13 Biosecurity and Phytosanitary Principles

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13.1 Introduction

Biosecurity is the practice of managing risks posed by biological organisms. In the context of agriculture, biosecurity aims to prevent the introduction of new pests or diseases to a region, manage the pests and diseases already present and minimize their spread to new regions. **Phytosanitary** principles are those aimed at protecting plant health and preventing the introduction and spread of plant pests and diseases, and apply in both local and international contexts. The term 'phytosanitary' is most often used when referring to goods intended for international trade.

Invasive species (including introduced agricultural pest species) can be managed by: i) preventing introduction; ii) detecting and responding to new introductions; iii) eradicating introduced species and iv) controlling spread of established species (CBD, 2002). Biosecurity practices can be aimed at any of these management points, and can be applied pre-border, at-border or post-border.

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It is preferable and less costly to prevent an introduction, rather than later management of a (possibly) widespread pest (Welsh *et al.*, 2021; Cuthbert *et al.*, 2022). This is accomplished largely by attempting to identify and control the introduction pathways through which an invasive organism may enter a new region, or by identifying particular harmful species and attempting to prevent their introduction (Colunga-Garcia *et al.*, 2013; Hulme, 2021; Jamieson *et al.*, 2022). Insects, mites and other agricultural pests are commonly introduced to new regions as contaminants on agricultural produce (such as fruit, plants or seeds) or as stowaways on transport vessels or other vectors like packing material (Faulkner *et al.*, 2016; Garnas *et al.*, 2016; Faulkner *et al.*, 2020a).

It is the responsibility of countries involved in agricultural trade to recognize the associated risks of transporting foreign organisms and to take actions to mitigate risks where possible. Protecting the health of crops is becoming an increasingly important and difficult task. This is compounded by the increasing volume of international trade, which puts a severe strain on inspections of commodities by importing and exporting trade partners, and the quarantine of commodities in importing countries to confirm that they are pest-free.

The benefits of a well-functioning biosecurity system are hard to quantify, as measures of possible future damage averted by prevention of pest entry are almost impossible to estimate (Welsh *et al.*, 2021; Cuthbert *et al.*, 2022; Nahrung *et al.*, 2023). As Nahrung *et al.* (2023) point out, only biosecurity failures are truly evident, with success being simply an absence of effect. Some studies have estimated a cost–benefit ratio by comparing the cost of invasive species to the cost of biosecurity implementation (Dodd *et al.*, 2020; Welsh *et al.*, 2021; Cuthbert *et al.*, 2022; Nahrung *et al.*, 2023). Invariably, these studies conclude that the costs of maintaining biosecurity are far less than those associated with later management of an invasive species should biosecurity fail. One of the largest studies to attempt a cost–benefit analysis is that by Dodd *et al.* (2020) in Australia. This study estimated that the return on investment was 30:1 – i.e. for each AUS dollar spent on biosecurity interventions, 30 AUS dollars were saved in future economic damages. If a similar ratio holds true for other biosecurity systems, then preventative measures are money well spent.

13.2 History of Biosecurity

The concept of plant biosecurity was first developed in response to the rapid, worldwide spread of grape phylloxera, *Daktulosphaira vitifoliae* (Hemiptera: Phylloxeridae), between the 1860s and 1880s (Fig. 13.1). The North American grapevine varieties, where phylloxera was native, were resistant to attack by the insect. However, the rest of the world predominantly planted European varieties, which were highly susceptible to phylloxera damage. Spread of the insect from its native range in North America to Europe resulted in widespread devastation of much of Europe's grape-growing regions, and then to those in the rest of the world. This led to agreements between countries to control its spread, with the first treaty in 1878 signed by Austria, France, Germany, Italy, Portugal, Spain and Switzerland (MacLeod *et al.*, 2010). This treaty included many of

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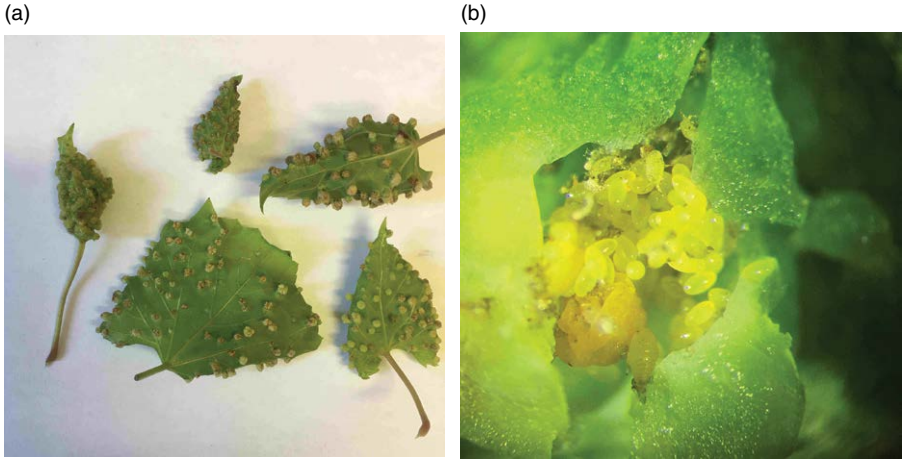


Fig. 13.1. A heavy infestation of grapevine phylloxera (*Daktulosphaira vitifoliae*) (Hemiptera: Phylloxeridae), showing **(a)** heavily galled leaves and **(b)** adults, crawlers and nymphs inside a gall. (Photographs provided by C. Kapp (Stellenbosch University).)

the principles still in practice today in international plant health, including the need for written assurance of pest-free status, prohibiting trade in certain high-risk materials and granting power to inspect incoming plant material.

Since then, these agreements have evolved and were formalised to culminate in the International Plant Protection Convention (IPPC), administered by the Food and Agriculture Organization (FAO) of the United Nations under the auspices of the World Trade Organization (WTO). The IPPC is an international treaty that sets out rules and standards for all transboundary movement of plants and plant products.

South Africa's history of plant biosecurity follows closely that of Europe. Following an outbreak of grape phylloxera in vineyards in the Cape Province in 1886, quarantine measures for all incoming rootstocks were introduced, and a quarantine station was established between Newlands and Rondebosch in Cape Town. As was the case globally, this formed the framework for plant quarantine procedures, first in South Africa and then in surrounding countries. When the IPPC was formed in 1951, South Africa became one of the first signatory members (Theyse, 2009).

Currently (2026), there are 185 member states (i.e. countries or independent territories) that are signatory to the IPPC and agree to abide by its legislation and standards (FAO-IPPC, 2022), including all nine southern African countries.

13.3 Phytosanitary Principles

According to the WTO, it is the right of all countries to protect their environment, agriculture and biodiversity as the State deems appropriate (Eschen *et al*., 2015). For international plant trade, the IPPC sets phytosanitary standards intended to form the basis of international cooperation in controlling the spread of

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any plant pest or pathogen. Phytosanitary protocols may differ between countries and between different commodities, as long as they fall within the standards set out by the IPPC (Eschen *et al.*, 2015). The IPPC guidelines for all phytosanitary matters are laid out in a series of publications, known as International Standards for Phytosanitary Measures (ISPMs). ISPMs are drawn up by scientific advisory panels, and each member state is entitled to make comments for changes before final adoption of the ISPM. New ISPMs and amendments are published as the need arises. Currently (2026) there are 46 ISPMs (FAO-IPPC, 2022), covering topics such as how to define and maintain pest-free zones, how to conduct phytosanitary inspections, and standards for treatment of wood packaging.

Countries belonging to the IPPC need to designate an organization to act as their National Plant Protection Organization (NPPO), which negotiates and implements all plant trade treaties and is the contact point for any international communication. The NPPO is responsible for implementation of phytosanitary actions within the country that may impact international trade, such as detection of new pests and prompt reporting of these to the international community. The details of each country's NPPO, as well as other phytosanitary and reporting information, can be found on the IPPC's website (https://www.ippc.int/en/countries/). African IPPC-member countries are represented by the Inter-African Phytosanitary Council (IAPSC), which is the continent's Regional Plant Protection Organization (RPPO). The IAPSC coordinates and provides support for plant protection activities within the African Union (https://auiapsc.org/).

Implementation of the IPPC's international standards can be challenging in Africa due to a lack of resources typically available to more developed nations. Due partially to its long coastline and large harbours, South Africa is the biggest importer and exporter of plants and plant products in southern Africa. For example, between 2011 and 2020, 44% of imports and 84% exports of fresh plant produce (termed 'vegetable' trade) in southern Africa came to or from South Africa[†] (World Bank, 2023). This puts South Africa in the unique position of acting as a 'filter' for goods travelling to or from neighbouring countries. As such, South Africa is an important stakeholder in plant biosecurity in the southern African region. This places a disproportionate amount of responsibility on South Africa to implement strong biosecurity and phytosanitary strategies to protect not only its own agriculture, but that of its neighbours as well.

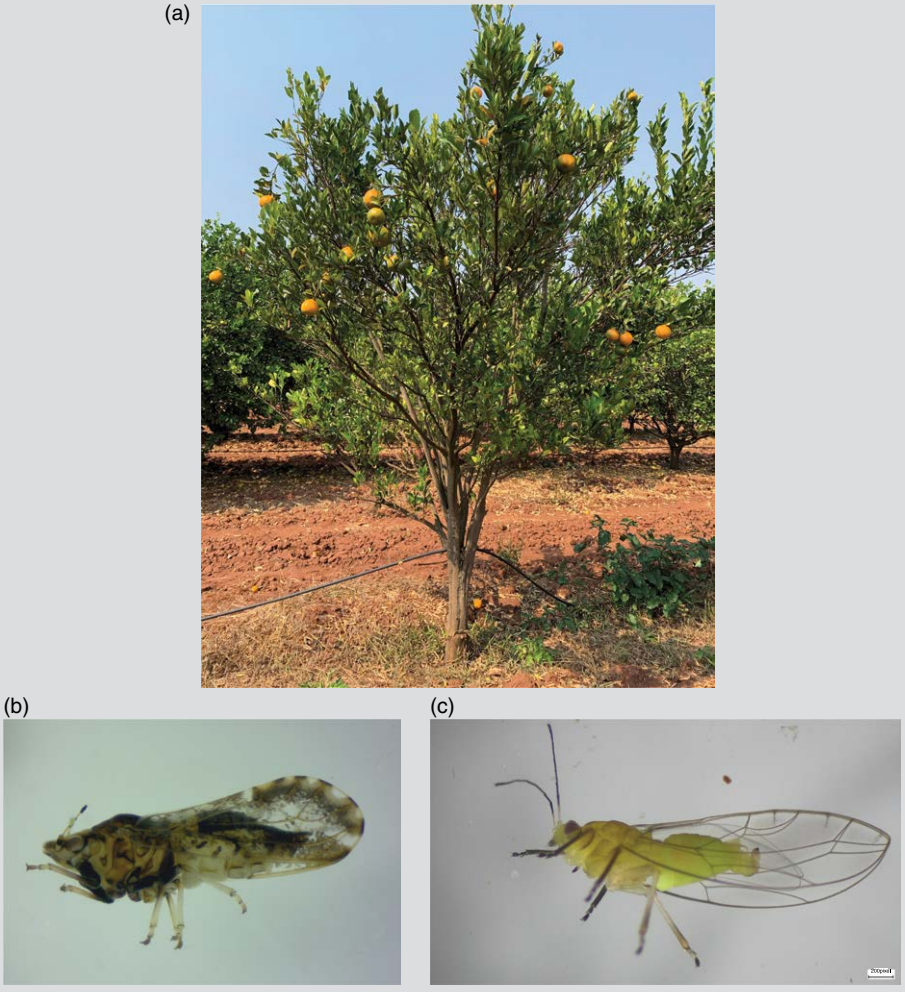
In the last decade, there have been increased calls for a regional approach to biosecurity in southern Africa (Faulkner *et al.*, 2020b). Much is being done by organizations across borders to further biosecurity cooperation in the region, such as the Forest Invasive Species Network for Africa (https://www.fao.org/forestry/fisna/en/), the Biosecurity Hub at the University of Pretoria (http://www.ia.up.ac.za/index.php/research-platforms/biosecurity-hub) and the citrus industry's HLB biosecurity action plan (see Box 13.1).

†For this comparison, we considered 'vegetable' imports and exports (which constitute most fresh plant produce) to or from South Africa, Lesotho, Eswatini, Mozambique, Zimbabwe, Botswana, Namibia, Angola and Zambia.

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Box 13.1. Asian Citrus Greening: Huanglongbing (HLB) and its vector, Asian Citrus Psyllid (ACP) *Diaphorina citri*

Huanglongbing (HLB), or Asian citrus greening, caused by the phloem-affecting bacterium '*Candidatus* Liberibacter asiaticus', is one of the most devastating diseases of citrus. Its main vector is the Asian citrus psyllid (ACP), *Diaphorina citri,* with the African citrus psyllid (ACT), *Trioza erytreae,* as a secondary vector. Symptoms include blotched mottling on the leaves and misshapen fruit, which colours prematurely from the stylar end and are bitter to taste. Affected trees will ultimately die (Box Fig. 13.1).



Box Fig. 13.1. Huanglongbing (HLB), '*Candidatus* Liberibacter asiaticus', causes greening of leaves and fruits, bitter-tasting fruit and eventually results in tree death **(a)**. HLB is vectored primarily by the Asian citrus psyllid (ACP), *Diaphorina citri* **(b)** and secondarily by the African citrus psyllid (ACT), *Trioza erytreae* **(c)**. (Photographs provided by W. Kirkman **(a)** and E. Mauda **(b,c)** (CRI).)

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Box 13.1. Continued.

In Africa, HLB was first detected in Ethiopia in 2009 (Saponari *et al*., 2010), and the presence of ACP was first confirmed in Tanzania in 2015 (Shimwela *et al*., 2016). Both vector and disease are spreading from these countries, and distribution models predict that much of east, central, western and sub-Saharan Africa has climates that are suitable for the establishment of this disease system (Ajene *et al*., 2020). Inevitably, HLB and ACP will reach citrus-producing regions in southern Africa, including the vast commercial production sites in South Africa (van Steenderen *et al*., 2024).

Since its detection in Africa, Citrus Research International (CRI), in consultation with world experts, has developed and implemented a multipronged ACP and HLB action plan in order to detect, delay and respond to the spread. This action plan includes identification of likely incursion pathways, and increased monitoring along these routes (van Steenderen *et al*., 2024). Additionally, the plan dictates responses based on various first detection scenarios, such as whether ACP or HLB is detected first, or both detected together; whether the detection is a point incursion or a natural range expansion and whether any trapped ACP carry HLB.

Concurrently, South Africa has developed an HLB-Safe System for citrus nurseries to ensure they remain HLB-free, even once the disease arrives in the country. This includes psyllid exclusion using netting and other structures, continual pest monitoring and control, and a strict 800 m citrus-free buffer-zone around HLB-Safe accredited nurseries.

13.4 Bilateral Trade Agreements

Bilateral trade negotiations may precede import or export **bilateral trade agreements** between countries. These trade agreements may include stipulations regarding the quantity and quality of the goods to be imported. For plant trade, the exporting country makes applications to the NPPO (or other representative organization) of the importing country for consideration of an agricultural commodity. This application usually includes information on the various pests and pathogens associated with the commodity, in the form of a pest and pathogen list. Information on the biology of the species, their distribution and pest status within the exporting country is given. This information is used by the importing country to conduct a pest risk analysis (PRA) (see section 13.5, this chapter) and respond with a list of pests of quarantine concern to them, as well as conditions for inclusion in a workplan or protocol to be agreed upon by both trading countries. The workplan or protocol constitutes the official procedures, including phytosanitary mitigation measures, which must be implemented to manage the risk of **quarantine pests** being introduced into new areas. The process of trade negotiations can be long and arduous, requiring visits and consultation with industry, biosecurity and government representatives in both countries. For example, the South African application to export apples to China was submitted in early 2003 but only officially signed in 2014, 11 years later (S. Johnson, personal observation), while that to export citrus to the Philippines was submitted in 2009 and the final bilateral protocol was signed in 2021, 12 years later (E. Carstens, personal observation).

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13.5 Pest Risk Analysis

Pest risk analyses (PRAs) are used to assess the risk an organism poses to a region, to determine whether actions are required to manage that risk and, if required, what these actions should be (Jamieson *et al*., 2022). There are four components to all risk analyses: i) hazard identification; ii) risk assessment; iii) risk management; and iv) risk communication (Kumschick *et al*., 2020a,b). The terms 'risk analysis' and 'risk assessment' are often used interchangeably, but a risk assessment is only one component of a full risk analysis (Roy *et al*., 2018; Kumschick *et al*., 2020a). PRAs underpin the regulation and pre-, at-, and post-border management of invasive organisms. They inform legislation by identifying which organisms should be regulated, provide justification for restrictions of trade and consumer activities, are used to identify priorities for surveillance and rapid response, and are used to communicate the risks posed to society (Saccaggi *et al*., 2016; Roy *et al*., 2018; Kumschick *et al*., 2020a).

The IPPC stipulates that countries have the right to set their own import conditions, including determining which pests are prohibited and which agricultural commodities are to be regulated (Eschen *et al*., 2015). These conditions must be based on science and international best practice (Eschen *et al*., 2015). A PRA is required by the IPPC as justification for any infringement of free trade (Eschen *et al*., 2015). Various factors can initiate a PRA. For example, importation of a new species for a specific purpose (e.g. research), importation from a new country or of a new commodity, or revision of existing import regulations, would all require a PRA to determine which organisms may be considered pests and what measures would be suitable to mitigate their risk (FAO-IPPC, 2019).

Because of their vital role in decision making, PRAs should be transparent, repeatable, reliable, robust, evidence-based, free of bias, and aligned with national and international agreements, policies and best practice (Kumschick *et al*., 2020b). To this end, the IPPC has developed an ISPM for compilation of PRAs as they relate to plant trade (FAO-IPPC, 2019), which sets out the information and questions that should be included in the PRA. However, this ISPM is not a detailed guide, and so different PRA schemes are implemented by different countries and applied in different ways (Eschen *et al*., 2015).

Most countries, including South Africa, use PRAs to draw up lists of plant pests prohibited from entering the country due to their unacceptably high level of risk. Another, sometimes complementary, approach is to place organisms that have been found to pose no risk on a 'permitted' list and only allow entry of these organisms (Hulme, 2006; Simberloff, 2006; Eschen *et al*., 2015). A PRA may also include measures suitable to mitigate the risk of an organism or pathway, and these would be stipulated in the protocol or workplan as a condition for import of that commodity (Eschen *et al*., 2015). If no measures are identified that would reduce the risk to an acceptable level, the commodity may be prohibited from entering the country (Eschen

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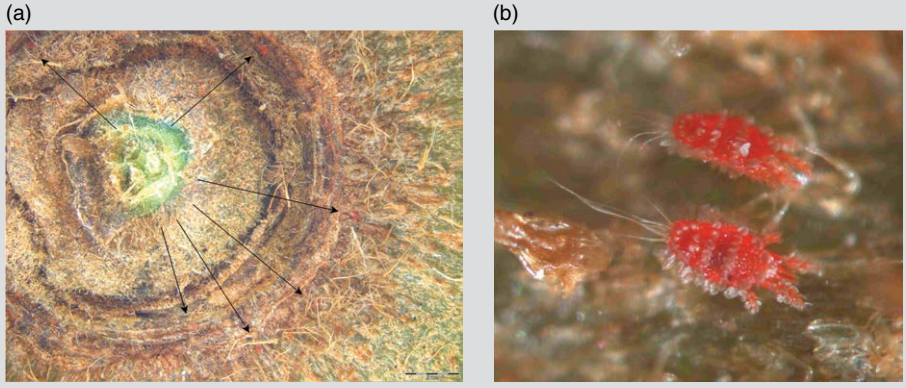
et al., 2015). Due to a lack of information on plant pests (e.g. taxonomy, distribution, impacts and introduction pathways), and resource limitations, prohibited pest lists are often incomplete. PRAs are often inconclusive, and many species have simply not been assessed (Saccaggi *et al.*, 2016). Therefore, unlisted species that have unknown quarantine status could pose a risk, but may still be permitted entry. Prohibited lists also need to be regularly revised and can become long and unwieldy (Hulme, 2006), as has been the case in South Africa (see section 13.6, this chapter). The permitted list approach could be used, but these lists are often too short to be useful and are still impacted by inconclusive PRAs (Hulme, 2006). Box 13.2 describes an example of how incomplete and changing information for PRAs and pest lists can impact trade.

Box 13.2. A tale of *Tuckerella*, Kiwifruit and Tea (from Saccaggi *et al.*, 2022)

In 2008, South Africa detected a *Tuckerella sp.* mite (at the time thought to be *Tuckerella flabellifera)* (Trombidiformes: Tuckerellidae) on kiwifruit imported from New Zealand (Box Fig. 13.2). All mites in this family are exclusively plant-feeding and polyphagous. Due to its unknown pest status, South Africa evoked the 'precautionary principle' and detained all subsequent kiwifruit imports from New Zealand pending laboratory confirmation that they were free of *T. flabellifera*. By 2010, this species had been added to the list of prohibited organisms on kiwifruit imports.

In response, New Zealand undertook research on the taxonomy and distribution of *T. flabellifera*. A report submitted to South Africa's NPPO concluded that kiwifruit was not a host for *T. flabellifera* and that it did not pose a biosecurity risk on this commodity (Zhang, 2011). Furthermore, the taxonomy and identification of *T. flabellifera* had been confused with that of *T. japonica*, which was a common pest of tea plants and was likely to be present in all countries where tea was grown (Beard *et al.*, 2013). Based on this evidence, South Africa removed *T. flabellifera* from the import requirements for kiwifruit, under the assumption that all previous interceptions were a misidentification of *T. japonica*.

Surveys were then undertaken to determine if *T. japonica* – which was supposedly cosmopolitan – did indeed occur on South African tea plantations. In 2014, a *Tuckerella* species



Box Fig. 13.2. *Tuckerella japonica* (at the time thought to be *T. flabellifera*) intercepted on kiwifruit: **(a)** the calyx of the kiwifruit, with arrows showing the location of the mites; and **(b)** a close-up of two mites. (Photographs provided by D. Saccaggi (CRI).)

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Box 13.2. Continued.

was collected from South African tea plantations, which was neither *T. japonica* nor *T. flabellifera*, but a new, undescribed species (Ueckermann, 2015).

Concurrently, with the new awareness of the close resemblance between *T. flabellifera* and *T. japonica*, South African scientists carefully examined all intercepted *Tuckerella* mites to be sure that they were not misidentified. In 2014 both species were intercepted together on a kiwifruit import, disproving the previous research that kiwi was not a host for *T. flabellifera*.

It is unclear what the host range of *T. flabellifera* is or whether *T. japonica* is present or not in South Africa, and the newly discovered *Tuckerella* species has not yet been given a name.

Currently, neither *T. flabellifera* nor *T. japonica* are prohibited organisms for South Africa.

This example emphasizes the need for ongoing research into the taxonomy and biology of pests to inform dynamic biosecurity decision making. Decisions are based on the best information available at the time, but it is important that decisions can change if new information becomes available.

13.6 Biosecurity in Practice

Biosecurity within the southern African region covers a number of aspects related to plant health, all with the goal of ensuring the continued economic viability of agricultural production. The measures applied fall into four main categories, all connected to agricultural plant production and trade. Firstly, preventing entry of foreign pests; secondly, detecting and eradicating new pests as quickly as possible; thirdly, managing and containing the spread of current pests within the region; and fourthly, ensuring that no pests are spread to other regions (CBD, 2002). These will be discussed in the sections below, with an emphasis on South Africa as an example.

13.6.1 Preventing entry of foreign pests

13.6.1.1 Pests in international trade

To minimize the risk of introduction of new pests and diseases via international trade, most countries impose import requirements on imported goods, such as the state of the goods (e.g. plant must be dormant), disinfestation treatments (e.g. pesticides) and border inspections. Countries typically rely heavily on border inspections to detect and reject illegal imports or those that contain pests (Saccaggi *et al*., 2016).

When goods arrive at the border, the first action taken is the inspection of these goods. In the case of illegally or unintentionally transported goods (e.g. fruit in passenger luggage), inspectors at the airports, seaports and land border posts randomly question and search incoming travellers and luggage for prohibited items. This action is intended to act more as a deterrent than a limiting measure in and of itself, as only a small percentage of incoming travellers can reasonably be inspected. Southern African countries have extremely limited capacity to police their borders (Saccaggi *et al*., personal observations),

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and the vast land borders between countries pose a particular problem with regard to regulating the arrival of food items that may contain pests (Faulkner *et al*., 2020a,b). The region has a large contingent of migrant workers who move regularly between neighbouring countries, making the task of inspection of incoming travellers particularly onerous. Prior to the detection of *Bactrocera dorsalis* (Diptera: Tephritidae) in South Africa in 2010 (see Box 13.3), an unofficial exemption was in place that allowed travellers to carry a limited number of food items (such as fruit or vegetables) for personal consumption. However, the detection of this pest highlighted the risks associated with transport of even a single infested fruit, and this practice has been stopped (Ramukhesa, 2018). Currently, no plant material of any kind is allowed to be transported across land borders without an import permit.

If, on border inspection, any of the specified standards are not met, including a prohibited pest/pathogen being present, then the consignment is considered 'non-compliant' and mitigation measures will be implemented (FAO-IPPC, 2001). Phytosanitary mitigation measures may range from treatment with a pesticide through to rejection or destruction of the consignment, depending on the severity of the non-compliance. South Africa strives to inspect 2% of any agricultural consignment entering the country, although this may vary depending on the risk associated with the commodity and the inspection capacity available at the time (Saccaggi *et al*., 2016, 2022).

Any phytosanitary mitigation measure applied (including rejection or destruction of the import) needs to be based on sound scientific principles if it is to fall within the legal framework of the IPPC. South Africa's agricultural import system is based on the Agricultural Pests Act of 1983 with many subsequent amendments (South African Government, 1983). Initially, this act formed the basis for a national list of prohibited species. However, as trade with the rest of the world increased, this single national list became increasingly cumbersome and was phased out by the end of the 1990s. At that stage, South Africa moved to a system of individual import conditions, whereby an import permit specific to each consignment was issued. Prohibited organisms could only be listed on the import conditions for a specific commodity if they were known to occur in the country of origin on that plant part and could cause environmental or economic damage. This allowed more focused import conditions and facilitated trade (Venter, 2019).

Unfortunately, this approach also resulted in loopholes in plant biosecurity protocols. For instance, if a pest was detected on a commodity for which it was not listed as a quarantine pest, there was limited legal recourse to prohibit the entry of that consignment. This could happen if a pest was overwintering on a non-host plant, or if it was detected on a consignment from a country where it wasn't yet reported as present (see Box 13.2 for a relevant example). Ironically, with an increasing range of commodities being imported, these individualized import conditions have become just as cumbersome, if not more so, than the original master list which they replaced. Currently, it is difficult, if not impossible, to ascertain if a particular organism is listed as a quarantine pest to South Africa, as each import condition would need to be checked individually (Saccaggi, personal observation).

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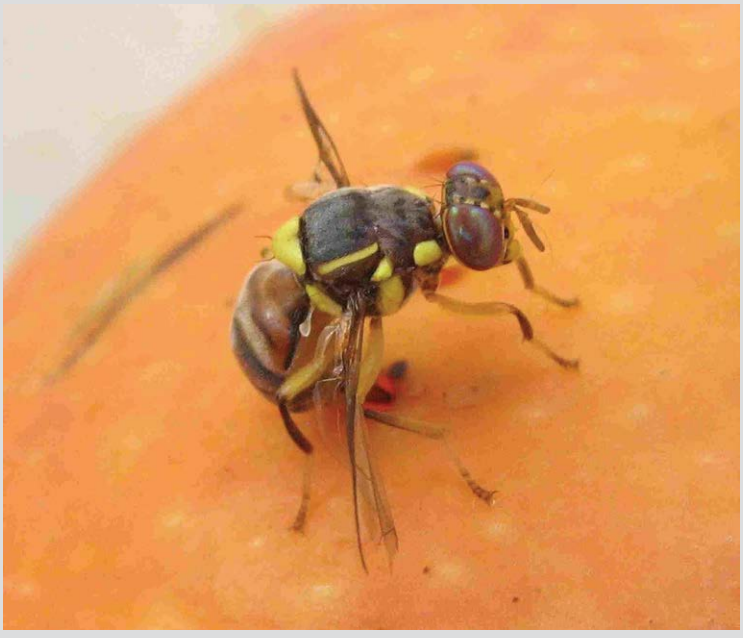
Box 13.3. The invasion of *Bactrocera dorsalis* in Africa and South Africa

Bactrocera dorsalis (Diptera: Tephritidae) is a fruit fly pest native to Asia, initially called *B. invadens* (Box Fig. 13.3). In Africa, it was first detected in Kenya in 2003 (Lux *et al*., 2003). After the first detection in Kenya, it spread quickly through African countries, including Tanzania, Benin, Uganda, Cameroon, Togo, Senegal, Ghana and Nigeria between 2003 and 2004 (Drew *et al*., 2005), Sudan in 2011 (Satti, 2011), and Zimbabwe and Mozambique in 2013 (José *et al*., 2013; Musasa *et al*., 2013).

In 2010, *B. dorsalis* was detected in South Africa near the Zimbabwean border (IPPC, 2010; Manrakhan *et al*., 2015), and an action plan for containment and extirpation was immediately drafted and implemented (Manrakhan *et al*., 2012). Early and strict application of this action plan contained the invasion of *B. dorsalis* to certain districts of Limpopo and Mpumalanga for six years, as well as slowed the spread to other provinces. It is currently present but under official control in Gauteng, KwaZulu-Natal, North West, Northern Cape and part of the Eastern Cape. It is absent from other provinces. Whenever *B. dorsalis* has been detected in new parts of the country, rapid delimitation and eradication efforts have followed.

Although extirpation was not always successful, it had a major impact on slowing the spread of the fly. Considering that between 2003 and 2010 (7 years) *B. dorsalis* spread almost 4000 km from Kenya to South Africa, its slow spread once it reached South African borders (approximately 1500km in 13 years) is considered a significant success.

All pest reports and notices of extirpation are published on the IPPC's website (https://www.ippc.int/en/countries/south-africa/pestreports).



Box Fig. 13.3. Oriental fruit fly, *Bactrocera dorsalis*. (Photograph provided by P. Stephen (CRI).)

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13.6.1.2 *Pests spreading from neighbouring countries and regions*

Entry of foreign pests can also be through the natural spread of the pest across land borders. Once new pests are established anywhere in Africa, it is often only a matter of time before they migrate to neighbouring countries. Thus, constant surveillance across the region, not only in each country, is critical if regional spread is to be controlled (Faulkner *et al*., 2020a,b). Countries have recognized the need for cooperation when dealing with agricultural pests and, thus, many NPPOs, researchers and companies work across borders in southern Africa (personal observation of all authors).

Collaborative projects aim to identify potential pest threats, monitor possible entry points of these pests and undertake national or regional surveys to monitor and contain their spread. An excellent example of such regional surveillance, cooperation and preparedness is the citrus industry's biosecurity action plan against Huanglongbing (HLB), '*Candidatus* Liberibacter asiaticus' (Jagoueix, Bové & Garnier) and its vector the Asian Citrus Psyllid (ACP), *Diaphorina citri* (Hemiptera: Psyllidae), along with South African legislation for control of these pests (South African Government, 2021) (Box 13.1).

13.6.2 Early detection and rapid response to new pests

Early detection of a new pest is of critical importance in biosecurity, and constant surveillance programmes should be in place to detect new pest incursions (FAO-IPPC, 2018). If detected early enough, it may be possible to eradicate a new pest population, or at least slow its rate of spread. If a new pest is detected within a country, it is the responsibility of the NPPO to immediately report that pest to the IPPC, regardless of the actions taken thereafter.

Southern African countries, and South Africa in particular, have a system of traps set up at high-risk sites and ports of entry to serve as an early warning for the incursion of specific quarantine pests. For instance, as part of its HLB Action Plan (Box 13.1), CRI and The Department of Agriculture jointly monitor more than 700 traps for ACP monthly. These traps are located in South Africa, Zimbabwe, Mozambique, Botswana and Eswatini, with traps concentrated in areas along the predicted incursion route (W. Kirkman and E. Carstens, personal observation).

The detection of a quarantine pest, whether in a dedicated trap, a routine survey or by chance, sets the wheels in motion to start a delimiting survey (FAO-IPPC, 2018) (see Chapter 3, this volume). This involves determining how far a pest has spread from the initial point of detection, using traps if possible and manual surveys if not. If another pest is detected in a trap or survey sample, this detection becomes the centre of another delimitation survey to narrow down the furthest location of spread. Sites are chosen to favour high-risk areas such as those where main or alternate hosts are present, or locations of packing facilities for the crop.

An example of a successful delimiting survey and action plan in South Africa is that taken when the Oriental fruit fly, *B. dorsalis*, was detected in 2010 in the Limpopo province near the border with Zimbabwe (Box 13.3). The detection was reported to the IPPC, and a delimiting survey

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and eradication programme were immediately undertaken, resulting in initially containing and then slowing the spread of *B. dorsalis* through South Africa. On the other hand, an example of a far less successful reaction to an introduced pest was that of polyphagous shot hole borer (Box 13.4).

Box 13.4. Polyphagous Shot Hole Borer (PSHB) – a pest that fell between the cracks

Euwallacea fornicatus, previously referred to as *Euwallacea* nr. *fornicatus* or *Euwallacea whitfordiodendrus*, the polyphagous shot hole borer (Coleoptera: Curculionidae: Scolytinae), was first reported in South Africa in the KwaZulu-Natal province in 2018 (Paap *et al*., 2018; IPPC, 2018), although present since at least 2012 when it was sampled in a DNA barcoding project (van Rooyen *et al*., 2021) (Box Fig. 13.4). The beetle has a symbiotic relationship with the fungus *Fusarium euwallaceae*, with the fungus usually killing the trees where reproduction of the beetle occurs. These trees are known as 'reproductive hosts'. The adult beetles bore into trees, creating galleries where they feed on the fungus, and where they lay their eggs and their larvae develop. Some trees are 'non-reproductive hosts'. The beetle attacks these trees, but the beetle does not reproduce. Only in some instances will the fungus introduced by the beetle cause disease in 'non-reproductive hosts', and these trees usually do not die. The beetle has since been detected in all provinces except Limpopo (Van Rooyen *et al*., 2021).



Box Fig. 13.4. The polyphagous shot hole borer (PSHB) on: **(a)** pecan nut tree, showing the beetle galleries with adults and larvae; and **(b)** London Plane tree, showing multiple entry holes and discharge from the tree. (Photographs courtesy of Forestry and Biotechnology Institute (FABI).)

Continued

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Box 13.4. Continued.

The PSHB has the biggest impact on ornamental trees such as oak, Chinese maple and boxelder, and the media has focused its reporting on the infestation and dying of these trees. However, the beetle could also impact agriculture, with avocado being the most susceptible agricultural crop (Paap *et al*., 2018, 2020). In early 2022, PSHB was detected in commercial pear orchards, but its long-term impact on deciduous fruit crops is unclear (Karsten, 2023).

Although detection of the PSHB should have elicited a rapid response, confusion as to which government department was responsible for its control led to critical delays in response (Paap *et al*., 2020). As the PSHB did not seem to pose a threat to agricultural crops at the time, its control was not the responsibility of the then Department of Agriculture, Forestry and Fisheries, but neither was it the responsibility of the then Department of Environmental Affairs, as the threat to native trees at the time was not yet proven. The biggest threat was to non-native trees in urban settings – historically, the responsibility of local municipalities. But without national government coordination and resources, local municipalities were unable to adequately deal with the problem. Measures to control the spread of the PSHB were only published in August 2021 as regulation R.725 (South African Government, 2025), and then only as regulations on agricultural crops, well after PSHB had been detected and after pest outbreaks in Johannesburg, George and Knysna (Paap *et al*., 2020). Legal regulations for PSHB relating to non-agricultural trees are still not finalized (Wilson, 2025).

By contrast, when PSHB was detected in Australia, a rapid response was initiated. Within a week of confirmation of the identity of the pest, there was a press release, the PSHB was added to an existing pest reporting app, and a webpage, phone number and email for PSHB sightings had been set up (Government of Western Australia, 2021; Paap, 2021).

13.6.3 Management and control of regulated pests already present

The focus of any pest management programme is to control pests so that they do not threaten the economic viability of the crop. For regulated pests, however, this management takes on a new focus as biosecurity concerns need to become part of the management programme. A regulated pest is one that is under official control in a country due to its regulatory status in exported goods. This regulatory status is defined by the destination country as quarantine (i.e. not present in that country) or regulated non-quarantine (present but represents an unacceptable risk in a particular commodity) (FAO-IPPC, 2021). A regulated pest is usually restricted to certain areas within a country and is intensively managed to minimize its presence in exported products.

Regulated pests are often controlled by designating pest-present and pest-free zones and prohibiting movement of host crops between these zones. For instance, in South Africa, permanent control measures are in place restricting the movement of citrus propagation material within the country due to the risk of spreading Citrus Black Spot (*Phyllosticta citricarpa*, Fungi: Botryosphaeriaceae), African citrus greening (*Candidatus* 'Liberibacter africanus', Bacteria: Phyllobacteriaceae) and its vector the African citrus psyllid (*Trioza erytreae*, Sternorrhyncha: Triozidae) (South African Government, 1983, 2022). Other restrictions have been put in place temporarily as needed to contain the

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spread of newly introduced pests, as was the case with *B. dorsalis* (Manrakhan *et al*., 2015) (Box 13.3). In South Africa, these measures are regulated by the Agricultural Pests Act and amendments regarding the movement of restricted goods (South African Government, 1983, 2022).

13.6.4 Prevent export of pests

Phytosanitary regulations are implemented with the intention of managing regulated pests and preventing their transport in exported goods. It is essential that all organizations involved in the export of agricultural products work together and adhere to these regulations, including growers, packhouses, shipping operators, industry bodies and government departments. Lack of adherence to regulations leads to pests being present in shipments, which ultimately leads to a loss of export markets.

Generally, the first requirement for a producer to be included in an export programme is for each participating orchard to be registered with the exporting country's NPPO and then approved by the NPPOs of both trading partners. The importing country may send inspectors before trade agreements are signed and sometimes may continue with inspections during the export season to assist with pre-border inspections. Packhouses and cold storage facilities must also be registered to be included in respective export markets. Registration of orchards, packhouses and storage facilities ensures accurate traceability of export fruit back to its origin should any non-compliance to protocols or workplans be detected.

The protocol for export may stipulate requirements for orchard management and the implementation of good agricultural practices, including specific mitigation measures for pests of quarantine importance, such as postharvest treatment, if necessary (e.g. cold sterilization treatments or irradiation; see Chapter 5, this volume), and measures to be applied during processing and packaging in the packhouse. If necessary, pre-export inspection sample size is stipulated, and some protocols allow for a reduction in the sample size if no phytosanitary problems are detected in the first two years of trade. After pre-export inspection, a phytosanitary certificate is issued indicating that an inspection was done, no quarantine pests were found and postharvest treatment was applied or will be conducted in transit. Lastly, the approved ports of entry are listed and inspection procedures at entry ports are stipulated.

Preharvest control refers to pest management during the growing season. This can follow the producer's normal pest management programme, or it may specify monitoring protocols, approved chemical applications, or thresholds for specific pests of quarantine concern. Thresholds for quarantine pest numbers are typically very low in these systems and may be difficult – if not impossible – to achieve via Integrated Pest Management (IPM)-friendly strategies such as cultural practices or biological control (see Chapters 2, 3, 4, 5, 6, 7 and 9, this volume). Thus, exported commodities often require additional chemical interventions to keep pest populations below the stipulated thresholds, and it may be challenging for farmers to maintain an IPM system on these crops.

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Postharvest control and mitigation measures are aimed at preventing infestation after harvest, during sorting in the packing line and to control pests that may not have been detected during initial inspection. Internal fruit-feeding pests (e.g. tephritid (fruit fly) or lepidopteran (moth) larvae) or pests that crawl into cavities in fruit (e.g. mealybugs or hemipterans) can be difficult to detect during visual inspections and require additional measures to safeguard trading partners. A wide range of postharvest treatments exist, ranging from thermal treatments (heat and cold), modified atmosphere, fumigation treatments or irradiation (see Chapter 5, this volume for details). The development of approved postharvest treatments requires large-scale trials in which the most tolerant life stage of the pest occurring on or in the commodity is targeted, and treatment efficacy is proven. Treatment efficacy equates to quarantine security with regard to the risk of establishment of a new invasive pest. In many cases, the importing country requires a 'probit 9' level of efficacy, i.e. zero survivors from 100,000 treated individuals at a statistical assurance of 95%.

Once a consignment is received in the importing country, inspections are done to confirm if the goods meet the specified standards, including having no phytosanitary pests present (see section 13.6.1, this chapter). Detection of a pest in these inspections can result in severe consequences for further trade between the countries.

Sometimes these components of control are combined into a formal 'systems approach' for exported goods. A systems approach relies on multiple independent risk-reduction strategies to cumulatively provide quarantine security. These strategies are implemented at different times in the growth, packing, shipment and delivery of the goods. Although systems approaches are more difficult to manage than standalone postharvest treatments, with a good understanding of the pest and host biology and how they relate to each other, systems approaches provide better protection against pests than any one strategy alone. The ISPMs provide standards for the adoption and implementation of a systems approach (FAO-IPPC, 2017). An example of a comprehensive systems approach adopted in southern Africa is the citrus industry's management approach for false codling moth (*Thaumatotibia leucotreta*, Lepidoptera: Tortricidae), which includes registration of orchards, pest monitoring throughout the season, pre-export inspection of fruit, specified risk levels, different export options depending on results of monitoring and inspections, and changes communicated and implemented as needed (Hattingh *et al.*, 2020).

13.7 Future Considerations for Biosecurity in Southern Africa

As is the case all over the world, southern Africa's current biosecurity systems are ill-equipped to respond to increasing globalization and trade. Unfortunately, biosecurity systems are difficult to assess (see section 13.1, Introduction, this chapter), and therefore current gaps or possible improvements are hard to identify or address (Saccaggi *et al*., 2016, 2022; Dodd *et al.*, 2020). It is clear, however, that a more nuanced approach is needed, rather than simply continuing to apply the same systems to larger volumes. Better risk profiling is needed

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so that high-risk taxa and introduction pathways can be identified and prioritized (Colunga-Garcia *et al*., 2013; Faulkner *et al*., 2014; Novoa *et al*., 2020; Saccaggi *et al*., 2022). Associated sciences need to be pursued to improve biosecurity, pest risk analyses, pest management and pest detection methods (Faulkner *et al*., 2014; Saccaggi *et al*., 2016; Kim *et al*., 2019; Measey *et al*., 2019; Jamieson *et al*., 2022). Further research is required to improve information on the distribution, biology, taxonomy and identification of pests, which in turn will improve the accuracy of PRAs.

A major future challenge for biosecurity within Africa is the introduction of the African Continental Trade Free Area (AfCTFA). This is a free trade zone within Africa, similar to that of the European Union (EU), where goods and travellers are only subject to biosecurity checks upon entry to the zone and thereafter are free to move unrestricted. In biosecurity terms, this would mean that the security of the entire zone will be compromised should one entry point be lacking in its biosecurity protocols (Faulkner *et al*., 2020b). Alternatively, AfCTFA may prompt growth of regional biosecurity systems, rather than those at a national level. This would enable better sharing of resources and information across the entire region to prevent the initial entry of a pest, rather than trying to control its subsequent spread across land borders (Faulkner *et al*., 2020b).

In the future, clear and consistently implemented biosecurity regulations and cooperation between African countries is likely to be more important than ever as the world and Africa become increasingly interconnected.

13.8 Conclusions

Agricultural biosecurity comprises all aspects of managing the economic and environmental risks posed by pest species. This includes preventing the entry of new pests in agricultural trade, surveillance and early response to new pests and the management of existing pests to ensure they are not present in exported goods. Each country is individually responsible for biosecurity implementation, but regional cooperation is encouraged. Where such regional cooperation has been applied, improvements in pest management and prevention have been evident (e.g. the biosecurity action plan for HLB, Box 13.1, this chapter).

13.9 Take-home Message

- Biosecurity is the practice of managing risks posed by biological organisms. In agricultural trade, biosecurity is used to prevent the entry or movement of new pests to or within a region. Biosecurity practices can be focused pre-border, at-border or post-border.
- International plant trade is governed by the IPPC and published ISPMs set guidelines and standards for best practice in plant biosecurity.
- Biosecurity is a joint responsibility between trading partners. It consists of managing pests in the exporting country, phytosanitary protocols and

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inspections of traded goods and pest surveillance including detection and reporting strategies in both countries.
- Future biosecurity within southern Africa should focus more on regional cooperation. This should include biosecurity protocols, such as pest surveillance and detection programmes, as well as sharing of research and expertise to protect the entire region.

13.10 Future Directions

Biosecurity is increasingly recognized as an integrated system, reaching from production, through harvest, packaging, export, distribution and consumption. It can no longer be viewed as a stand-alone border-protection measure, but rather as a system-wide global approach. Real-time data sharing, risk-based analyses and targeted decision making are critical to this change. Rather than a 'one-size-fits-all' approach, future biosecurity should look to the integration of technological advances, data interpretation and risk-based statistics to streamline biosecurity systems suitable for each pathway (Australian Government, 2021).

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