Chapter 6
The Biosecurity Continuum and Trade: Border Operations

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6.1 Introduction

With the advent of rapid transport systems, regulatory officials have seen a significant expansion in the international movement of plants and plant products from their centres of origin. The world's human population is predicted to rise to nine billion people by 2050 (Anon 2009a). Almost twice the current amount of food will be required to feed the world's population. Since many countries cannot support their current populations, international exchange of plants and plant products will inevitably increase substantially. The large-scale international transfer of plants and plant products has provided pathways for rapid, long-distance movement for many plant pests including invertebrates, weeds, and microorganisms (bacteria, fungi, and viruses). When new pests are introduced into areas where they did not previously exist, we see a significant potential for severe negative ecological, economic and aesthetic/social impacts. Introduced pests may arrive without antagonistic factors; competitive species that kept a pest in check in its original environment (or a pest relatively unimportant in its original habitat) may find another country's environment and flora more suitable and flourish to pest proportions. Endemic host species that have evolved in the absence of the introduced pest typically do not have the

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opportunity to develop resistance against the pest making them more vulnerable to attack. The converse is also true: Endemic pests can infect and damage newly introduced crops. Modern agricultural systems essentially evolved from 8 to 9 world centres of genetic sources (Harlan 1971). Modern (necessary and unnatural) intensive cultivation of genetically uniform monocultures frequently promotes damaging pest epidemics (Jones 2009).

Plant pests have played an important role in human history with some of the worst plant pest epidemics occurring as a result of entry and establishment of an exotic pest. Ancient Greeks and Romans had unpleasant experiences with plant diseases, particularly red rust of wheat. The Romans held an annual feast (the Robigalia) during which they would offer wine, burn incense and sacrifice a red dog to avert danger to the crops. The mass hallucinations in the Middle Ages, Joan of Arc's visions and the Salem witch-hunts may have been caused by the Ergot fungus (*Claviceps purpurea* (Fr.) Tul.) that attacked cereals such as rye and contaminated bread with LSD-like substances (Agrios 2005). The Irish potato famine of the 1840s was caused by the fungus *Phytophthora infestans* (Mont.) de Bary. The fungus found the mild, moist climate of Ireland more conducive than the cold arid mountain peaks of its homeland in South America. The fungus led to the starvation and death of more than 1.5 million Irish and caused the emigration of about the same number to the USA (Agrios 2005). Today about $1 billion per year is spent on fungicides to control the disease in the USA, Europe and developing countries (Forbes and Lizarraga 2010). The English are renowned tea drinkers, largely as a result of a plant disease, Coffee Rust (*Hemilia vastatrix* Berk. & Broome), which destroyed the colonial coffee plantations in Ceylon (Sri Lanka) in 1875. Coffee Rust forced the replacement of coffee with resistant tea plantations. The introduction of the Chestnut Blight fungus (*Cryphonectria parasitica* (Murrill) Barr) on imported lumber or live planting material from Asia in 1904 had a momentous impact on the natural flora of North America. Within 35 years the fungus destroyed 3.4 billion chestnut trees and by 1940, mature American Chestnut trees were virtually eliminated by this disease (Sect. 8.2.1; Agrios 2005).

An example of the introduction of an extremely damaging plant pest is the Gypsy Moth *Lymantria dispar* (Linnaeus). The USDA spends about US $12 million annually trying to slow its spread (Lodge et al. 2009). Gypsy Moth (GM) is an exceptionally damaging pest of hardwood forests and ornamental shade trees. Amateur Entomologist Leopold Trouvelot introduced it from France into Massachusetts in 1868/1869. Trouvelot was attempting to mate the moths with silkworms but they escaped from his house. Despite efforts to control GM, caterpillars have defoliated an estimated $>34 \times 10^6$ ha of hardwood forests in the USA since 1924.

Gypsy Moth continues to expand its range south and westward, predominantly by larval dispersal on wind currents and human-assisted movement of life stages such as egg masses on shipping vessels and cargo. Still, management costs would be far greater if the Asian biotype of *L. dispar* (AGM) became established in North America. European Gypsy Moth (EGM) females are flightless; AGM females can sustain flight up to 100 km (Rozkhov and Vasilyeva 1982). Also, AGM has a broader host range, with larvae feeding on over 600 species of plants (Baranchikov 1989). Multiple introductions of AGM into North America have occurred over recent decades with egg masses on ships and cargo arriving from ports in the

Russian Far East and Japan. All of these were subjected to aggressive eradication programmes and AGM has been prevented from establishing. Many countries maintain strict phytosanitary measures to minimise the risk of AGM entry including inspection and certification of vessels that visited high risk ports during the moth's flight season and inspection and trapping arrangements to monitor port areas.

Another notable introduction into the USA has been the Asian Longhorn Beetle (*Anoplophora glabripennis* (Motschulsky)), a polyphagous pest of healthy hardwood trees (Chap. 16). The beetle was first discovered in Brooklyn, New York in 1996 damaging Norway Maple trees and was probably introduced with solid wood packing material from China (Smith et al. 2001). Nowak et al. (2001) estimate the maximum potential urban impact of this pest in the USA is a loss of nearly 35 % of total canopy cover including 30 % tree mortality (1.2 billion trees) with a value loss of $669 billion.

The global ecological and economic impact of exotic plant pests on plant health is staggering. Today, conservative estimates suggest that plant pests (including pathogens, invertebrates and weeds) together annually destroy or impact 31–42 % of all crops produced worldwide (Agrios 2005). The total annual worldwide crop loss from plant diseases is about $220 billion. Roughly $38 billion is spent annually on pesticides (including fungicides, insecticides and herbicides) in Europe and the USA to control plant pests. Despite these control measures in the USA each year, crops worth $9.1 billion are lost to diseases, $7.7 billion to invertebrates and $6.2 billion to weeds (Agrios 2005). An additional 6–12 % of crop production is lost to post-harvest diseases. The losses are usually highest in developing countries; typically in areas where people are most in need of food. Consequently, measures that prevent or minimise the entry of plant pests are extremely important for the protection of a country's economic and social well-being.

An effective biosecurity management system is essential to support and protect primary agricultural producers and natural ecosystems from the entry of regulated pests[1]. Many plant pests capable of causing significant damage have not yet established around the globe. A robust border operation system is a primary component of a successful biosecurity strategy.

In Australia, New Zealand and USA, border operations provide two principal functions as part of the biosecurity continuum, viz. import regulations and export certification. Both functions are intimately linked as they rely on each other to achieve interdependent and synergistic outcomes. This chapter summarizes various phytosanitary risks associated with trade in plants and plant products and reviews the pathways and risk mitigation systems employed by border agencies in managing these risks. The chapter concludes with a brief discussion on the involvement of border agencies regarding exporting plants and plant products.

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[1] The International Plant Protection Convention (IPPC) defines a regulated pest as a quarantine pest or a regulated non-quarantine pest. The term '*quarantine pest*' incorporates the threat posed by insect pests, plant diseases and weeds as 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*' (ISPM 5 2009). A non-regulated pest is a pest whose presence in plants for planting affects the intended use of those plants with an economically unacceptable impact and which is therefore regulated within the territory of the importing contracting party (ISPM 5 2009).

6.2 Brief History of Plant Quarantine

The term "quarantine" is derived from the Latin word 'quarantum' (Italian 'quarantina') meaning "forty." Quarantine originally referred to the period of detention for ships arriving from countries after the *Black Death* reached Europe in 1347 (Morschel 1971). An isolation period of 40 days was applied to ships and their travellers to allow latent cases of the disease to develop before anyone was permitted to land. In many ways, the same concept still applies for imports of animals and plants today. During the early development of phytosanitary systems, the focus was on protection of human health from Bubonic Plague, Cholera and Small Pox. During the early and mid-twentieth century, focus extended to domestic animals and plants. Historically, we see a tendency to have a stronger focus on animal quarantine issues. This has been due to the small number of economically important domesticated-animal species; the dramatic impact exotic diseases can have on these animal host and the emotive response from the community compared with plant diseases. Most countries with advanced agricultural industries now have well-developed border operations in place. These operations are supported by appropriate legislative powers, which enable phytosanitary regulators to manage the risks posed by imported plants and plant products.

Today, the terms 'phytosanitary', 'plant quarantine' or 'plant protection' cover legislative and regulatory measures and associated activities designed to minimise the entry and spread of phytosanitary pests. One of the earliest plant phytosanitary laws was passed in 1873 in Germany with the prohibition of plants and plant products from the USA to prevent the introduction of Colorado Potato Beetle (*Leptinotarsa decemlineata* Say). In the USA, the first plant phytosanitary measure was introduced in 1891 when California established an inspection depot at the seaport of San Pedro (Mathys and Baker 1980). The Federal Plant Quarantine legislation was enacted during 1912. The National Plant Protection Organisation (NPPO) for the USA is the Plant Protection and Quarantine (PPQ) programme within the USDA Animal and Plant Health Inspection Service (APHIS). In Australia, plant phytosanitary regulations first came into operation on 1 July 1909 following introduction of the Quarantine Act during 1908. The Act still forms the basis of current phytosanitary regulations.

In New Zealand, the Biosecurity Act (1993) currently provides the legal basis for excluding, eradicating and managing regulated pests. However, there has been a long history of phytosanitary regulation. In 1884, the Codling Moth Act was passed after an outbreak of the moth threatened fruit production. This was followed by the Orchard and Garden Pests Act (1896) and in 1897 the government prohibited importation of plants and fruit infested by Codling Moth, scale insects or Queensland Fruit Fly and grapevine cuttings infected by *Phylloxera* sp. The Department of Agriculture administered the 1896 Act and began inspecting imported fruit and plants at principal ports in the 1890s. As well as complying with regulatory requirements of the importing country, other international agreements (including the Convention for International Trade in Endangered Species of Wild Fauna and Flora, CITES) must be complied with to protect species threatened by excessive commercial exploitation. Additional information on CITES can be obtained at: http://www.cites.org.

6.3 Objective and Principles of a Phytosanitary Regulatory System

The objective of a phytosanitary import regulatory system is to implement appropriate regulations to facilitate trade in plants and plant products in the least "trade restrictive" manner while minimising the introduction of regulated pests (Chap. 2). Phytosanitary systems consist of two components: (1) A legal framework covering the legislation, regulations and procedures; and (2) An official organisation responsible for delivery of services in compliance with international obligations (ISPM 20 2004). Some legislative powers required by regulatory agencies include: (1) Authority to enter premises where imported commodities or regulated pests may be present. (2) Power to detain, inspect, treat or test regulated articles. (3) Authority to destroy or re-export regulated goods. Typically, border agencies employ their own officers to operate the import regulatory system. Also, other government organisations, industry groups or individuals may be authorized to carry out defined functions on its behalf and under its control.

To be fully effective, a country's border programme must be coordinated on a national level and developed with consistency, transparency and scientifically justifiable policies that meet national and international regulations. Countries manage phytosanitary risks associated with plants and plant products in different ways, but the principles (as enumerated by Morschel 1971) are more-or-less the same:

1. Phytosanitary pest risks associated with imported goods and pathways are identified based on sound and transparent scientific analysis;
2. Risk mitigation strategies that minimise the entry and establishment of pests are least trade-restrictive and consistent with international agreements;
3. Appropriate legislation and regulations are developed and passed by the appropriate governing authority, regulations and usually promulgated by the National Plant Protection Organisation (NPPO); and
4. Regulations are reviewed and modified in response to changed pest status or extended to include other risk commodities or new hosts.

The Food and Agriculture Organisation (FAO) has developed a detailed explanation of the principles associated with the application of phytosanitary measures for international trade (ISPM 1 2006).

The principle agreement governing international movement of plant pests is the International Plant Protection Convention (IPPC) (see Sect. 2.2.3). The agreement prevents international movement and introduction of invasive pests and promotes appropriate measures for their control. The scope of the IPPC extends to protection of natural flora and covers direct and indirect damage by pests.

Countries cannot implement a "no risk" phytosanitary policy because the only no risk policy is a "no trade/tourist" policy, which is indefensible. Also, natural risk pathways (which cannot be managed) present a route for entry of exotic pests. The best a country can do regarding phytosanitary measures is to implement a "risk managed" approach and implement controls at pathways designed to reduce risks to an 'appropriate level of protection' (ALOP) also referred to as "the acceptable level of risk". The concept of ALOP for phytosanitary purposes is the level of protection a country decides is necessary to protect its plant health against the harmful effects of exotic pests. Where the risks of pests are above the ALOP, importing countries may require the application of measures to reduce the risks to specified and acceptable levels. Measures may include treatments, inspection and other procedures intended to reduce the pest risks (Sect. 2.2.5). In choosing and applying measures, a country must follow the IPPC principles of necessity, equivalence and harmonization. Although prohibition or total ban of trade will reduce the pest risks, this action may encourage people to deliberately bypass quarantine or smuggle products into the country thus bypassing managed systems and potentially creating a greater biosecurity risk. Further, prohibition of trade goes against international efforts to liberalise trade using the least trade restrictive measures. Restriction could result in retaliatory action by trading partners. As a consequence, international efforts established the World Trade Organisation (WTO) Agreement on the Application of Sanitary and Phytosanitary Measures (the SPS Agreement) to ensure that exchange in agriculture and food products is not impeded by trade barriers disguised as phytosanitary measures (WTO 1994; Sect. 2.2).

6.4 Role of a Phytosanitary Inspector

Phytosanitary inspectors examine and clear imported goods including plants and plant products, vessels, international mail, passengers and their baggage. Phytosanitary inspectors may be located at the main border entry points including airports, seaports, border road crossings, mail centres, cargo depots and post-entry plant quarantine facilities. Phytosanitary inspectors have a considerable responsibility as their decisions can influence the potential entry of pests and diseases. On a daily basis, inspectors decide whether a consignment or a passenger's goods meet the phytosanitary regulations of the country or whether further intervention and treatment is required. To carry out this task effectively, a phytosanitary inspector must have the ability to recognise diverse regulated articles, a basic knowledge of plant health and the main regulated pests of concern.

Inspectors must be familiar with the inspection techniques and the seizure, release and treatment of goods in the event a regulated pest is detected. Phytosanitary inspectors must have a comprehensive knowledge of the relevant national phytosanitary regulations and policies and understand their powers and limitations under the legislation. A high level of integrity and well-developed customer service skills are other desirable attributes; inspectors must be friendly and polite to members of the public while enforcing appropriate regulations. The regulations can sometimes be confusing to people, particularly for tired passengers that have travelled long distances from foreign countries and are unfamiliar with phytosanitary procedures.

Another role of a phytosanitary inspector involves issuing certificates for exported plant products. Officers should have a sound knowledge of local pests that may be of concern for the importing country.

6.5 Phytosanitary Risk Products

Imported plants and plant products (including live plants, seeds, plant produce, timber and soil) along with their associated packaging present a phytosanitary risk because they can be infected with or have the capacity to transmit or carry exotic plant pests.

Invertebrate pests have potential to directly damage plants and vector significant plant pathogens, particularly plant viruses. Insect vectors that transmit pathogens for a short time (hours) pose a lower biosecurity risk compared with vectors that persistently transmit pathogens for weeks or longer (Purcell and Almeida 2005). A pest's reproductive cycle can also influence invasion risk. For instance, parthenogenic (asexual) female insects can produce progeny without a male partner. Thus if a single female is introduced, then she could potentially generate a large pest population. Vectors (nematodes, aphids, thrips, mites, leaf hoppers, white flies, mealybugs and beetles) are targeted by border agencies even when these organisms are present in the importing country due to the risk of transmission of phytosanitary disease agents. A brief description of phytosanitary risk groups is provided below.

6.5.1 Live Plants

Imported live plants, often referred to as 'nursery stock' by phytosanitary agencies, consist of entire plants or parts of plants imported for growing purposes. Nursery stock includes cuttings, budwood, roots, bulbs, corms, rhizomes and tissue culture plantlets. (Seeds are considered separately below.) Live plants present the highest plant phytosanitary risk because they are an ideal vehicle for introducing regulated pests as well as being a potential weed threat. Because propagation is the primary objective of exchanging live plants, the chances of establishment and distribution of a pest is more likely given the availability of a suitable host to complete their lifecycle.

In addition to posing a risk of introducing exotic plant pests, live plants are now recognised as potential phytosanitary pests (i.e. weeds) in their own right. Introduced plants can quickly colonise a new environment. Without natural competitive forces, introduced plants can displace native plants, clog waterways and compete with cultivated crops for nutrients, water and light. Worldwide, weeds are estimated to cause crop losses worth nearly $150 billion annually (Agrios 2005; Chap. 20). An example of the potential damage an introduced plant can have on a natural ecosystem is demonstrated by the Prickly Pear Cactus (*Optunia inermis* de Candolle), introduced into Australia from South America in 1839. The cactus readily adapted to the arid conditions of Australia and rapidly displaced more than 24 million ha of native vegetation. The introduced weed was expanding at a rate of 400,000 ha per year until the moth *Cactoblastis cactorum* (Berg) was introduced in 1925, initiating one of the world's most successful biological control programmes (Kwong 2004). Many National Plant Protection Organisations (NPPOs, Regulatory Agencies) now require comprehensive Weed Risk Assessments (WRA) as part of the import conditions for new plant species to ensure the introduced plant does not itself become a phytosanitary pest. Detailed information about the WRA system used by Australia's border agency is available at: www.daff.gov.au/ba/reviews/weeds.

6.5.2 Seed and Grain

Due to their hardiness and durability, seed and grain have been internationally exchanged across borders for thousands of years (Chap. 5). The phytosanitary risks of seed and grain vary depending on the species, country of import and type of introduction. The end use is an additional factor considered by the NPPO; seed and grain imported for sowing and propagation present a higher biosecurity risk compared with seed imported for processing and consumption because typically the product will be processed or treated in such a way that reduces the viability of the seed and/or removes pests that may be present. Seeds of numerous species, including many flower and vegetable seeds, present a low phytosanitary risk because they are not hosts of significant phytosanitary pests and can be safely imported with no or only minimal phytosanitary intervention. This is expected given the long history and established trade in seed and grain between many trading partners. Long-established trade has presented numerous opportunities for pests to establish. Nevertheless, many serious pest risks are associated with seed and grain that have limited worldwide distribution. Examples include Khapra Beetle (*Trogoderma granarium* Everts), Karnal Bunt (*Tilletia indica* Mitra), Greater Grain Borer (*Prostephanus truncatus* (Horn)) and Sunflower Downy Mildew (*Plasmopara halstedii* (Farlow) Berlese & de Toni). Hosts of these species are restricted by some border agencies and require strict phytosanitary intervention measures.

6.5.3 Timber and Wooden Products

Timber and wooden products including solid wood packaging material (skids, flooring, pallets and dunnage), logs, woodchips, sawn timber and manufactured wooden products present a phytosanitary risk as they may be infested with a range of significant pests. Decayed and damaged timber is often used in dunnage and solid wood packaging; this material presents an ideal environment for pest infestation. Excessive bark on timber and wooden packaging further increases the potential risks because many insects and fungal pathogens readily inhabit the microclimate created by the bark. Many timber pests feed internally, revealing little or no evidence of their presence until they mature and emerge from their host many months or years later.

Many timber insects are cryptic and many timber and wood-inhabiting insects have been inadvertently transported around the globe in solid wood packaging. Mattson et al. (1994) estimated that more than 368 alien phytophagous insect species occur in American forest systems. Many of these invasive pests may have entered on wooden packaging material although the exact mode of entry is unknown (Haack et al. 2007). In the USA, the Asian Longhorn Beetle (*Anoplophora glabripennis* (Motschulksy)) (Chap. 16) and Emerald Ash Borer (*Agrilus planipennis* Fairmaire) are both suspected to have been introduced on wood packaging accompanying goods imported from Asia (http://www.asian-longhorned-beetle.com/ and http://www.emeraldashborer.info/). Both pests damage forest trees in the same way with their larvae feeding on the inner bark of the tree, thereby disrupting the tree's ability to transport water and nutrients. Asian Longhorned Beetle poses a serious threat to many species of deciduous hardwood trees and phytosanitary controls have been established around infested areas in the USA resulting in the removal of many thousands of infested trees. Emerald Ash Borer has killed more than 50 million ash trees and threatens most of the ash trees throughout North America (Kovacs et al. 2010).

Many plant pathogens can be transported in timber either directly or associated with insect vectors. Some of the more important plant pathogen risks include Chestnut Blight (*Cryphonectria parasitica* (Murrill) Barr), Sudden Oak Death (*Phytophthora ramorum* Werres et al.) and Pine Wilt Nematode (*Bursaphelenchus xylophilus* (Steiner & Buhrer) Nickle). During 2004 in Australia, spores of Guava Rust (*Puccinia psidii* Winter) were found associated with a shipment of eucalyptus timber imported from South America. This interception resulted in the suspension of all timber imports from countries where Guava Rust is present (Lawson 2007).

Newly manufactured plywood, veneer or reconstituted wood products such as particleboard, chipboard, medium and high-density fibreboard generally present minimal phytosanitary concerns. These products are highly processed and unlikely to be hosts of phytosanitary pests or diseases.

6.5.4 Fresh and Dried Plant Products

Fresh plant products may include fresh fruit, vegetables, cut flowers, herbs and spices intended for consumption but not for planting or growing. Given the perishable nature of fresh plant products, they generally pose a lower phytosanitary risk compared with live plants and seeds. Significant phytosanitary risks still may be associated with these products particularly invertebrate pests (e.g. fruit fly, thrips and aphids) and plant diseases such as Citrus Canker (caused by *Xanthomonas axonopodis* pathovar *citri* (Hasse) Vauterin et al.) (See Sects. 18.3 and 18.4). Fresh plant products that carry seeds or are capable of being propagated may pose a higher biosecurity risk and typically require additional risk assessment and mitigation.

Dried and durable plant products (excluding seed, grain and wooden articles) include: (1) Dried food of plant origin, flowers, foliage, herbs and spices; (2) souvenirs and handicrafts including mats, bags and baskets made from plant material and non-propagative stems such as bamboo, rattan, reed, cane and willow; (3) Christmas decorations, wreaths and ornaments including pine cones; and (4) Plant-based stockfeed.

Dried plant products generally pose a lower phytosanitary risk because most plant pathogens require a living host to remain viable. However, dried plant products may be infected or contaminated with the resting stages of plant pathogens, soil or seeds and infested with live insects. Dried plant packaging materials including straw, coconut fibre, rice hulls or similar plant material can carry exotic insect pests, pathogens and weed seeds and should not be used as packaging material for the international transfer of goods.

6.5.5 Highly Processed Plant Products

The method and degree of processing and the intended end-use of a commodity significantly influences the phytosanitary risk presented by plant products (ISPM 32 2009). Plant products that have been "highly" processed normally present fewer phytosanitary risks because the treatments typically remove the biosecurity viability of the pest. As such, importing requirements for commercially processed, packaged and labelled plant products including frozen, milled, pasteurised, fermented, cooked, pureed, pickled or suitably preserved (e.g. crystallised, jellied, salted) products are typically released based on verification of documentation to ensure compliance.

6.5.6 Soil

Soil deserves special mention because it can readily act as a medium for transporting many plant pests including invertebrates in their various stages of development, fungal sclerotes, bacterial spores, nematodes in a resting state and weed seeds of phytosanitary importance. For example, cysts of the Potato Cyst Nematode (*Globodera rostochiensis* (Wollenweber) Behrens, and *G. pallida* (Stone) Behrens) may remain viable in soil for 30+ years (Eyres et al. 2005). Soil can be readily moved in rooted plant material or as contamination on the outside of cargo containers and transport vehicles including used cars, farm and military machinery and earth moving equipment. Soil can also be a contaminant on passengers' personal goods including boots, tents, bikes, etc. Most NPPO's prohibit the movement of large quantities of soil that has not been treated to reduce the pest risk to an acceptable level (Anon 2011).

Peat is often imported for agricultural purposes or is used as a packaging material for plant bulbs. In theory, peat presents a minimal phytosanitary risk because it consists of composted vegetable matter and typically is acidic (presenting a harsh environment for pest survival). However, when collecting peat for international exchange we must ensure that it is free of soil and other phytosanitary risk material.

6.6 Phytosanitary Risk Pathways

A "zero risk" phytosanitary policy is impossible to implement because natural pathways including migratory birds, trade winds and ocean currents continually pose a route for entry of exotic pests. This is particularly true for windborne fungal diseases including rusts and smuts. Windborne plant pathogens, as evidenced by the presence of new diseases, are commonly discovered in New Zealand soon after they arrive in Australia (Sheridan 1989). This phenomenon is believed to be a result of the predominant direction of trade winds blowing west to east across the Tasman Sea between the two countries. In New Zealand, Poplar Leaf Rusts caused by *Melampsora medusa* Thümen and *M. larici-populina* Klebahn were recorded in 1973 (Dingley 1977), Oxalis Rust (*Puccinia oxalidis* Dietel & Ellis) in 1977 (Versluys 1977) and Stripe Rust of wheat (*Puccinia striiformis* Westendorp) in 1980 (Harvey and Beresford 1982). All were identified about 1 year earlier in Australia. Long-distance dispersal of rust spores across the Tasman Sea by wind currents is the commonly accepted explanation for many of these occurrences (Close et al. 1978).

Some countries have a natural geographic defence against the entry of many plant pests due to deserts, mountains or oceans but the advent of modern shipping and air freight combined with the liberalization of international trade has significantly increased the global movement of plants and plant products and this has reduced the effectiveness of these natural barriers.

The main risk pathways for movement of serious phytosanitary pests crossing international borders are due to: (1) Imported cargo involving trade in plants and plant products including potentially contaminated goods such as used agricultural, military and earthmoving equipment; (2) Passenger movement at airports and seaports including personal effects and the vessel itself; (3) International mail exchange; and (4) Unregulated movement across inter-country borders.

6.6.1 Imported Cargo

The international transport of commercial and non-commercial cargo in containers, shipping vessels and aircraft between countries is a cost effective and well-established practice. The increase in the number of sea containers transported around the world shows trade more than doubling during the past decade. In 2004, global merchandise trade was valued at US$ 8.9 trillion, compared with less than half that 10 years earlier and a mere US$58 billion in 1948 (Anon 2006). More than 80 % of international trade in goods is carried by sea transport. In 2008, world seaborne trade (goods loaded) increased by 3.6 % to surpass a record 8 billion tons (Anon 2009b). Border agencies must manage the risk posed by the imported cargo being transported, the packaging of goods (particularly regarding wood packaging) and the external and internal surfaces of containers. Cargo, packaging and shipping container can present potential pathways for the transport of many significant pests including Khapra Beetle, Asian Gypsy Moth, Giant African Snail and other hitchhiking (contaminating) pests.

Shipping containers can present a risk pathway particularly regarding soil contamination and other plant phytosanitary risk material adhering to the outside of the containers. Often, imported containers are moved between the port of entry and metropolitan areas, and they normally stand on hard surfaces with limited availability of host plants thereby reducing the risk of pest establishment. Empty containers are then reloaded and returned to the port for export. However some containers are destined for rural depots and soil and other contamination could dislodge during the transport process and potentially present a risk pathway for certain pests given the increased likelihood of suitable host plants being available. Stanaway et al. (2001) undertook a survey of the floors of 3,000+ empty sea cargo containers to estimate the quarantine risk of importing exotic insect pests into Australia. More than 7,400 live and dead insects were collected from 1,174 containers. No live infestations of timber-feeding insects were recorded but the collection of dead insects demonstrates that containers are regularly exposed to economically important regulated insects including timber pests, agricultural pests and nuisance pests. Stored product pests were found in more than 10 % of containers.

International aircraft and vessels including cruise ships, itinerant yachts and cargo ships present a risk pathway as they can carry food wastes, refuse in holds and galleys, imported cargo of bulk grain, timber products, stock feed and may also have live plants on board. In addition, the vessel itself has the potential to introduce hitchhiking pests. Two serious forestry pests, the Asian Gypsy Moth and the Burnt Pine Longicorn Beetle (*Arhopalus ferus* (Mulsant)) are regularly detected on international vessels that have visited high-risk ports during the insect's respective flight seasons. Female Asian Gypsy Moths are active flyers during July-September in the Russian Far East, China, Korea and Japan. Female moths are attracted to lights on shipping vessels and lay egg masses on the infrastructure (Walsh 1993). A similar situation occurs with adult Burnt Pine Longicorn Beetles contaminating vessels and hitching rides, normally in summer, on imported timber and cargo during the adult beetle's flight period (http://www.daff.gov.au/aqis/quarantine/pests-diseases/forests-timber/burnt-pine-longicorn).

Similarly, aircraft can be a pathway for the transport of pests around the world (http://www.pnas.org/content/103/16/6242.full). Insects can readily gain access to aircraft while the holds are open during loading operations or be transported in freight or carried on-board unwittingly by passengers in their luggage or on their person. Factors such as season, cargo type and time of departure (night or day) influence the risk of contamination in aircraft. In a study of hitchhiking insect pests on international cargo in aircraft at Miami International Airport from 1998 to 1999, Caton et al. (2006) found that contamination rates on flights were greatest during the wet season departing at night from the country of origin.

Global changes in trade and population migration are causing demands for agricultural products with new plants and plant products being imported from new global trading partners, often with limited biological knowledge of the associated pest risks. For example, international trade in cut flowers has grown significantly in volume during the last decade and so too has the number of countries exporting these goods. A decade ago most of this trade originated from European countries; currently, newer trading partners are entering this market. African countries are becoming a significant supplier, presently accounting for about 8 % of world exports of cut flowers. This trade in cut flowers is expected to grow (Areal et al. 2008). This spike in African exports is likely to bring a range of new phytosanitary pest risks associated with cargo pathways for pests unknown to science may arise. A recent example of this occurred in Australia with the detection of a Genus of thrips previously unknown to science being intercepted on plant produce imported from Kenya and Ethiopia (Mound 2009).

6.6.2 Passenger Movements at Airports and Seaports

As international air and sea travel has become more affordable with ever increasing exotic destinations being visited, phytosanitary risks are escalating. According to the Airports Council International, in 2010 more than 4.8 billion passengers travelled to 1,633 international airports in 179 countries and territories (Anon 2010b). Airport and seaport passengers pose a phytosanitary risk pathway often due to ignorance of the potential risks associated with an unusual wooden artefact they have purchased at a market place or seeds of some exotic plant they have collected.

Passengers can inadvertently transfer phytosanitary risks on their clothing, shoes and personal goods such as tents and bicycles. For example, over the last few years live Black-spined Toads (*Bufo melanostictus* (Schneider)) have been detected frequently by Australia's national plant protection agency concealed in empty shoes in the bags of passengers arriving from South East Asia (Anon 2008). Baker (1966) cultured fungi from shoes of air travellers arriving in Honolulu International Airport and identified 65 different fungal species. Likewise Gadgil and Flint (1983) examined 45 tents accompanying incoming passengers at Auckland International Airport and found a range of pathogenic fungi along with several live insects. Sheridan (1989) found 35 fungal genera mainly consisting of rust uredinospores and smut teliospores in a survey carried out on passengers clothing arriving at Wellington International Airport from Australia. About 10 % of the spores were viable with higher numbers of fungal spores recovered from passengers originating from a farm or recreational area compared with an urban area. While this pathway is difficult to regulate, travellers, particularly plant scientists, horticulturalists, farmers and other passengers who visit rural areas should at least be aware of the potential for this risk and take appropriate precautions including laundering of clothing and cleaning of shoes and equipment.

6.6.3 International Exchange of Mail

Rapid expansion of the Internet and international exchange of goods purchased through e-commerce mail order sites presents a major risk pathway for plant goods sent in the mail. This can be a high-risk pathway because the goods may carry foreign pests or seed and other propagating plant material that can pose a significant phytosanitary risk for countries. For instance, more than 137 million items of international mail are sent to Australia each year with over 400,000 items of quarantine interest being detected with mail order and Internet purchases making up a significant portion of the seized items (Anon 2010c).

6.6.4 Inter-country Borders (Regulated and Non-regulated People Movement)

Some countries have a natural geographical, seasonal and historical advantage in regard to phytosanitary border controls. Being surrounded by oceans, the international movement of people and goods through designated ports into Australia and New Zealand is easier to regulate compared with countries that share borders where controlled movement of people and plant products across borders is more difficult. Although commercial tourist traffic may be regulated, illegal border crossings by people bringing with them unregulated plants and plant goods can present a significant phytosanitary risk pathway.

Given the different climatic and growing seasons between the Northern and Southern Hemispheres, the likelihood of phytosanitary pests establishing on susceptible hosts under suitable environmental conditions is significantly influenced. Consider fresh fruit harvested in one hemisphere and exported to another country (and another hemisphere). The host material may be in a dormant state that will typically reduce the likelihood of the phytosanitary risk pathway. In addition, given the relatively recent international exchange of goods into Australia and New Zealand, pathways and establishment of many significant phytosanitary pests has been historically lower compared with Asian and European countries where trade has been occurring for many centuries.

6.6.5 Climate Change

Climatic conditions significantly impact crop production, population dynamics and pest risk distribution thereby influencing existing pest risk pathways (see Chap. 21; Scherm and Coakley 2003; Coakley et al. 1999). The earth is in a warming phase with 2000–2010 being the warmest decade since record keeping began in 1860 (Norse and Gommes 2003). Climate change will have significant implications for pest movements particularly for plant products imported from pest-free areas. Increased levels of greenhouse gases CO_2, (carbon dioxide) CH_4 (methane), NO_2 (nitrous oxide) and O_3 (ozone), combined with changes in temperature and rainfall, will affect the distribution of crops and pests (Chap. 21). Cooler areas will become more conducive for plant growth; drier areas will become less suitable for plant growth. Pest lifecycles are forecast to change with the potential for more generations per year (multivoltine) and different seasonal population peaks. This is likely to result in more movement of pathogens, particularly for plant virus transmission, due to increased vector activity associated with aphids, nematodes, thrips, mites and whitefly species (Jones 2009).

Climate change is predicted to increase the frequency and severity of extreme weather events and this may increase the likelihood of incursions at national and domestic borders and may impact on area freedom compliance. For instance, increased cyclonic activity in areas where Citrus Canker is present has expanded the distribution of this important citrus disease (Chap. 18). Emergency responses to natural crises (e.g. tsunami, flooding, famine), particularly in developing countries, typically result in a rapid food-aid response. This presents possible pathways for movement of exotic pests into countries that have more pressing issues compared with phytosanitary compliance.

6.6.6 Other Considerations

Several risk pathways must be managed by border agencies, including: (1) Removal of long-established pest control practices (pesticides and fumigants) may increase the presence of pests on plants and plant products exchanged internationally; (2) Economic challenges (loss of skilled staff and discontinued programme funding for pathogen testing) reduce availability of high-health planting stock; (3) Bioterrorism threats that involve deliberate introduction of exotic pests; (4) Escalating costs of managing new plant pest outbreaks with decreasing budgets will lead to acceptance of more pest incursions, and; (5) Military conflicts may cause breakdowns in biosecurity systems.

6.7 Risk Mitigation: Managing Plant Phytosanitary Risks

NPPO's rely on a range of mitigation processes to manage risks posed by the international trade of plants and plant produce. Risk mitigation strategies can be applied to goods before entry, at the border or post entry. Management systems may be based on one approach or involve a "systems approach" process integrating two or more processes. The systems approach reduces risk to meet the appropriate level of phytosanitary protection. Alternatively, processes are independent so if one system fails then a "backup" exists to offer added levels of protection that reduce risk to an acceptable level.

Regulatory measures commonly used for managing risk pathways associated with imported plants and plant products generally fall into one of several areas: Documentation and information management; Pest-free areas and pre-clearance; Inspection and detection systems; Treatment options; Re-export and/or commodity destruction; Post-entry plant quarantine; Stakeholder awareness and engagement; Enforcement and compliance; and "Other" (sundry) measures (Sect. 5.6).

6.7.1 Documentation and Information Management: Important Components for PPOs Mitigating Phytosanitary Risks

Documentation requirements and information management vary depending on the commodity and country and may include: (1) Import permits and phytosanitary certificates; (2) Incoming passenger cards; and (3) Electronic data analysis and risk profiling.

Import permits and phytosanitary certificates (Sect. 5.7) are documents commonly required by border agencies for the importation of plants and plant products (ISPM 12 2001). An import permit is a legal document that stipulates specified import requirements for a commodity that are legally binding. Import permits are issued by the importing country's NPPO. A phytosanitary certificate is an official government-to-government document stating that goods have been inspected according to appropriate procedures and are certified to be practically free from phytosanitary pests. Specific additional declarations may be required on the phytosanitary certificate to provide assurance that the imported products have been officially inspected, tested, treated or sourced from pest-free areas and that the goods conform to the phytosanitary regulations of the importing country.

Managing the risks of phytosanitary items entering on passengers or with their baggage at international airports and seaports is complex and difficult. Many NPPOs have designated "first ports of entry" where border officials clear international aircraft and shipping vessels including their goods, baggage, crew and passengers. Before landing, international aircraft may play an in-flight quarantine announcement alerting passengers of the importance of quarantine and the process to follow to comply with regulations. In some countries, disembarking crew and passengers are required to complete an incoming passenger card or similar legal document to declare items of phytosanitary concern including food, plants, parts of plants, traditional medicines and herbs, seeds, wooden articles, soil or articles with soil attached e.g. sporting equipment, and shoes. Passengers also must declare whether they have visited high-risk areas such as farms where they may have picked up phytosanitary risk items. In this way, a risk assessment of items being carried by passengers can be made by phytosanitary inspectors and directed for further assessment or treatment (Chap. 9).

Some border agencies employ specialist risk assessment officers at international airports to facilitate efficient passenger clearance. These officers assess risks posed by different pathways and flights so flights/passengers representing a lower risk can be cleared without further intervention. This allows border agencies to more effectively utilise limited resources to target risks. This includes clearing passengers who may be moving high-risk goods or have incorrectly declared goods and direct them to baggage examination or x-ray. The risk assessment officer plays a role in educating passengers on the importance of compliance with phytosanitary regulations and implications of false declarations that may result in issuance of an infringement notice, financial fine or court prosecution.

Phytosanitary activities at the border generate an enormous volume of data. Sophisticated computer technology enables regulatory authorities to utilise modern electronic systems that support risk mitigation associated with importation of plants and plant products. NPPOs typically have electronic databases that contain phytosanitary information relevant to the trade of plants and plant products. These databases allow prospective importers/exporters to determine what import conditions are required and whether a need exists for import permits, phytosanitary certificates, treatments and any other relevant information relating to the importing country's requirements. Australia's border agency maintains an import conditions (ICON) database that contains data on the import requirements for thousands of commodities (www.daff.gov.au/icon). New Zealand's plant import requirements are documented in a series of import plant health standards (http://www.biosecurity.govt.nz/enter/plants) and an electronic database (Plants Biosecurity Index) which details import specifications for seed and nursery stock of plants by genus/species (http://www1.maf.govt.nz/cgi-bin/bioindex/bioindex.pl). The USA maintains import/export conditions for plants and plant products (http://www.aphis.usda.gov/favir/ and http://www.aphis.usda.gov/import_export/plants/plant_imports/plant_inspection_stations.shtml).

Computer systems support detailed records of pest interceptions on imported goods; data can be analysed to identify risk pathways and risk profiles. This information enables border agencies to incorporate flexible intervention strategies to use border resources to target areas of greatest biosecurity risk so fewer resources are directed to low-risk activities. Data collection and risk modelling enables agencies to develop phytosanitary risk profiles.

Profiling is typically used at international airports, seaports and mail centres as a method of identifying high-risk passengers, goods, pathways, suppliers and importers. A profile is a set of characteristics created by analysing historical data on the incidence of phytosanitary risk material and/or compliance with regulations. For example, seasonal profiles can be used to target specific seasonal events (e.g. Asian Gypsy Moth peak flight-cycles) and cultural events known to the NPPO. Annual events such as the start of university terms (students returning from overseas with food items or other risk goods), religious or cultural events (Christmas, Chinese New Year, Easter, Ramadan and Sukkoth) and "one–off" events (sporting activities or conferences) are typical profile targets.

Other profiling models may include targeting a particular group of passengers who infrequently travel and may not be aware of phytosanitary regulations. This can be particularly effective in targeting groups of passengers who have a historical tendency of non-compliance (non-declaration) of phytosanitary risk items. Likewise, commercial importers with a poor compliance history may be targeted with a higher level of phytosanitary intervention including increased inspection or mandatory treatment. In the same way, risk profiling can be used to reduce intervention for specific types of imported cargo that historically present a lower phytosanitary risk. Profiles must be regularly analysed and reviewed to ensure they remain effective in light of new information that may alter the risk status.

6.7.2 Pest-Free Areas and Pre-clearance

Phytosanitary agencies recognise pest-free areas, and areas of low pest prevalence. A pest-free area is an area in which a specific pest does not occur as demonstrated by scientific evidence. The PFA is officially maintained by checks to verify freedom and/or phytosanitary measures to maintain freedom (ISPM 4 1996). This allows specified plant products to be exported with a lower level of phytosanitary intervention because goods can be certified free of specific regulatory pests and cleared more efficiently by the importing country. The term 'pest free area' can encompass all of a country (country freedom) or parts of a country (area freedom). The requirements for establishing "pest free areas" or "pest free places of production" are defined in ISPM 4 (1996) and ISPM 10 (1999). More detailed information on these standards is available from the IPPC website.

Pre-clearance involves performing pest inspections, testing and treatments in the country before export. Pre-clearance was first proposed in 1914 at the International Phytopathological Conference held in Rome (Morschel 1971) and is now used by border agencies around the world. The exporting country carries out Phytosanitary pre-clearance inspections and testing under an approved and auditable system or by officers from the importing country's phytosanitary service. Field inspections of the growing crop in the country of origin are a particularly effective tool in managing disease risks in plants that may be dormant or where the disease is latent. For example, the USDA (in co-operation with NPPO of many countries) has been performing pre-clearance of ornamental flower bulbs since 1951 (Santacroche 2008). In Australia, a pre-clearance scheme has been established with several trading countries for products that are treated with Methyl Bromide (Sect. 10.3.2). Under the Australian Fumigation Accreditation Scheme (AFAS), overseas fumigation companies are trained and accredited to perform Methyl Bromide fumigations. This has contributed to the effectiveness of such treatments.

Another pre-clearance arrangement, widely adopted internationally, manages the movement of wood packaging material. (ISPM 15 2002: *Guidelines for Regulating Wood Packaging Material in International Trade*). ISPM 15 was an important step in minimising the importation of timber pests associated with wood packing material in international trade. Some countries (including Australia and New Zealand) had an additional requirement that wood packaging be essentially "bark free" given the potential of bark to shelter numerous pests of phytosanitary concern and provide a site for re-infestation after fumigation treatment. Haack et al. (2007) examined the risk posed by residual bark and concluded that bark pieces larger than a "credit card" in size could enable bark beetle species to complete their lifecycles. Consequently, the ISPM 15 standard was revised in 2009 to define "bark–free" wood as 'wood from which all bark, except in grown bark around knots and bark pockets between rings of annual growth has been removed'. This standard accepts that vestigial bark may remain after the debarking process and sets out acceptable tolerance levels.

Pest-free areas and pre-clearance arrangements are mutually beneficial for importing and exporting countries. Importing countries benefit by early detection and elimination of plant pests, thereby reducing the chances of phytosanitary risks entering at the border. Exporters benefit because products that do not meet the phytosanitary requirements of the importing country can be removed during the early stages of the export process rather than at a later stage after much cost has been added to the product. Pre-clearance arrangements typically reduce the need for time-consuming and expensive on-arrival inspection at the port of entry, thereby making the process at the border more efficient.

6.7.3 Inspection and Detection Systems

Inspection of regulated goods is the most frequently used phytosanitary procedure employed worldwide to determine compliance with import requirements and detection of pests (ISPM 23 2005). Inspection of consignments confirms compliance with import or export requirements relating to regulated pests. Import inspections verify compliance with the importing country's phytosanitary requirements and detect pests of phytosanitary importance. An export inspection ensures the consignment meets regulatory requirements of the importing country at the time of inspection and may result in the issuance of a phytosanitary certificate. Inspections of imported/exported products involve three distinct processes (ISPM 23 2005): (1) Examination of documents accompanying the consignment; (2) Verification of the identity and integrity of the consignment; and (3) Examination for pests and other phytosanitary risk material.

Documents accompanying a consignment may include phytosanitary certificates, import permits, treatment certificates, manifests, airway bills, field inspection reports and other country-specific reports. The inspector examines and verifies that the documents and goods are clearly identifiable and the integrity of packaging is intact and consistent with phytosanitary requirements. An appropriate sample is taken from the consignment and examined for regulatory pests and other phytosanitary risk material. ISPM 31 (2008) provides guidance to NPPOs in selecting the most appropriate sampling method for inspection or testing of consignments to verify compliance with phytosanitary requirements. The inspector may use microscopic devices to detect microorganisms and small invertebrate pests and their life stages (e.g. mites and insect eggs). Some imported plant products (including cut flowers and foliage) are difficult to inspect under the microscope and other inspection techniques (including tapping or shaking produce over a sheet of white paper) are used to dislodge invertebrate pests. If regulatory requirements are met then consignments may be released or a phytosanitary certificate issued for exported goods. If phytosanitary requirements are not met then further risk-mitigation processes may be required depending on the nature of non-compliance. If regulated pests are detected then the inspector may seek advice from specialists (including entomologists and plant pathologists) or direct the consignment for appropriate treatment and other phytosanitary risk-mitigation measures consistent with import requirements.

Visual Inspections. Visual inspection and physical examination are commonly employed by border agencies for managing entry of phytosanitary risk items associated with passengers, international mail and imported cargo. Inspections can be simple (reviewing a passenger's written declaration and assessing compliance with regulations) or more detailed (examining a passenger's baggage). International mail is subject to border inspections depending on the level of risk taking into account seasonal factors, declarations on the package, country of origin and likelihood plants and plant products are present in the package. If goods are found contaminated with pests, soil or other phytosanitary risk material, then they are directed for further treatment or other risk mitigation including destruction, re-export and/or prosecution.

Inspectors at international cargo depots visually assess imported goods, equipment, timber and other traded products for signs of phytosanitary risks. Sea containers are transported around the world. Some NPPOs have developed requirements for imported containers and cargo, especially regarding container cleanliness and whether it is carrying wood packaging material, which can harbour wood-boring insects or fungi. The contents and external surfaces of imported containers may be subject to inspection for phytosanitary risk material including hitchhiking pests (e.g. snails), seeds and unacceptable levels of contamination (such as soil). If present this may result in delays because the container may require cleaning and re-inspection before it can be released.

Visual inspection of an entire consignment is impractical for large consignments of plants and plant products. A representative sample typically is drawn for examination. Sampling detects regulated pests and provides assurance the regulatory requirements have been met in the most cost effective and resource-efficient manner. ISPM 31 (2008) provides an overview of the goals and challenges of sampling and examines topics including sample size and selection, inspection efficiency, and random versus targeted sampling.

Different commodities require different sampling strategies. In Australia and New Zealand, a random 600-unit sample selected from homogeneous consignments of fresh produce (including fruit, vegetables and cut flowers) commonly is used. For most large shipments, this strategy provides a 95 % level of confidence that not more than 0.5 % of units in the consignment are infested. Inspectors at ports-of-entry in the USA select samples of imported commodities for inspection based on various protocols including flat 2 % of shipments, hypergeometric sampling or random sampling. The USDA's Agricultural Quarantine Inspection Monitoring (AQIM) programme is based on hypergeometric sampling. Hypergeometric protocols select inspection units (lots) by selecting the appropriate number of 'sample units' to provide a 95 % confidence level of selecting one or more sample units when the inspection unit is infested/infected at a rate of 10 % or higher. The USA now applies sample methods for shipments of "plants for planting" based on the hypergeometric probability distribution. Before importation, plant shipments are assigned a risk rating (high, medium, low, and risk monitoring), and sampled accordingly for inspection.

NPPOs typically use the International Seed Testing Authority procedures for drawing subsamples of seed shipments to inspect for phytosanitary risk items. This usually involves the collection of multiple random samples throughout the consignment including the top, middle and bottom of the bag/container and then blended to form a composite sample. After the sub-sample has been selected, a thorough visual inspection is completed looking for any signs of invertebrate pests, disease symptoms, weed seeds and other phytosanitary risk material. NPPOs stipulate which inspection technique to use depending on the type of product being imported and the acceptable level of protection. Inspection using statistically based sampling methods provides a level of confidence that the incidence of a pest must be below a certain level, but does not prove that a pest is absent from a consignment (ISPM 31 2008).

Optical aids commonly are used by phytosanitary officers during inspections of imported plants and plant products to help magnify pest specimens to a size suitable for detection. These aids vary in form and function and their suitability is dependent on the specific work location and function being undertaken. Relatively large invertebrate specimens and disease symptoms may require no or low magnification devices to detect them. The detection of tiny invertebrates and life stages (including eggs and nematode cysts) may require the use of a 10–30× hand lens or a microscope.

A bright light source (minimum 600 lux at the point of primary inspection) commonly is used when inspecting plants and plant products. An optical fibre or a cold light source is favoured over an incandescent light source because the former generally is brighter and does not generate heat (minimising drying and damage of the specimen). Greater magnification can be gained by using compound microscopes.

However, preparation and observation typically require a higher level of expertise and such specimens usually are forwarded to specialist entomologists and plant pathologists for assessment (Sects. 12.2, 13.5 and 13.6).

Other tools commonly used during phytosanitary inspections include: (1) White paper that provides a contrasting background and enables easier detection and collection of invertebrates during inspections; (2) Trays, sieves, paint brushes, forceps and probes to remove and collect specimens from hard to reach crevices, particularly around the calyx of fruit; (3) Vials containing 70 % ethanol or other suitable preservative to collect pests found during the inspection; (4) Plastic snap-lock bags to collect plant tissue with disease symptoms; (5) Pest interception forms with details of the pest found on the imported commodity to allow data to be collected on the risk pathway.

Border inspectors must follow correct specimen-handling protocols and preservation procedures when collecting pests because damaged invertebrates and disease specimens make identification more difficult. When collecting invertebrate pests, all available life stages (e.g. egg, larva/nymph, pupa, adult) should be collected as this assists in identification. Generally invertebrate specimens, with some exceptions, should be collected into 70 % ethanol or propylene glycol (1,2-propanediol). However, sending specimens preserved in 70 % ethanol through the mail is prohibited in most countries because 70 % ethanol is considered a 'dangerous good'. If internal feeders (beetle or moth larvae or "grubs") are detected, inspectors should leave the specimens in situ (on the plant material) and an entomologist should be contacted for advice. Likewise mealybugs and scale insects should be left attached to the plant tissue because removal can damage their mouthparts and make identification more difficult. Instead, leaf tissue around the insect should be carefully removed and placed into a dry vial or 70 % ethanol. Adult moths and mosquitoes should be collected dry in vials and placed into a freezer overnight; they should not be placed into ethanol or other liquids because the body and wing scales needed for identification will fall off. Where actionable pests are identified, consignments typically are directed for mandatory treatments including fumigation and/or insecticide dipping depending on the pest and product.

If suspect disease symptoms are observed on imported plants and plant products, then the consignment must be placed "on hold" pending advice from a plant pathologist. A representative sample showing the full range of disease symptoms should be collected and submitted to the plant pathologist by placing affected tissue in snap-sealed plastic bags. Heavily diseased samples are normally unsuitable for isolation as they usually have many saprophytic organisms (fungi or bacteria that grow on and derive nourishment from dead or decaying organic matter) making it difficult to isolate the causal pathogen. As such, samples consisting of healthy and diseased tissues are the best samples for submission. One leaf is generally not sufficient for pathologists to determine the causal agent or assess the health of the plant. Care must be taken when collecting disease specimens from live plants. Otherwise, damage can occur and lead to secondary disease infections. Secateurs or a sharp knife should be used for collecting diseased samples; instruments should be cleaned and disinfected with 70 % ethanol or other suitable disinfectants between samples.

Samples must be clearly labelled and carefully packaged, ideally wrapped in dry paper towel in snap-sealed plastic bags. When collecting samples from the field or from post-entry plant quarantine facilities, the specimens should be delivered to the plant pathologist as quickly as possible. When necessary, specimens should be stored in a refrigerator (not freezer) because the plant tissue deteriorates very quickly after collection. Deterioration makes the isolation and identification of the causal agent difficult. If plant disease samples are being sent through the post or overseas to specialists, then additional precautions must be taken including placing samples into plastic screw-top bottles to minimise the risk of breakage and escape during transit. When actionable diseases are detected, and depending on the risk status of the disease agent, the consignment may require treatment, be re-exported or destroyed. In situations where a phytosanitary disease is suspected, or has been confirmed in a post-entry plant quarantine facility, additional precautions are required including destruction of susceptible hosts and decontamination of the premise and equipment.

Detector Dogs. Detector dogs are another tool for inspection used by some NPPOs for managing phytosanitary risk pathways. Dogs used for the detection of phytosanitary risk material first began in Mexico during the 1970s and now are used in many countries:

http://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/detector_dog.pdf

Detector dogs are trained to search international mail, passenger's baggage and imported cargo to discover undeclared phytosanitary risk products. Detector dogs are particularly effective in discovering phytosanitary material including live plants, seed, plant produce and soil which can be difficult to detect with visual inspection and x-ray technology. In 1984, the USDA was the first NPPO to trial beagles to work amongst people at baggage collection points at international airports. With their enhanced sense of smell and friendly nature, beagles proved popular with the traveling public and are now commonly used by border agencies in media campaigns to educate the public on the importance of quarantine.

Two types of detector dogs are commonly used by border agencies. Passive dogs are trained to simply sit next to a passenger or their luggage when they detect phytosanitary risk material, waiting for their food reward. Passive dogs are typically used in baggage halls at international airports. Active dog breeds are trained to paw or nuzzle target items and are rewarded with a game of tug-of–war. Detector dogs are used at international mail centres, cargo centres and behind the scenes at international airports.

Detector dogs are also used by NPPOs in Australia and other countries for the detection of termites in timber products and high risk shipping vessels (e.g. yachts with timber products that have visited a risk port). Termites, particularly drywood termites, are cryptic insects that are difficult to detect because they leave little or no external symptoms of infestation and a visual inspection alone will often fail to detect them.

X-ray Imaging. X-ray transmission imaging equipment is used by NPPOs to detect organic material including live plants and soil. X-ray technology is commonly used to assist in the screening of passengers' baggage at airports and seaports, mail centres and cargo examination depots and is effective in detecting items of phytosanitary concern.

Inspections using trained phytosanitary inspectors, x-ray equipment and detector dogs are widely used by border agencies. But this approach has limitations. We cannot detect all pest and disease threats that are likely to be transported on plants and plant products. Many invertebrate pests are too small to detect or are hidden beneath bark or within products (e.g. wood borers). Infestation rates of target pests in the imported goods may be too low to detect. Also, there is an inherent probability of missing pests given the use of sampling procedures for inspections and testing. Similarly, plant pathogens may infect plants and seeds internally and not express obvious disease symptoms, thus evading detection at the point of entry. Several other risk mitigation measures are used by border agencies to further minimise the phytosanitary risk associated with imported goods.

6.7.4 Treatment Options

Treatments applied to imported goods to manage the phytosanitary risks associated with plants and plant products include chemical, irradiation, physical and controlled atmosphere treatments (Sect. 10.2). Selection of the most appropriate treatment depends on the pest, commodity and intended use of the goods. Given the variability between international agencies, detail of the dosage rates, exposure times and the temperature ranges used for the treatments is not provided (specific information is available from each border agency website).

Chemical treatments. Chemical treatments used for risk mitigation purposes include fumigation, application of pesticides and disinfectants (Sect. 10.3). Fumigation is one of the most common treatments applied to imported goods particularly for managing invertebrate pests in plants and plant products. A fumigant is a chemical usually delivered in a gaseous form at a certain concentration and timeframe to be lethal to a given pest. The toxicity of a fumigant depends on the temperature and respiration rate of the target pest. Generally, the lower the ambient temperature, the lower the respiration rate of the organism which tends to make the pest less susceptible. Fumigation at lower temperatures usually requires a higher dosage rate for a longer exposure period than fumigation at higher temperatures (Anon 2010a). Methyl Bromide, Phosphine, Ethylene Oxide and Sulphuryl Fluoride are four common fumigants used by border agencies (Sect. 10.3.2).

Methyl Bromide (CH_3Br) is the most frequently used fumigant for phytosanitary treatments because it is effective against a wide variety of plant pests (including insects, mites and ticks, nematodes and snails), has good penetrating ability and is rapid acting (Sect. 10.3.2). As a phytosanitary measure, Methyl Bromide is commonly used for the treatment of durable commodities, such as bulk grains, cereals and dried foodstuffs, wood packaging materials, wood and logs, as well as perishable commodities, including live plants and fresh fruit, vegetables and cut flowers.

Plant material generally tolerates Methyl Bromide fumigation well, although the degree of tolerance varies with species, stage of growth and condition of the plant material. Methyl Bromide accelerates the decomposition of plants in poor condition and can react with excess free water to create methyl bromic acid, which can damage plants and plant products. Methyl bromide cannot generally penetrate goods covered in plastic wrapping, lacquer and paints that present an impermeable finish. Methyl Bromide may also leave residues in particular food groups with high oil content (e.g. nuts) and is not used for treating these products. Moreover, Methyl Bromide is classified as an ozone-depleting substance. Under the Montreal Protocol on substances that deplete the ozone layer (1987) Methyl Bromide is being phased out under a mandatory timetable. Methyl Bromide used by NPPOs for phytosanitary and pre-shipment purposes is currently exempt from this protocol. Several alternative treatments to Methyl Bromide fumigation have been developed (See Sect. 10.3.2) along with technology for recapture of emissions on activated carbon from fumigation chambers.

Ethylene Oxide ($CH_2.O.CH_2$) is a fumigant used by regulatory agencies for fumigating dried plant products including herbs and spices but it kills living plants and is not recommended for use on seeds. Ethylene Oxide is a broad-spectrum fumigant and unlike Methyl Bromide can penetrate plastic packaging and varnished or lacquered wood products. Ethylene Oxide is a strong alkylating agent causing the replacement of labile hydrogen with an alkyl group on hydroxyl, carboxyl, sulfhydryl, amino and phenolic groups. The alkylation of these compounds affects cellular function and structure that ultimately leads to inactivation of cellular function and pest mortality. Ethylene Oxide fumigation under vacuum (minimum 50 kPa at 1,500 g/m^3 for 4 h at 50 °C or 1,500 g/m^3 for 24 h at 21 °C) is used primarily to sterilize materials that are not designed to be exposed to heat or steam. It is very effective as a killing agent of phytosanitary pests.

Phosphine (PH_3) is a highly toxic fumigant gas that diffuses rapidly, penetrates deeply and is commonly used as a fumigant for treating stored product pests in bulk grain (See Sect. 10.3.2). Phosphine is slow acting and requires long exposure times – typically 7 or more days to control insect pests (depending on temperature). Some life stages are more tolerant to Phosphine (eggs and pupae the hardest to kill); larvae and adults succumb more easily.

Sulphuryl Fluoride (SO_2F_2) is typically used by border agencies for controlling dry wood termites and other insects inhabiting timber and wooden products. The gas has excellent dispersion and penetrating qualities that enable it to infiltrate termite tunnels and crevices and kill the insects. However, Sulphuryl Fluoride is generally not used on foods, living plants or medicines destined for human or animal consumption (See Sect. 10.3.2). Sulphuryl Flouride is an identified greenhouse gas.

Other Treatments. Some NPPOs routinely use fumigants to eradicate invertebrates associated with imported plants and plant products. Other treatments may be used to achieve the same outcome. In New Zealand, imported nursery stock is treated for insects and mites using Methyl Bromide fumigation, Hot Water Treatment (dormant material only) (See Sect. 10.5.2) or a combination of insecticides (http://www.biosecurity.govt.nz/files/ihs/155-02-06.pdf). Whole plants also undergo treatment for fungal pathogens using Hot Water Treatment and/or broad-spectrum fungicides.

Other chemical treatments are used for managing other phytosanitary risks associated with plants and plant products. In Australia and New Zealand, certain cut flowers, stems and foliage capable of being propagated (including roses, gypsophila, chrysanthemums and carnations) must be treated to render them non-viable. The herbicide glyphosate is commonly used for this purpose. Similarly, fungicides may be used to manage fungal diseases that are present on imported cut flowers.

Under World Health Organisation (WHO) guidelines, some border agencies require international aircraft to be disinfected and/or disinfested to minimise the introduction and spread of unwanted insect pests and vectors of plant disease that may be inadvertently transported. This may include any of the following treatments:

1. Residual spray treatment of interior surfaces of cabins and cargo holds at intervals not greater than 8 weeks (conducted in the absence of passengers);
2. Pre-flight cabin treatment (conducted in the absence of passengers before embarkation) that lasts for a single flight;
3. Pre-flight cabin treatment and top of descent spray (consisting of a pre-flight treatment followed by further in-flight spray of a non-residual insecticide, carried out at top of descent as the aircraft starts its descent) that lasts for a single flight; and
4. On arrival cabin and hold treatment (conducted in the presence of passengers and crew prior to disembarking).

Further information can be obtained from the WHO web site: http://www.who.int/docstore/bulletin/pdf/2000/issue8/99-0285.pdf.

Disinfectants. A range of disinfectants is used by NPPOs to mitigate risk pathways for plants and plant produce. Alcohols, chlorines and quaternary ammonium compounds are used for treating and disinfecting the external surfaces of imported seed, live plants and to disinfect inspection benches and equipment. Alcohols work through the disruption of cellular membranes, solubilisation of lipids and denaturation of proteins by acting directly on sulphur-hydrogen functional groups. The antimicrobial action of alcohols is optimal in the 60–90 % range as the highly hydrophobic nature of plant cell walls inhibits penetration of pure alcohol into the cell. Alcohols are typically used as broad-spectrum disinfectants against vegetative bacteria, fungi and some viruses although they are not sporicidal. Chlorine agents including sodium hypochlorite are widely used as broad-spectrum disinfectants particularly for treating imported seed and epiphytic infections of imported plant propagation material. Chlorine is a highly active oxidising agent and disrupts the cellular activity of proteins. Chlorine and ammonia-based disinfectants are used in combination with high-pressure water for cleaning phytosanitary risk material from containers and vehicles.

Controlled Atmosphere. In addition to the fumigation gases used for phytosanitary pest control, atmospheric gases including oxygen, nitrogen and carbon dioxide can be manipulated to preserve imported plant products, a process referred to as "controlled" or "modified" atmosphere storage. Controlled atmosphere techniques are widely used in the storage of perishable plant products to retard ripening and reduce spoilage from plant microorganisms as well as controlling some insect pests (Morgan and Gaunce 1975; Aharoni et al. 1981). The most extensive use of controlled atmospheres for regulatory purposes is on grain and similar commodities. Controlled atmosphere procedures work by depleting oxygen or increasing the levels of carbon dioxide to asphyxiate organisms. Insects are generally killed more rapidly by carbon dioxide than they are by lack of oxygen.

Physical Treatments. Physical treatments (including heating, cooling and reconditioning) are used by some NPPOs to manage phytosanitary risks associated with imported plant products (Sects. 10.4 and 10.5). Unlike fumigants that primarily target invertebrate pests, physical treatments generally have a wider application and impact against a broader range of phytosanitary pests.

Heat treatments used by border agencies include incineration, moist heat at 121 °C for 15–30 min (autoclaving) and dry heat, commonly 160 °C for 2 h or 85 °C for 8 h, to sterilize and kill plant pests. Heat acts by disrupting membranes and denaturing proteins and nucleic acids. At about 50 °C most plant parasitic nematodes are killed whereas temperatures between 60 °C and 72 °C are required to kill most fungi and bacteria (Agrios 2005). At about 82 °C, most weeds, insects, plant viruses and the rest of the plant pathogenic bacteria are killed. Heat treatment is commonly used for treating timber and wooden products and phytosanitary waste. High-temperature forced-air is used as a phytosanitary treatment in Hawaii for treating papayas for fruit flies (Armstrong 1989). The treatment involves heating papayas with forced hot air until the temperature of the centre of the fruit reaches 47.2 °C for 3–7 h. At this temperature, Mediterranean Fruit Flies, Melon Flies and Oriental Fruit Fly eggs and larvae cannot survive. Relative humidity during the treatment must be maintained at 40–60 % to prevent damage to the fruit. Following treatment, the fruit are rapidly cooled until fruit pulp temperatures are below 30 °C to help preserve quality. Heat treatment may cause damage to some imported goods potentially igniting flammable items, melting glue and plastic coverings and making some items brittle after treatment e.g. straw hats.

Hot-water Immersion is used for treating fruits that are hosts of fruit flies, propagation material including seed, and dormant plant material such as cuttings and bulbs (Sect. 10.5.2). Hot water at temperatures ranging from 35 °C to 54 °C with treatment times lasting a few minutes to several hours are used for various host-pathogen combinations (Agrios 2005). In Australia, imported dormant grapevine cuttings undergo a mandatory hot water treatment of 50 °C for 30 min to eliminate risks associated with phytoplasma diseases and Pierce's disease (*Xylella fastidiosa* Wells et al.). Hot water treatment for seed was for many years the only means to control many seed-borne diseases and is still commonly used. Hot water treatment at 43 °C for 3 h is used for treating nematodes in ornamental bulbs. Hot water treatment works on the principle that dormant plant material can withstand the treatment temperature whereas the pathogen is killed.

Heat Therapy is another temperature treatment used by NPPOs to eradicate viruses from plants for propagation. Actively growing virus infected plants are placed into growth chambers at relatively high temperatures (ca 38 °C) for 6–12 weeks. At this temperature, plants continue to grow albeit slowly while most virus multiplication is temporarily halted. Meristem tips are aseptically removed and placed into culture or tiny pieces of explant tissue are budded onto virus-tested rootstocks. Plants are grown and tested to confirm the absence of the virus.

Cold Treatment (Refrigeration) (See Sect. 10.4) is widely used for controlling post-harvest diseases and insect pests of fresh produce and has been employed for many years. Cold treatments are relatively slow and typically are used for treating commodities travelling as sea freight in refrigerated containers or "reefers" where the goods can be maintained at low temperatures for extended periods. Low temperatures do not necessarily remove all the phytosanitary risks associated with plant produce, but they do mitigate many of the pest risks. Freezing at −18 °C for 7 days is an effective pest treatment process and is used by border agencies for treating wooden or dried plant products including herbarium specimens.

Cleaning/Reconditioning of Consignment. This is another form of physical treatment used to remove phytosanitary risk of contamination. Treatment depends on the level and type of phytosanitary risk. For instance, washing or pressure steam treatment are often used for removing soil and phytosanitary debris from imported containers, motor vehicles, farm machinery and earth moving equipment. The waste is then collected and disposed of in a "phytosanitary approved" manner. Other forms of reconditioning include:

1. Upon arrival, commodity processing begins to mitigate phytosanitary risks (e.g. grain milled into flour);
2. Australia's border agency requires imported fresh taro tubers to be 'topped and tailed' to limit their ability to be propagated; and
3. Berries and fruits are generally not permitted on cut flowers, foliage or dried plant products because they may contain viable seeds or may be infected by internally feeding insect pests.

Irradiation. Ionizing radiation (irradiation) is another pest-risk management treatment used to mitigate plant risk pathways (ISPM 18 2003; See Sect. 10.6). Three types of ionizing radiation used as regulatory treatments include:

1. Electrons generated from machine sources up to 10 MeV (eBeam);
2. Radioactive isotopes (e.g. gamma irradiation from cobalt-60 or cesium-137);
3. X-rays (up to 5 MeV).

The primary objective of irradiation as a phytosanitary measure is to prevent the introduction or spread of regulated pests. Irradiation is also used as a devitalization treatment of plants e.g. seeds may germinate but seedlings do not grow; tubers, bulbs and cuttings do not sprout (ISPM 23 2005).

Irradiation has several advantages over other treatments. Temperature and fumigation treatments involve generating data for each fruit-pest combination; irradiation treatments are developed for a pest species irrespective of the commodity (Anon 2002). Irradiation is known as a ‘cold process’ because the temperature of the processed product does not significantly increase and the treatment is effective against most insects and mites at dose levels that do not affect the quality of most food commodities (Anon 2002). Essentially, irradiation treatment generates short wavelength energy that passes through the treated product resulting in cellular breakdown and disruption to organic processes. As a phytosanitary treatment, irradiation can result in:

1. Mortality of the target pest;
2. Sterility of the pest (inability to reproduce);
3. Inability of the pest to emerge/fly; or
4. Devitalisation whereby plant parts including seeds, tubers, bulbs and cuttings cannot be propagated.

Unlike many chemical and physical phytosanitary treatments that result in death of target pests, the use of irradiation as a phytosanitary measure presents a new paradigm for border agencies because the treated consignment may not achieve the traditional phytosanitary criteria of total mortality of the pest. Irradiation may result in the pests’ inability to reproduce (sterility), inability to complete all the pest life stages or non-emergence of adults however the pests may still be alive. This presents a dilemma for phytosanitary officers who undertake pest inspections and may reject consignments due to the presence of live pests. Acceptance of irradiation treatments is dependent on sound and verifiable research to give confidence to regulatory agencies in accepting such products.

Despite these challenges, irradiation as a phytosanitary treatment is gaining increasing acceptance by NPPO’s (Anon 2002). The USDA first approved irradiation in 1997 for use on papayas from Hawaii for export to the mainland, followed by Guam, Puerto Rico and the U.S. Virgin Islands (Anon 2010a). In 2002, irradiation was approved as a phytosanitary treatment for all admissible fresh fruits and vegetables from all countries. New Zealand has approved irradiation as a phytosanitary treatment for Australian mangoes, papaya and lychee fruit.

6.7.5 Post-entry Plant Quarantine

Clearly, the international movement of germplasm as live plants (including potted plants, bare rooted plants, dormant cuttings and tissue cultures) and seed for breeding and crop improvement has significantly contributed to the development of global agriculture systems. However, trade in live plants also poses substantial biosecurity risk due to: (1) Their capacity as living hosts to introduce regulated pests, which may not be obvious at the entry point and (2) Phytosanitary treatments are more difficult for this pathway. NPPOs typically strictly regulate the importation of live plants and seeds. An excellent example of the risk posed by the unregulated exchange of plant germplasm was the inadvertent introduction of phylloxera (*Daktulosphaira vitifoliae* Fitch) into Europe in the mid 1880s resulting from attempts to manage another pest. Grapevine cuttings were imported from North America into Europe for study but unfortunately the vines were infected with powdery mildew. European vines were extremely susceptible to the disease and vineyards were threatened with total destruction. Given that North American vines were immune to the disease, thousands of American vines were imported to breed with European cultivars. Unfortunately, the root-inhabiting phylloxera was introduced on these cultivars along with two additional fungal pathogens, Downy Mildew and Black Rot. As a result of these uncontrolled introductions, millions of hectares of grapevines were destroyed and the French vineyards were almost entirely destroyed (Mathys and Baker 1980).

Many border agencies require an import permit for entry of live plants and seeds for propagation. The permit stipulates specific import conditions based on the pest risk and the type of planting material. Import conditions may be as simple as visual screening on arrival for certain low risk seed and ornamental hosts imported in tissue culture to mandatory treatments and extensive pathogen testing in Post Entry Plant Quarantine (PEPQ) facilities (known as Plant Quarantine Stations in the USA). The objective of PEPQ is to allow plants to pass through a period of growth so that NPPOs can screen and/or test for phytosanitary diseases before releasing the plants from quarantine. Regardless of the specific conditions, imported live plants must meet several basic import conditions including being clearly labelled with both genus and species names and being free of obvious pests symptoms. Imported live plants usually undergo a mandatory inspection on arrival and a phytosanitary treatment to manage insect pest risks.

The phytosanitary risk posed by live plants varies depending on several factors including: (1) Host-susceptibility to significant phytosanitary pests; (2) Economic and ecological impact of the pest on crops and native plant flora; (3) Country of origin and source (e.g. collected from wild versus commercial supplier); (4) Age of plant material; and (5) Type of plant imported (e.g. tissue culture plantlet versus rooted plant).

Live Plants. Imported live plants are typically classified into two or more risk categories. Low-risk plants include many ornamental species that are not hosts of significant plant pests. These plants are imported in tissue culture under sterile conditions, and then the likelihood of regulated pests being present is largely mitigated and may simply require visual inspection on arrival. If no obvious pests or diseases are present, then they can be released without further phytosanitary intervention. If the same ornamental plants are imported as bare rooted cuttings, then we see a greater risk of phytosanitary pests being present. Additional mitigation steps, including treatment and growth in PEPQ with disease screening, may be required. This process can be completed in Government PEPQ facilities or more commonly in approved private nurseries that conform to specific criteria and provide an appropriate degree of security and containment. These arrangements benefit the plant importing industries because they can access greater quantities of imported germplasm than would be possible if imports were restricted to the limited space in Government PEPQ facilities.

High-risk plants commonly include species that are hosts of particularly damaging pests that may significantly impact an industry, the environment or location the species poses a significant weed threat. In Australia, a few examples of high-risk plants include many commercial food crops (e.g. *Citrus*, *Fragaria*, *Malus*, *Prunus*, *Solanum*, *Triticum* and *Vitis* spp.), amenity and forest tree species (e.g. *Eucalyptus, Pinus, Quercus* and *Ulmus*) and ornamental hosts of significant plant diseases (e.g. Sudden Oak Death hosts). High-risk plants usually require active testing for the causal agents of these diseases and are typically placed in Government PEPQ facilities given the higher level of containment and diagnostic expertise required to perform disease testing.

Internationally, several high health-planting sources are recognised by border agencies as centres of excellence. These centres provide a high level of compliance with regulatory requirements including scientific integrity in pest and disease screening and other biosecurity processes. The post-entry phytosanitary requirements for certain plant material sourced from these suppliers can be significantly reduced or waived. Approved sources play an important role in the biosecurity continuum. However, they must regularly be audited by desk-top studies and/or site visits to ensure ongoing compliance with the importing country's regulations.

The international transportation of live plants (particularly rooted plant cuttings moving from one climatic zone in the Northern Hemisphere to the Southern Hemisphere or vice a versa) can be detrimental to plant survival. Plant health rapidly deteriorates while in transit. Combined with phytosanitary treatments, the likelihood of successful propagation very much depends on appropriate selection, preparation and transport of the plant material before importation. Planting material should be obtained from the highest health source available, ideally a pathogen tested source.

Regardless of the source, plant material should be free of obvious pest symptoms. If tissue culture plantlets are not available, then deciduous plants should be sent as young, fully-dormant hardwood or softwood cuttings in preference to rooted plants because of the reduced risk of viable plant diseases. One-year-old cuttings are less likely to have been damaged from pruning cuts, thereby providing fewer infection sites for wound pathogens. Likewise, most wood-rotting fungi are confined to the older central wood of roots, trunks and branches. Disease symptoms are typically more obvious on young tissue. When sending evergreen plants, excessive foliage should be removed to reduce dehydration; all soil from the root ball should be removed and the roots wrapped in damp paper. Plants should be clearly labeled with their full botanical name and loosely packed in a sturdy, padded box containing shredded paper or polystyrene packaging. A copy of the import permit should be attached to the outside of the packing box and labeled as "LIVE PLANT MATERIAL".

On arrival, plants immediately must be transferred to the inspection facility to allow border agency personnel to thoroughly examine the plants for pests and treat for pests as appropriate. Post phytosanitary care of plants after treatment (particularly fumigation) is extremely important for the survival of plants. Treated plants fumigated with Methyl Bromide should be ventilated for a few hours to allow gas to escape. Roots should be kept moist and not allowed to dry; foliage should not be watered for 24 h as any traces of fumigant gas may react with the water. Plants should be kept out of bright sunlight and strong winds for 2–3 days. A good biosecurity practice for dormant plants is to surface disinfect plants using 0.5–1.0 % sodium hypochlorite for 10 min with 0.1 % wetting agent followed by triple washings in tap water to remove the disinfectant.

Cuttings are then propagated or buds are taken from the cutting and budded onto pathogen-tested rootstocks and placed into appropriate PEPQ facilities. After the propagated plant cuttings have established, they are actively tested for viruses and other transmissible pathogens using biological indicators (herbaceous and woody plants), microscopic devices (light and electron microscopes), bacterial and fungal culturing, serological (ELISA) and molecular (PCR) tests as regulated by the importing NPPO.

Tissue Culture Plantlets. Like imported plants, tissue culture (in-vitro) plantlets should be obtained from the highest health source. Tissue cultures are the preferred method for transporting plant germplasm as it typically presents a lower biosecurity risk and is more robust for transport compared with live plant material. In-vitro plantlets should be transported in clearly labelled, air tight and transparent containers to allow inspection on arrival. The growth media should be free of antibiotics and have a high quantity of agar to firmly keep plantlets in place during transport. Low-risk ornamental tissue culture plantlets may simply require visual inspection on arrival and release. Higher risk plantlets may require a period of growth and assessment in PEPQ.

Seed. The importation process for seed for sowing follows the same principles as nursery stock. Certain species of permitted seed simply require visual examination for pests and if compliant may be released with no further phytosanitary intervention. Other species are prohibited or restricted and subject to strict import permit conditions including extensive disease testing in PEPQ facilities. Seed should be free of pulp, dried and free of obvious insect pests and symptoms. Imported seed may undergo mandatory Hot Water Treatment or surface disinfected with 0.5–1.0 % sodium hypochlorite for 10 min with 0.1 % wetting agent followed by triple washings in tap water to remove the disinfectant. Many seed borne diseases do not produce obvious symptoms and may need to be grown in PEPQ with appropriate observation and testing for pathogens of phytosanitary concern. This may include moist incubation whereby seeds are placed on moisten paper and incubated at specified temperatures followed by microscopic examination for the presence of fungal fruiting structures. Another technique for detection of fungal pathogens is the agar plating method whereby seed is placed on selective media (commonly malt extract and potato dextrose agar) and pathogens identified based on their macroscopic colony characteristics. Following testing, the plants are released or seed is harvested from the plants, re-inspected and released to the importer.

Pollen. The international exchange of pollen is less common although trade is significant for some genera such as *Actinidia* and *Pyrus*. Pollen should be collected from pathogen-tested plants or may be tested for pollen borne viruses and virus-like agents by ELISA and/or PCR. Pollen should be free of other floral parts, arthropod pests and fungal pathogens of bees.

PEPQ plays a significant role in the battle against disease entry. In Australia, significant plant diseases have been detected in PEPQ include Plum Pox Virus, Cedar Apple Rust (*Gymnosporangium juniperi-virginianae*), Chestnut Blight (*Cryphonectria parasitica*), Grapevine Corky Bark Virus, Grapevine Fan Leaf Virus and Cereal Smuts.

6.7.6 Re-export and Destruction

When a regulated pest is detected or where imported products fail to comply with the import regulations and no suitable treatment or other alternative risk mitigation system is available, the consignment is either destroyed using an approved process or re-exported. Methods for destruction used by NPPOs include: (1) Deep burial of waste at an approved location at a depth of greater than 2 m; (2) heat treatment and irradiation; (3) incinerations where phytosanitary risk items are burnt to ash; and (4) autoclaving. Re-export of a commodity is typically used for high-value commodities that are prohibited or where the importer does not wish to have the commodity treated or destroyed.

6.7.7 Public Awareness and Engagement

Public awareness and engagement by all stakeholders including government, industry and the public is an essential component of an effective biosecurity programme. Without active awareness and support by the broader community to the phytosanitary regulations, ignorance and non-compliance are likely outcomes. The key to successful community engagement is to involve stakeholders in the development of phytosanitary policies taking into account their views and concerns. In some countries, individuals can register with the border agency and provide input into development of phytosanitary policies and regulations. Industry consultative committees including export and import focused committees have been established with the express aim of consultation on border services and policies. In Australia, the border agency has developed a series of workshops for the cargo import industry to help raise awareness of pests of phytosanitary concern. The free courses target industry personnel working at import cargo depots, wharves and other risk locations helping to raise awareness of the major pests and diseases of concern as well as the major phytosanitary risk pathways and most importantly what to do if pests are detected.

Public awareness campaigns promoting phytosanitary awareness consist of many different facets:

1. *Internet sites, posters and handouts* in various foreign languages highlighting the importance of phytosanitary issues and showing the impact pests can have on agriculture and the environment;
2. *Giveaways* such as hats and pens to promote the importance of phytosanitary programmes; some border agencies have used phytosanitary signage on transport-vehicle tarps and sails for yachts to increase awareness of phytosanitary programmes among target groups;
3. *Phytosanitary awards* for industry groups and individuals who display and contribute to the meaning of phytosanitation. In Australia, the international electronic trading company "eBay" was awarded a national phytosanitary award in 2006 in recognition of efforts made to highlight to buyers and sellers of their legal responsibilities in trading plants and plant products;
4. *School programmes* to target children who are the next generation of travellers and to remind their parents of the importance of phytosanitary principles;
5. *Displays at overseas tourist bureaus and international travel expos* to target travel and shipping agencies about phytosanitary regulations and to spread information about phytosanitary issues to the travelling public;
6. *Displays at agricultural and horticultural shows* to target key risk groups including the public who may be interested in importing plants and plant products and to highlight to the rural sector the potential damage phytosanitary pests may cause to their industry; and
7. *Television* can be a particularly useful medium to get the phytosanitary message across to a wide audience. Several countries have successfully documented the challenges faced by border agencies in managing phytosanitary risks at the border.

A key message that should form part of a public awareness campaign involves the complexity and difficulty in managing risk pathways and the concept of *managed risk* or *acceptable level of protection*. This message is important; otherwise the community may develop unrealistic expectations of an NPPO and become unnecessarily critical when an exotic pest inevitably enters the country.

6.7.8 Enforcement and Compliance

Importers and exporters are responsible for being aware of and complying with all NPPO regulatory requirements before and after the import/export process. NPPOs commonly have enforcement and compliance branches that contribute to the integrity of border operations through investigation and enforcement activities. NPPO's typically have phytosanitary statutory authority and specific regulatory authority whereby regulatory officers have the power to impose fines (known in some countries as "infringement notices") for individuals who contravene phytosanitary regulations.

Phytosanitary infringement notices are used at international airports and seaports where passengers fail to declare items of phytosanitary concern and non-compliance is minor. More critical offences including deliberate smuggling of prohibited goods, falsification of phytosanitary certificates and breaking phytosanitary seals on containers/packaging. These offences are typically pursued by Compliance Officers and may result in more serious prosecutions with court action.

Many NPPOs have compliance agreements with third parties who have approval to undertake certain low-level activities on behalf of the Agency. These agreements are regularly audited to ensure compliance; appropriate sanctions are applied if conditions are contravened. This may include prosecution by the compliance branch or withdrawal of registration as a phytosanitary approved premise.

6.7.9 Access to Specialists

Timely and accurate pest identification and risk mitigation advice is crucial to the delivery of effective border operations. In line with international agreements, regulatory action can only be justified if the pest is of phytosanitary significance. Access to plant diagnostic specialists including entomologists, plant pathologists and botanists is a key element in identifying pests, diseases and weed seeds as well as providing timely advice in the delivery of inspection and certifications services and maintaining and enhancing science-based decisions.

Access to specialist diagnosticians and taxonomists is declining and delays in responding to phytosanitary questions can increase biosecurity risks. A technology increasingly used by border operations involves remote diagnostics, which allows access to a range of offsite specialist biosecurity experts within countries and across borders (Sect. 12.4). Remote diagnostics enable rapid and high resolution images of intercepted live pests to be taken by phytosanitary inspectors by simply connecting microscopic platforms to computers via a camera attachment and communicating with offsite diagnostic specialists via the internet (Sect. 12.5). The remote identifier can discuss the identification over the telephone, giving directions regarding the diagnostic features to check in order to identify the pest. This allows preliminary findings to be reached quickly, reducing waiting time from hours/days to minutes and thus enabling appropriate action to address the phytosanitary risk. Trials are underway to further develop and utilise technology using hand-held microscope devices and mobile phones to allow field-based inspectors to send images to diagnostic specialists. In addition, remote diagnostics is being used as a platform for training of technical specialists without the need to physically bring the specialist and trainees together.

The effectiveness of inspectors in the inspection and clearance of imported and exported plant material very much depends on their capability and confidence in knowing where to look (inspection technique), what to look for (ability to recognise pests) and what phytosanitary action to take when pests are detected. Access to work instructions, standard operating procedures, guidelines, pest data sheets, manuals and posters play a key role in ensuring regulatory decisions are consistent and compliant. Likewise, access to technical training in pest recognition, inspection techniques and treatment protocols from training specialists plays a key role in ensuring the effectiveness of a plant inspector. Some border agencies are now developing e-learning packages to deliver some of this information to phytosanitary inspectors who may be widely scattered around the country.

6.8 Role of Border Personnel in Export Functions

An effective import regulatory system is of paramount importance to exporters. Border inspection gives confidence to the overseas trading country of the commitment to preventing the spread of pests through science-based phytosanitary measures. Inspection also provides overseas countries with confidence about the exporting country's pest freedom. Freedom from major pests is a clear advantage in global trade and an important attribute for a country's export sector.

In contrast to importers who must meet the requirements of their country's phytosanitary regulations, exporters must meet the requirements of another country. As part of ensuring the goods meet the importing country's requirements, NPPOs verify exported goods are safe, accurately described and meet the foreign government's requirements. NPPOs may be required to issue phytosanitary certificates for exported products certifying that the goods have been inspected and found free from pests. Importing countries may request specific additional declarations as part of the certification providing an official government assurance regarding the phytosanitary status of a plant or plant product. This may require an importing country to conduct surveys, inspections or testing for particular pests in order to provide evidence that justifies the provision of the additional declaration. The type of inspection and documentation depends on the commodity and export-destination requirements.

Many NPPOs have international agreements with trading partners and are moving away from end-point inspections of the product to "quality assurance" based systems. Exporters now have greater responsibility for their products' quality and compliance with overseas government requirements with the NPPOs auditing the system to verify compliance. Such arrangements typically require an industry sector or exporting company to develop a hazard assurance framework to identify, control and eliminate hazards for products in line with the importing country's phytosanitary requirements. The system relies on accredited persons or competent staff to undertake particular roles including end-point inspections. The NPPOs role is to negotiate arrangements with importing countries and to approve and oversee the compliance of the process with participating parties including verification of certificates and auditing of the approved arrangements.

This chapter shows that phytosanitary/biosecurity regulation at the border is complex and typically expensive to develop and maintain. However the environmental, economic and social benefits of an effective biosecurity system can be readily demonstrated particularly when the costs and losses to plant production and biodiversity are considered.

6.9 Useful Links

The following links are provided for readers interested in obtaining more specific information concerning the import and export requirements of plants and plant produce.

1. **Australia**
   Import conditions for plants, grains and horticulture: http://www.daff.gov.au/aqis/import/plants-grains-hort
   Export conditions for plants, grains and horticulture: http://www.daff.gov.au/aqis/export/plants-grains-hort
2. **Canada**
   Import conditions for plant products: http://www.inspection.gc.ca/english/plaveg/plavege.shtml
   Export conditions for plants/plant products: http://www.inspection.gc.ca/english/plaveg/expe.shtml
3. **New Zealand**
   Import conditions for plant/forestry commodities: http://www.biosecurity.govt.nz/enter/plants
   Export conditions for plant/forestry commodities: http://www.biosecurity.govt.nz/regs/exports/plants
4. **United States of America** USDA-APHIS maintains a diverse set of links for import and export conditions for plants:
   http://www.aphis.usda.gov/import_export/plants/plant_imports/plant_inspection_stations.shtml
   http://www.aphis.usda.gov/favir/ (fruit and vegetable database)
   http://www.aphis.usda.gov/import_export/plants/plant_imports/Q37.shtml (plants/seed)
   http://www.aphis.usda.gov/permits/ (permits issued by APHIS PPQ)
   http://www.aphis.usda.gov/import_export/plants/manual/index.shtml (PPQ manuals)

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