REPORT

TO

SAWLOG PRODUCTION GRANT SCHEME (SPGS)
UGANDA

ENTOMOLOGY AND PATHOLOGY SURVEY WITH PARTICULAR REFERENCE TO *LEPTOCYBE INVASA*

23-26 JULY 2007

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1.0 **EXECUTIVE SUMMARY**

- This report reflects the outcome of a four-day survey of plantations, particularly *Eucalyptus* spp. in Uganda conducted by Prof. Jolanda Roux and Dr. Bernard Slippers from the Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, South Africa. The primary objective of the survey was to investigate the impact of the blue gum chalcid, *Leptocybe invasa*. A secondary aim was to identify the major diseases affecting forestry trees, in the areas visited. Due to time constraints this survey was restricted to a limited number of plantations.
- *Leptocybe invasa*, the blue gum chalcid, was first reported on *Eucalyptus* sp. in Uganda in 2002. It now occurs in all the eucalypt growing areas and is threatening to reduce this growing industry because of farmer's perspectives of the severity of the impact.
- *Leptocybe invasa* infested sites visited included Nileply (Jinja), Kifu, James Finley Uganda (Mwenge, Musizi, Bugambe Estates). Great variation in infestation levels were observed between the different areas visited.
- Disease surveys of *Eucalyptus* trees in Uganda, conducted in 1999, 2000 and 2001 identified several previously unknown fungal and bacterial diseases in Uganda. However, no detailed surveys have been conducted in the past six years. During this four day survey period a number of bacterial and fungal diseases were observed on *Eucalyptus* spp. Some, such as Botryosphaeria canker and bacterial wilt have previously been reported. Others, however, represent first reports for Uganda and East Africa.
- *Eucalyptus* trees grown in Uganda originate from a range of different seed sources, including South Africa, Zimbabwe and local collections. However, very little tree improvement has been done in Uganda. Thus, species are commonly planted over a broad geographic area, resulting in sub-optimal site matching.
- Growth of tree species, including *Pinus* and *Eucalyptus* spp., observed was highly impressive, especially when site and species were correctly matched. Clearly, great opportunities exist for plantation tree growth in Uganda.
- The threat of pest and disease outbreaks poses a serious problem for the tree industry in Uganda as no structures exist to effectively deal with such

outbreaks. It is imperative that formal structures are implemented without delay. These should ideally include representatives from private companies, private farmers, government and research organizations such as the University of Makerere and NaForri.

2.0 BACKGROUND

The demand for fuel wood and construction timber in Uganda is huge. It is estimated that more than 90% of Ugandans use charcoal for cooking, while all construction, even of modern high rise buildings in Kampala, uses poles for support purposes and scaffolding. Furthermore, the need for timber for carpentry, telephone poles, and other applications is also evident.

There is already incredible pressure on natural forests to supply in all the needs of Ugandans, and this is set to rise with the growing Ugandan economy. A number of faster growing, non-native, and tree species were introduced into Uganda in the last 100 years as alternative fuel and timber sources. *Eucalyptus* spp. are considered as the ideal tree to address demand for wood as it is fast growing and adaptable to a range of sites. They also now form the basis of many lucrative businesses, with a single telephone pole fetching 240 000 shillings.

Plantations and wood lots of *Eucalyptus* trees have been established in Uganda using a range of planting material. Seed mostly originates from local Ugandan seed sources, but seed has also been introduced from countries such as Zimbabwe and South Africa. This has been in an attempt to obtain improved material for planting. In recent years, clonal *Eucalyptus* plants were also introduced from South Africa to establish disease tolerant, faster growing plantations of *Eucalyptus* spp. James Finley Uganda (Pty) Ltd. has for example been planting *Eucalyptus* since 1994 and is currently the largest *Eucalyptus* grower in Uganda. They plant seed originating from both local seed sources, as well as seed imported from South Africa and Zimbabwe. Under the guidance of the Sawlog Production Growers Scheme (SPGS), many private individuals have also embarked on the establishment of plantations in Uganda, using seed from various sources, including Australia.

The growing plantation forestry industry in Uganda faces several challenges and threats. These threats include those posed by diseases and pests. Diseases caused by fungi and bacteria, and damage caused by insects, result not only in tree death, but also in reduction of growth and yield as well as reduced timber quality. Recently, a previously unknown Eucalyptus pest, the blue gum chalcid, known scientifically as *Leptocybe invasa*, was reported from Uganda and Kenya (**Appendix 8.1**). This pest has now become wide-spread in eastern Africa and has very recently been found in South Africa (**Appendix 8.2**). Infestation results in the malformation of leaves and shoots of trees, ultimately resulting in complete distortion of young trees.

No clear management strategies have been developed to reduce the impact of *Leptocybe invasa*, or any other pest and disease problem of plantation tree species in Uganda. This is of great concern to private tree growers in the country. Private growers have, therefore, requested SPGS to solicit the input of external consultants to assess a few of the plantation health issues in Uganda. This has been with particular focus on *L. invasa*, but more broadly to advise the growers on the requirements for maintaining a healthy industry in the country.

The Tree Protection Co-operative Programme (TPCP), of the Forestry and Agricultural Biotechnology Institute (FABI), based at the University of Pretoria in South Africa (www.fabinet.up.ac.za), is considered a world leader in plantation health issues. Prof. Jolanda Roux and Dr. Bernard Slippers of the TPCP were, therefore, asked to visit Uganda to assist SPGS. The aim of the one week visit to Uganda was to evaluate the *L. invasa* problem in Uganda and to make recommendations for the management of this problem. Furthermore, a general plantation health assessment was conducted within the constraints of the time available. This report presents the results of the investigation and it provides some recommendations that we hope will assist Uganda in ensuring plantation health in the future.

3.0 ITINERARY

22 July (Sunday)	Arrive Uganda in evening, met by Mr. Paul Jacovelli and check into hotel

23 July (Monday)	Meet with SPGS, Gatsby, tea growers and NFA representatives and travel to Jinja. Visit nursery and plantations of Nileply at Nsuube. Travel to Kifu and visit NaFORRI. Evening on own, isolations from samples, report writing
24 July (Tuesday)	Drive to Fort Portal. Stop at Kasana-Kasambya CFR near Mubende to look at *Pinus carribeae* var. *hondurensis* and *Auracaria cunninhamii*. Visit John Finley Uganda (JFU) Tea Estates, Mwenge and Botanical Gardens in Fort Portal.
25 July (Wednesday)	Drive to Hoima, stopping at Muzizi (JFU) Estate.
26 July (Thursday)	Visit JFU Bugambe Estate and drive back to Kampala
27 July (Friday)	Meeting with private company representatives, NFA, Uganda Gatsby, staff from Makerere University and others to report on findings of the field surveys and discuss actions for the future.
28 July (Saturday)	Report writing in Kampala as no space on flight to RSA
29 July (Sunday)	No flight to RSA, sight seeing and report writing
31 July (Monday)	Depart for South Africa at 07:30

4.0 GENERAL OBSERVATIONS

Nileply – Nsuube (Jinja area)

- The nursery which provides plants to Nileply is run by a private person. Seed used for growing of *Eucalyptus* is gathered from the surrounding *E. grandis* compartments. Some *Leptocybe* infestations were evident in the nursery, however, levels was relatively low (**Figure 1a**). Bacterial leaf spots were common on older leaves, as well as Phaeophleopsora leaf spot (**Figure 1b**). No other diseases were observed in the nursery.
- Compartments of *E. grandis* coppice stems, close to 10 years in age, showed termite damage, minimal *Botryosphaeria* infection and extensive wounding of stems. This compartment had only recently been thinned after not having received any silvicultural treatments for many years.

- A compartment of approximately one-year-old *E. grandis* trees showed extensive *Leptocybe* infestation. There were, however, several trees showing minimal infestation and possibly tolerance to infestation. Others were severely stunted and galled (**Figure 3a,b**). Extensive Phaeophleospora leaf spotting (**Figure 1b**), caused by *Kirramyces epicoccoides*, was common on trees affected by *Leptocybe*, showing a possible interaction between these agents. Bacterial blight was also common on these trees. Some trees, heavily infected by *Leptocybe* also showed nutrient disorders. *Quambalaria* infection was observed on the leaf margins and petioles of some *Leptocybe* infested shoots.

Kifu clonal nursery – NaFORRI

- Very low levels of *L. invasa* infestation were visible at the time of the visit. Variation in susceptibility to *L. invasa* was observed, and reported by the nursery manager, between the different *Eucalyptus* clones grown at the nursery (12 clones in total, 6 GU, 5GC, TAG5). Relatively mild infestation was observed in the clonal hedge banks. In the clonal trial planted in 2002, heavy *L. invasa* infestations were observed on some of the border row trees, originating from local land races.
- In the clonal hedges powdery mildew (**Figure 1c**) and bacterial wilt was observed. Both were clone specific. Bacterial wilt resulted in death of young trees.
- In the clonal trial, planted 2002, the most common problem observed was that of Botryosphaeria canker (**Figure 2a,c**), often associated with termite damage to trees (**Figure 2b**). Occurrence of the Botryosphaeria canker was not specific, with some trees of the same clones showing no signs of diseases, while single trees in the same plot were infected. Termite damage and associated Botryosphaeria infection was more severe on border rows. Symptoms of *Holocryphia* infection were found on a number of trees, however, the presence of this fungus could only be confirmed on one tree, on which orange fruiting bodies were evident.

Kabana –Kasambya CRF SPGS Show block

- This show block consisted of *Auracaria cunninghamii* and *Pinus carribeae* var. *hondurensis* planted in 2003. These trees show excellent growth and at four years already resembled trees of 8-10 years old in other parts of the world.
- In general these trees were very healthy and no mortality was observed. Some needle spot and death was observed on the hoop pine, while blue stain was visible on the basal dead branches of the *P. carribeae*.

James Finley Tea Estates – Mwenge

- Three compartments of *Eucalyptus* were visited on this estate. The first of these, before the main gate, consisted of trees planted from South African seed, in 2002. These trees should already have been harvested and were planted at a very high density. Many trees were covered in lichens and showed symptoms of Botryosphaeria canker (**Figure 3e**).
- The second compartment visited comprised of young coppice stems, less than one-year-old, also from South African seed. Some *L. invasa* infestation was starting, but it was not wide-spread in the compartment. Some signs of Mycosphaerella and Phaeophleospora leaf spot was visible, but at low levels. An adjacent compartment, planted from Zimbabwean seed (older coppice), showed the presence of Coniothyrium canker (**Figure 2d,e**).
- The third and final site inspected on this estate was a recently harvested compartment in which many of the coppice stems and stumps had died. Due to the age of the stumps it was not possible to determine exactly what had caused the death of these trees. However, kino rings, typical of Botryosphaeria infection (**Figure 2c**) was visible in the dead stumps, and could be one explanation for why these stumps died. Very little *L. invasa* infestation was observed.

Fort Portal Botanical Gardens

- A brief stop was made at the *E. grandis* planted in the 1950s and from which seed is now collected for planting in Uganda. In general these trees are very healthy and they represent good material for seed collection for planting in similar areas. A few trees showing extensive kino exudation from the wounds made from the climbing spikes used in seed harvesting were observed.

- In the nursery, bacterial blight of Eucalyptus seedlings, causing tip blight and leaf spot was evident (**Figure 1d,e**). Some dying *Pinus* seedlings, showing root rot symptoms were also observed.

John Finley Uganda – Muzizi Estate

- Three sites were inspected at this estate. At the first of these, *E. grandis* planted from South African seed, with Botryosphaeria canker and tip die-back were observed (trees planted in 2004). A number of trees in this compartment had already died. Termite damage was also evident on some of the trees. Adjacent to these trees, a young compartment, planted from South African seed in 2006, showed very heavy infestation of *L. invasa*. This was the most severe infestation seen so far on the survey trip. Some trees were very heavily infested and stunted, while some looked very healthy.
- The second site was at a coppice compartment where Coniothyrium and Botryosphaeria stem canker was common on these approximately 18-months old stems. Some trees also showed basal cankers of unknown cause.
- The final site visited was at a Uganda seed source *E. grandis* compartment, planted November 2006. Very early *L. invasa* invasion was observed on a few trees. An unknown leaf spot was very common on leaves. The spot was characterized by creamy/yellow blotches, often associated with holes in the leaves (**Figure 1f**). Low levels of a second leaf disease of unknown cause characterised by purple edges (which is similar to some *Cylindrocladium* infections), and damage by Phaeophleospora leaf disease was also observed.

John Finley Uganda – Bugambe (Hoima)

- The first site visited was planted to *E. grandis* from Zimbabwe seed (~18-month-old). *Leptocybe invasa* infestation of these trees was very severe, with some trees bending over with the weight of the galls (**Figure 3c**). Trees that had died from *L. invasa* infestation were observed in this compartment. Infestation appeared to occur in distinct patches in the compartment, with these patched spread throughout the compartment. Some Botryosphaeria infection was observed, but at very low levels.

- At a second site we investigated *E. grandis* coppice from Zimbabwe seed, less than one year in age. These trees were severely infested and adult wasps were present. The compartment was badly established with many dead stumps.
- No *L. invasa* was seen on *E. toralina* planted in 1998, or on the young naturally regenerated plants in the third compartment visited. Termite damage was evident on the surrounding *E. grandis* trees in this compartment, resulting in cracked bases.
- The final site on this estate was a compartment consisting of ~14month old *E. grandis* coppice stems (original trees from Zimbabwe seed). These trees were also severely infested by *L. invasa*, with many bending over. Great variation in infestation was, however, visible between individual trees in the compartment (**Figure 3d**).

5.0 CONCLUSIONS

- Our overall impressions of plantation forestry in Uganda are very positive. It was clear from our visit that the country has great potential to successfully grow *Eucalyptus* and *Pinus* spp., at an internationally competitive level. The industry must, however, take great care to protect these trees from pests and diseases. The recent introduction of *L. invasa*, for example, shows the seriousness of the potential impact of pests and diseases to the industry. It should serve as a stern early warning to forestry in Uganda. As with agriculture, great care should be taken in the selection of seed sources and other planting material, site preparation, sanitation and other silvicultural measures to ensure a healthy crop.
- *Leptocybe invasa* is clearly wide-spread in Uganda. It was observed in all the areas visited, however, clear differences in susceptibility were observed between trees. Furthermore, it seems that hotter, drier sites are more prone infestation than the cooler areas. However, this needs to be carefully investigated and established in statistically planned monitoring trials, spanning

more than one season. Badly managed (weeded) sites appeared to be particularly badly affected.

- Several diseases were observed at the sites visited. The most common disease observed was Botryosphaeria canker, a problem that has previously been reported from Uganda (**Appendices 8.3; 8.4; 8.5**). In a number of cases the Botryosphaeria canker were associated with termite infestation. These two factors, clearly have a considerable impact on *Eucalyptus* plantings in Uganda. Two other diseases of concern were Coniothyrium stem canker and bacterial wilt (**Appendix 8.4; 8.6**), both of which will require further study.
- Although there is a clear desire and need for a more formalized plantation health management system, this does not currently exist for Uganda. This is a problem that will need immediate action and can be solved successfully, as has been done elsewhere. A concerted industry effort will save time and money and will be essential to achieve successful tree health management. This is especially because pests and diseases move rapidly and across boundaries set by humans.
- The expertise to deal with plantation pests and diseases already exists in Uganda. Both a pathologist and entomologist with tree health experience, for example reside in Kampala and work at Makerere University. They clearly lack facilities, which should be relatively easy to source. With supplementation of their work through collaboration with groups in Uganda and in other African countries, diseases and pests can be successfully managed in Uganda. This is also true for other countries in the region.

6.0 RECOMMENDATIONS

It is imperative that all parties involved in plantation forestry in Uganda realize that there are no “quick fixes” in tree health management. Successful pest and disease management requires planning, long term vision, dedication and team work. We trust that the following recommendations will assist SPGS and Uganda in establishing the required networks to address these issues successfully. It is, however, important to recognise that many of these recommendations need to be supported by sound research findings. This is because in many cases, these are based only on our observations from the short visit to Uganda and our group’s experience with other disease and pest problems. Here it is also relevant to recognise that the specific conditions for *L. invasa* and other disease and pest problems in Uganda may not be the same as in other countries.

Integrated Tree Health Management Structure

Management of tree health issues in Uganda needs to be a long term project. Experience from other countries has shown that without structured tree health management, such programmes mostly fail or are ineffectual. Tree health management should take place as an industry initiative and should include representatives from:

Private growers/companies

Researchers (Makerere/NaFORRI)

Government

NFA

Dept. Agriculture (Quarantine)

Integrated pest and disease management

Tree health management will fail if it relies only on one or two aspects. It needs to be an integrated management strategy including all aspects of forestry. This is only achievable by basing the strategies on sound research and experience, rather than loose interpretations. Management should thus include:

Selection and breeding - This is a continuous process to keep ahead of new pests and pathogens. Pests and pathogens can rapidly adapt to new clones/provenances, thus plants resistant in 2005 might not still be resistant in 2008. Planting material should thus be continually screened for susceptibility. This requires detailed knowledge of the pests, pathogens and their populations.

Silviculture - Many diseases and pests are more severe under conditions that are unfavourable for the tree. Careful site matching, good planting practices, reduction of wounding during high risk periods, fertilizing, weeding etc. will all contribute to reducing the incidence and severity of diseases and pests.

Biological Control – This approach is especially feasible to manage pest problems. It has been used successfully for a number of plantation forestry pests and is currently been developed for *L. invasa*. While potentially very successful once established, there is normally a long lead-up requiring expert knowledge, international co-operation, intensive research and the necessary government approval to develop and implement such strategies.

Chemical Control – This route is not feasible for many pests and pathogens in plantation situations. It is also not feasible for large trees in the plantations, and expensive. A danger is that pests and pathogens can build up resistance to chemicals.

Quarantine – The intention here is to keep pests and pathogens out of a country, or out of a specific area in a country. Although there are many limitations, the longer an area remains free of a particular pest or pathogen, the more time one has to develop specific management strategies. The movement of infected material may also lead to the introduction of new genotypes of the pest or pathogen, resulting in more damage.

Sanitation – This is especially important in nurseries. All infected material should be removed and burned/buried. Equipment should be cleaned on a regular basis.

Short term solutions

- Removal and destruction of heavily infected trees, and sections of compartments. Replant with healthy, uninfected material suited to that specific area. Lowering populations of the wasps in a particular area by this measure, especially during the first year after planting, is likely to reduce the damage significantly. Monitor new plantings continuously, and remove and destroy particularly heavily infected plants or branches before the next generation of wasps emerges (recognised by exit holes on the galls). These plants are likely not to grow well and will only be a source of wasps that would attack other trees.
- Look into application of systemic insecticides at planting and at intervals thereafter. This could be very expensive, and specific insecticides will first have to be tested and then registered.
- Planting of resistant clones if available.
- Careful silviculture to ensure optimal health for new plantings. The effect of fertilizer application at planting to ensure rapid initial growth could be investigated.

Longer term solutions

- Biological control
- Selection and breeding
- Research to understand biology, ecology and population dynamics of *Leptocybe invasa* in order to optimize management strategies. This might be achieved in concert with a similar programme being developed in South Africa.
- Screening of material for resistance to diseases in Uganda
- Establish trial plots to quantify impact of weeding (and possibly systemic chemicals and/or fertilizer where feasible) on *Leptocybe* incidence (plots in different areas of country, including different seed sources in different areas to identify optimal sources for each area).

Expertise in Uganda

Tree health management requires a team effort, utilizing the experience and expertise of many different people. Some aspects can be done "in-company", while others are best sourced from elsewhere to save on time and money and to ensure that recommendations are made by experts in a particular field. These may include local experts, and/or consultants from other countries. Often, the most effective strategy is to make use of local experts with knowledge of the particular situation in that country. These experts, together with the company should be encouraged to maintain a global network of collaborators to provide a broader perspective and advance information on other threatening tree health issues.

Uganda is very fortunate to have tree health specialists in the country. Dr. Grace Nakabonge is a trained tree pathologist with experience in working with diseases of plantation forestry trees in Africa. Similarly, Dr. Philip Nyeko has training and extensive experience in working with plantation forestry pests. Both currently reside at the University of Makerere in Kampala and have expressed interest in working more closely with the forestry industry in Uganda. Both are also well connected to international groups dealing with tree health. It is our opinion that discussions with these scientists, and other such as those at NaFORRI, should be initiated as soon as possible. The aim must be to establish a research network to conduct the trials that need to be established to provide Ugandan forestry with sound tree health management strategies.

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We thank SPGS and their staff for their hospitality during our one week visit to Uganda. It was truly wonderful to meet such an enthusiastic and dedicated group of people. Our sincere thanks also go to James Finley Uganda (Pty) Ltd. for accommodation and lunch and assisting with the surveys. Furthermore, New Forests are thanked sponsoring the wrap up meeting in Kampala.

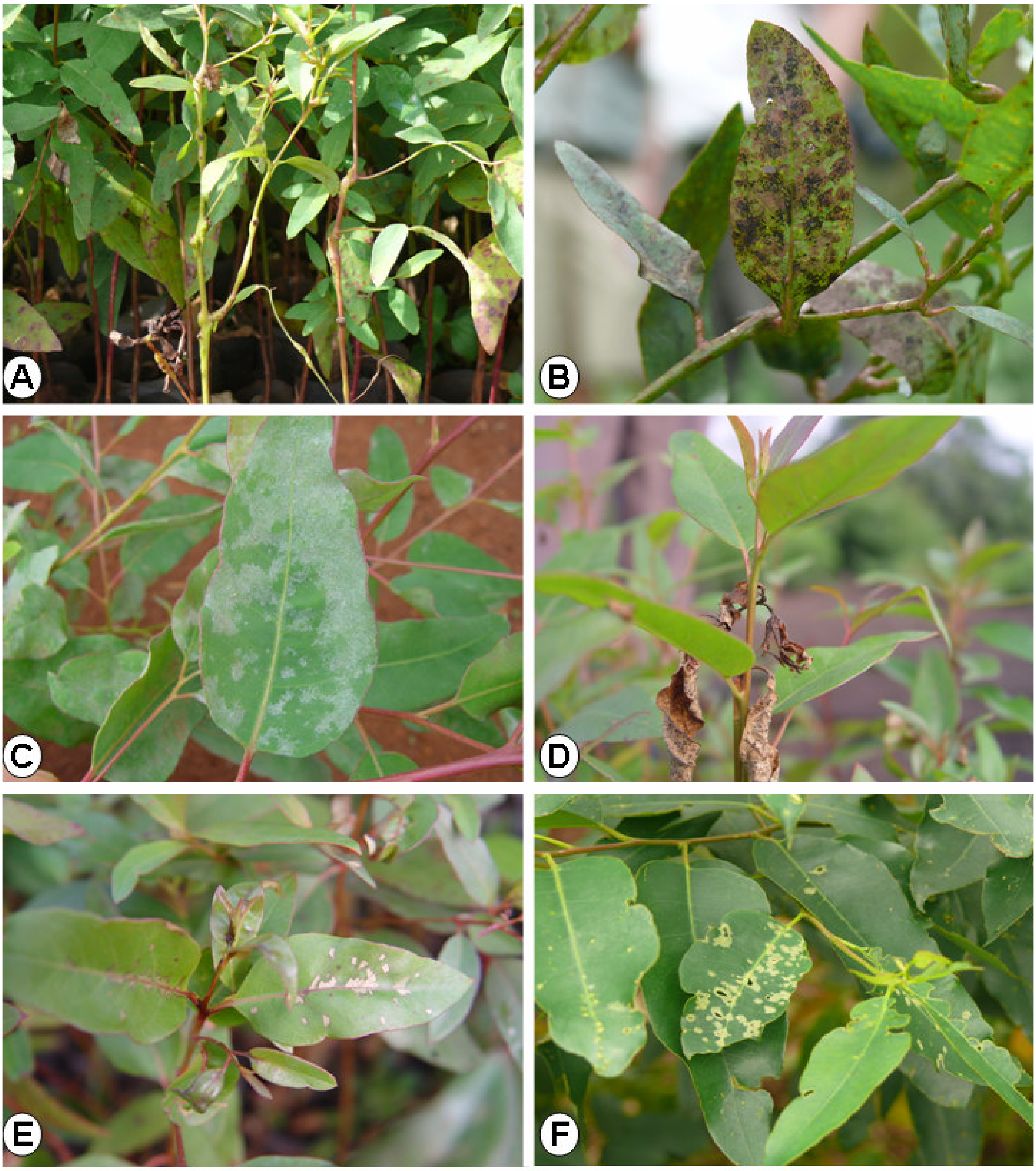

Figure 1: Tree health problems observed on *Eucalyptus* trees in Uganda. (A) *Leptocybe invasa* infestation of young *E. grandis* in a nursery, (B) Phaeophleospora leaf spot on *E. grandis* infested by *L. invasa*, (C) Powdery mildew symptoms, (D) Blight and leaf mortality caused by bacterial blight, (E) Leaf spot and leaf death caused by bacterial blight, (F) Unknown leaf spot on young *E. grandis* trees.

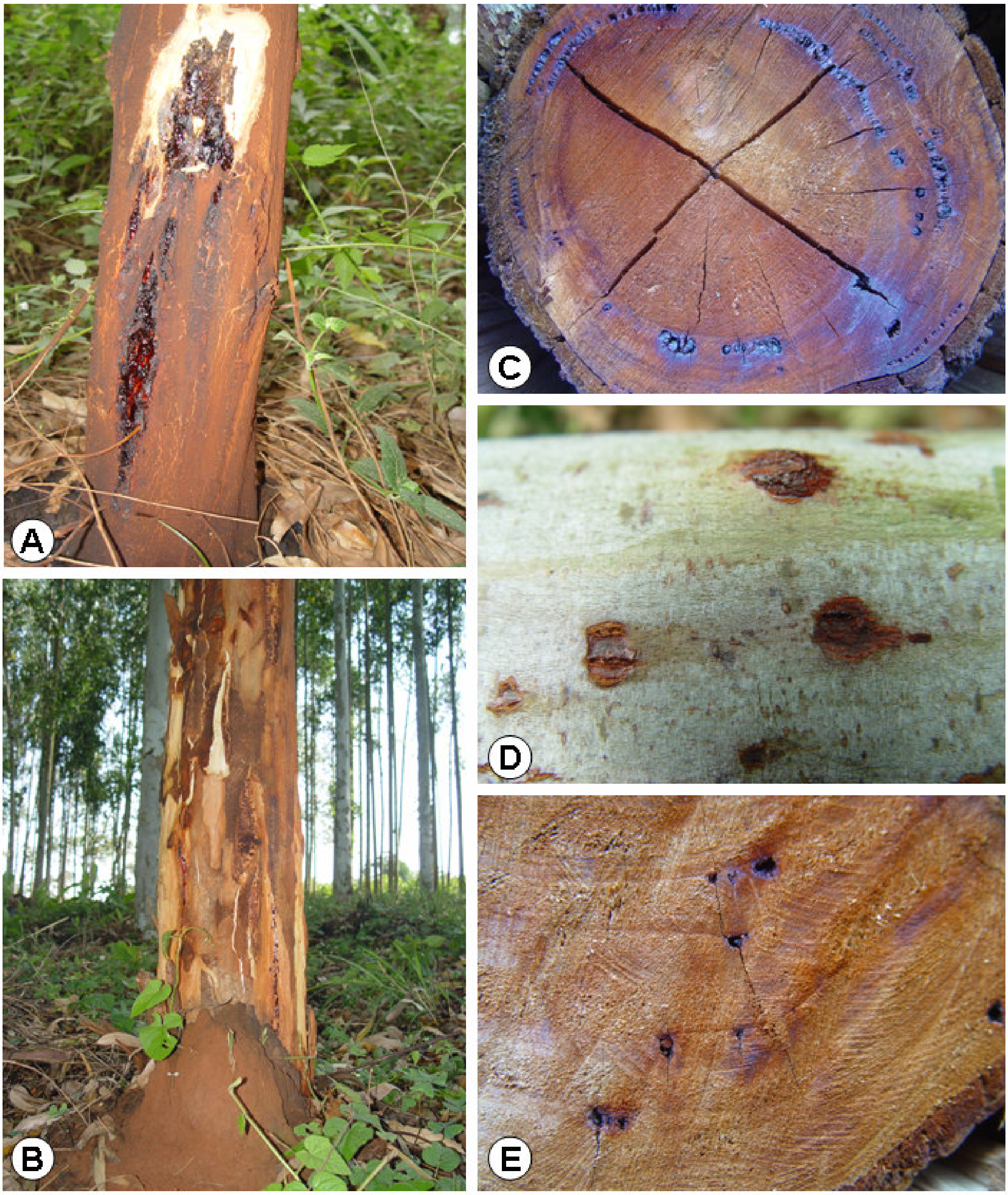

Figure 2: Stem disease symptoms on *Eucalyptus* trees in Uganda. (A) Bark discolouration, cracking and kino exudation caused by Botryosphaeria canker, (B) Termite damage to base of tree, resulting in Botryosphaeria canker, (C) Kino rings in the wood of a tree caused by Botryosphaeria canker, (D) Bark spots characteristic of Coniothyrium canker on main stem of tree, (E) Kindo pockets in the wood of tree characteristic of Coniothyrium canker.

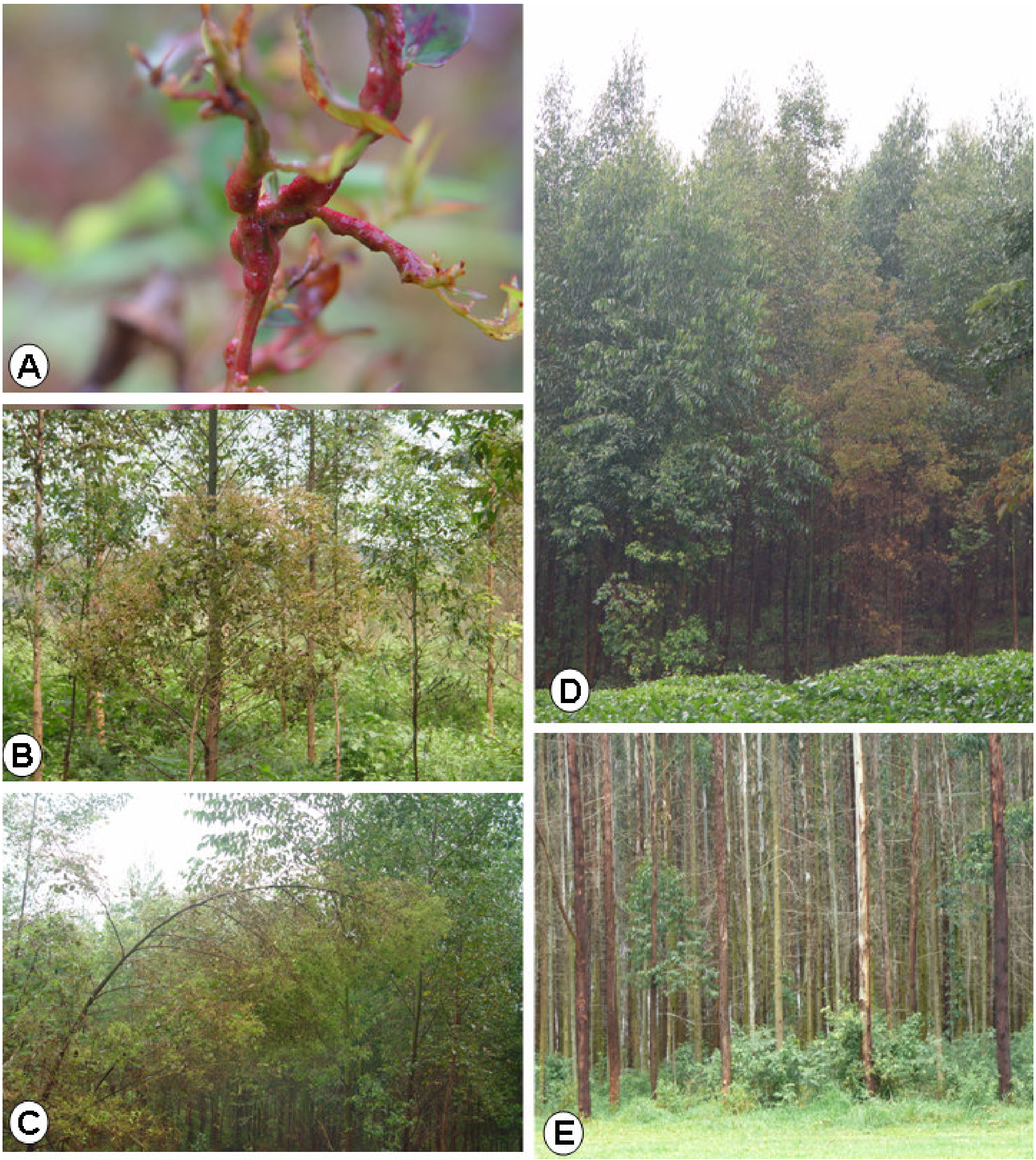

Figure 3: Pest and disease problems on *E. grandis* in Uganda. (A) Galling and malformation of petioles caused by *L. invasa* infestation, (B) Stunting of young tree caused by *L. invasa*, (C) Bending of main stem of tree as a resulting of heavy *L. invasa* infestation, (D) Variation in susceptibility to *L. invasa* infestation with healthy green trees and stunted, chlorotic trees with *L. invasa* infestation, (E) *Eucalyptus* compartment showing variation in Botryosphaeria stem canker infection, with infected trees showing red/black stems as a result of kino exudation from stem cracks.

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Farmers' knowledge, perceptions and management of the gall-forming wasp, *Leptocybe invasa* (Hymenoptera: Eulophidae), on *Eucalyptus* species in Uganda

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Abstract
Farmers growing *Eucalyptus* species in Uganda were interviewed using a pre-tested questionnaire to investigate their knowledge, perceptions and management of the *Eucalyptus* gall-forming wasp, *Leptocybe invasa* Fisher & LaSalle, with the aim of developing integrated management programme for the pest. Farmers were aware of, and concerned about, the gall problem on *Eucalyptus*, but the vast majority of them did not know the cause. Most farmers did not attempt to control the infestation because they did not know of suitable control methods and/or the cause of the problem. Farmers' control decisions were not influenced by their experience in cultivating *Eucalyptus* or their education level. Only 20% of 59 farmers interviewed had received advice on *L. invasa*, suggesting poor flow of information on tree pests to farmers. Nearly all farmers interviewed still wanted to plant *Eucalyptus*, and they saw the trees as a source of several products and services. Problems relating to the increasing emergence of alien insect pests in tropical forests, and challenges and strategies for effective management of forest pests in developing countries are discussed.

Keywords: Eucalyptus*, indigenous knowledge,* Leptocybe invasa*, pest management, plantation forestry*

1. Introduction

Arthropod pests are one of the major constraints upon the productivity of plantation forestry in Africa (Wagner et al. 1991; Nicolas et al. 1999). However, there continues to be very little information on tree farmers' perceptions of such pests, their management practices and decision-making processes (but see Nyeko et al. 2002; Nyeko and Olubayo 2005). In contrast, traditional pest management practices in agriculture have been studied for a number of cropping systems and the results used as inputs for developing integrated pest management packages (Norton et al. 1999; Bentley and Baker 2002). Farmers have the advantage over scientists in that they often have a life-long experience of growing their crop; experience which has been built up through regular observations and exchange of information through formal and informal actor networks (Van Mele and Van Chien 2004). As plantation forestry is developed and promoted, there is a need to integrate indigenous knowledge about pest identification and management techniques into the development processes in order to improve tree farmers' pest management practices.

One of the tree species most widely promoted in the tropics to meet the high and increasing demands for tree products and services is *Eucalyptus*. The popularity of *Eucalyptus* species is attributable to them being generally adaptable, having fast growth and good potential for sawn wood and processed wood products, high calorific value fuelwood and a variety of environmental and ornamental uses (Poore and Fries 1989). In Uganda, many organisations and government institutions promote the planting of *Eucalyptus* by local farmers. Recently, the Forestry Resources Research Institute (FORRI) introduced a number of *Eucalyptus* clones from South Africa into the country to increase the *Eucalyptus* production. The Integrated Rural Development Initiative (IRDI), a non-profit making non-governmental organisation (NGO), has been establishing *Eucalyptus* woodlots in some refugee settlements in Uganda to protect the environment while ensuring sustainable supply of tree products in the settlements. Commercial companies such as British American Tobacco (BAT) also encourage the establishment of *Eucalyptus* woodlots as an alternative supply of timber and fuelwood. However, to be successful, such schemes require good management, and good management depends on knowledge of growth constraints, including pests and diseases.

An insect pest, *Leptocybe invasa* (Hymenoptera: Eulophidae), has recently been reported on *Eucalyptus*

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species in several countries including Algeria, Iran, Israel, Italy, Jordan, Kenya, Morocco, Spain, Syria, Turkey and Uganda (Mutitu 2003; Mendel et al. 2004; Nyeko 2004). The adult of *L. invasa* is a very small (1.0 – 1.4 mm long) black wasp (Mendel et al. 2004). The species has been described as a new taxon of Australian origin (Mendel et al. 2004). It lays eggs in the bark of shoots or the midribs of leaves. 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 (Mendel et al. 2004). The galls can cause the twigs to split, destroying the cambium. Small circular holes, indicating exit points of adults from pupae, are common on the galls. Severely infested trees show gnarled appearance, stunted growth, lodging dieback and eventually tree death (Mendel et al. 2004; Nyeko in press).

In Uganda, several concerns have been raised about the *L. invasa* infestation on *Eucalyptus* (Nyeko in press), but there has been no study on farmers' knowledge and perceptions of the pest problem, and their coping strategies. This paper documents farmers' knowledge, perceptions and management of *L. invasa* with the aim of developing integrated management of the pest. In addition, problems relating to emergence of such alien insect pests in tropical forests, and challenges and strategies for effective management of forest pests in developing countries are discussed.

2. Material and methods

The study was conducted in January and February 2006. In total, 59 respondents were interviewed using a pre-tested questionnaire in the districts of Arua, Isingiro, Kumi, Masindi, Mbale, Ntungamo, Sironko and Tororo in Uganda. The districts belong to five agroecological zones in the country: Eastern lowlands (Tororo and Kumi), Eastern highlands (Mbale and Sironko), Lake Albert crescent (Masindi), Southern drylands (Ntungamo and Isingiro) and West Nile (Arua) where severe *Leptocybe invasa* infestation on *Eucalyptus* species has been reported (Nyeko in press). Farmers to be surveyed were selected from lists of farmers that were obtained from FORRI and BAT.

Most survey questions were open-ended in order to avoid limiting farmers' opinions. Data were collected on farmers' social and educational profiles as well as on their experiences of cultivation of *Eucalyptus*. Special emphasis was placed on exploring farmers' awareness of *Leptocybe invasa* and its infestation, advice they had recived on the pest, and their management practices against it. Specifically, farmers were asked to list and rank the following: (i) five causes of *Eucalyptus* mortality they had observed in the previous year, (ii) five main reasons for cultivating *Eucalyptus*, and (iii) five main problems they encountered in cultivating *Eucalyptus*. Farmers were also asked to rank the level of *L. invasa* infestation on different age categories (< 1 year, 1 – 3 years, 3 – 5 years and > 5 years old) of their *Eucalyptus* stands into the following classes: (i) none (no tree infested), (ii) low (< 20% of trees infested), (iii) moderate (20 – 50% of trees infested), and (iv) high (> 50% of trees infested). In order to elicit farmers' ability to manage *L. invasa*, farmers were asked to advise their neighbours or friends who might seek their advice on the pest. Finally, information was sought on farmers' future plans on cultivating *Eucalyptus*. In this we tried to understand the importance of *Eucalyptus* in farmers' livelihoods.

In each district, one research assistant who was conversant with the most commonly spoken local language was recruited and trained by the principal researcher to guide the researcher to the farmers and translate questions into the local language during the interviews. All interviews were conducted in farmers' *Eucalyptus* stands. This enabled researchers to crosscheck farmers' answers regarding the pest status with field observations.

The survey data were encoded, entered into a spreadsheet for collation and checking and then analysed with the SPSS statistical package (release 10 for windows) (Bryman and Cramer 2001). In addition to using descriptive statistics to summarise data, Pearson correlation was used to determine if farmers' educational level and their experience in cultivating *Eucalyptus* influenced their decision to control *L. invasa*. For this analysis, farmers' experiences (year since each farmer first planted *Eucalyptus* on his/her farm) were grouped into three categories; less than 5 years, 5 – 10 years and more than 10 years experience. Similarly, formal education level was categorized into none, primary, lower secondary, higher secondary and post secondary diploma or certificate.

3. Results

3.1. Profiles of respondents

The vast majority (92%) of respondents were from male-headed households. Most (93%) respondents were married and very few were either single (3%) or widowed (3%). Up to 73% of the respondents were *Eucalyptus* plantation/woodlot owners. Other respondents included relatives of plantation owners (15%), employees working in plantations (10%) and one was a wife to a plantation owner. The majority (70%) of the respondents were full time farmers, 25% were part-time and a further 5% were away from the districts where they established their *Eucalyptus* plantations. Most (97%) of the respondents had some formal education although the majority (41%) of them were only educated to primary level. Some (27%) of the respondents had attained diploma or post secondary certificates while 25 and 3% of them had left education in lower and higher secondary schools, respectively. The farmers acquired their land mainly through inheritance (56%) and purchase (36%). A few (7%) of them cultivated *Eucalyptus* on land owned by the Ugandan government (2%), schools (3%) and a church (2%). One respondent was the manager of a *Eucalyptus* stand in a forest reserve owned by the Uganda National Forestry Authority in Tororo district.

3.2. Cultivation of Eucalyptus *species*

Farmers' experience in cultivating *Eucalyptus* ranged from less than 1 year (first planting in 2005) to about 75 years (first planting in 1930). *Eucalyptus grandis* was the most commonly planted species (78% of total respondents). Other *Eucalyptus* species planted included *E. camaldulensis* planted by 29% of respondents, *E. saligna* (14%), *E. citriodora* (2%) and *E. robusta* (2%). The number of *Eucalyptus* trees the farmers had planted on their land varied markedly, with the majority (41%) having more than 2000 trees. Twenty four percent of the farmers had 100 – 500 trees, 20% had 1000 – 2000 trees while 15% had 500 – 1000 trees. Up to 73% of the respondents established their *Eucalyptus* stands using the taungya system only, 24% used grassland planting and only 3% of them had used both taungya and grassland planting. When asked to rate the mortality of their *Eucalyptus* in the previous year, 48% of the respondents ranked the mortality as low (less than 20% of trees dead), 25% moderate (20 – 50% trees dead), 20% high (More than 50% of trees dead) and 7% reported no dead trees. Farmers cited 11 causes of *Eucalyptus* mortality (Table I). Termites were the most commonly reported cause of tree death, accounting for 28% of 86 responses. Drought reported by 20% of respondents and unidentified diseases (16%) were also highly cited mortality causes. Three farmers showed the researchers trees that had typical symptoms of *Botryosphaeria* infection (cracks and oozing of brown sap from the stem), and they claimed that the disease had been the worst problem on their stands in the previous year. Similarly, four respondents presented samples of *Eucalyptus* infested by *Leptocybe invasa*, which they considered to be most damaging on their *Eucalyptus* stands.

Only 37% of the respondents had received advice on growing *Eucalyptus*. The farmers received such advice from various sources including, district forest department (38%), FORRI (14%), friends and/or neighbours (14%), secondary school teachers (10%), district department of agriculture (4.8%) and National Agricultural Advisory Services (NAADS) (4.8%).

Farmers mentioned several reasons for cultivating *Eucalyptus* (Table II). The commonly cited reasons for growing *Eucalyptus* were to supply construction materials (30% of 194 responses), fuelwood (29%) and income (28%). The majority of respondents (66% of total respondents) ranked income as their first reason for growing *Eucalyptus* compared with only 14% and 12% for fuelwood and construction materials, respectively. Very few farmers ranked boundary marking, environmental protection, beekeeping, draining swamp and ease of management as their first reasons for growing *Eucalyptus* (Table II).

Farmers mentioned a number of problems they faced when cultivating *Eucalyptus* (Table III). Insect pests and diseases were the most commonly and highly ranked problems, followed by lack of technical advice and lack of good quality planting material. One farmer claimed not to have any major problem in cultivating *Eucalyptus*, while 8% of farmers mentioned theft of their trees, suggesting inadequate supply of *Eucalyptus* products.

3.3. Knowledge and perceptions of Leptocybe invasa and its infestation

All of the respondents had observed the symptoms of *Leptocybe invasa* infestation on *Eucalyptus*.

Table I. Farmers' ranking of the causes of *Eucalyptus* mortality on their farm in the previous year.

Causes	Rank (number of responses)				Total responses*	
	1st	2nd	3rd	4th	No.	%
Termite	18	9	1	0	28	32.6
Drought	12	6	2	0	20	23.3
Disease	12	3	1	0	16	18.6
Late tending	4	1	0	0	5	5.8
Leptocybe invasa	4	0	0	0	4	4.7
Livestock	0	1	2	1	4	4.7
Unknown	3	0	0	0	3	3.5
Water logging	1	1	0	0	2	2.3
Vandals	0	1	1	0	2	2.3
Fire	1	0	0	0	1	1.2
Beetle	0	1	0	0	1	1.2

*Multiple responses were possible since most farmers cited more than one causes of tree mortality.

Table II. Farmers' main reasons for cultivating *Eucalyptus* species in Uganda.

Reasons for growing *Eucalyptus*	Rank (number of respondents)					Total responses*	
	1st	2nd	3rd	4th	5th	No.	%
Timber for construction	7	29	20	1	1	58	29.9
Fuelwood	8	22	23	3	0	56	28.9
Income	39	7	6	3	0	55	28.4
Boundary marking	1	0	3	4	1	9	4.6
Environmental protection	1	0	0	5	1	7	3.6
Windbreak	0	0	1	1	1	3	1.5
Beekeeping	1	0	0	1	0	2	1.0
Draining swamp	1	0	0	0	1	2	1.0
Easy management	1	0	0	0	0	1	0.5
Medicine	0	0	0	1	0	1	0.5

*Multiple responses were possible as most farmers planted *Eucalyptus* for more than one reason.

However, the majority of them (93%) pointed out that they did not know the cause of the problem. When asked to name the cause of the infestation, the few farmers who claimed to know cited ants (one farmer), an unidentified insect (one farmer), small white insects (one farmer) and an unidentified disease (one farmer). The majority (87%) of the farmers first observed *L. invasa* infestation on *Eucalyptus* between the years 2000 and 2005, with nearly half (49%) of them seeing the symptoms for the first time either in 2004 or 2005. Two farmers (one from Arua and the other from Ntungamo district) recalled seeing the problem for the first time in 1997 (the earliest time reported). Most farmers (60%) reported *L. invasa* infestation to be most common in the dry season although 25% perceived the damage to be common throughout the year. Some of the respondents (15%) were not sure of the seasonal variation in the incidence of *L. invasa* infestation.

The majority of farmers who had *Eucalyptus* seedlings or coppices less than 1-year-old ranked the incidence of *L. invasa* infestation on this growth stage as high (more than 50% of trees attacked) (Table IV). In contrast, most farmers who had *Eucalyptus* stands older than 1 year reported either no or low *L. invasa* infestations on these cohorts (Table IV). When asked to mention the effects of *L. invasa* infestation on *Eucalyptus*, the majority (46%) of farmers reported that the insect reduces the growth rate of *Eucalyptus*; 29% reported reduced growth and tree mortality; 12% mentioned reduced growth and tree deformation; 9% cited reduced growth, tree deformation and mortality; 2% had observed tree deformation only; 2% mention tree deformation and mortality; and 2% were not sure.

Up to 48% of the respondents claimed that they had observed *L. invasa* infestations on other tree species and/or crops. The farmers mentioned a total of 13 other plant species that they perceived was attacked by *L. invasa* galls (Table V). Of these, cassava was by far the most commonly mentioned species followed by oranges and mangoes (Table V). When farmers presented samples of the plants they perceived were infested by *L. invasa* to the researchers, no typical *L. invasa* gall damage on any of the samples were observed. Cassava samples showed symptoms of the cassava mosaic virus infection. Samples of oranges, mangoes, *Spathodea campanulata* and *Annona senegalensis* had leaf galls, which were not typical of *L. invasa* infestation. Banana and coffee samples were yellowish and wilting. The *Thevolia* species observed had curled leaves with yellowish strips, possibly caused by a virus. *Markhamia lutea* was infested by unidentified species of aphid and scale insects. No samples of maize, beans and groundnuts were observed during the study because these crops were out of season.

Table III. Farmers' ranking of their main problems in cultivating *Eucalyptus* in Uganda.

Problems in growing *Eucalyptus*	Rank (number of respondents)					Total responses*	
	1st	2nd	3rd	4th	5th	No.	%
Insect pests and diseases	28	14	9	0	1	52	32.7
Lack of technical advice	8	9	6	3	0	26	16.4
No quality planting material	4	10	5	1	0	20	12.6
Lack of ready market	3	4	4	1	0	12	7.5
Drought	2	5	4	1	0	12	7.5
Livestock damage	3	0	1	3	1	8	5.0
Thieves	1	3	1	0	0	5	3.1
Lack of labour	2	3	0	0	0	5	3.1
Lack of tools	1	1	1	0	0	3	1.9
Weeds	0	2	0	0	1	3	1.9
Lack of money	2	1	0	0	0	3	1.9
Fire	1	1	0	0	0	2	1.3
Limited of land	1	0	0	0	1	2	1.3
Poor soils	1	0	0	1	0	2	1.3
Stinging bees	0	0	0	1	0	1	0.6
Water logging	0	0	1	0	0	1	0.6
Malicious damage	1	0	0	0	0	1	0.6

*Multiple responses were possible as each farmer could cite more than one problem encountered in cultivating *Eucalyptus*.

Table IV. Farmers' ranking of *Leptocybe invasa* damage on different growth stages of *Eucalyptus*.

Growth stage	Damage level (number of responses)*				Total responses	
	None	Low	Moderate	High	No.	%
< 1 year old	0	5	8	35	48	39.7
1–3 years old	16	17	9	9	51	42.1
3–5 years old	12	4	1	2	19	15.7
> 5 years old	2	1	0	0	3	2.5

*None refers to no tree infested by *L. invasa*; low, less than 25% of trees in stand infested by *L. invasa*; moderate, 25–50% of trees infested; high, more than 50% of trees infested.

Table V. Farmers' observations of *Leptocybe invasa* infestation on plants other than *Eucalyptus* species.

Tree/crop species	Total responses	
	No.	%
Manihot esculenta Grantz (cassava)	18	47.4
Citrius species (oranges)	5	13.2
Mangifera indica L. (mangoes)	3	7.9
Musa species (banana)	2	5.3
Spathodea campanulata Beauv.	2	5.3
Thevolia species	1	2.6
Persea americana Mill. (avocado)	1	2.6
Markhamia lutea (Benth.) K.Schum.	1	2.6
Phaseolus vulgaris L. (beans)	1	2.6
Coffea species (coffee)	1	2.6
Arachis hypogaea L. (groundnuts)	1	2.6
Zea mays L. (Maize)	1	2.6
Annona senegalensis Pers.	1	2.6
Total	38	100.0

3.4. *Control of* Leptocybe invasa

The vast majority (80%) of farmers had not attempted any control measure against *L. invasa*. The farmers cited a number of reasons for doing so. The majority of them mentioned lack of knowledge on suitable control methods (59%) followed by lack of knowledge on the cause of the problem (20%), lack of money (8%), and lack of interest (3%). One farmer claimed that he had not yet seriously thought about controlling the pest. Farmers' formal education level ($r = -0.189$; $P = 0.151$) and experience in cultivating *Eucalyptus* ($r = 0.022$; $P = 0.868$) showed no significant relationship with their decision to control *L. invasa*.

Of the 12 farmers who attempted to control *L. invasa*, 42% reported using chemicals only, 33% cultural methods only and 17% both chemicals and cultural methods. One farmer attempted foliar application of a liquid fertilizer, which he claimed was highly effective against *L. invasa*. The cultural control methods attempted by farmers included foliar application of ash dissolved in water (two farmers), uprooting infested seedlings by hand (two farmers), cutting off infested trees (one farmer), pruning infested trees (one farmer), and weeding (one farmer). The farmer who pruned affected trees claimed that the method was highly effective against *L. invasa*. In contrast, those who uprooted *L. invasa* infested seedlings reported this method was not effective. Application of ash was reported to be either ineffective (one farmer) or moderately effective (one farmer). Weeding and cutting of infested trees were reported to be moderately effective. The farmers who applied chemicals reported using foliar application of Sumithion (fenitrothion), Marathon (imidacloprid), malathion, Fenkil, diamethoate and Ambush (permethrin). Of these Sumithion, Malathion and Ambush were reported to be ineffective while Fenkil and diamethoate were reported as being highly effective against the insect.

3.5. *Advice on* Leptocybe invasa

The majority (81%) of farmers had not received any advice on *L. invasa*. The few who had received some advice did so from various sources (Table VI). The advice given to farmers ranged from preventive measures to cultural, mechanical and chemical control methods, which most of the farmers perceived as useful (Table VI). However, one farmer noted that the advice to cut and burn *L. invasa* infested trees was not useful in controlling the pest in his *Eucalyptus* stand. When suggesting advice on pest management to neighbours or friends who might be interested in planting *Eucalyptus*, farmers proposed several options (Table VII). Most farmers (42% of 67 responses) recommended planting resistant types of *Eucalyptus* (22%), which they could not specify, and seeking advice from experts (19%). Some farmers (8%) pointed out that they would not offer any advice because of their inadequate knowledge of the insect.

3.6. *Future plans on cultivating* Eucalyptus *species*

The majority (95%) of farmers were still interested in planting *Eucalyptus* species despite the problems they had encountered in cultivating the species. They wanted to do so mostly for income generation (85% of total respondents), supply of construction materials (80%) and fuelwood (78%). Other reasons that some farmers considered important for future planting of *Eucalyptus* were environmental protection (15%), boundary marking (7%), beekeeping (3%), fast growth (2%), good coppicing ability (2%), less labour demanding (2%) and availability of land (2%). Of the few (5%) farmers who were not interested in planting *Eucalyptus* in the future, two had inadequate land and one was discouraged by *L. invasa* infestation.

Farmers commonly mentioned their own stands or nurseries (39% of total respondents) and open

Table VI. Advice received by farmers on *Leptocybe invasa* infestation in Uganda.

		Useful			Total responses	
Advice	Source*	Yes	No	NA*	No.	%
Wait, we are still researching	DFD, DDA, FORRI	2	1	0	3	18.8
Spray with chemicals	DDA, FORRI	2	1	0	3	18.8
Plant resistant types of *Eucalyptus*	NFA, NFC	1	1	0	2	12.5
Cut and burn affected trees	DAD, FORRI	1	0	1	2	12.5
No chemical can control the pest	DFD	0	1	0	1	6.3
Weed properly	NFA	1	0	0	1	6.3
Plant healthy seedlings from a good source	NFA	1	0	0	1	6.3
Ensure timely planting	NFA	1	0	0	1	6.3
Apply liquid fertilizer (rapid grow)	DFA	1	0	0	1	6.3
Beware of a disease on *Eucalyptus*	DFD	1	0	0	1	6.3
Total		11	4	1	16	100.0

*NA, advice not yet applied; DFD, District Forest Department; DAD, District Department of Agriculture; FORRI, Forestry Resources Research Institute; NFA, National Forestry Authority; NFC, Nyabyeya Forestry College; DFA, District Farmers' Association.

Table VII. Summary of the advice farmers would offer to friends/neighbours interested in planting *Eucalyptus* species.

Advice	Total responses No.	%
Plant resistant *Eucalyptus* species	15	22.4
Seek advice from experts	13	19.4
Cannot advise because of inadequate knowledge on the insect	5	7.5
Plant, some will survive	4	6.0
Plant, but beware of the problems	4	6.0
Plant, and spray with chemicals	4	6.0
Plant, control methods may be developed in future	3	4.5
Plant, and manage (weed) your plantation well	3	4.5
Prune-infested trees	3	4.5
Plant and wait for whatever comes out	2	3.0
Plant, the problem can be seasonal	2	3.0
Buy seedlings from a technical person	2	3.0
Plant different tree species from *Eucalyptus*	2	3.0
Plant, there are inadequate tree products in the area	1	1.5
Plant, it is a sure source of income	1	1.5
Mix manure with soil before planting	1	1.5
Plant, the problem is like any other tree and crop disease	1	1.5
Collect seeds from trees which are not attacked	1	1.5
Total	67	100.0

markets (37%) as sources of their planting materials (seeds and/or seedlings) for future planting. A few farmers planned to obtain their planting materials from FORRI (9%) and district forest departments or NFA (9%). The least mentioned sources of planting materials were neighbours (2%) and BAT (2%). One farmer pointed out that he needed to be informed about *Eucalyptus* species which are resistant to *L. invasa* before he could decide on the source of planting material.

4. Discussion

4.1. Emergence of alien insect pests in tropical forests

Results of this study further exemplify the problems caused by alien pests of trees in the tropics. Several insect pests of *Eucalyptus* from Australia have emerged in exotic plantations in tropical countries where they cause more serious damage than in Australia, apparently due to absence of their natural enemies. The empirical review of pest outbreaks in tropical forest plantations by Nair (2001) provides excellent examples of such pests, including curculionids, *Gonipterus scutellatus, G. gibberus* and *G. platensis*; the cerambycid, *Phoracantha semipunctata* and *P. recurva* recorded in south Africa, Zambia and South America; the chrysomelid, *Trachymela tincticollis* found in South Africa; the flower feeding beetle, *Drosophila flavohirta* observed in Madagascar and South Africa; and the scale insect, *Icerya purchasi* reported in Angola, Malawi and India. In the 1990s the cypress aphid, *Cinara cupressivora*, precipitated a crisis, especially on *Cupressus lusitanica* in eastern and central Africa (Murphy 1996). Similarly, the pantropical spread of Leucaena psyllid, *Heterosylla cubana*, from its centre of origin in the Caribbean to Hawaii in 1984, then to Asia and in Africa in 1990s inflicted major damage to *Leucaena leucocephala* (Napompeth 1994). Such pests will continue to appear in exotic plantations in the tropics (Nair 2001; Wingfield et al. 2001), posing a serious threat to the productivity of plantations and thus the livelihoods of people and industries that rely on them.

The increasing emergence of pests of trees in the tropics has been attributed to a number of factors. First, the trend in tropical plantation forestry has been to establish fast-growing exotic trees as pure stands. Exotic tree species run a high risk of attack by alien pests (Murphy 1998; Wingfield et al. 2001). Similarly, monocultures especially of genetically similar trees are associated with increased probability of pest outbreaks and can transform sporadic pests into permanent problems (Cock 2003). Second, there has been rapid increase in the area of tree plantation and on-farm trees in the last few decades and poor tree species-site matching, especially in sub-Saharan Africa (Murphy 1998). Third, the proliferation of international trade and travel, and the resultant overstretching of quarantine services, is a major factor influencing accidental introduction of alien pests (Bright 1999). Forest products such as packaging materials can be particularly important in facilitating the movement of pest species (Cock 2003). An example of this is the arrival of the devastating *Eucalyptus* snout beetle, *Gonipterus scutellatus*, in South Africa in 1916 in a consignment of apples from Tasmania (Annecke and Moran 1982). Fourth, several studies indicate that climate change can increase the range of many insects and thus their pest status (Watson 2001). However, empirical evidence on the effects of climate change on the invasion of alien insect pests in tropical forests is lacking.

4.2. Challenges to effective management of alien tree pests in developing countries

Forest pest management programmes in many developing countries have remained inadequate, although there are some examples of success, primarily through the use of classical biological control and host plant resistance (Wylie 2002; Day et al. 2003; Tribe 2003). In response to some countries' need for control of invasive alien pests, several forestry pest management programmes have been started in developing countries mostly with external support from international agencies (Cock 2003; Day et al. 2003). Although such programmes created opportunities to effect institutional development while addressing the immediate problem of forest pest management, there still exist a myriad of institutional and socio-economic barriers (Speight and Wylie 2001).

In most developing countries national plant protection organizations have been given extensive powers to control imports and exports, disposal, inspection and survey and treatment of plant and plant products, but they lack the means to implement the regulations. This situation is more alarming for forest pest management, which has low priority relative to the more pressing agricultural pest problems (Nair 1991). Often, the mechanism for monitoring and detecting forest pests, and rapid plans to allow for eradication of new invasions are lacking. Without sound monitoring and law enforcement teams, early detection and rapid response to new invasions are impossible and countries are left with expensive management options, often when the new invasive species has resulted in large-scale losses (Anon. 2005). Moreover the high cost of managing forest pest outbreaks generally prevents large-scale treatment, except in developed countries. National forestry programmes in low-income countries thus need to shift emphasis from such 'corrective' forest pest management to 'preventive' forest pest management. In developed countries, the trend in managing forest pests indicates increasing development of preventive methods such as pest risk analysis, quarantine laws and regulations, early detection methods, and public education programmes (Cock 2003).

Additional barriers to effective management of forest pests in developing countries are the small number of forest entomologists, their inadequate training in the concepts and techniques of IPM, and the lack of or inadequate support for research in forestry at institutional and national levels (Nair 1991). For example, analysis of forest pest management in 15 African countries by Akanbi and Ashiru (1991) showed that the plant protection services in all the countries involved very small teams, sometimes comprising a single person with little or no support facilities to practice effective plant protection. Some countries such as Malawi had excellent permanent forest pest monitoring teams in the past, but these teams have not been retrained in the last few years and many that have left have not been replaced (Anon. 2005).

The weak institutional, human and physical resources to address forest pest problems in developing countries are a handicap to the access, generation and transfer of vital information for making informed decisions on tree pests. Globally, there is an increasing body of relevant information that national forestry programmes need to access and contribute to, but the wherewithal to do this is lacking in many developing countries. There is inadequate sharing and exchange of tree pest information between different stakeholders, including the different arms of government, the private sector, civil society and the general public (Dix 1996). In the present study, for example, the vast majority of farmers were not only unaware that *L. invasa* is the cause of the gall damage on their *Eucalyptus*, but also reported not knowing the insect. Such limitations in farmers' knowledge clearly define the need for research and extension services.

4.3. Suggestions for improving management of forest pests in developing countries

4.3.1. Institutional strengthening. Most developing countries need major reforms in national forestry programmes for institutional strengthening, training and regional cooperation based on sustainable forest pest management strategies and implementing these in forest management plans. The main focus of such programmes must be on overall forest health, whether it be the case of forest monocultures, polycultures or natural forests (Murphy 1998). As pointed out by Dix (1996), assistance from international agencies in, for example, establishing research partnerships and information programmes, and providing financial and administrative support may be necessary for such programmes to succeed.

4.3.2. Political support. Successful implement of IPM often needs the right political structure and priorities, and change in attitude across a broad spectrum of stakeholders, at the national and international levels (Dix 1996; Neuenschwander et al. 2003). Governments need to develop the necessary infrastructure and institutional arrangements to effectively promote plant protection capacities and guarantee compliance with the related international agreements, conventions and treaties (Neuenschwander et al. 2003). This requires, among other things, appraisal and effective implementation of national policies that have direct and indirect effects on forestry, and in particular forest health.

4.3.3. Research. More research on forest pest management in developing countries needs to be directed into problem solving, involving multidisciplinary approaches with emphases on applied studies and transfer of appropriate technologies. Experience from IPM indicates that the complexity of ecologically based pest management may become a major limitation to its implementation (Wylie 2002). For example, farmers often lack the biological and ecological information necessary to implement IPM (Abate 2000). One way of empowering such farmers is through an educational system that combines aspects of western technical knowledge with local knowledge (Trutmann et al. 1996). The farmers' field school approach and community advisory concept (Van Huis and Meerman 1997; Norton et al. 1999; Price 2001) could be excellent ways for agencies promoting tree growing to both generate and spread information about integrated management of tree pests such as *L. invasa* among farmers.

Research is necessary to develop sustainable, low technology, environmentally sound and cost-effective pest management strategies to particular local conditions. Important components that should be examined in an integrated approach include pest monitoring and detection, biological control methods, host resistance and silvicultural practices (Wylie 2002). Particular emphasis needs to be given to identification of IPM strategies such as use of resistant host tree species, correct tree germplasm-site matching and the conservation of natural enemies, which prevent or reduce the risk of pest problems occurring.

4.3.4. Information exchange. Synthesis, simplification and transfer of tree health information among researchers, extension agents, policy makers, tree growers, suppliers of forestry supplements, and private agencies are important in speeding up successful development and implementation of sustainable pest management. Forest extension agencies and scientists, in particular, need to become more active and interested participants for this to be successful. Cooperative activity among tree growers, suppliers of forestry supplements, and development agencies as well as the scientific community could facilitate information flow and rapid response to pest invasion and, thus, reduce pest management costs. For example, such cooperatives can link local communities to national and international research and development facilitators as partners in compiling, sharing and integrating their respective knowledge bases from which management options are derived for evaluation and adaptation in specific localities by local communities themselves. Internationally, tree pest information networks such as the Forest Invasive Species Network for Africa (FISNA) formed in 2005, could provide excellent channels for exchange of information on forest invasive species between countries and/or continents. Such networks could also be useful in alerting relevant agencies about new invasive species, and providing policy advice on trans-boundary movement and phytosanitary measures (Anon. 2005).

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PEST ALERT
Blue Gum Chalcid

Introduction

The Blue Gum Chalcid, *Leptocybe invasa* Fisher & LaSalle, (Hymenoptera: Eulophidae) is a new genus and species that was first recorded in the Middle East in 2000 and has spread to most Mediterranean countries and to many of the *Eucalyptus* areas in northern and eastern Africa. It was detected in Uganda and Kenya in December 2002, and more recently from Tanzania where it is reported to spread fast and cause serious damage to young plantations and nursery seedlings. It was reported in South Africa in June 2007 and poses a serious threat to *Eucalyptus* forestry. Monitoring is of critical importance to now determine the distribution of the pest.

Damage

The insect forms galls on the mid-ribs, petioles and stems of new growth of young trees, young coppice as well as nursery seedlings, thereby stunting growth. Galls induced by this wasp can cause substantial injury to young trees and may eventually seriously weaken the tree. In an outbreak situation wasp pressure is intensive and all new growth may be damaged. The impact of the wasp on the development of an adult tree is not yet clear, although galls can be found on most leaves if the wasp occurs in large numbers (Figs A & B).

Distribution and host range

Although this wasp is probably native to Australia, its Australian distribution is still unknown. Presently, the wasp is reported from Algeria, Iran, Israel, Italy, Jordan, Kenya, Morocco, Spain, Syria, Turkey and Uganda. Suitable hosts for this insect include: *E. camaldulensis, E. globulus, E. gunii, E. grandis, E. botryoides, E. saligna, E. robusta, E. bridgesiana, E. viminalis* and *E. tereticornis.*

Description of the insect

The female is a small wasp with average length of 1.2 mm. The head and body are brown in colour with slight to distinct blue to green metallic shine (Figs C & D). Only females have emerged from rearing procedures so far and not a single male has been recoded.

Symptoms and gall development

When exposed to new growth, wasps insert their eggs in the epidermis of the upper sides of newly developed leaves, 0.5-5 cm in length, on both sides of the midrib, in the petiole of such leaves and in the parenchyma tissue of twigs. The attack takes place within 1-2 weeks of the bud break out. There are 5 stages of gall development reported on *E. camaldulensis* in Israel.

Stage 1 begins 1-2 weeks after oviposition, with the first symptoms of cork tissue appearing at the egg insertion spot. This stage is characterized by a small change in the morphology of the attacked tissue, the cork scar becomes bigger and the section of the midrib that carries the eggs often changes its colour from green to pink.

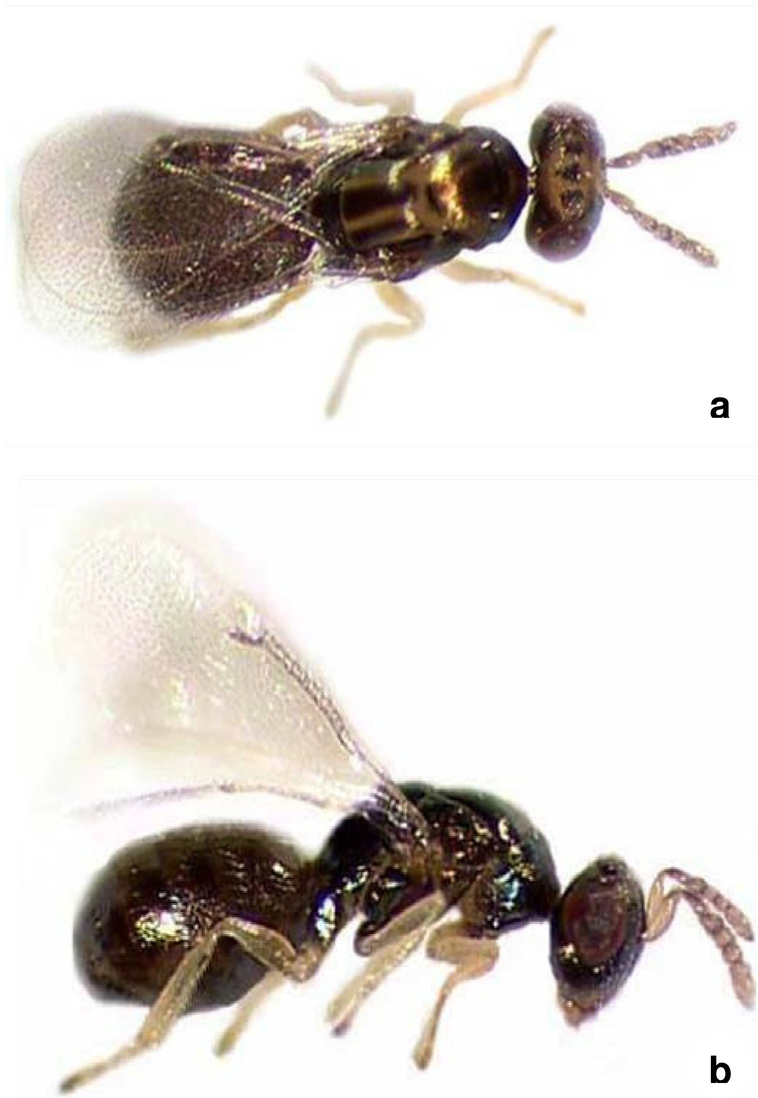
Stage 2 is characterized by development of the typical bump shape and the galls reach their maximum size of about 2.7 mm wide.

Stage 3 is characterized by the fading of the green colour on the surface that tends to change to pink while retaining its typical gloss.

Stage 4 is characterized by the loss of glossiness of the gall surface, with colour changes to light or dark red according to whether the galls are present on the leaves or on the stem.

Stage 5 is characterized by emergence holes of the wasps where the colour changes to light brown on the leaf and red on the stem.

The bluegum chalcid, *Leptocybe invasa*



Photos: Zvi Mendel

a, b) Close-up of female *Leptocybe invasa* wasps (1.2 mm ave. length)

Damage caused by *Leptocybe invasa*

Photos J. Roux © FABI, University of Pretoria

c) Young galls and (d) older galls showing exit holes of the wasp *Leptocybe invasa* on the midrib of *Eucalyptus* leaves

tpcp

Damage caused by *Leptocybe invasa*

Photos J. Roux © FABI, University of Pretoria

e, f) Galls showing exit holes of the wasp *Leptocybe invasa* on the young *Eucalyptus* branches and leave petioles

tpcp

Damage caused by *Leptocybe invasa*

Photos J. Roux © FABI, University of Pretoria

g) Extensive galling on leaves and twigs of *Eucalyptus*
h) Stunting of *Eucalyptus* due to *L. invasa* attack in Tanzania. The tree in the foreground is the same age as the resistant clones in the background