Food and Agriculture Organization
of the United Nations

Baseline survey on emerging pests in Eastern Africa

Programme support to the establishment of the Eastern African Emerging Pests Programme on Early Warning, Preparedness and Response System

2024

CABI

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Abbreviations

ACC	Agro-chemicals Control Division
ALOP	appropriate level of protection
ASAL	arid and semi-arid land
AU-IAPSC	African Union Inter-African Phytosanitary Council
CABI	Centre for Agriculture and Bioscience International
CAR	Central African Republic
CEDA	Centre for Environmental Data Analysis
CERIP	Contingency Emergency Recovery Implementation Plan
COVID-19	coronavirus disease 2019
CPC	Crop Protection Compendium
CPDN	Caribbean Pest Diagnostic Network
CPF	Country Programming Framework
DCIC	Department of Crop Inspection and Certification
DEFRA	Department for Environment, Food and Rural Affairs
DLCO-EA	Desert Locust Control Organization for Eastern Africa
DLIS	Desert Locust Information Service
DPs	diagnostic protocols
EAC	East African Community
EAHB	East African Highland banana
ELISA	enzyme-linked immunosorbent assay
EPPO	European and Mediterranean Plant Protection Organization
EPPRD	Emergency Plant Pest Response Deed
ESRS	European Sustainability Reporting Standards
FAMEWS	Fall Armyworm Monitoring and Early Warning System
FAO	Food and Agriculture Organization of the United Nations
FAW	fall armyworm
FCM	false codling moth
GDP	gross domestic product
HST	horizon scanning tool
IPM	integrated pest management
IPP	International Phytosanitary Portal
IPPC	International Plant Protection Convention
ISC	Invasive Species Compendium
ISPMs	International Standards for Phytosanitary Measures
IUCN	International Union for Conservation of Nature
KEPHIS	Kenya Plant Health Inspectorate Service
KIIs	key informant interviews
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MIDIMAR	Ministry of Disaster Management and Refugee Affairs
MITT	multi-institutional technical team
MoALFC	Ministry of Agriculture, Livestock, Fisheries and Cooperatives
MoU	memorandum of understanding
MRL	maximum residue level
NAPPO	North American Plant Protection Organization
NIFA	National Institute of Food and Agriculture
NLCC	National Locust Control Centre
NPDN	National Plant Diagnostic Network
NPHERU	National Plant Health Emergency Response Unit
NPPO	National Plant Protection Organization

NSCS	National Seed Certification Service
PBCRC	Plant Biosecurity Cooperative Research Centre
PCN	potato cyst nematode
PCR	polymerase chain reaction
PHA	Plant Health Australia
PMP	Pest Management Plan
PQIS	Phytosanitary and Quarantine Inspection Services
PRA	pest risk analysis
PRISE	Pest Risk Information SErvice
RECs	Regional Economic Communities
RH	relative humidity
RPPO	Regional Plant Protection Organization
SDGs	Sustainable Development Goals
SDM	species distribution model
SFE	Subregional Office for Eastern Africa
SPS	sanitary and phytosanitary
UNDAF	United Nations Development Assistance Framework
VCG	Vegetative Compatibility Group
WTO	World Trade Organization

The black sooty mould of mango mealybug.

Executive summary

The global and regional spread of pests has increased dramatically in recent years. Globalization, trade and climate change, as well as reduced resilience in production systems due to decades of agricultural intensification, have all played a part. One of the significant threats to sustainable crop production across Eastern African countries in general is the increasing phenomenon of introduction and spread of emergent/transboundary pests.

In recent years, several pests have been introduced and spread to several countries, reaching epidemic proportions. Outbreaks of newly introduced pests and the resurgence of endemic pests can cause significant losses to crops, pastures and forests, thereby threatening the livelihoods of vulnerable farmers, pastoralists and the food and nutrition security of millions at any time.

The Food and Agriculture Organization of the United Nations (FAO) Subregional Office for Eastern Africa (SFE) has begun a broad-based initiative to understand the needs of the countries in the subregion for enhancing their early warning, preparedness and response systems for regional plant pest risk reduction and mitigation.

As part of the initiative, the Centre for Agriculture and Bioscience International (CABI) conducted a baseline survey to establish the status of early warning, preparedness and response systems for emerging pests in the nine Eastern African countries which are part of SFE. The survey involved a desk review of emergent pests. This report describes the status of their distribution in eastern Africa, biological characteristics, description of hosts and symptoms on hosts as well as their economic importance and associated phytosanitary risks.

In addition, a virtual training on pest risk analysis (PRA) using CABI tools was conducted in March 2021. As part of the training, four pests were identified as a priority for the subregion, given their high risk of introduction to SFE countries: mango mealybugs (*Rastrococcus iceryoides* and *Rastrococcus invadens),*[1] banana Fusarium wilt disease tropical race 4 (*Fusarium oxysporum* f. sp. *cubense*) and khapra beetle (*Trogoderma granarium*). Consequently, a qualitative pest-initiated risk analysis was conducted for the four priority pests as comprehensively described in Section 3 of this report. The assessment showed that all pests had a high likelihood of entry, spread and establishment in Eastern African countries, resulting in adverse economic impacts. Detection surveys and reporting of pest status is urgent for mango mealybugs (*Rastrococcus iceryoides* and *Rastrococcus invadens*). *Rastrococcus iceryoides* has already been detected in Kenya, and *Rastrococcus invadens* has also recently been detected in Burundi, Rwanda and Uganda. Equally, urgent pest surveillance plans are required to monitor and detect the presence of banana Fusarium wilt disease tropical race 4 (*Fusarium oxysporum* f. sp. *cubense*). We recommend a joint workshop to review and validate the PRA outcomes presented in this report.

The survey also involved an assessment that utilized mixed approaches to gather information on the capacity of the nine national plant protection organizations (NPPOs) on early warning, preparedness and response systems for emerging pests. Data collection was done through scorecards completed by NPPO heads and online questionnaires (using the Survey Monkey tool) targeted at both public and private sector players. To complement this information, key informant interviews with relevant stakeholders in the plant health sector were held. The findings from this assessment are discussed in more detail in Sections 4 to 8.

Results from the survey indicated a lack of legal frameworks to support detection, early warning, preparedness and response systems at national and regional levels. Where legal frameworks exist, there is limited human, financial and infrastructural capacity for rapid response to eradicate or contain pests. We recommend a review of the existing plant protection acts and legislation to support early warning, preparedness and response systems. In some instances, there is a need to support countries to draft these laws and regulations. We also recommend pest-listing activities for countries to develop lists of quarantine and non-quarantine pests and undertake national contingency planning for prioritized pests.

[1] *Rastrococcus invadens*, commonly known as mango mealybug, is also referred to as fruit tree mealybug in the CABI Crop Protection Compendium (CPC).

Section 1

Background

© FAO/Pius Utomi Ekpei

8 April 2017, Maiduguri, Nigeria – People stand under a mango tree near Gongolong Village, Jere Local Government Area, 11 kilometres from Maiduguri metropolitan in Borno, northeast Nigeria.

Context

The nine Eastern African countries that comprise FAOSFE, i.e. Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, South Sudan and Uganda, have a total population of about 264.1 million as of 2019, with a combined GDP of USD 258.2 billion (UN, 2019; World Bank, 2019). One of the major threats to economic growth and sustainable development across all the nine SFE countries is the increasing phenomenon of the introduction and spread of emergent pests.

The global and regional spread of pests has increased dramatically in recent years. Globalization, trade and climate change, as well as reduced resilience in production systems due to decades of agricultural intensification, have all played a part. According to CABI, five invasive alien species studied cause USD 0.9 billion to USD 1.1 billion in economic losses to smallholder farmers across six Eastern African countries each year, equating to 1.8 to 2.2 percent of total agricultural GDP for the subregion. These losses are expected to grow to USD 1.0 billion to USD 1.2 billion per year over the next five to ten years, highlighting and justifying the urgent need for coordinated responses at national, regional and international levels. Invasive species are an important threat to economic growth and sustainable development. The achievement of the United Nations Sustainable Development Goals (SDGs) is significantly hampered by the impact of invasive species.

Pests can easily spread to several countries and reach epidemic proportions. Outbreaks of newly introduced pests and the resurgence of endemic pests cause huge losses to crops, pastures and forests, threatening the livelihoods of vulnerable farmers, pastoralists and the food and nutrition security of millions at any time. A significant component of food losses and trade opportunities in agriculture are attributed to pests and to food safety threats, including biological toxins, microbial contaminants and pesticide residues.

In Eastern Africa, invasive species worsen existing chronic food insecurity situations. There are numerous interventions in the subregion that target specific pests or agricultural production issues but few address overarching institutional capacity gaps that prevent the establishment of a sustainable enabling environment necessary to promote trade and investments in the agriculture sector, thereby protecting the livelihoods of so many who depend on agriculture. These gaps are omitted from most project interventions, leaving it to the governments to address them.

Emergent pests spread in three principal ways: trade or other human-mediated movement, weather and wind-borne environmental forces, and insect or other vector-borne pathogens. Overall, the incidence of emergent pest species affects the livelihoods of millions in Eastern African countries and calls for urgent and sustained interventions. The key element to achieve this is by strengthening and maintaining a regional pest risk reduction and mitigation system through early warning, preparedness and response.

The objective of this study is to enhance the early warning, preparedness and response capacities of NPPOs and agriculture extension services in the nine SFE countries. The intervention by FAO is designed to safeguard productivity and reduce vulnerabilities to shocks affecting food and nutrition security, and to strengthen the relevant capacities to cope with these threats. The overall output is to raise awareness of emerging pests in the Eastern African subregion to avert production losses with a view to develop a roadmap for surveillance, monitoring and early response.

The objectives of this study are directly linked to FAO Strategic Objective 2: "To make agriculture, forestry and fisheries more productive and sustainable", and Strategic Objective 5: "Increase the resilience of livelihoods to threats and crises", as well as to the FAO Regional Office for Africa's (RAF) Regional Initiative 2: "Promote sustainable, inclusive, proven innovative practices and principles of production and post-production processes (Sustainable Production Intensification and Value Chain Development in Africa)". The proposed actions are also relevant to the Country Programming Frameworks (CPFs) and to the United Nations Sustainable Development Cooperation Framework, formerly known as the United Nations Development Assistance Framework (UNDAF), of all frontline states as they address pertinent issues related to capacity building, disaster risk management and gender-effective response to food and agricultural threats that all the nine countries are striving to address.

Study objective

The aim of this baseline study was to establish the status of early warning, preparedness and response systems for emerging pests in the nine SFE countries: Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, South Sudan and Uganda. The specific objectives included:

- assessment of the list of plant pests of concern to the subregion;
- conducting three regional PRAs;
- assessment of surveillance and pest diagnostics capacity in the subregion;
- assessment of contingency planning and incident management in the subregion;
- assessment of eradication, containment and control measures;
- assessment of available tools from FAO (FAMEWS, eLocust3), CABI and the private sector to enhance a system for early warning;
- review of existing regional and international technical resources that could be customized/ made available to NPPOs of the target countries.

Organization of the report

This report is organized into eight sections. The first section contains background information, the structure of the report, the approach used in conducting the study and a description of the phytosanitary systems in the target countries. In Section 2, the major emerging pests of concern to the Eastern Africa Subregion are described. The regional PRA conducted for three plant pests is presented in Section 3. The next three sections contain information on the assessments done with regards to surveillance capacity and pest diagnostics (Section 4), contingency planning and incident management (Section 5), eradication, containment and control measures (Section 6) and early warning and reporting (Section 7). Finally, Section 8 contains an inventory of existing regional and international technical resources.

Figure 1 : *Farmers use a maize-thresher machine provided by FAO to reduce post-harvest loss in Gewane district of Afar region in Ethiopia. FAO supports the Afar regional government's effort to improve the livelihood of pastoral and semi-pastoral households.*

Methodology

Study approach

The baseline study included desk reviews of the applicable legal frameworks supporting early warning, preparedness and response systems for emerging pests, survey questionnaires administered through the Survey Monkey tool (see Annex 1) and key informant interviews (KIIs) with competent authorities, agricultural extension officers, export associations and research scientists in plant health in the target countries (see checklist in Annex 2). A scorecard highlighting the key areas necessary for early warning, preparedness and response systems for emerging pests was also shared with NPPOs for scoring according to applicable status per country (see Annex 3).

Sources of information

Data for this baseline study were collected from various stakeholders in the plant health system, including public and private sector players. Respondents and key informants included regulators, associations of importers and exporters, extension agents and research scientists. Different sets of online questionnaires targeting different categories of respondents were completed through the Survey Monkey tool, and feedback collated for analysis. Respondents from seven Eastern African countries (Burundi, Ethiopia, Kenya, Rwanda, Somalia, South Sudan and Uganda) took part in the survey by completing at least one of the survey tools (online questionnaire, country scorecard or KII). Djibouti and Eritrea did not take part in the survey. Overall, 140 respondents completed the online questionnaires (Table 1), 18 KIIs were conducted with public and private sector players from five countries (Table 2) and four NPPOs (Burundi, Kenya, Rwanda and Somalia) completed the country scorecards.

Table 1: Number of respondents in each country by category

Respondent category	Countries							
	Burundi	Ethiopia	Kenya	Rwanda	Somalia	South Sudan	Uganda	Total
Extension officers/plant quarantine inspectors	2	0	53	11	6	0	9	**81**
Research institutions (local and international)	1	0	34	4	2	1	2	**44**
Import/export associations	1	2	8	4	0	0	0	**15**
Total	**4**	**2**	**95**	**19**	**8**	**1**	**11**	**140**

Table 2: Number of key informant interviews conducted

KII category	Countries					
	Burundi	Kenya	Rwanda	Somalia	Uganda	Total
Public sector	1	6	3	1	3	**14**
Private sector	-	4	-	-	-	**4**
Total	**1**	**10**	**3**	**1**	**3**	**18**

Note: KII = Key informant interview.

Challenges of the study

The challenges encountered with the baseline study were mainly related to the remote nature of data collection, occasioned by the coronavirus disease 2019 (COVID-19) restrictions. In many cases, there were delayed responses from NPPOs in completing the scorecard. At the time of writing this report, Djibouti, Eritrea, Ethiopia, South Sudan and Uganda had not shared their scorecards.

Links to the online questionnaires were circulated via email and social media such as WhatsApp, where networks already existed for countries such as Kenya, Rwanda and Uganda. Lack of responses (from Djibouti and Eritrea) and limited responses to the questionnaires (from Ethiopia, Somalia and South Sudan) limit the amount of information obtained for these countries. Even where countries had a high response rate to the online questionnaires, incomplete questionnaires limited the amount of information obtained for particular questions.

While key informant interviews were successful for Kenya, Rwanda, Somalia and Uganda, Burundi was affected by the poor internet network and language barrier, although the KII checklist was completed and shared via email.

To compensate for these limitations, extensive desk reviews were undertaken to collate information that was available through project reports and other documentation in the areas of surveillance capacity and pest diagnostics, contingency planning and incident management, eradication, containment and control measures and early warning and reporting. For Djibouti, Eritrea, Ethiopia and South Sudan, limited information was available online and requests for information sent to contact persons were not successful.

Description of phytosanitary systems

BURUNDI: The Directorate of Vegetable Protection (DPV) of the Plant Protection Directorate is the NPPO of Burundi created by Decree 100/154 of 19 October 1993 organizing the Ministry of Agriculture and Livestock. The NPPO's mandate is to oversee the implementation of the national plant protection policy including the control and approval of plant protection products, conduct a national plant health inspection to prevent plagues and assess the efficiency of the techniques and products used, and promote the commercialization of plant protection products. The implementation of these functions is supported by Decree-Law No. 1/033 of 30 June 1993 on plant protection in Burundi, Decree No. 100/55 of 23 March 2016 on the Protection of New Varieties of Plants; Decree No. 100/251 of 24 September 2012 on Establishing, Missions, Composition and Operation of the National Seed Commission; and Law No. 1/08 of 23 April 2012 on the Organization of the Seed Sector. Burundi is a Member of the World Trade Organization (WTO) and a contracting party to the International Plant Protection Convention (IPPC).

DJIBOUTI: The Directorate of Agriculture and Forests under the Ministry of Agriculture, Water, Fisheries, Livestock and Marine Resources is the NPPO. Its mandate includes inspection of plants and products of plant origin and issuance of phytosanitary certificates. Under the reorganization of the Ministry of Agriculture, Livestock and the Sea (Law No. 200/07/05), the National Directorate of Agriculture and Forests includes the Plant Production Department and the Forest and Desertification Control Service. The Plant Production Department under the Plant Production and Protection Subdivision is responsible for the control and management of crop predators, and the control of plants and products of plant origin imported or exported to avoid the introduction of new diseases or dangerous genetic strains. Djibouti is a member of WTO and a contracting party to the IPPC.

ERITREA: The Regulatory Services Department of the Ministry of Agriculture (MoA), which was established in 2003, is the NPPO of Eritrea. Its mandate includes the regulation of the import inspection and export certification processes, ensuring the safety of fresh food plants (fresh fruits and vegetables) and plant products in processing plants, inspection, and regulatory services to ensure the production of quality seeds, the subsequent issuing of seed certification for quality seeds, and inspection and regulatory services for ensuring the safety and quality of agrochemicals, including the safe disposal of unwanted agrochemicals. The functions of the NPPO are supported by the Plant Quarantine Proclamation No. 156/2006, whose objective is to prevent the introduction and spread of pests through the importation of plants and plant products, take appropriate measures for the control of introduced pests and in exportation, prevent the presence of pests in plants and plant products. Eritrea is a contracting party to the IPPC.

ETHIOPIA: The Crop Protection Department of the Ministry of Agriculture is the NPPO for Ethiopia. It is mandated to regulate the movement of plants and plant products to avoid introduction of exotic plant pests and diseases into the country. It is supported by the Plant Protection Decree No. 56 of 1971 and Plant Quarantine Regulation No. 4 of 1992. Ethiopia is a contracting party to the IPPC.

KENYA: The mandate of KEPHIS includes the enforcement of sanitary and phytosanitary regulations including the protection of seeds and plant varieties; support to the administration and enforcement of food safety measures; establishment of service laboratories to monitor the quality and levels of toxic residues in agro-inputs, irrigation water, plants, soils and produce; plant variety testing and description; seed certification and plant quarantine control; and regulation of import and export of plants and plant materials. These functions are supported by the Plant Protection Act (Cap. 324), the Seeds and Plant Varieties Act (Cap. 326), the Agricultural Produce (Export) Act (Cap. 319) and the Suppression of Noxious Weeds Act (Cap 325). Kenya is a contracting party to the IPPC.

RWANDA: The Rwanda Inspectorate, Competition and Consumer Protection Authority (RICA) is the NPPO. RICA's mandate includes enforcement of the Rwanda plant health laws and regulations for phytosanitary measures necessary for trade, plant pest/disease monitoring, surveillance and diagnosis, conducting pest risk analysis and inspection and certification. The implementation of these functions is supported by the Plant Health Protection Law No. 16/2016, which determines modalities for plant health protection, provides for strategies meant to control and contain the establishment of pests or diseases and matters connected with living organisms. Rwanda is a Member of WTO and a contracting party to the IPPC.

SOUTH SUDAN: The Department of Plant Protection of the Ministry of Agriculture and Food Security is the NPPO. South Sudan is a contracting party to the IPPC.

SOMALIA: The Plant Protection Department of the Ministry of Agriculture and Irrigation is the designated NPPO. The Plant Protection and Quarantine Law of 2019 has been drafted and is awaiting approval by Parliament. The purpose of the Plant Protection and Quarantine Law is to ensure the stabilization and development of agricultural production through the prevention of the introduction and spread of pests and the facilitation of international trade and market access of Somalia's plant and plant products. Somalia is a contracting party to the IPPC.

UGANDA: The Department of Crop Inspection and Certification (DCIC) is the NPPO of Uganda. DCIC is under the Directorate of Crop Resources of the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF). The DCIC consists of three divisions, namely the Phytosanitary and Quarantine Inspection Services Division (PQIS), the National Seed Certification Services Division (NSCS) and the Agro-chemicals Control Division (ACC). The DCIC's mandate is to support sustainable inspection and certification in conformity with national and international phytosanitary, seed/planting materials and agrochemicals control requirements for improved food security, nutrition and household income. The implementation of these functions is supported by the Plant Protection and Health Act of 2015, the Plant Variety Protection Act of 2014, the Agricultural Chemicals (Control) Act of 2006 (No. 1 of 2007), Seeds, the Plant Act of 2006 (No. 3 of 2007) and the Produce Protection Act (Cap. 32). Uganda is a member of WTO and a contracting party to the IPPC.

Section 2

Pests of concern in the Eastern African Subregion

Introduction

Plant pests pose the greatest threat where there are few natural factors to limit their spread and people do not have experience in managing them, particularly when they are first introduced into ecologically favourable conditions. Such occurrences often cause huge economic impact and, in the majority of cases, affect marginalized communities most severely. Recently, the spread of emergent species has increased dramatically, and the enhanced movement of goods and people following trade liberalization, has renewed the need for international and regional cooperation in the prevention and management of transboundary pests.

A desk review of emergent pests was conducted, taking into consideration the key transboundary pests that are significant to economies, trade and/or food and nutrition security in the nine countries in the Eastern Africa Subregion. The pests are also those that can easily spread to other countries and reach epidemic levels, and whose effective management requires cooperation among multiple countries.

Prior to this study, SFE had undertaken a prioritization exercise and came up with a list of 12 priority plant pests for the subregion, which include:

- **Insect pests:** Desert locust (*Schistocerca gregaria*), fall armyworm (*Spodoptera frugiperda*), tomato leaf miner (*Tuta absoluta*), oriental fruit fly (*Bactrocera dorsalis*), papaya mealybug (*Paracoccus marginatus*), red palm weevil (*Rhynchophorus ferrugineus*), cochineal (*Dactylopius coccus*), mango mealybug (*Rastrococcus invadens*), polyphagous shot hole borer (*Euwallacea whitfordiodendrus*) and brown marmorated stink bug (*Halyomorpha halys*).
- **Plant diseases:** Maize lethal necrosis disease (MLND), wheat rusts (stem, leaf and stripe), banana bunchy top virus (BBTV), potato cyst nematode (*Globodera rostochiensis* and *G. pallida*), citrus huanglongbing (greening) disease (*Candidatus Liberibacter asiaticus*) and banana Fusarium wilt disease tropical race 4 (*Fusarium oxysporum* f. sp. *cubense*).
- **Noxious weeds:** Parthenium weed (*Parthenium hysterophorus*), mesquite (*Prosopis juliflora*) and water hyacinth (*Eichhornia crassipes*).

Summary data sheets of the above pests, including information on their respective key host crops, their economic importance once introduced into a country and the phytosanitary risks associated with their spread into new boundaries, obtained from the literature review and in particular the CABI Crop Protection Compendium, are presented in the next section. In addition, the presence or absence of the pests in the nine target countries is presented in Table 3.

Figure 2: *10 June 2020, Lokichar, Kenya – Hopper bands of desert locust infest a remote area in Turkana County, Kenya. An increasing number of second-generation immature swarms continue to form in northwest Kenya.*

Summary data sheets on emergent insect pests

Desert locust (*Schistocerca gregaria*)

HOSTS: Mainly acacia, pigeon pea, cotton, cassava, wheat, maize, sorghum and sugar cane.

GEOGRAPHICAL DISTRIBUTION IN AFRICA (FAO, 2020a)

Present: Djibouti, Eritrea, Ethiopia, Kenya, South Sudan, Somalia, Sudan, Uganda, United Republic of Tanzania.

Absent: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Egypt, Equatorial Guinea, Eswatini, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, Togo, Tunisia, Zambia, Zimbabwe.

BIOLOGY: The life cycle of *S. gregaria* takes 2.5 to 5 months. The female locust oviposits on the sandy soil and lays about 20 to 130 eggs per pod. Soil incubation can take 25 to 70 days, depending on temperature. The eggs moult five times and the first instar nymphs are black in colour. Wing pads are visible in the fourth and fifth instars. The fifth moult results in an immature adult called a fledgling. The disappearance of pink colour from the hind legs of immature adults shows maturity. The females become sexually active and are able to copulate. They then search for oviposition sites by probing the soil with the tip of their abdomen where they push the ovipositor into the soil and make a hole. The abdomen stretches to about twice its normal length and then eggs are laid. The top of the egg pod is filled with a frothy substance, which hardens quickly (Keerthi *et al.*, 2020; Symmons and Cressman, 2001).

SYMPTOMS ON MAIN HOSTS: Desert locust swarms can devastate any vegetation completely, including debarking trees. There is external feeding on fruits and growing points. The leaves become shredded and webbed. The inflorescence frass is visible. Desert locusts feed on the whole plant (CABI, 2021).

ECONOMIC IMPORTANCE: Swarms of desert locusts can cause devastating effects on vegetation and crops (as they feed on young tender points) and can even debark trees (CABI, 2021).

PHYTOSANITARY RISK: Desert locust swarms are aided by wind and are known to swim over long distances across boundaries (CABI, 2021).

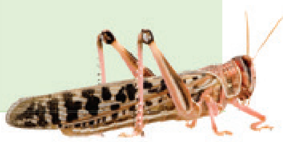


Figure 3: *Schistocerca gregaria.*

Fall armyworm (*Spodoptera frugiperda*)

HOSTS: Mainly maize, rice, sorghum, sugar cane and wheat, but also other vegetable crops and cotton.

GEOGRAPHICAL DISTRIBUTION IN AFRICA
(FAO, 2018; CABI, 2021)

Present: Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Democratic Republic of the Congo, Côte d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Togo, Uganda, United Republic of Tanzania, Zambia, Zimbabwe.

Absent: Algeria, Libya, Morocco, Tunisia.

BIOLOGY: The pest undergoes a complete life cycle of egg, larva, pupa and adult. The adult female lays eggs at night in clusters of 100 to 300 on the lower leaves of the host. Egg hatching takes two to ten days and the mortality rate is high due to attack by parasitoids and climatic factors. The young larvae migrate to the whorl. The larval stage has six instars which take 14 to 21 days, depending on diet and temperature conditions. There is gregarious feeding by the first two instars on young leaves, causing a characteristic "windowing effect" or skeletonizing. The larvae become cannibalistic in the second and third instar stages, causing a few larvae to be present per whorl.

The pupal stage takes 9 to 13 days and occurs inside a loose cocoon in maize cob kernels and sometimes in between leaves on the host. The adults emerge at night and fly for many kilometres. The females then settle to ovipost in the first four days of their life. Sandy clay soils are suitable for pupation and adult emergence (Day *et al.*, 2017).

SYMPTOMS ON MAIN HOSTS: The larva is the most destructive stage. The seedlings are fed on within the whorl. The plant base is cut by the larvae and the reproductive structures of the mature plants are attacked. The leaves of maize are eaten and the whorl becomes a mass of larval frass, ragged edges and holes. On tomato plants, buds and growing points may be eaten and fruits pierced. The leaf lamina on maize is skeletonized, causing "window pane" damage. The larval instars make large holes on leaves. Severely infested fields appear as if they have been hit by hailstones. The pest destroys silk and develops tassels, reducing ear fertilization. It bores holes through the maize kernels. Cob damage can lead to fungal infection by *Fusarium* and *Aspergillus* species, loss of grain quality and quantity (Baudron *et al.*, 2019).

ECONOMIC IMPORTANCE: Fall armyworm defoliates the vegetative parts of plants, resulting in crop losses. Losses of 25 percent to 50 percent have been reported on maize in Zimbabwe (Chimweta *et al.*, 2019).

PHYTOSANITARY RISK: Fall armyworm is present in over 50 countries, including all the nine SFE countries. The pest has been intercepted in agricultural commodities including *Coriandum, Eryngium, Pisum, Rosa, Capsicum, Eustoma, Solanum* and *Zea* mays exported to the European Union (EU) (EUROPHYT). At the Eastern Africa regional level, no interception data or alert has been issued on this pest on traded fresh agricultural produce.

Figure 4: Maize crop is attacked by the fall armyworm at Orchi Farm, Zimbabwe (left). *Spodoptera frugiperda* (right).

Tomato leaf miner (*Tuta [Pthorimaea] absoluta*)

HOSTS: Mainly tomato plants (*Solanum lycopersicum*) and other cultivated and wild plant species of the Solanaceae family such as potato (*S. tuberosum*), aubergine (*S. melongena)*, pepino (*S. muricatum*) and black nightshade (*S. nigrum [S. americanum]*) (Cherif and Verheggen, 2019).

GEOGRAPHICAL DISTRIBUTION IN AFRICA (CABI, 2021)

Present: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Comoros, Democratic Republic of the Congo, Egypt, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gambia, Ghana, Kenya, Lesotho, Libya, Madagascar, Malawi, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, South Africa, Sudan, Togo, Tunisia, Uganda, United Republic of Tanzania, Zambia, Zimbabwe.

Absent: Central African Republic, Chad, Congo, Côte d'Ivoire, Djibouti, Gabon, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Sierra Leone, Somalia, South Sudan.

BIOLOGY: *Tuta (Pthorimaea) absoluta* undergoes four biological stages which are egg, larva, pupa and adult (Abbes *et al*., 2012). Females and males of *Tuta (Pthorimaea) absoluta* have a lifespan of 14 and 7 days respectively. Upon mating, the female lays about 260 individual elliptical eggs on the underside of leaves, stems and sepals. The oyster-white to bright yellow eggs are 0.35 mm long. During the embryonic phase they become brown before eclosion (Imenes *et al*., 1990). The eggs hatch after four days into whitish first-instar larvae which progressively turn green upon feeding on plants. The second and third instars vary in colour based on the ingested food, for instance light pink when feeding on either leaflets or ripe fruits. A patterned prothoracic shield and a pink back characterize the fourth-instar larvae (Abbes *et al*., 2012). The larva stage takes about 8 to 12 days to develop to prepupae and pupae that leave the mines and build silk cocoons on either leaflets or in the soil. The pupation stage takes 10 days as they become adults of about 10 mm long with silverfish-grey scales (Imenes *et al*., 1990).

SYMPTOMS ON MAIN HOSTS: Damage is caused by the feeding activity of the larval stage of this insect, resulting in irregular mines on the leaf and fruit surfaces. Subsequently, damaged leaves shrivel and may fall off, decreasing the photosynthetic capacity of the plant and potentially decreasing the plant's ability to defend itself from other biotic stresses. Under heavy infestation, leaves acquire a burnt appearance. The galleries and mines in the leaves alter the general development of the plant and can cause necrosis. They also provide suitable entry routes for secondary infection by pathogens, further increasing the damage and cost of control, and lowering the market value of the fruits. Damage to the growing tips of the plant results in their death, halting the development of the plant and negatively affecting the yield of the crop.

ECONOMIC IMPORTANCE: Yield losses of about 80 to 100 percent have been reported on tomato crops in both greenhouse and open-field production systems (Rwomushana *et al*., 2019). High impact is associated with the high cost of production due to additional costs of pest control products a decrease of marketable products and increased phytosanitary measures from non-infested countries.

PHYTOSANITARY RISK: The pest can easily spread to neighbouring countries through contaminated tomato packaging materials (wood and non-wood, and infested seedlings, fruits, plant parts or growing medium such as soil and coco peat) (Tonnang *et al*., 2015; CABI, 2021).

Figure 5: Tuta (Pthorimaea) absoluta *(left) and* Tuta (Pthorimaea) absoluta *infestation on tomato (right).*

Oriental fruit fly (*Bactrocera dorsalis*)

HOSTS: Mainly sugar apple, mango, capsicum, watermelon, citrus, cucumber, courgette, apple, banana and avocado.

GEOGRAPHICAL DISTRIBUTION IN AFRICA

Present: Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Equatorial Guinea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Togo, Uganda, United Republic of Tanzania, Zambia, Zimbabwe.

Absent: Algeria, Djibouti, Egypt, Eritrea, Lesotho, Libya, Malawi, Morocco, Sao Tome and Principe, Seychelles, Somalia, South Sudan, Tunisia.

BIOLOGY: Eggs (7–8 mm) are oviposited by females into ripening fruits. Oviposition marks are characterized by a dark green puncture which later becomes yellowish-brown due to wound healing. The eggs hatch into larvae after 2 to 10 days. The larvae dig tunnels on the host surface before moving into the flesh and core for 14 to 16 days. Fully developed larvae emerge from the fruit, which they feed on and destroy before pupating on the ground. The adults emerge from the pupae exuvia leaving an exit hole. The adults are glycogenic and survive on honeydew for 28 to 34 days.

SYMPTOMS ON MAIN HOSTS: The second and (partly) third larval stages cause qualitative damages to the fruits through sucking of the pulp and premature fruit fall.

ECONOMIC IMPORTANCE: Highly invasive pest with a broad host range. Infested fruits and vegetables have reduced quality and are usually discarded due to rotting. The presence of the larvae on exported fruits and vegetables leads to loss of market as the pest is a quarantine pest in most export markets. Additional costs arise from pest management measures (Ibáñez and Oliva, 2019).

PHYTOSANITARY RISK: Pest movement from one country to another is mainly through the importation of infested fruits and vegetables or travelling passengers. Adult fruit flies can fly over short distances from infested to non-infested farms.

Figure 6: *Oriental fruit fly (left) and oriental fruit fly damage on citrus.*

Papaya mealybug (*Paracoccus marginatus*)

HOSTS: Highly polyphagous. Papaya is the preferred host, as well as a wide range of vegetables, fruits and ornamentals.

GEOGRAPHICAL DISTRIBUTION IN AFRICA

Present: Ghana, Kenya, Mauritius, Mozambique, Nigeria, Togo, Uganda, United Republic of Tanzania.

Absent: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gambia, Gabon, Guinea, Guinea-Bissau, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Morocco, Namibia, Niger, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Tunisia, Zambia, Zimbabwe.

BIOLOGY: The pests reproduce sexually whereby the adult female deposits 100 to 600 eggs into her waxy ovisac over a period of one to two weeks (Muniappan *et al*., 2008). Miller, Williams and Hamon (1999) reported the ovisac length can be twice or more as long as its body. The miniature-like adult females, crawler, hatch after ten days from the eggs. The females and males have five and four instars respectively. The last instar is a pupa, whereby the nymph develops into a winged adult through metamorphosis. The female larvae form adult undergoes three immature stages.

SYMPTOMS ON MAIN HOSTS: The colonies of papaya mealybug excrete honeydew that coats plant surfaces to prevent photosynthesis. They damage the leaves and fruit skins by inserting their stylet into the epidermis and sucking the sap, simultaneously injecting toxic substances responsible for stunting, chlorosis, early leaf and fruit fall, distortion and even plant death (Galanihe *et al*., 2011; Macharia *et al*., 2017).

ECONOMIC IMPORTANCE: Yield losses of 91 percent on papaya farms have been reported (Macharia *et al*., 2017), affecting the papaya fruit export industry and vegetable production and ornamental plants.

PHYTOSANITARY RISK: The pest can naturally be dispersed through own movement (e.g. crawlers), wind dispersal of infested leaves and plant parts, and vector transmission (moving infested machinery, clothing, animals and soils, for example). Dispersal over long distances can also occur through movement of infested fruits, seedlings and growing media from infested to non-infested areas/countries (Mani and Shivaraju, 2016; CABI, 2021).

Figure 7: *Infestation by papaya mealybug on papaya fruits (left), on papaya leaf stalks (centre) and advanced infestation on papaya fruits.*

Red palm weevil (*Rhynchophorus ferrugineus*)

HOSTS: Mainly palms in the family *Arecaceae* (CABI, 2021)

GEOGRAPHICAL DISTRIBUTION IN AFRICA

Present: Djibouti, Egypt, Libya, Mauritania, Morocco, Tunisia.

Absent: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Ghana, Guinea, Guinea-Bissau, Eritrea, Eswatini, Ethiopia, Gambia, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Togo, Uganda, United Republic of Tanzania, Zambia, Zimbabwe.

BIOLOGY: Younger palms (< 20 years) are preferred by female weevils that lay 300 to 500 eggs (3 mm) on petioles and trunk wounds. The larval stage has three instars that are characterized by voracious feeding as they develop into prepupae and pupae. During pupation, the larvae develop an oval-shaped cocoon of fibre and leaves the palm. At this stage of inactivity, the weevils become sexually mature. An adult emerges from a cocoon after 13 to 17 days. The adult has the potential to fly as they infect other palms.

SYMPTOMS ON MAIN HOSTS: The pest attacks the vascular tissues of the crown and progresses to the lower leaves to either cause crown loss or leaf wilt. The damages caused by these pests predispose the palm to secondary infections caused by opportunistic plant pathogens. The high infestations are characterized by sounds produced by the larvae burrowing and chewing the trunk.

ECONOMIC IMPORTANCE: *R. ferrugineus* can cause serious damages on palm trees, including ornamental palm trees and dates. Losses of between 1 to 5 percent have been reported in costs associated with curative treatments of infested palms (El-Sabea *et al.*, 2009).

PHYTOSANITARY RISK: *R. ferrugineus* can be introduced over long distances through imported palms and planting materials used by growers or ornamental seedling growers, landscapers or individuals.

Cochineal (*Dactylopius coccus*)

HOSTS: Mainly members of the *Cactaceae* family such as *Opuntia ficus-indica, Cereus* and *Opuntia* (prickly pear).

GEOGRAPHICAL DISTRIBUTION IN AFRICA

Present: Egypt, Ethiopia, South Africa.

Absent: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Comoros, Central African Republic, Chad, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Sudan, Sudan, Togo, Tunisia, Uganda, United Republic of Tanzania, Zambia, Zimbabwe.

BIOLOGY: The winged male and wingless female mate to give birth to nymphs. The nymphs shield themselves from direct sunlight and dehydration by secreting a waxy white substance over their bodies. The nymphs have red pigment but appear either whitish or greyish due to the secreted substance over their bodies (Eisner, 2003). The first nymphal stage, known as "crawler", is dispersed by wind from the previous feeding spot that has long wax filaments to the new host (Mow *et al.*, 2008). The males become sexually mature through feeding on the cactus and start to fertilize the eggs.

SYMPTOMS ON MAIN HOSTS: The pest sucks the sap from the cacti leaves, leading to the weakening of the plant. The waxy mass produced to shelter the eggs reduces the cactus' photosynthesis rate.

ECONOMIC IMPORTANCE: *D. coccus* (cochineal, insect) is a source of natural red dye used in the textile and food industries. It is also used as a biocontrol agent for the management of invasive *Opuntia* spp. Berhe *et al.* (2020) reported negative damage to cactus pear production in the Tigray region of Ethiopia.

PHYTOSANITARY RISK: Accidental and intentional introductions for use in the dye industry.

Mango mealybug (*Rastrococcus iceryoides*)

HOSTS: Main hosts include mango, cotton, coffee and citrus. The host plants of this polyphagous pest represent over eight plant families, including cucurbits and *Ficus.*

GEOGRAPHICAL DISTRIBUTION IN AFRICA

Present: Kenya, Malawi, United Republic of Tanzania.

Absent: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Lesotho, Liberia, Libya, Mali, Madagascar, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Togo, Tunisia, Uganda, Zambia, Zimbabwe.

BIOLOGY: The adult female is broadly oval and slightly rounded to convex in lateral view. There are nine to ten generations per year. Reproduction is sexual and each female lays 450 to 585 eggs in a white, wax ovisac under the body. The first-instar nymphs settle on leaf undersides on terminal shoots but migrate to twigs when the population increases. The adult male has one pair of wings, well-developed limbs, lacks mouthparts and lives only a few days (Makale *et al.*, 2020b).

SYMPTOMS ON MAIN HOSTS: The insects suck phloem sap and eliminate copious sugary honeydew, which fouls nearby surfaces and provides a medium for sooty mould growth. The mould blocks light and air from the leaves, impairing photosynthesis and gaseous exchange. Infestation results in leaf yellowing and desiccation, drop of leaves and inflorescences, poor fruit set and fruit drop. Mango seedlings in nurseries may be attacked. The honeydew attracts attendant ants that feed on it. While doing so, they protect the mealybug from natural enemies, clean up waste that would otherwise be detrimental to the first instars and also help in spreading the mealybug (Makale *et al.*, 2020b).

ECONOMIC IMPORTANCE: Wide host range of crops especially fruit trees, causing damage to growing plants and seedlings in the nursery. Mango mealybug is a quarantine pest in most export markets.

PHYTOSANITARY RISK: Mostly through the import of infested fruits and infested planting materials across borders.

Mango or fruit tree mealybug (*Rastrococcus invadens*)

HOSTS: Main hosts include mango, breadfruit, citrus, *Ficus* and bananas.

GEOGRAPHICAL DISTRIBUTION IN AFRICA

Present: Benin, Burkina Faso, Burundi, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Gabon, Ghana, Nigeria, Rwanda, Senegal, Sierra Leone, Togo, Uganda.

Absent: Algeria, Angola, Botswana, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Djibouti, Egypt, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Kenya, Gambia, Guinea, Guinea-Bissau, Lesotho, Liberia, Libya, Madagascar, Mali, Malawi, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Sao Tome and Principe, Seychelles, South Africa, Somalia, South Sudan, Sudan, Tunisia, United Republic of Tanzania, Zambia, Zimbabwe.

BIOLOGY: There are four different females of the mango mealybugs based on the wax colour and pattern, colour, size and prominence of the fluted markings on the ovisac. The apterous females lay eggs in a sculpted white wax ovisac. The eggs hatch into nymphs. The sex of the nymphs in the first two instars is difficult to determine. The nymphs develop into pupae that have wing pads that progressively increase in size. The female adults are approximately 3.9 mm long and 2.5 mm wide.

SYMPTOMS ON MAIN HOSTS: Nymphs, especially the first and second instars, are the destructive stage that infests the ventral surface of the leaves on the terminal shoots. These pests advanced to attack the inflorescence and the young shoots, causing yellowing of leaves and their gradual fall. Heavy infestation of mango mealybugs also causes shedding of leaves followed by reduced fruit-setting.

ECONOMIC IMPORTANCE: *R. invadens* is an invasive pest. Accumulation of honeydew and the development of sooty mould can cause death to plants (CABI, 2021).

PHYTOSANITARY RISK: The movement of plants for planting from one country to another and movement of farm machinery and equipment may aid in the spread of the pest over short distances (CABI, 2021).

Khapra beetle (*Trogoderma granarium*)

HOSTS: Main hosts include groundnuts, barley, millet, sesame, sorghum, wheat and maize.

GEOGRAPHICAL DISTRIBUTION IN AFRICA

Present: Algeria, Burkina Faso, Egypt, Libya, Madagascar, Mali, Mauritius, Morocco, Niger, Nigeria, Senegal, Somalia, Sudan, Tunisia, Zambia, Zimbabwe.

Absent: Angola, Benin, Botswana, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Malawi, Mauritania, Mozambique, Namibia, Rwanda, Sao Tome and Principe, Seychelles, South Africa, South Sudan, Sierra Leone, Togo, Uganda, United Republic of Tanzania.

BIOLOGY: The larval development is characterized by about four to five larval moults for males and females, respectively (Hadaway, 1956). Genetically, there are two larvae where the first undergoes facultative diapause and the second cannot. Upon completion of the larval stage, they seek refuge (for example in stores) away from their feeding spots depicted by reduced respiration and remain inactive (Burges, 1963). Period moulting occurs in these larvae under a gradual increase in the respiration rate. The larvae can survive in diapause for nine months without food and up to six years with food. A temperature shock and availability of food lead the larvae to develop into pupae that remain under the skin of the larvae. The adult emerges from the pupal skin with the potential to copulate. The females (virgin) secrete a sex pheromone and mate once with the males. A female can lay approximately 35 eggs that are oviposited for up to 12 days. The adult females die after oviposition whereas the males live for one to four more days. The adults have wings but are not known to fly.

SYMPTOMS ON MAIN HOSTS: The pest affects cereals in the stores but there are no reports of damage caused in the field. Heavy infestation can completely destroy the grain stock through their feeding. In addition, the pest has been reported to decrease the mineral contents of grains (Jood *et al.*, 1992).

ECONOMIC IMPORTANCE: *T. granarium* is a serious pest of grains and stored products (CABI, 2021).

PHYTOSANITARY RISK: Movement of infested grains through imports, infested transport equipment such as shipping containers and farm equipment (CABI, 2021).

Asian citrus psyllid (*Diaphorina citri*)

HOSTS: Mainly rutaceous plants such as oranges, lemons and *Murraya paniculata.*

GEOGRAPHICAL DISTRIBUTION IN AFRICA

Present: Ethiopia, Kenya, Mauritius, Nigeria, United Republic of Tanzania (CPC, 2021; Ajene *et al.*, 2020; Rwomushana *et al.*, 2017).

Absent: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Eswatini, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Lesotho, Liberia, Libya, Madagascar, Mali, Malawi, Mauritania, Morocco, Mozambique, Namibia, Niger, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Togo, Tunisia, Uganda, Zambia, Zimbabwe.

BIOLOGY: The female deposits about 800 eggs on the tips of growing shoots in her lifetime. The eggs are a pale yellow; when reaching maturity they become bright orange having two red eye spots. The eggs hatch into nymphs that undergo five instar stages. The nymphal instars are characterized by an increase in size and development of wing pads. Some nymphs are pink with a pair of red compound eyes, but others develop either bluish-green or pale orange abdomens when mature (Tsai and Liu, 2001). The pest life cycle may take two to seven weeks depending on temperature conditions.

SYMPTOMS ON MAIN HOSTS: Infestation by the pest causes twisting and stunted shoots on the host plant, to create a rosette-like appearance. The pest produces honeydew and sooty mould, making the leaves curl and drop prematurely (Ajene *et al.*, 2020; Rwomushana *et al.*, 2017).

ECONOMIC IMPORTANCE: *D. citri* is a vector of the very serious citrus huanglongbing (greening) disease caused by the bacterium *Liberibacter asiaticus*. The pest also causes defoliation, dieback and damage to the growing points of fruit trees (CABI, 2021).

PHYTOSANITARY RISK: *D. citri* can move over long distances through the movement of infested planting materials.

Polyphagous shot-hole borer (*Euwallacea fornicatus*)

HOSTS: The main host is avocado.

GEOGRAPHICAL DISTRIBUTION IN AFRICA

Present: South Africa.

Absent: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Egypt, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Malawi, Mali, Madagascar, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Sudan, Sudan, Togo, Tunisia, Uganda, United Republic of Tanzania, Zambia, Zimbabwe.

BIOLOGY: Until recently, *E. fornicatus* was synonymized with other species. Females bore a bifurcated or simple tunnel in the twigs and small branches of the host so that it encircles the stem. Egg-laying begins as soon as the entrance tunnel is completed. Eggs are laid singly or in small clusters. Males are produced in much smaller numbers but develop more rapidly than females. The males cannot fly and do not normally leave the parental gallery, although they sometimes emerge and crawl on the surface of the bark. Occasionally, these males may enter a gallery made by another female and mate with the females in that gallery system; thus, a very small amount of cross-breeding occurs. The larvae live in longitudinal tunnels in small twigs and the transverse branch galleries in larger branches. After emergence from the pupal stage, the young females remain in the galleries for several days, during which time they are fertilized by their brothers. Mated females emerge through the original entrance tunnel and fly to new hosts. The life cycle lasts approximately 22 days. *E. fornicatus* feeds on symbiotic fungi (*Fusarium euwallaceae*) cultivated in the xylem of woody plants (CABI, 2021). *Fusarium euwallaceae* is the major cause of branch dieback. Active flight is one of the main means of movement to previously uninfected areas. Adult females can fly up to 400 m, but will usually attack hosts in a range of 35 m. However, the increasing global movement of commodities has significantly increased the transport of this and related species in timber and wood packaging material, such as dunnage and crating.

SYMPTOMS ON MAIN HOSTS: *E. fornicatus* bores and tunnels into stems and branches of healthy trees and causes damage through mass accumulation. Females usually colonize the base of secondary branches, resulting in localized branch dieback. In tea, bushes become debilitated. In avocado, the initial infestation is characterized by white exudates from the beetle entrance holes (CABI, 2021).

ECONOMIC IMPORTANCE: *E. fornicatus* can destroy natural forests and commercial avocado orchards.

PHYTOSANITARY RISK: Potential risk of introduction through importation of infested wood packaging materials, timber, dunnage and crafting (CABI, 2021).

Brown marmorated stink bug (*Halyomorpha halys*)

HOSTS: Wide host range including citrus, persimmon, soybean, apple and peach.

GEOGRAPHICAL DISTRIBUTION IN AFRICA

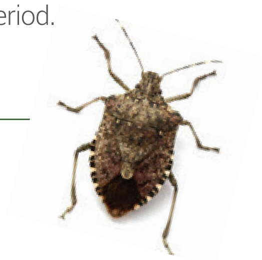
Present: Not yet detected in Africa.

Absent: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Egypt, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Togo, Tunisia, Uganda, United Republic of Tanzania, Zambia, Zimbabwe.

BIOLOGY: *H. halys* is a multivoltine species with up to five generations in different regions. Adult specimens of *H. halys* range from 12 to 17 mm in length, with a humeral width of 7 to 10 mm. As the name indicates, brown marmorated stink bugs are generally brownish and marbled or mottled with dense punctuation. Eggs are smooth and pale in colour, approximately 1.3 mm in diameter by 1.6 mm in length, and are laid in clusters of 20 to 30. Larvae are brightly coloured, black and reddish-orange. There are five nymphal instars (Wyniger and Kment, 2010).

The brightly coloured, black and reddish-orange first instars remain clustered about the egg mass after hatching and move away once moulting to second instars has occurred. There are five nymphal instars.

Development from egg to adult takes 40 to 60 days depending on temperature and photoperiod.



SYMPTOMS ON MAIN HOSTS: Adults and nymphs feed on fruit trees and other vegetable crops, causing depressed or sunken areas on fruits and leaves. Damage on fruits results in corky spots on the fruit, premature fruit abortion and poor seed set in crops such as maize or soybean. In soybeans, this can result in a 'stay green' effect where pods fail to senesce at the edges due to *H. halys* feeding injury (CABI, 2021).

Damage is caused by the feeding activity of the pest. On tree fruits, feeding injury causes depressed or sunken areas that may become 'cat-faced' as the fruit develops. Late season injury causes corky spots on the fruit. Feeding may also cause fruiting structures to abort prematurely. Similar damage occurs in fruiting vegetables such as tomatoes and peppers, although frequently later in the season. Feeding can cause the failure of seeds to develop in crops such as maize or soybean. There is frequently a distinct edge effect in crop plots as *H. halys* has an aggregated dispersion and moves between crops or woodlots. In soybeans, this can result in a 'stay green' effect where pods fail to senesce at the edges due to *H. halys* feeding injury. *H. halys* is a vector of Paulownia witches' broom (CABI, 2021).

ECONOMIC IMPORTANCE: Social nuisance in houses and residential areas. High infestations can cause 25 percent to 90 percent loss in stone fruit production (Nielsen and Hamilton, 2009).

PHYTOSANITARY RISK: Movement of fresh fruits, vegetables and nursery seedlings infested with egg masses, nymphs and adults on personal items like luggage (CABI, 2021).

Summary data sheets on emergent plant pathogens

Maize lethal necrosis disease (MNLD)

HOSTS: Mainly maize and other plants from the *Poaceae* family.

GEOGRAPHICAL DISTRIBUTION IN AFRICA

Present: Ethiopia, Kenya, Rwanda, Uganda, United Republic of Tanzania.

Absent: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Eswatini, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Togo, Tunisia, Zambia, Zimbabwe.

BIOLOGY: The disease is caused by a combination of two viruses, maize chlorotic mottle virus (MCMV) and sugarcane mosaic virus (SCMV). MCMV is transmitted mechanically and spread by several insect vectors including maize thrips (*Frankliniella williamsi*), maize rootworms (*Diabrotica undecimpunctata*, *Diabrotica longicornis* and *Diabrotica virgifera*), cereal leaf beetles (*Oulema melanopus*), corn flea beetle (*Systena frontalis*) and *Chaetocnema pulicaria* (CABI, 2021). Infection of maize by any of the viruses alone does not cause MLND. Symptoms of MLND are more severe than the additive symptoms of either MCMV or the potyvirus virus alone. The virus complex causes severe systemic necrosis which culminates in the death of the plant.

SYMPTOMS ON MAIN HOSTS: MCMV causes a variety of symptoms in maize, depending on genotype, age of infection and environmental conditions. The symptoms range from a relatively mild chlorotic mottle to severe stunting, leaf necrosis, premature plant death, shortened male inflorescences with few spikes, and/or shortened, malformed, partially filled ears.

ECONOMIC IMPORTANCE: High yield losses of up to 100 percent (Wangai *et al*., 2012). MNLD affects maize grains and seed production and quality. The use of insecticides increases the cost of production for farmers.

PHYTOSANITARY RISK: High risk of spread of MNLD through trade in infected seeds.

Wheat stem rust (*Puccinia graminis*)

HOSTS: Mainly wheat, oats, barley, rye and other plants from the *Poaceae* family.

GEOGRAPHICAL DISTRIBUTION IN AFRICA

Present: Algeria, Angola, Burundi, Democratic Republic of the Congo, Egypt, Eritrea, Kenya, Ethiopia, Libya, Madagascar, Malawi, Morocco, Mozambique, Nigeria, Rwanda, Sudan, Tunisia, Uganda, United Republic of Tanzania, Zambia, Zimbabwe.

Absent: Benin, Botswana, Burkina Faso, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Djibouti, Equatorial Guinea, Eswatini, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Lesotho, Liberia, Mali, Mauritania, Mauritius, Namibia, Niger, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, Somalia, South Sudan, Togo.

BIOLOGY: *P. graminis* is a macrocyclic, heteroecious rust, with five distinct spore stages. The urediniospores of *P. graminis* are dikaryotic (n + n), dehiscent, thick-walled and covered with spines. They are elliptical and about 20 × 30 µm. The uredinial, or red summer stage, is initiated by germination of a urediniospore on its grassy host, penetration, development of an intracellular mycelium with intracellular haustoria, and subsequent sporulation of uredinia to form new urediniospores. The recycling of the uredinial stage is the major means whereby the fungus initiates and perpetuates an epidemic.

The teliospores are two-celled, thick-walled (with up to five wall layers) and are thickened at the apical end. As infected plants mature, urediniospore formation ceases and teliospore formation commences, either in the same or in new (telia) fruiting structures. At this stage, the infections become black, hence the name black rust, and mature teliospore represent the only true diploid state of the fungus. Germination of teliospores and subsequent maturation result in the formation of haploid basidiospores. At the spermatial stage, the pycnia are normally formed on the adaxial leaf surface, often in clusters. At the aecial stage, the aeciospores infect the grassy host, completing the fungal life cycle (CABI, 2021).

SYMPTOMS ON MAIN HOSTS: The symptoms of the disease appear as large, elongated and brown pustules (uredosori) on the stem, sheath and leaf. Later on, these brown pustules change into black-coloured large pustules (teleutosori). Grains of the infected plants are shrivelled, much lighter in weight and thus reducing the yield. The pathogen shows a balanced host parasitic relationship. Even in the severe infection, the parasite does not cause much serious damage except that the growth of the plants may be somewhat retarded and the grains may be of reduced size and poor quality.

ECONOMIC IMPORTANCE: *P. graminis* causes yield losses in wheat production and costs associated with control measures (CABI, 2021).

PHYTOSANITARY RISK: *P. graminis* spores can be carried away by wind over long distances and across boundaries (CABI, 2021).

Banana bunchy top virus (BBTV)

HOSTS: Mainly *Musa* species and other plants from the *Musaceae* family.

GEOGRAPHICAL DISTRIBUTION IN AFRICA

Present: Angola, Benin, Burundi, Cameroon, Central African Republic, Democratic Republic of the Congo, Egypt, Equatorial Guinea, Eritrea, Gabon, Malawi, Mozambique, Nigeria, Rwanda, South Africa, Uganda, Zambia.

Absent: Algeria, Botswana, Burkina Faso, Cabo Verde, Chad, Comoros, Congo, Côte d'Ivoire, Djibouti, Eswatini, Ethiopia, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Mali, Mauritania, Mauritius, Morocco, Namibia, Niger, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Sudan, Sudan, Togo, Tunisia, United Republic of Tanzania, Zimbabwe.

BIOLOGY: BBTV is transmitted by an aphid vector (*Pentalonia nigronervosa*) and is disseminated in vegetative planting material, but is not transmitted by mechanical inoculation. Following aphid inoculation, symptoms generally do not appear until a further two or more leaves have been produced, with this period varying between 19 days in summer to 125 days in winter.

SYMPTOMS ON MAIN HOSTS: Disease symptoms usually appear about a month after infection. Plants can become infected at any stage of growth and there are some initial differences between the symptoms produced in aphid-infected plants and those grown from infected planting material. In aphid-inoculated plants, symptoms usually appear in the second leaf to emerge after inoculation and consist of a few dark green streaks or dots on the minor veins on the lower portion of the lamina. The streaks form 'hooks' as they enter the midrib and are best seen from the underside of the leaf in transmitted light. The 'dot-dash' symptoms can sometimes also be seen on the petiole. The following leaf may display whitish streaks along the secondary veins when it is still rolled. These streaks become dark green as the leaf unfurls. The leaves become dry and brittle and stand more erect than normal, giving the plant a rosetted and 'bunchy top' appearance.

The first symptoms are dark green streaks on the lower portion of the leaf's midrib and later on the secondary veins. Removing the waxy white coating on the midrib makes it easier to see the streaking. The streaks consist of dots and short lines, the so-called 'Morse code' pattern, the most diagnostic symptom of bunchy top virus. As the infection progresses, streak symptoms become more evident on the leaf blade. Dark green hook-like extensions of the veins can also be seen in the narrow, light green zone between the midrib and the lamina. The short hooks point down along the midrib towards the petiole. These hooks are best observed from the underside of the leaf by holding the leaf to the light. Suckers from an infected stool can show severe symptoms in the first leaf to emerge. The leaves are rosetted and small, with very chlorotic margins that tend to turn necrotic. Dark green streaks are usually evident in the leaves. Infected plants rarely produce a fruit bunch after infection and do not produce in subsequent years (CABI, 2021).

ECONOMIC IMPORTANCE: BBTV is a serious pest of bananas and can be devastating in banana plantations (CABI, 2021).

PHYTOSANITARY RISK: BBTV is spread through movement of infected banana-planting materials such as corms and young banana suckers. The vector of the BBTV virus, banana aphid *Pentalonia nigronervosa*, is already present in most of the FAOSFE countries, including Kenya, Rwanda, Somalia, Uganda and the United Republic of Tanzania (CABI, 2021).

Huanglongbing bacteria *Liberibacter asiaticus* (HLB), Asian greening disease

HOSTS: Mainly rutaceous plants such as sweet orange, mandarin and tangelo trees.

GEOGRAPHICAL DISTRIBUTION IN AFRICA

Present: Ethiopia, Kenya, Mauritius (CABI, 2021; Ajene *et al*., 2020).

Absent: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Eswatini, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Togo, Tunisia, Uganda, United Republic of Tanzania, Zambia, Zimbabwe.

BIOLOGY: Huanglongbing (HLB) is presumptively caused by phloem-limited bacteria, the motile bacteria, *Candidatus liberibacter* spp. The psyllid vector for HLB is *Diaphorina citri*. In citrus, there are three forms of concern: the Asian, African and American forms. The Asian form of HLB expresses symptoms in both cool and warm conditions. HLB can be graft-transmitted, but transmission rates are variable because of the irregular distribution of bacteria within the host plant. HLB can be acquired by both nymphs and adults, which can maintain and transmit the disease throughout their three- to four-month lifespan. HLB is systemic and has an incubation period of three months to multiple years before symptoms are visible.

SYMPTOMS ON MAIN HOSTS: The first symptom of HLB is usually the appearance of a yellow flush of growth on an infected tree, hence the name huanglongbing, which translates from Chinese as "yellow shoot disease". Progressive yellowing and thinning of the entire canopy follows, leaves turn pale-yellow and display characteristic blotchy mottling or vein yellowing, point upwards and are reduced in size. In the early stages of infection, diagnosis can be difficult as trees remain symptomless; however, chronically infected trees become sparsely foliated and show extensive twig dieback and eventually premature death, which can occur several months to years after infection. The abnormally bitter fruits are often small, lopsided with aborted dark seeds, and remain green in part (hence the origin of the name greening) and drop prematurely, reducing yields. Severe symptoms in trees have been observed one to five years after the onset of the first symptoms, depending on the age of the tree at the time of infection, but also on the number of infections per tree, which are often multiple. The disease's rapid progress, combined with the impact on yield and quality of fruits, means that affected orchards can lose their economic viability within seven to ten years after planting, and total death by 13 years. Mathematical models based on HLB epidemiology have shown that once detectable infections occur in 5 percent of trees within an orchard, it is likely that 90 percent of the orchard is infected.

ECONOMIC IMPORTANCE: Huanglongbing bacteria *Liberibacter asiaticus* (HLB) or Asian greening disease is a serious bacterial disease of citrus (CABI, 2021). Crop losses from HLB of 30 to 100 percent have been reported in Africa (da Graca and Korsten, 2004).

PHYTOSANITARY RISK: Introduction of *Liberibacter*-infected citrus budwood or trees of *Rutaceae* into new areas, or introduction of the bacteria-laden Asian psyllid (*Diaphorina citri*), a vector of the disease.

Figure 8: *Image of citrus greening disease-infected tree (left) in citrus; fruit of HLB-infected citrus tree showing colour inversion (right).*

Black leg disease of potato (*Dickeya solani*)

HOSTS: Potato, *Hyacinth orientalis* and *Cyperus rotundus*.

GEOGRAPHICAL DISTRIBUTION IN AFRICA

Present: Not yet detected in Africa.

Absent: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Togo, Tunisia, Uganda, United Republic of Tanzania, Zambia, Zimbabwe.

BIOLOGY: *D. solani* is closely related to *D. dadantii* based on DNA–DNA hybridization data and average nucleotide identity (ANI) values and this has led some to speculate that it may be a subspecies of the latter (CABI, 2021). The pectinolytic *Dickeya* spp. are Gram-negative bacteria causing severe disease in a wide range of plant species. These phytopathogens produce plant cell wall-degrading enzymes that can macerate the tuber and stem tissues, thus provoking disease symptoms. *D. solani* is less susceptible to attack from soil saprophytic bacteria and is highly efficient as a colonizer of the growing potato plant when compared against another member of the genus *Dickeya* pathogenic to potato in Northern Europe, *D. dianthicola*.

SYMPTOMS ON MAIN HOSTS: Blackleg may develop early (early blackleg) in the season after plants emerge and is characterized by stunted, yellowish foliage with a stiff, upright habit.

Symptoms caused by *D. solani* on potato, specifically blackleg and top wilt of the growing potato plant and soft rot of tubers, are indistinguishable from those produced by other plant pathogenic bacteria (CABI, 2021).

The lower part of the belowground stem of such plants is dark brown to black and extensively decayed. The pith region of the stem is susceptible to decay and in infected plants, this decay may extend upward in the stem, far beyond the tissue, with externally visible symptoms. Blackleg may also develop late in the season and appears as black discoloration of previously healthy stems, accompanied by a rapid wilting and yellowing of the leaves. Black discoloration of the stems always starts below ground and moves up the stem, often until the entire stem is black and wilted. Tubers get infected via the stolon by which the tuber is attached to the plant or via the soil by the bacterium in the root zone spread from infected tissue or infested irrigation water. Disease development in mature stems results in leaves turning yellow and wilting, leading to premature senescence. When the entire stem is affected, it decays and becomes desiccated. Tubers first become decayed at the stolon attachment site where the tuber tissue becomes blackened and soft. As disease progresses, the entire tuber may decay, or the rot may remain partially restricted to the tissue inside the vascular ring (inner perimedullar). Potatoes stored in environments with poor aeration and high humidity get a condition known as "hard rot" 2, where lesions caused by the bacterium found around lenticels or mechanical damage become arrested when conditions improve. Once the blackleg bacterium incites decay, the growth of secondary bacteria often contributes to the decay process, modifying the symptomatology of the disease.

ECONOMIC IMPORTANCE: Yield losses of up to 30 percent have been reported in Israel (Tsror *et al.*, 2009).

PHYTOSANITARY RISK: Trade in latently infected seed potato, bulbs, tubers/rhizomes (Toth *et al.*, 2011) due to a poor seed certification and testing process (CABI, 2021).

Summary data sheets on emergent nematode pests

Yellow potato cyst nematode (PCN) (*Globodera rostochiensis*)

HOSTS: Mainly the *Solanaceae* family, such as potato, tomatoes, aubergine and associated wild plants.

GEOGRAPHICAL DISTRIBUTION IN AFRICA

Present: Algeria, Egypt, Kenya, Libya, Rwanda, Sierra Leone, South Africa, Tunisia, Uganda.

Absent: Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Sao Tome and Principe, Senegal, Seychelles, Somalia, South Sudan, Sudan, Togo, United Republic of Tanzania, Zambia, Zimbabwe.

BIOLOGY: The eggs (ca. 500 eggs) of *G. rostochiensis* are retained within the cyst body and no egg sacs are produced. The eggshell surface is smooth and no microvilli are present. Some eggs can survive within the cyst for as long as 30 years, although by this time very few are viable. Hatching in water is normal, especially within the "hatching season" when most of the environmental factors are stable. Hatching is increased by the stimulus of a hatching factor found in the host root diffusate. The females emerge from the root cortex about one month to six weeks after invasion by the second-stage juveniles. They are pure white initially, turning golden yellow on maturation. The stylet is divided equally in length between the conus and the shaft. An important diagnostic feature is the backward slope of the stylet knobs.

Cysts contain eggs and are formed from the hardened dead cuticle of the female. Newly produced cysts may still show an intact vulval basin but older cysts, particularly those which have been in the soil for many seasons, will have lost all signs of their genitalia with only a hole in the cuticle to show the position of the fenestral basin.

The male (length = 0.89–1.27 mm; width at excretory pore = 28 μm ± 1.7 μm; head width at base = 11.8 μm ± 0.6 μm; head length = 7.0 μm ± 0.3 μm; stylet length = 26 μm ± 1.0 μm) is vermiform in shape with a short tail and no bursa. On fixation, the body assumes a curved shape with the posterior region twisted at a 90-degree angle to the remainder of the body. The second-stage juvenile (body length = 468 μm ± 100 μm; width at excretory pore = 18 μm ± 0.6 μm) hatches from the egg, the first moult taking place within the egg. The juvenile, like the male, is vermiform with a rounded head and finely tapered tail (CPC, 2021). The life cycle takes approximately 45 days, during which time the males will moult and become vermiform, leave the host root and fertilize as many females as possible before dying about 10 days or so after first leaving the root.

SYMPTOMS ON MAIN HOSTS: Potato cyst nematodes, in common with other cyst nematodes, do not cause specific symptoms of infestation. Initially, crops will display patches of poor growth and plants in these patches may show chlorosis and wilting (CPC, 2021). Yield loss and smaller tubers are common symptoms of PCN. In heavily infested soils, plants have reduced root systems and often grow poorly due to nutrient deficiencies and water stress. Plants may senesce prematurely, as they are more susceptible to infection by fungi such as *Verticillium* spp. when heavily invaded by potato cyst nematodes.

ECONOMIC IMPORTANCE: Yield losses of about 50 to 60 percent have been reported. The use of nematicides increases the cost of production, especially where there are no PCN-resistant varieties available (CABI, 2021).

PHYTOSANITARY RISK: Potato cyst nematodes can easily be moved from one place to another through seed potato trade, breeding and propagation materials, infested soils attached to farm equipment, animals and personal protective equipment such as gumboots, flooding or flowing irrigation water, movement of tableware potato that sometimes are planted by farmers and farming enthusiasts (CABI, 2021).

White potato cyst nematode (*Globodera pallida*)

HOSTS: Mainly the *Solanaceae* family, such as potato, tomatoes, aubergine and associated wild plants.

GEOGRAPHICAL DISTRIBUTION IN AFRICA

Present: Algeria, Kenya, Tunisia.

Absent: Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Egypt, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Togo, Uganda, United Republic of Tanzania, Zambia, Zimbabwe.

BIOLOGY: A cyst of *G. pallida* contains as many as 500 eggs, which will form the next generation. The eggs can remain viable for many years before gradually deteriorating. Factors affecting hatching are very similar to those that affect *Globodera rostochiensis*. Various hatching stimuli are known, for example root diffusate and certain organic and inorganic chemical compounds. *G. pallida* hatches at around 10 °C or less and is adapted to develop at cool temperatures between 10 °C and 18 °C (CABI, 2021). The second-stage juvenile is the infective stage and, upon hatching, invades the host just behind the root tip. The juveniles move up or down the root until they receive a specific signal, which is likely to be of a chemical nature, to set up a feeding site in the form of a syncytium. The female has an almost spherical body from which the neck and head protrude. *G. pallida* females are either white or cream, depending on pathotype, when they break through the cortical root cells, and this phase lasts for four to six weeks. The juveniles of *G. pallida* and *G. rostochiensis* are very alike, but *G. pallida* juveniles are generally larger: the body length is greater and the stylet is longer and more robust, with anteriorly facing stylet knobs as opposed to those of *G. rostochiensis*, which have smaller, backward-sloping knobs. The juvenile is folded four times within the egg and the tail tapers to a rounded point. There is never a golden or yellow stage as in *Globodera rostochiensis*. The male is vermiform and usually assumes an open C-shape upon death and fixation, the short-rounded tail twisting through 90 to 180 degrees. The body annules are regular along the body and there are three bands in the lateral field, which narrows both posteriorly and anteriorly with a heavily sclerotized head (CABI, 2021).

SYMPTOMS ON MAIN HOSTS: Potato cyst nematodes, in common with other cyst nematodes, do not cause specific symptoms of infection. Initially, crops display patches of poor growth and affected plants may show chlorosis and wilting, with poor top growth. Affected plants suffer yield loss and tubers are smaller. In addition, plant dwarfing, surface cracking, reduced root system and early senescence are common symptoms for infected plants (CABI, 2021)

ECONOMIC IMPORTANCE: Yield losses of about 50 to 60 percent have been reported. The use of nematicides increases the cost of production especially where there are no PCN-resistant varieties available (CABI, 2021).

PHYTOSANITARY RISK: Potato cyst nematodes can easily be moved from one place to another through seed potato trade, breeding and propagation materials, infested soils attached to farm equipment, animals and personal protective equipment such as gumboots, flooding or flowing irrigation water, movement of tableware potato that sometimes are planted by farmers and farming enthusiasts (CABI, 2021).

Summary data sheets on emergent noxious weeds

Parthenium weed (*Parthenium hysterophorus*)

HOSTS: An annual invasive herb.

GEOGRAPHICAL DISTRIBUTION IN AFRICA

Present: Botswana, Comoros, Djibouti, Egypt, Eritrea, Eswatini, Ethiopia, Kenya, Madagascar, Mauritius, Mozambique, Rwanda, Seychelles, Somalia, South Africa, Uganda, United Republic of Tanzania, Zimbabwe.

Absent: Algeria, Angola, Benin, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Lesotho, Liberia, Libya, Malawi, Mauritania, Mali, Morocco, Namibia, Niger, Nigeria, Sao Tome and Principe, Senegal, Sierra Leone, South Sudan, Sudan, Togo, Tunisia, Zambia.

BIOLOGY: *Parthenium hysterophorus* is an erect, branched, aromatic, annual (or short-lived perennial), herbaceous plant with a deep taproot. The species reproduces by seed and has vigorous growth. It can grow up to 2.5 m, especially in exotic conditions. Shortly after germination, the young plant forms a basal rosette of pale green, pubescent, strongly dissected, deeply lobed leaves, 8 to 20 cm in length and 4 to 8 cm in width. The rosette stage may persist for considerable periods during unfavourable conditions (such as water or cold stress). Both leaves and stems are covered with short, soft trichomes, of which four types have been recognized and are considered to be of taxonomic importance within the genus. Flower heads are both terminal and axillary, pedunculate and slightly hairy, being composed of many florets formed into small white capitula, 3 to 5 mm in diameter. Each head consists of five fertile ray florets (sometimes six, seven or eight) and about 40 male disc florets. Seeds (achenes) are black, flattened, about 2 mm long, each with two thin, straw-coloured, spathulate appendages (sterile florets) at the apex which act as air sacs and aid dispersal (CABI, 2021). Other vector transmission (biotic) is mainly by domestic and feral animals.

SYMPTOMS ON MAIN HOSTS: *Parthenium* aggressively colonizes disturbed sites. It is considered as one of the "100 most invasive species in the world" by the International Union for Conservation of Nature (IUCN – Global Invasive Species Database, 2021). It is extremely prolific, capable of producing up to 30 000 seeds per plant – a major attribute behind its invasive nature (Rwomushana *et al*., 2019). It is reported as a major weed in field crops in more than 45 countries (CABI, 2021a) affecting the production of crops, animals, human and animal health, and biodiversity as well as by inhibiting germination of a wide range of food and vegetable crops. Its invasive success has been majorly attributed to its allelopathic capacity.

ECONOMIC IMPORTANCE: Yield loss has not been fully evaluated. However, crop yield losses as high as 50 percent have been reported in different studies. The presence of the invasive weed reduces the quality of forage and is a serious weed in farmland and fruit orchards. *Parthenium* is an effective and aggressive colonizer, especially of disturbed landscapes, where it is capable of displacing native plant species and of reducing pasture carrying capacities by as much as 80 percent to 90 percent. *Parthenium* can also alter soil texture, pH, organic matter and N, K and P content. *Parthenium* has allelopathic properties, which likely contribute to the ability of the weed to displace native species in addition to having negative impacts on human and animal health (Rwomushana *et al*., 2019).

PHYTOSANITARY RISK: The tiny seeds of *Parthenium* can easily be transported through contaminated grain seeds, blown away by wind or transported through water and flooding, vehicles, machine and farm equipment, soils, compost, manure and sand to different habitats such as farmlands and motorways (CABI, 2021a).

Mesquite (*Prosopis juliflora*)

HOST: Broadleaved perennial invasive pest.

GEOGRAPHICAL DISTRIBUTION IN AFRICA

Present: Algeria, Botswana, Burkina Faso, Cabo Verde, Chad, Djibouti, Egypt, Eritrea, Ethiopia, Gambia, Ghana, Guinea-Bissau, Kenya, Libya, Madagascar, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Senegal, Somalia, South Africa, South Sudan, Sudan, Uganda, Tunisia, United Republic of Tanzania, Zimbabwe.

Absent: Angola, Benin, Burundi, Cameroon, Central African Republic, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Equatorial Guinea, Eswatini, Gabon, Guinea, Lesotho, Liberia, Malawi, Rwanda, Sao Tome and Principe, Seychelles, Sierra Leone, Togo, Zambia.

BIOLOGY: *P. juliflora* is a tree 3 to 12 m tall, sometimes shrubby with spreading branches; wood hard; branches cylindrical, green, more or less round- or flat-topped, somewhat spiny with persistent, green (sometimes glaucous or greyish, not reddish) foliage, glabrous or somewhat pubescent or ciliate on the leaflets; spines axillary, uninodal, divergent, paired or solitary and paired on the same branches, sometimes absent, not on all branchlets, measuring 0.5 cm to 5.0 cm long, being largest on strong, basal shoots. Leaves bipinnate, glabrous or pubescent, one to three pairs of pinnae (rarely four pairs). It reproduces sexually; *Prosopis* species are generally assumed to be self-incompatible. Although very large numbers of flowers are produced, not all are fertile and high rates of ovary abortion are found. *P. juliflora* usually begins to flower and fruit after two to three years, but this is highly dependent upon site conditions, as trees as young as 12 months have been observed to flower in the Sahel, and trees 15 years or older on poorly exposed sites have never been seen to flower (CABI, 2021b). The seeds of *P. juliflora* possess an inherently high level of dormancy. The hard seed coats must be broken or weakened to allow water absorption by the seed and for germination to occur. All *Prosopis* species can survive in areas with exceptionally low annual rainfall or very long dry periods but only if the roots can tap groundwater or another permanent water source within the first few years, adapting well to arid and semi-arid land (ASAL) regions.

Prosopis species exhibit high levels of variability in morphological characters. The reproductive self-incompatibility and obligate outcrossing observed tends to lead to large phenological variation, being a combination of both clinal (continuous) variation in response to broad climatic factors and ecotypic (discontinuous) variation in response to disjunct environmental factors (CABI, 2021b).

SYMPTOMS ON MAIN HOSTS: *P. juliflora* invades by outcompeting other plant species, especially native biodiversity. It forms monocultures that can displace other species, negatively affecting local biodiversity. Carrying capacity is greatly reduced due to displacement of palatable grasses and their inhibition to germinate through shading and allopathic attributes, negatively impacting incomes especially for the pastoralist communities. In terms of human and animal health, the hard and poisonous thorn causes physical injuries to human skin and deforms the human body. Several factors favour *P. juliflora's* rapid distribution in the environment. Its ability to adapt to a wide range of climatic conditions, its effective dispersal mechanism, its allelopathic effect, prolific nature, large seed bank in the soil environment and its fast-growing and vigorous coppicing abilities are among the principal factors (Abdulahi, Ute and Regasa, 2013).

ECONOMIC IMPORTANCE: Highly invasive species that quickly outcompetes other vegetation. It grows very fast, blocking paths and roadways. In some areas it is an important source of fodder and fuel (CABI, 2021).

PHYTOSANITARY RISK: Accidental introduction through the movement of feeding livestock across countries. There are speculations of intentional introduction for fodder, fuel or ornamental plants (CABI, 2021).

Water hyacinth (*Eichhornia crassipes*)

HOSTS: Freshwater perennial invasive weed.

GEOGRAPHICAL DISTRIBUTION IN AFRICA

Present: Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Democratic Republic of the Congo, Equatorial Guinea, Eswatini, Ethiopia, Gabon, Ghana, Guinea-Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritius, Morocco, Mozambique, Niger, Nigeria, Rwanda, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Togo, Uganda, United Republic of Tanzania, Zambia, Zimbabwe.

Absent: Algeria, Cabo Verde, Chad, Comoros, Congo, Djibouti, Egypt, Eritrea, Gambia, Guinea, Lesotho, Libya, Mauritania, Namibia, Sao Tome and Principe, Somalia, South Sudan, Tunisia.

BIOLOGY: *E. crassipes* is a floating weed of tropical and subtropical freshwater lakes and rivers, especially those enriched with plant nutrients. The plant is very variable in size, seedlings having leaves that are only a few centimetres across or high, whereas mature plants with good nutrient supply may reach one metre in height. Plants in an uncrowded situation tend to have short, spreading petioles with pronounced swelling, while in a dense stand they are taller, more erect and with little or no swelling of the petioles (CABI, 2021). Leaves consist of a petiole (often swollen, 2 cm to 5 cm thick) and blade (roughly round, ovoid or kidney-shaped, up to 15 cm across). The base of the petiole and any subsequent leaf are enclosed in a stipule up to 6 cm long. Roots develop at the base of each leaf and form a dense mass. The roots are usually 20 cm to 60 cm long, though they can extend to 300 cm. The ratio of root to shoot depends on the nutrient conditions, and in low-nutrient conditions, they may account for over 60 percent of the total plant weight. They are white when formed in total darkness but often purplish under field conditions, especially in conditions of low nutrients. The inflorescence is a spike that develops from the apical meristem, but tends to appear lateral owing to the immediate development of an axillary bud as a 'renewal' or 'continuation' shoot. Once the inflorescence fully emerges from the leaf sheath, flowers all open together, starting at night, completing the process in the morning, and withering by the next night when the peduncle starts to bend down.

The flowers of *E. crassipes* are tristylous, but unlike some other tristylous species, there is no incompatibility between the different forms. Hence pollination (mainly by wind) can result in a good seed set. *E. crassipes* propagates vegetatively and by seed. After flowering, the peduncle is deflexed, the capsules mature and seeds are eventually released below water.The seeds are capable of germinating immediately but may remain dormant for many years. Germination is encouraged by aerobic conditions and alternating temperatures. Seedlings are rooted in mud initially but become free-floating as a result of wave action or rising water levels.

SYMPTOMS ON MAIN HOSTS: As a result of its rapid growth and large biomass, *E. crassipes* has a range of detrimental effects, which include physical interference with water transport, communication and access; fishing, mechanical damage to hydro-electric installations and other structures such as bridges; reduced irrigation flow can indirectly cause crop losses but there can also be direct interference and competition from water hyacinth where it occurs in flooded rice; environmental degradation and a reduction in biodiversity (CABI, 2021). Other detrimental effects include evapotranspiration, reduced dissolved oxygen levels and increased sedimentation as a result of decomposition. *E. crassipes* may reduce water quality in various ways and encourage mosquitoes, snails and other organisms associated with human illnesses, including malaria, schistosomiasis, encephalitis, filariasis and cholera.

ECONOMIC IMPORTANCE: Water hyacinth is a major freshwater invasive weed. It grows very fast, blocking waterways, rivers and lakes, and affecting fishing, water transport, recreational activities and biodiversity (CABI, 2021).

PHYTOSANITARY RISK: Accidental introduction as water ornament, or potted plants (CABI, 2021).

Table 3: List of priority emergent pests and their status in the nine FAOSFE countries

Pest	Crop/plant hosts	FAOSFE country									Comments/Remarks
		Burundi	Djibouti	Eritrea	Ethiopia	Kenya	Rwanda	Somalia	South Sudan	Uganda	
Desert locust (*Schistocerca gregaria*)	Wide host range	×	✓	✓	✓	✓	×	✓	✓	✓	Ongoing efforts to control DL led by FAO DLCO in collaboration with ministries of agriculture in the affected countries.
Fall armyworm (*Spodoptera frugiperda*)	Wide host range: maize, rice, sorghum, sugar cane and wheat, but also other vegetable crops and cotton	✓	✓	✓	✓	✓	✓	✓	✓	✓	Present in all nine SFE countries.
Tomato leaf miner (*Tuta absoluta*)	Wide host range of *Solanaceae* family	✓	✓	✓	✓	✓	✓	✓	✓	✓	Present in all nine FAOSFE countries.
Oriental fruit fly (*Bactrocera dorsalis*)	Wide host range: mango, citrus, cucumber, apple, capsicum, watermelon, etc.	✓	×	×	✓	✓	✓	×	×	✓	Absence of reports may be a consequence of lack of surveillance and pest detection mechanisms.
Papaya mealybug (*Paracoccus marginatus*)	Wide host range of *Solanaceae* family	×	×	×	×	✓	×	✓	×	✓	Absence of reports may be a consequence of lack of surveillance and pest detection mechanisms.
Red palm weevil (*Rhynchophorus ferrugineus*)	Wide host range of *Arecaceae* family	×	✓	×	×	×	×	✓	×	×	Absence of reports may be a consequence of lack of surveillance and pest detection mechanisms.
Cochineal (*Dactylopius coccus*)	Mainly *Cactaceae* family, e.g. *Opuntia ficus-indica, Cereus, Opuntia* (prickly pear)	×	×	×	✓	×	×	×	×	×	Absence of reports may be a consequence of lack of surveillance and pest detection mechanisms.
Mango mealybug (*Rastrococcus iceryoides*)	Citrus, coffee, cotton, mango, cocoa, Indian siris	×	×	×	×	✓	×	×	×	×	Absence of reports may be a consequence of lack of surveillance and pest detection mechanisms.
Mango or fruit tree mealybug (*Rastrococcus invadens*)	Mango, breadfruit, citrus, ficus, bananas	✓	×	×	×	×	✓	×	×	✓	Absence of reports may be a consequence of lack of surveillance and pest detection mechanisms.
Maize lethal necrosis disease, MLND	Mainly maize and other plants from *Poaceae* family	×	×	×	✓	✓	✓	×	×	✓	Absence of reports may be a consequence of lack of surveillance and pest detection mechanisms.
Wheat rusts (stem, leaf and stripe)	Mainly wheat, oats, barley, rye and other plants from the *Poaceae* family	✓	✓	×	✓	✓	✓	×	×	✓	Absence of reports may be a consequence of lack of surveillance and pest detection mechanisms.

Table 3 *(Continued)*

Pest	Crop/plant hosts	FAOSFE country									Comments/Remarks
		Burundi	Djibouti	Eritrea	Ethiopia	Kenya	Rwanda	Somalia	South Sudan	Uganda	
Banana bunchy top virus, BBTV	Mainly bananas and other plants in the *Musaceae* family	✓	×	✓	×	×	✓	×	×	✓	Absence of reports may be a consequence of lack of surveillance and pest detection mechanisms. Virus vector *Pentalonia nigronervosa* is already present in most countries in Africa.
Yellow potato cyst nematode, PCN (*Globodera rostochiensis*)	*Solanaceae* family: mainly potato, tomato, aubergine and associated wild plants	×	×	×	×	✓	✓	×	×	✓	Virtually present in most potato-growing areas. Absence of reports may be a consequence of lack of surveillance and pest detection mechanisms.
White potato cyst nematode, PCN (*Globodera pallida*)	*Solanaceae* family mainly potato, tomato, aubergine and associated wild plants	×	×	×	×	✓	×	×	×	×	Absence of reports may be a consequence of lack of surveillance and pest detection mechanisms.
Citrus huanglongbing, HLB (Asian greening disease) (*Liberibacter asiaticus*)	*Rutaceae* plants, e.g oranges and lemons	×	×	×	✓	✓	×	×	×	×	Absence of reports may be a consequence of lack of surveillance and pest detection mechanisms.
Asian citrus psyllid, ACP (*Diaphorina citri*)	*Rutaceae* plants, e.g oranges and lemons	×	×	×	✓	✓	×	×	×	×	Absence of reports may be a consequence of lack of surveillance and pest detection mechanisms.
Parthenium weed (*Parthenium hysterophorus*)	Invasives annual herb/weed	×	✓	✓	✓	✓	✓	✓	×	✓	Absence of reports may be a consequence of lack of surveillance and pest detection mechanisms.
Mesquite (*Prosopisjuliflora*)	Perennial weed	×	✓	✓	✓	✓	×	✓	✓	✓	Absence of reports may be a consequence of lack of surveillance and pest detection mechanisms.
Water hyacinth (*Eichhornia crassipes*)	Freshwater annual invasive weed	✓	×	×	✓	✓	✓	×	×	✓	Absence of reports may be a consequence of lack of surveillance and pest detection mechanisms.
Polyphagous shot hole borer (*Euwallacea hitfordiodendrus*)	Main host is avocado	×	×	×	×	×	×	×	×	×	Absent in all nine SFE countries.

Table 3 *(Continued)*

Pest	Crop/plant hosts	FAOSFE country									Comments/Remarks
		Burundi	Djibouti	Eritrea	Ethiopia	Kenya	Rwanda	Somalia	South Sudan	Uganda	
Brown marmorated stink bug (*Halyomorpha halys*)	Wide host range including citrus, persimmon, soybean, apple and peach	×	×	×	×	×	×	×	×	×	Absent in all nine FAOSFE counties.
Banana Fusarium wilt disease tropical race 4 (*Fusarium oxysporum* f. sp. *cubense*)	Mainly bananas and other *Musaceae* species	×	×	×	×	×	×	×	×	×	Absent in all nine SFE countries.
Black leg disease of potato (*Dickeya solani*)	Potato, *Hyacinth orientalis* and *Cyperus rotundus*	×	×	×	×	×	×	×	×	×	Currently absent in all nine FAOSFE countries. Weak seed potato certification system and exchange of seed potato and ware potato present a high risk of invasion.

Notes: ✓: presence of pest; ×: absence of pest.

Section 3

A qualitative pest-initiated risk analysis

A critical output of the PRA training conducted for SFE countries in March 2021 involved conducting a qualitative pest-initiated risk analysis for the four priority pests identified at the training: mango mealybugs (*Rastrococcus iceryoides* and *Rastrococcus invadens*), banana Fusarium wilt disease tropical race 4 (*Fusarium oxysporum* f. sp. *cubense*) and khapra beetle (*Trogoderma granarium*). This section describes the scope of the PRAs, the methodology used and the report of the PRA conducted for each of the pests.

Scope

The scope of this qualitative pest-initiated PRA was limited to the four pests identified by participants from the nine SFE countries during the virtual PRA training held in March 2021.

This PRA report and conclusions are expected to inform the establishment of a regional early warning, preparedness and response mechanism to emerging pests. It identifies the most likely pathways for the introduction, areas of establishment, spread and possible impacts that would arise from the introduction of the pests to the PRA area.

The PRA area

The PRA area was limited to the nine SFE countries, namely Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, South Sudan and Uganda.

PRA methodology

In the current analysis, PRA was defined as indicated in International Standards for Phytosanitary Measures (ISPM) 5 as the process of evaluating biological or other scientific and economic evidence to determine whether an organism is a pest, whether it should be regulated, and the strength of any phytosanitary measures to be taken against it (ISPM2, 1995; revised IPPC, 1997; ISPM 2, 2007); (ISPM 11), (FAO, 2017); A pest is "any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products" (FAO, 1990; revised ISPM 2, 1995; IPPC, 1997; CPM, 2012). A quarantine pest is a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (FAO, 1990; revised FAO, 1995; IPPC,1997).

The PRAs were conducted using CABI decision support tools including the PRA tool, Horizon Scanning Tool (HST) and the Crop Protection Compendium (CABI), and were done in accordance with the guidelines provided in the following ISPMs:

- Framework for Pest Risk Analysis (ISPM 2), (FAO, 2007)
- Glossary of Terms (ISPM 5), (FAO, 2021)
- Pest Risk Analysis for Quarantine Pests (ISPM 11), (FAO, 2017)
- Pest Risk Analysis for Non-Quarantine Pests (ISPM 21), (FAO, 2004)

This assessment was conducted following the three interrelated stages of a pest-initiated PRA:

- Stage 1: Initiation
- Stage 2: Risk Assessment
- Stage 3: Risk Management

Stage 1: Initiation

Initiation identifies the pest(s) and pathway(s) that are of quarantine concern and should be considered for risk analysis in relation to the identified PRA area.

PEST IDENTIFICATION: The initiation point for this PRA was the selection of the four high-risk pests identified by participants of the March 2021 virtual PRA training that targeted the nine SFE countries. The four pests identified were (1) mango mealybug (*Rastrococcus iceryoides*), (2) mango or fruit tree mealybug (*Rastrococcus invadens*), (3) banana Fusarium wilt disease tropical race 4 (*Fusarium oxysporum* f. sp. *cubense*) and (4) khapra beetle (*Trogoderma granarium*).

Stage 2: Pest risk assessment

A pest risk assessment (for quarantine pests) is "the evaluation of the probability of the introduction and spread of a pest and of the likelihood of associated potential economic consequences" (FAO, 2021). Pest categorization and assessment of the likelihood of entry (introduction), establishment, spread and potential impacts were done according to ISPM 11: Pest risk analysis for quarantine pests (FAO, 2017). Details of how to assess the "likelihood of entry", "likelihood of establishment", "likelihood of spread" and economic impacts of a pest are given in ISPM 11 (FAO, 2017). A detailed description of the qualitative decision criteria for the assessment of the probability of entry, establishment and spread, and economic impacts is given in Annex 4.

PEST CATEGORIZATION: All four pests were considered for further risk analysis following a rapid assessment of their distribution and potential impacts, to determine whether phytosanitary measures were required. The rapid assessment also focused on the following aspects:

i. identity of the pest;
ii. biology of the pest;
iii. distribution status (absence/presence) in the PRA area;
iv. host plants;
v. symptoms on main hosts;
vi. regulatory status of the pest in the country/area at risk;
vii. potential for establishment and spread in PRA area and elsewhere; and
viii. potential for economic consequences in PRA area.

LIKELIHOOD OF ENTRY/INTRODUCTION: The likelihood of entry of the selected pests into the PRA area was individually assessed, following guidelines outlined in ISPM 11 (FAO, 2017). This assessment considered all possible pathways that could facilitate the entry of the pests, their potential to survive in transport and storage conditions, likelihood of successful transfer to a suitable host and existing pest management procedures.

IDENTIFICATION OF PATHWAYS FOR A PRA INITIATED BY A PEST: All relevant pathways for each pest, both intended and unintended, were identified and evaluated. Pathways considered included a plant for planting pathway, plant product pathways such as through fruits and vegetables, grains, seeds, woods, dried or stored plant products, stowaway pathway such as through containers and packaging materials, machinery and equipment, people and their luggage/equipment, soils, sand and gravel. Other pathways evaluated included natural pathways such as water and wind. The pathways were evaluated based on their:

i. association with the pathway at origin;
ii. survival during transport or storage;
ii. survival of existing pest management procedures; and
iv. transfer to a suitable host.

PROBABILITY OF ESTABLISHMENT: The likelihood of establishment of the selected pests into the PRA area were individually assessed, including their capability to reproduce and perpetuate in the PRA area by considering its life cycle, host range, epidemiology and survival in the area where the pest currently occurs. The following factors were considered in assessing the likelihood of establishment:

i. availability, quantity and distribution of hosts in the PRA area;
ii. environmental suitability of the PRA area;
iii. pests' potential for adaptation;
iv. reproductive strategy of the pest;
v. pest survival mechanisms; and
vi. cultural practices and control measures in the PRA area.

PROBABILITY OF SPREAD: The likelihood of spread of the selected pests into the PRA area was individually assessed. The presence of natural enemies was also assessed using information on the pests' biology, where they currently exist and their potential to move on their own or through associated commodities to find suitable hosts.

The following factors were considered in assessing the likelihood of spread:

i. suitability of the natural and/or managed environment for natural spread of the pest;
ii. presence of natural barriers;
iii. potential for movement with commodities or conveyances;
iv. intended use of the commodity;
v. potential vectors of the pest in the PRA area; and
vi. potential natural enemies of the pest in the PRA area.

CONCLUSION ON THE LIKELIHOOD OF INTRODUCTION, ESTABLISHMENT AND SPREAD: This PRA used qualitative descriptors (low, medium and high with values of (1), (2) and (3) respectively to estimate the probability of entry, establishment and spread.

The overall criteria for likelihood of introduction, establishment and spread **were combined and qualitatively assigned as low (1), medium (2) and high (3).**

ASSESSMENT OF POTENTIAL CONSEQUENCES: This assesses the likely consequences if the pests or disease agents were to enter, establish and spread in the PRA area. The assessment considers the direct and indirect effects of the pests and their economic and environmental consequences. The requirements for assessing potential consequences are given in ISPM 11 (FAO, 2017). The following factors were considered in assessing the likely consequences of the pest:

i. Direct economic and social consequence on:
    a. plant life health in the existing geographical range and potential effects in the PRA area: direct effects of the pest on each potential host in the PRA area, or those effects which are host-specific such as known or potential host plants (in the field, under protected cultivation, or in the wild), type and frequency of damage, crop losses (in yield and quality) and the efficacy and cost of control measures (including existing ones); and
    b. environmental reduction or displacement of keystone plant species.
ii. Indirect economic and social consequences:
    a. eradication and control;
    b. domestic trade: effects on volumes, quality, prices available for domestic markets;
    c. international trade: effects on export markets including access to export markets; and
    d. environment.

OVERALL RISK ESTIMATION: The summary of risk assessment of entry/introduction, establishment and spread was combined with the summary of likelihood of potential consequences.

Stage 3: Pest risk management

Pest risk management describes the process of identifying and implementing phytosanitary measures to manage risks to achieve the appropriate level of protection (ALOP) for FAOSFE countries while ensuring that any negative effects on trade are minimized. ISPM 11: Pest risk analysis for quarantine pests provides details on the identification and selection of appropriate risk management options and notes that the choice of measures should be based on their effectiveness in reducing the likelihood of entry of the pest.

Pest risk analysis for *Rastrococcus iceryoides* (mango mealybug) and *Rastrococcus invadens* (mango or fruit tree mealybug)

Stage 1: Initiation

Mealybugs are small, oval, soft-bodied, slow-moving insects covered with white powdery wax. They are sucking insects that injure plants by extracting large quantities of sap. Heavy infestations can lead to stunted growth, deformed leaves and stems, and death of plants. During their feeding and development, they produce honeydew, which attracts ants and the development of sooty mould (CABI, 2021). Mealybugs prefer warm, humid, sheltered sites away from adverse environmental conditions and natural enemies. Many mealybug species pose serious problems for agriculture, particularly when introduced into new areas of the world where their natural enemies are not present (Miller *et al*., 2002).

Mealybugs develop from an egg and through several nymphal (immature instar) stages before undergoing a final moult into the adult form. In some species, the late instars may be non-feeding. After moulting, the male mealybug emerges as a tiny, winged form, while the adult female mealybug is oval and up to about 4 mm long. Adult females and nymphs are covered in a white waxy substance that is moisture-repellent and protects them against desiccation. Reproduction in mealybugs is sexual or parthenogenetic, and there may be multiple generations per year.

PEST CATEGORIZATION

a. *Rastrococcus iceryoides* (Green, 1908)

Phylum: Arthropoda; **Class:** Insecta; **Order:** Hemiptera; **Family:** Pseudococcidae

Other scientific names: *Ceroputo iceryoides* (Lindinger, 1958); *Dactylopius* (Pseudococcus) *obtusus* (Newstead, 1911); *Phenacoccus iceryoides* (Green, 1908); *Phenacoccus obtusus* (Lindinger, 1913); *Rastrococcus cappariae* (Avasthi and Shafee, 1983).

International common name: Mango mealybug. Others: Downey snow line mealybug.

PEST DISTRIBUTION

Present: Kenya, Malawi, Rwanda, United Republic of Tanzania, Zanzibar. Other countries (Asia): Bangladesh, Hong Kong, India, Indonesia, Malaysia, Singapore, Sri Lanka (CABI, 2021).

Absent in SFE countries/PRA area: Burundi, Djibouti, Eritrea, Ethiopia, Somalia, South Sudan, Uganda.

BIOLOGY AND REPRODUCTION: The adult male has one pair of wings, well-developed limbs, lacks mouthparts and lives only a few days. The female lays eggs only after fertilization, laying about 450 to 585 eggs in a white, waxy ovisac that remains attached under its abdomen. The eggs hatch after 6.6 days.

Moulting occurs to form flat oval to yellow nymphs. Some nymphs resemble adults. To develop wings, the older male nymphs will secrete a tiny fluffy cocoon. The young mealybugs hatched are very active. Female and male nymphs moult three and four times, respectively, taking about 20.4 to 31 days in females and 18 to 26 days in males to become adults (CABI, 2021). The adult female is soft-bodied and wingless. Females remain clustered around the shoots, fruits or leaves, and do not move unless disturbed. The pest takes around 30 days to grow through all the nymphal stages under normal conditions. It can withstand warm climatic conditions. The insect stays active and reproduces all year round in warm climates (Williams, 2004).

HOST RANGE: Main hosts include mango, cotton, coffee and citrus. This polyphagous pest has over eight plant families as hosts, including cucurbits and *Ficus* (CABI, 2021). Ben-Dov (1994) records hosts from over 31 plant families.

SYMPTOMS ON MAIN HOST: Infestation of the pest starts after production of the first and second instar nymphs on the leaves at the terminal shoot of the plant. The pest then increases in populations, which move to the inflorescence and young shoots. Infected leaves become chlorotic, then defoliate.

Fruits are also infected by these pests. Leaf shedding, inflorescence, reduced fruit setting and dropping of young fruits occur in severe infestation. The honeydew excreted as the pest feeds, causes sooty mould on the fruit, reducing the market value (CABI, 2021). Photosynthetic ability is reduced by the sooty mould on the leaves, and this can cause the leaves to drop. The pest can cause damage ranging from 30 percent fruit loss to total fruit loss (CABI, 2021).

b. *Rastrococcus invadens* Williams

Preferred common name: Fruit tree mealybug. Others: Mango mealybug.

Phylum: Arthropoda; **Class:** Insecta; **Order:** Hemiptera; **Family:** Pseudococcidae

PEST DISTRIBUTION

Present: Bangladesh, Benin, Burkina Faso, Burundi, China, Congo, Côte d'Ivoire, Democratic Republic of the Congo, French Guiana, Gabon, Ghana, India, Indonesia, Lao People's Democratic Republic, Malaysia, Nigeria, Pakistan, Philippines, Rwanda, Senegal, Sierra Leone, Singapore, Sri Lanka, Thailand, Togo, Viet Nam.

Absent in SFE countries PRA area: Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Uganda.

BIOLOGY AND REPRODUCTION: *R. invadens* females produce first-instar larvae, which, under field conditions in tropical Africa, moult within 10 to 12 days into second instars. The second instar lasts 7 to 8.5 days, and slight differences can be observed between the sexes. Third-instar males form a cocoon and go through to a fourth instar over 8 to 11 days; third-instar females take 6.5 to 8.5 days before moulting to adults. Overall, males take ca 28 to 31 days from hatching to last moult. The short-lived adult males are capable of mating upon emergence. Females take 25 to 27 days from hatching to adult emergence. The pre-reproductive period of the females lasts for 17 to 18 days and they can survive up to 225 days (CABI, 2021).

HOST RANGE: Main hosts include mango, breadfruit, citrus, *Ficus* and bananas. In Western Africa, Agounké *et al*. (1988) listed 45 species of host plants from 22 families attacked by or harbouring populations of *R. invadens*, and Biassangama *et al*. (1991) listed 23 species from Central Africa. Since then, a total of over 100 host plant species have been found in Africa, particularly where populations of this insect are abundant on the primary host, mango. Not all these hosts could sustain populations of *R. invadens* (CABI, 2021).

SYMPTOMS ON MAIN HOST: The pest affects quality of production. Losses occur on economically important crops due to the excessive production of honeydew which acts as a substrate for mould growth, especially when there is a high pest population. The honeydew covers the fruits, leaves and stem. The weight of mangoes can be reduced by 51 percent (Tobih *et al*., 2002). The pest feeds externally on the fruit and causes inflorescence; leaves that have been completely covered by honeydew become chlorotic. The fruits drop prematurely. It can also damage the whole plant.

PRA SCOPE AND APPROACH

This is a pest-initiated PRA for *Rastrococcus iceryoides* (mango mealybug) and *Rastrococcus invadens* (fruit tree mealybug). The two pests were selected to be of quarantine concern to the PRA area. *R. iceryoides*, and *R. invadens* have been grouped together because of similar biology and ecology and will be reviewed as such in this PRA. All associated pathways that can represent any means that allow the entry or spread of a pest will be evaluated. Selected pathways will be assessed individually for probability of entry and risk management.

PREVIOUS PRA, CURRENT STATUS AND PEST INTERCEPTIONS

There are no previous documented PRAs undertaken on *Rastrococcus iceryoides* (mango mealybug) and and *Rastrococcus invadens* (mango or fruit tree mealybug). While there are new reports on the pests in some countries within the FAOSFE PRA area, *R. invadens* has only been reported in Burundi and Rwanda and is under official control (IPPC, 2019). *Rastrococcus iceryoides* has only been reported in Kenya and Rwanda.

R. invadens has been intercepted at entry points in the USA on imported mango fruit from India, Pakistan and the Philippines and on *Caladium*, cola and *Strongylodon* from Nigeria (Miller *et al*., 2014). *R. iceryoides* has been intercepted in Australia on fresh herb/curry leaves, on aquatic plants from Singapore to England; on *Codiaeum* sp. and *Citrus* spp. from Sri Lanka to the USA (Williams, 2004); and on *Codiaeum* and *Murraya* from India, Malaysia and Sri Lanka to the USA (Miller *et al*., 2014). There are no reported interceptions from the neighbouring countries.

Rastrococcus iceryoides (mango mealybug) and *Rastrococcus invadens* (mango or fruit tree mealybug) pest risk analyses have been undertaken by Australia during risk analyses for the import of mangoes from India (Biosecurity Australia, 2008) and in PRA on mealybugs and associated viruses they transmit on fresh fruits, vegetables, cut flower and foliage imports (DAWR, 2019). No previous pest risk analyses were conducted by the countries in the PRA area.

Both *Rastrococcus iceryoides* (mango mealybug) and *Rastrococcus invadens* (mango or fruit tree mealybug) are invasive pests with a wide host range and capable of spreading fast where natural enemies are absent. The two pests remain quarantine pests in most of the FAOSFE PRA area. Given the new reports in some of the countries in the PRA area, and the outputs from the Horizon Scanning Tool, it is critical to undertake PRA to understand the pathways of potential entry, likelihood of spread, establishment and possible measures to limit the entry and spread of these pests into new areas of the FAOSFE countries under consideration.

Stage 2: Pest risk assessment

Assessment of the likelihood of introduction/entry of *Rastrococcus iceryoides* (mango mealybug) and *Rastrococcus invadens* (mango or fruit tree mealybug).

I. ASSESSMENT OF LIKELIHOOD OF ENTRY

a. Plants for planting pathway

Mango mealybug (*Rastrococcus iceryoides*) and mango or fruit tree mealybug (*Rastrococcus invadens*) have a wide host range with more than 100 host species, especially in the families of Moraceae, Rutaceae, Anacardiaceae, Musaceae, Apocynaceae. *R. iceryoides* can be found feeding on mangoes, citrus, grapevines, cacao, guava and cotton, while *R. invadens* prefers citrus, mango and bananas. These pests are particularly damaging for young seedlings and trees. The instar nymphs and adult females feed on young shoots, inflorescence and fruits, and the underside of leaves. Preferred hosts and alternative hosts grow in tropical warm conditions that favour the development of *R. iceryoides* and *R. invadens*. High infestation levels have been reported throughout the season (CABI, 2021).

At the regional level, there is active trade and exchange of plants for planting, especially through the porous borders between countries sharing borders. The movement of infested planting material such as seedlings, may have contributed to the spread of *R. invadens* in Western Africa (Neuenschwander *et al*., 1994). Where the plants for planting are moved through borders uninspected, it poses a huge risk of introduction. *In-vitro* plants are not considered a pathway for the introduction of mealybug.

Mealybugs are likely to be associated with plants for planting such as fruit seedlings, fruits and vegetables transported both within the country and exported regionally and internationally. Both adults and immature stages can survive low-temperature storage conditions. Mealybugs may overwinter during unfavourable temperature conditions through slowed or halted development of nymphs and other pre-adult stages. They overwinter as second instars (Miller, 2005), and some as adults, first instars, and/or eggs (such as citrus mealybug *Planococcus citri* (Kerns, Wright and Loghry, 2015). There is a high probability that viable female mealybugs present on the fruit at point of export would still be viable on arrival over short and long distances. Interceptions reported by the USA on fruits and vegetables transported in refrigerated conditions confirm that they can survive cold transportation (Miller *et al*., 2014).

Both immature stages and adults are borne externally on the underside of the leaves. The presence of moulds can easily be detected during visual inspection at entry points. However, crawlers hiding within the plant crevices and fruit pedicels may not be easily detected. Simple dissection or microscopic examination using hand-held devices such as hand lenses may be helpful. However, these tools and methods are rarely used during the movement of produce such as fruits, vegetables and seedlings. Additionally, imports through the porous borders with minimum or no documentation and lack of inspection of fruits and vegetables pose a higher risk of introducing the pest into neighbouring countries.

Insecticides do not generally provide adequate control of the mealybugs' waxy coating. Other measures such as pruning of infested branches only reduce the infestation levels. Due to the wide host range, pest management practices may achieve considerable success in the commercial fields but less success in natural habitats. Biological control in Western Africa has resulted in successful control of the pest, both in commercial and natural habitats.

Introduction of mango mealybugs (*Rastrococcus iceryoides* and *Rastrococcus invadens*) through a planting materials pathway is rated as **high (3)** with a high confidence level.

b. Fruits and vegetables pathway

At the regional level, there is active trade and exchange of fresh fruits such as mangoes and citrus between countries, especially through the porous borders. These fruits may be harvested and packed at farm level without any further sorting or post-harvest treatment to remove nymphs, adult mealybugs or fruits with sooty mould. Mealybugs are relatively small; they are often found hiding between fruit crevices and under the fruit calyx areas that are difficult to detect during harvesting, sorting, packaging and inspections at the entry points. The situation is made worse where movement is through the unofficial porous borders where no inspection is done of the imported fruits. *R. invadens* has been intercepted on *Caladium*, cola and *Strongylodon* from Nigeria, Philippines, Thailand and Viet Nam to the USA (Miller *et al*., 2014). Adult *R. iceryoides* have been intercepted on aquatic plants from Singapore to England; on *Codiaeum* sp. and *Citrus* sp. from Sri Lanka to the USA (Williams, 2004), and on *Codiaeum* and *Murraya* from India, Malaysia and Sri Lanka to the USA (Miller *et al.*, 2014). Mealybugs have been detected on imported mango fruit in the USA (Miller *et al*., 2014), an indication that they can survive some existing pest management procedures.

While imported fruits and vegetables are mainly for human consumption, waste materials are generated at the point of sale, at the open-air markets, supermarkets and at consumption stages, i.e. households. Fruit skins, peels, blemished, overripe fruits and vegetables and seedlings will be thrown away/discarded into waste bins or open fields. Immature stages may complete development on discarded waste.

Introduction of mango mealybugs (*Rastrococcus iceryoides* and *Rastrococcus invadens*) through the fruits and vegetables pathway is rated as **high (3)**, with **high (3)** confidence level.

c. Hitchhiking

Movement of machinery, equipment, land vehicles, people's clothing and their luggage/equipment can introduce the mealybugs into clean fields over short and long distances (CABI, 2021).

Movement of contaminated farm machinery for harvesting and field cultivation may be contaminated with eggs, crawlers, nymphs and adults of the mealybugs and can introduce the pest into clean fields over short and long distances (CABI, 2021). Contaminated clothing, footwear and possessions, such as farm personal protective clothing and camping gear, may present a possible vector for the pest and introduce the pests over short or long distances.

Introduction of mango mealybugs (*Rastrococcus iceryoides* and *Rastrococcus invadens*) through the hitchhiking pathway is rated as **medium (2) with high (3)** confidence.

d. Natural dispersal

Mealybugs can disperse through all their life stages. Young crawlers may be carried by wind and gravity. The chances of successful migration would be low, but with large numbers of progeny, there is at least some successful movement between plants over short distances unaided in search of suitable hosts. Due to their small size, crawlers can be dispersed by wind to neighbouring plants.

Introduction of mango mealybugs (*Rastrococcus iceryoides* and *Rastrococcus invadens*) through natural dispersal over long distances is rated as **low (1) with high (3)** confidence, though this could change with short distance spread.

Summary of assessment of likelihood of entry/introduction: The likelihood that mango mealybugs (*R. iceryoides* and *R. invadens*) will be introduced into the PRA area is rated **high (3)** with **high (3)** confidence. *R. iceryoides* has already been reported in Kenya while *R. invadens* has been reported in Burundi and Rwanda.

II. ASSESSMENT OF THE LIKELIHOOD OF ESTABLISHMENT

a. Availability, quantity and distribution of suitable hosts

Rastrococcus iceryoides and *Rastrococcus invadens* are highly polyphagous and have a wide host range with more than 100 host species, especially in the families of Moraceae, Rutaceae, Anacardiaceae, Musaceae and Apocynaceae. *R. iceryoides* can be found feeding on mangoes, citrus, grapevines, cacao, guava and cotton, while

R. invadens prefers citrus, mango and bananas. Host species of these mealybugs are widespread in cities, towns and horticultural production areas throughout the PRA area, either as domesticated or as wild hosts. If introduced into the PRA area, there is high possibility of the pest establishing rapidly (CABI, 2021). The risk of mango mealybugs (*Rastrococcus iceryoides* and *Rastrococcus invadens*) establishing on both domesticated and wild hosts is rated as **high (3)**, with a **high (3)** confidence level.

e. Presence of suitable environment

Currently, *Rastrococcus iceryoides* (mango mealybug) and fruit tree mealybug (*Rastrococcus invadens*) are distributed in a range of geographical regions similar to many parts of the PRA area under consideration. *R. invadens* is present in Southeast and South Asia and Africa. The risk of mango mealybugs *(Rastrococcus iceryoides* and *Rastrococcus invadens)* establishing on both domesticated and wild hosts is rated as **high (3),** with a **high (3)** confidence level.

f. Reproductive potential and adaptability of the pest

R. iceryoides is known to reproduce sexually, and mating must occur for viable eggs, 450 to 585, to be produced. *R. invadens* is capable of producing eight generations a year in India, taking about 31 to 84 days to complete the life cycle. Egg-laying by females is dependent on temperature, with fewer eggs laid at high temperature. One generation develops every one to three months depending on temperature. In the PRA area, due to warm temperatures and the availability of hosts, faster development and more generations are expected. Their risk of establishing in the PRA area is therefore rated as **high (3)**, with a **high (3)** confidence level.

g. Availability of suitable vector, if transmitted by vector

Mango mealybugs (*Rastrococcus iceryoides* and *Rastrococcus invadens*) are free-living and do not require a vector for their establishment in the PRA area.

h. Control measures for management

Controls in place for other pests of economic concern, may reduce the likelihood of establishment of mealybugs in agricultural ecosystems but not in uncultivated areas with potential hosts. Conventional pesticides such as Chlorpyrifos may not achieve total eradication of the pest. Therefore, it is likely that there would be little impact to limit the establishment of these mealybugs in the PRA area. It is therefore rated as **medium (2)** with a **high (3)** confidence level.

i. Time of the year at which import takes place

Import of fruits and vegetables and planting material exchanges across the borders in the PRA occur throughout the year across seasons. The likelihood of establishment, if the pests are introduced, is rated as **high (3)**, with a **high (3)** confidence level.

Summary of likelihood of establishment: The suitability of the environment, availability of hosts, high reproductive rate and adaptability all support the establishment of *R. iceryoides* and *R. invadens* with a rating of **high (3)** with a **high (3)** confidence level.

III. ASSESSMENT OF THE LIKELIHOOD OF SPREAD

a. Suitability of the natural and/or managed environment for the natural spread of the pest

R. iceryoides and *R. invadens* are distributed in a range of geographical regions similar to many parts of the PRA area under consideration. The main hosts – mangoes, citrus, grapevines, cacao, guava, cotton and bananas – are found both in cultivated fields and natural environments. The suitability of the natural and/or managed environment for the natural spread of *R. iceryoides* and *R. invadens* is rated as **high (3)**, with a **high (3)** confidence level.

b. Presence of natural barriers

Natural barriers exist between these areas within the PRA area. There are extremely dry areas, mountains, lakes and rivers between these areas within the PRA area. While it might be difficult for the mealybugs to move across such long distances and natural barriers unaided, movement of the mealybugs will be through infested fruit, vegetables and planting materials and through hitchhiking on contaminated farm machinery and clothing. The likelihood that the presence of natural barriers may enhance spread of *R. iceryoides* and *R. invadens* is rated as **medium (2)**, with a **high (3)** confidence level.

c. Existing natural enemies/biological control agents in the PRA area

Coccinellids are common predators of *R. iceryoides*. Several natural enemies attack *R. invadens*, including encyrtid parasitoids (*Anagyrus mangicola* and *Gyranusoides tebygi*). These species are both endophagous parasitoids, specific to *R. invadens*. Classical biological control by use of parasites, parasitoids and predators like *Gyranusoidea tebygi* and *Anagyrus mangicola* has led to satisfactory control of the mango mealybug in Western Africa, for example in Togo. However, these are not present in the PRA area. Since it will take some time before the local natural enemies parasitize or predate the mealybug, the likelihood of spread of the mealybug has been rated as **high (3)**, with a **high (3)** confidence level.

d. Intended use of the commodity

Exchange of the hosts – fruits and vegetables – is mainly for human consumption and processing. Seedlings may mainly be for seedling nurseries, planting in fruit orchards and landscaping. These commodities may be moved from one country to another and within the country, thereby aiding the spread of mealybug eggs, nymphs and adults. The likelihood of spread of the mealybug has been rated as **high (3),** with a **high (3)** confidence level.

e. The potential for movement with commodities or conveyances

R. iceryoides and *R. invadens* can be spread to suitable hosts in new areas through the movement of infested fruits, vegetables and planting materials, and through hitchhiking on farm machinery and clothes of people who have been in direct contact with infested material. This is rated as **high (3)** with a **high (3)** confidence level.

f. Availability of suitable vector, if vector transmitted

Mealybugs do not require a vector for their establishment in the PRA area.

Summary of the likelihood of spread: These are the suitability of the natural and/or managed environment for the natural spread of the pest, lack of natural barriers, lack of natural enemies/biological control agents in the PRA area, diverse uses of fruits and vegetables that are a host of these mealybug and high potential to hitchhike on farm equipment as well as in travellers' luggage and equipment. *R. iceryoides* has already been reported in Kenya while *R. invadens* has been reported in Rwanda. They continue to spread to other new areas. This has been rated **high (3)**, with a **high (3)** confidence level.

IV. ASSESSMENT OF THE LIKELIHOOD OF CONSEQUENCES

a. Direct economic consequences

R. iceryoides and *R. invadens* may cause significant economic damage to crops. *R. invadens* has been associated with mango losses estimated at 89 percent in Benin, and considerably affecting yield on citrus and on many horticultural crops and shade trees. Fruit infestation can result in poor quality of fruits, with significant reductions in ash content, crude fibre and sugar levels of ripe and unripe fruit and protein, fat and carbohydrate levels. *R. iceryoides* is highly damaging to seedlings in nurseries, as reported on mangoes (CABI, 2021). Other important agroforestry trees such as neem trees and jackfruits will be at risk. Damage caused by pest mealybugs includes weakening plant vigour to decrease yield and impacting the appearance of produce to reduce market value. Direct economic consequence is rated **high (3)**, with a **high (3)** confidence level.

b. Direct impact on the environment

R. iceryoides and *R. invadens* are invasive species and have a wide host range. Heavy infestation can kill young seedlings. In addition, some species of pest mealybugs may have some impact on native mealybug fauna through competition for the same or similar resources. Management of the mealybugs in public places and orchards will involve additional costs to rogue and remove infested trees and seedlings. If introduced, the direct impact of the pest on the environment is rated **medium (2)**, with a **high (3)** confidence level.

c. Direct social impact

Vögele *et al.* (1991) reported that in Togo, livelihoods were negatively affected by reduced roadside fruit sales. Childhood malnutrition was thought to have increased from the reduced provision of fruits with high vitamin A and C content. Increased fly numbers were believed to have been promoted by excess honeydew, causing a nuisance to villagers and tourists. The presence of mealybug on fruit trees may reduce the aesthetic value of orchards and gardens due to sooty mould on tree leaves and bark. If introduced, the social impact of the pest is rated **medium (2)**, with a **high (3)** confidence level.

d. Indirect impact on eradication and control

If introduced, *R. iceryoides* and *R. invadens* will increase the cost associated with surveillance, monitoring, eradication and control activities in the PRA area. Research costs and other associated costs of integrated pest management (IPM) options such as cultural, physical, biological and chemical control methods will result in additional costs and efforts. Biological control programmes have been successful for *R. invadens*. This will involve introducing biological control agents in PRA area. Classical biological control is expensive. If introduced, plant protection products such as insecticides would need to be used to manage the pests; indirect impact on eradication and control is rated **medium (2),** with a **high (3)** confidence level.

e. Indirect impact on international trade

R. iceryoides and *R. invadens* will have significant impact on international trade of fruits and vegetables. Loss of trade and access to markets may threaten small-scale farmers' incomes and livelihoods. Major export markets will review their phytosanitary requirements for host fruits such as mangoes, citrus and vegetables, including planting materials. *R. invadens* has been intercepted at entry points in the USA on imported mango fruit from India, Pakistan and Philippines and on *Caladium*, cola and *Strongylodon* from Nigeria (Miller *et al*., 2014). *R iceryoides* has been intercepted in Australia on fresh herb/curry leaves, on aquatic plants from Singapore to England; on *Codiaeum* sp. and *Citrus* sp. from Sri Lanka to the USA (Williams, 2004); on *Codiaeum* and *Murraya* from India, Malaysia and Sri Lanka to the USA (Miller *et al*., 2014). Such interceptions may lead to loss of export market, stringent phytosanitary measures such as produce treatment and inspection, thus increasing the cost of production and export and disrupting existing export trade. The use of pesticides will also increase the risk of maximum residue levels (MRL) in fruits and vegetables.
If introduced, the pest's indirect impact on international trade is rated **high (3)**, with a **high (3)** confidence level.

f. Indirect impact on domestic trade

Domestic trade of host fruits, vegetables and plant seedlings may be controlled to manage the spread of the pests into new areas. This will affect access to fruits and vegetables by the general population and other stakeholders dependent on these fruits and vegetables. If introduced, indirect impact on domestic trade is rated **medium (2)**, with a **high (3)** confidence level.

g. Indirect impact on the environment

Introduction of *R. iceryoides* and *R. invadens* will result in additional use of pest control products such as insecticides for their control. Additional insecticide use on farms and orchards will affect the environment through soil and water contamination, and will repel and kill non-target insect biodiversity including pollinator populations. The use of pesticides will also increase the risk of MRL in fruits and vegetables. Due to the negative indirect impact on the environment, this is rated **medium (2)**, with a **high (3)** confidence level.

Summary of likelihood of consequences: If introduced into the FAOSFE PRA area, *R. iceryoides* and *R. invadens* will have a significant impact on the environment, on crop production and quality and on the international market. They will also have social impacts on communities and amenities. The impact of these pests is therefore rated as **high (3)**, with a **high (3)** confidence level.

CONCLUSIONS

R. iceryoides and *R. invadens* are key invasive pests with a wide host range of crops and uncultivated plants. There is a high risk of introduction/entry, establishment and spread of these pests in the PRA area. The probability of entry, establishment and spread in the PRA area, as well as the potential impacts, are ranked **high**.

Likelihood of entry: The most likely pathways of entry for *R. iceryoides* and *R. invadens* (infested fruits and vegetables, plants for planting, hitchhiking during transport of produce, movement of farm machinery, and clothing and equipment of people travelling across countries) are ranked high. Natural spread may occur over short distances between neighbouring farms.

Likelihood of establishment: The wide host range, availability of hosts in the PRA area, high reproductive rate and adaptability, all support an establishment rating as high for *R. iceryoides* and *R. invadens*. In addition, the climatic conditions in the PRA area have similarities with those where the pest is currently known to occur. Therefore, the likelihood of establishment is **high**.

Likelihood of spread: The likelihood of spread is **high** and is enhanced by the suitable climate and wide array of host plants present in the PRA area, as well as the high reproductive potential of both *R. iceryoides* and *R. invadens*.

Likelihood of consequences: If introduced, the likelihood of consequences of *R. iceryoides* and *R. invadens* is **high**, with significant economic, social and environmental impacts in the PRA region. In the countries where they have been reported, they have resulted in significant reduction of crop yield and quality, including indirect impact on the environment and biodiversity.

Stage 3: Pest risk management

The effectiveness of the proposed phytosanitary measures or a combination of measures was considered according to ISPM 11 (FAO, 2017). Risk management measures have been recommended for *R. iceryoides* and *R. invadens* as follows:

MITIGATING THE RISK ON HOST PLANTS FOR PLANTING FROM COUNTRIES WHERE *R. ICERYOIDES* AND *R. INVADENS* OCCUR

Importing plants for planting from the pest-free areas and rigorous visual pre-export inspections in the country of origin and at entry points are important. Continuous inspections and monitoring of the orchards where imported planting materials are planted are proposed. Planting materials of any of the listed host plants that are imported without import permits or otherwise imported through porous borders, should be intercepted and destroyed to reduce possible entry into any of the FAOSFE countries where *R. iceryoides* and *R. invadens* have not been detected. In-vitro plants of any of the listed host plants are not considered a pathway and will be a safe option for imports of planting materials.

MITIGATING THE RISK ON FRUITS AND VEGETABLES FROM COUNTRIES WHERE *R. INVADENS* AND *R. ICERYOIDES* OCCUR

Importing plants for fruits and vegetables from pest-free areas or areas of low-pest populations with inspection at point of exits and entry is important. Fruits and vegetables should be harvested from orchards that are free from *R. iceryoides* and *R. invadens* and/or have effective control measures for the pests. Sampling of the imported fruits and vegetables should be done to get a representative sample size to enable detection of the pests. Fruits and vegetables, fruit calyxes and accompanying leaves must be inspected for young nymphs and mealybug adults. Any fruits and vegetables imported without documentation such as import permits and phytosanitary certificates and with no indication of place of origin should be destroyed.

MITIGATING THE RISK OF HITCHHIKERS FROM COUNTRIES WHERE *R. ICERYOIDES* AND *R. INVADENS* OCCUR

Fruits that passengers ferry via road, air travel and foot should be destroyed; there should be cleaning or disinfestation of contaminated machinery moving from one country to another.

LEGISLATION AND PHYTOSANITARY POLICIES

FAOSFE countries that have Kenya and Rwanda as neighbours should undertake immediate surveillance to determine the presence and spread of *R. iceryoides* and *R. invadens* and revise their pest distribution records and pest lists appropriately. Listing *R. iceryoides* and *R. invadens* in national and regional quarantine pest lists is key in the management of the pests. There is a need to establish surveillance and eradication programmes in preparation for possible introduction, establishment and spread. Due to the favourable climatic conditions, abundance of host plants in both wild and cultivated habitats and lack of effective control, *R. iceryoides* and *R. invadens*, if introduced, are likely to be established. Given the detection of *R. iceryoides* in Kenya and *R. invadens* in Rwanda, efforts to undertake the evaluation of parasitoids/predators for classical control should begin in earnest.

Pest risk analysis for banana Fusarium wilt disease tropical race 4 (*Fusarium oxysporum* f. sp. *cubense*)

Stage 1: Pest initiation

Banana is a fruit crop that represents the fifth most important agricultural crop in trade (Aurore *et al*., 2009). Its production is challenged by Fusarium wilt, a soil-borne disease caused by the fungus *Fusarium oxysporum* f. sp. *cubense* (*Foc*) (Ploetz, 2006; Dale *et al*., 2017). The pathogen produces chlamydiospores and can persist for more than 30 years in the absence of the host (Dita *et al*., 2010). The disease was first reported in Australia (Ploetz and Pegg, 1997) and has since spread globally through the exchange of planting material (Ploetz, 2015). This disease wiped out the Gros Michel banana industry in the mid-twentieth century. The use of resistant Cavendish cultivars helped in management of *Fusarium oxysporum* f. sp. *cubense* (*Foc*) race 1. However, the pathogen mutated and a new strain of Foc called the tropical race 4 (TR4) attacked a diverse range of banana varieties including the Cavendish clones. Foc TR4 was restricted to East and Southern Asia for 20 years. From 2010 onwards, it has spread to countries in Southeast and South Asia (India, Lao People's Democratic Republic, Myanmar, Pakistan and Viet Nam), Africa (Mozambique) and the Near East (Israel, Jordan, Lebanon and Oman). Susceptibility of enset bananas to FoC TR4 is still unknown.

PEST CATEGORIZATION

Preferred scientific name: *Fusarium oxysporum* f. sp. *cubense* tropical race 4 (E.F. Sm.), Snyder and Hansen, 1940.

Phylum: Ascomycota; **Class:** Sordariomycetes; **Order:** Hypocreales; **Family:** Nectriaceae.

International common names: Fusarium wilt of banana; TR4.

F. oxysporum f. sp. *cubense* has been divided into races based on its pathogenicity on reference host cultivars. Among the most significant races of *F. oxysporum* f. sp. *cubense* pathogenic to edible banana, race 1 affects mainly the cultivar Gros Michel; race 2 affects bananas of the Bluggoe subgroup; race 4 affects all cultivars in the Cavendish subgroup grown in subtropical climates plus cultivars susceptible to races 1 and 2 (ProMusa, 2020; Baker *et al*., 2008). Tropical race 4 (TR4) causes disease on hosts in the tropics and subtropical race 4 (SR4) affects plants in the subtropics exposed to predisposing abiotic factors such as cold stress. Foc strains have also been classified into vegetative compatibility groups (VCGs), with TR4 classified as VCG 01213 (Ploetz and Churchill, 2011). Both races 1 and 2 are reported to be endemic in the PRA area, but Foc TR4 is absent (CABI, 2021).

PEST DISTRIBUTION

Present: Australia (Northern Territory, Queensland), China (Fujian, Guangdong, Guangxi, Hainan, Yunnan), Colombia, India (Bihar, Gujarat, Madhya Pradesh, Uttar Pradesh), Indonesia (Borneo), Israel, Jordan, Lao People's Democratic Republic, Lebanon, Malaysia, Mayotte, Myanmar, Mozambique, Oman, Pakistan, Philippines, Taiwan Province of China, Thailand, Türkiye, Viet Nam (Curry, 2020).

Absent in these SFE countries' PRA area: Burundi, Djibouti, Eritrea, Ethiopia, Somalia, South Sudan, Uganda.

HOST RANGE: The main host of Foc TR4 is plants of the Musae family – *Musa* spp. (banana), *Musa acuminata* (wild banana); *Musa balbisiana*, *Musa textilis* (manila hemp) – and Heliconiaceae family (*Heliconia caribaea*, *Heliconia mariae* and *Heliconia psittacorum* (Pérez-Vicente *et al*., 2014). TR4 also attacks cultivars susceptible to races 1 and 2, and additional cultivars such as Barangan (Lakatan subgroup, AAA genome group). Banana varieties Cavendish with genome AAA, Pome (AAB), Bluggoe (ABB) and Pisang Awak (ABB) Indiizi or apple bananas are susceptible to the disease. Foc TR4 is strongly pathogenic to the commercially important banana variety Cavendish (AAA) of species *Musa acuminate*. EAHB cultivars (genome group AAA) are also grown in Burundi, Democratic Republic of the Congo, Kenya, Rwanda and United Republic of Tanzania. They are generally resistant to the race 1 and 2 strains that cause Fusarium wilt. Preliminary results suggest that they might also be resistant to TR4 (ProMusa, 2020). Other hosts of Foc TR4 include weeds – *Chloris inflata* (syn. *C. barbata*), *Euphorbia heterophylla* and *Tridax procumbens* have been reported as alternative hosts of Foc TR4 in Australia (Hennessy *et al.*, 2005). *C. inflata* is present in Kenya, *E. heterophylla* and *T. procumbens* are both present in Ethiopia, Kenya and Uganda (CABI, 2021).

SYMPTOMS ON MAIN HOSTS: Leaf yellowing progressing from older to younger leaves. Yellow leaves remain erect and may collapse at the petiole and hang down the pseudostem. Intense wilting occurs when the pathogen colonizes and establishes in the vascular system. There is discoloration of the rhizome internally, which varies from pale yellow in the early stages of infection to dark red and finally black (Molina *et al.*, 2009). In the pseudostem, the xylem vessels become necrotic and splitting at the base is observed. The progression in internal symptoms will influence external symptoms. The fruit does not exhibit any symptom. Severely infected plants die and the whole plant falls (Li *et al.*, 2011). The disease cycle starts again on a new plant that does not show obvious symptoms. Infected suckers do not show symptoms until later on.

PRA SCOPE AND APPROACH

This is a qualitative pest-initiated PRA for banana Fusarium wilt disease tropical race 4 (*Fusarium oxysporum* f. sp. *cubense*). The pest is of quarantine concern to the PRA area. This is a pest-initiated PRA and all associated pathways that can represent any means that allow the entry or spread of a pest are evaluated.

PREVIOUS PRA, CURRENT STATUS AND PEST INTERCEPTIONS

There are no previous documented PRAs undertaken in the PRA area. Baker *et al*. (2008) undertook a pest risk assessment on *Fusarium oxysporum* f. sp. *cubense* conducted by France for its overseas departments in French Guiana, Guadeloupe, Martinique and Réunion. Xie *et al*. (2011) undertook PRA on *Fusarium oxysporum* f. sp. *cubense* on bananas in the Fujian and Guangdong provinces of China. All the PRAs have rated the potential of entry, establishment and spread as high, with high negative impacts on banana production in the PRA areas. Foc TR4 has recently been detected in the French Department of Mayotte on banana variety Silk (AAB) and Bluggoe (ABB) (Aguayo *et al.*, 2021). Foc TR4 has recently invaded Mozambique but remains under official control. Foc TR4 poses a great threat to food security in Africa where bananas are key crops for both nutrition and livelihood incomes. Banana Foc TR4 remains a quarantine pest in most countries in Africa, including the PRA area – the nine FAOSFE countries.

TR4 can cause severe damage and so the spread must be contained. The fungus is commonly spread in infested suckers and rhizomes, as well as in soil, water and farm machinery. Its ability to survive without its host for up to 30 years (Ploetz, 2006) and its wider host range than other Foc strains give TR4 great potential for spreading to new locations (CABI, 2021). The PRA area has suitable climatic conditions for the survival of this pest. The PRA area lies within the tropics with warm and wet climatic conditions. The pest has been reported in two tropical climates in Africa, including Mozambique (IPPC, 2013; Viljoen *et al*., 2020) and Mayotte (Aguayo *et al*., 2021; EPPO, 2020). There is no effective chemical control or any natural enemies that may prevent the establishment or limit the spread of TR4.

The economic impact of TR4 infection in a crop depends on the host that has become infected, and the environmental conditions in which the interaction occurs. TR4 affects a range of banana varieties, including the economically important Cavendish banana, which is commonly grown in large monocultures. The spread of Foc TR4 to these plantations can impact the whole crop, causing significant financial impact to commercial banana growers and exporters. The annual cost of TR4 has been calculated for some countries. In Malaysia, the annual loss was calculated as USD 14.1 million; for Indonesia, the value was USD 121 million (Hermanto *et al*., 2011) and losses on Cavendish bananas in Taiwan Province of China due to the fungus were valued at USD 253.3 million. In 2015 a dynamic model was developed to estimate the potential economic impact of TR4 on the Australian banana industry if it continues to spread via natural and human-initiated means and has predicted annual losses of over AUD 138 million.

Bananas, the main hosts of Foc TR4, are an important staple food in many countries, particularly in the least developed countries, and Fusarium wilt is one of the most devastating biotic constraints to its production. As well as affecting the availability of bananas for farmers' consumption, TR4 is also a major concern for bananas that are exported, which are usually the susceptible Cavendish variety. Losses due to TR4 can therefore have a large impact on the incomes and employment of farmers (FAO, 2019).

Stage 2: Pest risk assessment

Assessment of the likelihood of introduction/entry of *Fusarium oxysporum* f. sp. *cubense* covered the following aspects:

I. ASSESSMENT OF THE LIKELIHOOD OF ENTRY

Identification of pathways of entry was based on the following pathways:

a. Plants for planting pathway

There is a high probability of entry of this pest in the PRA area as bananas are extensively vegetative-propagated planting materials. Infected bulbs, tubers, corms, rhizomes, roots and stems (Ploetz, 2006) can move hyphae and spores over long and short distances through the movement of planting materials. At the regional level, there is an undocumented exchange of plants for planting, especially through the porous borders between neighbouring countries. There is no documented exchange of planting materials within the PRA area with Mozambique where the disease has been reported. Official exchange of banana planting materials remains tissue culture materials that have no risk of introduction of Foc TR4.

The likelihood of introduction of Foc TR4 through the planting materials pathway is rated as **low (1)**, with a **low (1)** confidence level.

b. Hitchhiking

The fungus is commonly spread in infested suckers and rhizomes, as well as soil, water and farm machinery. The pathogen can survive without its host for up to 30 years (Ploetz, 2006). Infested soil attached to farm machinery, equipment, vehicles, people's clothing and their luggage/equipment, farm clothes and footwear, can introduce Foc TR4 into clean fields over short and long distances (CABI, 2021). Spores of TR4 can be carried by domestic animals (such as pigs and sheep), moving from an infected plantation to a plantation of healthy plants. The conidia can also be carried on the exoskeleton of insects such as the black banana weevil, *Cosmopolites sordidus,* and can be introduced into clean fields over short distances (Curry, 2020). In Mozambique, the spread of Foc TR4 to other farms in the neighbourhood to Metocheria farms was linked to the movement of farm workers and vehicles between farms (Viljoen *et al*., 2020). The spread of Foc TR4 to Israel is linked to possible movement of farm workers, soil, stray wild pigs, other animals and agricultural produce from contaminated fields in Jordan (Maymon *et al*., 2020). Unconfirmed reports indicate that contaminated workers' protective clothing may have been the source of inoculum in the introduction of Foc TR4 in Mozambique.

The likelihood of introduction of Foc TR4 through the hitchhiking pathway is rated as **medium (2)** with a **high (3)** confidence level.

c. Natural dispersal

Foc TR4 produces micro- and macroconidia which can spread via surface water, rivers and streams. If spores get into irrigation water stores, such as reservoirs, they can also spread to new plantations when the contaminated water is used for irrigation. It is suspected that Foc TR4 spread to other banana plants within the farm and other neighbouring farms through contaminated irrigation and river water (Viljoen *et al*., 2020). Severe flooding in northern Mozambique in 2015 has been linked to the spread of Foc TR4 in banana farms in northern Mozambique (Viljoen *et al*., 2020).

The likelihood of introduction of Foc TR4 through natural dispersal over long distances is rated as **medium (2)** with a **high (3)** confidence level, even though this could change with short distance spread.

Summary of assessment of the likelihood of entry/introduction: The likelihood that Foc TR4 will be introduced into the PRA area is rated **medium (2)** with a **high (3)** confidence level.

II. ASSESSMENT OF THE LIKELIHOOD OF ESTABLISHMENT

a. Availability, quantity and distribution of suitable hosts

Of the countries in the FAOSFE PRA area, Burundi, Djibouti, Eritrea, Ethiopia, Somalia, South Sudan and Uganda have suitable hosts for Foc TR4. Main hosts of Foc TR4 such as the Musae family – *Musa* spp. (banana), *Musa acuminata* (wild banana), *Musa balbisiana*, *Musa textilis* (manila hemp) – and Heliconiaceae family (*Heliconia caribaea*, *Heliconia mariae* and *Heliconia psittacorum* (Pérez-Vicente *et al*., 2014) are grown and managed in small-, medium- and large-scale family gardens or in wild habitats in the PRA area. Different varieties of bananas grown in the PRA area have varied susceptibility to Foc TR4.

Banana varieties Cavendish with genome AAA, Pome (AAB), Bluggoe (ABB) and Pisang Awak (ABB), Indiizi or apple bananas are susceptible to the disease. Foc TR4 is strongly pathogenic to the commercially important banana variety Cavendish (AAA) of the species *Musa acuminata*. East African Highland banana (EAHB) cultivars (genome group AAA) are also grown in Burundi, Democratic Republic of the Congo, Kenya, Rwanda and the United Republic of Tanzania. They are generally resistant to the races 1 and 2 strains that cause Fusarium wilt. Preliminary results suggest that they might also be resistant to TR4 (ProMusa, 2020). Foc TR4 can attack a wide host range of cultivars, including those susceptible to races 1 and 2. Other wild hosts of Foc TR4 – *Chloris inflata* (syn. *C. barbata*), *Euphorbia heterophylla* and *Tridax procumbensi* – that have been reported as alternative hosts of Foc TR4 in Australia (Hennessy *et al*., 2005) are present in the PRA area. *C. inflata* is present in Kenya; *E. heterophylla* and *T. procumbens* are both present in Ethiopia, Kenya and Uganda (CABI, 2021). In case of introduction, these weeds can act as inoculum reservoir for Foc TR4. Foc TR4 has a high potential for quick establishment as Cavendish and other susceptible varieties and alternative hosts are present in the PRA area. Therefore, the risk of establishing on both domesticated and wild hosts is rated as **high (3)** with a **high (3)** confidence level.

b. Presence of suitable environment

The PRA area has similar climatic conditions (tropics and subtropics) as the areas where Foc TR4 has been reported. For instance, the climatic and environmental conditions in Mozambique, where Foc TR4 has devastated banana production (Viljoen *et al.*, 2020), and recently Mayotte (Aguayo *et al.*, 2021), are quite similar to those of the PRA area. Environmental stress such as wet, dry or extremely hot conditions enhances the development and establishment of this pathogen. Once introduced to the soil, the spores can survive for up to 30 years in plant debris and soil (Ploetz, 2006). Foc TR4 risk of establishing in the PRA due to suitable environment in the PRA area is rated as **high (3)** with a **high (3)** confidence level.

c. Reproductive potential and adaptability of the pest

TR4 produces micro- and macroconidia which can spread via surface water, rivers and streams. Spores of TR4 can be carried by domestic animals (pigs, sheep, etc.) moving from an infected plantation to a plantation of healthy plants. The conidia can also be carried on the exoskeleton of insects such as the black banana weevil, *Cosmopolites sordidus*. The pathogen is soil-borne and produces chlamydospores that can survive dormant in the soil for more than 30 years as chlamydospores in infected plant debris, in soil or alternative hosts (Ploetz, 2006). Chlamydospores germinate and infect healthy roots of the susceptible hosts, producing more mycelium, conidia and chlamydospores within a short period (CABI, 2021). The ability of the pathogen to survive for long periods under unfavourable environmental conditions increases its ability to survive under different conditions and in the absence of a susceptible host. The risk of establishing in the PRA area is rated as **high (3)** with a **high (3)** confidence level.

d. Availability of suitable vector, if vector transmitted

Spores of TR4 can be carried by domestic animals (pigs, sheep, etc.) moving from an infected plantation to a plantation of healthy plants. The spread of Foc TR4 to Israel is linked to possible movement of farm workers, soil, stray wild pigs, other animals and agricultural produce from contaminated fields in Jordan (Maymon *et al*., 2020). The conidia can also be carried on the exoskeleton of insects such as the black banana weevil, *Cosmopolites sordidus* (Meldrum *et al*., 2013; Curry, 2020). These vectors are present in abundance in the PRA area. It is therefore rated as **high (3)** with a **high (3)** confidence level.

e. Control measures for management

Foc TR4 is a systemic pathogen that attacks the vascular system of the host. There is currently no effective method to control TR4 in a plant that is already infested. Moreover, because the pathogen is soil-borne and produces chlamydospores that can survive dormant in the soil, uprooting infested plants and replanting another susceptible variety will mean that the new crop will eventually also become infected. Controlling of Foc TR4 remains in the use resistance- and pathogen-free planting materials. Foc TR4 is strongly pathogenic to most available banana variety Cavendish (AAA). Cavendish somaclonal varieties have been tested and show resistance to the disease. They are not available in the PRA area. Other banana varieties like EAHB cultivars (genome group AAA) grown in the PRA area have been reported to be resistant to TR4 (ProMusa, 2020). As it is likely that if introduced, immediate eradication and containment may not be possible, the likelihood of establishment was rated as **high (3)** with a **high (3)** confidence level.

Summary of likelihood of establishment: The suitability of the environment, availability of hosts, high reproductive rate and adaptability all support a high likelihood of Foc TR4 establishment in the PRA. Likelihood of establishment is therefore rated **high (3)**, with a **high (3)** confidence level.

III. ASSESSMENT OF LIKELIHOOD OF SPREAD

a. Suitability of the natural and/or managed environment for natural spread of the pest

Foc TR4 produces micro- and macroconidia which can spread via surface water, rivers and streams. Presence of water bodies within the PRA area constitutes a great risk of the spread of the Foc TR4 pathogen to disease-free areas within the countries and to other countries. Rapid spread of the Foc TR4 in China has been linked to use of infected planting material and contaminated irrigation water from Pearl River (Xu *et al*., 2003). Rainfall, run-off and flooding can transmit Foc TR4 through infected debris, contaminated soil and water over short and long distances (Dita *et al*., 2018). Severe flooding in northern Mozambique has been associated with the rapid spread of Foc TR4 in farms, making containment of the pathogen impossible (Viljoen *et al*., 2020). The suitability of the natural and/or managed environment for the natural spread of Foc TR4 is rated as **high (3)**, with a **high (3)** confidence level.

b. Availability of suitable vector, if vector transmitted

Spores of TR4 can be carried by domestic animals (pigs, sheep, etc.) moving from an infected plantation to a plantation of healthy plants. Spread of Foc TR4 to Israel is linked to the possible movement of farm workers, soil, stray wild pigs, other animals and agricultural produce from contaminated fields in Jordan (Maymon *et al*., 2020). The conidia can also be carried on the exoskeleton of insects such as the black banana weevil, *Cosmopolites sordidus* (Meldrum *et al*., 2013; Curry, 2020). Passive movement of the pathogen over long and short distances is through the introduction of infected planting materials or soils attached to farm equipment, tools or clothing and shoes (Ploetz *et al*., 2015). These vectors are present in abundance in the PRA area. It is therefore rated as **high (3)**, with a **high (3)** confidence level.

c. Intended use of the commodity

The main pathway is through planting materials. If planting materials are infested with the pathogen, they can contaminate the soil and remain viable for up to 30 years (Ploetz, 2006). The likelihood of spread has been rated as **high (3)**, with a **high (3)** confidence level.

d. The potential for movement with commodities or conveyances

Pathogen-infected planting materials or infected soils and plant debris can move the pathogen over short and long distances. The recent invasion of Foc TR4 in Mozambique from Southeast Asia is attributed to the movement of contaminated farm equipment, clothes, footwear, tools, containers, etc., which had been used in Foc TR4-infested areas (Ploetz *et al*., 2015). Heavy flooding and the use of contaminated irrigation water can also carry the pathogen to new areas (Viljoen *et al*., 2020; Xu *et al*., 2003). It is possible that if introduced the pathogen will spread very fast through infected susceptible planting materials, irrigation water of naturally. This is rated as **high (3)**, with a **high (3)** confidence level.

Summary of the likelihood of spread: Because of the suitability of the natural and/or managed environment for the natural spread of the pest, and its high potential to hitchhike on farm equipment, in travellers' luggage and equipment, Foc TR4 has a high likelihood of spread in the PRA area. It has been rated as **high (3)**, with a **high (3)** confidence level.

IV. ASSESSMENT OF THE LIKELIHOOD OF CONSEQUENCES

a. Economic consequences

The impact of TR4 infection in a crop depends on the host that has become infected and the environmental conditions in which the interaction occurs. TR4 affects a range of banana varieties, including the economically important Cavendish banana, which is commonly grown in large monocultures. The spread of TR4 to these plantations can impact the whole crop, causing significant financial impact to commercial banana growers and exporters.

The annual cost of TR4 has been calculated for some countries. In Malaysia, the annual loss was calculated as USD 14.1 million; for Indonesia, the value was USD 121 million (Hermanto *et al*., 2011); and losses on Cavendish bananas in Taiwan Province of China due to the fungus were valued at USD 253.3 million. In 2015 a dynamic model was developed to estimate the potential economic impact of TR4 on the Australian banana industry if it continued to spread via natural and human-initiated means, which has predicted annual losses of over AUD 138 million. Control of the pathogen through the use of pesticides is not effective. The costs of associated biosecurity programmes at regional, national and individual farm levels are expensive and may not be sustainable. Field sanitation programmes such as the use of foot baths, fencing, clean planting materials, testing of planting materials and breeding of resistant varieties are very costly. In Mozambique, several farms where Foc TR4 was detected filed for bankruptcy due to lack of funds to manage the biosecurity procedures to reduce the spread of the disease (Viljoen *et al*., 2020). EAHB cultivars (genome group AAA) grown in the PRA area have been reported to be resistant to TR4 (ProMusa, 2020). This might reduce the impact of Foc TR4 on general banana production. However, the impact might be high on other varieties that are susceptible to Foc races 1 and 2, like Cavendish varieties.

Direct economic consequence is rated **medium (2)**, with a **high (3)** confidence level.

b. Impact on the environment

Fields under banana production may need to change due to invasion by Foc TR4. Other uses such as a change to oil palm production have been reported in the Philippines (ProMusa, 2020). In the PRA area, contaminated lands may be abandoned. Pathogen containment, especially through controlled use and treatment of contaminated irrigated water, may render such waters not useful for other activities. Loss of benefits is associated with landscape and serenity due to low or no presence of banana plantations. If introduced, the impact of the pest on the environment is rated **medium (2)** with a **low (1)** confidence level.

c. Social impact

Bananas, the main hosts of TR4, are an important staple food in many countries, particularly in the least developed countries, and Fusarium wilt is one of the most devastating biotic constraints to its production. In addition to affecting the availability of bananas for farmers' consumption, TR4 is also a major concern for bananas that are exported, which are usually the susceptible Cavendish variety. Losses due to TR4 can therefore have a large impact on income, employment of farmers and consumption patterns in the PRA area (FAO, 2019). If introduced, the social impact of the pest is rated **medium (2)** with a **high (3)** confidence level.

d. Impact on international trade

The spread of Foc TR4 in a Cavendish plantation can impact the whole crop, causing significant financial impact to commercial banana growers and exporters in Southeast Asia and Latin America (Ploetz and Pegg, 2000) and in Mozambique. In the PRA area, there is the export of bananas of Cavendish, apple and EAH varieties between the countries in the region. However, the export potential of Cavendish bananas and others, such as apple bananas, that are susceptible to Foc TR4 is increasing. Apart from production, no ban on exports is expected as the banana fruits are not affected by Foc TR4. The spread of Foc TR4 may present a big constraint in this growing market potential for several countries in the PRA area. If introduced, Foc TR4 impact on international trade is rated **high (3)** with a **high (3)** confidence level.

e. Impact on domestic trade

High banana variety diversity is produced and traded at the in-country agricultural markets. This includes mostly EAH bananas for cooking, apple bananas, Cavendish and other local varieties for ripening. The Cavendish and apple bananas are susceptible to Foc TR4. If Foc TR4 is introduced, it is expected that production and local trade of the Cavendish and apple bananas will reduce both in volume and quality and that the prices of the produce at the local market will increase, making them unaffordable to most people. If introduced, impact on domestic trade is rated **medium (2)** with a **high (3)** confidence level.

Summary of the likelihood of consequences: If introduced into the FAOSFE PRA area, Foc TR4 will have a severe impact on the economy in terms of the quantity and quality of bananas produced in the region, on the environment, and in terms of the social impacts on the community and the consumption of bananas. The likelihood of consequences due to the impact of Foc TR4 is rated **high (3)** with a **high (3)** confidence level.

PRA CONCLUSIONS

Foc TR4 is a key invasive pest with a wide host range of crops and uncultivated plants. There is a high risk of introduction/entry, establishment and spread of these pests in the PRA area. The probability for entry, establishment and spread in the PRA area, as well as the potential impacts, are ranked **high**.

Likelihood of entry: The most likely pathways of entry for Foc TR4 are mainly through infested plants for planting and hitchhiking during movement of contaminated farm machinery, clothing and equipment of people travelling across countries. Natural spread may occur over short distances between neighbouring farms through contaminated water in irrigation channels, streams and rivers. The likelihood of entry is rated high.

Likelihood of establishment: The wide host range, including susceptible wild hosts in the PRA area, high reproductive rate and adaptability, all support an establishment rating as high for Foc TR4. In addition, the climatic conditions in the PRA area are similar to those in areas like Mozambique where the pest is currently known to occur in Africa. Therefore, the likelihood of establishment is high.

Likelihood of spread: The likelihood of spread is high and is enhanced by the suitable climatic conditions and a wide array of susceptible host plants and wild plants present in the PRA area, uncontrolled movement of farm machinery, tools, equipment and people who may carry infected planting materials as well as the high reproductive potential and survival of Foc TR4.

Likelihood of consequences: If introduced, the likelihood of consequences from Foc TR4 is high, with significant economic, social and environmental impacts in the PRA region. In countries where Foc TR4 has been reported, it has resulted in a significant reduction of crop yield and quality including abandonment of Cavendish plantations and direct impacts on the environment and biodiversity. There is a huge risk to the export market of Cavendish and apple bananas.

Stage 3: Pest risk management

Using the conclusions from pest risk assessment, pest risk management options were identified to manage risks in order to achieve the acceptable level of protection (ALOP) for the PRA area – the nine SFE countries. The effectiveness of the proposed phytosanitary measures or a combination of measures was considered according to ISPM 11 (FAO, 2017). Risk management measures for Foc TR4 have been recommended for consideration as follows:

MITIGATING THE RISK ON HOST PLANTS FOR PLANTING FROM COUNTRIES WHERE FOC TR4 OCCUR TO THE FAOSFE PRA AREA

- Prohibiting the importation of planting materials such as corms, suckers or banana packaging materials like leaves.
- Only disease-free *in-vitro* planting materials should be allowed between countries. These must be inspected and tested for Foc TR4 at entry points. *In-vitro* plants of any of the listed host plants are not considered a pathway and will be a safe option for imports of planting materials for breeding and planting.

MITIGATING THE RISK ON HITCHHIKERS FROM COUNTRIES WHERE FOC TR4 OCCUR

- Banana planting materials (corms, suckers) ferried by passengers via road, air travel and on foot should be destroyed across borders.
- Decontamination of used vehicles, machinery and equipment with prior use or intended use in agricultural areas, in forests, etc. Guideline under ISPM 41 on the international movement of used vehicles, machinery and equipment should be followed.
- Decontamination of personal equipment, such as hiking gear, gumboots and farm protective clothes, of passengers or tourists travelling from countries where Foc TR4 has been reported.

LEGISLATION, PHYTOSANITARY POLICIES AND RESEARCH

- Declare and list Foc TR4 as a quarantine pest.
- Develop regional and national Foc TR4 contingency plans for detection, eradication and containment actions.
- Strict implementation of ISPM 41 on the international movement of used vehicles, machinery and equipment from countries where Foc TR4 has been reported. This applies to used military equipment as well.
- Establish routine surveillance programmes at regional level to detect incursions, especially with neighbouring countries that have reported Foc TR4.
- Create awareness of the imminent risk of Foc TR4 invasion in the FAOSFE countries among policymakers, researchers, border inspectors and stakeholders, private sector growers and other small-scale banana growers.

RESEARCH

- Collaborative screening for Foc TR4-resistant banana varieties.
- Development of resistant varieties that can replace the susceptible Cavendish varieties.
- Identification of plant protection products that can be used in the treatment of Foc TR4 pathogen.
- Research on the susceptibility of enset bananas to Foc TR4 should be investigated.

FARM-LEVEL BIOSECURITY MEASURES

- Create awareness among farm workers of Foc TR4, its symptoms and identification.
- Use of disease-free planting materials certified as clean.
- Observe field sanitation, for example the use of clean farm equipment and tools and decontamination after use on other fields; installation of foot and motor vehicle and equipment baths in big plantation farms; use of farm equipment and clothing.
- Fencing of banana farms to limit movement of visitors and animals in and out of the farm.
- Surveying/scouting of the bananas for insect pests and diseases.
- Record-keeping and sharing of information with authority in case of any abnormal pests.
- Soil and water management to reduce cross-contamination of fields.

Pest risk analysis for khapra beetle (*Trogoderma granarium*)

Stage 1: Pest initiation

Khapra beetle is a major pest of ground cereals, whole grains, copra, stored products and dried foods and fruits (CABI, 2021). The pest originated from the Indian subcontinent and was spread to other continents through the movement of people and trade. It is one of the most important quarantine pests worldwide (Eliopoulos, 2013), including the major wheat-producing countries – Australia, Canada, Russia and the United States. It has been classified as one of the 100 worst invasive species globally (Athanassiou *et al*., 2019). It can live on food with very low moisture content and withstand starvation for up to three years (Ahmedani *et al*., 2009). Khapra beetle larvae reduce the quality, grade and weight of grain (Ahmedani *et al*., 2011). It also causes contamination of stored products, making them unsafe for human consumption.

PEST CATEGORIZATION

Preferred scientific name: *Trogoderma granarium*.
Preferred common name: Khapra beetle.
Name phylum: Arthropoda; **Class:** Insecta;
Order: Coleptera; **Family:** Dermestidae.

PEST DISTRIBUTION

Present: Algeria, Burkina Faso, Egypt, Libya, Madagascar, Mali, Mauritius, Morocco, Niger, Nigeria, Senegal, Somalia, Sudan, Tunisia, Zambia, Zimbabwe.

Absent: Angola, Benin, Botswana, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Equatorial Guinea, Djibouti, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Malawi, Mauritania, Mozambique, Namibia, Rwanda, Sao Tome and Principe, Seychelles, Sierra Leone, South Africa, South Sudan, Togo, Uganda, United Republic of Tanzania.

HOST RANGE: Main hosts include groundnuts, barley, millet, sesame, sorghum, wheat, maize, rice, cotton and other dried stored products.

SYMPTOMS ON MAIN HOSTS: *T. granarium* may remain hidden deep in the stored food for relatively long periods. In bag stores, the first signs of infestation are masses of hairy cast larval skins, which gradually push out from the crevices between sacks; this is a sign that the stored food should be fumigated immediately. The larvae crawl over and consume the grain (CABI, 2021).

PRA SCOPE AND APPROACH

T. granarium is a serious pest of cereal grains and oilseeds, and many countries, including Australia, Burundi, China, Kenya, Uganda, United Republic of Tanzania and the USA, have specific quarantine regulations against possible importation. Massive populations of the insect may develop and grain stocks can be completely destroyed. Infestations of *T. granarium* are well known in large-scale stores, but there appear to be no documented cases of infestations in farms.

PREVIOUS PRA, CURRENT STATUS AND PEST INTERCEPTIONS

No previously documented PRAs have been undertaken in the PRA area. *T. granarium* is absent in the PRA area. Khapra beetle (*T. granarium*) presence in Somalia has been refuted. Although there has been no official surveillance and communication to the IPPC to report its absence, for this PRA it shall be assumed that khapra beetle is absent in Somalia. EPPO has given the pest the status of an A2 quarantine organism (Anon, 2007). Khapra beetle has been intercepted at borders periodically by the Australian quarantine (Castalanelli, 2011; Day and White, 2016). Paini and Yemshanov (2012) modelled the arrival of khapra beetle to Australia and identified Busan (Republic of Korea) and Kaohsiung (Taiwan Province of China) to be the most likely sources for khapra beetle arrival, with Melbourne port being the likely point of entry into Australia.

Pest risk assessment undertaken in the USA in 1998 and reviewed in 2005, rated the economic impact from *T. granarium* as high due to the high likelihood of establishment, and impact on production volume and the quality of other host crops traded internationally (Pasek, 2004; French and Venette, 2005). No PRA has been undertaken on *T. granarium* in any of the nine FAOSFE countries.

Massive populations of the insect may develop and grain stocks can be completely destroyed. Infestations of *T. granarium* are well known in large-scale stores but there appear to be no documented cases of infestations in farms. Losses due to *T. granarium*, sometimes in conjunction with other storage pests, have been reported in the literature and are summarized as follows. Losses in wheat grain stored in PVC bins after 90 days were 23.06 percent due to *T. granarium*, *Tribolium castaneum*, *Sitophilus oryzae* and *Rhyzopertha dominica*, compared with 1.73 percent in fumigated bins (Singh *et al*., 1994). *T. granarium* has also been shown to decrease the mineral content of maize (Jood *et al*., 1992).

Stage 2: Pest risk assessment

Assessment of the likelihood of introduction/entry of *T. granarium.*

I. ASSESSMENT OF THE LIKELIHOOD OF ENTRY

Identification of pathways of entry was based on the following pathways:

a. Plant products: grain seeds, dried and stored plant products

T. granarium has a wide host range of grain/seeds and dried stored products. Most FAOSFE countries import grains of barley, wheat, maize, rice and other dried stored products which are main hosts of the pest. The larvae of *T. granarium* are serious pests of oilseeds, and damage cereals. Large quantities are moved between countries and may contain all stages of the organism. The probability of the pest being associated with the pathway at origin is very high. All stages of the pest are present and grains/oilseeds are more infested in optimum conditions where pest management measures are not properly applied.

The likelihood of introduction of *T. granarium* through plant products (grain seeds, dried and stored plant products) is rated **high (3)** with a **high (3)** confidence level.

b. Shipping containers

Various life stages of *T. granarium* hide in the crevices and cracks and floorboards of shipping containers, where they can remain undetected for a long time. Shipping containers get contaminated by carrying infested grains/seeds of wheat, rice or dried products from countries where khapra beetles are present. Under unfavourable weather conditions and lack of food, diapausing larvae may survive about nine months; they live up to six years with favourable weather and food availability (Ahmedani *et al.*, 2009; CABI, 2021). Due to this ability to diapause for long, they can go undetected and pose a huge risk of introduction to khapra-free countries where shipping containers are used to deliver grains and other dried products. Several interceptions of various life stages of khapra beetle have been made in Australia on contaminated shipping containers (Day and White, 2016) and in the USA (French and Venette, 2005).

The likelihood of introduction of *T. granarium* through contaminated shipping containers is rated **high (3)** with a **high (3)** confidence level.

c. People and their luggage/equipment

T. granarium can move over short and long distances through luggage with infested grains/seeds or dried plant products, especially for travellers from countries with khapra beetle. Interceptions at USA border points include undeclared contaminated dried pigeon peas on luggage ferried by travellers from Sudan, and dried coriander seeds from India (Pasek, 2004; Day and White, 2016). In the nine FAOSFE countries, there are no rigorous passenger luggage inspections or logs of interceptions made on travellers' luggage.

The likelihood of introduction of *T. granarium* through infested undeclared plant products in passenger luggage is rated **medium (2)**, with a **high (3)** confidence level.

d. Natural dispersal

T. granarium cannot fly, and natural spread is limited to short distances, within bulk storage facilities and houses, etc. Long-distance entry/introduction of khapra is mainly through movement of infested grains/seeds and other dried plant production by human activities such as travelling and trade of grains/seeds. The likelihood of introduction of *T. granarium* through natural spread is rated **low (1)** with a **high (3)** confidence level.

Summary of assessment of the likelihood of entry/introduction: The likelihood that *T. granarium* will be introduced into the PRA area is rated **high (3)** with a **high (3)** confidence level.

II. ASSESSMENT OF LIKELIHOOD OF ESTABLISHMENT

a. Availability, quantity and distribution of suitable hosts

The FAOSFE PRA area – Burundi, Djibouti, Eritrea, Ethiopia, Somalia, South Sudan and Uganda – have suitable hosts of *T. granarium*. The host crops such as groundnuts, barley, millet, sesame, sorghum, wheat, maize, rice and cotton are actively cultivated, harvested, dried and stored by farmers in the PRA area. These countries also import dried plant products through sea shipment, using containers that may be infested with the pest. While most grains/seeds may be imported from khapra-free countries, shipment containers may present the risk of contamination of the grains/seeds and dried plant products. In case of introduction, the presence of suitable hosts enhances the risk of establishment of *T. granarium* in the PRA area. Therefore, the risk of establishment is rated as **high (3)** with a **high (3)** confidence level.

b. Presence of suitable environment

The beetle occurs in hot, dry conditions, predictably in areas which, for at least four months of the year, have a mean temperature greater than 20 °C and an RH below 50 percent (CABI, 2021). Larval development in *T. granarium* does not occur at temperatures below 21 °C, but can proceed at very low humidity, for example at 25 °C and two percent relative humidity (RH). Development is most rapid in hot, humid conditions, taking about 18 days at 35 °C and 73 percent RH. *T. granarium* is present in Zambia and Zimbabwe (EPPO, 2020), countries with climatic conditions similar to those in the PRA area. Viljoen (1990) reported suitable climate for the establishment of *T. granarium* in Southern Africa. The climatic conditions within the PRA area offer optimum development conditions for *T. granarium* and the risk of establishing in the PRA area is rated **high (3)** with a **high (3)** confidence level.

c. Reproductive potential and adaptability of the pest

T. granarium has four life stages: eggs, larvae, pupae and adult. Females lay between 60 and 500 eggs depending on the number of mating times with males. Larval development requires temperatures of above 21 °C but can develop with very low humidity between 25 °C and two percent RH (CABI, 2021). Larval development is faster in hot and humid conditions, taking about 18 days at

35 °C and 73 percent RH. Pupal development is unaffected by humidity and varies in length from five days at 25 °C to three days at 40 °C. Under unfavourable weather conditions and lack of food, diapausing larvae may survive about nine months; they live up to six years with favourable weather and food availability (Ahmedani *et al.*, 2009). Due to this reproductive potential and ability to diapause for long, the risk of establishing in the PRA area is rated as **high (3)** with a **high (3)** confidence level.

d. Availability of suitable vector, if vector transmitted

T. granarium has four life stages – eggs, larvae, pupae and adult, which are spread through infested grains/seed and dried products through human activities such as travel and trade in contaminated commodities, shipping containers and other packaging materials. *T. granarium* does not need vectors for transmission and the risk of establishing in the PRA area is therefore rated as **low (1)** with a **high (3)** confidence level.

e. Control measures for management

These include insecticidal dust such as pirimiphosmethyl, chlorpyrifos–methyl, actellic, phosphine, malathion and some pyrethroids (Ahmedani *et al.*, 2007). Controlled atmospheres, for example CO_2 in small structures and heat treatment which involves 60 °PP°C exposure for 30 minutes, are also used. Gaseous and liquid insecticides, mainly methyl bromide and phosphine, have also been used to control khapra beetles because they are cost-effective and simple to use. Methyl bromide is banned or controlled in the PRA area. The diapausing ability of *T. granarium* larvae reduces the effectiveness of chemical treatment. Chemical treatment does not protect the commodity from reinfestation.

Numerous predators and parasites of *T. granarium* have been recorded. These include the hemipteran *Amphibolus venator*, the mites *Acaropsis docta* and *Pyemotes* sp., the protozoan *Adelina tribolii* and the parasitic wasps *Anisopteromalus calandrae*, *Dinarmus basalis*, *Holepyris* spp. and *Synopeas* spp. Except for *Anisopteromalus calandrae*, which is present in Kenya, these predators and parasites are not present in the PRA area. In addition, biological control has not been practised against *T. granarium*. It is likely that if introduced past the ports of entry, immediate eradication and containment may not be possible, therefore the likelihood of establishment is rated as **high (3)** with a **high (3)** confidence level.

Summary of the likelihood of establishment: The suitability of the environment, availability of hosts, high reproductive rate and adaptability all support a high likelihood of *T. granarium* establishment in the PRA area. It is therefore rated as **high (3)** with a **high (3)** confidence level.

III. ASSESSMENT OF LIKELIHOOD OF SPREAD

a. Suitability of the natural and/or managed environment for natural spread of the pest

The movement of *T. granarium* through natural spread is limited as it cannot fly. Transport of infested commodity or shipping containers is the most likely pathway of spread over short and long distances. There are many suitable main hosts in the PRA area such as maize, millet, sorghum, cotton, groundnuts, rice, barley, wheat and sesame, which are widely grown in the PRA area. Existing temperatures in the PRA area are suitable for the development of khapra beetles. If undetected, khapra beetles are expected to grow very fast in grain storage or processing facilities. Khapra beetle infestation or spread has not been reported to be aided by flooding or movement through water.

The suitability of the natural and/or managed environment for the natural spread of *T. granarium* is rated as **medium (2)** with a **high (3)** confidence level.

b. Availability of suitable vector, if vector transmitted

T. granarium does not need vectors for transmission and is therefore rated as **low (1)** with a **high (3)** confidence level.

c. Intended use of the commodity

The main purpose of imported grains/seeds and dried products is for processing, repackaging and distribution to points of sale such as shops and supermarkets, and home consumption. Interceptions have been made in Australia (Day and White, 2016) and the USA (Pasek, 2004) in grain handling facilities and residential areas, including cars in Australia (Day and White, 2016). The likelihood of spread from point of introduction if undetected remains high. Spread of the pests due to intended use of grains/seeds and dried plant products is rated **high (3)** with a **high (3)** confidence level.

d. The potential for movement with commodities or conveyances

The expected rate of spread of *T. granarium* with commodities or conveyances in the PRA area is high. *T. granarium* may remain hidden deep in the stored food for relatively long periods. In bag stores, the first signs of infestation are masses of hairy cast larval skins, which gradually push out from the crevices between sacks. The larvae may remain undetected and continue to consume in-transit grains/seeds. Once imported through the countries with seaports such as Kenya, Somalia and neighbouring United Republic of Tanzania, contaminated shipping containers and grains/seeds will move to multiple countries in the PRA area and spread the pest.

It is possible that, if introduced, the pathogen will spread very fast through contaminated shipping containers, grains/seeds and dried plant products. This is rated as **high (3)** with a **high (3)** confidence level.

Summary of the likelihood of spread: Because of the suitability of the natural and/or managed environment for the natural spread of the pest, and the high potential to spread through movement of infested grains/seeds and dried plant products, shipping containers and the presence of suitable hosts in the PRA area, *T. granarium* has a high likelihood of spread in the PRA area. It has been rated as **high (3)** with a **high (3)** confidence level.

ASSESSMENT OF THE LIKELIHOOD OF CONSEQUENCES

e. Economic consequences

T. granarium is a serious pest of cereal grains and oilseeds. Many countries, including Australia, Burundi, China, Kenya, Uganda, United Republic of Tanzania and the USA, have specific quarantine regulations against possible importation of khapra beetle in grain/seeds and other dried plant products. Infestations of *T. granarium* are well known in large-scale stores and can have severe economic consequences on the quality of grains/seeds or dried plant products. There appear to be no documented cases of infestations on farms. Infested maize shows reduced levels of protein, gluten, crude fat, ash, reducing and non-reducing sugars, and sedimentation value decreased with increased numbers of damaged grain (Ahmedani *et al*., 2011) with low mineral content (Jood *et al*., 1992). Cast skins and hairs will reduce the quality and make the infested commodity unpalatable or unmarketable. Control of the pest in the grains/seeds will include the use of insecticides, which are costly to small-scale farmers and processors and will increase their cost of production.

Direct economic consequence is rated as **high (3)** with a **high (3)** confidence level.

f. Impact on the environment

Khapra beetle infestation is expected to be confined to grain handling and storage facilities and food processing plants; it is not expected to have a direct or indirect impact on the environment or on biodiversity. Introduction of *T. granarium* into the PRA area will increase the use of insecticides used for the control of the pest in grain/seed storage facilities and processing plants. The use of insecticides and other control options like fumigants may negatively affect the environment and insect biodiversity. If introduced, the pest's impact on the environment is rated as **medium (2)** with a **medium (2)** confidence level.

g. Social impact

Main hosts include groundnuts, barley, millet, sesame, sorghum, wheat, maize and rice, which are important crops for both food security and livelihoods. At household level, farmers store harvested grains in containers and sacks that are likely to be infested by the pests, reducing the palatability and use of the produce. Farmer groups or cooperatives in value chains such as wheat and rice may be highly impacted by *T. granarium* through reduced volumes and quality. This may result in loss of jobs or reduction of wages due to reduced processing volumes or costs of pest management. Losses and costs of pest management are likely to have a considerable impact on income, employment of farmers and consumption patterns of grains/seeds and dried plant products in the PRA area. If introduced, the social impact of the pest is therefore rated as **medium (2)** with a **high (3)** confidence level.

h. Impact on international trade

T. granarium is a serious pest of cereal grains and oilseeds. Many countries, including Australia, Burundi, China, Kenya, Uganda, United Republic of Tanzania and the USA, have specific quarantine regulations against possible importation of khapra beetle in grain/seeds and other dried plant products. The presence of khapra beetle in any of the countries in the PRA area is likely to result in significant trade restrictions, especially on the export of grains/seeds and other dried plant products from that country to the region, or on international trade in these products. Countries in the PRA area are exporters of grains such as sesame, maize and groundnuts. These are likely to be impacted through the restrictions and strict phytosanitary measures imposed. If introduced, the impact of *T. granarium* on international trade is rated as **high (3)** with a **high (3)** confidence level.

i. Impact on domestic trade

The volumes and quality of locally traded grains/seeds and other dried products of maize, wheat, barley, groundnuts and sesame are likely to be affected by *T. granarium*. Infestations by the pest will affect the volumes and increase the cost of production due to the use of insecticides and the need for special storage facilities/bags. National controls on the movement of grains within the country may be implemented to mitigate the spread of the infestation. Poor quality grains may result in low prices on domestic produce. If introduced, khapra beetle impact on domestic volumes and quality of traded grains/seeds is rated **medium (2)** with a **high (3)** confidence level.

Summary of the likelihood of consequences: If introduced into the FAOSFE PRA area, *T. granarium* will have severe consequences for the economy by affecting the quantity and quality of grains/seeds and dried plant products produced in the region. It will have a medium impact on the environment, medium social impacts and a high impact on international trade. The likelihood of consequences of *T. granarium* is therefore rated as **high (3)** with a **high (3)** confidence level.

PRA CONCLUSIONS

T. granarium is a key pest with a wide host range of grains/seeds and dried plant products. The probability for entry, establishment and spread in the PRA area, as well as the potential impacts are ranked high.

Likelihood of entry: The most likely pathways for entry of *T. granarium* is infested grains/seeds and dried plant products and contaminated shipping containers. Travellers' luggage containing infested grains/seeds poses a high risk of introducing the pest into the PRA area.

The likelihood that *T. granarium* will be introduced into the PRA area is rated **high (3)** with **high (3)** confidence.

Likelihood of establishment: The availability of a wide host range in the PRA area (such as maize, sorghum, rice, sesame and groundnuts) as well as the pest's high reproductive rate and adaptability, including the ability to diapause in unfavourable conditions, implies that the likelihood of establishment is high.

Likelihood of spread: The likelihood of spread is high, enhanced by the suitable climatic conditions, wide array of suitable host plants present in the PRA area, widespread movement of imported grains/seeds and shipping containers in the region and uncontrolled movement of harvested grains/seeds within the PRA countries.

Likelihood of consequences: If introduced, the likelihood of consequences from *T. granarium* is likely to be high, with significant economic, social, environmental and trade impacts in the PRA region. There is a huge risk to the export market as a result of tighter restrictions on grains/seeds and dried plant products.

Stage 3: Pest risk management

Using the conclusions from the pest risk assessment, pest risk management options are proposed to manage risks and achieve the acceptable level of protection (ALOP) for the PRA area – the nine SFE countries. The effectiveness of the proposed phytosanitary measures, or a combination of measures, was considered according to ISPM 11 (FAO, 2017). Risk management measures for *T. granarium* have been recommended for consideration as follows:

MITIGATING THE RISK OF INTRODUCTION THROUGH THE IMPORTATION OF INFESTED GRAINS/SEEDS AND DRIED PLANT PRODUCTS TO THE FAOSFE PRA AREA

- Prohibiting the importation of grains/seed and dried products from countries where *T. granarium* is present.
- Fumigation of all imported grains/seeds or dried plant products using phosphine.
- Heat treatment of all imported grains/seeds or dried plant products.

MITIGATING THE RISK OF HITCHHIKERS FROM TRAVELLERS' LUGGAGE

- Review travel guidelines and issue travel alert notices on the importation of any plant materials, especially from countries where khapra beetle is known to occur.
- Strengthen enforcement of declaration, inspection, destruction and possible fines on plant products undeclared in travellers' luggage.
- Raise awareness among travellers regarding *T. granarium* and the risks associated with the introduction of the pest.

LEGISLATION, PHYTOSANITARY POLICIES AND RESEARCH

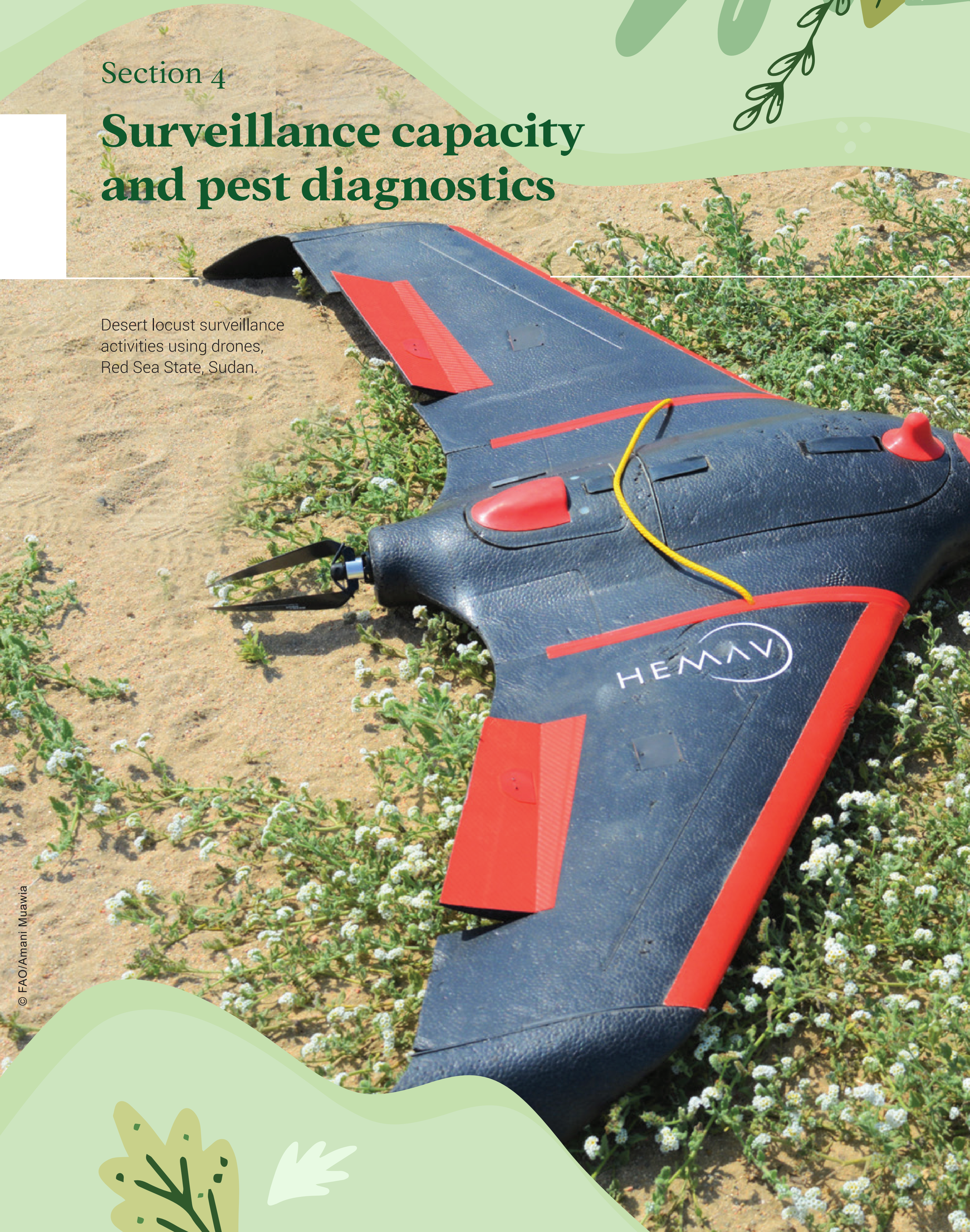
- Declare and list *T. granarium* as a quarantine pest.
- Develop regional and national *T. granarium* contingency plans for detection, eradication and containment actions.
- Establish routine surveillance programmes at regional level to detect incursions, for example through installation and monitoring of *T. granarium*-specific pheromone traps to detect incursions at high-risk areas such as the main seaports and container depots.
- Implement IPPC guidelines for container inspections by NPPOs.
- Create awareness of *T. granarium* among both public and private sector players such as importers of grains/seeds, shipping and logistics service providers.

BIOSECURITY MEASURES FOR CONTAINER DEPOTS, GRAIN/SEED HANDLING AND FOOD PROCESSING FACILITIES

- Create awareness among logistics service providers and roleplayers in the sea containers supply chain regarding good practices and container cleanliness.
- Install and monitor *T. granarium*-specific pheromone traps to detect the pest at container depots, grain/seed handling and food processing facilities.
- Develop a rapid response mechanism for decontamination and eradication of *T. granarium* together with private sector owners for detection at container depots, grain/seed handling and food processing facilities.

Section 4

Surveillance capacity and pest diagnostics



Desert locust surveillance activities using drones, Red Sea State, Sudan.

Status of surveillance capacity in SFE countries

Surveillance is defined as an "official process which collects and records data on pest presence or absence by survey, monitoring or other procedures" (ISPM 5 Glossary of phytosanitary terms). Contracting parties to the IPPC are required to conduct surveillance for pests and develop and maintain adequate information on pest status in order to support pest categorization and scientific justification for their phytosanitary measures (Article VII.2(j) of the IPPC, 2006; ISPM 1; ISPM 6 on Guidelines for surveillance provides frameworks to undertake pest surveillance and report on pest status in an area as guided by ISPM 8: Determination of pest status in an area).

This study provides baseline information and status of surveillance to detect the presence of pests, their spread and any changes to pest population density. Under this baseline study, we looked at the legal framework that supports pest surveillance and diagnostics, national strategies on surveillance for priority pests, ongoing monitoring activities for priority pests, institutional mechanisms and networks in place to support surveillance, and finally standardized data tools for the collection, curation and analysis of data.

Legal frameworks through the plant health/ protection acts and legal notices supporting surveillance are only available in a few countries such as Burundi, Eritrea, Somalia and Uganda. In other countries such as Kenya and Rwanda, the plant protection laws and acts do not refer to pest surveillance. Even where there are legal frameworks that support surveillance, most surveillance activities are non-existent and occur only during a plant health emergency such as new pest invasions or under specific projects.

Table 4: Legal frameworks for surveillance and pest diagnostics

Country	Legal frameworks for surveillance and pest diagnostics
Burundi	The Plant Protection Act of 2017 provides for the establishment of a Plant Health Surveillance and Intervention Service, which is responsible for monitoring plant pests throughout the country and conducting plant health surveys to assess the extent of the damage caused by NTS and the efficiency of the techniques and products used.
Djibouti	No information available.
Eritrea	Plant Quarantine Proclamation (No. 156/2006) supports the surveillance and inspection of growing plants, including areas under cultivation and wild flora, and of plant material in storage or transport, to report the occurrence, outbreak and spread of pests, and to prevent the introduction or spread of pests; and the protection of endangered areas, and the designation, maintenance and surveillance of pest-free areas and areas of low pest prevalence.
Ethiopia	Plant Quarantine Council of Ministers Regulation No. 4/1992 empowers the Ministry of Agriculture to control insect pests, disease-causing pathogens, weeds and vertebrate pests in the country and prevent their entry from other countries. It provides for the appointment of inspectors who, among other roles, enter upon and conduct a survey at any area of land to determine whether it is infested or infected by plant pest. It does not provide for pest surveillance.
Kenya	The Plant Protection Act (CAP 324), the Kenya Plant Health Inspectorate, Service Act, 2012, the suppression of noxious weeds (Cap 325) and the Agricultural Produce (Export) Act (Cap 319) provide the legal framework through which the authority carries out phytosanitary regulatory services. The Plant Protection Act (CAP 324) includes rules for the prevention of entry and spread of pests and access to and destruction of infectious articles. The Plant Protection Act does not include the legal framework for official pest surveillance. The Act is currently under review to include official surveillance and coordination between national and county pest surveillance units.
Rwanda	The Rwanda Plant Protection law (No. 16/2016) does not highlight the legal framework for pest surveillance in the country. The Rwanda Institute for Conservation Agriculture and the Rwanda Agriculture and Animal Resources Development Board collaborate with other institutions like FAO to undertake surveillance of priority crops and during pest invasions.

Country	Legal frameworks for surveillance and pest diagnostics
Somalia	A new Plant Protection Act is under development. It mandates the Department of Plant Protection of the Federal Ministry of Agriculture with the responsibility of surveillance of growing plants to report the occurrence, outbreak and spread of pests or harmful organisms and to test seeds, pest control products, water, soil, fertilizers and other related diagnoses through registered laboratories.
South Sudan	The legal framework that will support surveillance and diagnostics, as well as other plant protection measures, is currently under development. There is an ongoing survey and diagnostic support on *Tuta absoluta*, desert locust, rodents, harmful quelea birds and fruit flies, with support from development partners such as FAO.
Uganda	The Plant Protection and Health Act of 2015 provides for the formation of a technical committee that, among other roles, provides scientific guidance on the conduct of pest risk analysis, pest surveillance and evaluation of germplasm, and develops and tests quick phytosanitary pest and disease diagnostic procedures. It also gives plant inspectors powers to conduct pest surveillance and pest risk analysis for the purposes of quarantine, documentation and provision of information; and to develop and test quick phytosanitary pest and disease diagnostic procedures.

In most countries under this study, there are regular surveillance and monitoring for migratory pests such as desert locust and African migratory locust, African armyworm and *Quelea quelea*, with support from the Desert Locust Control Organization for Eastern Africa (DLCO-EA) and FAO. However, there are no routine or active surveillance or pest-monitoring programmes to detect new pests or establish pest status for the identified key crops or pests. In Rwanda, there are attempts to undertake pest monitoring at the beginning and the end of the planting season for some of the key crops like maize, beans, coffee and tea. Due to budget limitations, not all crops are covered.

In Uganda, active surveillance and monitoring of pests are commodity-based, for example coffee and banana surveillance and monitoring programmes supported by projects. In Burundi, surveillance data are routinely processed and made accessible through pest report/notification and publications (Table 5). However, Burundi is not included in the IPPC pest reports. In Kenya, there is pest surveillance for food security crops but this is mostly triggered by new pest invasions and/or outbreaks. Data collected during the survey of new pests are published in peer-reviewed journals and rarely added to the IPPC pest reporting portal.

Table 5: Status of pest surveillance in FAOSFE countries

Assessed parameters	Country								
	Burundi	Djibouti	Eritrea	Ethiopia	Kenya	Rwanda	Somalia	South Sudan	Uganda
Established official process for detecting, collecting and recording information on the presence or absence of emergent pests.									
1. No pest surveillance in place for the prioritized crops.							✓		
2. Pest surveillance in place for some of the prioritized crops and pest status occasionally reported.						✓			
3. Active pest surveillance for the prioritized crops and pest status always reported.					✓				
4. Surveillance data routinely processed and made accessible through pest report/notification and publications.	✓				✓				

Note: * A blank cell indicates that no information was available.

From the reports, growers and exporters associations in Kenya indicated that it is mandatory to conduct surveillance for specific crop pests as a requirement by their NPPO in order to export products. For example, the exporters associations that took part in the survey indicated that pest surveillance was consistently undertaken by the organizations in Burundi (100 percent) and Kenya (75 percent) as part of their pest management programme on behalf of their members. The respondents also reported that they consistently collate, analyse and share pest surveillance data with respective NPPOs, farmers and producer groups, as one of the requirements by their respective NPPOs, to export products. In Burundi (N = 1) and Kenya (N = 4), 100 percent and 25 percent of respondents respectively were reported to have had a consignment rejected at export or on arrival at the country of destination due to the presence of plant pests. At least 25 percent of respondents in Kenya have had their consignment seized, confiscated or treated at import due to detection of a plant pest.

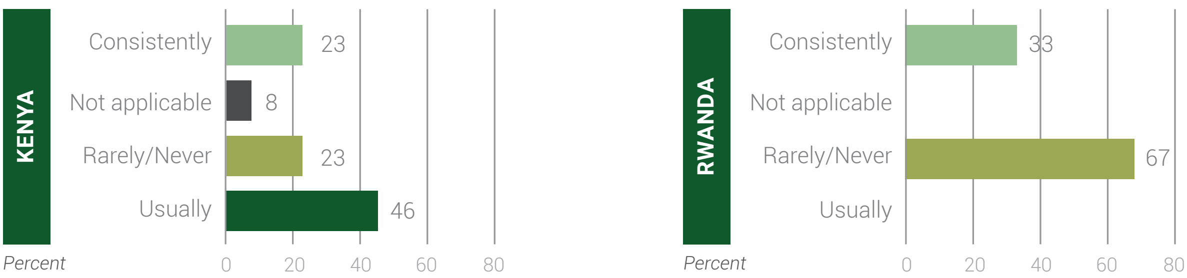
Members of growers and exporters associations scout for pests while the crops are actively growing and share their observations with the farmer and producer groups as well as with customers and regulators. This assessment identified more monitoring activities for false codling moth (FCM; *Thaumatotibia leucotreta*) and fruit flies for export crops such as avocado, capsicum, roses and mangoes. Kenya has undertaken nationwide surveillance and detected potato cyst nematode *Globodera pallida* (Mburu *et al*., 2018). Rwanda has undertaken delimiting surveys for the mango mealybug in the country. The pest status has already been reported to the IPPC as a new record for Rwanda (IPPC, 2019) and will be published in a peer-reviewed journal. In all countries under the current baseline study, there was no active surveillance for pests with a high potential for entry into the countries or the region.

Apart from Rwanda, where surveillance data are analysed, published and new pests are reported to the IPPC, surveillance data for the majority of countries are published in peer-reviewed journals with rare reports to the IPPC. Due to the spatial and time scale under which these are undertaken, they are less impactful and inconsistent, making it difficult to undertake seasonal comparisons of data over time.

From the survey it was noted that the majority of inspectors (36 percent to 100 percent) were usually involved in supporting surveillance by their respective NPPO in the reporting countries. For example, at least 20 percent of inspectors in Rwanda and 5 percent in Kenya who took part in the survey, were consistently involved in supporting surveillance done by their NPPO. However, 20 percent to 50 percent had not participated in surveillance activities. At least 59 percent, 50 percent and 20 percent of inspectors in Kenya, Uganda and Rwanda, respectively, indicated that they are usually involved in the collection, analysis and sharing of pest surveillance data with stakeholders, whereas a majority (67 percent) of inspectors in Somalia and at least 20 percent and 14 percent from Rwanda and Kenya, respectively, were consistently involved in data collection, analysis and sharing of pest surveillance data.

The researchers from Kenya and Rwanda who participated in the survey reported that they consistently undertake pest surveillance as part of their research mandate and on behalf of their members (23 percent and 33 percent for Kenya and Rwanda, respectively), and that they usually (46 percent) undertake surveillance for Kenya. A majority (67 percent in Rwanda) reported that they rarely/never undertake pest surveillance. At least 8 percent of the researchers did not find this as part of their mandate in Kenya. In terms of data-sharing relating to pest surveillance, 31 percent and 33 percent of respondents in Kenya and Rwanda, respectively, consistently collated, analysed and shared pest surveillance findings, with the same number reporting that they usually share these data. Approximately 23 percent of researchers in Kenya and 33 percent in Rwanda rarely/never collated, analysed and shared these findings.

Figure 8: *Frequency of undertaking surveillance (research organizations)*



Does your organization undertake pest surveillance?

In terms of the capacity of the personnel involved in surveillance, the majority (75 percent) of inspectors in Uganda and at least 38 percent, 33 percent and 20 percent in Kenya, Somalia and Rwanda, respectively, agreed that their training on surveillance methods for specific pests of concern was adequate. On the other hand, 48 percent (Kenya) and 20 percent (Rwanda) disagreed, i.e. they did not have adequate training in surveillance methods, and with 10 percent to 40 percent opting not to comment on this. Regarding collection, processing and submission of samples, a majority (75 percent in Uganda and 62 percent in Kenya) and at least 40 percent and 33 percent for Rwanda and Somalia, respectively, indicated that they do not have the necessary tools to undertake these tasks.

A similar response was reported for tools and resources required to cover the area under surveillance adequately with only 33 percent, 20 percent and 10 percent for Somalia, Rwanda and Kenya, respectively, agreeing to having the necessary tools. In terms of pest delimitation, a majority (50 percent in Uganda and 67 percent in Somalia) and at least 48 percent and 40 percent in Kenya and Rwanda, respectively, of inspectors reported being confident in the detection and delimitation of those pests for which they are responsible for conducting surveillance. The majority (60 percent to 75 percent) of the inspectors also agreed to their NPPOs having technical expertise in pest diagnosis and reporting.

Table 6: Capacity of plant quarantine inspectors in FAOSFE countries

		Kenya				Somalia				Rwanda				Uganda			
No.	**Parameters assessed**	**A**	**D**	**RNS**	**SA**	**A**	**D**	**RNS**	**SA**	**A**	**D**	**RNS**	**SA**	**A**	**D**	**RNS**	**SA**
1.	My training on surveillance methods for specific pests of concern is adequate	✓	x	x	✓	✓		x	✓	✓	x	x	✓	✓		x	
2.	I have the necessary tools to collect, process and submit samples for pest diagnostics	✓	x	x	✓	✓	x	x		✓	x	x			x	x	
3.	I have the tools and resources to cover the area under surveillance adequately	✓	x	x		✓	x	x		✓	x	x			x		

Note: A: Agree; D: Disagree; RNS: Rather not say; SA: Strongly agree.

Pest diagnostics capacity in SFE countries

Diagnostic capacity is an essential support service to surveillance activity, especially specific surveillance activities (detection, delimiting surveys) which lead to early detection of new pests, determination of pest status and a final report to the IPPC and other trading partners. However, diagnostic capacity is still low, especially under plant health emergencies such as new pest invasions. Specific surveillance is rare in the countries under the current study and is usually carried out after unusual pest occurrence has been reported to authorities through the media or another forum. The diagnostic capacity for plant protection authorities, extension agents and farmers is usually limited at the point of a plant health emergency. The diagnostic capacity for both plant protection authorities, extension agents and farmers are usually limited at the point of a plant health emergency. This mismatch is due to a lack of contingency plans, early warning and capacity building on the identification of high-risk plant health pests.

Desk review results show that several agencies are involved in the provision of plant health laboratory services in all the FAOSFE countries under the study. These include national laboratories such as those in the ministries of agriculture and universities, as well as private laboratories in international research organizations. In cases of new plant pests, service provision on diagnosis involves mainly national laboratories collaborating with the NPPOs and international laboratories.

Somalia NPPO reported a lack of diagnostic capacity including networks with other laboratories in the region to assist with quick diagnosis. Burundi and Rwanda reported the existence of relatively adequate capacity and networks to help with rapid diagnosis. Kenya reported a high level of diagnostic capacity, including the use of modern technologies such as enzyme-linked immunosorbent assay (ELISA) and polymerase chain reaction (PCR), remote peer-to-peer diagnostics available through social media platforms such as WhatsApp and Telegram with fellow staff members and scientists. However, there was no remote diagnostic capacity with web-based camera-mounted microscopes in any of the NPPOs surveyed (see Table 7).

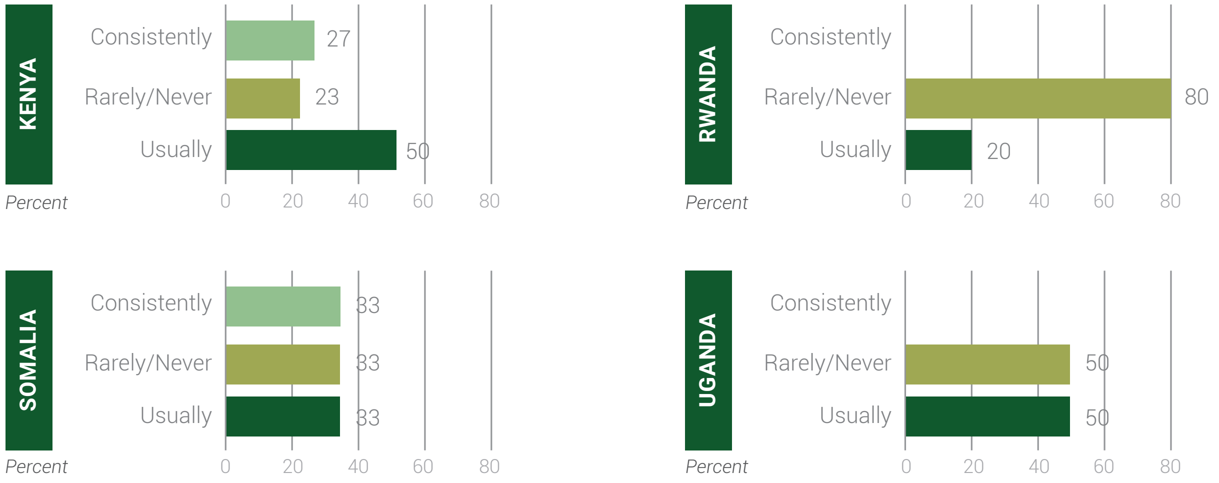
From the survey, approximately 70 percent of plant inspectors and extension agents in Kenya indicated that they have had training on pest identification for key pests they are responsible for surveying, with only 20 percent in Rwanda and 50 percent Uganda reporting that they have had such training.

Table 7: Status of pest diagnostics skills, protocols and equipment available for quick diagnosis of emerging pests.

Assessed parameters	Country								
	Burundi	Djibouti	Eritrea	Ethiopia	Kenya	Rwanda	Somalia	South Sudan	Uganda
Pest diagnostics skills, protocols and equipment available for quick diagnosis of emerging pests.									
1. Diagnostic capacity, including laboratory capacity for quick diagnosis of emerging pests not available, no network with other laboratories.							✓		
2. Some diagnostic capacity, including laboratory capacity for diagnosing emerging pests available and networks with other authorized laboratories for diagnosis of emerging pests.	✓					✓			
3. Diagnostic capacity with modern and rapid diagnostic tools such as ELISA and PCR equipment available.									
4. Remote peer-to-peer diagnostics available via social media platforms, with local and international diagnostic experts.					✓				
5. Established official remote diagnostics with web-based camera-mounted microscopes with networks with local, regional and international diagnostic laboratories and experts.									

Note: * Blank cells indicate that information was not available.

Figure 9: Percentage of respondents (inspectors) trained in pest identification



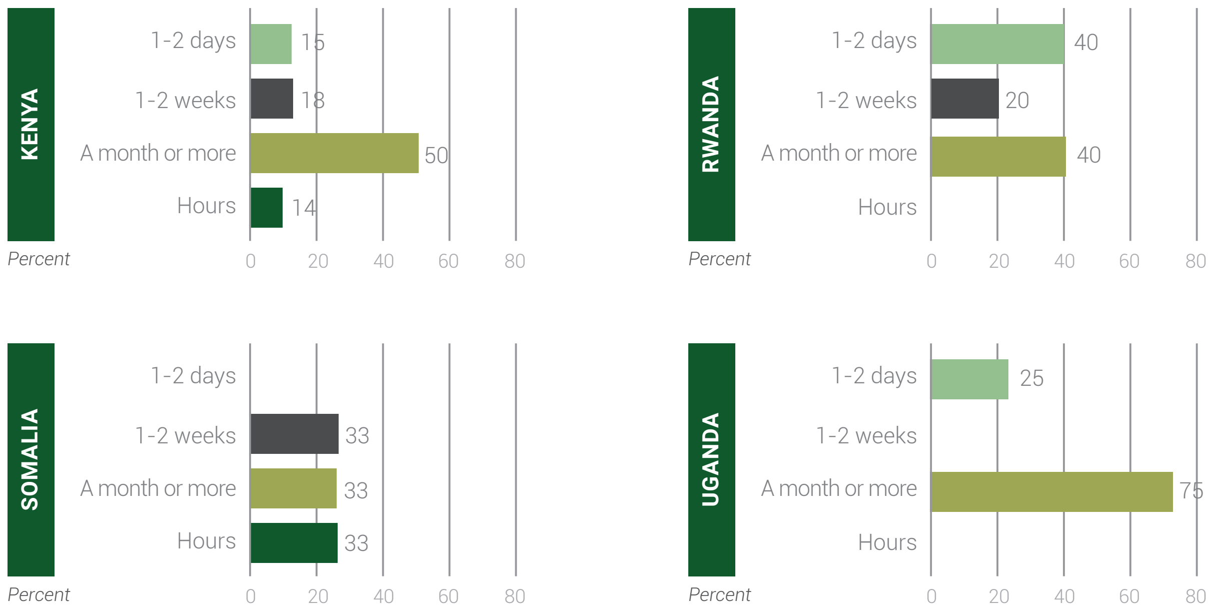
How often have you had pest identification training for the key pests that you are responsible for surveying?

Only 40 percent of plant inspectors and extension agents who responded have submitted samples to the national plant health laboratories for diagnosis in Kenya and Rwanda, with no submission reported by respondents from Uganda. Where samples have been submitted for diagnosis, it takes longer to diagnose and get results back. Approximately 50 percent of the respondents in Kenya and 75 percent in Uganda indicated that it took one to two months to get results back. Rwanda sample results took a shorter time, with 40 percent of respondents indicating a feedback period of one day to two weeks. Exporter/importers rarely submit samples to national laboratories for analysis in Burundi and only 25 percent submit samples to national laboratories in Kenya. However, the respondents indicated that they submit samples to other institutions for diagnosis, with 100 percent and 25 percent for Burundi and Kenya, respectively, reporting to consistently submitting samples to organizations other than national laboratories.

At least 25 percent of the respondents in Kenya indicated that they have never sent samples for diagnosis to another organization. Regarding satisfaction on the feedback of diagnosis, 100 percent of respondents in Burundi and 25 percent in Kenya indicated they are usually satisfied with diagnostic and pest management feedback from NPPO. At least 25 percent of respondents in Kenya were dissatisfied with feedback from the NPPO regarding diagnostic and pest management. The major categories of samples submitted were pathology, virology, entomology and nematology.

In cases of plant health emergencies, a quick turnaround from the time samples are submitted to when the results are released is paramount for pest eradication and containment. In the surveyed NPPO laboratories, there is a long turnaround time. Remote diagnostics may support filling this gap, acting as a triage system for rapid response before official diagnosis is sought.

Figure 10: Average response time reported by inspectors for samples submitted to labs for identification



Over 90 percent of research scientists in Kenya (N = 14) and 60 percent in Rwanda (N = 3) indicated that their research institutions have the capability to conduct pest diagnosis for priority research crops. However, only a few of them had experience in remote diagnostics, whether by web-based real-time diagnostics or static image analysis.

For example, the majority (100 percent and 75 percent for Burundi and Kenya, respectively) reported not having used any web-based remote diagnostic services to identify pest problems. It is likely that the few respondents who referred to having used remote diagnostic, was through pest images shared via WhatsApp or Telegram.

Figure 11: Percentage of respondents (inspectors) using remote diagnostic tools

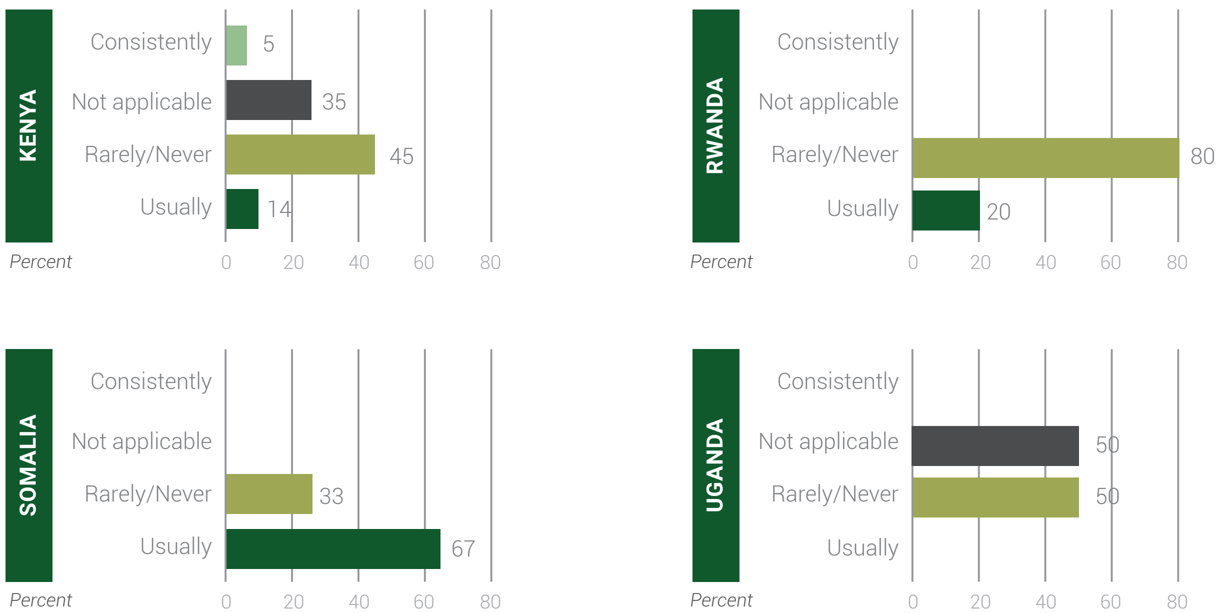
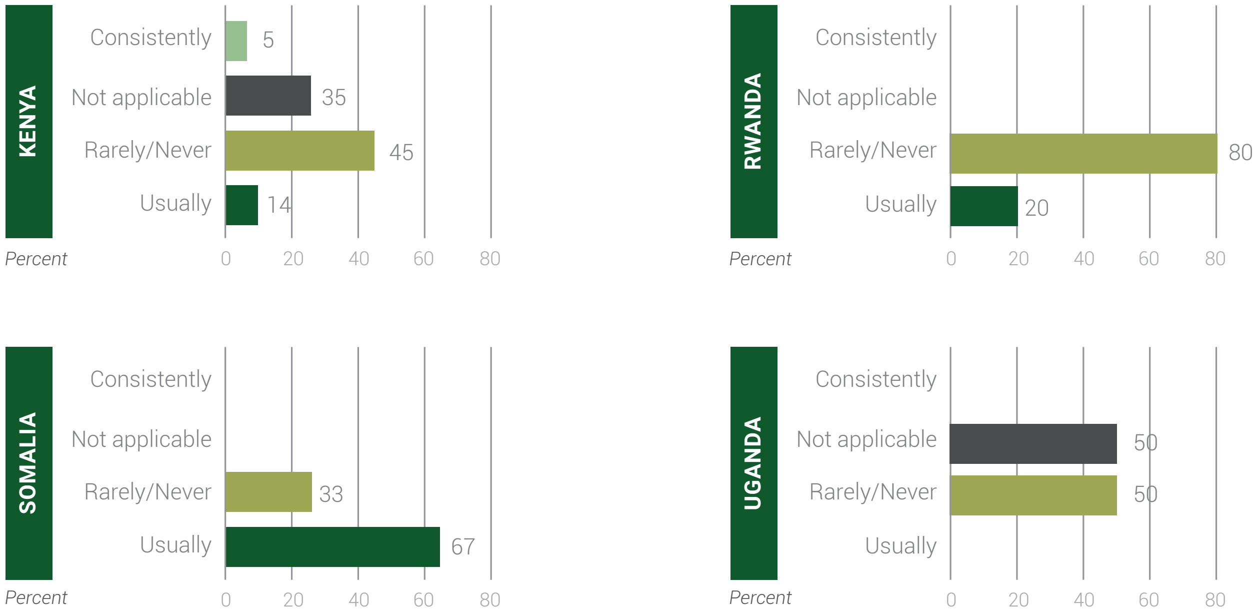


Figure 12: Percentage of respondents (researchers) using remote diagnostic tools

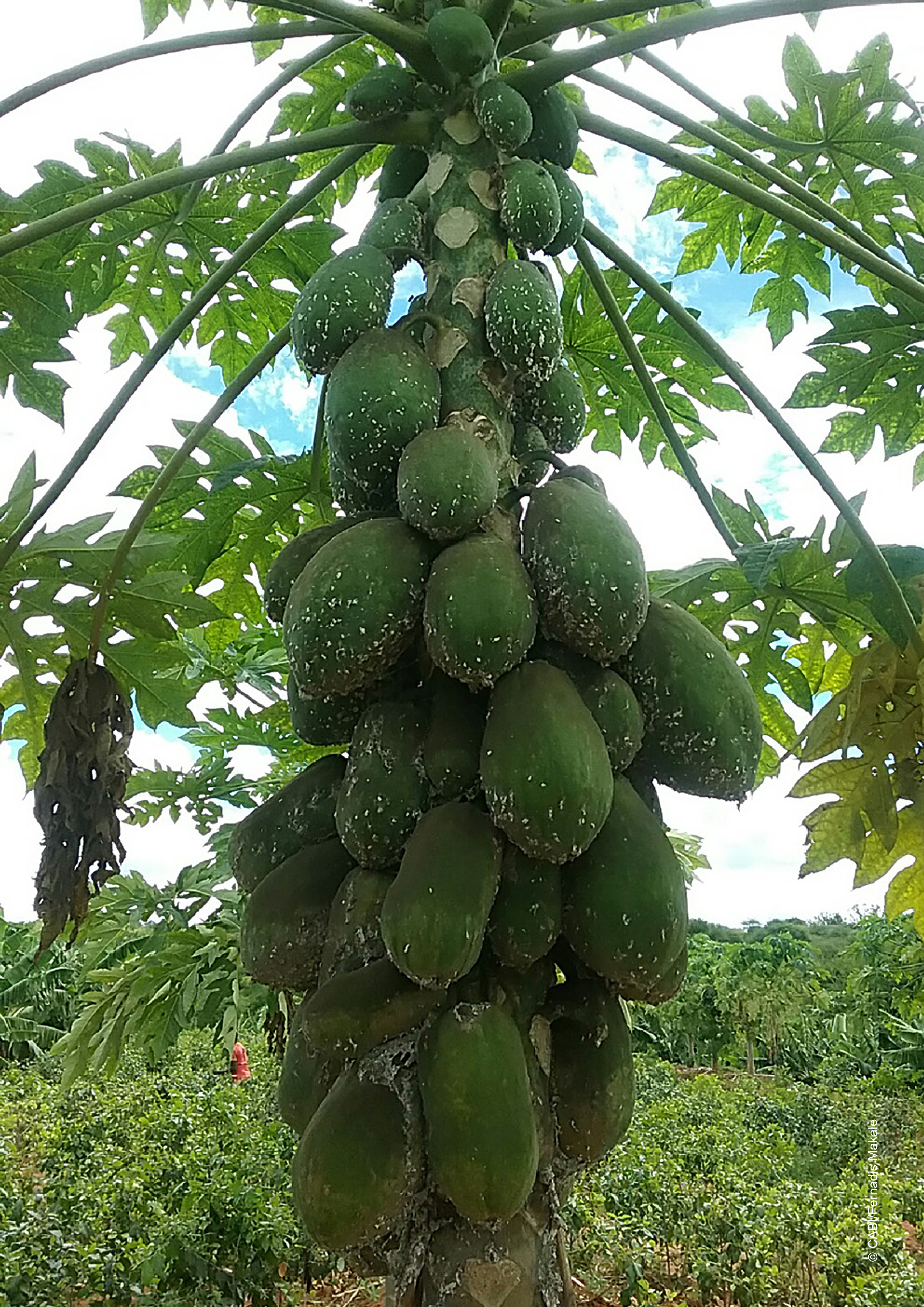


CHALLENGES

1. Lack of a legal framework to support surveillance and mobilization of funds.
2. Weak public–private partnerships in pest surveillance.
3. Lack of harmonized tools for pest data collection, analysis and sharing.
4. Lack of a national pest surveillance strategy.
5. Lack of awareness and capacity to diagnose most pests with high risk of introduction.
6. Diagnosis of samples and feedback takes too long to properly support plant health emergencies.

RECOMMENDATIONS

1. Develop public–private partnership framework to increase private sector participation and contribution to pest surveillance activities.
2. Develop a country/regional pest surveillance strategy.
3. Develop pest surveillance standardized tools for data collection, analysis and sharing. ELocust3M was recommended for scaling up to include other pests in the region.
4. Develop a national network of plant health experts to support with rapid diagnosis.
5. Pilot the use of remote web-based/real-time diagnostic microscopes or other real-time diagnostic tools.



Section 5

Contingency planning and incident management

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Contingency plans are typically developed by the authorities responsible for planning and responding to incursions of pests and diseases. They cover the technical and regulatory aspects for confirming suspected cases and prevent the pests or pathogens from entry and establishment. Contingency plans are key for the official control of pest incursions, introduction and outbreaks and serve to strengthen plant health control and protection systems. A pest incursion is defined as an isolated population of a pest recently detected in an area, not known to be established, but expected to survive for the immediate future. A pest introduction is the entry of a pest resulting in its establishment in a new area.

Official controls are often undertaken by institutions responsible for national plant pest control such as NPPOs, crop protection or plant protection departments of the ministries of agriculture, or in collaboration with other institutions such as agricultural research and national government departments responsible for the enforcement of agricultural or environmental laws. Official controls are defined as the active enforcement of mandatory phytosanitary regulations and the application of mandatory phytosanitary procedures with the objective of eradication or containment of quarantine pests or for the management of regulated non-quarantine pests (ISPM 5; Glossary of Phytosanitary Terms).

Contingency plans ensure rapid, effective and well-coordinated response to pest incursions, entry or outbreaks that have been assessed and found to likely significantly impact on crop production and the economic and social environment in a region, country or area. Currently, the IPPC does not have a harmonized approach for such plans, but recommends under ISPM 9 Guidelines for pest eradication programmes that contracting parties develop contingency plans to address specific pests or pest groups that have a high potential for introduction and for which an eradication plan is deemed both feasible and necessary before the pest is detected in an area. Contingency plans can be generic or pest-specific and can be implemented in a specific area or wider area. Under EPPO, standards on national regulatory control systems (PM 9, PM 9/10[1]) have been developed and specify generic elements for contingency plans for an emergency response to a pest outbreak or a suspected incursion/introduction of a pest. These elements can be used to develop generic or specific pest contingency plans (EPPO, 2009). There are 12 essential elements of contingency plans:

1. Background information on the pest (for pest-specific plans only);
2. Initiation of a contingency plan;
3. Official actions on presumptive diagnosis;
4. Official actions to eradicate the pest after final confirmation;
5. Review of measures in cases of prolonged official action;
6. Determining completion of statutory action;
7. Command structure;
8. Stakeholder consultation;
9. Internal communication and documentation;
10. External communication;
11. Testing and training of personnel;
12. Evaluation and revision of contingency plan.

These elements have been used to develop generic and pest-specific contingency plans by European Union (EU) Member States, including the Generic Contingency Plan for Plant and Bee Health in England by the Department for Environment, Food and Rural Affairs (DEFRA) (DEFRA, 2017) and pest-specific plant health contingency plans such as *Thaumatotibia leucotreta* (DEFRA, 2020) and *Xylella fastidiousa* (DEFRA, 2019). Plant Health Australia (PHA) has developed the Australian Emergency Plant Response Plan (PLANTPLAN), which includes nationally harmonized guidelines covering management and response procedures for emergency plant pests affecting the Australian plant industries (PHA, 2019) and has listed selected plant pests such as *Phytophthora ramorum* and *Bactrocera dorsalis* (syn. *B. invadens*, *B. papaya* and *B. philippiensis*) under Schedule 13 of the Emergency Plant Pest Response Deed (EPPRD) Plan (PHA, 2020). The EPPRD is a formal binding agreement that includes national government, territory government and national plant industry bodies, indicating roles and contributions in the management and funding, decision-making in responses/activities to emergency plant pests. The above contingency plans have resulted in the successful eradication and containment of pests in the European and Mediterranean Plant Protection Organization (EPPO) region and Australia.

In most African countries' emergency response to pest incursions, new introductions or outbreaks are reactionary, ad hoc, uncoordinated and with short-term incident management objectives. Pest incursions, introductions and outbreaks are a common occurrence in Africa, but the response to these incursions and outbreaks continues to be reactive and uncoordinated due to a lack of contingency plans and funds to eradicate or contain them.

A desk review was undertaken to establish the regulatory frameworks that support the development of contingency plans for plant health in the nine FAOSFE countries and document the status of existing efforts for contingency planning and incident management.

Legal frameworks for contingency planning and incident management

BURUNDI

Burundi has a national committee for the prevention and management of pests and diseases under the Ministry of Agriculture. No contingency plans exist for any priority plant pests. Any emergency measures are to be undertaken by the Minister of Agriculture, in collaboration with the Minister of Environment, following the detection of pests posing a potential threat to agriculture and the environment. There is no evidence of emergency funds.

DJIBOUTI

Contingency plans are available for desert locust under the regional project – The Appraisal ESRS for the Emergency Locust Response Program. The programme includes operations in Djibouti, Ethiopia, Kenya and Uganda. The desert locust response programme is building on the existing Djibouti Nutrition Project (P164164), with similar activities. Due to a lack of information and non-responses to the survey, it is not clear if other contingency plans have been developed or are in use for other plant health pests in Djibouti.

ERITREA

Due to a lack of information and non-responses to the survey, it is not clear if there are legal frameworks or if contingency plans have been incorporated into other regulations and laws developed or in use for other plant health pests in Eritrea.

ETHIOPIA

The Plant Quarantine Council of Ministers Regulation No. 4/1992 does not guide the plans for mitigation for the restricted plants and prohibited plants listed under schedules I and II of the regulation. No formal emergency action team has been established to act at the early emergence level. The team is established when pests reach high levels and are easily seen. Due to a lack of information and non-responses to the survey, it is not clear if other contingency plans have been developed or are in use for other plant health pests in Ethiopia.

KENYA

There are no contingency plans for plant health emergencies. The Plant Protection Act CAP 324 of 2012 does not provide for the establishment of contingency funds or a national task force for plant health. Collective national emergency funds can only be accessed after a declaration of emergency by the minister. Actions during a plant health emergency are usually delayed or not undertaken due to a lack of funds. The Multi-Institutional Technical Team (MITT) is an ad hoc group formed during the fall armyworm (FAW) incursion to analyse data and advise the Cabinet Secretary of the Ministry of Agriculture, Livestock, Fisheries and Cooperatives (MoALFC) on the threat and possible actions. The concept of MITT has not been officially recognized by the MoALFC and the members, nor have their roles and responsibilities been officially defined.

The recent emergence of the locust invasion has necessitated the development of a pest management plan (PMP) on desert locust control Contingency, Emergency Recovery Implementation Plan (CERIP), under the MoALFC, supported by FAO and the World Bank. The Contingency Emergency Response component of the Kenya National Climate

Smart Agriculture Project was also reactivated following a request by the Government of Kenya. The locust control CERIP aims to enable stakeholders involved in desert locust control to monitor and mitigate negative environmental and social impacts associated with use of pesticides (MoALFC, 2020). The proposed contingency plan is short-term and lacks the essential components of such contingency plans. The Plant Protection Act of 2012 is currently under review and has taken into consideration the establishment of the Kenya Plant Health Protection fund, the National Plant Health Emergency Response Unit (NPHERU) and the Country Plant Health Emergency Response Unit responsible for dealing with plant health emergencies.

RWANDA

Chapter III of the Rwanda Plant Protection Law of 2016 supports the activities to be undertaken for the containment and eradication of pests and diseases. The National Disaster Management Policy requires that all institutions involved draw up a contingency plan which specifies the national measures required to maintain a high level of awareness and preparedness and is to be implemented in the event of a disease outbreak.

A national contingency plan for animal and plant diseases has been developed by the Ministry of Disaster Management and Refugee Affairs (MIDIMAR) for the prevention of potential current and future risks of animal and plant health (MIDIMAR, 2016). It lists the lead institutions under each action and the supporting government institutions. There is a national platform for disaster risk reduction under MIDIMAR.

SOMALIA

There are legal frameworks to support contingency plans and incident management. No contingency funds are available in cases of plant health emergencies. Most activities or actions carried out during a phytosanitary emergency are ad hoc, with no established standard operating procedures with clear actions to be undertaken. Due to limited technical and financial resources, the emergency action team are rarely active. A desert locust contingency plan has recently been developed as part of the FAO- and World Bank-funded project "Locust Control Contingency Emergency Recovery Implementation Plan", which is anchored in the Somalian Federal Ministry of Agriculture and Irrigation (FMoAI, 2020). The project aims to enable stakeholders involved in the desert locust control to monitor and mitigate negative environmental and social impacts associated with the use of pesticides. However, the proposed contingency plan for desert locust is short-term, lacks essential components of such contingency plans and considerations of actions for future risks of desert locust invasions.

The proposed Plant Protection and Quarantine Law of 2019, highlighted under Article 25 on emergency action, refers to the ministerial advice on the control plan to be followed for the emergent pest and cooperation and authorities from local public bodies, farmers, associations or private control enterprises to assist in the control of the pest emergency. There are no contingency funds or mobilization mechanism for funds to support contingency plans for future pest incursion, introductions and outbreaks.

SOUTH SUDAN

There are no contingency plans in South Sudan. A five-year strategic plan for FAW and desert locust was recently developed with support from FAO. No contingency funds are available for emergency actions in case of new pest incursions and outbreaks. In the case of FAW and desert locust strategies, private partnerships have been fostered, which include community-based organizations and the World Food Programme. The team of experts trained in rapid response under the FAW and desert locust projects may be recommended for the national task force. However, there is a need for further training of these experts and the development of response strategies for other plant health pests.

UGANDA

The Plant Protection and Health Act of 2015 (Part II – Administration, Officers and Duties, Section 7) provides for the establishment of a Plant Protection and Health Technical Committee with defined membership and roles, including providing scientific guidance on the conduct of pest risk analysis, pest surveillance and evaluation of germplasm. Under Part III (Prevention and Control of Pests, Weeds and Diseases, Section 13 on Contingency measures for the containment of outbreaks of pests), it is indicated that where there is sufficient evidence that field crops in any part of Uganda are in danger of serious damage by outbreaks of pests, the minister may, by statutory declaration, bring into force in such areas all rules made under Section 9, and any other measures stipulated under this Act, to contain the outbreak of pests (Republic of Uganda, 2015).

Table 8: Status of contingency planning and incidence management in FAOSFE countries

Assessed parameters	Country								
	Burundi	Djibouti	Eritrea	Ethiopia	Kenya	Rwanda	Somalia	South Sudan	Uganda
Standard operating procedures and responsibilities for stakeholders for action									
1. Activities/actions carried out during a phytosanitary emergency are ad hoc	✓	✓	✓		✓	✓	✓	✓	✓
2. Standard operating procedures established with clear actions to be undertaken									
3. Emergency action team is ad hoc and rarely active					✓	✓	✓		
4. Emergency action team established and supported by legislation or MoUs	✓								
5. Roles and responsibilities for teams/ stakeholders established by legislation or by binding agreements									
6. Contingency funds not established and available and emergency actions delayed due to a lack of resources					✓				
7. Contingency funds established and available when urgently needed during phytosanitary emergency									

Note: Blank cells indicate that no information was available.

CHALLENGES

1. Lack of harmonized guidelines/approaches for the development of contingency plans at regional and national levels.
2. Lack of early warning systems to enhance detection, rapid response and eradication of new pests.
3. Lack of pest lists for prioritization of development of contingency plans.
4. Lack of a regulatory framework for the establishment of contingency and incident management plans.
5. Lack of funds for the development and implementation of contingency plans for pests.

RECOMMENDATIONS

1. Support the establishment of legal and institutional frameworks for contingency planning and incidence management for the FAOSFE countries that lack such frameworks.
2. Develop guidelines for contingency plans outlining general arrangements, requirements and organization, and legal and policy frameworks for contingency plans for pest incursions and/or outbreaks.
3. Develop pest-specific response plans for selected pests with a high likelihood of introduction and impacts at:
   - regional level to address pests of high risk of introduction to a region, for example the EAC;
   - national level to address pests of high risk of introduction into a particular country.
4. Resource mobilization:
   - Establish a pool of technical experts who can be mobilized at short notice (Rapid Response Technical Team).
   - Establish a funding mechanism for emergency response.
   - Establish rapid diagnostic systems, including remote diagnostics capability and networks of diagnostic centres and experts.
5. Information management and communication:
   - Develop strategies for public awareness-creation and engagements on the pest and actions to be taken. This may include how the public may be involved in the detection of the pests as well as their eradication and management.
   - Identify and define information-sharing channels and media engagement.

Seed physiologist with entomologist working in the quarantine laboratory, Harare, Zimbabwe.

Section 6

Eradication, containment and control measures

ISPM 9 Guidelines for pest eradication programmes provide guidance on the development of a pest eradication programme and for reviewing the procedures of an existing eradication programme. When a new destructive pest invades an area, rapid preliminary investigation may be undertaken to establish the pest's behaviour in the area of origin, its spread and economic impact, current extent of infestation, potential economic and environmental consequences of the pest, current technology and available resources for eradication and a cost-benefit analysis of the pest eradication programme. Pest eradication may also be undertaken for established pests or indigenous pests in defined areas. However, eradication programmes are not common in plant health and especially so in Africa.

Numerous new invasions in the region, such as *Tuta absoluta,* fall armyworm and fruit flies, have already become established. Challenges in containing or eradicating the pests include the absence of clear national and regional coordination, underfunding and lack of capacity to support surveillance for early detection of new pests and the support of quick actions to eradicate or contain the pest invasions. The African Union Inter-African Phytosanitary Council (AU-IAPSC) and the regional plant protection organization (RPPO) identified harmonization of regional and subregional plant intelligence and early warning systems, pest reporting, preparedness and contingency plans for transboundary pests as key areas for capacity building of AU Member States (AU-IAPSC, 2015).

At the East African Community (EAC) regional level, there is little or no activities focusing on pest eradication, containment and control in plant health. Article 105 (2) (f) of the EAC SPS protocol provides for the establishment of joint programmes for the control of animals and plants, diseases and pests. The current five-year contingency plan 2018–2023 focuses on humans and animals (EAC, 2019).

To achieve emergency containment and eradication actions, existing plant protection legislation is necessary to provide powers to undertake such actions. This baseline study reviewed the status of pest eradication, containment and control measures in the nine FAOSFE countries. The study assessed if the existing plant protection acts/legislation support the declaration of pests of concern and making orders for eradication, entry into properties to survey and collect samples, declaration of quarantine zones, restriction of movement of plants, plant products and destruction of infested/infected plant material.

A desk review of the existing plant protection regulations and other plant health legislation indicates that there are supportive legal frameworks for pest eradication, containment and control for most of the FAOSFE countries (see Table 9). However, lack of enforcement has led to limited success in the eradication of targeted pests or any new pest invasions. In Somalia, the proposed Plant Protection and Quarantine Law of 2019 has taken into consideration the legal requirements for pest eradication, containment and control. This proposed plant protection and quarantine law has only been approved by the lower house of parliament and is awaiting approval by the upper house of parliament and the signature of the president.

Table 9: Legal requirements for pest eradication, containment and control

Legal requirements for pest eradication, containment and control	Does the existing legal framework support NPPO's actions on pest eradication, containment and control?								
	Burundi	Djibouti	Eritrea	Ethiopia	Kenya	Rwanda	Somalia	South Sudan	Uganda
Declaration of quarantine pest status	✓		✓	✓	✓	✓			✓
Authority for inspectors to access farms and commercial premises	✓		✓	✓	✓	✓			✓
Authority to undertake inspection, take samples and confiscate	✓		✓	✓	✓	✓			✓
Authority for destruction, treatment of plants and plant materials suspected to be infected with any pest or disease, or weeds	✓		✓	✓	✓	✓			✓
Authority to declare a quarantine area	✓		✓	✓	✓	✓			✓
Authority to control movement of plants and plant materials suspected to be infected with any pest or disease, or weeds	✓		✓	✓	✓	✓			✓

Notes: Blank cells indicate that no information was available.

Selected examples of eradication, containment and control of pests

A desk review of the status of pest eradication, containment and control measures for invasive pests, including invasive plant species, revealed no reports of successful pest eradication in the FAOSFE countries in Africa. Official reports from South Africa have described the eradication of *Bactrocera dorsalis* (oriental fruit fly) in parts of the Cape Province in 2018 (IPPC, 2021). Other successful pest eradication programmes include recent reports of the eradication of *Thaumatotibia leucotreta* (false codling moth [FCM]) in 2014 after first detection reports in 2013; and *Anoplophora glabripennis* in the Netherlands in 2016 after its first detection in 2010 (IPPC, 2021). Argentina created the National Fruit Fly Control and Eradication Programme (PROCEM) in 1994 for the eradication of Mediterranean fruit fly *Ceratitis capitata* Wied. (Diptera: Tephritidae) and the South American fruit fly *Anastrepha fraterculus*, reported in the central and southern valleys in Mendoza province and in the Patagonian productive valley to be free of the pests in 2019 (IPPC, 2021).

Australia has reported several successful pest eradications, including recent reports of the eradication of *Phyllosticta cavendishii* (banana freckle) in 2019 after the first detection in 2013 on the Cavendish banana variety. In 2009, Australia reported the eradication of *Xanthomonas axonopodis pv. citri* (citrus canker) after its detection in 2004; *Globodera rostochiensis* (potato cyst nematode [PCN]) in 2010 after a 24-year eradication programme; *Conopomorpha cramerella* (cocoa pod borer) in 2014 after detection in 2011; *Xanthomonas fragariae* (angular leaf spot) in strawberry in 2011 after detection in 2010. New Zealand declared *Bactrocera tryoni* eradication in 2015 (IPPC, 2017).

Plant pest eradication programmes are not common in Africa. Examples may be limited to attempts at eradication, containment and control, which include that of water hyacinth (*Eichhornia crassipes*) management in Lake Victoria in Kenya. Introduced in the 1990s in Lake Victoria, *Eichhornia crassipes* spread rapidly, causing negative impacts on waterway transport and the fishing industry. To manage the spread, several management options have been employed, including physical, biological, mechanical and chemical. Classical biological control using *Neochetina eichhorniae* and *N. bruchi* physical control was implemented to limit the spread of the weed in the lake. These regional efforts were coordinated through the Lake Victoria Environmental Management Project, with funding from the World Bank, and were successful in limiting the rapid spread of the weed, but not in elimination (Kusewa and Njoka, 2005). The uncoordinated response between neighbouring countries of Lake Victoria and communities around the lake, and the lack of periodic augmented releases of the biological control agents, have contributed to the eradication being unsuccessful.

Status of pest eradication, containment and control in SFE countries

The authority and capability to control or eradicate nationally important plant pests present in the country, such as through domestic movement control, the establishment of quarantine areas, biosecurity measures (including farm biosecurity), isolation and/or eradication, were assessed. The following is the baseline report on eradication, containment and control measures in FAOSFE countries.

Table 10: Status report on pest eradication, containment and control in FAOSFE countries

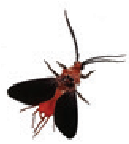
Status	Country								
	Burundi	Djibouti	Eritrea	Ethiopia	Kenya	Rwanda	Somalia	South Sudan	Uganda
Official control of movement of high-risk plant materials including imported plant breeding materials and planting materials									
1. NPPO does not monitor high-risk plant material, does not follow up, does not collect data once importation on planting material has been approved.							✓		
2. Clear guidelines exist for tracking and monitoring identified high-risk planting material with routine inspection and data collection for decision-making.	✓				✓	✓			
Quarantine and biosecurity facilities maintained									
1. No quarantine and biosecurity facilities are available for evaluation of high-risk plant health materials, including biological agents (biocontainment).							✓		
2. Quarantine and biosecurity facilities are available for evaluation of high-risk plant health materials including biological agents (biocontainment).					✓	✓			
3. Quarantine and biosecurity facilities including open quarantine facilities holding high-risk materials are routinely inspected and monitored to ensure compliance.	✓				✓				
4. Regulations exist to support the confiscation and destruction of high-risk materials when necessary.					✓				
Emerging pests eradication programmes/activities									
1. No/lack of capability to implement plant pest control or eradication programmes for priority quarantine pest or new pest invasions.					✓		✓		
2. National guidelines established for pest control or eradication programmes exist for priority quarantine pests, with limited success in the eradication of target pest invasions.	✓				✓	✓			
3. Successful national prevention, control or eradication programmes for priority pests with clear progress to eradicate new pest invasions.									

Notes: Blank cells indicate that no information was available.

Researchers were asked to find out if they have actively requested the NPPO/MoA for support to destroy or contain a pest from spreading. Responses from 50 percent to 60 percent of research scientists in Rwanda and Kenya (N = 17) indicated that they have made regular requests to their NPPO/MoA for support to destroy or contain a pest from spreading, while 40 percent to 50 percent of scientists have never made such requests. Over 50 percent of exporters/importer associations in Rwanda and 80 percent in Kenya have never reported the presence of pests/diseases on imported material or otherwise to the NPPO/MoA for support to destroy or contain the pest from spreading. This indicates low awareness by the private sector in agricultural production systems of their role in pest eradication, containment and control.

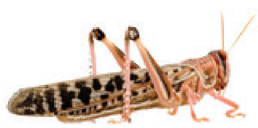
CHALLENGES

- Poor enforcement of regulations on pest eradication and containment of pests;
- Lack of coordinated effort at national and regional levels for pest risk evaluation and actions;
- Lack of quick access to pest control products during new pest invasion;
- Lack of quarantine facilities for screening and evaluation of biological control agents and biopesticides for control of new pests.



RECOMMENDATIONS

- Strengthen the enforcement of regulations on pest eradication and containment.
- Develop policy or guidelines for approval of the use of pest control products during an emergency.
- Develop protocols and facilities rapid efficacy testing and appraisals based on active ingredients already approved for other pest-crop combinations.
- Encourage efforts to harmonize regulations for assessing the testing and use of biological control agents.
- Establish public–private partnerships, especially with the pesticide industry, that enhance collaboration and co-sharing of resources during pest outbreaks or invasions.
- Establish regional quarantine facilities for the testing and mass-rearing of biological control agents and biopesticides before release into the environment.



FAO and the Government have been distributing pheromone traps to lure the male adult moths into sealed compartments, Harare, Zimbabwe.

Section 7

Early warning and reporting

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Rwanda-Gatsibo district: Fall Armyworm Community Focal Persons Training, a CBFAMFEW USAID supported project.

It is widely recognized that, in addition to preventing unwanted introductions, early warning and rapid response systems are crucial for mitigating the impacts of biological invasions. However, the capacity to detect and respond promptly to new invasions in the region is often limited. Measures to prevent either unwanted introductions or the spread of already established alien invasive species are rarely applied, whereas new invasions are often detected or publicized only when effective response is no longer feasible. As a result, it is necessary to improve the regional capacity for timely detection and reporting of new invasions. This would facilitate timely and reliable risk assessments to enable implementation of effective management responses, as necessary. To be effective, such early warning systems should include measures to detect the occurrence of new pests, supported by correct diagnosis of the pest and other related information. This information would then provide a basis for risk assessments to assess the severity of the threat and consequently identify the best options for managing the pest.

To analyse the main organizational requirements needed to guarantee a sound early warning and rapid response, a questionnaire was circulated to the NPPO and other relevant institutions in the nine target countries in the FAOSFE. The results from the survey and desk review, including legal frameworks for early warning and pest reporting, are presented in Table 11.

Table 11: Legal frameworks for early warning and pest reporting

Country	Legal frameworks for early warning and pest reporting
Burundi	The Plant Protection Decree-Law of 2017 provides for the protection of plants, plant products and plants for planting. It gives guidance for the prevention of introduction and spread of plant pests in Burundi and supports compliance with export market requirements. The law gives guidance on the detection and reporting of new pests by citizens to the NPPO.
Djibouti	-
Eritrea	The Plant Quarantine Proclamation No. 156/2006 provides for the declaration of any pest as a quarantine pest or a regulated non-quarantine pest and the periodic updating and dissemination of lists of plant material and other regulated articles, the importation of which into Eritrea is prohibited or restricted based on pest risk analysis or applicable international standards.
Ethiopia	The Plant Quarantine Council of Ministers Regulation No. 4/1992 provides for the declaration of a new plant pest in an area by the minister and updating of the list of restricted plants and other articles.
Kenya	CAP 324 under Section 3 on Rules for Prevention of the Spread of Pests provides for the reporting of the occurrence of any pest or disease specified in the rules, and the collection and transmission of specimens of any pest or diseased plant. The Act is currently under review to include pest surveillance and refine pest reporting.
Rwanda	Law No. 16 of 2016 provides for obligatory requirements of any person to report any new or suspected unknown plant pests to the NPPO, declaration of pest outbreaks, areas affected and pest-free areas.
Somalia	-
South Sudan	-
Uganda	The Plant Protection Act 2015 (Part III on Prevention and Control of Pests, Weeds and Diseases, Section 9) provides that the minister may make rules for prevention of spread of pests on the reporting to relevant government officials and publication of any occurrence, suspected occurrence or threat of introduction of specific harmful organisms, and any pertinent facts concerning the threat of occurrence, occurrence, or control of harmful organisms.

Note: * Blank cells indicate that no information was available.

EARLY WARNING AND PEST REPORTING AT NATIONAL LEVEL

National level reporting of any potential new pests, pathogens or new hosts by farmers, extension agents and research scientists is either low or non-existent. Lack of awareness and incentives among the citizens and research scientists, and lack of enforcement mechanisms were reported as key, contributing to low reports at national level (see Table 12). In the survey, research scientists in Kenya reported slow responses by the NPPO to notifications sent via emails on new plant pests identified through their research activities. Lack of quick follow-up by the NPPO discouraged some of the scientists from reporting due to fear of control of publications of such new reports. There were also cases where the NPPO collaborated with plant health scientists to publish new pest reports in peer-reviewed journals, but with very few or no reports of new pests to the IPPC.

Table 12: Status of early warning and reporting in SFE countries

Assessed parameters	Country								
	Burundi	Djibouti	Eritrea	Ethiopia	Kenya	Rwanda	Somalia	South Sudan	Uganda
Established plant health early warning mechanism									
1. No mechanisms for the early detection of emerging pests					✓	✓	✓		
2. Established networks at local, national and regional level to collect and collate pest data									
3. Pest-monitoring data received, processed and analysed and pest-warning or forecasting reports generated	✓								
Early warning dissemination and communication									
1. No early warning dissemination and communication strategy					✓	✓	✓		
2. Early warning and communication strategy in place with clear roles and activities supported by legislature	✓								
3. Regular engagement with stakeholders involved in early warning to review strategy, performance of previous early warning activities reaches and gather feedback from targeted users									
4. Previous early warning activities are documented and/or archived for learning and future use									
Public awareness campaigns (general public, farmers and producers' organizations)									
1. No public awareness campaigns on priority pests							✓		
2. Ongoing public awareness campaigns on priority pests	✓				✓	✓			
3. Pest warning messages are clear and consistent and easy to understand by targeted stakeholders									
Pest reporting									
1. No mechanism to communicate eminent pest risk							✓		
2. Established communication mechanism to inform the public and stakeholders of an eminent pest threat	✓								
3. New pest reports rarely reported to trading partners and the IPPC					✓				
4. New pest reports routinely reported to trading partners and the IPPC						✓			

Notes: Blank cells indicate that no information was available.

Pest reporting to the International Plant Protection Convention

Reporting the occurrence, outbreak and spread of pests is a key element of the National Reporting Obligations under the IPPC (Article VIII.1[a]). Timely reports from countries are encouraged to enable contracting parties to adjust as necessary their phytosanitary import requirements and to take actions to mitigate any changes in pest risk to their country. The IPPC publishes pest reports on the International Phytosanitary Portal (https://www.ippc.int/en/countries/all/pestreport/) and pest reports and bulletins (available on https://www.ippc.int/en/countries/reportingsystem-summary/all/).

Desk review of existing reports and publications on the IPPC website on pest reports indicates low compliance with pest reporting obligations (Art. VIII.1a) among the nine SFE countries. Between 2014 and 2019, only five new pest reports had been officially reported to IPPC by SFE countries (IPPC, 2021). Of the five reports, two were from Kenya, two from Rwanda and one from Uganda (see Table 13). With the exception of Djibouti, all the other eight SFE countries reported the presence of FAW to the Food Chain Crisis and Early Warning Bulletin (FAO, 2020b). However, there were no official reports to the IPPC.

Table 13: Status of pest reports to the IPPC for FAOSFE countries

FAOSFE countries	Pest identity	Description	Reported date to IPPC
Burundi	XX	XX	XX
Djibouti	XX	XX	XX
Eritrea	XX	XX	XX
Ethiopia	XX	XX	XX
Kenya	*Tuta absoluta* (GNORAB)	New pest in Kenya: preliminary surveillance report on *Tuta absoluta*	9 Jun 2014
	Maize chlorotic mottle virus (MCMV00)	Status of maize lethal necrosis disease (MLND) in Kenya	27 June 2014
Rwanda	Maize chlorotic mottle virus (MCMV00)	New pest of maize: maize lethal necrosis in Rwanda	15 July 2015
	Mango mealybug (*Rastrococcus invadens* Williams)	New pest of mango and ornamentals in Rwanda	28 Oct. 2019
Somalia	XX	XX	XX
South Sudan	XX	XX	XX
Uganda	Sugarcane mosaic virus (SCMV00)	New pest of maize: maize lethal necrosis	5 April 2013

Notes: XX: No new pest reports to the IPPC for the last 10 years.
Source: IPPC https://www.ippc.int/en/countries/all/pestreport/

ISPM 19 provides guidelines on lists of regulated pests; quarantine pests, including pests which are the subject of provisional or emergency measures; or regulated non-quarantine pests. It is good practice and a requirement of the IPPC to update the list of regulated pests when there is any change to prohibitions, restrictions or requirements, change in pest status, result of a new or revised PRA or even a change in taxonomy. Only Burundi reported their list of regulated pests to the IPPC in 2006. However, this list is outdated and needs to be updated to reflect the numerous new pests that may have changed status. There are attempts by some NPPOs in the region to develop pests lists as reported during the survey by key informants. In Uganda, over 700 pests with a high risk of introduction have been listed. However, the list has not been officially published on the institutional website or reported to the IPPC.

Rwanda indicated that a list of quarantine pests has been developed and is currently under review for sharing through the Rwanda Trade portal (https://rwandatrade.rw). While other pest reporting on (i) emergency actions (Art. VII.6) and (ii) pest status (Art. VII.2j) is bilateral in nature and information can also be made available through the IPPC website, no reporting of any emergency action has been reported by any of the countries under review. It is unclear if any of the countries have shared any information on previous and/or ongoing emergency actions or update of pest status with their trading.

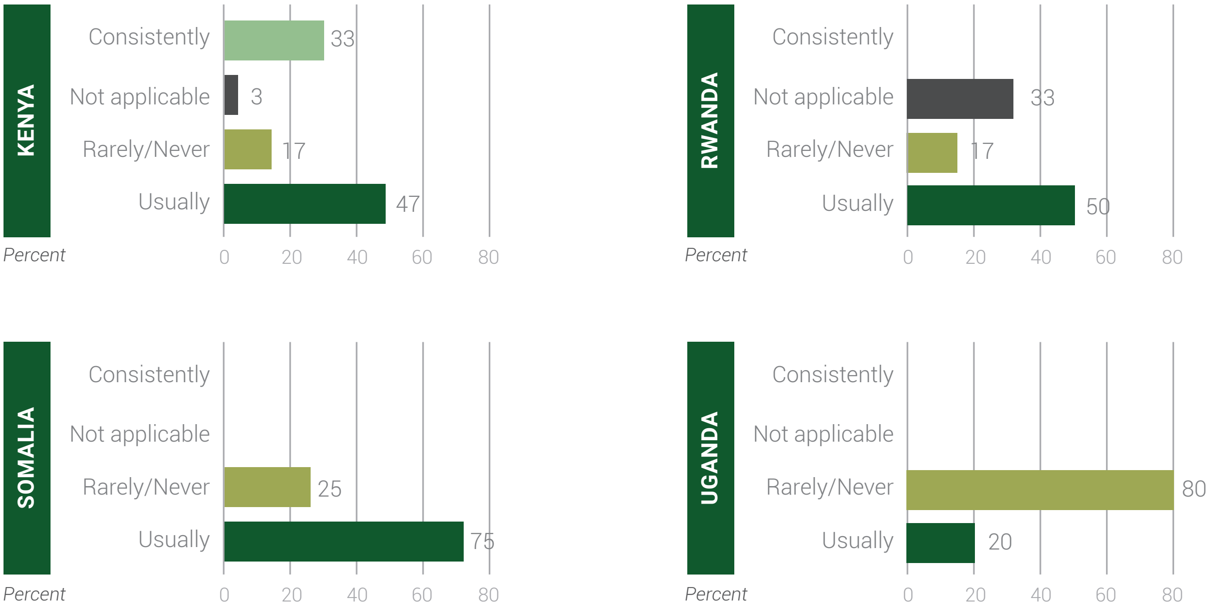
From the survey, only Kenya and Rwanda completed this section and answered in the affirmative concerning the parameters that were assessed. Concerning informing the NPPO/MoA of new pests/diseases, 43 percent and 67 percent of the respondents in Kenya and Rwanda, respectively, consistently reported new pests or diseases while undertaking research. Seven percent for Kenya and 33 percent for Rwanda indicated that they rarely/never reported the same. The majority (67 percent) of the respondents in Rwanda and 29 percent in Kenya did not find it applicable to them to report the presence of pests or diseases on imported material. However, 21 percent of respondents in Kenya reported the presence of pests or diseases. In terms of active requests to the NPPO/MoA for support to destroy or contain pests from spreading, 29 percent and 33 percent of respondents from Kenya and Rwanda, respectively, reported that they consistently made the request, with 21 percent and 33 percent for Kenya and Rwanda, respectively, reporting that they usually made a request to NPPOs to contain pests. Twenty-nine percent of respondents rarely/never made such requests. Regarding the mandate of NPPOs under the IPPC to report new pests to trading partners and the IPPC, 64 percent of respondents from Kenya rated consistently their NPPO to fulfilling this mandate, with 33 percent of respondents from Rwanda reporting the same. A majority (67 percent) of respondents from Rwanda reported not knowing how this mandate is fulfilled by their NPPO.

In terms of pest alerts, at least 15 percent of researchers in Kenya and 33 percent in Rwanda have never received pest alerts from NPPO/MoA and a further 23 percent reported usually receiving pest alerts. At least 23 percent of researchers in Kenya and 67 percent in Rwanda have never received any pest alerts from NPPOs. These alerts were mainly delivered through digital communication tools. National television (54 percent), email (38 percent) and radio (31 percent) were the top ranked modes of communication. Twitter (31 percent) and WhatsApp (15 percent) were the other social media tools used in information dissemination regarding new pests.

In terms of membership, at least 31 percent and 67 percent of respondents in Kenya and Rwanda, respectively, indicated that their organizations were members of the National Pest Surveillance task force. A similar number (38 percent and 67 percent for Kenya and Rwanda respectively) reported that they were members of the National Pest Risk Analysis task force. For the National Pest Eradication task force, at least 54 percent and 33 percent of respondents in Kenya and Rwanda reported that their organizations were members of the task force. The respondents were also asked to describe their interaction with respective NPPOs. At least 45 percent and 30 percent of the respondents indicated an "often" collaboration and infrequent contact respectively. Approximately 5 percent described the interaction as "family", while about 25 percent reported that they had no contact with their NPPOs.

The majority of the plant inspectors in the reporting countries indicated that they usually actively report to their respective NPPOs, with 33 percent of respondents from Kenya reporting consistently. However, a majority of respondents in Uganda (80 percent) and at least 25 percent, 17 percent and 17 percent of the respondents in Somalia, Kenya and Rwanda, respectively, have not reported new pests to their NPPOs/MoA. At least 47 percent and 33 percent of respondents in Kenya and Rwanda indicated that their respective NPPOs consistently fulfilled the obligation of reporting new pests to trading partners and the IPPC. At least 25 percent, 23 percent, 20 percent and 17 percent of inspectors from Somalia, Kenya, Uganda and Rwanda, respectively, did not know if their respective NPPOs were fulfilling this obligation under the IPPC.

Figure 13: Percentage of inspectors reporting pest alerts to NPPOs



From the export/import associations' perspective, only three countries (Burundi, Kenya and Rwanda) responded. There was some active reporting to the NPPO/MoA by the associations from all the reporting countries. Hundred percent of import/export associations consistently reported new pests/diseases in Burundi and 17 percent in Kenya; while 17 percent and 50 percent in Kenya and Rwanda, respectively, usually reported new pests to NPPOs/MoA. Thirty-three percent of respondents in Kenya, however, did not report any new pests/diseases to NPPOs during crop production. Similar numbers were reported for the presence of pests/diseases on imported material. Hundred percent and at least 50 percent of respondents in Burundi and Kenya, respectively, rated consistently their respective NPPO/MoA in fulfilling their mandate under the IPPC, especially reporting new pests to trading partners. At least 33 percent of respondents in Kenya indicated that their NPPO usually fulfilled this obligation. However, 50 percent and at least 17 percent of respondents in Rwanda and Kenya did not know how this obligation is fulfilled by their respective NPPOs.

At least 5 to 67 percent of the inspectors reported consistently receiving pest alerts from NPPO/MoA with 75 percent, 62 percent and 25 percent of inspectors in Rwanda, Kenya and Uganda, respectively, indicating that they usually get pest alerts from their respective NPPOs. However, about half of inspectors in Uganda, 33 percent, 25 percent and 24 percent in Somalia, Rwanda and Kenya, respectively, indicate that they have never received pest alerts from NPPOs or other organizations.

Pest-specific alert apps have also been used to report on pest presence. Respondents were asked to report on the use or experience of these tools (FAO FAMEWS, eLocust3, ProMED and PRISE) in reporting pest/disease presence. The majority (62 percent) and at least 33 percent of the respondents indicated not having used FAO FAMEWS in Kenya and Rwanda, respectively. At least 33 percent in Rwanda reported they usually use the tool. Similarly, 54 percent of respondents in Kenya indicated never using the eLocust3 tool for early warning of desert locusts. Hundred percent and at least 54 percent of the respondents in Rwanda and Kenya, respectively, indicated that this did not apply to them. For the ProMED early warning tool, at least 46 percent in Kenya reported never using the tool. The Pest Risk Information SErvice (PRISE) early warning tool was used by at least 15 percent of respondents in Kenya. Thirty-eight percent and 33 percent of respondents in Kenya and Rwanda, respectively, reported never using the tool. A majority (67 percent) in Rwanda and at least 46 percent in Kenya reported "Not applicable" when asked.

Regarding early warning tools for pests, FAO FAMEWS, eLocust3, ProMED and PRISE were assessed. At least 25 percent of the respondents in Kenya reported using FAO FAMEWS for early warning, while 100 percent of the respondents in Burundi (N = 1) have never used the tool.

eLocust3 was rarely/never used by respondents in Burundi (100 percent) and Kenya (50 percent). Similar numbers were reported for ProMED and PRISE in Burundi and Kenya. Approximately 33 percent of inspectors in Somalia reported that they consistently use FAO FAMEWS, with at least 33 percent, 25 percent, 25 percent and 14 percent of inspectors in Somalia, Uganda, Rwanda and Kenya, respectively, indicating that they usually use this tool. When asked to score and rate the technical resources available to them in implementing their duties, all the plant quarantine inspectors from Kenya, Somalia, Uganda and Rwanda indicated that they are provided with access to pest risk information by their respective NPPOs. However, this was more in Somalia (100 percent), Kenya (94 percent) and Rwanda (83 percent), compared with only 40 percent in Uganda.

The eLocust3 toolkit (see Box 1) was used by 67 percent and 19 percent of inspectors on a usual basis and only 5 percent consistently by inspectors in Kenya. However, the majority (52 to 100 percent) of inspectors in the reporting countries indicated that they have not used the tool. A similar outcome was reported for ProMED and PRISE, for example only 5 percent of the inspectors in Kenya reported using PRISE (see Box 2). All the respondents representing the export associations in Burundi and at least 50 percent of respondents in Kenya indicated that they consistently and usually received pest alerts from NPPO/MoA. Other institutions that send pest alerts were FAO (fall armyworm) and Sunripe (aphids) in Kenya, and DPV (Banana Xanthomonas wilt). Radio and national television were top ranked communication channels for pest alerts in Burundi, while WhatsApp and email were the commonly used communication tools in Kenya.

BOX 1: The FAO eLocust 3 kit

An innovative technology developed by FAO and partners is helping to improve early warning by enabling rapid detection of locust outbreaks and green vegetation likely to become sites of locust infestations. Released in 2014, eLocust3 is a tried and tested data recording and transmission system, suitable for difficult and remote locations where monitoring is a challenge. The device consists of a robust tablet and custom-designed software, which enable field staff to gather data and transfer it in real-time via satellite from the field to their national locust centres before transmission to the Desert Locust Information Service (DLIS) at FAO headquarters in Rome. eLocust3 is the latest update to the eLocust series, which has proved effective in early warning and preventive control in locust-affected countries. Information obtained via eLocust3 is used to assess the current situation, forecast its development and warn locust-affected countries and the international donor community of likely locust invasions and plagues. Designed for use in areas with no internet connection, the device is suitable for monitoring large expanses of inaccessible territory. A navigation feature enables locust survey and control teams to pinpoint and find their way to areas of green vegetation and potential locust infestations. This tool, based on new advances in technologies, could be adapted and replicated for other migratory or sedentary crop pests as a way of monitoring pest levels and implementing more timely control, as needed.

BOX 2: Pest Risk Information SErvice

CABI's Pest Risk Information SErvice (PRISE) is an innovative crop pest and disease risk forecasting product designed for smallholders and commercial producers in developing countries. Bringing together a broad range of stakeholders, including plant protection authorities, space experts, private sector companies and the farmers themselves, PRISE uses state-of-the-art crop and pest modelling techniques to provide users with advanced warning of a damaging outbreak and appropriate advice to mitigate crop losses.

03 October 2018, Rome, Italy

Speaker's Corner - Keith Cressman, AGPMM.

eLocust and drones.

Committee on Agriculture (COAG), 26th Session, 1- 5 October 2018, FAO headquarters (Atrium).

CHALLENGES AFFECTING EARLY WARNING

1. Lack of infrastructure to support mass messaging of farmers and other stakeholders on eminent threats.
2. Lack of coordinated networks of researchers, extension officers and farmers to identify plant health issues in time and communicate the same to authorities for action.
3. Lack of diagnostic capacity and quick diagnostic tools or turnaround time to enable quick identification of plant health issues.

CHALLENGES AFFECTING PEST REPORTING

1. Reporting obligation to the IPPC on pest status, pest lists and emergency actions is weak.
2. Bureaucracy on rules and procedures for pest reporting approvals within the NPPO structure.
3. Lack of enforcement of the reporting obligation to the NPPO by scientists, farmers, etc.
4. Lack of motivations/incentives for plant health scientists and/or lack of awareness on pest reporting obligations.
5. Technical scientific diagnostic capacity contributing to low research data on new pests.
6. Financial capacity to support pest surveillance to identify new pests, confirm pests' status.
7. Lack of legal frameworks to support enforcement of pest reports from farmers, commercial growers and research scientists on any potential new pests, pathogens or new hosts.

RECOMMENDATIONS

1. Sensitization of NPPOs on benefits of pest reporting vis-à-vis the cost of non-reporting, for example leading to interception of exports.
2. Diagnostic capacity support (tools/equipment, personnel and network with experts).
3. Support countries to develop pest lists and review existing ones where available.
4. Encourage national pest reporting at all levels, i.e. national and regional plant protection organizations, AU-IAPSC and the Regional Economic Communities (RECs) such as the EAC.
   - National pest reporting through regional plant protection organizations reporting template (IPPC, 2009) popularized for use by FAOSFE countries.
   - Building capacity of RECs to support Member States in their obligations to the IPPC, and other reports such as emergency actions (Art. VII.6) and pest status (Art. VII.2j) to regional trading partners.
   - Capacity-building of extension officers, researchers and the general public on national pest reporting of any potential new pests, pathogens or new hosts to the NPPO. These may include a fact sheet on what and how to report to the NPPO, and a toll-free number to enable extension officers, researchers and the general public to report any potential new pests, pathogens or new hosts they have observed directly.
5. Capacity-building for decision-makers, NPPO contact points and notification points on reporting obligation; the IPPC (Article VIII.1(a): official pest reporting obligation and ISPM 17 on pest reporting.

Section 8

Regional and international technical resources

An inventory of existing regional and international technical resources is presented in this chapter. Respondents in the target countries were asked to list technical tools they use as plant health information resources, early warning pest information sources, diagnostic tools, pest listing and prioritization tools, pest risk analysis tools and other relevant plant health tools.

These resources have been grouped into four main categories, i.e. pest alerts and early warning, pest reporting, pest diagnostic tools and pest surveillance tools.

Pest alert and early warning systems

Described as timely surveillance systems that collect information on a pest/disease in order to trigger prompt management interventions, pest alerts and early warning systems play a crucial role in maintaining high priority pest lists that inform port inspection and quarantine regulations. Early warning systems provide up-to-date, accurate information on emerging plant pests that may be a threat to agriculture or natural resources if they become established in new countries (Table 14). For that reason, the target audience of each early warning system differs and may be associated with NPPOs or regional plant protection organizations to focus on the needs of the stakeholder regions. Early warning systems also differ in methodology and information sources (Noar *et al*., 2021). Several early warning systems are in use around the world and could be adopted in SFE countries.

EPPO ALERT LIST AND EPPO REPORTING SERVICE

The European and Mediterranean Plant Protection Organization (EPPO) generates an EPPO Alert List, which is a list of plant pests and pathogens that may pose a risk to the 52 member countries of EPPO (Roy, 2011). The pests on the EPPO Alert List are chosen by the EPPO Secretariat based on the scientific literature and on suggestions by the NPPOs of the EPPO member countries. Other factors warranting inclusion of a pest in the EPPO Alert List are newly described pests, reports of spread to new geographical locations, and reports of major outbreaks in the EPPO region. The list will also contain a fact sheet detailing the known hosts and distribution, type of damage, mode of dissemination and potential pathways for spread to new geographical locations.

NORTH AMERICAN PLANT PROTECTION ORGANIZATION PHYTOSANITARY ALERT SYSTEM

This is a web-based system that provides official pest reports from the NPPOs of Canada, Mexico and the United States. The phytosanitary alert system also provides emerging pest alerts, which are news items about plant pests and pathogens that are not established in this region. These news items are obtained from public sources, including scientific journals, newspapers, records from port-of-entry interceptions and domestic plant pest surveys. The official pest reports and the emerging pest alerts are intended to provide early warning to member countries about pests of concern to the region (Roy, 2011).

ProMED

ProMED is an e-mail list that disseminates information pertaining to disease outbreaks that may affect human health, both directly, as in human pathogens or toxins, and indirectly, as in diseases of plants and animals that are important for agriculture. Subscribers can choose different ProMED mailing lists based on their areas of interest and their geographic region (Carrion and Madoff, 2017). ProMED focuses on outbreaks in new geographic regions, newly described diseases, and diseases for which the causal agent is unknown.

INTERNATIONAL PLANT PROTECTION CONVENTION (IPPC) PEST REPORTS

The IPPC is a plant health agreement signed by over 180 countries. National plant protection organizations of each member country submit official pest reports as needed concerning the occurrence, outbreak, spread or eradication of organisms that are quarantine pests in that country or that are quarantine pests for neighbouring countries and trading partners. These pest reports are posted on the IPPC website, enabling the NPPOs of other countries to respond with appropriate changes to phytosanitary requirements (IPPC, 2006b).

INTERNATIONAL PLANT SENTINEL NETWORK

The International Plant Sentinel Network is founded on the premise that historically many devastating plant pests were either not known to science or not known to be pests in their native ranges. Once these pests were introduced to new geographical regions, they caused severe damage to plants that did not co-evolve with them (Rigling and Prospero, 2018).

PESTLENS

PestLens serves as an early warning system for the Plant Protection and Quarantine programme of the Animal and Plant Health Inspection Service of the United States Departement of Agriculture (USDA-APHIS-PPQ) concerning plant pests and pathogens that may pose a threat to United States agriculture and natural resources. Data on pests are monitored weekly from a list of over 300 scientific journals, NPPO reports, Google alerts, newspapers, e-mail lists concerning invasive species and other plant-health-related websites. The analysts evaluate content from each of these sources for its relevance to PPQ, which is determined by several factors, including whether the information is new to PPQ, whether the plant pest is of quarantine significance to the United States, the potential economic impact of the pest if it were introduced, the likelihood of a pathway for introduction, and the likelihood that action by PPQ may be needed to prevent its introduction. The scope of PestLens includes new host information, new distribution records, detection of a pest in a new country where it is not yet established, eradication of a pest from a country, descriptions of new species with pest potential, and other research that may be of regulatory interest (Noar *et al.*, 2021).

FALL ARMYWORM MONITORING AND EARLY WARNING SYSTEM

The Fall Armyworm Monitoring and Early Warning System (FAMEWS) is a free mobile application for Android cell phones from FAO for the real-time global monitoring of the fall armyworm (FAW). This multilingual tool allows farmers, communities, extension agents and others to record standardized field data whenever they scout a field or check pheromone traps for FAW. Data from the app provide valuable insights on how FAW changes over time with ecology, to improve knowledge of its behaviour and guide best management practices. All collected data are used by FAO countries and partners to map and monitor current infestations. The app is designed to expand with the evolving needs of farmers, analysts and decision-makers, and can be used anywhere in the world.

eLOCUST3

This tool supports the longstanding United Nations programme to track and monitor the desert locust across its range (FAO, 2016). The eLocust3 system is the tool used by national survey and control officers in all locust-affected countries for recording field observations during survey and control operations. eLocust3 is multifaceted with eLocust3M, eLocust 3G and eLocust3w used to collect log details about habitat, vegetation, soil, rainfall, locusts, control and safety before transmitting the data in real time by satellite to that country’s National Locust Control Centre (NLCC). All frontline countries affected by desert locusts have a centralized NLCC responsible for monitoring their territory. Data from each country is collated into a single file and sent by email on a daily basis to the Desert Locust Information Service (DLIS) at FAO headquarters in Rome.

PEST RISK INFORMATION SERVICE

Pest Risk Information SErvice (PRISE) is an innovative crop pest and disease risk forecasting product designed for smallholders and commercial producers in developing countries. Bringing together a broad range of stakeholders, including plant protection authorities, space experts, private sector companies and the farmers themselves, PRISE uses state-of-the-art crop and pest modelling techniques to provide users with advanced warning of a damaging outbreak and appropriate advice to mitigate crop losses. PRISE uses static and dynamic data sources to drive pest risk models of insects and pathogens life cycles which are driven primarily by environmental factors. The pest risk modelling component uses data in the AgroMet Data Cube to derive pest life stage and risk indicators. This information is communicated to users via a pest risk Bot in the Telegram messaging system which is used by Plantwise plant doctors. The system driving PRISE is modular and can be implemented in a distributed or centralized arrangement, using cloud processing. Users access the system outputs via a website or application programming interface (API). The system is currently hosted by the Centre for Environmental Data Analysis (CEDA), a partner in the project.

Table 14: Pest alerts and early warning systems

Early warning system name	URL
PestLens	https://pestlens.info/
EPPO reporting service	https://gd.eppo.int/reporting/
North American Plant Protection Organization	http://pestalerts.org
ProMED	https://promedmail.org/
International Plant Protection Convention pest reports	https://www.ippc.int/en/countries/all/pestreport/
FAO FAMEWS	http://www.fao.org/fall-armyworm/monitoring-tools/famews-mobile-app/en/4T
PRISE	https://www.spacefordevelopment.org/catalogue/pest-risk-information-service-prise-cabi/
FAO eLocust3	http://www.fao.org/ag/locusts/en/activ/DLIS/eL3suite/index.html

Pest diagnostic tools and resources

Pest diagnosis refers to the process of detection and identification of a pest (IPPC, 2021). This diagnosis can either be web-based or offline and/or laboratory-based.

PLANTVILLAGE NURU APP

PlantVillage Nuru App is an online platform on which farmers post images of their crops for experts to diagnose problems. PlantVillage hosts the largest open access library of crop health knowledge in the world. The dataset contains more than 50 000 images of dozens of plant diseases. The tool uses artificial intelligence to diagnose pest problems submitted by users.

PESTPOINT

This is a virtual diagnostic software developed by Australia's Plant Biosecurity Cooperative Research Centre (PBCRC). It harnesses the power of social media to help identify crop pests quickly. PestPoint is used on mobile devices and inexpensive digital microscopes can use Pestpoint® to draw on the collective expertise of local, regional, national or international networks to provide faster pest identification, enabling immediate steps to be taken to reduce negative impact. During its development, CABI supported the piloting of the tool for use in selected African countries under the Australia–Africa Plant Biosecurity Partnership. Major challenges reported during the pilot included bureaucracy issues related to sharing pest information with experts outside the country and authenticity of diagnosis given the quality of images shared.

PLANTWISE KNOWLEDGE BANK PEST DIAGNOSTIC SERVICES SUPPORT

The Knowledge Bank Pest Diagnostic Tool allows users to identify the symptoms observed on a crop. It is an open access gateway to actionable plant health information and services – from diagnostic and management advice to maps of pest locations and customized alerts on pest news.

i. CABI's PestSmart Diagnostic Field Guide: This is an eBook designed to support diagnostic decision-making by showing the relationships between common symptoms on plants and the various possible causes. Packed with images and tables of pests and the symptoms they cause, it takes the learning further, by beginning to dissect what is the actual cause of any particular symptom that may be found in the field.

ii. CABI's crop pest Diagnostic Simulator app: The Diagnostic Simulator is a fun and interactive tool to test the user learning on plant diagnosis. The highly realistic graphics on the app give the learner the opportunity to zoom in on symptoms, turn the plant around, cut the plant open and look inside the plant. Users are asked to name the symptoms (and are scored on their symptom recognition) and then to make a diagnosis (also scored on the quality of their diagnosis). This app is available for Android devices only, through the Google Play store.

Figure 14: View of CABI's PestSmart tool on tablet, computer and mobile device.
Source: CABI

UC IPM'S PLANT PROBLEM DIAGNOSTIC TOOL

The University of California state-wide IPM (UC IPM) programme helps residents, growers, land managers, community leaders and other professional pest managers prevent and solve pest problems with the least unintended impacts on people and their surroundings. UC IPM works through cooperative extension to deliver information to clients in every California county. Web and printed publications provide a wealth of how-to information about identifying and managing pests, and the programme also provides online training courses. UC IPM is a part of the UC Division of Agriculture and Natural Resources. The tool can be accessed from https://www2.ipm.ucanr.edu/diagnostics/.

CARIBBEAN PEST DIAGNOSTIC NETWORK

The web-based Caribbean Pest Diagnostic Network (CPDN, previously CRDN) database provides a collaboration and communication tool for plant inspectors, scouts, consultants, extension personnel and diagnosticians to share information on plant pests. The system uses field data and digital media as tools for enhancement of diagnosis of plant disease, insect, weed, invasive species, plant management physiology and nutrient problems.

Through interactions on the Internet between field personnel and diagnostician or experts, problems can be quickly communicated and assessed. Specialists around the world can perform diagnosis and identification and provide best management practice recommendations to the users. The archived CPDN database becomes a resource for research, educational programs, and classroom teaching. The tool can be accessed from https://cpdn.ifas.ufl.edu/.

ISPM 27: DIAGNOSTIC PROTOCOLS FOR REGULATED PESTS

This standard provides guidance on the structure and content of the IPPC diagnostic protocols for regulated pests. The protocols describe procedures and methods for the official diagnosis of regulated pests that are relevant for international trade. They provide at least the minimum requirements for reliable diagnosis of regulated pests (IPPC, 1997).

The purpose of harmonized diagnostic protocols is to support efficient phytosanitary measures in a wide range of circumstances and to enhance the mutual recognition of diagnostic results by NPPOs, which may also facilitate trade. Furthermore, these protocols should aid the development of expertise and technical cooperation, and they may also be relevant to the accreditation and/or approval of laboratories. NPPOs may, however, use other methods for diagnosing the same pests in addition to this elaborated in the guidelines (IPPC, 2006a). Diagnostic protocols contain the minimum requirements for reliable diagnosis of the specified regulated pests and provide flexibility to ensure that methods are appropriate for use in the full range of circumstances. The methods included in diagnostic protocols are selected on the basis of their sensitivity, specificity and reproducibility, and information related to these factors is provided for each of these methods.

The Technical Panel on Diagnostic Protocols established in 2004 proposes priorities for protocols to be developed on specific pest species or groups of species, identifies specialists to develop each protocol, supervises the production of diagnostic protocols, and considers other topics related to the diagnosis of regulated pests.

IDENTIFICATOR

Identificator is a web-based tool used to help non-experts in identifying plant diseases, based on the selection of pictures and/or short text descriptions (when no suitable images exist) representing the symptoms on a specific sample of plant organs. The system is based on a multi-access key of identification and specifically on the selection of pictures by the user and can be used remotely from a desktop as well as from a smart phone or personal digital assistant (Pertot *et al*., 2012).

NATIONAL PLANT DIAGNOSTIC NETWORK

The National Plant Diagnostic Network (NPDN) is an internationally respected consortium of plant diagnostic laboratories. It was established in 2002 by USDA-NIFA (National Institute of Food and Agriculture) and the Office of Homeland Security to enhance agricultural biosecurity by detecting instances of biological attacks. It is a premier diagnostic system with the ability to quickly detect and accurately identify plant pests and pathogens and to communicate timely and accurate information. The tool can be accessed from https://www.npdn.org/public/about.

CABI PLANTWISE PLANT CLINICS

Plantwise is a global programme led by CABI, which helps farmers lose less of what they grow to plant health problems. Working closely with national agricultural advisory services, Plantwise has established a global plant clinic network, run by trained plant doctors, where farmers can find practical plant health advice. Plant clinics work just like clinics for human health: farmers visit with samples of their crops, and plant doctors diagnose the problem and make science-based recommendations on ways to manage it. The plant clinic network is reinforced by the Plantwise Knowledge Bank, a gateway to practical online and offline plant health information, including diagnostic resources, best-practice pest management advice and plant clinic data analysis for targeted crop protection. Together, these two unique resources are part of the Plantwise approach to strengthen national plant health systems. The tool can be accessed from www.plantwise.org.

Table 15: Pest diagnostic tools and resources: summary of use in FAOSFE countries

Plant pest diagnostic tool/ resources name	URL
Plantwise Knowledge Bank Pest Diagnostic services support	https://www.plantwise.org/KnowledgeBank/diagnostictool
UC IPM's plant problem diagnostic tool	https://www2.ipm.ucanr.edu/diagnostics/
Caribbean Pest Diagnostic Network (CPDN)	https://cpdn.ifas.ufl.edu/
ISPM 27: Diagnostic protocols for regulated pests	https://assets.ippc.int/static/media/files/publication/en/2016/01/ISPM_27_2006_WithoutApp2_En_2015-12-22_PostCPM10_InkAmReformatted.pdf
Identificator	https://apps.apple.com/us/app/plant-disease-identifier/id1524625944
The National Plant Diagnostic Network	https://www.npdn.org/public/about
CABI Plantwise plant clinics	www.plantwise.org
PlantVillage Nuru App	https://play.google.com/store/apps/details?id = plantvillage.nuru&hl = en
Pestpoint	https://stories.scienceinpublic.com.au/subject/pestpoint/

Pest surveillance tools and resources

Surveillance is described as an official process which collects and records data on pest presence or absence by survey, monitoring or other procedures (IPPC, 2021). Several tools exist to support plant pest surveillance.

ISPM 6: GUIDELINES FOR SURVEILLANCE

The ISPM 6 (Guidelines for surveillance) refers to "the components of survey and monitoring systems for the purpose of pest detection and the supply of information for use in pest risk analyses, the establishment of pest-free areas and, where appropriate, the preparation of pest lists." Surveillance is an obligation of the NPPO and underpins other obligations and phytosanitary decision-making. Plant pest surveillance thus plays a key role in the overall mandate of the NPPO and is required by Article IV.2(b) of the IPPC (IPPC, 2016). There are several survey types: response, delimiting and traceback surveys. The IPPC has developed a guide on plant pest surveillance to enhance understanding of the principal requirements of surveillance programmes for national plant protection organizations (IPPC, 2016). Several other ISPMs related to pest surveillance include:

- **a. ISPM 1:** Phytosanitary principles for the protection of plants and the application of phytosanitary measures in international trade
- **b. ISPM 2:** Framework for pest risk analysis
- **c. ISPM 3:** Code of conduct for the import and release of exotic biological control agents
- **d. ISPM 6:** Guidelines for surveillance
- **e. ISPM 7:** Phytosanitary certification system
- **f. ISPM 8:** Determination of pest status in an area
- **g. ISPM 10:** Requirements for the establishment of pest-free places of production and pest-free production sites
- **h. ISPM 11:** Pest risk analysis for quarantine pests
- **i. ISPM 17:** Pest reporting
- **j. ISPM 19:** Guidelines on lists of regulated pests
- **k. ISPM 21:** Pest risk analysis for regulated non-quarantine pests
- **l. ISPM 22:** Requirements for the establishment of areas of low pest prevalence
- **m. ISPM 26:** Establishment of pest-free areas for fruit flies (Tephritidae)
- **n. ISPM 29:** Recognition of pest-free areas and areas of low pest prevalence
- **o. ISPM 31:** Methodologies for sampling of consignments
- **p. ISPM 32:** Categorization of commodities according to their pest risk

From the survey, 100 percent and 25 percent of respondents in Burundi (N = 1) and Kenya (N = 4), respectively, consistently used or referred to ISPMs and other technical resources and tools of the IPPC in their operations. Twenty-five percent of respondents in Kenya indicated that they usually referred to these standards. However, 50 percent did not use or refer to these standards.

NATIONAL PEST LISTS

These are divided into two categories, i.e. commodity pest list (a list of pests present in an area that may be associated with a specific commodity) and host pest lists, which refers to a list of pests that infest a plant species, globally or in an area (IPPC, 2021). It is also important to note whether a pest is a quarantine/regulated or regulated non-quarantine pest.

Risk analysis and prioritization tools and resources

Pest risk analysis refers to the process of evaluating biological or other scientific and economic evidence to determine whether an organism is a pest, whether it should be regulated, and the strength of any phytosanitary measures to be taken against it (IPPC, 2006). There are existing resources and tools that are recommended to assist in undertaking risk analysis.

ISPM 2: GUIDELINES FOR PEST RISK ANALYSIS

This standard describes the process of pest risk analysis for plant pests for the purpose of preparing phytosanitary regulations by NPPOs. Pest risk analysis (PRA) consists of three stages: initiating the process for analysing risk, assessing pest risk and managing pest risk. Initiating the process involves the identification of pests or pathways for which the PRA is needed. Pest risk *assessment* determines whether each pest identified as such, or associated with a pathway, is a quarantine pest, characterized in terms of likelihood of entry, establishment, spread and economic importance. Pest risk *management* involves developing, evaluating, comparing and selecting options for reducing the risk. PRA is only meaningful in relation to a defined "PRA area" considered to be at risk. This is usually a country, but can also be an area within a country, or an area covering all or parts of several countries (for example the area covered by an RPPO). The primary ISPMs relevant to pest risk analysis are ISPM 2: Framework for pest risk analysis, ISPM 11: Pest risk analysis for quarantine pests, and ISPM 21: Pest risk analysis for regulated non-quarantine pests.

CABI PEST RISK ANALYSIS TOOL

The pest risk analysis tool is a decision-support tool that presents scientific information from the CABI Crop Protection Compendium (CPC) to aid the selection of appropriate measures for reducing the risk of pest introduction and facilitating the safe movement of plants and plant products. The tool can be accessed from https://www.cabi.org/cpc/pest-risk-analysis/.

CABI HORIZON SCANNING TOOL

The Horizon Scanning Tool supports decision-making and helps to identify, categorize and prioritize invasive species threats. The tool uses CABI data to generate a list of species that are absent from the selected "area at risk" but present in "source areas", i.e. geographic areas with similar climates to your "area at risk", neighbouring areas or selected trading partners. Users will be able to generate lists of species, refine their results by pathways, taxonomic groups, habitats, hosts and plant parts in trade and access linked species datasheets in the Invasive Species Compendium (ISC) and Crop Protection Compendium (CPC). The tool can be accessed from https://www.cabi.org/horizonscanningtool.

Pest reporting resources

ISPM 17: PEST REPORTING

This standard describes the responsibilities of and requirements for contracting parties in reporting the occurrence, outbreak and spread of pests in areas for which they are responsible. It also provides guidance on reporting the successful eradication of pests and establishment of pest-free areas (IPPC, 2017). NPPOs have the responsibility to collect pest information by surveillance and to verify the pest records thus collected. Occurrence, outbreak or spread of pests that are known (on the basis of observation, previous experience, or pest risk analysis) to be of immediate or potential danger should be reported (under the IPPC [Article VIII.1(a)]) to other countries, in particular to NPPOs of neighbouring countries and of countries that are traded with. Pest reports should contain information on the identity of the pest, location, pest status and nature of the immediate or potential danger. They should be provided without undue delay, preferably through electronic means, through direct communication, openly available publication or the International Phytosanitary Portal (IPP). In addition, information for pest reporting may be obtained directly by the NPPO or may be available to the NPPO from a variety of other sources (such as research institutions and journals, websites, growers and their journals, and other NPPOs). General surveillance by the NPPO includes the review of information from other sources. Also, reporting is obtained from resources/tools previously detailed under early warning systems.

Internet resources

These include the following:

i. **INTERNATIONAL PLANT PROTECTION CONVENTION** (IPPC) (accessible from www.ippc.int/en/): The IPPC website contains ISPMs and links to other multinational plant protection organizations.

ii. **PHYTOSANITARY RESOURCES:** The Phytosanitary Resources page includes over 300 technical resources that are open-access, including e-learning modules, manuals, training materials (including e-learning), diagnostic protocols, videos, advocacy materials, photographs, a roster of consultants and databases of projects and activities. These guides and training materials can be accessed from https://www.ippc.int/en/core-activities/capacity-development/guides-and-training-materials/. The guides and training materials also include e-learning content on, among other topics, PRA, reporting obligations and fact sheets, including those for sea container cleanliness.

iii. **EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION (EPPO)** (http://www.eppo.int/): This organization is an RPPO and coordinates numerous aspects of plant protection across most European countries. EPPO has produced a number of standards on phytosanitary measures and plant protection products.

iv. **NORTH AMERICAN PLANT PROTECTION ORGANIZATION (NAPPO)** (http://www.nappo.org/): This organization is an RPPO and coordinates numerous aspects of plant protection across North American countries. NAPPO has produced a number of standards on phytosanitary measures.

v. **THE PLANT PROTECTION COMMITTEE (COSAVE)** (http://www.cosave.org/): This organization is an RPPO and coordinates numerous aspects of plant protection across South American countries. COSAVE has produced a number of standards on phytosanitary measures.

vi. **CABI CROP PROTECTION COMPENDIUM** (http://www.cabi.org/cpc): The CPC is the world's most comprehensive site for crop protection information. The compendium contains fact sheets on a wide diversity of pests.

vii. **CABI INVASIVE SPECIES COMPENDIUM (ISC)** (http://www.cabi.org/isc): The Invasive Species Compendium (ISC) is an encyclopaedic resource of science-based information to support decision-making in invasive species management worldwide. The compendium contains fact sheets on a wide diversity of invasive species around the world

viii. **PLANTWISE KNOWLEDGE BANK** (http://www.plantwise.org/knowledgebank): An open-access gateway to actionable plant health information and services, from diagnostic and management advice to maps of pest locations and customized alerts on pest news.

A farmer shows a caterpillar found on a tomato plant on his farm, and the damage it has done to his crop, Yambio County, South Sudan.

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Annex 1 : Survey questionnaires

RESEARCH INSTITUTIONS (NATIONAL AND INTERNATIONAL) QUESTIONNAIRE

1. Priority crops (food security and international trade)

List the priority crops, including fruits and vegetables, for your country (five crops of food security significance and five of international trade significance).

The list is in order of priority.

2. Plant health risk knowledge/information

What are priority pests for the listed crops that you perceive as key for food security and international trade (list in order of priority).

Already present in the country		Absent in the country but with a high risk of introduction	
Crop	**Pest**	**Crop**	**Pest**
1.		1.	
2.		2.	
3.		3.	
4.		4.	
5.		5.	

Is the list of crops and pests that form the core focus of your work decided based on discussions with (select all that apply):

[ ] the NPPO

3. Pest reporting

Does your organization actively inform the NPPO/MoA of any new pests/diseases you may be aware of while conducting your research work?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Specify the recent pests you have brought to the attention of the NPPO/MoA.

As a researcher, have you actively reported the presence of a pest/disease on imported material?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Specify.

As a researcher, have you actively requested the NPPO/MoA for support to destroy or contain a pest from spreading?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Specify.

Under the IPPC, NPPOs are mandated to report new pests to the trading partners and IPPC. How do you rate your NPPO/MoA in fulfilling this obligation?

[1] Don't know; [2] Rarely/Never; [3] Usually; [4] Consistently; [5] Not applicable.

Suggest recommendations for NPPO to improve on this.

4. Pest diagnostics

Does your organization have the capability to conduct pest diagnosis for the crops that are the basis of your research? [Y] [N]

Specify the areas where your organization is particularly strong in terms of pest diagnostics (select all that apply):

[ ] Bacteriology; [ ] Mycology; [ ] Virology; [ ] Nematology; [ ] Entomology; [ ] Weeds; [ ] Molluscs; [ ] Other, specify:

Have you submitted samples to the NPPO/MoA national laboratories for diagnostics?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.
Specify.

In the last years, kindly indicate the number of samples in each pest category that you have submitted for diagnosis locally and internationally:

Pest category	Local laboratory	International labs
Pathology		
Virology		
Entomology		
Nematology		
Others		

Specify the collaborating laboratories.

Of the above, how many of these were the first reports of new pests?

List below:
1.
2.
3.
4.
5.

Do you have experience in remote diagnostics, whether by web-based real-time diagnostics or static image analysis?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.
Give more information (e.g. which is the supporting institution, costs, frequency, etc.):

5. Plant pest surveillance

Does your organization undertake pest surveillance as part of its research mandate or on behalf of its members?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.
Specify.

How often does your organization collate, analyse pest surveillance data and share findings?

[1] We don't; [2] Rarely/never; [3] Usually; [4] Consistently.
Specify.

With whom does your organization share its surveillance findings? (Select all that apply):

[ ] with farmers/producer groups
[ ] NPPO
[ ] conferences (nationally or internationally)
[ ] published work
[ ] other partners, specify:____

What are the web-based tools that are utilized at your organization to collect pest surveillance data? List and give the name of the pest and crop and the tool used.

6. Pest alerts and early warning

Have you received any pest alert from the NPPO/MoA/any other institution?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.
Specify the pest. From which organization was the alert sent?

By what means was the pest alert delivered?

[1] SMS; [2] Radio; [3] Email; [4] National TV; [5] WhatsApp; [6] Twitter; [7] Others (specify).

Have you used or benefited from the following early warning tools?

a) FAO FAMEWS
[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

b) eLocust3
[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

c) PRISE
[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

d) ProMED
e) Pest alert systems not listed above? Specify:_____

7. Cooperation, collaboration and partnership

Is your organization a member of the following task forces/groups:

a) National pest surveillance task force

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.
Describe your role:

b) National pest risk analysis task force

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.
Describe your role:

c) National pest eradication task force

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.
Describe your role:

Describe your interaction with the NPPO of your country:

[ ] No contact; [ ] Infrequent contact; [ ] Collaborate often on specific crops and pests; [ ] Practically family.

IMPORT/EXPORT ASSOCIATIONS/GROUPS QUESTIONNAIRE

1. Priority crops (food security and international trade)

In your opinion, what are the ten priority crops, including fruits and vegetables, for your organization/ member groups?

The list is in order of priority.

2. Plant health risk knowledge/information

What are priority pests for the listed crops above that you know should be certified "free-from" to allow import or export? That is, which pests should not be in the consignment, whether imported or exported (list in order of priority):

Already present here in the country		Absent in the country but with a high risk of introduction from another country(ies)	
Crop	**Pest**	**Crop**	**Pest**
1.		1.	
2.		2.	
3.		3.	
4.		4.	
5.		5.	

3. Pest reporting

Does your organization actively inform the NPPO/MoA of new pests/diseases you may be aware of during your crop production or processing?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Specify recent pests you have brought to the attention of the NPPO/MoA.

As a producer, have you actively reported the presence of a pest/disease on imported material or otherwise to the NPPO/MoA for support to destroy or contain the pest from spreading?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Specify.

Under the IPPC, NPPOs should report new pests to the trading partners and IPPC. How do you rate your NPPO/MoA on this obligation?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Give comments and suggest recommendations for the NPPO to improve on this.

4. Pest diagnostic support

Do you submit samples to the NPPO/MoA laboratories for diagnostics?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Specify.

Do you submit samples to other organizations in the country for diagnostics?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Specify.

In cases where you have submitted samples to the NPPO, have you been satisfied with the diagnostic and pest management feedback from the NPPO?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Specify.

In the last years, kindly indicate the number of samples in each pest category that you have submitted for diagnosis locally and internationally:

Pest category	Local laboratory	International labs
Pathology		
Virology		
Entomology		
Nematology		
Others		

Specify the name of collaborating laboratories.

How many of these were the first report of new pests?

List below:

1.
2.
3.
4.
5.

Have you used web-based remote diagnostics services to identify pest problems?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

If yes, give more information.

5. Pest surveillance

Does your organization undertake pest surveillance as part of your pest management programme or on behalf of your members?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Specify.

Does your organization collate, analyse pest surveillance and share with the NPPO/farmers/producer groups or other partners?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Specify.

What are web-based tools used at your organization or by members to collect pest scouting/surveillance data? List and give the name of the pest and crop and the tool used.

Is conducting surveillance for specific crop pests a requirement to export your products?
[ ] Yes [ ] No

Have you had a consignment rejected at export or on arrival at the country of destination because of the presence of a plant pest?
[ ] Yes [ ] No

Have you had a consignment seized, confiscated or treated at import due to the detection of a plant pest?
[ ] Yes [ ] No

6. Pest alert and early warning

Have you ever received a pest alert from the NPPO/MoA/any other institution?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Specify the pest. From which organization was the alert sent?

By what means was the pest alert delivered?

[1] SMS; [2] Radio; [3] Email; [4] National TV; [5] WhatsApp; [6] Twitter; [7] Others (specify).

Have you used or benefited from the following early warning tools?

a) FAO FAMEWS

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

b) eLocust3

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

c) CABI Pest Risk Information Service

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

d) ProMED

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

e) Others not listed above: ______

Does your organization or members utilize or refer to any of the International Standards for Phytosanitary Measures, technical resources and tools of the IPPC?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

List the ISPM and tools and how you use them.

EXTENSION OFFICERS/PLANT QUARANTINE INSPECTORS QUESTIONNAIRE

1. Priority crops (food security and international trade)

In your opinion, what are the priority crops, including fruits and vegetables (5 crops on food security and 5 for international trade) for your country?

The list is in order of priority.

2. Plant health risk knowledge/information

What are priority pests for the listed crops above that you perceive as key for food security and international trade (list in order of priority)?

Already present in the country		Absent in the country but with a high risk of introduction from another country(ies)	
Crop	**Pest**	**Crop**	**Pest**
1.		1.	
2.		2.	
3.		3.	

Does the NPPO/MoA provide you with access to pest risk information as follows:

[ ] Pest risk management information for specific crop/pests/pathways

[ ] Pest data sheets (identification and management)

[ ] CABI crop compendium

[ ] Internet access to research pests

[ ] Other databases: Specify: ____

3. Pest reporting

Do you freely inform the NPPO/MoA of new pests/diseases you may be aware of during your extension service or inspections (field, nursery, packhouse or other)?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Specify recent pests you have brought to the attention of the NPPO/MoA.

As an extension officer/plant quarantine inspector, have you willingly reported the presence of pests/diseases to the NPPO?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Specify.

Under the IPPC, NPPOs are mandated to report new pests to the trading partners and IPPC. How do you rate your NPPO/MoA on obligation?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Suggest recommendations for the NPPO to improve on this.

4. Pest diagnostics

Have you submitted samples to the NPPO/MoA laboratories for diagnostics?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Specify.

In the last years, kindly indicate the number of samples in each pest category that you have submitted for diagnosis locally and internationally:

Pest category	Local laboratory	International labs
Pathology		
Virology		
Entomology		
Nematology		
Others		

Specify the collaborating laboratories.

How many of these were the first reports of new pests?

List below:

1.

2.

3.

4.

5.

How often have you had pest identification training for the key pests that you are responsible for surveying?

Have you used remote diagnostics, whether web-based, linked to a microscope or taken digital images for pest diagnosis?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Give more information.

What is the average time it takes for you to get a sample to a diagnostic lab and for it to be identified?

[ ] hours; [ ] 1–2 days; [ ] 1–2 weeks; [ ] a month or more.

5. Pest surveillance

Have you been involved in supporting the surveillance by the NPPO team?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Specify.

Are you involved in data collection, analysis of pest surveillance and sharing with farmers/producer groups?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Specify.

What are the web-based/mobile-based tools used to collect pest scouting/surveillance data? List and give the name of the pest and crop the tool is used on.

If you are directly involved in pest surveillance, please rate the following statements:

My training on surveillance methods for specific pests of concern is adequate.
[1] Disagree; [2] Agree; [3] Strongly agree; [4] Rather not say.

I have the tools necessary to collect, process and submit samples for pest diagnostics.
[1] Disagree; [2] Agree; [3] Strongly agree; [4] Rather not say.

I have the tools and resources to cover the area under surveillance adequately.
[1] Disagree; [2] Agree; [3] Strongly agree; [4] Rather not say.

I am confident in the detection and delimitation of pests for which we are responsible for conducting surveillance.
[1] Disagree; [2] Agree; [3] Strongly agree; [4] Rather not say.

The NPPO has the technical expertise to diagnose and report on the pests of concern.
[1] Disagree; [2] Agree; [3] Strongly agree; [4] Rather not say.

6. Pest alert and early warning

Have you received a pest alert from the NPPO/MoA/any other institution?

[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.
Specify the pest. From which organization was the alert sent?

By what means was the pest alert delivered?

[1] SMS; [2] Radio; [3] Email; [4] National TV; [5] WhatsApp; [6] Twitter; [7] Others (specify).

Have you used the following early warning tools?

FAO FAMEWS
[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

eLocust3
[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Pest risk information service
[1] Not applicable; [2] Rarely/never; [3] Usually; [4] Consistently.

Share your feedback on early warning tools:

a) FAO FAMEWS
b) eLocust3
c) Pest risk information service
d) Other early warning tool

Annex 2: Checklist for key informant interviews

Focus areas	Proposed questions
Priority crops (food security and international trade)	What are the priority crops: For food security? For international trade?
Priority emerging/invasive pests	What is the current priority of emerging/invasive pests for these crops: Food security? International trade? Have these been subjected to risk analysis?
Pest risk analysis	What drives PRA activity: For market access? For import control? Is PRA activity output consolidated into a database? Describe the database, if any: Are the PRA outputs incorporated into: • Pest risk management information products for use by inspectors and extension officers? • Risk-based phytosanitary policy/legal instruments or directives? • An early warning system and communicated to stakeholders? If yes, how?
Surveillance capacity and pest diagnostics: • Assess country pest diagnostic capacity • Explore and communicate recommendations for remote diagnostics	National strategy on surveillance for the priority pest: Is there pest monitoring in place for any of the priority pests? What are the institutional mechanisms and networks in place to support the surveillance activities? Is there a standardized data collection process, curation and analysis in place? Is the database of pests accessible? To whom?
Contingency planning and incident management: • Assess the best practices and lessons learned across the nine countries • Communicate results and provide recommendations on contingency planning and incidence management	Is there a national early warning strategy? Is there a national emergency fund? Is there a national task force in force? What are public-private partnerships? MoU? Agreements? What are the modalities for cost-sharing with the private sector players?

Eradication, containment and control measures: • Assess the best practices and lessons learned across the nine countries • Communicate results and provide recommendations on eradication, containment and control measures	Is there a national pest eradication strategy? Are there pest response plans? Are they operational? Are the plans tested and reviewed? Is there a legal framework under which eradication, containment and control measures can be implemented? Are these plans costed and funds available/accessible in case they are needed?
Early warning and reporting: • Assess available tools from FAO (FAMEWS, eLocust3), CABI and the private sector to enhance a system for early warning • Assess the best practices and lessons learned across the nine countries • Communicate results and provide recommendations on early warning and reporting	Is there an early warning strategy? Is there a national early warning system manager? Are public awareness and education campaigns undertaken? Do you utilize any of these tools – FAMEWS, eLocust3, PRISE? Any feedback on these? What other early warning tools are you aware of/use for pest data collection? What are the challenges you face in pest reporting? What are the challenges you face with the early warning?
Overview/review of existing regional and international technical resources	What other technical resource do you utilize with emergent pests and related phytosanitary issues? Are these resources made available to personnel and relevant stakeholders to help them perform their roles better? If not, what measures/resources are needed to remedy the situation? Are public awareness and education campaigns undertaken?

Annex 3: Country scorecard

Notes for completing scorecard				
Column C: For Sections B to F, unless indicated otherwise, complete using numerical values (1, 2, 3, etc.) that correspond to the selected appropriate response in Column B				
Column D: Provide reasons for the selected response in Column C				
Column E: Indicate source of information regarding the specific parameter				
COUNTRY		**Designated NPPO**		
Plant health parameter	Description of parameter	Select appropriate description from Column B	Comments	Source of information/ link to information
A. Priority crops, including fruits and vegetables (the list is in order of priority)				
List in order of priority: food security crops	List five priority crops			
List in order of priority: export priority crops	List five priority crops			

B. Pest risk analysis – the capacity to conduct pest risk analysis (PRA) and apply scientifically based phytosanitary measures and to institutionalize risk-based approaches				
The NPPO has established and maintained a general list of pests occurring in the country	1. General pest list not available/ accessible			
	2. General pest list available/ accessible for a few crops and not regularly updated			
	3. General list of pests available and accessible for many crops and regularly updated			
The NPPO has established list of quarantine pest for the country	1. Quarantine pest list not available/ accessible			
	2. Quarantine pest list available/ accessible for a few crops and not regularly updated			
	3. Quarantine pest list available and accessible for many crops and regularly updated			
The capacity and authority of the NPPO to make decisions regarding regulated articles, based on internationally accepted and harmonized	1. The NPPO does not have access to minimum scientific information, does not conduct pest risk analysis, and phytosanitary measures are not supported by scientific evidence			
	2. The NPPO does have access to minimum scientific information to conduct pest risk analysis, and phytosanitary measures are supported by scientific evidence			
	3. The NPPO has a PRA team in place to undertake PRA for import control and market access			
	4. Previous PRA documents not available and accessible online for reference			
	5. Database of previous PRA available and accessible online for reference			
C. Surveillance capacity and pest diagnostics – established official process for detecting, identifying and recording information on the presence or absence of emergent pests				
Established official process for detecting, collecting and recording information on the presence or absence of emergent pests	1. No pest surveillance in place for the prioritized crops listed in A			
	2. Pest surveillance in place for some of the prioritized crops and pest status occasionally reported			
	3. Active pest surveillance for the prioritized crops and pest status always reported			
	4. Surveillance data routinely processed and made accessible through pest report/notification and publications			

Pest diagnostics skills, protocols and equipment available for quick diagnosis of emerging pests	1. Diagnostic capacity including laboratory capacity for diagnosing emerging pests not available, no network with other laboratories			
	2. Some diagnostic capacity available, including laboratory capacity for diagnosing emerging pests, as well as networks with other authorized laboratories for diagnosis of emerging pests			
	3. Diagnostic capacity available, with modern and rapid diagnostic tools such as ELISA and PCR equipment			
	4. Remote diagnostics available through peer-to-peer diagnosis via social media platforms, with local and international diagnostic experts			
	5. Established official remote diagnostics via web-based camera-mounted microscopes with networks connecting local, regional and international diagnostic laboratories and experts			
D. Contingency planning and incident management, including access to special fund established to address phytosanitary emergencies and emerging issues such as new invasions and outbreaks				
Standard operating procedures and responsibilities for stakeholders for action	1. Activities/actions carried out during a phytosanitary emergency are ad hoc			
	2. Standard operating procedures established, with clear actions to be undertaken			
	3. Emergency action team is ad hoc and rarely active			
	4. Emergency action team established and supported by legislation or MoUs			
	5. Roles and responsibilities for teams/stakeholders established by legislation or by binding agreements			
	6. Contingency funds not established and available and emergency actions delayed due to a lack of resources			
	7. Contingency funds established and available when urgently needed during a phytosanitary emergency			

E. Eradication, containment and control measures – the authority and capability to control or eradicate nationally important plant pests present in the country, such as through domestic movement control, establishing quarantine areas, biosecurity measures (including farm biosecurity), isolation and/or eradication				
Official control of movement of high-risk plant materials, including imported plant breeding materials and planting materials	1. The NPPO does not monitor high-risk plant material, no follow up made, does not collect data once importation on planting material is approved			
	2. Clear guidelines exist for tracking and monitoring identified high-risk planting material with routine inspection and data collection for decision-making			
Quarantine and biosecurity facilities and maintained	1. No quarantine and biosecurity facilities are available for evaluation of high-risk plant health materials, including biological agents (biocontainment)			
	2. Quarantine and biosecurity facilities are available for evaluation of high-risk plant health materials, including biological agents (biocontainment)			
	3. Quarantine and biosecurity facilities, including open quarantine facilities holding high-risk materials, are routinely inspected and monitored to ensure compliance			
	4. Regulations exist to support the confiscation and destruction of high-risk materials when necessary			
Emerging pests eradication programmes/ activities	1. No/lack of capability to implement plant pest control or eradication programmes for priority quarantine pest or new pest invasions			
	2. National guidelines established for pest control or eradication programmes exist for priority quarantine pests, with limited success in eradication of target pest			
	3. Successful national prevention, control or eradication programmes for priority pests with clear progress to eradicate new pest invasions			
F. Early warning and reporting capacity to establish surveillance for early detection of emerging pests and respond rapidly to any outbreaks				
Established plant health early warning mechanism	1. No mechanisms for the early detection of emerging pests			
	2. Established networks at local, national and regional levels to collect and collate data on pests			
	3. Pest monitoring data received, processed and analysed and pest warning or forecasting reports generated			

Early warning dissemination and communication	1. No early warning dissemination and communication strategy			
	2. Early warning and communication strategy in place with clear roles and activities supported by legislature			
	3. Regular engagement with stakeholders involved in early warning to review strategy, performance of previous early warning activities reach and gather feedback from targeted users			
	4. Previous early-warning activities are documented and/or achieved for learning and future use			
Public awareness and campaigns (general public, farmers' and producers' organizations)	1. No public awareness campaigns on priority pests			
	2. Ongoing public awareness campaigns on priority pests			
	3. Pest-warning messages are clear and consistent and easy to understand by targeted stakeholders			
Pest reporting	1. No mechanism to communicate eminent pest risk			
	2. Established communication mechanism to inform public and stakeholders of eminent pest threat			
	3. New pests rarely reported to trading partners and IPPC			
	4. New pests routinely reported to trading partners and IPPC			
Early warning tools	Based on your experience, provide comments on the tools listed below, and their challenges			
	1. FAMEWS			
	2. eLocust3m			
	3. PRISE			
	4. CROP MONITOR FOR EARLY WARNING			
	5. CropMon			
List other early warning tools utilized				
G. Overview/review of existing regional and international technical resources available to NPPO staff				
ICT tools				
Other web-based tools				
Gap areas where other tools may support				

Annex 4: Qualitative risk assessment criteria rating

A. Likelihood of entry

What is the probability of the pest being associated with the pathway at origin?

This is an estimation of the probability that the pest may be able to enter the pathway at the point of origin. Factors to consider: (i) prevalence of pest in the source area, (ii) occurrence of life stage able to associate with pathway, (iii) seasonal timing and (iv) pest management procedures applied at place of origin.

The rating is considered:

Low (1): The export area is recognized as an area of low pest prevalence; the commodity is not a preferred host for the pest; viable life stages are unlikely to occur on the harvested commodity and the pest is not usually associated with the plant part for export.

Medium (2): The commodity is an occasional host for the pest; the plant part for export is not the preferred feeding site for the pest and effective management practices are applied in the field prior to harvest.

High (3): The commodity (plant part) is a preferred host and a preferred feeding site for the pest and no effective field management practices exist or are applied.

What is the probability of the pest surviving during transport/shipment?

This assesses the likelihood that the pest will survive and remain with the commodity from packing through arrival at the port of entry in the importing country. The biology of the pest and information on the conditions of shipment of the given commodity are examined. The likelihood that the pest is able to survive or increase/multiply during shipment is considered, speed and conditions of transport. Factors to consider: (i) duration and vulnerability of life cycle, (ii) previous interceptions of the pest and (iii) commercial procedures during transport (such as refrigeration).

The rating is considered:

Low (1): The pest is unlikely to survive or multiply during shipment.

Medium (2): The pest can survive or multiply during shipment.

High (3): The pest will survive and multiply during shipment.

What is the probability of the pest surviving or evading existing pest management and post-harvest treatment procedures?

This assesses the likelihood of the pest surviving pest management practices during production and post-harvest processing, packing and preparation for shipment.This includes pest management options using cultural or chemical methods/practices during harvesting, sorting, produce cleaning and other treatments such as brushing, dipping, culling and cold storage. Factors to consider: (i) inspection methods and quality control, (ii) certification schemes and (iii) chemical treatment.

The rating is considered:

Low (1): The pest or symptom can be removed during post-harvest processing, handling, packing and preparation for shipment, as well as no chances of reinfestation.

Medium (2): The pest or symptom is difficult to spot and be removed during post-harvest processing, handling, packing and preparation for shipment as well as limited chances of reinfestation.

High (3): The pest or symptom cannot be removed and/or detected during post-harvest processing, handling, packing and preparation for shipment, and reinfestation is likely to occur.

What is the probability of transfer to a suitable host or, in the case of potential weeds, habitat?

This assesses the likelihood that the pest will find suitable hosts in the PRA area, distribution and proximity of suitable hosts (consider the host species and other hosts in the same species) in the PRA area, intended use of the commodity and risk from by-products and their disposal. Factors to consider: (i) dispersal mechanisms, including vectors; (ii) number of destinations; (iii) proximity to suitable hosts/habitats; (iv) seasonality during which the associated hosts may be imported; (v) intended use of the associated commodity (for example for planting, processing and consumption); and (vi) risks from by-products and waste.

The rating is considered:

Low (1): The pest attacks a single species or multiple species within a single genus with limited distribution in the PRA area, limited self-dispersal mechanism.

Medium (2): The pest attacks multiple species within a single plant family only available in select areas of the PRA area such as on commercial farms.

High (3): The pest attacks multiple species among multiple plant families widely distributed throughout the PRA area; no alternate hosts are needed to complete development or, if needed, are widely available.

What is the probability of being detected at point of entry?

This assesses the likelihood that the pest will go undetected under current inspection procedures at the point of entry. The likelihood of detecting the pest during inspection will depend on a number of factors including: (i) ease of detection of life stages which are likely to be present; (ii) location of pest on commodity; and (iii) symptom of expression and the ability to be distinguished from other organisms.

The rating is considered:

Low (1): The pest can be detected during inspection at the entry point on the external surface visually or with the aid of a hand lens.

Medium (2): The pest is an internal feeder and is detected only through destructive sampling (cutting) of the commodity.

High (3): The pest can only be detected using special diagnostic techniques.

B. Likelihood of establishment

What is the probability that suitable hosts or, in the case of potential weeds, habitats are available in the PRA area?

This assesses the likelihood that the pest will find suitable hosts in the PRA area. Consider: (i) the abundance of main hosts and alternate hosts and how they are distributed; (ii) geographic proximity of hosts/habitats to pathway destinations; and (iii) presence of other suitable plants that could be new hosts.

The rating is considered:

Low (1): The pest attacks a single species or multiple species within a single genus with limited distribution in the PRA area.

Medium (2): The pest attacks multiple species within a single plant family only available in select areas of the PRA area such as on commercial farms.

High (3): The pest attacks multiple species among multiple plant families widely distributed throughout the PRA area; no alternate hosts are needed to complete development or, if needed, are widely available.

If transmitted by vectors, what is the probability that suitable vectors are available in the PRA area?

This assesses the likelihood of the presence of natural vectors or related species with vector potential in the PRA area posing a high risk of spread within the PRA area.

The rating is considered:

Low (1): A vector is likely to be absent from the PRA area.

Medium (2): A vector is likely to be present at low prevalence in the PRA area.

High (3): A vector is present and at high prevalence in the PRA area.

What is the probability that climatic conditions and other abiotic factors will allow the pest to establish in the PRA area?

This assesses the suitability of the environmental conditions in the PRA area as compared with those of the area where the pest is established, and how the pest is likely to behave in the PRA area. Where possible, climatic modelling systems may be used to compare climatic data on the known distribution of a pest with that in the PRA area. Consider: (i) known distribution of the pest within ecoclimatic zones in the PRA area, (ii) whether hosts are grown in protected cultivation, and (iii) soil factors for soil-borne pests.

The rating is considered:

Low (1): The environmental conditions for the successful establishment of the pest are occasionally present in the PRA area.

Medium (2): The environmental conditions for the successful establishment of the pest are present in the PRA area.

High (3): All environmental conditions for the pest's establishment are present in the PRA area.

What is the probability that the reproductive potential and adaptability and other biological characteristics of the pest will enable its establishment?

This assesses the pest characteristics which may enable the pest to reproduce effectively in the new environment, such as parthenogenesis/self-crossing, duration of the life cycle, number of generations per year, overwintering/survival stage (ability to survive periods of climatic stress and complete their life cycles, etc.). Factors to consider: (i) reproductive and survival strategies, (ii) genetic adaptability and (iii) minimum population needed for establishment.

The rating is considered:

Low (1): The pest has low reproductive potential (can only reproduce after fertilization, has a long development period (more than six months) and/or limited ability to adapt to harsh conditions.

Medium (2): The pest has either high reproductive potential (can reproduce by both parthenogenesis and after fertilization), the development period is medium (one to six months) and/or some of the development stages can survive and/or adapt to harsh conditions.

High (3): The pest can reproduce both sexually and parthenogenetically, and after fertilization its development period is short (less than a month). All development stages survive and/or adapt to harsh conditions.

What is the probability that existing control measures for other pests in the PRA area are unable to prevent establishment?

This assesses the readiness of pest control options used on the main hosts and related wild hosts in the PRA area that are currently used for related pests, which reduce the probability of establishment may be considered. Pests for which control is not feasible should be considered to present a greater risk than those for which treatment is easily accomplished. The availability (or lack) of suitable methods and products for eradication should be assessed. Consider: (i) cultural practices such as irrigation, planting and harvesting methods, and (ii) pest control programmes.

The rating is considered:

Low (1): There are several suitable and effective control measures available in the PRA area.

Medium (2): There are few suitable control measures available in the PRA area.

High (3): There is no suitable control measures available in the PRA area.

What is the probability that existing natural enemies in the PRA area are unable to prevent establishment?

This assesses the presence of natural enemies already in the PRA area which reduce the probability of establishment. Pests for which natural enemies/biological control agents are not available should be considered to present a greater risk.

The rating is considered:

Low (1): There are several suitable natural enemies/biological control agents readily available in the PRA area.

Medium (2): Few natural enemies/biological control agents are available in the PRA.

High (3): There are no natural enemies/biological control agents available in the PRA area.

C. Likelihood of spread

What is the expected rate of natural spread in the PRA area?

This assesses the dispersal capability of the pest, i.e movement of the pest from the pathway to a suitable host via natural means, vector- or human-assisted, and the speed and range of dissemination. Consider: (i) rate and distance of spread elsewhere, and (ii) natural barriers in the PRA area.

The rating is considered:

Low (1): The pest has potential for natural spread locally (at the point of introduction) in the PRA area within a year, has limited natural dispersal capacity, no other dispersal agents are present, and evidence elsewhere shows that the spread has been slow and limited.

Medium (2): The pest has potential for natural spread in one to two agroecological zone of the PRA area within a year, has moderate natural dispersal capacity, few dispersal agents are present, and spread of the pest in other parts of the world has been moderate.

High (3): The pest has potential for rapid natural spread to all production areas of the PRA area, has high natural dispersal capacity, several dispersal agents are present, such as natural forces (for example wind and water), by vectors or human-assisted, and evidence exists that the pest is rapidly spreading or has rapidly spread in other parts of the world.

If transmitted by vectors, what is the expected rate of spread by vectors in the PRA area?

Occurrence of known natural vectors or related species with vector potential in the PRA area pose a high risk of spread within the PRA area.

The rating is considered:

Low (1): Vector is likely to be absent from the PRA area.

Medium (2): Vector is likely to be present at low prevalence in the PRA area.

High (3): Vector is present and at high prevalence in the PRA area.

If a commodity pathway has been identified as one of the pathways of entry, what is the probability that the intended use of the commodity increases the rate of spread?

This assesses the likelihood of the intended use of the identified commodity to aid transfer to a suitable host or habitat. If the commodity associated with the pathway is used for processing, consumption or planting, their disposal of waste and by-products will all affect the chances of the pest transferring to a suitable host and spreading in the PRA area. If the commodity is used for planting, for example seedlings, the risk can be considered to be high. Consider: (i) the intended use of the commodity associated with the pathway for example for planting, processing or consumption; (ii) disposal of waste and by-products; and (iii) number and location of expected destinations.

The rating is considered:

Low (1): The commodity associated with the pathway will be sent directly to a post-entry quarantine facility where it will be used and subsequently destroyed; the commodity is intended for research purposes in a controlled environment; the commodity is intended for processing.

Medium (2): The commodity associated with the pathway is intended for consumption and will be distributed to special markets.

High (3): The commodity associated with the pathway is intended for planting and will be distributed to farms across the PRA area.

What is the probability of the pest spreading to an area of higher economic importance than the area of introduction?

This assesses the close proximity to suitable hosts that are more likely to enhance the spread of the pest from the area of introduction.

The rating is considered:

Low (1): Host crops are not close to the entry points or transit routes.

Medium (2): Host crops are spread close to entry points or transit routes.

High (3): Host crops are within the entry points or transit routes.

D. Economic, environmental and social impacts

1) What is the level of economic loss to agriculture, forestry or horticulture associated with this pest in its existing geographic range as well as in the PRA area?

Introduced pests can cause a variety of direct and indirect economic impacts. These impacts include: (i) reduction in crop yield or quality; (ii) loss of domestic/export markets due to a reduction in prices or demand; (iii) increase in production costs (including costs of control); and (iv) vectoring of other pests of economic importance.

Low (1): Pest likely to cause none of the above impacts.

Medium (2): Pest likely to cause any one or two of the above impacts.

High (3): Pest likely to cause at least three of the above impacts.

2) What is the level of economic loss to agriculture, forestry or horticulture associated with this pest in the PRA area?

Introduced pests can cause a variety of direct and indirect economic impacts. These impacts include: (i) reduction in crop yield or quality; (ii) loss of domestic/export markets due to reduction in prices or demand; (iii) increase in production costs (including costs of control); and (iv) vectoring of other pests of economic importance.

Low (1): Pest likely to cause none of the above impacts.

Medium (2): Pest likely to cause any one or two of the above impacts.

High (3): Pest likely to cause at least three of the above impacts.

3) Potential impact on native biodiversity associated with this pest in its existing geographic range as well as in the PRA area?

Introduced pests can cause a variety of direct and indirect environmental impacts. These impacts include (i) reduction of ecologically significant species by direct infestation; (ii) impact on threatened or endangered species, for example through habitat destruction; (iii) stimulating the use of biological or chemical control programmes; (iv) impact in plant communities/changed community structure; and (v) hybridization with native species and/or pest has many biotypes and strains.

Low (1): Pest likely to cause none of the above impacts.

Medium (2): Pest likely to cause any one or two of the above impacts.

High (3): Pest likely to cause at least three or more of the above impacts.

4) Potential impact on native biodiversity associated with this pest in the PRA area?

Introduced pests can cause a variety of direct and indirect environmental impacts. These impacts include (i) reduction of ecologically significant species by direct infestation; (ii) impact on threatened or endangered species, for example through habitat destruction; (iii) stimulating the use of biological or chemical control programmes; (iv) impact in plant communities/changed community structure; and (v) hybridization with native species and/or pest has many biotypes and strains.

Low (1): Pest likely to cause none of the above impacts.

Medium (2): Pest likely to cause any one or two of the above impacts.

High (3): Pest likely to cause at least three or more of the above impacts.

5) What is the level of negative social impact associated with this pest in its existing geographic range as well as in the PRA area?

Introduced pests can cause a variety of direct and indirect social impacts. These impacts include (i) employment loss; (ii) impact on well-being: aesthetic and historical value; (iii) impacts on industries such as tourism, energy, fishing; and (iv) loss of land-use function: agriculture, living area.

Low (1): Pest likely to cause none of the above impacts.

Medium (2): Pest likely to cause one or two of the above impacts.

High (3): Pest likely to cause at least three or more of the above impacts.

6) Impact on local quarantine/regulatory measures

The local quarantine regulations for introduced pests can potentially affect movement of material within the PRA area. The introduced regulatory measures may significantly have a cost bearing. Quarantine measures are required to contain both the plant and any quarantine pest potentially associated with it so that neither can escape a facility or region before the required inspection, testing, treatment and verification activities have been completed and the consignment is released.

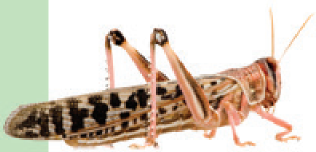
Low (1): Unlikely to change the local quarantine regulatory framework.

Medium (2): Likely to change the local quarantine regulatory framework.

High (3): Most likely to change the local quarantine regulatory framework.

Overall rating

The summation of the values for the likelihood of entry, likelihood of establishment, spread and assessment of economic impacts were combined and qualitatively assigned as low (1), medium (2) and high (3).



Annex 5: Institutions participating in key informant interviews

Country	Institution/Organization	No of KIIs conducted
Burundi	Ministry of Agriculture – Plant Protection Directorate	1
Kenya	Ministry of Agriculture, Livestock, Fisheries and Cooperatives – Plant Protection Services Division	2
	Ministry of Agriculture, Livestock, Fisheries and Cooperatives – Horticultural Division	1
	Kenya Plant Health Inspectorate Services	1
	Kenya Agricultural Livestock Research Organization	1
	Fresh Produce Consortium of Kenya	1
	Horticultural Crops Directorate	2
	Agrochemicals Association of Kenya	1
	FAO Desert Locust Control team at the Plant Protection Services Division	1
Rwanda	Rwanda Agricultural Board	1
	Rwanda Inspectorate, Competition and Consumer Protection Authority	2
Somalia	Ministry of Agriculture, Department of Plant Protection	1
Uganda	Ministry of Agriculture, Animal Industry and Fisheries – Department of Crop Protection	2
	Ministry of Agriculture, Animal Industry and Fisheries – Department of Crop Inspection and Certification	1
	Total	**18**

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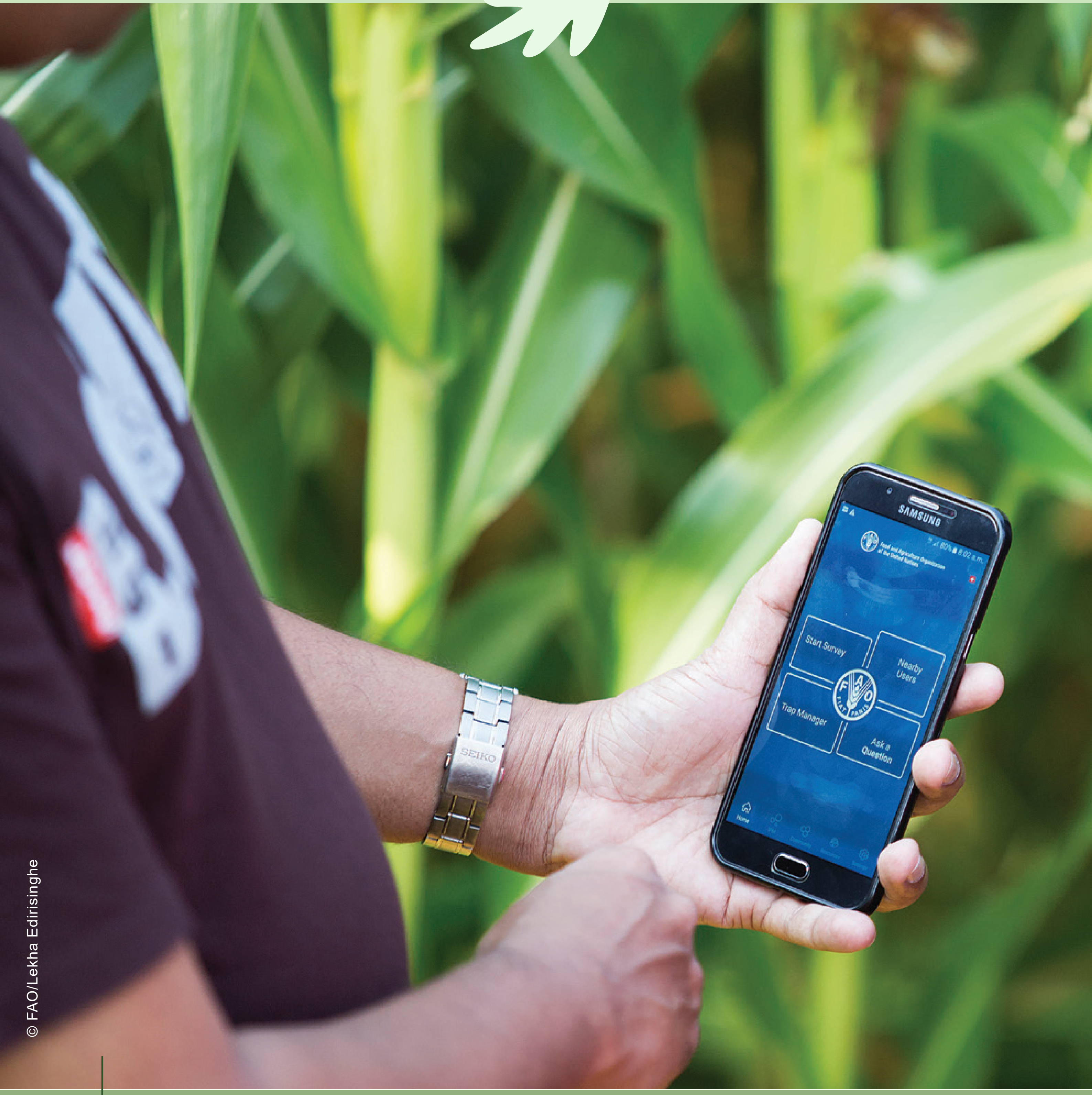

FAO team introduce the new FAMEWS mobile application to farmers during a visit to fall armyworm-infested maize cultivation.


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