Bacterial fruit tree quarantine pathogens – a threat to biosecurity in South Africa

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Quarantine bacterial plant pathogens present a serious threat to the biosecurity of South Africa's fruit tree industry, posing significant risks to agricultural productivity, trade and biodiversity. Pathogens such as *Candidatus* Liberobacter asiaticus, *Xanthomonas citri* pv. *citri, Erwinia amylovora* and *Xylella fastidiosa* can cause widespread economic losses in fruit crops, including citrus, apples, pears, grapes and olives. Managing these pathogens is challenging due to their ability to spread rapidly, often by the movement of infected plant material and/or by insect vectors. Limited diagnostic capabilities, few chemical control options, and the emergence of pathogen resistance also hamper effective management. This review highlights the importance of an integrated approach should an incursion occur, which would initially involve eradication, improved surveillance and public awareness. Strengthening these biosecurity practices is essential in safeguarding the agricultural sector and ensuring continued fruit trade viability.

Significance:

- This review highlights the significant threat posed by quarantine bacterial fruit tree pathogens to South Africa's agricultural biosecurity. These pathogens endanger essential fruit crops, and an outbreak could lead to severe losses, trade restrictions, and socio-economic impacts.
- The review also highlights the challenges that would likely be faced if an incursion should occur. It advocates for an integrated management approach including eradication, surveillance, public awareness, and robust phytosanitary measures, legislative support and inter-agency collaboration. This approach could ensure that we safeguard the agricultural sector and mitigate potential crises.

Introduction

Throughout history, biological invasions have been linked to human activities.[1] Globalisation and international trade in the 20th century have intensified the movement of pathogens, increasing the risk of their introduction into new environments. In these locations, pathogens can find suitable hosts and environments conducive to infection, resulting in epidemics. Climate change further exacerbates the problem, as changing temperatures and precipitation patterns can create favourable conditions for the proliferation of these pathogens and their vectors.[2]

Since 1878, European nations have legislated laws limiting the international movement of plants.[1] In South Africa, the government recognised the importance of preventing the entry of quarantine pests in 1948, with the appointment of Dr SJ du Plessis as the 'Chief of Quarantine'. Today, the phytosanitary regulatory system is governed by the *Agricultural Pest Act 1983 (Act No. 36 of 1983)* and its regulations. South Africa is also a signatory to the World Trade Organization Agreement on the Application of Sanitary and Phytosanitary Measures (WTO-SPS Agreement)[3] and the International Plant Protection Convention (IPPC)[4]. The Agreement grants member countries the right to apply sanitary and phytosanitary measures necessary for the protection of human, animal and plant health. The purpose of the IPPC is to secure coordinated, effective action to prevent and to control the introduction and spread of pests and pathogens of plants and plant products.

Plant biosecurity is critical to protecting agricultural productivity, biodiversity and the national economy. Fruit tree production in South Africa is increasingly threatened by the emergence of bacterial pathogens, especially those classified as quarantine pathogens, i.e. "pathogens of potential economic importance to the area endangered thereby and not yet present there [classified as A1 quarantine pathogens by the European Plant Protection Organisation (EPPO)], or present but not widely distributed and being officially controlled [A2 quarantine pathogens]"[5]. Their appearance would significantly impact on tree health and yields, and have the potential to destroy these agricultural sectors. Their presence will also lead to trade restrictions, as countries could impose stringent phytosanitary import requirements and/or phytosanitary measures to prevent the introduction and establishment of foreign pathogens in non-affected countries. The introduction and spread of pests and pathogens in Africa have already caused significant economic and environmental consequences in numerous countries over recent decades.[6] The introduction of a quarantine pathogen would destabilise agricultural economies, harm food security, and erode the competitiveness of African agricultural exports.

The production of citrus and pome fruits contributes significantly to food security, employment and export revenue in South Africa. These two agricultural sectors together employ approximately 200 000 people annually. In the 2021/2022 season, over 2 MT of citrus fruit and 1.8 MT of pome fruit were produced for both local consumption and the export market.[7] Approximately 77%, 45% and 50% of citrus, apples and pears, respectively, were exported in this same season. The production of table olives and olive oil is a growing market in the country. In the 2021/2022 season, 1400 tons of table olives and 1.5–2.0 million litres of olive oil were produced, with a small percentage exported to Namibia and Botswana.[8] These commodities thus play a key role in South Africa's agricultural economy.

This review explores the threat posed by *Candidatus* Liberobacter asiaticus, *Xanthomonas citri* pv. *citri, Erwinia amylovora* and *Xylella fastidiosa* to plant biosecurity in South Africa, highlighting their potential impact and the phytosanitary measures needed to mitigate risks. The review does not comprehensively discuss the biology, ecology, epidemiology and management of the diseases as there are numerous recent reviews already published on these topics.

Huanglongbing

Huanglongbing (HLB), or citrus greening, is caused by *Candidatus* Liberobacter asiaticus (CLas) and is the most destructive disease of citrus because of its ability to spread rapidly and cause severe damage to citrus production and fruit quality, and the difficulty involved in its control. The disease has devastated the Florida citrus industry, with a reported incidence of 100%.[9] No control of this disease has been found, beyond preventing the trees from becoming infected.

Pathogens and their vector

Candidatus Liberobacter asiaticus (CLas), *Candidatus* L. africanus (CLaf) and *Candidatus* L. americanus (CLam) cause HLB. They are Gram-negative, unculturable Alphaproteobacteria belonging to the *Rhizobiaceae*. As CLaf and its associated vector, the African citrus psyllid *Trioza erytreae*, are already present in South Africa, the focus of this review is on CLas and its vector, the Asian citrus psyllid (ACP), *Diaphorina citri.*

Both psyllid species, *T. erytreae* and ACP, have been shown to vector CLas.[10] Although no transmission tests have been undertaken, CLas has been detected in other psyllid species, *Cacophylla citrisuga*[11] and *Diaphorina communis*[12]. Neither of these two species is reported to be present in South Africa.

ACP is a phloem-feeding insect that thrives when soft, young shoots are present and at temperatures between 20 °C and 27 °C that favour its reproduction.[13] Acquisition of the bacterium and transmission efficiency vary with environmental conditions, feeding duration, life cycle stage and plant tissue type[14] and with the pathogen population in new shoots[15]. ACP is reported to maintain CLas, in a persistent manner, for 12 weeks[16], covering the approximate 90-day lifespan of the psyllid[17].

Hosts

Natural hosts of CLas are species in the *Rutaceae*, with Valencia sweet oranges, mandarins, tangelos and grapefruit being the most susceptible[18], while Eureka lemons, Persian limes and Carrizo citranges are more tolerant[19]. No resistant seedlings or scion-rootstock combinations have been identified for use in commercial citrus production.[20]

Although *Murraya exotica* and *Swinglea glutinosa* have been shown to be hosts of ACP[21], in HLB-endemic areas, they are considered unimportant alternative hosts of the pathogen[22]. However, *M. exotica,* together with *Citrus aurantifolia,* have been described as "preferred hosts" of ACP.[18] In South Africa, *M. exotica* is classified in the *National Environmental Management: Biodiversity Act 10 of 2004* (NEMBA) category 1b[23], i.e. invasive species which must be controlled and, wherever possible, removed and destroyed. It is, however, still commercially available as an ornamental plant locally.

Various non-Rutaceae hosts have been shown experimentally to become infected with CLas; for example, dodder (*Cuscuta* spp.) can transmit CLas to periwinkle plants (*Catharanthus roseus*), tobacco (*Nicotiana tabacum*)[24] and tomato (*Lycopersicon esculentum*).[25] *Pithecellobium lucidum* is regarded as an opportunistic host of HLB in China.[26]

Symptoms

The bacterium colonises the phloem, leading to chlorosis of veins and adjacent tissues, followed by blotching (mottling) of the leaf, premature leaf loss, twig dieback, feeder rootlet and lateral root decay, and decline in vigour, ultimately leading to tree death.[27] Affected trees are stunted, multiple flowers appear off-season, most of which fall off, and fruit is small and irregularly shaped with a rind that is thick, pale and remains green at the bottom. The fruit has a bitter taste. ACP and CLas thrive above 30 °C, and, at these temperatures, CLas reaches high titres in trees, favouring acquisition and transmission by ACP. Environmental stress, extreme temperatures and moisture adversely affect HLB-infected trees.[28]

Distribution and means of movement between countries

HLB is causing significant economic losses and tree death in citrus-producing regions across Asia, the Americas and Africa. In Africa, CLas has only been reported to occur in Ethiopia and Kenya.[29] ACP, however, is reported to be present in Kenya, Tanzania, Ethiopia, Nigeria, Benin and Ghana.[29] As HLB and ACP are present in Kenya, natural spread is expected to follow host plant corridors through Mozambique into South Africa, Zimbabwe or Eswatini.[30] Movement of the vector is greater in spring and summer, and it is able to disperse at least 2 km within 12 days.[31]

Human-mediated activities, such as the illegal movement of plant material, are a serious risk for the spread of CLas and ACP, and this means of dispersal has already been implicated in the long-distance transmission of HLB. Thus, phytosanitary and quarantine measures need to be strictly enforced to restrict the movement of citrus plants in the entire region. One of the challenges will be detecting and removing citrus trees grown for own use in rural and urban areas.

CLaf has been located on the citrus seed coat[32], but appears not to be seed-transmitted. Seedlings do not develop typical HLB symptoms from infected seed and the pathogen has not been found in seedlings germinated from HLB-affected seed.[32] Thus seed transmission, if it occurs, does not appear to play a significant role in CLas dispersal.

Threat to the South African citrus industry

HLB is a regulated disease in South Africa and, as such, the citrus industry – notably Citrus Research International and the South African Department of Agriculture – have put together a HLB/ACP Action Plan.[33] This Plan is led by a steering committee and its objectives are to ensure preparedness, surveillance and a response should an incursion occur. Ongoing surveillance and monitoring efforts along the borders of South Africa, Mozambique, Zimbabwe, Eswatini, Botswana and Zambia are routinely taking place.[34]

Numerous models have been used to predict the potential distribution of CLas and ACP in different climate change scenarios. They are generally continent or country focused. In one study, moderate and extreme climate scenarios were modelled in Africa, and large areas of western, eastern and sub-Saharan Africa, including South Africa, were found to be suitable for the establishment of CLas[35] and ACP[36].

Management

There are no curative methods to control HLB. If an incursion of either CLas and/or ACP enters a new region, the first immediate action is to determine the extent of the outbreak. Thereafter, efforts should be directed towards preventing as many trees as possible from becoming infected by eliminating infected trees and keeping the ACP population as low as possible. Also, only healthy, disease-free certified trees should be planted. This strategy implemented in Brazil resulted in their ability to maintain citrus production and the competitiveness of the industry.[37] One of the reasons the outbreak in Florida reached 100% incidence was because the growers did not remove infected trees to eliminate inocula, but rather focused on employing nutritional programmes to improve tree health.[8] Improved fertigation did not result in decreased HLB.

Citrus canker

Citrus canker, especially Asiatic canker caused by *Xanthomonas citri* pv. *citri* (Xcc), is a major threat to sustainable crop production and food security worldwide. All commercial citrus cultivars are affected by the disease, and there is no strategy to minimise the spread of the pathogen in orchards. The introduction of the pathogen into a country where it is absent has national and international trade implications. Thus, efforts to eradicate the disease in the USA, New Zealand, UK and South Africa have been attempted, in some cases successfully, but in others it has reappeared.

Pathogens

Initially, there were five pathovars of *X. citri*, namely, *citri, aurantifolii* (pathotypes B, C, D) and *citrumelo* (pathotype E). Pathotypes D and E were later shown to belong to other causal agents of citrus diseases. They are members of the *Xanthomonadaceae* (Gammaproteobacteria). As the most aggressive pathovar is Xcc[38], this pathogen will be the focus of this review.

Hosts

Citrus canker is most severe on grapefruit, some sweet oranges, Mexican limes, lemons, trifoliate oranges, the pointed leaf hystrix, and their hybrids used for rootstocks.[38] Resistant cultivars are calamondin, kumquats and mandarins. In a study by Licciardello et al.[39], 32 ornamental species within the Rutaceae were artificially inoculated with Xcc. The majority exhibited no symptoms or a weak reaction to Xcc. The most susceptible species were *Eremocitrus glauca* and *Murraya ovatifoliolata*, neither of which is widely grown in South Africa.

Symptoms

Symptoms of citrus canker include dieback, erumpent lesions on the leaves, stems and fruit, defoliation, premature fruit drop, and reduced fruit quality.[39,40] A water-soaked margin develops around necrotic lesions.[39] The abaxial (bottom) surface of the leaf develops necrotic lesions while lesions on the adaxial (top) surface are oily, water-soaked brown spots with a distinct yellow halo. Host cell expansion (hypertrophy) and cell division (hyperplasia) occur, leading to raised blisters. The erupting epidermis due to these activities is a key diagnostic feature of the disease, and lesions occur on leaves, stems and fruits.[41] Wounding by the Asiatic citrus minor (*Phyllocnistis citrella*) significantly increases symptom severity.[42] The disease is most severe under humid, warm, cloudy conditions with wind and rainfall. Ideal temperatures for growth of the bacterium are between 25 °C and 30 °C.[38] Symptoms can appear after 4–7 days under ideal conditions, but may take longer (i.e. more than 60 days) when these conditions are not ideal.[43]

Eradication of citrus canker in South Africa

Two incursions of citrus canker occurred in South Africa. The first was in the 1905/1906 growing season when Marsh grapefruit trees were imported from Florida and planted in the government's experimental orchard in Bela Bela (Limpopo Province). The disease spread in the orchard to orange and lemon trees. All infected trees were removed and burnt, and the disease was eventually eradicated from the farm. In 1916, a severe outbreak occurred in two nurseries in the North West Province when infected nursery stock was obtained from the government orchard. All the trees were destroyed.[44] During the 1917/1918 season, infected *Citrus trifoliata* seedlings were imported from Japan by growers. The eradication campaign was implemented in 1917 with all infected trees destroyed; trees were not allowed to be planted within 4.8 km of an infected orchard without a permit. Strict quarantine and restrictions on replanting were imposed, and, 10 years after this outbreak, the areas were declared free of the pathogen.[45] Inadvertent re-introduction is "highly likely" despite the quarantine restrictions that are in place.[46] Citrus canker has been eradicated from Australia at "least five times"[37].

Distribution and means of movement between countries

Citrus canker is present in Asia, Africa, South America and parts of the USA. In Africa, the disease is present in Burkina Faso, the Comoros, the Democratic Republic of the Congo, Côte d\'Ivoire, Ethiopia, Gabon, Madagascar, Mali, Mauritius, Réunion, Senegal, Seychelles, Somalia, Sudan and Tanzania.[46] It was formerly found in Mozambique.[47]

Citrus canker can be introduced into new areas through the movement of infected citrus fruits and propagative materials. These means of introduction have been suggested as the source of the pathogen in Brazil[48] and the USA[49] from Japan. Human-assisted dispersal has played a role in the distribution of the disease.[37] In urban areas, backyard citrus is a major source of inoculum.[37]

Threat to the South African citrus industry

It has been nearly 100 years since citrus canker was eradicated in South Africa, and to our knowledge it has never reappeared. This means that the import restrictions put in place by the South African Department of Agriculture have been successful. However, for this to continue to be the case, laws pertaining to introductions, greater stringency at customs for the illegal importation of plant material, and surveillance will need to be put in place and maintained.

Management

As with the majority of bacterial plant diseases, a curative strategy to eradicate citrus canker is not an option. Where the disease is already present, management strategies rely on cultural practices and phytosanitary practices.[49] In a new area or country, once the causal agent is identified by a specialist in the field, an eradication campaign should immediately be implemented. This will mean the immediate destruction of infected trees, which, in South Africa, may be complicated by the presence of trees in subsistence and urban gardens. Collaborative strategies between the South African Department of Agriculture, the Agricultural Research Council, the citrus industry and the growers will be essential.

Fire blight

Fire blight, caused by *Erwinia amylovora*, is a highly destructive, complex disease of apples (*Malus domestica*), pears (*Pyrus communis*) and other related species in the *Rosaceae*. In countries where fire blight occurs, outbreaks are often sporadic, with disease development rapidly occurring, leading to the loss of the entire orchard.[50] The ability of the pathogen to spread rapidly makes it a difficult disease to manage. It can cause extensive losses in fruit yields and lead to trade restrictions on fruit exports. Fire blight also affects the longevity and productivity of fruit trees, further exacerbating the economic burden on growers and increasing management expenses.

Pathogen

The causal agent of fire blight is *Erwinia amylovora*, a member of the *Erwiniaceae* and Gammaproteobacteria. It is Gram negative.

Hosts

In the Rosaceae, most of the hosts of *E. amylovora* are in the subfamily *Maloideae,* with a few belonging to the subfamilies *Rosoideae* and *Amygdaloideae*.[51] Besides numerous ornamental hosts, apricot, plum, loquat, quince trees and *Rubus* species are also hosts of this pathogen.[52] However, plum and apricot trees, amongst others, are considered to be non-hosts.[52] *Erwinia amylovora* has also been detected in non-Rosaceae hosts, especially in the undergrowth of orchards and in weeds.[53] They have been suggested as probable sites for multiplication and dispersion of the pathogen.

Symptoms

Symptoms occur on all above-ground parts of the tree, including blossoms, fruit, leaves, shoots, branches, trunks, and, when the rootstock is susceptible, near the graft union.[54] When numerous shoots are infected, the tree appears to be burnt due to its blighted appearance. The bacteria may progressively invade the rest of the tree from the infected flowers and shoots. Infected bark becomes darker than normal and when the outer bark is removed, the inner tissue is water-soaked, often with reddish streaks that later turn dark brown to black. As disease progression slows, lesions become sunken and sometimes cracked at the margins, forming a canker.[53] During periods of high humidity, the tissue that the pathogen has invaded produces a milky sticky exudate composed of *E. amylovora* cells encapsulated with an exopolysaccharide matrix.

Erwinia amylovora may be present in trees that appear to have no apparent fire blight symptoms.[55] The pathogen also transitions from an epiphytic stage on the plant surface (flowers, leaves and shoots) to an endophytic phase within the host tissue.[56] The pathogen can grow in a wide range of temperatures ranging from 4 °C to 37 °C, with an optimum of 28 °C.[57] Blossom blight epidemics only occur when temperatures are above 18 °C. Infections are more severe when conditions are humid or after rain[58], allowing the pathogen population to reach a specific cell density before infection can occur[50]. *Erwinia amylovora* cells can also enter a viable but not culturable state to withstand unsuitable environmental conditions.[5]

Distribution and means of movement between countries

Fire blight was first described in the USA in 1780; thereafter it was detected in Canada in the 1800s.[52] It was identified in New Zealand in 1919 – the only country in the Southern Hemisphere where the disease now occurs. It is present in over 50 countries. In Africa, it occurs in Algeria, Egypt, Morocco and Tunisia.[52]

Australia is the only country that has successfully eradicated fire blight. In 1997, symptoms were observed on *Cotoneaster* in the Royal Botanic Gardens in Melbourne and diagnostic tests confirmed the causal agent as *E. amylovora.*[59] An intensive eradication programme was undertaken, and national surveys conducted for three years following the detection of the pathogen have confirmed the absence of the disease in all Australian states.[60]

Long-distance spread of *E. amylovora* is through the movement of budwood or infected plant material. Local spread of the disease is due to the exudates produced by infected trees, which are easily transported by birds, insects, wind or rain. Fruit is not considered a means of introducing the pathogen into a new area or country.[61] *Erwinia amylovora* has been shown to survive and to be transmitted by the Mediterranean fruit fly (*Ceratitis capitata*)[62] and other insects. Honeybees (*Apis* spp.) visiting infected flowers are responsible for inter-flower transmission during bloom[63]. Pollen from plants such as hawthorn[64] and apple[54] have been reported to harbour *E. amylovora* cells.

Threat to the South African pome fruit industry

In 1975, Erskine[65] recognised the threat posed by fire blight and described how the introduction of the pathogen into South Africa could be prevented. His recommendations included imposing strict quarantine regulations on the importation of nursery stock. In a study on the potential invasion risk levels of fire blight into apple orchards worldwide, South Africa was found to be highly suitable based on climate suitability models.[66]

Management

The most effective method of keeping fire blight out of South Africa is to impose or keep imposing strict phytosanitary measures on the importation of apple and pear scions and seedlings. If fire blight appears, management options are limited, and an eradication campaign should immediately be implemented. Surveys and continuous monitoring in areas at high risk must take place.

Diseases caused by *Xylella fastidiosa*

Xylella fastidiosa, the cause of olive quick decline syndrome, Pierce’s disease of grapevine, almond, coffee and oleander leaf scorch, citrus variegated chlorosis and diseases on other nut and shade trees, is considered to be one of the most dangerous plant pathogens in the world. Its emergence in Europe has resulted in substantial economic losses. Its presence in the olive groves of Apulia, Italy in 2013, for example, caused a socio-economic disaster.[67] About 40% of the citrus trees growing in Brazil are affected by citrus variegated chlorosis, and annual losses can be as high as USD120 million.[68]

Pathogen

Xyllela fastidiosa is a xylem-limited Gammaproteobacterium in the family *Xanthomonadaceae*. Four distinct subspecies have been described: (1) *X. fastidiosa* subsp. *pauca*, causing olive quick decline syndrome, citrus variegated chlorosis and coffee leaf scorch, (2) *X. fastidiosa* subsp. *fastidiosa* causing Pierce's disease of grapevine, (3) *X. fastidiosa* subsp. *multiplex* causing almond leaf scorch and other diseases on nut and shade trees and (4) *X. fastidiosa* subsp. *sandyi* causing oleander leaf scorch.[69] Some subspecies appear to be host specific while others can infect several plant hosts.[70] *Xyllela fastidiosa* can engage in interstrain recombination, and this can result in new strains with host ranges different from the parent strains.[71]

Vectors

Two xylem-sap feeding insects are able to vector *X. fastidiosa*: the sharpshooter leafhoppers (Cicadellidae, subfamily Cicadellinae) and spittlebugs (Cercopoidea, families Aphrophoridae, Ceropidae and Clastopteridae).[72] The pathogen is persistent but non-circulative in non-moulting adult insect vectors and is propagated within vectors, which allows them to transmit the bacterium for months after acquisition from an infected plant.[73] There is no vector–bacterial strain specificity.[74] The natural dispersal of the pathogen is by the insect vectors only.

Hosts

Xyllela fastidiosa can infect both dicotyledonous and monocotyledonous plants. These include economically important agricultural and ornamental plants.[70] The pathogen can also establish non-symptomatic associations with many plants as a commensal endophyte.[70] The list of plants associated with this pathogen includes more than 350 species.

Symptoms

Symptoms caused by *X. fastidiosa* are highly variable and depend on the host plant, bacterial strain and environmental conditions, which include the growing conditions of the plant and its phenological state.[75] The most common symptoms are marginal necrosis and scorching of leaves, leaf wilt, premature defoliation and tree decline, which includes stunting of shoots and twigs.[75]

Distribution and means of movement between countries

Xylella fastidiosa occurs over a wide range of climatic zones. Until the 2010s, the pathogen was only known to occur in the Americas. It first appeared in southern Italy in 2013 in olive trees[76], thereafter spreading to other parts of Italy, France, Spain and Portugal. It is known to occur in Iran, Israel, Lebanon and Taiwan.

Xyllella fastidiosa is unable to spread by contact, air diffusion, or by seed, except pecan.[77] Natural spread is by the insect vector, which can be transported by wind over long distances. The pathogen is also spread by trade and movement of infected plants, and this is an important risk factor for local and global spread.

Threat to the South African olive and other fruit industries

If any one of the diseases caused by *X. fastidiosa* should occur in South Africa, it is highly unlikely that successful eradication would be possible. Thus far, no eradication efforts have been successful in any part of the world where new incursions have occurred. This is due to several factors, including the long latent period (1–10 months, depending on the host), and an extremely broad host range.[78] Climate change prediction models have suggested that the severity of Pierce's disease of grapevine might switch from low/moderate to high in some of the most economically important grapevine growing regions of the world, including South Africa.[79]

Management

Once plants are infected with *X. fastidiosa*, there is no effective treatment. Current options to minimise spread include removal of infected plants, severe pruning and control of the insect vectors with insecticides. Suppressing pathogen populations and reducing transmission of the vectors is currently the only option.

Measures to prevent the entry of quarantine pathogens into South Africa

Phytosanitary regulations, including disease-free certification schemes, are in place to prevent the entry of contaminated seed, propagative material (cuttings and rooted seedlings/cuttings), tubers, rhizomes, bulbs and scions into South Africa. These measures have thus far prevented the entry of all four bacterial pathogens, but continuous monitoring of potential hosts needs to be enforced. Those pathogens vectored by insects are more difficult to regulate. Both CLas and *X. fastidiosa* can potentially enter the country with their vectors by crossing our borders unimpeded. Again, monitoring their hosts for possible signs of either the vector and/or pathogens is essential, especially in bordering neighbouring countries.

Eradication strategies necessary for the prevention of establishment of quarantine pathogens

Eradication of quarantine or exotic plant pathogens involves the removal of all infected plant material in a specific area. This would include the destruction of large numbers of infected plants and those deemed to be at risk, including alternative hosts within quarantine zones. This process can cause both economic and social conflict, as was observed with olive quick decline syndrome in Italy.[70] Quarantine restrictions are enforced, which includes prohibitions on planting susceptible hosts, movement of host material, equipment, soil and produce. There is a loss of market access which can cost a specific industry millions of rands. Guidelines for managing these incursions are set out in the South African Emergency Plant Pest Response Plan.[80] The plan aims to offer an "effective rapid response to the detection, identification and mitigation of an emergency plant pest incursion in South Africa".

Eradication campaigns face numerous challenges, which is why many are unsuccessful. These challenges can include incomplete eradication of the pathogen due to hidden foci of infection, and natural re-invasions and re-introduction by short- or long-distance movement of infected material from contaminated areas. The time between introduction and identification of the causal agent and/or vector can also allow inoculum to accumulate to a point at which eradication or even containment is impossible. However, despite these challenges, campaigns to eradicate fire blight and citrus canker in Australia and citrus canker in South Africa have been successful.

Conclusion

Quarantine bacterial fruit tree pathogens are a significant threat to plant biosecurity in South Africa, with potentially devastating consequences for agriculture, trade and the environment. Addressing this threat requires a comprehensive approach that includes improved surveillance, diagnostics, quarantine measures, research and education. By strengthening plant biosecurity measures, South Africa can protect its agricultural sector, safeguard biodiversity and ensure the continued prosperity of its farming communities.

Data availability

There are no data pertaining to this article.

Declarations

I am an Associate Editor of the *South African Journal of Science*. I have no AI or LLM use to declare.

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