thus helping overcome challenge of pesticide resistance and chemical residues. Although limited studies have conducted a comprehensive cost benefit analysis of using bio-controls, the approach has been termed as the most cost effective method because of the sustainability it offers coupled with social and economic benefits. While this strategy may not provide the actual cost of the biocontrol options, growers are advised that the cost may depend on the specific option, geographical location and the manufacturers or producers costing.

4.4.1 Use of parasitoids

Parasitoids lower the population of whitefly species (*B. tabaci* and *T. vaporariorum*) via parasitism and host feeding. The most and widely used parasitoids are of genera, *Encarsia* and *Eretmocerus* with several success cases on the efficacy of *Encarsia formosa* and *Eretmocerus eremicus* reported (Stansly P.A and Naranjo S.E. (eds.). The *Encarsia* species occur naturally and can either be introduced right at the begging of the crop before appearance of whitefly or on its first appearance. However, it is very sensitive to pesticides hence careful attention should be paid to the spray programme for both insecticides and fungicides. *E. Formosa* should be introduced routinely on a preventative basis. *E. eremicus* has proven very effective in controlling both *B. tabaci* and *T. vaporariorum* and its thus useful for controlling mixed infestations of the two whiteflies (Stansly P.A and Naranjo S.E. (eds.); van Driesche et al. 2001). . *E. formosa and E. eremicus* formulations are commercially available. More details on the usage, mode of action, application and dosage rates can be obtained from the product's label as well as manufacturer's information sheets.

4.4.2 Use of predators

Predators are being used to control *B. tabaci* principally under greenhouse conditions. Majority of the predators are ladybird beetles, predaceous bugs, lacewings, phytoseiid mites, and spiders. The predatory mite, *Amblyseius swirskii* is one of the most effective natural enemies, being active on most vegetable species, except tomatoes, with extensive use in pepper, cucumber and eggplant (Calvo et al., 2008; Nomikou et al., 2001). Use of additional predator species and parasitoids has helped in solving the incompatibility of *A. swirskii* with tomato plants. Several *A. swirskii* based microbial pesticides formulations are available and registered in several countries for management of whiteflies in horticultural crops. Several studies have reported a reduction in *B. tabaci* populations in plots treated with *A. swirskii* compared with controls (Calvo et al., 2008; Bolckmans et al., 2005; Namikou et al., 2001). In Spain *A. swirskii* has played a major role in controlling *B. tabaci* in pepper with elimination of whitefly populations from pepper crop that received eight whitefly adults per week over a 3-week period followed by a single release or either 25 or 50 mites per plant (Calvo et al., 2008). Effectiveness, host range and compatibility of *A. swirskii* with other natural enemies has led to its widespread adoption in greenhouse pepper and other protected vegetable crops in Spain and elsewhere (Stansly P.A and Naranjo S.E. (eds.). Moreover, *A. swirskii* can be released preventively when the crop is flowering and remains present in the crop throughout the entire growing season, even while pests levels are very low (Bolckmans et al., 2005).

In Africa, *A. Swirskii* has been recorded in Cabo Verde and Egypt. *Amblyseius swirskii* is native to Israel, Italy, Cyprus, Turkey, Greece and Egypt, and can be found on various crops including apples, apricot, citrus, vegetables and cotton (EPPO 2013). Since 2005, *Amblyseius swirskii* has been released or tested as a biological control agent in many European countries, as well as North America, **North Africa**, China, Japan and Argentina (Arthurs et al. 2009, Cedola and Polack 2011, EPPO 2013, Kade et al. 2011, Sato and Mochizuki 2011, Chen et al. 2011). Hence, in recent years, the range of *A. swirskii* may have expanded considerably in areas with suitable climatic conditions for its survival, including Senegal (Kade et al., 2011).

Macrolophus pygmaeus is a reputed predator of the whiteflies *B. tabaci* and *Trialeurodes vaporariorum* and recently has also reported its efficacy in reduction of tomato leaf miner *(Tuta absosuta).* Better control of *T. absoluta* and *B. tabaci* was achieved at the higher abundance of the predator. Other authors have also reported the ability of this mirid to reduce the abundance of these two pests when they were present at the same time.

The dusty lacewing (*Conwentzia Africana*) is considered an important predator of *B. tabaci* in East and southern Africa and has been observed feeding directly on nymphs in Malawi and Kenya.

Predatory mite (*Amblydromalus limonicus*) is registered in some countries for control of whiteflies under greenhouses production. *Amblydromalus limonicu*s is distributed widely in temperate to subtropical regions of North, Central and South America, and present in Hawaii, New Zealand (Moraes *et al.*, 2004) and Australia (Steiner *et al.*, 2003; Steiner and Goodwin 2005).

4.4.3 Use of entomopathogenic fungi

Entomopathogenic fungi (EPF) infect and kill development stages of the whitefly species. Some of the commercial preparations available include *Metarhizium anisopliae, Verticillium lecanii, Paecilomyces fumosoroseus* and *Beauveria bassiana* (Stansly P.A and Naranjo S.E. (eds.). Several biopesticide formulations of the EPF are available commercially and registered in several countries for management of whiteflies in horticultural crops.

B. bassiana infects whiteflies when applied as part of a formulation and has a broad range of targets including whitefly, thrips, mealybugs and aphids. It can be tank mixed with adjuvants, insecticidal soaps or oils. No residual harmful effect has been observed on beneficial insects. However, under dry conditions fungi may have limited activity, as they prefer humid conditions to infect the target insects (Abdelghany, 2015).

4.4.4 Use of neem based bio-pesticides

Neem-based pesticides inhibit growth and development of immature stages, repel whitefly adults and reduce egg laying. They also significantly reduce the risk of Tomato Yellow Leaf Curl Virus transmission. Adding 0.1 to 0.5% of soft soap can enhance the efficacy of neem-based pesticides (Biovision, 2021a).). Although all parts of neem tree possess botanical properties for pest control, the most potent results have been obtained with neem seed or oil, because of the high concentration of azadirachtin (Rovest and Deseo, 1991; Dimetry et al., 1996). A field experiment conducted by (Nzanza and Mashela, 2012) showed that fermented plant extracts of neem had insecticidal properties to maintain lower population densities of whitefly in tomatoes.

Note that, even if it is a natural biopesticide, some good agricultural practices (recommended dose rate, number and frequency of applications, and the pre-harvest interval) should be applied to avoid residues and toxicity on the produce.

4.5 Chemical control

Whiteflies are difficult to control once established, as they are often tolerant to chemical pesticides. In designing an IPM programme, farmers should take into account proper selection and application to avoid overuse of pesticides with the same mode of action (Horowitz et al., 2011; Gyeltshen and

Hodges, 2010). A systems approach to insecticide resistance management should be used. Rotation between active ingredients from at least three different modes of action groups (i.e. contact, systemic, translaminar) is recommended to avoid development of resistance to a particular active ingredient (EPPO, 2003).

Growers should observe proper application, responsible use and good handling practices of the products, which would help maximize their benefits, limit potential pesticide residues in crops and the environment as well as help avoid pest resurgence and resistance. Application should be made at the appropriate time in the cycle (e.g. adult and/or nymphal stage). Application should be initiated before the whitefly population increases to damage levels otherwise inappropriate timing of sprays may contribute to increased severity of whitefly infestation. Many pesticides have residual activity, hence specific reapplication intervals should be checked as per the product label (EPPO, 2003).

Proper selection of pesticides is necessary to review product characteristics, applications and costs, then select the ones that provide the most cost-effective treatment with minimal undesirable effects (EPPO, 2003). It is advisable to take into account compatibility of the active ingredients with the bio-control agents or biopesticide while focusing on use of selective substances rather than broad-spectrum products to avoid impact on the bio-controls (Cioffi, 2013). Some products can be active against predators for months after application, but have limited or negligible impact on pest populations after the initial application. Therefore, it is important to consider whether it is necessary to apply chemical pesticides particularly if they have a long residual impact on beneficial populations. Table 5 shows some of the active substances that are approved by the EU and have proven efficient to control whiteflies in various horticultural crops.

Table 5: List of active substances with proven efficacy against whiteflies

Substance	Efficacy*
Fatty acids	+++
Beauveria bassiana	++++*** **
Garlic extract	+**
Geraniol	0****
Parafine oil	++
Lecanicillium muscarium	+++
Maltodextrine	+++
Paecilomyces fumosoroseus	+++
Terpenoid Blend QRD 460	++

* Based on the efficacy identified in Annex 1

** substance proposed by firms

*** efficacy also confirmed in COLEAD trials

**** potentially effective substance because of confirmed repellency

0 = no reference

+ = few references mentioning efficacy (1)

++ = few references mentioning efficacy (2)

+++ = moderately numerous references (3 to 5)

++++ = numerous references mentioning the efficacy (6 to 8)

A case study: combined use of insect parasitoids and entomopathogenic fungi

The compatibility and efficacy of the parasitoid *Eretmocerus hayati* and the Entomopathogenic Fungus *Cordyceps javanica* for Biological Control of Whitefly B. tabaci was evaluated through a study by Ou et al.(2019). The study assessed the impact of *C. javanica* on the parasitism rate of the *E. hayati* and also compared their separate and combined potential in the suppression of *B. tabaci* under semi-field conditions. The findings showed that mortality of *E. hayati* increased with higher concentrations of *C. javanica*, but these higher concentrations of fungus had low pathogenicity to both the *E. hayati* pupae and adults relative to their pathogenicity to *B. tabaci* nymphs. Bioassay results indicated that *C. javanica* was harmless and slightly harmful to the pupae and adults of *E. hayati* respectively on the basis of IOBC criteria, and that *E. hayati* could parasitize all nymphal instars of *B. tabaci* that were pretreated with *C. javanica*, with its rate of parasitism being highest on second-instar nymphs. The parasitoids from second and third-instar *B. tabaci* nymphs infected with *C. javanica* had progeny with increased longevity and developmental periods. The study also established that combined application of *C. javanica* and *E. hayati* suppresses *B. tabaci* with higher efficiency than individual applications of both agents.

Reference

Ou D, Ren L-M, -Liu Y, Ali S, Wang X-M, Ahmed MZ, Qiu B-L. Compatibility and Efficacy of the Parasitoid Eretmocerus hayati and the Entomopathogenic Fungus Cordyceps javanica for Biological Control of Whitefly Bemisia tabaci. Insects. 2019; 10(12):425. https://doi.org/10.3390/insects10120425

4.6 Monitoring and surveillance of whitefly populations

At the farm level, a sound scouting system provides essential information for making management decisions as well as evaluating the effectiveness of management practices. Regular or daily scouting and examination of crops will lead to early detection and timely management of whiteflies. It will detect the presence and estimate population of whiteflies, their natural enemies (predators and parasitoids) and other pests (Crop Life International, 2014). For early detection, scouting is done for adults and eggs that are usually found on young leaves. Flying whiteflies are seen when the crop is disturbed. Presence of sooty mould and the presence of ants on host plants should also be checked. Yellow sticky traps can be used in monitoring the presence of whiteflies. Inspection tools like hand lens can be used to examine leaves and other areas for better visibility of eggs.

More details about the monitoring of whitefly populations at the farm level are included in the Field management brochure available here

At the country level, the National Plant Protection Organization should institute a monitoring programme to establish occurrence and spread of whiteflies species especially those of quarantine importance. Detection or delimiting surveys can be undertaken as guided by ISPM 6 (*Guidelines for Surveillance*). A good surveillance program should be incorporated with a management framework.

4.7 Specific measures during harvest

4.7.1 Phytosanitary treatment

Care should be taken during harvesting such that plants or plant commodities infested with whiteflies are not harvested or are subjected to a phytosanitary treatment accordingly. Some of the treatments that can be applied include: cold storage, controlled atmosphere, washing, brushing, waxing, dipping and heating.

4.6.2 Sanitation

Rejects during harvesting should be put in sealed bags or containers, and discarded appropriately. Because whiteflies may be dispersed via transport, infested plant material should not be transported in unsealed or open trucks and containers.

4.6.3 Laboratory testing

Other than visual examinations to determine presence of whiteflies in plant materials, laboratory diagnostics should also be undertaken for confirmatory purposes. This is important especially in determining the type of species monitored. Official diagnostic protocols should be applied in laboratory testing.

4.8 Post-harvest measures to control whitefly

4.8.1 Sorting, grading and transportation

Growers and processers should institute a quality management system that excludes whiteflies and other pests during post harvest handling. Sorting should be done carefully such that eggs and other live stages of whiteflies are detected and infested produce isolated. Maintaining harvested commodities in cold room and cold chain transportation may help in killing adult stages that may have been unnoticed. Infested commodities such as fruits infested with whitefly eggs can be sorted and cleaned.

5. POST-HARVEST MONITORING AND INSPECTION AT THE FARM AND PACK HOUSE

5.1 Post-harvest monitoring and inspection at the farm

After the produce has been harvested from the farm, it should be taken to a holding area in order to screen out whiteflies from the produce entering the pack house. In the holding area, a representative sample (minimum 2%) should be obtained and inspected for all the life stages of whiteflies. These life stages are; egg, nymphs, and adults. For inspection of the adult whiteflies, a bunch of the harvested produce is held with one hand and the foliage gently tapped with the other hand to check for adult whiteflies. If adult whiteflies are present, they will fly out of the bunch. For inspection of whitefly eggs, the underside of the younger leaves are examined keenly using a hand lens of at least X10 magnification. For inspection of whitefly nymphs, the underside of the older leaves are examined keenly using a hand lens of at least X10 magnification (Queensland Government, 2021).

Produce infested with any of the life stages of whiteflies should be isolated from the pest free produce and destroyed appropriately. Furthermore, a follow-up in the field where the whitefly infested produce was harvested should be done and appropriate management measures taken to control the pest.

Additionally, monitoring of whiteflies in the harvested produce is done by placing yellow sticky cards at strategic points in the holding area The quality controller in the farm should check the yellow sticky card regularly for presence of whiteflies. Observation of whiteflies on the yellow sticky traps is an indication that whiteflies maybe present in the harvested produce and the sample size for inspection should be increased.

More details about the post-harvest monitoring of whitefly populations and the inspection at the farm are included in the «Field management brochure for whiteflies» available here

5.2 Post-harvest monitoring and inspection at pack house

Inside the pack house, monitoring of whiteflies is done by placing the yellow sticky cards in the pack house (Biovision, 2021d; Kumar et al. 2017). The sticky cards should be placed at strategic points particularly near the door entrance, near the windows and at different points inside the pack house. These cards should be examined regularly for presence of whiteflies and replaced periodically.

Other than monitoring, physical inspection of the harvested produce against whiteflies in the pack house should be done at three points. These are; before grading (pre-grading), during grading, and after grading (post-grading). At the pre-grading stage, a representative sample (minimum 2%) should be taken and inspected for all the life stages of whiteflies. When the produce is being graded, a quality controller should sample the produce being graded and inspect it for whitefly infestation. After the produce has been graded and packed ready for dispatch from the pack house, a sample should be taken and inspected for presence of whiteflies. In all the three stages at the pack house, inspection procedure should be similar to that conducted at the produce holding area.

Produce infested with whiteflies should be isolated from the pest free produce and destroyed appropriately. Such produce should not be dispatched from the pack house to the market. A follow-up in the field where the whitefly infested produce was harvested should also be done and appropriate management measures taken to control the pest.

More details about the post-harvest monitoring of whitefly populations and the inspection at the pack house are included in the «Packhouse brochure for management of whiteflies in ACP countries» available here

6. PEST RISK ANALYSIS, SURVEILLANCE AND INSPECTION BY NPPO

6.1 Pest risk analysis (PRA)

NPPO should conduct pest risk analysis (PRA) for whiteflies on new plant species intended to be imported into their country if the new plant species are known to be host of whiteflies. PRA is necessary particularly if the new plant species being imported into the country is known to be host to whitefly species which are quarantined or are regulated non-quarantine species. The pest risk analysis entails assessing the likelihood of introduction into the country of a quarantine whitefly species or a regulated non-quarantine whitefly species through the plant materials being imported and the magnitude of impact the pest is likely to cause after being introduced. In assessing the likelihood of the pest being introduced, the probability of entry, establishment and spread are considered. In determining the magnitude of impact, the economic, environmental and social harm are assessed. PRA should be conducted in accordance to ISPM 2 (*Guidelines for pest risk analysis*), ISPM 11 (*Pest risk analysis for quarantine pests*) and ISPM 21 (*Pest risk analysis for regulated non-quarantine pests*) as the case may be.

6.2 Surveillance and inspection

NPPO officers should conduct regular surveillance and inspection of whiteflies at the production sites of fresh agricultural produce. This is particularly important to production facilities growing plants for planting destined for the EU market. Surveillance and inspection visits to the farms involve four main stages. These are;

i. Audit of crop protection systems of the farm
ii. Field inspection of plants in the farm
iii. Audit of post-harvest checks in the pack house
iv. Final produce inspection

6.2.1 Audit of crop protection systems of the farm

During the visit to the farm, NPPO officers should first audit the crop protection systems in the farm. It involves interrogating the crop protection manager in the farm on the systems they have put in place for the management of whiteflies. It also includes scrutiny of the crop protection reports. Specifically, the NPPO officer should determine whether;

- The farm has a scouting system for whiteflies
- There is a dedicated team that monitor whiteflies among other pests in the farm
- The frequency of scouting per week
- The methodology used in scouting
- Specific strategies used in control of whiteflies
- Pest and spray records are available

Moreover, NPPO officer should audit the sanitation protocols in the farm aimed at controlling whiteflies and whitefly-vectored viruses. In particular, the NPPO officer should examine the following sanitation areas;

- Inspection procedures for new plant materials entering the farm
- Weed management strategies adopted in the farm as weeds serve as alternative hosts for whitefly.

- Disposal methods for whitefly infested plants debris, and plants showing viral symptoms
- Hands and tool disinfection protocols as a pre-cautionary measure against whitefly transmissible viruses.

Additionally, NPPO officer should appraise the capacity building program present in the farm aimed at increasing the workers knowledge and skills on whiteflies detection and management. The NPPO officer should request for documentary evidence (such as certificates) that show that the staff in the farm responsible for scouting and pest management are trained in this area.

6.2.2 Field inspection of plants in the farm

After auditing the crop protection systems in the farm, NPPO officer should visit the production area to validate the information shared by the crop protection manager in the farm. In particular, the NPPO officer should sample some fields within the farm and examine the plants for whiteflies infestation. Among the fields he should sample those that had a history of whitefly infestation from the pest records available in the farm.

In the field, the officer should randomly select ten plants per one hundred square meters and carefully examine the undersides of these plants' leaves for the presence of whitefly adults, nymphs and eggs with the aid of a 10X hand lens. NPPO officer should inspect the underside of both the older and younger leaves as most of the adults, eggs and younger nymphs of whiteflies are found on the younger leaves whereas majority of the older nymphs are found on the older leaves (Queensland Government, 2021). Sampling and inspection of whiteflies should be repeated at various sections of the field so as to adequately sample the whole field. In particular, the sampling should be representative enough so as to cover different crop species, varieties, phenological stages, and agronomic practices if such differences exist in the same field. Moreover, special attention should be paid at the edges of the farm, at the entrance of the greenhouse and where there is presence of weeds within the field as these are hotspots for whiteflies. The NPPO officer should also examine the yellow sticky cards in the fields for the presence of whiteflies. NPPO officer should check whether the yellow sticky cards are distributed at a rate of one card per 100 square metre and placed 50 cm above the crop canopy (University of Massachusetts Amherts, 2021).

The NPPO officer should carry the following equipment to assist in field inspection;

- Hand lens of at least 10X magnification to assist in observing the whiteflies especially the eggs and nymphs
- An aspirator to aid in collecting samples of whitefly adults
- Insect vials containing 70% alcohol to keep the collected whiteflies
- Sampling bags to collect virus symptomatic plant tissues
- Sticker labels for the identification of the collected specimens
- A pen and a field note-book to record the observations made

Insect samples are kept in 70% alcohol while plant tissues collected should be kept in a cool box during transportation. These samples are analyzed in details in the laboratory to confirm the whitefly species or the viral disease from the plant samples. If whiteflies are detected during inspection, the NPPO officer should;

- Advise the management of the farm to take appropriate action to control the pest;
- Recommend to the farm to increase the checks against whiteflies at the pack house; and
- Send an alert to the NPPO officers inspecting the produce from that particular farm at the port of exit to increase the checks for whitefly.

6.2.3 Audit of post-harvest checks

After field inspection, the NPPO officer should also audit the post-harvest systems in the farm aimed at screening out whiteflies from the harvested produce. In particular, he should examine the quality control checks against whiteflies at the following points;

- Reception area of the produce from the farm to the grading hall.
- During the grading process.
- Post-grading of produce before dispatch from the farm.

At each of the three stages, the NPPO should inquire the mitigation measures taken by the farm whenever whiteflies are detected. The NPPO officer should also request for quality control reports at each of the three stages of quality control for closer scrutiny. Moreover, NPPO officer should request for documentary evidence (such as certificates, Standard Operating Procedures (SOPs)) which show that the quality controllers and workers working in the pack house are trained on whitefly detection in the produce.

6.3 Final produce inspection

This inspection is done to the produce which is bound for shipment. It is done at the port of exit before plant movement documents are issued. NPPO officer should carry out an effective inspection on the final produce against whiteflies before issuance of a phytosanitary certificate. The inspection should follow the guidelines issued in ISPM 7 & 12 (*Phytosanitary certification system, Phytosanitary certification*). The inspection should guarantee that the produce being exported is free from all life stages of whiteflies. Effective inspection involves three steps. These are;

i. Documentary checks
ii. Produce inspection
iii. Issuance of plants movement documents/ phytosanitary certificate

6.3.1 Documentary checks

The exporter of plant material should present to the NPPO documents bearing the details of the consignment intended for export. The details include; plant species, quantity of plant material to be exported, name and address of the exporter, name and address of the importer, country of origin, destination country and intended use of the product. The NPPO officer should scrutinize the documents to ensure all relevant sections are properly filled and all the accompanying documents as stipulated in the plant import permit are provided.

6.3.2 Produce inspection

The NPPO officer should determine the sampling size based on the quantity of the consignment. The NPPO officer should randomly sample at least 2% of the consignment for inspection. For a farm with recent history of whitefly infestation or whose produce has been intercepted at the international market in recent times, higher sampling size is recommended. The sampled produce should be removed from the boxes/packages and putting them on the inspection bench. Thereafter, the NPPO officer should carefully examine the presence of whiteflies in the sample with the help of a hand lens with at least X10 magnification.

For inspection of the adult whiteflies, a bunch of the harvested produce is held with one hand and the foliage gently tapped severally with the other hand to check for the adults whiteflies. If adult whiteflies are present, they will fly out of the bunch. For inspection of whitefly eggs, the underside of the younger leaves is examined while for nymphs, the underside of the older leaves is examined.

Whiteflies are introduced into new places through movement of plant materials that are bearing live stages such as eggs. Imported host plants for planting and plant commodities i.e. fruits or leaves should be inspected for compliance on freedom of whitefly species. It is not feasible to inspect all imported consignments. A framework on sampling should be established at farm and national levels in line with the guidelines of ISPM 31 (*Methodologies for sampling consignments*).

6.3.3 Issuance of plant movement documents

If whiteflies (and other quarantine pests) have not been observed during the inspection, NPPO officer should issue the exporter with a phytosanitary certificate or other plant movement documents as the case maybe. The phytosanitary certificate should be issued in accordance to ISPM 12 (*Phytosanitary certificates*). Moreover, for some plant materials destined to the EU market, additional declaration in line with regulation EU 2019/2072 annex VII, annex VIII, and annex X should be made to the effect that the produce is free from *Bemisia tabaci.* Additionally, if the imported plant materials are for planting into EU territory, the place of production of such produce was free from *Bemisia tabaci* and if *Bemisia tabaci* was detected, appropriate management measures were undertaken. However, if whiteflies are detected during inspection at import in EU on all kind of products or regulated material, the consignment is rejected and destroyed appropriately. A follow-up in the field to trace the origin of whitefly infested produce maybe necessary.

7. DOCUMENTATION

All along the supply chain, procedures for inspection and monitoring should be documented and Standard Operating Procedures (SOPs) developed to guide and train the operators and inspectors. SOPs should be always available to the operators and inspectors and for inspection by the NPPO. All monitoring and inspection activities should be consigned in a register at the farm, packinghouse, transport and the NPPO.

8. ANNEX 1: LIST OF PLANT PROTECTION PRODUCTS EFFICACIES AGAINST WHITEFLIES

Summary of the information collected on the efficacy of the substances.

N.B. For the selected substances not authorised in the EU, the research on efficacy was not carried out very far, except for the substances of interest in terms of residue risk.

Active ingredient	EU Status	Reference mentioning efficacy
Abamectine	Approved	7,8,10,24
Acephate	Not approved	8
Acétamipride	Approved	6,7,8,10,11,13,19
Acide citrique	/	
Acides gras	Approved*	8,12,19
Afidopyropen	Not approved	13
Alpha-cyperméthrine	Not approved	
Ail (extrait)	Approved	22
Amitraze	Not approved	4
Azadirachtine	Approved	4,7,8,12, 22,24
Beauveria bassiana	Approved*	2,4,7,8,12,19
Beta-cyflutrine	Not approved	
Bifenthine	Not approved	4,7,8,11,13
Buprofezin	Approved	1,4,6,8,10,11,12
Carapa procera (huile)	/	
Chlorantraniliprole	Approved	7
Chlorpyrifos-ethyl	Not approved	8
Clitoria ternatea (Natural extract from the Butterfly Pea)	/	13
Cyperméthrine	Approved	
Cyantraniliprole	Approved	7,8,10,13
Cyromazine	Not approved	
Deltaméthrine	Approved	4,19
Diméthoate	Not approved	
Diafenthiuron	Not approved	3,6,13
Diazinon	Not approved	
Dinotefuran	Not approved	8,10,11,12,13
Emamectin benzoate	Approved	13
Etofenprox	Approved	
Fenoxycarb	Not approved	4

Fenpropathrin	Not approved	4
Fenproximate	Approved	12
Flonicamide	Approved	15,19
Flubendiamide	Approved until 31 August 2024	
Flupyradifurone	Approved	10
Geraniol	Approved	
Huile de paraffine	Approved*	8,13
Huile minérale	Approved*	12
Imidacloprid	Not approved	1,4,6,7,8,10,12
Kinoprène	Not approved	8
Lambda-cyhalothrine	Approved	7
Akanthomyces muscarius (formerly *Lecanicillium muscarium or Verticillium lecannii)*	Approved*	5,16,19
Lufenuron	Not approved	
Malathion	Approved	7
Maltodextrine	Approved	9,19,23
Metarhizium brunneum (formerly *Metarhizium anisopliae*)	Approved*	5,7,19
Methomyl	Not approved	
Monosultap	/	
Novaluron	Not approved	6,8
Orange oil (D-limonene)	Approved	14,19
Oxymathrine (matrine)	Not approved	18
Capsicum extract	Not approved	
Paecilomyces fumosoroseus	Approved*	2,8,12,19
Profenofos	Not approved	
Pymetrozine	Not approved	4,6,7,8,10,19
Pyrethrine	Approved	12,19
Pyridaben	Approved	8
Pyriproxyfen	Approved	6,8,10,11,12,13,19
Pyrifluquinazon	Not approved	8,10
Spinetoram	Approved	17
Spirodiclofen	Not approved	
Spiromesifen	Not approved	8,10,11,19
Spirotetramate	Not approved	8,10,12,13
Sulfoxaflor	Approved	7
Tagetes oil	Not approved	8
Terpenoid Blend QRD 460	Approved	20, 21
Thiaclopride	Not approved	6,19
Thiamethoxam	Not approved	7,6,8,10,12,19
Zeta-cypermethrin	Not approved	

* approval by type or strain

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