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Risk of spread of banana diseases in international trade and germplasm exchange

David R Jones*

ABSTRACT

Many important pathogens that affect banana have not yet reached the limits of their distribution. Isolates of the fungus *Fusarium oxysporum* f. sp. *cubense* that wilt Cavendish cultivars in the South-East Asian tropics are seen as a significant threat to the Latin American/Caribbean region. Fungal leaf pathogens found in the Asian region that could have serious effects on production in the New World are *Mycosphaerella eumusae* and *Guignardia musae.* The bacterial pathogens causing blood disease in Indonesia and enset wilt in Ethiopia are confined geographically at the moment, but pose a threat as they are beginning to spread. The virus diseases bunchy top and bract mosaic are significant in countries where they are present and their movement to new areas should be prevented. Infected planting material is seen as the main vehicle for the long-distance dissemination of banana pathogens. The international movement of germplasm and planting material as tissue culture is viewed as a much safer option than suckers and corms. However, virus pathogens still pose a risk as they can be carried in tissue culture. Spread of pathogens can occur when banana leaves used to wrap food and protect fruit are transported. Seed and fruit may also facilitate dissemination. *Heliconia* is an important alternative host of the Moko pathogen.

INTRODUCTION

This paper has two main objectives. The first is to give the reader an appreciation of some of the serious problems that affect banana around the world and threaten production should they be introduced to new areas. The second is to outline ways in which these diseases can spread internationally and the measures that can be taken to reduce the chances of spread. This latter topic impinges on trade and quarantine issues.

THE WORLD'S WORST BANANA DISEASES

The world's most serious banana diseases are presented in Table 1 together with general details of their distribution. A cursory glance at the table shows that while some serious diseases occur in all of the four main geographical regions, others do not. There is still scope for the spread of important pathogens between major continents. In addition, not all of these pathogens are present in all the countries in the region in which they are found so more local spread is still possible.

The first banana farmers in South-East Asia and Australasia would have selected those early edible banana clones that were palatable and gave maximum yields. This material would have propagated and disseminated between clan members and traded between ethnic groups, eventually spreading to areas outside the centre of origin. By this means, banana plants would have spread throughout tropical Asia. Later, traders and migrants are believed to have transferred banana clones from Asia to Africa. It is only in relatively recent historical times that banana plants were distributed throughout the Pacific by Polynesians and taken to the Americas by Europeans.

It is remarkable that most of the major diseases

* Consultant in International Agriculture. 12 Charlotte Brontë Drive, Droitwich Spa, Worcestershire WR9 7HU, UK

Table 1. Serious banana diseases, their causal agents and geographical distribution.

Disease	Causal Agent	Australasia/ Pacific	Mainland Asia	Africa	Latin America/ Caribbean
Fusarium wilt of 'Gros Michel' and 'Bluggoe'	*Fusarium oxysporum* f. sp. *cubense* races 1 and 2	+	+	+	+
Fuasarium wilt of Cavendish cultivars in the tropics	*Fusarium oxysporum* f. sp. *cubense* tropical race 4	+	+	-	-
Sigatoka/yellow Sigatoka	*Mycosphaerella musicola*	+	+	+	+
Black leaf streak/black Sigatoka	*Mycosphaerella fijiensis*	+	+	+	+
Eumusae leaf spot	*Mycosphaerella eumusae*	-	+	+	-
Freckle	*Guignardia musae*	+	+	?	?
Moko	*Ralstonia solanacearum* race 2	+	-	-	+
Blood	*Ralstonia* sp.	+	-	-	-
Bacterial wilt of Enset	*Xanthomonas capestris* pv. *musacearum*	-	-	+	-
Bunchytop	*Banana bunchytop virus*	+	+	+	-
Bract mosaic	*Banana bract mosaic virus*	+	+	-	-
Banana streak	*Banana streak virus*	+	+	+	+
Banana mosaic	*Cucumber mosaic virus*	+	+	+	+
Burrowing nematode	*Radopholus similis*	+	+	+	+
Root lesion nematode	*Pratylenchus coffeae*	+	+	+	+
Root lesion nematode	*Pratylenchus goodeyi*	+	-	+	-

key: + recorded; - not recorded; ? records questionable

that affect banana today were not spread worldwide during periods of crop dissemination. Was it because most serious pathogens had not evolved to attack cultivated banana at this time or was it because they were isolated in remote areas of cultivation?

Most of the important diseases that threaten banana cultivation today began to spread and become important in the 20th century following improvements in methods of shipping fruit, which led to commercial export production. During this period, a few genotypes were extensively planted and planting material was transported between locations on an unprecedented scale. The resulting monoculture over wide areas set the scene for the development of disease epidemics.

FUSARIUM WILT

Fusarium wilt is a lethal disease of the banana's vascular system caused by the fungus *Fusariuum oxysporum* f, sp. *cubense* (Ploetz and Pegg, 2000). It is likely that the disease was afflicting susceptible banana cultivars in many locations around the world by the time it was first described on the highly susceptible cultivar 'Silk' in Australia in 1876 (Bancroft, 1876). *Fusarium oxysporum* f. sp. *cubense* may have been affecting banana rhizomes very early in the evolution of the crop and, as an exception to the general rule, may have been carried to new areas in the first waves of transported germplasm. The pathogen can be carried without symptoms, but even symptoms on corms of susceptible cultivars may not have been associated in pre-scientific cultures with the later decline and death of plants.

It was only after commercial production of the cultivar 'Gros Michel' started in the Americas late in the 19th century that the disease reached prominence. Here it acquired the name Panama disease after the country where it first caused extensive damage. Although the pathogen was almost certainly moved around and increased in the Americas with 'Gros Michel' planting material, it is highly likely that it pre-existed in many locations in small plantings of cultivars like 'Silk', which were introduced in colonial times. Luckily for the industry, a commercially acceptable cultivar resistant to populations of *F. oxysporum* f. sp.

cubense present in the Americas was found in the form of the Cavendish cultivar 'Valery'.

Since the turn of the 20th century, *F. oxysporum* f. sp. *cubense* has been recognised in most banana-growing areas with the notable exception of islands in the South Pacific, parts of Melanesia, countries around the Mediterranean Sea and Somalia (Stover and Simmonds, 1987; Pegg *et al.*, 1993). Although its initial spread to many countries may have happened many years ago, it continues to spread even today. Circumstantial evidence indicates that migrants from Java may have introduced the pathogen into the island of New Guinea fairly recently.

Perhaps the greatest threat to export banana production comes from Cavendish-attacking populations of the Fusarium wilt pathogen designated *F. oxysporum* f. sp. *cubense* tropical race 4. Luckily, populations of this particular form of the pathogen have not spread outside the South-East Asian/Australasian region. If this pathogen were to establish and spread in the Latin American/Caribbean region then Cavendish cultivation would become uneconomical just as the production of 'Gros Michel' became uneconomical in the 1950s. However, this scenario of total destruction of export crops should not eventuate today. An outbreak of Fusarium wilt on a commercial plantation of Cavendish in the Latin American/Caribbean region would almost certainly be quarantined. In addition, the industry would by necessity replant exclusively with plants derived from tissue-cultured to avoid dissemination of the pathogen with traditional planting material. The practice of annual cropping, which is gaining popularity in Taiwan and the Philippines, would also be expected to reduce the effects of the disease.

SIGATOKA DISEASES

Sigatoka/yellow Sigatoka disease, caused by a foliage-killing fungus *Mycosphaerella musicola*, became the second major problem on export plantations after Fusarium wilt. It reached the maximum extent of its distribution and potential to cause economic loss during its period of global expansion in the 1930s-1960s. The pathogen must have been originally quite restricted in its distribution in South-East Asia before exploding on to the international scene. What caused this explosion? Was it a mild pathogen that evolved and became much more pathogenic around the time of its first record in Java (Zimmermann, 1902) and then took advantage of pathways of spread facilitated by modern man's improved transport systems? Although intercontinental spread by aerial dissemination was suggested (Stover, 1962), this now seems unlikely given that ascospores quickly lose their viability on exposure to UV light (Parnell *et al.*, 1998) Dispersal by the movement of diseased planting material seems much more likely (Jones, 2000b).

Black leaf streak/black Sigatoka, which is caused by *M. fijiensis,* is presently the most important leaf spot disease of banana. It is now approaching the full extent of its range of distribution, having begun its global spread from the South-East Asian/Pacific region in the early 1970s (Carlier *et al.*, 2000a). The only significant Cavendish production areas free of this leaf spot are in the French Antilles, the Windward Islands, the Canary Islands, India and Australia. More virulent than Sigatoka/yellow Sigatoka and attacking a wider range of genotypes, it is now the most significant problem on commercial Cavendish clones. The costs of chemical control are high and resistance to some active ingredients of serious concern. Genetic engineering has been promoted as the only way of improving Cavendish cultivated for export, but consumer resistance to genetically modified foods is going to be a limitation for sometime to come even if a resistant clone is bred.

The latest Sigatoka-type disease to be documented has been given the name eumusae leaf spot. It is caused by *M. eumusae.* This pathogen is sufficiently different in morphology and in sequences of the ITS of ribosomal DNA from *M. musicola* and *M. fijiensis* to be a distinct species (Carlier *et al.*, 2000b,c; Crous and Mourichon, 2002). First recognised from specimens collected in India in 1992, the pathogen has since been found to be present in Sri Lanka, West Malaysia, Thailand, Vietnam, Mauritius and Réunion. Recently re-examined herbarium specimens from Nigeria, suggest that it was present in that country in 1989 (Carlier *et al.*, 2000b,c). *Mycosphaerella eumusae* undoubtedly has a wider distribution range in Asia and perhaps Africa, but this needs to be determined. Like *M. fijiensis,* the pathogen attacks banana clones in the Cavendish and Plantain subgroup. It has also been recorded on

'Mysore' (AAB), a cultivar resistant to *M. fijiensis.* It is too early to determine if this leaf spot pathogen poses a more significant threat than *M. fijiensis*, but its introduction to areas where it does not yet occur should be avoided.

FRECKLE

Freckle is a disease that is primarily found in the Asian and Australasian/Pacific regions. It is caused by *Guignardia musae*, a fungus that is better known under its anamorph name of *Phyllostica musarum* (syn. *Phyllostictina musarum*) (Jones, 2000a; Jones and Stover, 2000). The pathogen is as significant a problem in export plantations of Cavendish cultivars in Taiwan and the Philippines as black leaf streak/black Sigatoka. 'Pisang Berangan' (AAA, syn. 'Lakatan') is also seriously affected when grown in plantations in West Malaysia. In addition, plantain is known as a host in South-East Asia. As well as leaves, the peel of fruit is attacked. Unsightly blemishes reduce the market value of export fruit so strict controls are employed to reduce its effects. Although *G. musae* has been recorded in the Caribbean, typical symptoms have not been seen in this region. It is possible that misidentifications have been made in the past (Jones, 2000a). This pathogen is another that needs to be excluded from Latin American/Caribbean growing areas.

BACTERIAL DISEASES

The lethal vascular disease Moko, caused by soil-borne *Ralstonia solanacearum* race 2, has been a problem in commercial banana plantations in Central America and parts of South America and the Caribbean since it first appeared in Trinidad the 1890s (Rorer, 1911). Insects can carry the pathogen from diseased plants to the flowers of nearby plants. Man's activities, such as pruning and movement of suckers, also helps spread. A number of strains with different cultural, epidemiological and host range characteristics have been recognised (Thwaites *et al.*, 2000). The only authenticated occurrence of Moko outside the Latin American/Caribbean region has been in the Philippines. An outbreak on Cavendish in export plantations on Mindanao has been attributed to the importation of planting material from Honduras in 1968 (Buddenhagen, 1994). However, reports of the non-lethal, bacterial disease bugtok, which mainly affects fruit of the cooking banana clones 'Saba'(ABB) and 'Cordaba' (ABB) in the Philippines, and is also caused by *R. solanacearum* race 2, predates this event. One explanation is that there may have been two separate introductions of the same pathogen into the Philippines from the Latin American/Caribbean region.

Blood disease has similar effects to Moko in that affected plants are usually killed. This disease, which has only been reported from Indonesia, is caused by a soil-borne bacterium that has not been officially classified. A formal description of the pathogen, which has some characteristics similar to *R. solanacearum* race 1 and some similar to *Pseudomonas syzygii*, is required (Thwaites *et al.*, 2000). Like Moko, blood disease is believed spread by planting material, insects and pruning. Gauman (1921) examined over 100 banana cultivars and found none to be resistant. Blood disease has increased its area of distribution within Indonesia in recent years. Further spread, especially to the Latin American/Caribbean region, needs to be prevented.

The latest serious bacterial problem to spread that affects banana is bacterial wilt of enset caused by *Xanthomonas campestris* pv. *musacearum* (Thwaites *et al.*, 2000). Until recently, this bacterium was confined to Ethiopia where it causes a vascular wilt of cultivated enset (*Ensete ventricosum*) and occasionally banana. However, in 2001, there was an outbreak on banana in Bulyanti village in the Mukono district of central Uganda, which was cause for concern. Some farmers experienced total loss of crop (M. Rutherford, CABI, 2002, personal communication). Like Moko and blood disease, bacterial wilt of enset is spread locally by cultural practices and long distances by the movement of infected planting material. It most likely reached Uganda from Ethiopia by means of human activities. This disease must be prevented from spreading further.

VIRUS DISEASES

The most serious virus disease of banana is bunchy top caused by *Banana bunchy top virus*, which is transmitted locally by *Pentalonia nigronervosa*, the black banana aphid (Thomas and Iskra-Caruana, 2000). The first recorded outbreaks of bunchy top were in Cavendish plantations in Fiji in 1889, but it was most present at this South Pacific location much earlier (Magee, 1953). The origin of

bunchy top is still a mystery. However, one can speculate that farm labourers, who migrated to Fiji in colonial times to service the local sugarcane industry, may have carried infected Cavendish propagating material from the Indian subcontinent. However, this theory was never raised as a possibility by the noted Australian bunchy top researcher C.J.P. Magee, who in fact suggested that the disease may have reached Sri Lanka in planting material from Fiji (Magee, 1953).

In the 1920s, bunchy top threatened to destroy the Australian banana industry, which was only saved by the identification of an aphid-borne virus as the causal agent and the application of strict quarantine controls. These controls, which are still in force today, prevent the disease becoming a major constraint to production. Bunchy top has never been eradicated from any country where it occurs. It is a continuing problem in commercial export plantations in the Philippines. Exclusion is the best means to avoid the effects of the disease. The virus should never be allowed entry to the Latin American/Caribbean growing region.

Bract mosaic disease was first recognised in 1979 and named in 1988 (Frison and Putter, 1989). Symptoms of bract mosaic, which is caused by *Banana bract mosaic virus*, have been seen in the Indian subcontinent and in the Philippines (Thomas *et al.*, 2000). So named because conspicuous mosaics in the bracts are an obvious symptom, bract mosaic has been reported to cause losses of up to 40% in cooking bananas in the Philippines. In commercial plantations of Cavendish in the Philippines, there is a correlation between bract mosaic and high fruit rejection rates due to misshapen fingers. In India, the French plantain cultivar 'Nendran' is particularly susceptible. Distorted suckers, undersized fruit and brittle petioles and peduncles are reported to be symptoms of the disease known locally as kokkan (Thomas *et al.*, 2000). The disease is transmitted within plantations by aphids, including *P. nigronervosa*, and long distances by the movement of planting material. Bract mosaic is another serious disease that should be prevented from reaching the Latin American/Caribbean region.

Banana streak, caused by *Banana streak virus*, has been found on every banana-producing continent, especially in cultivars with an AAB genome, such as plantain. Symptoms resemble those of banana mosaic and as such the disease was first described in Cavendish in the Côte d'Iviore (Yot-Dauthy and Bové, 1966). However, unlike all but the most severe strains of banana mosaic, streaks on leaves usually turn necrotic. In addition, necrosis can be seen on the leaf midrib and petiole. Other symptoms can include, pseudostem base splitting, internal necrosis of the pseudostem, aberrant bunch emergence, reduced bunch size, distortion of the fingers, fruit peel splitting and necrotic fruit spots. Symptoms have been found to be periodic being more pronounced after temperature fluctuations, such as occur between seasons At times, symptoms may be absent. Effects of the disease seem to increase as the number of crop cycles increases. Spread of the disease occurs by mealybug vector locally and in propagating material over longer distances. In commercial situations, banana streak has been reported as a major problem in some plantations in the Los Rios area of Ecuador. There, infection results in basal splitting of Cavendish, which increases susceptibility to bacterial infection. In India, plots of 'Poovan' ('Mysore', AAB) in Tamil Nadu have to be replanted every three years because of loss of productivity. Planting material of 'Mysore' is almost totally infected by *Banana streak virus* in India. Infection is usually high in plantain also. Genomic sequences of the virus capable of giving rise to infection are integrated into the B genome of cultivated banana. Infections can arise during *in vitro* propagation and are believed related to stress factors. This phenomenon has caused complications for breeding programmes (Lockhart and Jones, 2000b).

Banana mosaic is caused by *Cucumber mosaic virus* and has been reported world-wide. Infection occurs when the virus is transmitted by aphid vector from weed hosts, such as *Commelina*, or crop hosts, such as cucurbits, to young banana plants. Symptoms include line patterns and chlorotic mosaics on leaves and fruit. Severe strains cause necrosis first evident in the cigar leaf, leaf distortion and loss of yield. Symptoms are said to be more severe in the winter (Stover, 1972), but this may have arisen from the time when they were confused with those of banana streak. Following an increase in the use of tissue culture-derived planting material, incidences of banana mosaic in new plantations has also increased (Lockhart and Jones,

2000a). Low lying, succulent young banana plants are believed more attractive to the aphid vector than traditional planting material.

NEMATODE PATHOGENS

The burrowing nematode (*Radopholus similis*) is found practically everywhere Cavendish cultivars are grown. It results in a weakened root system that results in yield reductions and uprooting. Losses in commercial plantations have been estimated to be between 75 and 5% depending on the soil conditions, especially fertility, control practices and climatic conditions. Isolates differing in their pathogenicity have been identified (Sarah, 2000) and efforts should be made to prevent further dissemination.

The root lesion nematodes *Pratylenchus coffeae* and *P. goodeyi* occur widely, but not universally, on banana throughout the tropics. However, they are not commonly found on commercial plantations of Cavendish cultivars. Of the two, *P. coffeae* is more widespread. It has been reported to cause up to 60% losses in plantain crops in places in Africa. *Pratylenchus goodeyi* seems adapted to cooler climates and is the most serious pathogen at elevations above 700m in Cameroon. *Pratylenchus* species cause damage to roots and corms is identical to that of *R. similis* (Gowen, 2000). Again, further spread of these nematodes should be avoided.

INTERNATIONAL DISSEMINATION OF THE WORLD'S WORST BANANA DISEASES

Natural spread of the serious banana diseases is usually slow. Those fungal pathogens that produce windborne spores, such as the *Mycosphaerella* species that cause the Sigatoka diseases, have more chance than others to naturally disseminate. However, the main agent of spread of the pathogens responsible for the world's worst banana diseases is man. The ways in which these pathogens can be transported in different types of banana material is outlined in Table 2.

The movement of planting material, such as suckers and corm pieces, provides the greatest opportunities for disease dissemination. This movement was probably responsible for the intercontinental spread of all the widespread pathogens listed in Table 1. It was also the most likely means of spread of Moko disease from Latin America to the Philippines, blood disease between Indonesian islands and bacterial wilt of enset between Ethiopia and Uganda. The movement of new germplasm from country to country as conventional planting material is now regarded as

Table 2. Possibility of pathogens causing banana diseases infecting various types of banana material

	Banana Material					
Banana Disease	Suckers (with attached leaves)	Corms or corm pieces	Sterile tissue cultures	Seed	Leaves (used as decoration or to wrap food)	Fruit
Fusarium wilt	+	+	-	-	-	-
Sigatoka/yellow Sigatoka	+	-	-	-	+	-
Black leaf streak/black Sigatoka	+	-	-	-	+	?
Eumusae leaf spot	+	-	-	-	+	-
Freckle	+	-	-	-	+	+
Moko	+	+	-	-	+	+
Blood	+	+	-	-	+	+
Bacterial wilt of enset	+	+	-	-	+	?
Bunchy top	+	+	+	-	+	?
Bract mosaic	+	+	+	-	+	?
Banana streak	+	+	+	+	+	?
Banana mosaic	+	+	+	+	+	?
Burrowing nematode	+	+	-	-	-	-
Root lesion nematodes	+	+	-	-	-	-

Key: + pathogen causing the disease can be infecting the material
- pathogen causing the disease cannot infect the material
? pathogen causing the disease may infect the material, but proof is lacking or needs confirmation

extremely dangerous and should be avoided at all costs.

TISSUE CULTURE

The movement of banana germplasm as sterile tissue culture is much less dangerous. It significantly reduces the chances of material being transported that is infected with fungi, bacteria and nematodes. However, there is a risk that virus pathogens could be carried within the *in vitro* plants. Plants selected as sources of meristems for tissue culturing need to be tested for viruses to ensure freedom from virus infection (Diekmann and Putter, 1996). Therapeutic techniques have been developed that will remove some viruses from meristem cultures and research is in progress to solve remaining problems. However, these methods are/will be complicated and are not likely to be available as routine procedures for commercial consignments. They have an application in removing viruses from valuable germplasm stocks, such as bred hybrids, that presently cannot be exploited because of infection.

BANANA SEED

Seed is not commercially utilised as banana planting material and is only infrequently moved internationally. However, there is evidence that *Banana streak virus* and *Cucumber mosaic virus* may be seed transmitted (Table 2). Plants arising from seed should be tested for these viruses unless the mother plants have been tested. In addition to viruses, it has been considered likely that seed may be contaminated externally with pathogenic bacteria, such as *Ralstonia solanacearum* race 2. Seed entering Australia has to be surface disinfected with a 5% sodium hypochlorite solution for 10 minutes at room temperature. This recommendation has been endorsed by the Food and Agriculture Organization of the United Nations (Diekmann and Putter, 1996).

BANANA LEAVES AND FLOWERS

In some societies, banana leaves are used as ornaments on special occasions and for wrapping foods. In most banana producing countries, banana leaves are used to cushion and protect banana fruit from the sun during transportation from places of production to market. The long distance movement of leaves that could be infected by pathogens is viewed as a quarantine risk. The spread of black leaf streak/black Sigatoka in Central America may have been accelerated when plantains and green reject export bananas cushioned by infected leaves were trucked across international borders (Stover, 1980). Imported banana leaves and leaf trash should be destroyed. Leaf trash may be found in boxes of commercially packed banana fruit.

It is possible that cut flowers of ornamental *Musa* species, such as *M. ornata* and *M. velutina*, could be traded internationally. The quarantine risks associated with this trade have not been evaluated. Usually, wild *Musa* species have a high resistance to the pathogens that attack cultivated banana.

BANANA FRUIT

Fruit may also carry disease. Freckle, Moko and blood diseases are obvious examples. The pathogens causing these diseases are known to infect fruit. A recent paper from Venezuela suggests that small sporulating lesions of *M. fijiensis* can form on fruit of 'Harton' (AAB, Plantain subgroup) (Cedeno *et al.*, 2000). However, Sigatoka lesions have never been reported on fruit of Cavendish cultivars.

If infected fruit or the peel of infected fruit is discarded in the vicinity of banana plants, there is a possibility that these pathogens would establish. Ascospores of *G. musae* could be actively discharged into air currents. Bacterial pathogens could find their way to banana roots. It has been suggested that blood disease may have been introduced to Java with fruit from Sulawesi that was discarded when found to be diseased (Thwaites *et al.*, 2000). It is also likely that fruit from a plant with a systemic virus disease would contain virus particles. However, the chances of the appropriate insect vector feeding on the peel of a discarded banana and then moving to a banana plant and feeding is an unlikely event. A viruliferous insect vector hitchhiking with banana produce may have a better chance of passing on the infection.

The risk from spores of banana pathogens carried passively on or with fruit is also a quarantine consideration. Research in Brazil has found that large numbers of conidia of *M. fijiensis* are present on the surfaces of fruit of 'Prata Anã' (AAB, Pome

subgroup) from areas where black leaf streak/black Sigatoka is present. These spores retain their viability for 18 days. On cardboard and polyethylene surfaces, such as is used in packaging banana fruit, viability of spores has been found to extend to 30 days (L. Gasparotto, EMBRAPA, 2002, personal communication). However, it is difficult to show that spores in these situations would initiate infections. One would suppose that there is a chance that conidia on fruit and packaging discarded in banana plots could be splashed onto leaves during rainstorms.

The shipment of fruit from commercial plantations in Mindanao in the Philippines to Australia has recently been deemed by the Australian quarantine authorities to carry too great a risk of introducing Moko, freckle and black leaf streak/ black Sigatoka diseases. As a consequence, an application to import fruit into Australia from the Philippines has recently been rejected.

ALTERNATIVE HOSTS OF BANANA PATHOGENS

Alternative hosts of banana pathogens may also provide a means of entry into a new country (Jones and Diekmann, 2000). Luckily, most banana pathogens seem specific to *Musa* and few have been found to infect hosts in other genera. A notable exception is *R. solanacerum* race 2, the cause of Moko disease, which also infects *Heliconia* species. In 1989/90, a survey of 20 *Heliconia* nurseries in Hawaii found five with plants affected by heliconia wilt. Bacteria isolated from some plants were pathogenic on banana. Fortunately, the problem was discovered before spread of Moko to the local banana industry occurred. A tightening of quarantine regulations was proposed (Ferreira *et al.*, 1991). At about the same time, *R. solanacearum* race 2 was found in northern Queensland in Australia causing a wilt of ornamental *Heliconia* imported from Hawaii (Akiew and Hyde, 1993). Prompt quarantine action resulted in the eradication of the pathogen before banana plants in the area could be infected. These incidents show the importance of strict quarantine procedures to ensure that *Heliconia* moving in the international trade is free of bacterial infection.

Ensete ventricosum (enset) is a host of *Xanthomonas campestris* pv. *musacearum*, which also kills banana. It is not known whether other species of *Ensete*, which could be traded as unusual ornamentals, are susceptible. Caution would be the best policy until more is known. Certainly any *Ensete* and *Musa* from Ethiopia should be considered as a possible host. Enset may also be a host of *Banana streak virus*, though this has not been proven (Tessera and Quimio, 2000).

It is known that *Musa textilis* (abacá) is susceptible to bunchy top and bract mosaic in the field. Species in the genera *Alpinia, Alocasia*, *Colocasia, Hedychium, Heliconia* and *Strelitzia* have either been suspected or implicated as alternative hosts of *Banana bunchy top virus,* but there is still no definite proof that any of them are hosts (Thomas and Iskra-Caruana, 2000).

Sugarcane bacilliform virus, which is closely related to *Banana streak virus*, occurs widely in sugarcane (Lockhart and Jones, 2000b). The virus also infects banana after transmission by mealybug vector to give symptoms similar to those of banana streak. Sugarcane could be a potential source of inoculum of virus that affects banana (Jones and Diekmann, 2000).

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