Diseases of plantation forestry trees in eastern and southern Africa

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Plantation forestry is of growing importance in many countries of southern and eastern Africa. With the increased planting, the threat of pests and diseases to these new timber resources has also grown. The significance of pests and diseases to forestry plantations not only applies to the countries in which they are being set up, but also to neighbouring states where plantations are already established. Disease surveys have previously been conducted in East Africa, but mostly more than 20 years ago. We have undertaken a series of surveys in Kenya, Malawi, Mozambique, Tanzania and Zambia to obtain information on the present disease situation in eastern and southern Africa. Some diseases known from other areas of the world were identified and many of these represent new reports from the countries in which they have been found. The diseases encountered included cankers caused by species of *Chrysoporthe, Botryosphaeria* and *Coniothyrium zuluense* on *Eucalyptus* species; leaf and shoot diseases caused by species of *Mycosphaerella* and *Cylindrocladium* on *Eucalyptus* spp.; root rot caused by *Armillaria* spp. on *Eucalyptus, Pinus* and *Acacia* spp.; die-back and canker on *Pinus* spp. caused by *Diplodia pinea* and on *Acacia mearnsii* Phyrophthora root rot and wilt caused by *Ceratocystis albifundus* Some of these diseases can impart serious economic losses, so that forestry companies and organizations in East and southern Africa will need to re-vitalize or establish breeding and selection programmes to identify disease-tolerant planting stock. The preliminary surveys reported here provide a basis for the establishment of an effective African tree health network.

Introduction

Plantations of non-native trees have been grown in Africa for more than 100 years.[1,2] The most common species involved include those of *Eucalyptus, Pinus, Acacia* and *Cupressus.* These trees are grown especially for construction timber and fuel, while in southern Africa this timber also sustains a thriving paper and pulp industry.[1] Timber and wood chips such as those from *Tectona grandis, Acacia mearnsii* and *Eucalyptus* species are also exported to Asian and European markets.

Most forest plantation trees grown in eastern and southern Africa are established from seed, commonly imported from South Africa or Australia. Some trees are, however, propagated from locally collected seed produced in the countries where the trees are grown. Malawi, for example, collects seed locally from improved seed stands. Although seedlings provide a broad genetic base of planting stock for plantation establishment, there has been limited selection and site matching. Some serious disease and pest outbreaks have arisen as a consequence of planting minimally selected stock. There has, however, been a strong drive to improve plantation forestry in eastern and southern Africa and to obtain disease- and pest-tolerant trees. This is especially true in Ethiopia, Kenya, Mozambique, Tanzania, Uganda and Zimbabwe, where *Eucalyptus* plantations are being established based on high-quality plants, including hybrids, derived from vegetative propagation. Furthermore, considerable resources are being allocated to the training of forestry staff and tree improvement. These efforts, aimed at strengthening the forestry business, also embrace research on pests and diseases that might significantly reduce the value of the forest crop if left unmanaged.

The adverse effects of diseases and pests of non-native plantation forest trees are well known in Africa. In the 1960s, Dothistroma needle blight caused by *Dothistroma septosporum*[3] severely damaged plantations of *P. radiata* in East Africa.[4,5] Despite considerable research and concerted efforts, including chemical control, to reduce the impact of the disease, the planting of *P. radiata* had to be abandoned.[5–8] Another disease that has seriously affected the choice of tree species for planting in East Africa is cypress canker, caused by *Seiridium cupressi.*[6,9,10] This disease led to raising the less desirable, but more disease-tolerant *C. lusitanica* in favour of the preferred *C. macrocarpa.*[5,6] An insect pest responsible for considerable damage during the last decade is the cypress aphid, *Cinara cupressi,* which caused the widespread mortality of *C. lusitanica,* and has threatened the planting of this cypress-canker-tolerant species.[11]

Political instability and related factors have resulted in the long-term neglect of forestry in many East African countries. This situation has changed in recent years, however, leading to renewed interest in forestry. After the disease surveys conducted in the 1960s, there have been only sporadic reviews, including the mention of some tree pathogens in checklists and a small number of investigations of specific disease problems, such as Armillaria root rot in Ethiopia and Kenya,[12–14] investigations into the die-back of *Pinus* species in Tanzania[15] and a review of forest diseases in Tanzania.[5] More recently, disease surveys have been conducted in Uganda[16] and Ethiopia,[17] while studies on the causal agents of Armillaria root rot have continued.[18–20] The aim of the study reported here was to expand the scope of surveys of diseases affecting plantation forestry trees in eastern and southern Africa, excluding South Africa. The primary objective was to establish a foundation to support programmes aimed at tree improvement and the exclusion of pathogens from new planting areas in Africa.

Materials and methods

Surveys of *Eucalyptus* spp., *Pinus* spp. and *A. mearnsii* were conducted in Kenya, Malawi, Mozambique, Tanzania and Zambia. Trees showing symptoms of root disease, leaf spots, cracks on stems and branches, cankers, wilting, tip and branch die-back were examined. Material was collected and isolations performed in standard isolation media. For the isolation of ascomycetes and their anamorphs, Malt Extract Agar (MEA, 20 g Biolab Malt Extract, 15 g Biolab Agar, Biolab, Midrand, South Africa) amended with streptomycin sulphate (0.001 g vol^{-1},

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Sigma) was used. To isolate basidiomycetes, a selective medium containing benomyl and streptomycin[21] and for the isolation of oomycetes a selective medium (NARP) containing antibiotics and fungicide in Corn Meal Agar (1.7%, Biolab) was used.[22]

Several different isolation techniques were used, depending on the disease symptoms observed. *Armillaria* spp. were isolated directly from mycelial fans formed under the bark of affected trees on the same day of collection. Bark was split from the wood to expose fresh mycelial fans, after which small sections of the mycelial mat was excised with a scalpel and plated onto agar medium containing benomyl. Plates were incubated at ~20–25°C until the onset of growth. Species of *Mycosphaerella* were isolated using the technique described by Crous,[23] in which ascospores were discharged onto the surface of MEA and single germinating spores transferred to clean MEA plates. For the isolation of other ascomycetous fungi, symptomatic material was split into two parts, half of which was incubated in moist chambers to induce growth and sporulation of fungi, while the other half of the sample was surface sterilized and isolations were made directly from the leading edges of lesions onto MEA. Where *Ceratocystis* spp. were suspected to be involved in disease, a carrot baiting technique was used.[24] All isolates collected during this survey were deposited in the culture collection (CMW) of the Tree Protection Co-operative Programme (TPCP), University of Pretoria, South Africa.

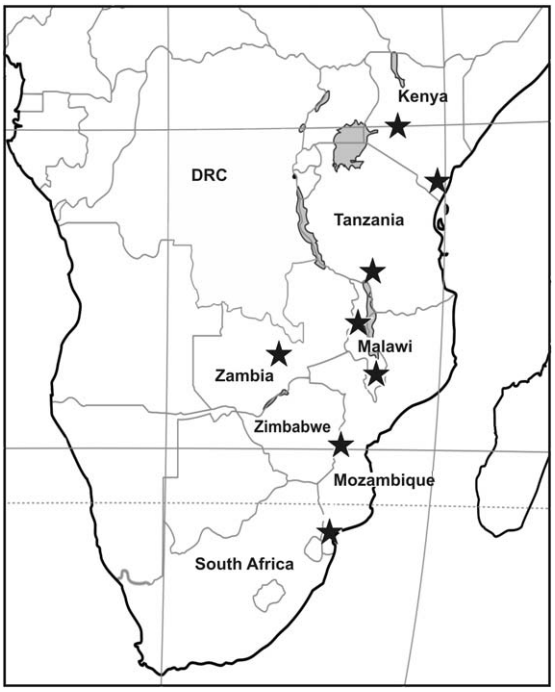


Fig. 1. Map showing the countries in Africa where surveys were conducted for this study. Stars indicate the approximate position of major survey sites.

Results

Disease symptoms

The disease symptoms observed included those of vascular wilt, die-back, stem cankers, leaf and shoot diseases and root rot. The majority of plantations inspected included various *Eucalyptus* spp. However, in Tanzania extensive plantations of *A. mearnsii* were surveyed and plantations of *Pinus* spp. were present in all areas and were also considered. In Mozambique, plantations were in southern Maputo province and around Chimoio in Manica province. In Malawi, *Pinus* and *Eucalyptus* trees around Zomba, Mt Mulanje, Dedza and in the Viphya Mountains were inspected and in Tanzania, plantations of *Eucalyptus* and *A. mearnsii* were surveyed in the southwest of the country near the town of Njombe. Surveys in Kenya focused on *Eucalyptus* plantations on the tropical coast near Malindi and also farther inland towards Nairobi and Eldoret. Only one plantation of *E. grandis* was surveyed in Zambia, near the town of Kitwe. The areas surveyed (Fig. 1) covered tropical and temperate climatic regions, representing a wide range of altitudes (0–2000 m a.s.l) as well as temperature ranges and soil types.

Diseases of *Eucalyptus* species

The most commonly planted *Eucalyptus* species included in this study was *E. grandis.* In Kenya, clones of *E. grandis* hybridized with *E. camaldulensis* (GC), as well as hybrids of *E. grandis* and *E. urophylla* (GU), were also examined. *Eucalyptus globulus* trees were inspected in Tanzania and they were found scattered in most of the countries visited.

The most common disease of *Eucalyptus* spp. was Botryosphaeria canker. Symptoms of this disease included tip die-back on young trees and stem cankers (Fig. 2) on older trees. Internally, trees showed extensive kino accumulation and some wood rot. Fruiting bodies of *Botryosphaeria* spp. were common on dead branches in all plantations surveyed, confirming the presence of this opportunistic pathogen in all areas. At one of the sites, in the Kakuzi area of Kenya, Botryosphaeria canker was especially common and severe. Here, trees were planted in areas affected by regular flooding, followed by desiccation of the soil and termite infestation. Both stem cankers and basal cankers were visible on *E. camaldulensis* trees. Stumps of some clonal hedge plants in a Nairobi (Kenya) nursery also displayed die-back and stem canker symptoms associated with *Botryosphaeria* infection.

Stem cankers caused by *Coniothyrium zuluense,* characterized by small, discrete necrotic lesions on the bark of affected trees, were found in only two areas. These were in the south of Mozambique, near the South African border, and in the Mt Mulanje area of Malawi. No symptoms of this disease were found in Tanzania, Kenya or Zambia. Disease in Mozambique was mild, whereas in Malawi more extensive cankers on branches and growth tips were observed.

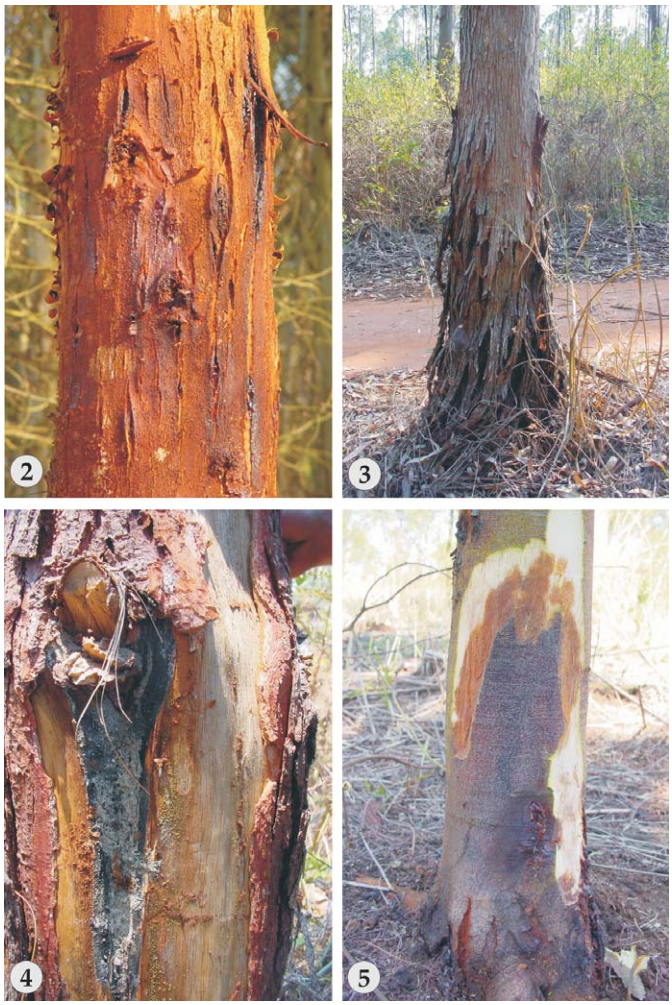
Ceratocystis spp. were found infecting wounds on stems of *E. grandis* trees in Malawi, Tanzania and Kenya. These wounds usually resulted from harvesting operations. Stumps remaining after harvesting or thinning were also commonly infected by *Ceratocystis* spp. Although these species were present, no associated vascular wilt disease symptoms were seen.

Mycosphaerella leaf disease (MLD) was common on *E. globulus* trees in all areas surveyed. In some cases, infection resulted in defoliation of juvenile leaves. Leaf spots with signs of *Mycosphaerella* infection were also found on *E. grandis, E. saligna* and *E. camaldulensis,* but these were of minor importance and were not associated with severe defoliation.

Cankers on *E. grandis* caused by *Chrysoporthe* spp. were found in Mozambique, Malawi, Kenya and Zambia, and on *E. urophylla* in Kenya. Typical symptoms were the cracking and swelling of the bark at the bases of infected trees (Fig. 3). All affected trees were more than five years old. This disease was found in tropical areas such as Malindi in Kenya and in cooler, mountainous areas including Mt Mulanje in Malawi and Chimoio in Mozambique.

Cylindrocladium shoot blight and damping-off was common in nurseries in Kenya. In nurseries where forest soil was used as planting medium, damping-off was especially common. Vegetatively propagated cuttings of some clones displayed cankers and mortality with profuse sporulation of *Cylindrocladium* spp. on the canker surfaces. Samples from hedge plants in neighbouring Uganda also had leaf spots and blight apparently caused by a *Cylindrocladium* species.

Armillaria root rot was found on *E. grandis* in two areas in western Kenya. Approximately 10-year-old trees were found



Figs 2–5. **2**, Cracks and kino exudation caused by Botryosphaeria canker of *E. grandis;* **3**, canker of a *Eucalyptus* tree caused by a *Chrysoporthe* species; **4**, Diplodia infection of a branch stub of *P. patula;* **5**, Phytophthora root rot of an *A. mearnsii* tree.

dying of infection by an *Armillaria* sp. near Kericho and young *E. grandis* (less than a year old) near Nandi Hills displayed Armillaria root rot. Plantations in both of these areas were close to tea estates where Armillaria root rot has previously been recorded.

Infection of *Eucalyptus* leaves by *Phaeophleospora epicoccoides* was common on older, senescing leaves of various *Eucalyptus* spp. in all areas inspected. There was no evidence of leaf death associated with these infections. *Aulographina eucalypti* spots were also common, similarly not resulting in defoliation.

Diseases of *Pinus* spp.

Armillaria root rot was found on *P. elliotii* in the Viphya Mountains of Malawi and north of Nairobi (Uplands) in Kenya. Affected trees ranged from ~5 years old in the Kenyan plantation to more than 15 years in Malawi.

Canker and die-back associated with infections by *Diplodia pinea* were common on *Pinus* spp. in all areas considered. Infection resulted in stain and lesions originating at the branch stubs (Fig. 4) as well as die-back of branches and tops of trees. The pathogen was also found sporulating abundantly on old pine cones and branches in all plantations visited.

Dothistroma needle blight appears to be restricted to *P. radiata* in trial sites in Kenya or on old trees of this species. In some selection trials infection by *D. septosporum* resulted in extensive needle fall.

Diseases of *Acacia* spp.

Armillaria root rot was found on *A. mearnsii* trees near the town of Kakuzi in central Kenya. Affected trees showed basal cankers and gum exudation from this tissue. Young fruiting bodies of an *Armillaria* species were also observed growing from the roots of a diseased tree. Infection by *Armillaria* sp. resulted in the death of the affected trees. The diseased *A. mearnsii* trees grew in close proximity to tea plants that also displayed symptoms of Armillaria infection.

Ceratocystis wilt, also known as wattle wilt, caused by the pathogen *Ceratocystis albifundus,* was found in Kenya and in Tanzania. Infection resulted in rapid wilt and death of trees of all ages.

Symptoms of Phytophthora root rot were common in Kenya and Tanzania. Symptoms are initially similar to those of Armillaria root rot, with the exudation of gum from the bases of affected trees. On older trees, the bark had turned black, resulting in the symptom known as 'black butt'. Discoloration of the phloem was found when bark was removed from the bases of affected trees (Fig. 5). Trees of all ages were affected and the disease was especially common and severe in southwestern Tanzania.

Discussion

This study represents a preliminary investigation of diseases of *Eucalyptus, Pinus* and *A. mearnsii,* established in plantations in Mozambique, Malawi, Tanzania, Kenya and Zambia. To the best of our knowledge, this is the first overview of diseases of these trees in these areas in approximately 30 years. These results form a basis for more intensive disease surveys and they also provide basic information that can be used to establish risk assessment protocols in the area. Moreover, valuable contacts have been established between foresters and forest managers in eastern and southern Africa, where little is known regarding diseases of plantation forest trees. This will facilitate future surveys and will also contribute to the establishment of an effective forest health network in Africa.

Cankers on *Eucalyptus* spp. caused by *Chrysoporthe cubensis* (formery *Cryphonectria cubensis*)[25] were first found in Africa in 1960, when the fungus was collected in the Democratic Republic of Congo.[26] This was followed by reports from Cameroon,[27] and the Republic of Congo.[28] Canker caused by *Chr. austroafricana* was first reported from South Africa in the 1990s.[29] These pathogens also occur on other trees residing in the Myrtales, including clove (*Syzygium aromaticum)* in Asia and Zanzibar[25,30] and *Tibouchina* species in Colombia[31] and South Africa.[32] Recently, *Chr. austroafricana* was also reported from native *Syzygium* spp. in South Africa.[33] To date, *Chr. austroafricana* has been reported only from South Africa and it has been suggested that it might be native to the African continent.[33]

This study has resulted in first reports of cankers on *Eucalyptus* spp. from Mozambique, Malawi, Kenya and Zambia associated with infection by a *Chrysoporthe* sp. In all cases, the disease was characterized by cankers at the bases of mature trees. The presence of this important disease implies that surveys should now be conducted to determine whether it also occurs on young trees, as is the case in South Africa.[29] Isolates of the *Chrysoporthe* sp., associated with cankers in these countries, must also be fully identified to determine whether they represent *Chr. cubensis, Chr. austroafricana* or a possibly unidentified species. This work will have significant implications for quarantine in the area.

Coniothyrium stem canker of *Eucalyptus* spp. is considered to be one of the most threatening diseases to commercially planted *Eucalyptus.* The disease, caused by *C. zuluense,*[34] was first reported from South Africa but has more recently been found in several South and Central American countries,[35] Ethiopia,[36] Uganda,[36] Asia[37] and Hawaii.[38] Its discovery in Malawi and

Mozambique was not surprising given its occurrence in South Africa, Ethiopia and Uganda. Its absence in Zambia, Tanzania and Kenya was somewhat surprising, given that surveys in Kenya were detailed and unlikely to have overlooked the disease.

Some *Ceratocystis* spp. were isolated from wounds on *Eucalyptus* trees in Tanzania and Kenya. Species of *Ceratocystis* include some important tree pathogens.[39] In recent years, wilt of *Eucalyptus* spp. caused by *C. fimbriata* has been reported from Uruguay,[40] Brazil,[41] the Republic of Congo[41] and Uganda.[16] Infection by the pathogen results in rapid wilt and death of susceptible trees. A recent study in South Africa showed that at least two pathogenic *Ceratocystis* spp. (*C. fimbriata* and *C. pirillifromis*) readily infect stem wounds on *Eucalyptus* spp. and that they could emerge as serious pathogens in plantations in the future.[42] It will thus be important to initiate more detailed studies of the *Ceratocystis* spp. from wounds in the countries surveyed to determine the impact of these fungi on tree and stump survival.

Botryosphaeria canker was the most common disease of *Eucalyptus* observed in this study. In many cases, disease symptoms were associated with some form of stress to trees, either linked to environmental conditions, unfavourable silvicultural practices or off-site plantings. In the Kakuzi area of Kenya where *E. camaldulensis* was severely affected by Botryosphaeria canker, damage was to both the stems and the bases of trees. These trees were, however, subjected to regular moisture extremes, placing them under severe stress. Several species of *Botryosphaeria* occur on *Eucalyptus* spp. in Africa. These include *B. parva, B. eucalyptorum* and *B. eucalypticola* from South Africa,[43,44] *B. ribis, B. rhodina* and an unknown species from Uganda,[16,45] *B. parva* from Ethiopia[46] and *B. rhodina* from Republic of Congo.[28] All of these species can be pathogenic on *Eucalyptus* spp. and are linked to stress-associated disease. The establishment of new plantations should thus take the presence of these pathogens into account as well as careful matching of planting stock to site to avoid stress.

Cylindrocladium spp. are common pathogens of *Eucalyptus* and *Acacia* spp., particularly in nurseries.[47] They result in damping-off of young seedlings as well as leaf disease and defoliation, shoot blight and cankers on the stems of young plants. In South African nurseries, both *Eucalyptus* and *A. mearnsii* plants can be severely damaged by *C. pauciramosum*.[48] Of the nurseries inspected in this study, only plants in Kenya and Uganda showed signs of *Cylindrocladium* infection, including damping-off, leaf disease and stem cankers. These nurseries have all embarked on sanitation measures to reduce the *Cylindrocladium* inoculum. Many nurseries, however, rely on soil collected from plantations and forests as a planting medium and on stream water for irrigation. These are common sources of *Cylindrocladium* inoculum and so cost-effective sanitation will have to be found to reduce diseases, including those caused by *Cylindrocladium* spp. in African nurseries.

Mycosphaerella leaf disease was common in most countries surveyed. *E. globulus* is highly susceptible to infection by *M. nubilosa* in South Africa[49] and this fungus appeared to damage juvenile leaves of these trees in the study areas. Spots bearing fruiting structures of *Mycosphaerella* spp. were also present on other *Eucalyptus* spp., but these were not associated with defoliation. Several *Mycosphaerella* spp. have been reported from southern and East Africa.[23,50,51] These species display differences in host range and the age at which leaves are infected. The dominant species in South Africa is *M. nubilosa,* which results in severe defoliation of juvenile leaves of cold-tolerant *Eucalyptus* spp., such as *E. nitens* and *E. globulus*.[51] Some *Mycosphaerella* spp., capable of more serious disease on mature foliage, occur in Australia and South East Asia[23,52,53] and every effort must be made to exclude them from Africa.

Armillaria root rot was found in many of the *Pinus* plantations and was also present on *Eucalyptus* spp. and *A. mearnsii* in Kenya. This disease has previously been reported from *Pinus* and *Eucalyptus* spp. in many parts of Africa. At least five species of *Armillaria* infect trees in East and southern Africa.[18,19,54,55] Trees examined in this survey had all been planted in close proximity to, or on, former agricultural lands including those where tea had been propagated. Armillaria root rot is well known on tea trees in Africa and old tea roots and stumps have probably served as sources of inoculum for infection of plantation trees.

We inspected a relatively small number of plantations of *Pinus* spp. The most common disease problem in these plantations was infections of branch stubs, as well as branch and tip die-back on trees. *Diplodia pinea* was apparently the pathogen responsible for these symptoms, as has been shown in South Africa. The fungus has a cosmopolitan distribution, resulting in tree death, especially after environmental stress and damage to trees by, for example, hail.[56,57] Careful attention to matching species to sites, site preparation and seedling quality will be important to reduce damage by this pathogen.

Dothistroma needle blight caused by *D. septosporum* has been one of the most damaging diseases of non-native forest trees in Africa.[7] Damage due to this disease has largely been reduced by planting non-susceptible species such as *P. patula.* In our study, *D. septospora* was found only in *P. radiata* trial plots in Kenya. The disease thus appears to have been reduced to minor importance during the past four decades. However, inadvertently planting susceptible species could result in serious damage and the recent discovery that two species of fungi cause dothistroma needle blight[3] might mean that a second species threatens other *Pinus* spp. grown as exotics in Africa.

Phytophthora root rot was encountered on *A. mearnsii* wherever this tree was examined. The disease does not always result in tree death but it severely affects bark quality and it slows growth. In South Africa, the disease is predominantly caused by *P. nicotianae,*[58] although species such as *P. meadii* and *P. boehmeriae* have also been found on diseased trees.[59] Studies have been initiated to identify the species of *Phytophthora* collected from *A. mearnsii* during the course of this study, especially in Tanzania, where Phytophthora root rot is a considerable problem.

Wilt of *A. mearnsii* caused by *C. albifundus* was found in Kenya and Tanzania, considerably extending the known geographical distribution of this pathogen. Previously, the pathogen was known only from South Africa[60,61] and Uganda.[62] It has been suggested that *C. albifundus* is native to Africa and that it spread to non-native *A. mearnsii*.[63,64] Surveys are currently under way to determine its occurrence on native African tree species.

Although this paper reports the results of surveys of a limited number of plantations, it serves to indicate the number of new reports and changes in disease profiles since the previous comprehensive surveys were conducted in eastern Africa. With the rapid increase in plantation forestry based on exotics in eastern and southern Africa, it is crucial to establish plantation health networks to protect their trees and also to prevent the possible introduction of pathogens and pests that might affect native African biodiversity.

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