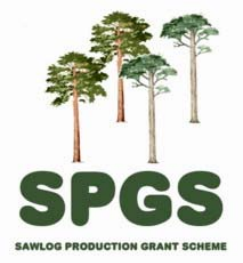
OCCURRENCE OF PESTS AND DISEASES IN TREE NURSERIES AND PLANTATIONS IN UGANDA

A STUDY COMMISSIONED BY THE SAWLOG PRODUCTION GRANT SCHEME (SPGS)



Prepared by
Associate Professor Philip Nyeko and Dr. Grace Nakabonge
Department of Forest Biology and Ecosystems Management
Faculty of Forestry and Nature Conservation
Makerere University
P.O Box 7062, Kampala,
Uganda.

Tel: 256 (0)414 543647 (Office), 256 (0)392 967729 (cell)
Fax: 256 (0)41 533 574
E-mail: nyeko@forest.mak.ac.ug and nakabonge@forest.mak.ac.ug

October 2008

CONTENTS

List of Tables

List of Figures

List of Plates

EXECUTIVE SUMMARY

● Tremendous efforts and resources have gone into commercial forest enterprises in Uganda recently. However, such developments may be frustrated by pests and disease problems. Very little is known about the risks posed by, and the management of, pests and diseases in commercial forestry in the country. Equally worrying is the lack of effective mechanisms to handle tree pest and disease problems in the country. This study was commission by SPGS to provide baseline information that could be used to develop and disseminate management strategies for pests and diseases in tree nurseries and plantations in Uganda.

● This report provides information on pests and diseases that were observed from June to August 2008 in tree nurseries and plantations in various parts of Uganda. Emphasis is placed on the incidence and severity of these problems, and their symptoms and/or signs, impacts and possible management strategies. Finally, the report highlights areas for tree pest and disease research and dissemination in Uganda.

● A number of pests and diseases were observed in tree nurseries and plantations. The incidence and severity of most of them markedly varied in the different parts of the country. *Leptocybe invasa*, bacterial wilt and birds in nurseries; and *L. invasa*, termites, *Botryosphaeria* canker, *Fusarium* wilt, pine wilt, livestock and wildlife in plantation were found causing damage that require immediate management interventions.

● Good silvicultural practices are necessary for the management of most of the pests and diseases observed. *Eucalyptus* clones showed marked variations in the incidence and severity of, particularly *L. invasa, Botryosphaeria* canker and *Mycosphaerella* leaf spots. This is indicates a good scope for using resistant or tolerant planting materials in managing these problems. Judicial application of pesticides may be necessary for some pests and diseases such as termites, rodents and powdery mildew. Opportunities exist in Israel for collaborating on the biological control of *L. invasa* using parasitoids.

● Immediate research is recommended to confirm the cause of pine wilt, and for identifying tree germplasms which are resistant and/or tolerant to important pests and diseases. Monitoring pest and disease problems should be part and partial of their management programmes. We recommend a monitoring mechanism that should effectively engage tree farmers and pest and disease specialists, rather than the latter alone.

● There are a number of potential ways to ensure timely and accurate dissemination of information on tree pests and diseases. We recommend the use of SPGS clients meetings, seminars, short courses, leaflets, brochures, pest and disease databases and press releases for this. Capacity building and close collaboration between the SPGS and other stakeholders, especially farmers, nursery and plantation officers, and pest and disease specialists will be necessary for successful dissemination of tree pest and disease information.

1.0 INTRODUCTION

There are high and increasing demands for tree products and services in Uganda. To cope with this situation, the option often taken is to plant fast growing, adaptable, highly utilisable, exotic tree species such as *Eucalyptus* and pines. Many projects, government institutions and non-governmental organisations (NGOs) in Uganda promote the planting of trees for local farmers in order to meet this premise. For example, the Sawlog Production Grant Scheme (SPGS) is promoting private commercial forest plantation in the country with remarkably high interests generated in the sector. Several forest reserves in the country have been allocated by the Uganda National Forestry Authority (NFA) to private tree planters in order to meet the high land demand for commercial tree plantations. Commercial companies such as British American Tobacco (BAT) and James Finlay Tea Company also encourage the establishment of woodlots as an alternative supply of timber and fuelwood. The Uganda Gatsby Trust is spearheading the growing of clonal Eucalyptus in the country. However, to succeed, such schemes require good management and good management depends on knowledge of growth constraints, including pests and diseases.

Woodlots and forest plantations, especially monocultures of genetically similar trees, are highly vulnerable to insect pests and diseases (Wingfield *et al*., 2001; Cock, 2003). Indeed, there is increasing emergence of new insect pest and disease problems on plantation trees in the tropics. For example, outbreaks of the conifer aphid, *Cinara cuppressivora*, on cypress in eastern and central Africa (Murphy, 1998; Day *et al*., 2003), the sirex wood wasp, *Sirex noctilio*, on pines in South Africa (Tribe, 2003; Hurley *et al*., 2007), and now the blue gum chalcid, *Leptocybe invasa*, on *Eucalyptus* species in many countries in Africa, Asia, the Middle East and Europe (Mutitu, 2003; Mendel *et al*., 2004; Nyeko, 2005; EPPO, 2006) illustrate how such pest problems raise serious concerns to developers of tropical tree plantation enterprises. Recent tree health studies in Uganda have indicated serious pest and disease problems such as *L. invasa* galls, termite infestation, *Botryosphaeria* stem canker and dieback on some widely planted tree species (Roux, 1999; Nyeko, 2005; Nyeko and Olubayo, 2005; Nyeko *et al*. 2007, Roux and Slippers, 2007; Nyeko *et al*., in press). However, little is known about the cause, distribution, host range, population variability and magnitude of such pest and disease problems in plantation enterprises in the country. Pest and disease problems cannot be controlled effectively unless something is known about their causes. Failure to

assess the threat of a particular pest or disease organisms could result in ignoring serious pests and diseases or over-reacting to minor ones.

1.1 Objectives

The aim of this study was to provide baseline information that could be used to develop and disseminate management strategies for pests and diseases in commercial forest plantations in Uganda. The specific objectives were to:

(i) Identify pests and diseases of tree species used in commercial forest plantations
(ii) Determine the current status on incidence, severity and distribution of pest and disease problems in commercial tree nurseries and plantations
(iii) Provide recommendations to the Sawlog Production Grant Scheme (SPGS) on possible management strategies for observed pests and diseases and how such information could be disseminated to tree growers

2.0 MATERIALS AND METHODS

2.1 Survey

Field surveys were conducted from June to August 2008, focusing on agroecological zones where commercial forest plantations have been established in Uganda. In every zone visited, tree nurseries and plantations belonging to SPGS clients were first selected and, where necessary, additional stands or nurseries within the zone were examined. Lists of tree farmers were sought from SPGS.

Every tree nursery and plantation visited, hereafter referred to as site, was examined for pest and disease incidence. Discussions were first held with site managers on pests and diseases on their trees. This was followed by moving at least halfway into the site. In sites where more than 5% of total trees where visually estimated to have a pest or disease, plots each consisting of 20 seedlings, saplings or mature trees were randomly established in order to quantify the pest and/or disease problems. In such sites, a total of three plots were established for each tree species or clone. Every sample plant in every plot was scored for the incidence and severity of any observed pest and/or disease at the site. The incidence of each pest and disease was expressed as the proportion of total seedlings, saplings or mature trees sampled having the

pest infestation or disease. The severity of every observed pest and disease problem was visually scored on each sample plant as: (1) none, (2) low, (3) moderate and (4) severe.

During the survey, symptomatic samples of diseases and insect pests were collected for authoritative laboratory identification and reference collection. Photographs of such samples were taken using a digital camera. Diseased plant tissues were collected and kept in paper bags while insect samples were preserved in vials under 70% ethanol for laboratory diagnoses.

2.2 Laboratory diagnoses

Insect samples were identified using reference resources at Makerere University. Samples of infected plant tissues were subjected to detailed microscopic examination for pathogens. Direct isolations from infected plant samples onto a range of media were carried out at Makerere University. The media included Potato Dextrose Agar (PDA), and selective media for the isolation of *Armillaria, Phythophthora, Pithium* and *Fusarium* species. Nutrient agar (16g nutrient broth, 20g agar) was used for the isolation of phytopathogenic bacteria. Fungal isolation included the transfer of pieces of mycelium, or fruiting bodies from diseased plant tissues directly onto the growth medium, incubating symptomatic plant material in moist chambers to induce sporulation, and inoculating segments of plant parts with disease symptoms onto growth media. Plates were left at room temperature or incubated at 25^{o} C (for suspected soil-borne pathogens) to induce fungal growth.

3.0 RESULTS

Overall, nurseries and plantations belonging to 21 SPGS clients, two private tree farmers and one nursery operator not supported by SPGS, the National Forestry Authority (NFA), James Finlay (U) Ltd. (a private tea company) and Gatsby Trust Uganda were examined (Figure 1 and Appendix 1). In total 14 nurseries, 33 plantations, 2 *Eucalyptus* clonal trials (Ikulwe and Kyembogo), and 2 multi-species and provenance trials at Mwenge and Bugambe tea estates were examined. The pest and disease problems observed are described below.

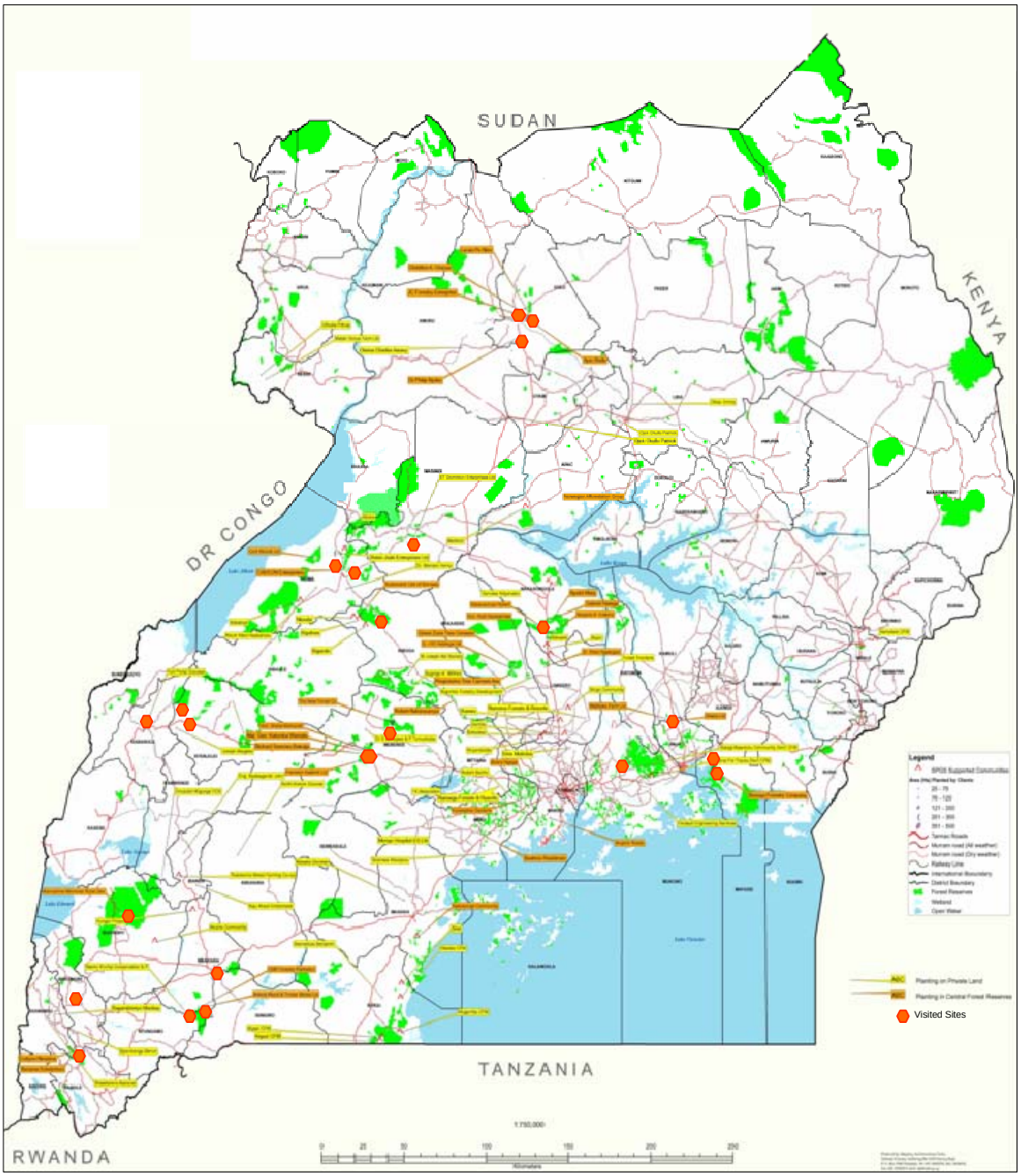


Figure 1: Sites (nurseries and plantations) visited during this study. Some sites had plantations and/or nurseries belonging to more than one person or group of farmers.

3.1 Pests and diseases in nurseries

3.1.1 Pests

Infestations by two insect species (*Leptocybe invasa* and an *Aphis* species) and birds were observed on seedlings in nursery (Plate 1 and Appendix 1). Generally these pest problems occurred in few nurseries (Appendix 1) and were observed on *Eucalyptus* species and clones, and pines. *Leptocybe invasa* (Plate 1a) was found causing galls (Plate 1b) on *Eucalyptus* at NFA nurseries in Mbarara and Gulu, Gatsby Tust (GT) nurseries at Kifu and Kyembogo, and The New Forest Company (NFC) nursery in Mubende. This insect lays its eggs in the bark of shoots or leaf midribs and petioles. The eggs develop into minute, white, legless larvae within the host plant. The developing larvae induce coalescing galls to form on the host plant tissue. Except at Kymbogo, all the nurseries infested by *L. invasa* either had adjacent *Eucalyptus* trees infested by this pest or the infested seedlings had overstayed in the nursery. At Kyembogo, *L. invasa* infestation was observed only in the mother garden on plantlets of clone GC 540 that had recently been brought from Kifu, suggesting that the seedlings were infested from Kifu nursery.

The incidence of *L. invasa* in Gulu, Mbarara and Kyembogo nurseries was less than 5%. At NFC nursery, this insect infested all *Eucalyptus grandis* seedlings that had overstayed in the nursery (previous season's planting). No 1 to 2-month old *E. grandis* and *E. urophylla* seedling was infested by the pest in this nursery. The incidence and severity of *L. invasa* infestation at Kifu varied among *Eucalyptus* clonal hybrids (Table 1). Clones GC 540 and GC 784 had high incidence of *L. invasa* galls (> 80%) while GU 7, GU 21 and GU 609 clones were not infested by the insect. Most *L. invasa* infested seedlings had low gall severity (Table 1).

An unidentified species of aphid (Plate 1c) was observed on a few hedges at Kyembogo mother garden (< 1%), and the severity of infestation was low. Damage by birds was observed at a nursery belonging to Kamusiime Memoral Rural Development Pilot Scheme at Rutoto, Bushenyi district. The farmers reported that birds (weaver birds, chicken, etc.) remove cotyledons of their pines during germination (Plate 1d).

Table 1: Percentage incidence and severity of *Leptocybe invasa* galls on 3-6 month old Eucalyptus clonal hybrids at Kifu nursery.

Clone	Incidence	Severity*			
		None	Low	Moderate	High
GC540	86.7[d]	13.3	56.7	26.7	3.3
GC784	81.7[d]	18.3	38.3	41.7	1.7
GC514	31.7[bc]	68.3	26.7	3.3	1.7
GC550	18.3[ab]	81.7	16.7	1.7	0.0
GC796	10.0[ab]	90.0	10.0	0.0	0.0
GU8	8.3[ab]	91.7	8.3	0.0	0.0
GU607	5.0[ab]	95.0	5.0	0.0	0.0
GC578	3.3[ab]	96.7	1.7	1.7	0.0
GU7	0.0[a]	100.0	0.0	0.0	0.0
GU21	0.0[a]	100.0	0.0	0.0	0.0
GU609	0.0[a]	100.0	0.0	0.0	0.0

* None = no infestation observed; low = galls on < 25% of total leaves; moderate = galls on 25-50% of total leaves; high = galls on > 50% of total leaves. For incidence, means followed by the same letter within a column are not significantly different at 5% probability level.

3.1.2 Diseases

Diseases of *Eucalyptus* in nurseries included bacterial leaf spot and wilt, *Mycosphaerella* leaf spot and powdery mildew (Plate 2). Typical symptoms of bacterial leaf spot and wilt disease observed included brown leaf spots with water-soaked centres (Plate 2a), wilting of sprouts on hedges in mother garden (Plate 2b), mortality of hedges especially in soggy sites (Plate 2c) and shoot dieback (Plate 2d). This disease was observed on *Eucalyptus* clones at Kifu and Kyembogo nurseries and to a much less extent (< 1% of total seedlings in nursery) at Precision Sawmill Ltd (on *E. grandis*), and NFC (on *E. grandis* and *E. urophylla*) nurseries in Mubende. The incidence of this disease was generally high on all clones at Kifu and Kyembogo (Table 2). Clones GC78, GC784 and GC 796 at Kifu and GU7, GU8 and GC 578 at Kyembogo had most seedlings in high severity class (> 50% of total leaves per seedling infected) (Figure 2).

Mycosphaerella leaf spot (Plate 2d) was observed at Kifu, Mbarara and Kyembogo and NFC nurseries. The incidence of this disease was generally low in all the nurseries. At Kifu, it occurred on seven of the 11 Eucalyptus clones examined (Table 2). Overall, the incidence and severity of this disease were low. The highest incidence (10%) was observed on GC540.

Powdery mildew (Plate 2e) was observed at Kifu and Kyembogo. The incidence of this disease was very low at Kifu (<1%, so not scored), but was high on all the clones at Kyembogo (Table 2), but all infected seedlings had low severity of the disease (< 25% of leaves infected).

Table 2: Percentage incidence of bacterial leaf spot (BLS) and *Mycosphaerella* leaf spot (MLS) and powdery mildew (PM) on 3-6 month old *Eucalyptus* clones at Kifu and Kyembogo nurseries.

Clone	Kifu		Kyembogo		
	BLS	MLS	BLSN	BLSMG	PMN
GC540	100.0^{a}	10.0^{c}	-	-	-
GC784	76.7^{ab}	1.7^{bc}	-	-	-
GC514	80.0^{ab}	0.0^{b}	-	-	-
GC550	100.0^{a}	0.0^{b}	-	-	-
GC796	100.0^{a}	5.0^{bc}	88.3	75.0^{b}	100.0^{b}
GU8	35.0^{b}	0.0^{b}	98.3	97.7^{a}	70.0^{ab}
GU607	100.0^{a}	0.0^{b}	-	-	-
GC578	100.0^{a}	23.3^{a}	91.7	88.3^{a}	83.3^{ab}
GU7	55.0^{ab}	6.7^{bc}	100.0	93.3^{a}	53.3^{a}
GU21	70.0^{ab}	6.7^{bc}	-	-	-
GU609	80.0^{ab}	1.7^{bc}	100.0	81.7^{ab}	100.0^{b}

BLSN = is bacterial leaf spot in nursery (seedlings in trays); BLSMG = bacterial leaf spot on hedges in mother garden; PMN = powdery mildew in nursery. Means followed by the same letter within a column are not significantly different at 5% probability level.

The only disease observed on pine seedlings in nursery was *Fusarium* wilt. This disease occurred on pines in two of the nurseries visited (Appendix 1). The disease is characterized by yellowing, browning, wilting and eventually mortality of seedlings (Plate 3a). However, yellowing and wilting of pine seedlings in some nurseries were apparently attributable to late pricking out (Plate 3b), use of insufficient mycorrhizal soil (Plate 3c) and seedlings overstaying in nursery (Plate 3d).

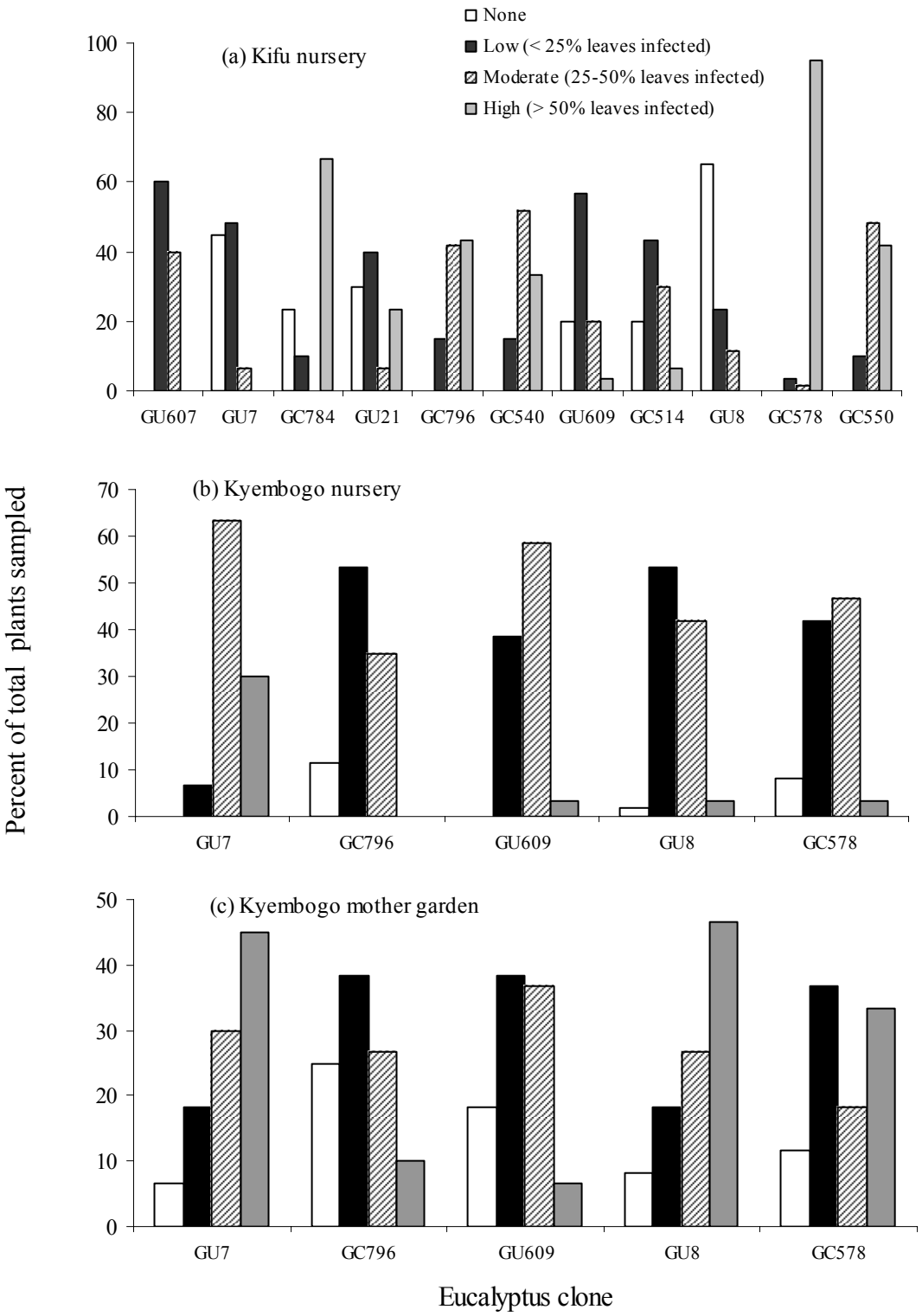


Figure 2: Percentage of *Eucalyptus* clone plantlets in different severity classes of bacterial leaf spot at Kifu and Kyembogo nurseries. A total of 60 plantlets sampled for each clone.

3.2 Pests and diseases in plantations

3.2.1 Qualitative assessment

Pests

A number of pest problems associated with insects and mammals were observed in plantations. A total of four insect-caused problems were observed, viz. galls caused by *Leptocybe invasa* (Plate 4), root and/or stem cutting by termites (Plate 5), sap sucking by the black pine aphid (*Cinara cronartii*?) (Plate 6) and defoliation by *Phymateus viridipes* (Plate 7). *Leptocybe invasa* occurred in all less than 3-year old eucalyptus plantations visited, except those in Mafuga, Kabale. Trees infested by *L. invasa* showed conspicuous galls with adult emergence holes on twigs (Plate 4a) and leaves (Plate 4b). Severely infested trees were stunted (Plate 4c) or gnarled (Plate 4d). A few 1-year old *E. grandis* at Nile ply plantation in Jinja died of severe *L. invasa* infestation. This site also had dense weeds that apparently suppressed treed growth.

The most damaging termite species was *Macrotermes bellicosus*. This species build large mounds with conspicuous vents (Plate 5a). It was observed on all growth stages of *Eucalyptus*, but was especially damaging to seedlings (Plate 5b) and saplings (Plate 5c,d). A *Pseudacanthotermes* species (termite) was observed feeding mainly on dry bark tissues on *Eucalyptus*, but this species was reported by some farmers in Gulu as damaging to their newly planted pine and *Eucalyptus* species. The black pine aphid (Plate 6a) and *Phymateus viridipes* (Plate 7) occurred in very few plantations (Appendix 1), and no tree mortality resulting from their infestation was observed. Colonies of black aphids were associated with sooty mould (Plate 6b) and an unidentified species of ants (Plate 6c), which were attracted to honey dew produced by the aphid. A species of lady bird beetle (Plate 6d) was found foraging on black pine aphids.

Other pests problems observed were inflicted by wildlife and livestock, and generally occurred in few plantations (Plate 8 and Appendix 1). Damage by wildlife included, and stem and root cutting by rats (Plate 8a-c) debarking and stem breaking by monkeys (Plate 8d,e) observed in Mafuga Central Forest Reserve. Some farmers in Kikonda and Kasana Kasambya reported browsing of less than one year old pine seedlings by wild animals suspected to be antelopes. Browsing and trampling by goats (Plate 8f) were observed in one plantation.

Diseases and unknown ill-health problems

A total of five diseases were observed in plantations. *Botryosphaeria* canker (Plate 9) occurred in all stands of *Eucalyptus grandis* that was at least 4 year old, but the disease was not observed on *Eucalyptus* stands less than one-year old. *Eucalyptus* trees that were infested by termites often had exudation typical of *Botryosphaeria* infestation, suggesting that the disease has some association with termite damage. Leaf spots (Plate 10a) and blotches (Plate 10b), and shoot mortality (Plate 10c) caused by bacteria was observed on a few (<5%) young *Eucalyptus* clones (< 1 year old) at Busoga Forest Company, *E. grandis* at Nile ply plantation in Nsube Central Forest Reserve and CADCON Enterprises in Hoima district. Similarly, the incidence and severity of *Mycosphaerella* leaf spot and Powdery mildew were low in plantations. *Mycosphaerella* leaf spot occurred mainly on lower leaves, especially in young plantations (< 2 years old). Powdery mildew was observed only in a young (< 1 year old) *Eucalyptus grandis* stand at Bavame Enterprises, Mafuga Forest Reserve.

A wilt disease of pine (Plate 11) occurred in all the pine plantations visited, except those belonging to Kamusiime Rural Development pilot Scheme in Bushenyi and *Pinus patula* in Mafuga Central Forest Reserve. Typical symptoms of the disease include yellowing of foliage, which starts from shoot tips (Plate 11a) and commonly spread throughout the crown (Plate 10 b). White resinous exudates on lower stem (Plate 11c) and roots (Plate 11d), and rotten roots (Plate 11d) are common on infected trees. Severely infected trees eventually wilt and die (Plate 10b). In a few cases, shoot and branch dieback preceded by yellowing were observed. This disease occurred characteristically in patches of about 1-10 trees. The incidence of the disease was less than 5% in all the pine plantations visited. The disease was most common on 2-5 year old *P. caribaea* and *P. oocarpa*. At Global Woods, the disease was most prevalent in compartments of *P. oocarpa* and *P. caribaea* that were earlier planted to pines. Dead stumps of the previous trees were common in these compartments. Laboratory analysis on selective media for *Phytophthora* species, *Armillaria* species, *Fusarium* species and bacteria did not isolate any of these suspected species. *Botryosphaeria* was isolated on PDA agar from samples from several sites.

Three other tree health problems were observed, but their causes were not clear. One of these was a blight-like problem observed on *P. patula* (Plate 12) at a stand at Rutoto, Bushenyi

district. Laboratory analysis did not isolate any pathogen from plant samples collected from this stand. The second problem was browning of *Cupresus lusitanica* foliage (Plate 13) observed in Rwoho Central Forest Reserve, Mbarara district. The browning is similar to the symptoms of cypress aphid (*Cinara cupressivora*) infestation, but this insect was not observed on symptomatic trees. No pathogen was isolated in laboratory analysis of plant samples with this problem. Another unknown problem was a crown discoloration of pines observed on a few seedlings at Rwoho (Plate 14). Needles of such seedlings turned whitish, especially towards their tips, and were abnormally small toward the shoots.

3.2.2 Quantitative assessment

The incidence and severity of *Leptocybe invasa* galls, termite infestation and *Botryosphaeria* canker were scored in stands that were visually estimated to have more than 5% of tress with the pest and/or disease problems. *Leptocybe invasa* infestation was scored in 10 stands located in 7 districts (Table 3). The incidence and severity of the pest infestation varied among the districts (Table 3). The highest incidence (81% of 60 trees scored) of the pest was observed in Kiboga followed by Jinja. The stands scored in Mayuge and Hoima had significantly lower incidence of the pest than those scored in any of the districts (Table 3).

Table 3: Incidence and severity of *Leptocybe invasa* galls on *Eucalyptus grandis* in selected districts.

District	Total trees sampled	Stand age (yrs)	Incidence	Severity (% of total trees)			
				None	< 25%	25-50%	> 50%
Kiboga	60	2	81.7[a]	20.0	31.7	21.7	26.7
Jinja	120	0.5, 1	74.3[a]	25.8	29.2	13.3	31.7
Mbarara	60	1	65.0[ac]	35.0	33.3	13.3	18.3
Mubende	60	2	63.3[ac]	36.7	40.0	16.7	6.7
Kamuli	60	1	60.0[ac]	40.0	25.0	10.0	25.0
Mayuge	120	1,2	43.7[bc]	56.7	29.2	10.8	3.3
Hoima	120	1,1.5	34.1[b]	65.8	8.3	15.0	10.8

For incidence, means followed by the same letter within a column are not significantly different at 5% probability level.

The most severe termite infestation (50% of trees killed by termites) was observed in a 2.5 year old *Eucalyptus grandis* stand belonging to Global Woods in Kikonda, Kiboga district (Plate 5d). Another stand that was severely infested by termites (42%) was a less than 1 year

old *E. grandis* stand belonging to CADCON Enterprises in Hoima. The damaging termite species in these stands was *Macrotermes bellicosus*, which had several active mounds in and around the plantations. The incidence of termite infestation at Ikulwe *Eucalyptus* clonal trial was generally very high (Table 4), but most of the infestation was limited to the outer bark. The predominant termite species observed at this trial was a *Pseudacanthotermes* species. A few active mounds of *M. bellicosus* were observed in gardens neighbouring the trial.

Table 4: Percentage survival and incidence of termite infestation and *Butryosphaeria* canker on *Eucalyptus* germplasms at Ikulwe, Mayuge district.

Clone	Survival	Termite incidence	Canker incidence
Control (local race)	65.6	88.1	28.6
GC514	87.5	71.4	0.0
GC540	96.9	67.7	0.0
GC550	89.1	84.2	0.0
GC578	95.3	70.5	0.0
GC784	89.1	54.4	0.0
GC796	85.9	38.2	9.1
GU21	95.3	68.9	0.0
GU607	70.3	100.0	2.2
GU609	62.5	100.0	7.5
GU7	79.7	90.2	0.0
GU8	84.4	87.0	0.0
Tag5	70.3	82.2	0.0

The incidence and severity of *Botryosphaeria* canker was scored at the Ikulwe *Eucalyptus* clonal trial (Table 4), Busoga Forest Company, New Forest Company and James Finlay's Mwenge tea estate (Table 5). At Ikulwe, the incidence of *Botryosphaeria* infection varied markedly among the *Eucalyptus* germplasms (Table 4). The local provenance (control) had the highest incidence of the disease while 9 of the 12 clones were not infected. Among the clones, only GC 796 (9%), GU 609 (8%) and GU 607 (2%) were infected by *Botryosphaeria,* but all these clones had low severity (canker occurring on < 25% of stem and no dieback or epicormic shoots) of the disease. The incidence of this disease on *Eucalyptus grandis* (South African provenance) was highest at James Finlay's tea estate (61%) and lowest at Busoga Forest Company (Table 5). Most *Botryosphaeria* infected trees had cankers on less than 50% of the surface of the main stem, and they did not have shoot dieback and epicormic shoots (Plate 9b).

Table 5: The incidence and severity *Botryosphaeria* canker on *Eucalyptus grandis* plantations in different districts.

Site	Total trees sampled	Stand age (yrs)	% Incidence	% of trees in severity class			
				None	< 25%	25-50%	> 50%
BFC, Mayuge	60	10	8.3	91.7	5.0	3.3	0.0
NFC, Mubende	60	2.5	15.0	85.0	11.7	1.7	1.7
JF, Kyenjojo	120	3,6	60.8	39.2	39.2	18.3	3.3

BFC = Busoga Forest Company; NFC = New Forest Company; JF = James Finlay Ltd. Severity scores: 1 = no *Botryosphaeria* canker observed; 2 = *Botryosphaeria* canker occurring on < 25% of stem with no dieback; 3 = *Botryosphaeria* canker occurring on 25-50% of stem with no dieback; 4 = *Botryosphaeria* canker occurring on > 50% of stem and/or with tip dieback and/or epicormic shoots.

4.0 DISCUSSION

A number of pests and diseases were observed in nurseries and plantations during this survey. Several of them were reported in Uganda earlier, but little has been discussed on their potential severity, impacts and management. In this section, we summarise information on the observed pests and diseases with emphasis on these aspects.

4.1 Pests

Leptocybe invasa

The occurrence of *L. invasa* infestation on *Eucalyptus* species and clones in most sites visited is consistent with earlier observations that the pest is widespread in Uganda (Nyeko *et al*. in press). However, this pest was absent in Mafuga Central Forest Reserve, which is located in a zone that seems to be outside the ecological range of the insect (Nyeko *et al*. in press). The impact of *L. invasa* on tree health can be severe although most infested trees do not die of the attack. No universal control package currently exists for *L. invasa*. The marked variations observed in the levels of infestation of *L. invasa* on *Eucalyptus* germplasms indicate good opportunities for selecting planting materials which are resistant or highly tolerant to this pest. Planting susceptible germplasms such as *E. grandis* requires caution rather than abandonment. In the nursery, seedlings should not be carried forward to the next planting season as this exposes them to more risk of *L. invasa* infestation. Maintaining *Eucalyptus* trees or stands in the vicinity of nurseries also exposes seedlings to high risk of *L. invasa* infestation since such trees can be breeding sites for the pest. Application of systemic insecticides such as

diamethoate may control the pest in nurseries. However, this method should not be the first option not only because of environmental and economic concerns, but there is also a risk of the insect developing resistance.

Loses caused by *L. invasa* in *Eucalyptus* plantations may be substantially reduced through good silvicultural practices. The aim here is to minimise any stress to seedlings and saplings. Such practices include good site selection and preparation, planting healthy and vigorous seedlings, planting at the onset of the rainy season, proper weeding particularly in the first 1-2 years of planting or coppicing, and removal of severely infested seedlings or saplings. The rule of thumb should be not to plant any seedling having *L. invasa* galls. This allows more time for seedlings to establish before they are 'discovered' by the pest. Well established and vigorously growing seedlings and saplings often overcome moderate *L. invasa* infestation (25-50% of leaves and/or shoots having galls).

The most sustainable approach to the management of *L. invasa* lies in biological control. Four parasitic wasps (*Quadrastichus mendeli, Selitrichodes kryceri* and two *Megastigmus* species) imported from Australia are currently being evaluated in Israel and Turkey (*Megastigmus* species). The results seem encouraging, and the Israeli scientists have organised a short course on this to be held in November 2008.

Termites

Termites are well known notorious pests in plantation forestry in the tropics. Their damage can take various forms depending on the termite species involved. These include: stems cut near the base; attack just below the ground surface, extending upwards until the stem is ring-barked or downwards until the tap root tapers off and is severed; roots are penetrated and hollowed out; stem is penetrated and galleries excavated within it. Earth tubes on the ground or trees are common in termite infested areas. Generally, the impacts of termite infestations are more severe on young and stressed trees. However *Macrotermes* species, especially *M. bellicosus*, can cause high mortality of more than 5-year old trees of susceptible species such as *Eucalyptus grandis* and *Grevillea robusta*.

Control of mound building species such as *M. bellicosus* has traditionally been mound destruction, especially through physical queen removal and application of insecticides. The use of products such as local brew dregs, hot water, oil and farmyard manure and used batteries (dry cells) to destroy termite mounds are widely reported, but their efficacy are rarely evaluated and no recommendations exist on application doses. It is important to note that dead mounds can be recolonised by the same or different termite species. This indicates the need for regular monitoring for active termite mounds in and around nurseries and plantations, especially a few months after swarming of the reproductive alates (often erroneously called white ants). The following practices may also help minimise termite damage:

- Application of less persistent insecticides such as chlorpyrifos, isofenphos, carbosulfan, carbofuran, permethrin and decamethrin during land preparation, planting and as new mounds or damage appear. Powder and granular formulations of some insecticides such as chlorpyrifos (Dusban) and fipronil (Regent 3G) are available on the market in Uganda. These can be applied in termite infested nurseries during soil mixing to protect seedlings or in planting holes at planting.
- Planting termite tolerant tree species or provenances
- Use healthy and vigorous planting stock
- Use of polythene sheets in nurseries
- Sufficient watering of seedlings just before planting out to minimise water stress in the first few days after planting
- Planting seedlings out on time (i.e. on the onset of the rainy season when the soil is wet to a depth of 20-30 cm.).

Black pine aphid

The observed pine aphid (*Cinara cronartii*?) is a sap sucker. *Cinara cronartii* causes significant damage to pine plantations, particularly when trees are stressed such as during dry spells. Severely infested trees show yellowing of crowns, dieback and sometimes tree mortality. The aphid also produces honey dew on which sooty moulds grow. The mould may markedly reduce photosynthesis on pine trees. The symptoms of severe infestation by this pest (yellowing, and shoot, branch or tree mortality) were not observed during the survey, possibly because the survey was conducted in the wet season which is unfavourable for the

pest to cause significant impact. Thus the observe infestation level does not warrant immediate control measures. The pest population and damage dynamics need to be monitored closely in order to make informed control decisions. Indigenous natural enemies such as the lady bird beetle observed feeding on the aphid could substantially suppress the population of the insect. Such natural enemies should be conserved in plantations, for example, by avoiding application of broad spectrum insecticides. In South Africa a parasitic wasp (*Pauesia* species) has been introduced for biological control of *Cinara cronartii*.

Phymateus viridipes

This insect has long been reported to be a minor or occasionally important pest of various crops and tree species in eastern and southern Africa. In Uganda, a localised outbreak has recently been reported on *Alnus acuminata* in Kabale district (Nyeko *et al*., 2002a,b). The nymphs (hoppers) feed aggressively and can cause extensive defoliation. The impact of infestation by this pest on tree health is, however, generally low as defoliated trees often recover. Unless shoot tips are damaged, it may not be economical to control this insect. Where necessary and practically feasible (e.g. in about 1-year old plantations) chemical sprays may be effective.

Livestock and wildlife

Grazing and browsing by livestock and wildlife can be immense and a menace in forest plantations, especially in the early stages of their development. Because of extensive nature of tree plantations, the use of fences and ditches to control such pests may be impractical. The use of guards may be effective in checking trespass by livestock and wildlife such as weaver birds, antelopes and monkeys, but not nocturnal feeders such as rats and moles. Legal action against owners of stray livestock may be effective (Nyeko 2002c), but this has to be taken cautiously as good public relations with communities neighbouring plantations is essential. Damage by wildlife such as *rodents* (rats, mice, moles, squirrels, chipmunks and porcupines), *primates* (e.g. monkeys), *lagomophs* (hares and rabbits) and *artiodactyls* (deer, antelopes, pigs and buffaloes) may be minimised by trapping and removal, poison baits or controlled hunting. Effective weed management may minimise damage caused by rodents, which prefer busy habitats.

4.2 Diseases

Bacterial blight and dieback

Bacterial blight and dieback has been reported in Uganda previously (Roux 1999; Nakabonge et al., 2003; Roux and Slippers, 2007) and is known to occur on *Eucalyptus* in many countries (Roux 1999; Old et al., 2003). In South Africa, the disease has been recorded on *Eucalyptus clones*, hybrids and species including *E. grandis*, *E. saligna*, *E. dunii*, *E. nitens*, *E. smithii*, *E. grandis* x *E. camaldulensis* (GC) and *E. grandis* x *E. urophylla* (GU). The disease generally affects trees less than 2 years old (Roux 1999). Differences in susceptibility of *Eucalyptus grandis* clones have been reported, providing excellent opportunities for selecting tolerant materials. In this survey, all the *Eucalyptus* clones showed very high incidence of the disease in nurseries. This suggests limited scope for selecting for tolerant planting materials among the existing clones in Uganda. Additional commercially important *Eucalyptus* germplasms need to be introduced and rigorously tested to determine their level of tolerance to the disease.

Bacterial wilt

The impact of bacterial wilt disease can be high, especially during the wet season and in sites located in highly humid and soggy sites. Up to 30% tree mortality has been reported in severely infected plantations of *Eucalyptus urophylla* in northern Vietnam at one year after planting (Old *et al*., 2003). According to Old *et al.* (2003) no control practices for bacterial wilt in *Eucalyptus* plantations have been evaluated, nor can any be recommended. Cutting of disease trees, for example, is not effective as the pathogen would remain in infected roots and infested soils. However, stringent weed control followed by a fallow period may greatly reduce the incidence of the disease (Roux 1999). Similarly, good silvicultural practices may reduce the impact of this disease in nurseries. Proper drainage of soggy sites such as the Kyembogo mother garden is necessary to reduce soil moisture and humidity which enhance outbreaks of bacterial wilt and dieback. Reduction in watering frequency during wet seasons and timely cutting of ramets may reduce losses caused by the disease.

Botryosphaeria canker

This disease is known to be common on *E. grandis* and clones of the species. It has also been reported on *E. nitens*. Symptoms of *Botryosphaeria* infections are common on drought stressed trees. Management of *Botryosphaeria* infection is complicated because the pathogen

is endophytic. That is, it infects healthy leaf and stem tissue without showing any symptoms. It remains in this latent phase until the infected tissue is stressed. Marked variations were observed in the incidence of *Botryosphaeria* canker among *Eucalyptus* clones, indicating good opportunity for selecting resistant or highly tolerant clones to the disease. Early detection and removal of infected trees may reduce losses caused by this disease. The highly recommended management option for *Botryosphaeria* canker disease is good matching of germplasms (species, clones and hybrids) to climatic and edaphic factors and avoidance of stress through good silvicultural practices, especially thinning and pruning. Such practices may include, for example, use of standard pruning practices to avoid excessive injuries to trees, pruning at the onset of the rainy season to minimise stress to pruned trees, disinfecting pruning and thinning saws, early detection and thinning of infected trees, and careful removal of thinnings from infected stands to minimise disease spread.

Mycosphaerella leaf spot

Mycosphaerella infection on *Eucalyptus* is widely reported (see review by Old *et al*. 2003). In Uganda, it has recently been reported on *E. globulus* in Kabale and *E. grandis* in Bushenyi (Roux 1999). These findings and our results suggest that the disease is widely spread in Uganda though no outbreak of the disease has yet been reported in the country. Impacts of *Mycosphaerella* infection on tree health are variable, depending on the fungal species, host specificity, host physiology and climate (Old *et al*., 2003). We found high variability in the incidence and severity of the disease among *Eucalyptus* clones in nursery, indicating that selection for resistant planting materials can be effective in managing the disease.

Powdery mildew

Several *Oidium* species (Erysiphaceae) are known to cause powdery mildews on various *Eucalyptus* species in various tropical and temperate countries, especially in nurseries. Severe infection causes leaf distortion, necrosis and premature leaf fall. Control and management of powdery mildew have recently been reviewed by Old *et al*. (2003). These include: (1) early recognition and prompt removal of infected plants, (2) destruction of fallen leaves to reduce inoculum potential, (3) spraying with fungicides such as benomyl, chlorothalonil, triademefon, maneb or zineb; and (4) application of commercial biological products

containing *trichoderma harzianum* T39, *Ampelomyces quisqualis*, *bacillus* and *Ulocldium* in greenhouse crops.

***Fusarium* wilt.**

This is one of the most common diseases of pines seedlings. In Uganda, there is apparently no published report on *Fusarium* wilt of pines in nurseries. Typical symptoms include scattered chlorotic or curled leaves, tip dieback, wilting, and stunting as the disease progresses. Seedling foliage often turns reddish brown just before the seedling dies. Root systems lack fine roots and there is extensive decay of root bark. A number of *Fusarium* species cause disease of pine seedlings in nursery. Good sanitation (e.g. disinfecting tools, rouging infected seedlings, etc.), use of well decomposed soils, use of polythene sheets and well regulated application of water may reduce the incidence and spread of *Fusarium* infection in nursery. Fungicides that have been reported as effective in controlling *Fusarium* diseases include prochloraz manganese, tebuconazole and propamocarb hydrochloride.

Pine wilt

The cause of the wilt disease of pines was confirmed in this study. Some farmers indicated that previous observations implicated moisture stress and *Armillaria*, but these have not been verified through laboratory analysis or experimentally. We are not convinced the problem is caused by moisture stress since a number of new infections were observed in the wet season when the survey was conducted. The yellowing and wilting symptoms are typical of those described for *Armillaria* root rot on pines. However, no typical signs of *Armillaria* (such as thick mat of white mycelium under the bark of roots or root collars of dead or dying trees, black boot-lace rhizomorphs and mushrooms near the base of infected trees) was observed during our survey. In addition, dead wood tissues at the stem base of infected trees were not spongy as would be expected for *Armillaria* infections. Our laboratory analysis on selective media did not isolate *Armillaria, Phythopthora, Fusarium* or bacteria, suggesting that these are not the cause of the disease. We isolated *Botryosphaeria* from a number symptomatic plant samples, but we are not convinced that this fungus is the primary cause of the problem since it is air borne and the disease is typical of a soil borne problem. We strongly recommend further isolations (including nematodes) and pathogenicity test to confirm the cause of this

problem. Although the incidence of this disease was generally low, the impact may be substantial as all infected trees apparently die.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Research and management

● A number of pests and diseases were observed in tree nurseries and plantations. The primary cause(s) of a few diseases (yellowing and wilting of pines in plantations, and yellowing/browning of *Cupressus lusitanica*) were not obvious, and therefore remain unconfirmed. The field pine wilt, which is widespread in Uganda, requires immediate further work to confirm the primary cause. This can be accomplished through additional isolation, identification and pathogenicity test.

● The incidence and severity of pests and diseases varied among sites in different districts. This underscores the need for careful analysis of site conditions when selecting planting materials for the different agroecological zones in the country. For example, less precaution for the management of *Leptocybe invasa* may be needed currently by farmers planning to plant *Eucalyptus* species in Mafuga, where the pest is absent, than those in other parts of the country were there is high infestation by the pest.

● Not all pests and diseases observed may require immediate control. Priority pests and diseases for management currently could be *Leptocybe invasa*, Bacterial blight and birds in nurseries; and *L. invasa*, termites, *Botryosphaeria* canker, *Fusarium* wilt, pine wilt, livestock and wildlife in plantation.

● Various short- and long-term solutions to tree pests and diseases in Uganda have recently been suggested elaborately by Roux and Slippers (2007). We reiterate here the need for good silvicultural practices, use of resistant and tolerant germplasms, careful application of pesticides and biological control in relation to the pests and diseases observed in this survey. Good silvicultural practices are vital in the management of most of the pests and diseases we observed, and these are achievable in the short term. *Eucalyptus* clones showed marked variations in the incidence and severity of, particularly *L. invasa, Botryosphaeria* canker and *Mycosphaerella* leaf spots. This is indicative of good opportunities to use resistant or tolerant

planting materials in managing these pests and diseases. Research trials should be established urgently to evaluate a broad spectrum of tree germplasms for their resistance or susceptibility to such pests and diseases under various ecological conditions in Uganda. Judicial application of pesticides may be necessary for some pests and diseases such as termites, rodents and powdery mildew. Biological control of *L. invasa* seems promising. There is an urgent need for entomologists in Uganda to liaise with Israeli scientists with the aim of evaluating the recently identified parasitoids of this pest in Uganda.

● Timely pest and disease management requires their effective monitoring. Pests and diseases that show low incidence and severity currently may, for example, develop into serious problems with changing environmental conditions. In addition, new pests and diseases may emerge. Immediate identification of such problems would be necessary for timely management interventions. A simple and cost effective pest and disease monitoring mechanism could involve selection and guidance of some nursery and plantation managers to periodically report pest and disease situations at their sites to tree pest and disease specialists at a focal point, for example, Makerere University. This can provide a rapid monitoring and analysis of pest and disease dynamics in various parts of the country.

● Tree pest and disease problems are complex and do not respect national borders. Regional and international collaboration are necessary to strengthen research capacity in dealing with such problems. To this end, formal linkages with well established research institutions such as the Forestry and Agricultural Biotechnology Institute (FABI) and the Institute of Commercial Forestry Research (ICFR) in South Africa, and the Kenya Forestry Research Institute are necessary.

5.1 Dissemination

The SPGS could champion the following to improve dissemination of information on tree pests and diseases in Uganda:

● Sensitisation of tree farmers on tree pests and diseases during SPGS clients meetings and seminars

● Developing and distributing leaflets and brochures on specific pests and diseases to farmers.

● Conducting short courses to train nursery and plantation managers and forest extension staff on basics of pest and disease identification, monitoring and management.

● Developing a database on existing and potential tree nursery and plantation pests and diseases in Uganda

● Press release on specific pests and disease problems, e.g. to alert farmers on pest and disease outbreaks

● Building infrastructural capacity for research and dissemination: laboratories for tree pest and disease diagnoses exist at the Faculty of Forestry and Nature Conservation, Makerere University and the National Forestry Resources Research Institute (NaFORRI). However, these laboratories lack some essential facilities for accurate diagnosis and reporting of pest and disease problems rapidly.

● Strengthening collaboration between SPGS, commercial tree farmers, pest and disease specialists and other relevant stakeholders. Our Department at Makerere University could be a useful contact point for tree and disease problems in Uganda. The Department has experienced tree pest and disease professionals with extensive linkages within and outside Uganda.

ACKNOWLEDGEMENTS

We gratefully acknowledge SPGS for providing us the opportunity and financial support for conducting this study and presenting the results in a seminar. We thank the tree farmers, and nursery and plantation managers for their excellent hospitality and enthusiasm. Mr. Gerald Kyeyune ably assisted in laboratory analyses.

REFERENCES

Cock, M.J.W. (2003). *Biosecurity and Forests: An introduction with particular emphasis on forest pests.* Forest Health and Biosecurity Working paper FBS/2E. FAO, Rome Italy. 61pp.

Day, R.K., Kairo, M.T.K., Abraham, Y.J., Kfir, R., Murphy, S.T., Mutitu, K.E. & Chilima, C. (2003). Biological control of Homopteran pests of conifers in Africa. In: *Biological control in IPM systems in Africa* (Ed. P. Neuenschwander, C. Borgemeister & J. Langewald). CAB International, Wallingford, UK. Pp. 101-112.

EPPO (2006). EPPO alert list: *Leptocybe invasa* (Hymenoptera: Eulophidae)- Blue gum chalcid.http://www.eppo.org/QUARANTINE/Alert_List/insects/leptocybe_invasa.htm

Hurley, B.P., Slippers, B. & Wingfield, M.J. (2007). A comparison of control results for the alien invasive woodwasp, *Sirex noctilio*, in the southern hemisphere. *Agriculture Forest Entomolology* **9**, 159-171.

Mendel, Z., Protasov, A., Fisher, N. & La Sallae, J. (2004). Taxonomy and biology of *Leptocybe invasa* General and sp. n (Hymenoptera: Eulophidae), an invasive gall inducer on Eucalyptus. *Australian Journal of Entomolology* **43**, 51 – 63.

Mukiibi, J.K. & Tizikara, C. (2001). Agricultural research in Uganda. In: *Agriculture in Uganda Volume 1: General information* (Ed. J.K. Mukiibi). National Agricultural Research Organisation (NARO) and Technical Centre for Agricultural and Rural Cooperation (CTA), Fountain, Kampala, Uganda. Pp. 231-241.

Murphy, S.T. (1998). Protecting Africa's trees. *Unasylva* **49**, 57-61.

Mutitu, K. E. (2003). *A pest threat to Eucalyptus species in Kenya*. KEFRI Technical Report. 12 pp.

Nakabonge G., Coutinho, T.A. Roux, J. & Wingfield M.J. (2003) Bacterial blight of *Eucalyptus* species in Uganda. 8th International congress of Plant Pathology, "Solving problems in the real world 2nd – 7th February 2003, Christchurch, NewZealand.

Nyeko, P. & Olubayo, F.M. (2005). Participatory assessment of farmers' experiences on termite problems in agroforestry in Tororo district, Uganda. *Agricultural Research and Extension (AgREN)*, Paper No. 143. ISBN 0 85003 744 1

Nyeko, P. (2005). The cause, incidence and severity of a new gall damage on *Eucalyptus* species at Oruchinga refugee settlement in Mbarara district, Uganda. *Uganda Journal of Agricultural Sciences* **11**, 47-50.

Nyeko, P., Mutitu, E.K. & Day, R.K. (in press). *Eucalyptus* infestation by *Leptocybe invasa* in Uganda. *African Journal of Ecology*. Paper ref. MB 272.

Nyeko, P.; Edwards-Jones, G. & Day R. K. (2002a). Insect herbivores and pathogens of *Alnus* species in Uganda. *Agroforestry Systems*. 56: 117-127.

Nyeko, P.; Edwards-Jones, G. and & Day R. K. (2002b). Population dynamics of herbivorous insects and potential natural enemies on *Alnus* species in Kabale district. *Agroforestry Systems*, 56: 213-224.

Nyeko, P.; Edwards-Jones, G.; Day, R. K. and Thomas, R. (2002c). Farmers' knowledge and perceptions of pests in agroforestry with specific reference to *Alnus* species in Kabale district, Uganda. *Crop protection*, 21: 929-941.

Nyeko, P.; Mutitu, E.K. & Day, R.K. (2007). Farmers' knowledge, perceptions and management of the gall-forming wasp, *Leptocybe invasa* (Hymenoptera: Eulophidae), on *Eucalyptus* species in Uganda. *International Journal of Pest Management* **53**, 111-119.

Old, K.M., Wingfield, M.J & Yuan, Z.Q. (2003). Manual of diseases of Eucalyptus in South-East Asia. *Centre for International Forestry Research*. Bogor, Indonesia.

Roux, J. & Slippers, B. (2007). Entomology and pathology survey with particular reference to leptocybe invasa 23-26 July. Report submitted to the Sawlog Production grant Scheme (SPGS) Uganda.

Roux, J. (1999). Pathology survey of plantation forest trees in southern Uganda. A report prepared for the Ugandan Forestry Department and SFD. *Tree Pathology Cooperative Programme*, University of Pretoria, South Africa.

Tribe, G.D. (2003). Biological control of defoliating, and phloem- or wood-feeding insects in commercial forestry in southern Africa. In: *Biological control in IPM systems in Africa* (Ed. P. Neuenschwander, C. Borgemeister & J. Langewald). CAB International, Wallingford, UK. Pp. 113-129.

Wingfield, M.J., Slippers, B., Roux, J. & Wingfield, B.D. (2001). Worldwide movement of exotic forest fungi, especially in the tropics and the southern hemisphere. *Bioscience* 51, 134-140.

(a)

(b)

(c)

(d)

Plate 1: Pests observed in tree nurseries. (a) *Leptocybe invasa*; (b) *L. invasa*-induced galls on a *Eucalyptus grandis* seedling; (c) a colony of an unidentified aphid species on *Eucalyptus* clone; (d) bird damage (cut tips and missing seedlings in pots) on newly germinated *Pinus caribaea* seedlings.

(a)

(b)

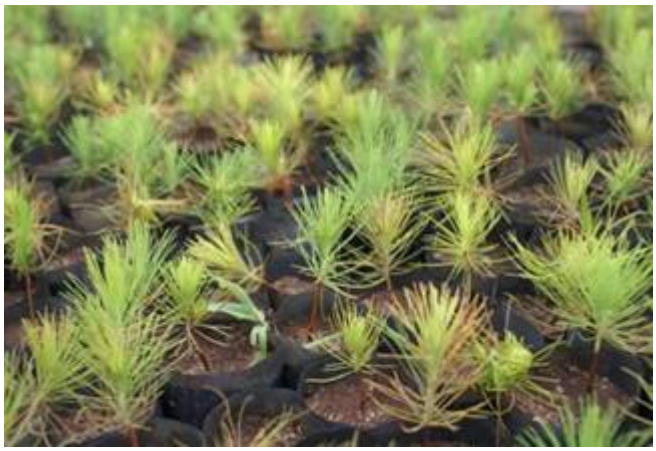
(c)

(d)

(e)

(f)

Plate 2: Diseases of *Eucalyptus* observed in nursery. (a) Bacterial blight; (b) severe bacterial blight infection causing tip dieback of sprouts on a hedge in mother garden; (c) Mortality of hedges caused by bacterial blight in mother garden; (d) bacterial tip die back on plantlets in pots; (e) *Mycospheraella* leaf spot; (f) Powdery mildew on leaves of plantlets in pots



(a)

(b)

(c)

(d)

Plate 3: Ill health of *Pinus caribaea* seedlings in nursery. (a) Typical *Fusarium* infection; (b) wilting of seedlings caused by late pricking out to fill 'empty' pots; (c) yellowing of seedling tips caused by insufficient use of mycorrhiza soil; (d) discolouration resulting from overstay of seedlings in nursery

(a)

(b)

(c)

(d)

Plate 4: Typical symptoms of *Leptocybe invasa* infestation on *Eucalyptus* species in the field. (a) Galls with emergence holes on twigs; (b) galls with emergence holes; (c) stunted severely infested tree; (d) bent severely infested tree.

(a)

(c)

(b)

(d)

Plate 5: *Macrotermes bellicosus* (termite) mound and its damage on *Eucalyptus grandis*. (a) *M. bellicosus* mound characterized by large vents; (b) less than 1-year old *E. grandis* killed by *M. bellicosus*; (c) *M. bellicosus* root damage on 2.5 year old *E. grandis*; (d) 2.5-year old *E. grandis* felled by *M. bellicosus*

(a)

(b)

(c)

(d)

Plate 6: Black pine aphid (*Cinara* sp.) and organisms associated with its colonies. (a) Black pine aphid on *Pinus caribaea* shoot; (b) sooty mould on *P. caribaea* shoot infested by black aphid; (c) ants foraging on honey dew produced by black aphids; (d) a lady bird beetle on *P. caribaea* shoot found predating on black aphids.

Plate 7: *Phymateus viridipes* defoliating *Pinus patula*.

(a)

(b)

(c)

(d)

(e)

(f)

Plate 8: Wildlife and livestock damage on plantation trees. (a) Eucalyptus seedlings uprooted and eaten by rates; (b) *Cupressus lusitanica* debarked by rats (c); mortality of *Cupressus lusitanica* due to debarking and root damage by rats; (d) debarking of *Pinus patula* by monkeys; (e) stem breaking of *P. patula* by monkeys; (f) goats browsing and trampling on *P. caribaea* (note inserts).

(a)

(b)

(c)

(d)

Plate 9: *Botryosphaeria* infection on *Eucalyptus grandis*. (a) *Botryosphaeria* canker on tree stem; (b) epicormic shoots on tree stem resulting from *Botryosphaeria* infection (c) exudates oozing from *Botryosphaeria* canker on tree stem; (d) Tree stand infected by *Botryosphaeria* (brown stems).

(a)

(b)

(c)

Plate 10: Typical symptoms of bacterial infection observed on *Eucalyptus clones* at about 3-months after field planting. (a) Leaf spot; (b) blotched and curled leaf; (c) shoot mortality.

(a)

(b)

(c)

(d)

Plate 11: Yellowing and wilting of *Pinus caribaea*. (a) initial symptoms of yellowing; (b) yellow and wilted trees; (c) resin exudation at the lower stem of infected tree; (d) resin exudation on and rooting of roots.

Plate 12: Blight-like wilting of *Pinus patula* due to unidentified cause

Plate 13: *Cupressus lusitanica* stand with brown foliage.

Plate 14: *Pinus caribaea* seedling at Rwoho Central Forest Reserve with unknown crown discoloration.

Appendix 1: Pests and diseases observed at different sites

Farmer/company name	Land ownership	District	Tree species	BGC	TM	APD	PV	MS	BS	PM	BC	PW	FW	FB	RM	MK	BD	LS
Ankole wood & timber Ltd	CFR-Rwoho	Mbarara	*P. caribaea*	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-
Apio stella	CFR-Opok	Gulu	*P. caribaea*	-	-	-	-	-	-	-	-	**	-	-	-	-	-	-
Bakojja richard	CFR-Kasana kasambya	Mubende	*P. caribaea*	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-
	Nursery		*P. caribaea*	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-
			E. grandis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Arucaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Busoga Forest Co.	CFR-South Busoga	Mayuge	*P. caribaea*	-	-	*	-	-	-	-	-	*	-	-	-	-	-	-
			E. grandis	**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			E. clones	-	*	-	-	-	*	-	-	-	-	-	-	-	-	-
			Maesopsis eminii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CBM Forestry plantation	CFR-Rwoho	Mbarara	*P. caribaea*	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-
Christine a. Omoya	CFR-Opok	Gulu	*P. caribaea*	-	*	-	-	-	-	-	-	*	-	-	-	-	-	-
Dr. P. Nyeko	CFR-Opaka	Gulu	*P. caribaea*	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-
			P. oocarpa	-	*	-	-	-	-	-	-	*	-	-	-	-	-	-
			Araucaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			oocarpa x caribaea	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-
E.T. Dominion Ent. Ltd.	PRIVATE LAND	Masindi	*P. caribaea*	-	-	-	-	-	-	-	-	*	-	-	-	-	-	*
			P. patula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gen. E.K. Wamala	CFR-Kasana kasambya	Mubende	*P. caribaea*	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-
			P. patula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hon. S.K. Mishambi	CFR-Kasana kasambya	Mubende	*P. caribaea*	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-
JC Forestry enterprise	CFR-Opok	Gulu	*P. caribaea*	-	*	-	-	-	-	-	-	*	-	-	-	-	-	-
			Tectonis grandis	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-
			Araucaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kalagi family nursery	PRIVATE LAND	Mukono	*P. caribaea*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			E. grandis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kamusiime MRDPS	CFR-Kasyoha-Kitomi	Bushenyi	*P. caribaea*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			P. oocarpa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			P. patula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			E. grandis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Nursery		*P. caribaea*	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-
			P. patula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			T. grandsis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix 1 continued.

Farmer/company name	Land ownership	District	Tree species	BGC	TM	APD	PV	MS	BS	PM	BC	PW	FW	FB	RM	MK	BD	LS
			E. grandis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lacan pe nino	CFR-Opok	Gulu	P. caribaea	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-
			P. oocarpa	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-
			E. grandis	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Tectonia grandis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nile Plywoods Ug. Ltd.	CFR-Nsube	Jinja	E. grandis	***	**	-	-	-	-	-	-	-	-	-	-	-	-	-
	CFR Ngereka		P. carribaea	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-
	CFR Lubanyi			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Precision Sawmill Ltd.	CFR-Kasana kasambya	Mubende	P. caribaea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			E. grandis	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Nursery		P. caribaea	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-
			E. grandis	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-
The New Forests Co.	CFR-Namwasa	Mubende	P. caribaea	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-
			E. grandis	**	-	-	-	-	-	-	*	-	-	-	-	-	-	-
	Nursery		P. caribaea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			E. grandis	-	-	-	-	-	***	-	-	-	-	-	-	-	-	-
			E. urophylla	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-
			Bathedavila sp.	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-
			Maesopsis eminii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wakitaka Farm Ltd	CFR-Ngereka	Jinja	P. caribaea	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-
			Maesopsis eminii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Grevillea robusta	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-
Evelyne Ninsiima	Mafuga	Kabale	P. patula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CADACON Enterprises	Kyedikyo	Hoima	P. caribaea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			E. grandis	*	***	-	-	-	**	-	-	-	-	-	-	-	-	-
Bavame Enterprises	Mafuga	Kabale	P. patula	-	-	-	-	-	-	-	-	-	-	-	**	-	-	-
Benon Bangowaki	PRIVATE LAND	Rukungiri	P. patula	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-
			E. grandis	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
James Finlay	PRIVATE LAND	Kyenjonjo	E. grandis	*	-	-	-	-	-	-	**	-	-	-	-	-	-	-
	Germplasm trial		Various spp.	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-
		Hoima	E. grandis	**	-	-	-	-	-	-	*	-	-	-	-	-	-	-
	Germplasm trial		Various spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix 1 continued.

Farmer/company name	Land ownership	District	Tree species	BGC	TM	APD	PV	MS	BS	PM	BC	PW	FW	FB	RM	MK	BD	LS
Global Woods	Kikonda	Kiboga	P. oocarpa	-	-	-	-	-	-	-	**	-	-	-	-	-	-	-
			P. caribaea	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-
			E. grandis	**	**	-	-	-	-	-	-	-	-	-	-	-	-	-
NFA	Rwoho	Mbarara	P. patula	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-
			P. caribaea	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-
			P. oocarpa	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-
			E. grandis	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-
			C. lusitanica	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-
	Periurban plantation	Mbarara	E. grandis	***	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Nursery	Mbarara	P. caribaea	-	-	-	-	-	-	-	-	**	-	-	-	-	-	-
			E. grandis	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mafuga	Kabale	P. patula	-	-	-	-	-	-	-	-	*	-	-	*	*	-	-
			P. caribaea	-	-	-	-	-	-	-	-	-	-	-	*	*	-	-
			C. lusitanica	-	-	-	-	-	-	-	-	-	-	-	****	-	-	-
	Oruha	Kyenjonjo	P. caribaea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sirisiri	Masindi	P. carribaea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Kasana kasambya	Mubende	P. carribaea	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-
			Araucaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Katugo	Nakasongola	P. caribaea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gatsby Trust	Kifu nursery	Mukono	10 clones	**	-	-	-	*	***	*	-	-	-	-	-	-	-	-
	Kifu clonal mother garden	Mukono	10 clones	*	-	-	-	*	*	-	-	-	-	-	-	-	-	-
	Kifu clonal trial	Mukono	10 clones	-	*	-	-	-	-	-	*	-	-	-	-	-	-	-
	Kyombogo DATIC nusery	Kabarole	5 clones	*	-	-	-	-	**	**	-	-	-	-	-	-	-	-
	Kyombogo mother garden	Kabarole	5 clones	-	-	-	-	-	****	*	-	-	-	-	-	-	-	-
	Kyombogo conal trial	Kabarole	5 clones	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ikulwe trial	Mayuge	12 clones	-	**	-	-	-	-	-	*	-	-	-	-	-	-	-

BGC= *Leptocybe invasa*; TM = termites; APD = aphid; PV = *Phymateus viridipes*; MS = *Mycosphaerella* leaf spot; BS = bacterial leaf spots; PM = Powdery mildew; BC = *Botryosphaeria* canker; PW = pine wilt; FW = *Fusarium* wilt; Foliage browning; RM = rats and moles; MK = monkeys; BD = birds; LS = livestock. - = damage not observed, * low or minor damage; ** moderate damage; *** severe damage; **** = very severe damage.