23

DISEASE MANAGEMENT: EXCLUSION, ERADICATION AND ELIMINATION

Helen Ogle

Contents

23.1 Introduction

Most pathogens of biological and economic significance to Australia have been introduced. For example, the root rot fungus *Phytophthora cinnamomi* is believed by some to have been introduced into south western Australia early this century. It has since spread to many parts of the country and is having a major impact on the native flora and fauna as well as on crops such as avocados and proteas. Poplar rust (*Melampsora medusae*) is thought to have been introduced with plant material illegally smuggled into Australia in 1972. Within months, the fungus had spread as wind-borne inoculum to most parts of eastern Australia, ruining the potentially profitable poplar plantation industry before it even became established. Similarly, the stripe rust fungus (*Puccinia striiformis*) is thought to have been introduced on seeds smuggled into Australia in 1979. Alternatively, it may have entered the country as spores on the clothing of a person returning to Australia from eastern Europe. The fungus subsequently became naturalised and caused serious losses in susceptible wheat cultivars throughout the eastern Australian wheat belt, particularly in the southern, winter rainfall regions.

From these examples it is obvious that one way to restrict the development of epidemics of plant diseases is to prevent pathogens entering regions where they do not normally occur. This strategy for controlling disease is known as **exclusion**. Exclusion ensures that the level of inoculum in an area remains at zero so that there is no chance of a disease epidemic developing. Exclusion is achieved by quarantine, by sanitation or by using planting material that is free from disease. Exclusion can be practised on a national, state, regional or individual property basis.

If outbreaks of disease are observed in new geographical areas, attempts may be made to **eradicate** the pathogen from that area. If propagating material, soil, potting media or water supplies are contaminated with a pathogen, attempts may be made to **eliminate** the pathogen. Both eradication and elimination aim to return the level of initial inoculum in an area to zero.

23.2 Quarantine

It is generally accepted that the first international quarantine measures were imposed in 1374 when the city of Venice banned the entry of travellers suspected of being infected with bubonic plague. In fact, the term 'quarantine' is derived from the Italian word '*quarantina*' referring to a 40-day detention period applied to ships arriving in certain countries from areas where diseases such as bubonic plague, cholera and yellow fever occurred.

The term quarantine has come to mean the establishment by public authorities of protective barriers against the dissemination of injurious pathogens. The goal of plant quarantine is to protect agriculture and the environment from avoidable damage by hazardous organisms introduced by human activities. This goal is achieved by government-established restrictions on the movement of plants, plant products, soil, cultures of living organisms, packing material and commodities as well as their containers and means of transport. The restrictions are designed to prevent the establishment of plant pathogens in areas where they do not occur.

In Australia, outbreaks of the human disease smallpox in the 1850s and 1870s and the discovery of the grapevine destroying aphid, *Viteus vitifoliae* (*Phylloxera vastatrix*), at Geelong in 1875 ensured that quarantine was given full attention. The Commonwealth Quarantine Act came into effect on July 1 1909 and the Australian Quarantine Service was created later in the same year. Australia's quarantine policy and operational procedures are currently administered by the Australian Quarantine and Inspection Service (AQIS).

The evolution of quarantine philosophy and practice in Australia

The quarantine service of any nation functions in a complex and constantly changing environment which is influenced by economic and social considerations as well as biological factors. Consequently, the philosophy and practice of quarantine continues to evolve.

Total bans (embargoes)

During and immediately after World War II many quarantine controls failed and, with improved transportation and increased demands for trade, there was an increase in the spread of diseases around the world. This lead to a total ban by Australia on imports of many species and many products.

Control over illegal importation became more difficult as the methods available to those wishing to evade quarantine controls became more sophisticated. In addition, the constant demand for new products and improved cultivars from overseas lead to the realisation that, for many species, it is best to control imports and use the best available techniques to detect diseases. This approach was believed to involve less risk than total bans, which induce people to smuggle banned products into the country.

Acceptable risk

It was gradually recognised that an effective quarantine system prevents the entry of dangerous, exotic pathogens but does not block the movement of plant products and germ plasm. Since the mid 1970s, the quarantine service has been operating an 'acceptable risk' policy based on a process of risk assessment. 'Acceptable risk' is that point at which the decision-maker determines that the potential risks posed to a nation by a proposed import are small enough to be manageable. This process provides protection against the entry into Australia of unwanted diseases while permitting the international flow of goods and people to continue as freely as possible.

In assessing acceptable risk, the need to conform with international trade obligations under the General Agreement on Tariffs and Trade (GATT), to facilitate passenger and cargo movements and the legitimate movements of plants, animals and their products and to contribute to the conservation of flora and fauna must all be considered. Internationally, Australia was perceived to be using quarantine regulations as de facto trade barriers to protect Australian growers from competition from overseas producers. This was not acceptable under the GATT arrangements so our quarantine system had to be made more open to scrutiny. AQIS responded by adopting the concept of pest risk analysis.

Pest risk analysis

As international trade in agricultural products has increased, Regional Plant Protection Organisations (such as AQIS) have cooperated with the United Nations Food and Agriculture Organisation in attempts to 'harmonise' their phytosanitary (quarantine) practices. Cooperating countries are signatories to the International Plant Protection Convention (IPPC) which came into force in 1952. An IPPC Secretariat has been established to facilitate the development of international standards, guidelines and recommendations in plant quarantine. All Regional Plant Protection Organisations have recognised that the assessment of the risks presented by trading in plants and plant products needs to be based on sound and structured biological principles and that the best way to manage the risks is through the process of pest risk analysis.

Pest risk analysis is the systematic assessment and management of risks due to exotic pests and diseases. In this context, a pest is defined as any form of plant or animal life, or any pathogenic agent, injurious or potentially injurious to plants or plant products.

Pest risk analysis typically has three stages. The first is **risk identification** which involves identifying whether the organism in question qualifies as a quarantinable pest according to the IPPC's definition.

The second stage, **risk assessment**, is the process of establishing an estimate of the probability of the target pest being introduced into the country. Pathogens carried on air currents, by insects or by birds are not amenable to control by quarantine. However, pathogens spread on the host, on host parts or on inert material such as packaging or containers can be controlled by quarantine. Risk assessment may also involve estimating the probability of the target pest becoming established. In this context, computer simulation programs such as CLIMEX can be used to decide where climatic conditions are conducive to the establishment of pathogens.

Risk management, the third stage, involves establishing options to assist quarantine in reducing the risk of introduction and establishment of the target pest. Options that may be considered include obtaining propagating materials from areas free from the target pest, certification schemes and/or closely regulated postharvest sampling inspection regimes. Post-entry quarantine practices such as fumigation, treatment with systemic fungicides, controls on movement and end use of commodities or holding and inspecting plant material in quarantine glasshouses may also be considered.

Pest risk analysis ends when a decision is made on whether the proposed import should be permitted or not. A degree of risk is unavoidable. However, accepting some risk reflects the requirements that quarantine must be flexible to meet changing demands, new technology and changing levels of resources, to avoid establishing unjustified trade barriers and to provide a level of security against the entry of unwanted diseases that is considered cost effective and scientifically justifiable.

A recent review of quarantine in Australia concluded that industry, government and the general public would have to cooperate to achieve the objectives of quarantine in the context of pressures from world trade, tourism and international obligations. It recommended an increased emphasis on monitoring and surveillance within Australia including the development of planned responses to the entry of unwanted organisms. The review also emphasised the need for a higher status for plant quarantine because over the last 25 years, about ten times more plant pests and diseases than animal pests and diseases have entered the country.

The significance of quarantine

Australia's position as an island continent is a natural defence against invasions of exotic diseases. Furthermore, the inhospitable nature of much of Australia's environment to many organisms also acts as a natural defence against invasion by pathogens. This natural defence means that the native flora has evolved in the absence of many pathogens and has not developed resistance to these pathogens. Similarly, the imported plants on which agriculture depends are also vulnerable to exotic diseases because there is little incentive to breed or select strains of crop plants resistant to diseases that do not occur in Australia. Therefore, both the native flora and agricultural crops are likely to be severely damaged if new pathogens are introduced.

Northern Australia is particularly vulnerable to the introduction of unwanted diseases because of its sparse population and its proximity to Papua New Guinea and Indonesia through the islands of the Torres Strait. In addition, traditional trading links between the islands of the Torres Strait act as pathways for the transmission of diseases. In response to this risk, the Northern Australian Quarantine Strategy (NAQS) was developed. Under NAQS, monitoring, sampling and surveying for pests and diseases in Northern Australia and in neighbouring countries has been increased. In addition, use of existing sources of intelligence is being improved and closer local contact to enhance public education, liaison and cooperation encouraged. The capability of AQIS officers in the area to respond by land, sea or air to perceived threats has also been improved.

Pathogens of quarantine significance to Australia

The entry into Australia of a number of pathogens could be very costly economically, aesthetically or environmentally. Past experience with diseases newly introduced into other countries suggests that, at least in some cases, severe damage to native hosts could be expected. The destruction of the American chestnut forests by the chestnut blight fungus (*Cryphonectria parasitica*) following its introduction from Asia in the early 1900s is a prime example of the damage that can result from the introduction of a disease to a new area.

Fireblight, caused by the bacterium *Erwinia amylovora*, is a serious disease of apples and pears which has not been recorded in Australia (Table 29.3), although it has been present in New Zealand since 1919. The disease is believed to have reached New Zealand from America and has, according to Schumann (1991), since been carried from New Zealand to Europe. Australian apple cultivars are susceptible to fireblight and pear cultivars highly susceptible. Computer simulations indicate that most apple and pear growing regions would experience severe fireblight in most seasons because weather conditions in Australia are frequently favourable for disease development. Other bacterial diseases that threaten Australian crops are listed in Chapter 29.

Many trees such as pines (especially *Pinus radiata*), poplars and willows have been introduced into Australia for commercial or aesthetic reasons. Most of the diseases recorded on these plants overseas do not occur here. For example, only one, probably indigenous, rust has been reported on conifers although many exist in other countries. Overseas, western gall rust (*Peridermium harknessii*) causes severe damage on nearly all species of pines, including *P. radiata*, and poses a potential threat to the softwood industry should it be introduced. Dutch elm disease (*Ophiostoma ulmi*), chestnut blight (*Cryphonectria parasitica*) and many other diseases pose threats to introduced tree species. In the last 25 years, rusts of poplars and weeping willows, dothistroma needle blight of pines and marssonina leaf spot of white poplar have been introduced and spread to varying degrees before being detected. They are now well-established on their hosts in Australia. Sugar cane smut (*Ustilago scitaminea*) and sugar cane downy mildew (*Perenosclerospora sacchari*) are already established in Papua New Guinea and Indonesia. With the sugar industry worth $350 million in north Queensland alone, these diseases are a major threat if they reach Australia.

Australia and New Zealand are free from many nematode problems because of effective quarantine regulations. A number of parasitic nematodes such as the soybean cyst nematode (*Heterodera glycines*), the pine wood nematode (*Bursaphelenchus xylophilus*) and the citrus burrowing nematode (*Radopholus citrophilus*) pose serious threats if introduced to either country. Virus diseases that could severely damage crops if introduced to Australia and New Zealand are discussed in Chapter 30.

There are many diseases recorded overseas on hosts in plant families, such as Myrtaceae, which are widespread in the Australian flora. For example, the South American rusts of members of the Myrtaceae, especially guava rust (*Puccinia psidii*), can attack species of *Eucalyptus*, *Callistemon* and *Melaleuca*. Similarly, the canker-forming fungus *Cryphonectria cubensis*, first described in Cuba in 1917, can attack several species of *Eucalyptus*. Introduction of any of these pathogens could be a serious threat to the native flora.

The mycoflora of southern hemisphere countries in particular has received little study apart from the fungi attacking major crop plants. As yet unrecognised diseases are a potential hazard and a quarantine problem for all Australian plants, especially the native flora.

Pathogens that have recently arrived in Australia

Black sigatoka disease of bananas caused by *Mycosphaerella fijiensis* was found in the Torres Strait Islands and at the Lockhart River and Bamaga in Far North Queensland in 1981. Banana plants in affected areas were destroyed and not replanted until a year later using disease-free plants. The disease re-appeared at

Bamaga in 1984 and a new eradication program was initiated followed by replanting of resistant varieties. The disease was found again at Weipa in June 1996 leading to the destruction of about 8,000 plants which are being replaced with disease-resistant varieties. Another outbreak occurred in the Daintree area in mid 1997. It appears that the pathogen has been repeatedly introduced into Australia. With the banana industry worth over $75 million in north Queensland alone, losses associated with spread of this pathogen would be serious. In countries such as Costa Rica, banana plantations are sprayed up to 45 times each year to control black sigatoka disease. The estimated cost of controlling black sigatoka should it establish in north Queensland is over $3 million annually (see Chapter 28 for more information on this disease).

The potato cyst nematodes, *Globodera rostochiensis* and *G. pallida*, are also recent arrivals. *G. rostochiensis* was discovered in Western Australia in 1986. Infected properties were immediately quarantined and infected soil fumigated. Soil from most of the state was prohibited entry to other states to prevent spread of the nematode. However, both species of potato cyst nematode were subsequently found in Victoria in 1991. These nematodes are particularly destructive and have the potential to severely limit potato production, especially in cooler parts of the continent. Further details of these nematodes are given in Chapter 31.

Chrysanthemum white rust, *Puccinia horiana*, was first found in Victoria in 1986 and an immediate eradication campaign began across Australia. Unfortunately, the disease has spread to all other states. The industry has responded by developing resistant varieties which now comprise 90% of field plantings. The alternative is to use chemicals which are estimated to cost $5 million per annum Australia-wide. Flower growers are vigorously opposing a move by AQIS to revoke the rust's status as a quarantinable disease fearing the entry of strains of chrysanthemum white rust to which existing cultivars are not resistant as well as twelve other diseases specific to chrysanthemums that are not yet present in Australia. They also fear that the mass introduction of chrysanthemum plants could lead to the introduction of a pest or disease of minor consequence to chrysanthemums but of major importance to indigenous members of the family Asteraceae.

Quarantine within Australia

Australians are very mobile and there is a real danger that travellers will spread diseases from one state or area to another. Consequently, the various states have established regulations restricting the entry of certain products. For example, no plants or seeds of banana or its relatives in the genus *Musa* are allowed into coastal shires of New South Wales north of Taree or into Queensland because of the risk of introducing the potentially devastating banana bunchy top virus. Similarly, potato tubers and plants from Victoria and Western Australia where the potato cyst nematode occurs are not allowed into the other states. In some cases, plant materials may be allowed entry if certified to be free from a particular disease or if they come from an approved breeding scheme.

Quarantine areas may be set up within individual states to contain diseases in one area. As an example, pawpaw (papaya) and cucurbit seedlings are not to be taken from south east Queensland into the area north of Bundaberg which is free from papaya ringspot virus (= watermelon mosaic virus 1). Similarly, entry of seed potatoes (tubers) into New South Wales shires where seed potatoes are produced is restricted to prevent the entry of the powdery scab fungus, *Spongospora subterranea*. Banana plants cannot be taken to North Queensland from south eastern Queensland or northern New South Wales because of the risk of spreading Panama disease (Fig. 23.1). A recent outbreak of race 4 of Panama disease (see Chapter 28) in bananas in the Northern Territory is being contained by destroying the affected plants and placing the infested property under quarantine. No vehicles are allowed on or off the property and people who are allowed entry to the property must not take their footwear out of the quarantine area.

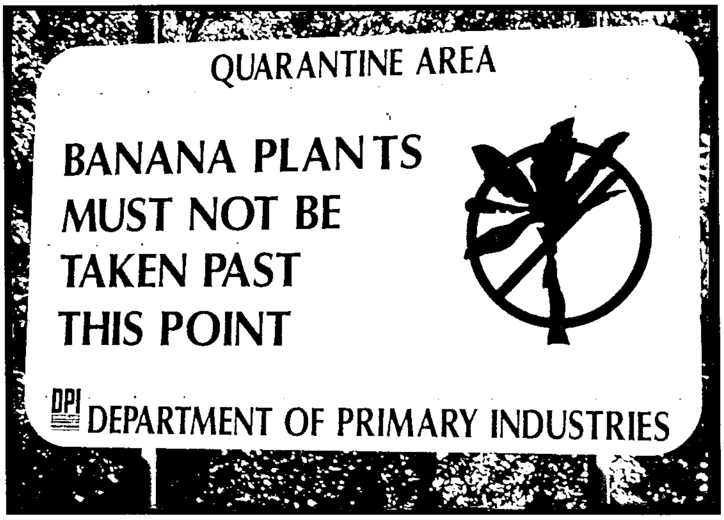

Figure 23.1 A banana quarantine sign in southern Queensland. (From the Banana Industry Protection Board of Queensland, 1996.)

On a very local scale, growers bringing new plants onto their properties should keep these plants separate from the rest of their plants until they are sure that they are not bringing unwanted diseases onto the property, unless the plant material has been certified as being free from disease.

23.3 Sanitation

Sanitation is a basic requirement for preventing the spread of disease to new areas or, on a smaller scale, to new plants or plant products. It involves all procedures that prevent such spread. It can also be used effectively, under appropriate conditions, to reduce the amount of inoculum available at the beginning of a new growing season in areas where a pathogen is already established.

Propagules of plant pathogens and seeds of parasitic plants can be carried from one area to another on farm machinery, tools, equipment and clothing. For example, the dieback fungus (*Phytophthora cinnamomi*) has been spread through the eucalypt forests of Western Australia by logging machinery. Workers who smoke may spread tobacco mosaic virus to susceptible crops on their hands. Australian cotton crops are at risk from pathogens imported into Australia on second-hand machinery from the United States of America. Thorough washing should remove most propagules from machinery, tools, hands, etc. Similarly, washing produce, its containers and the walls of storage areas should reduce the risk of future infections. Baths of copper sulphate solution should kill propagules of pathogens carried on footwear and are often placed at the entrance to glasshouses or areas known to be free from soil-borne pathogens. Pots, potting mixes and hydroponic equipment should not be reused unless disinfested because there is a risk that they are contaminated and may infect plants grown in them.

Soil or components of potting media stored for future use must be protected from contamination by pathogens, pests and weeds. This can be achieved by storing the materials under cover (if feasible), by protecting them from dust and by ensuring they are raised above the surrounding land and drain freely so they cannot be contaminated by water-borne pathogens. The surfaces on which the materials are stored should be clean, easy to disinfest and cleaned between batches of materials.

When dividing vegetatively propagated plants there is a high risk of transferring viruses from one plant to another. So it is important to ensure that viruses on cutting tools are deactivated in solutions such as trisodium phosphate between plants. It is also important to ensure that no sap that may contain virus particles remains on the work surface. This can be achieved by working on sheets of newspaper which are removed and replaced between plants. Similarly, plant sap on hands could easily be transferred from one plant to the next. This can be prevented by washing the hands thoroughly in soap and water after handling each plant.

Removing and disposing of infected leaves, flowers, branches and any other plant material reduces the amount of inoculum available to begin a new epidemic. In the past, ploughing under or burning of plant debris remaining in the field after a crop was harvested was a popular practice that reduced the level of inoculum at the commencement of the next season see Chapter 25). However, with the current trend towards minimum tillage and stubble retention to prevent soil erosion and maintain soil fertility, ploughing under and burning are no longer practised to the same extent. As a result, pathogens that survive between seasons on plant debris and that were previously not economically important have become important. In cereals, this change in cultural practices lead to an increase in the significance of the septoria diseases and yellow spot (*Pyrenophora tritici-repentis*). In the 1920s and 30s, bananas from northern New South Wales and Queensland were often unsaleable when they reached southern markets because of the high incidence of squirter disease (black end) caused by the fungus *Nigrospora sphaerica*. The source of infection was traced to banana trash which had been allowed to accumulate around packing sheds. Removal of the trash overcame the problem.

23.4 Disease free propagating material

Propagating material such as seeds, cuttings, root-stocks, buds, tubers, rhizomes, bulbs and corms can carry pathogens to new areas, either in or on plant tissues. It is essential that propagating material being introduced to new areas be free from disease. This can be achieved by producing planting material in areas free from the pathogen or in areas not suitable for the pathogen or its vector (in the case of vector-transmitted pathogens). It can also be achieved by carefully inspecting plant material for the presence of pathogens. If pathogens are found, the materials can either be destroyed or treated to kill the harmful organisms.

Inspection

Inspection may involve visual appraisal of disease symptoms, sorting procedures and techniques for the isolation and identification of pathogens. Propagating material can be inspected during growth, at harvesting, in storage, at market or before planting. For example, banana planting material approved by the

Department of Primary Industries, Queensland is inspected twice over a period of several months while it is growing to ensure it is free from Panama disease (see Chapter 28), burrowing nematodes (see Chapter 31), banana bunchy top virus (see Chapter 30) and weevil borers.

Sorting procedures include separating healthy from diseased or suspect propagating material by hand, sieving, fanning mills (involving sieves and a strong air current) or immersion of seed samples in liquids to facilitate density separation. Many seed-borne pathogens and infections cannot be observed directly and consequently various diagnostic tests have been developed. Fungal pathogens can often be identified from germinating surface-sterilised seeds on sterile agar media or filter paper. Seed-borne bacterial and viral infections require more sophisticated methods of isolation and identification. A number of latent bacterial infections in plants are difficult to detect and may often be overlooked in the selection of propagation materials. It has been suggested by some workers that susceptible parent stock be tested on selective culture media before any mass propagation commences. Tests based on serological and molecular techniques have been developed for identifying some pathogens (see Chapter 11).

Physical and chemical treatments

Propagules of many pathogens live in or on propagating material and can be easily transferred to disease-free areas on the propagating material. However, these organisms can be eliminated from the propagating material by physical (usually heat) or chemical treatments.

The application of heat to infected planting materials has been successful in controlling some plant pathogens. Heat treatments are most useful in controlling infections that are so deep in the planting material that fungicides are unable to penetrate the host tissues. The success of any heat treatment applied to propagating materials depends on the differential temperature tolerances of the host and the pathogen. The host tissues must be able to withstand higher temperatures than the pathogen during the treatment period. In some cases the effect of heat may be indirect due to the production of fungitoxic substances by the host. These substances may arise from anaerobic respiratory pathways, especially when hot water treatments are employed.

Immersing propagating material in hot water successfully eliminates a number of fungal pathogens. For example, infected wheat seed can be presoaked in cold water for 4–6 hours before immersion in water at 54°C for 10 minutes to control loose smut (*Ustilago tritici*). Similarly, leaf spot of brassicas caused by *Alternaria brassicae* and *A. brassicicola* can be controlled by immersing infected seed in water at 50°C for 18 minutes. Rhizomes of mint (*Mentha* sp.) can be immersed in water at 44°C for 10 minutes and then placed in cold water to control mint rust (*Puccinia menthae*). However, this procedure is only effective when the rust persists as urediniospores rather than as teliospores which are more resistant to environmental extremes. Fusarium dry rot (*Fusarium oxysporum*) can be eliminated from the cormels (small corms) of gladioli by soaking the cormels overnight in water and then immersing them in water containing 5% alcohol at 54°C for 30 minutes. Hot water treatments have also been effective in controlling stem and bulb nematodes (*Ditylenchus dipsaci*) in some bulbs (e.g. *Narcissus* spp.) and the ratoon stunt bacterium (*Clavibacter xyli*) in sugar cane planting material (setts).

Dry heat treatments have been successful in inactivating seed-borne viruses such as tomato mosaic virus (5 days at 70°C, 1 day at 80°C), cucumber green mottle mosaic virus (3–6 days at 76°C) and lettuce mosaic virus (3 days at 80°C).