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Mitigation Measures for Invasive Insect Pests on *Eucalyptus* Spp. in East Africa: A Review

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ABSTRACT

Eucalyptus spp. plantation forestry is expanding rapidly to meet wood and fibre demands internationally, including in Eastern Africa (especially Kenya, Uganda and Tanzania). However, *Eucalyptus* spp. plantations in eastern Africa are increasingly being damaged by invasive insect pests. In particular, the Australian invasive pests; *Gonipterus scutellatus* complex (Eucalyptus snout beetle), *Leptocybe invasa* (Blue gum chalcid), *Thaumastocoris peregrinus* (Bronze bug), and *Glycaspis brimblecombei* (Red gum lerp psyllid) pose a serious threat to *Eucalyptus* spp. plantations in eastern Africa. This is a trend that has also been noted in other parts of Africa and globally. Factors that influence introduction, establishment and spread of Australian invasive insect pests include: the expanding planting of Eucalyptus in intensive plantations over large areas, increased human trade and transport, natural dispersal mechanisms across borders, and a growing pool of established exotic pests in the neighbouring regions. Therefore, there is increasing pressure to develop more effective management strategies for the invasive pests and more rapidly than in the past. Some of the strategies that are employed in pest management and require improvement include: strengthening phytosanitary and quarantine measures at ports of entry, selection and deployment of resistant/tolerant host tree genotypes, and international and regional collaborations to prevent the entry and management of invasive species. In this review we assess on the knowledge generated in recent studies concerning forest pests and further consider methods/policies that could be employed or improved to mitigate the threat of invasive pests associated with *Eucalyptus* spp. in the Eastern Africa region.

Key words: *Eucalyptus* spp, Pest management, *Gonipterus scutellatus*, *Thaumastocoris peregrinus, Leptocybe invasa, Glycaspis brimblecombei*

INTRODUCTION

There has been an increasing number of invasive *Eucalyptus* pests in the eastern Africa region in the recent past. The productivity of these trees in this region is particularly threatened by a growing list of serious Australian invasive pests such as *Gonipterus scutellatus* complex (Eucalyptus snout beetle; Coleoptera: Curculionidae: Gonipterini), *Leptocybe invasa* Blue gum chalicid (Eucalyptus gall wasp; Hymenoptera: Eulophidae), *Thaumastocoris peregrinus* (Bronze bug; Hemiptera: Thaumastocoridae) (Mendel *et al*., 2004; Nyeko *et al*., 2007; Wingfield *et al*., 2008 and Garnas *et al*., 2012), and most recently *Glycaspis brimblecombei* (Red gum lerp psyllid; Hemiptera: Psyllidae) in 2014 (*unpublished*). Factors that are thought to influence the increasing rate of introduction and spread of these and other invasive insect pests include the expanding planting of *Eucalyptus* in intensive plantations over large areas, increased human trade and transport, natural dispersal across borders, and a growing pool of established exotic pests in the neighbouring regions (Hanfling and Kollmann, 2002; Wingfield *et al*., 2013; Garnas *et al*., 2012).

Since the 1990's, there has been a concerted effort to expand the deployment of *Eucalyptus* in plantations leading to increased numbers of woodlots of these species in the East African landscapes. The key driving forces behind this expansion include the tree's (i) high tolerance across a wide range of climatic and edaphic conditions, (ii) short rotation times (10 years or less depending on the location), (iii) increasing demand for wood fuel for the tea and tobacco processing industries, (iv) increased use in the expanding construction and telecommunication infrastructure. Most of the *Eucalyptus* growers are small-scale farmers who use these trees to supplement their incomes in difficult socio-economic conditions, for boundary marking, to reduce water and wind soil erosion and other ancilliary applications (Oballa *et al*., 2010).

To meet this increased demand for Eucalyptus timber, deliberate action was initiated in the early 1990's by the Governments of Kenya, Uganda and Tanzania. This goal was in part accomplished via a technology transfer project to increase access to *Eucalyptus* germplasm through introduction and testing suitable *Eucalyptus* hybrid clones from South Africa. The project was aimed at improving productivity through research into clone-site matching (Oballa *et al*., 2010) and has led to increased planting of highly uniform *Eucalyptus* species and clones in the region. Oballa *et al*. (2010) estimated that in Kenya, the *Eucalyptus* farming industry was valued at Kshs. 30 billion (approx. US $330 million).

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The mode of introduction employed in the expansion of *Eucalyptus* germplasm worldwide (including in East African region) has been through seeds and cuttings (scion) transfer. Efforts were made to reduce the chances of introduction of *Eucalyptus* natural enemies by introducing the germplasm only via quality certified seeds (Wingfield *et al*., 2008; Paine *et al*., 2011). However, the uniformity of this homogenised host tree species over large, and increasingly contiguous regions has made these plantations vulnerable to the establishment of invasive insect pests and their spread once introduced. As in other regions, these introduced pests typically also escape their own set of natural enemies that regulate their populations, thus contributing to their ability to reach pest status (Kean and Crawley, 2002; Garnas *et al*., 2012). There is consequently a need to develop rapid, cost-effective and efficient mitigation and management measures to counter the economic losses associated with both the rapid rates introduction and spread of invasive pests.

This review identifies possible mitigation and management options that can be employed to reduce invasion and impact of the increasing invasive *Eucalyptus* pests in East Africa, especially in Kenya. The strategies discussed are a review of possible management options practiced for Eucalyptus invasive pests.

Strategies to mitigate and manage *eucalyptus* invasive insect pests

Various methods can be employed to reduce the introduction and to facilitate the management of invasive insect pests in the east Africa region and in particular Kenya. Some of the key methods include (i) strengthening phytosanitary and quarantine measures at ports of entry, (ii) selection and growing of resistant/tolerant host tree species genotypes, (iii) international and regional collaboration to prevent entry of invasive and (iv) implementation of biological control, etc.

Strengthening phytosanitary and quarantine measures

Strengthening of phytosanitary and quarantine measures at country and regional levels would reduce entry of invaders such as insect pests. This could be achieved through the establishment of pest databases, training of relevant staff at ports of entry, and implementation and improving on the International Standards Phytosanitary Measures (ISPMs) (FAO, 2011; Wingfield *et al*., 2015). There is need to continue expanding, updating and sharing international and regional pest databases (e.g. CABI pest compendium) of potential invasive insect pests from different regions of the world, including the origin of the tree (e.g. Australia in the case of

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Eucalyptus). Such information should be available online and regularly updated. The relevant phytosanitary inspectors (e.g. Kenya Plant Health Inspectorate Service (KEPHIS) in case of Kenya) should be trained by FAO pest protection unit on how to use these databases and how to identify and prevent entry of potential invasive insect pests from various and likely sources. The acquired knowledge of the increasing potential invaders should be used to help phytosanitary officers to be alert for likely potential invasive insect species on goods at ports on entry likely at airports and harbours.

The implementation of ISPMs that are associated with prevention on the entry of invasive pest species should be implemented both at region and country levels and where possible even be improved. Although these are set as the minimum standards worldwide by FAO, regions or countries could improve on them and set their own standards. Some of the ISPM include ISPM No. 15 on Guidelines for Regulating Wood Packaging Material in International Trade to reduce the chance of wood borers and nematodes being move from one world trading region to another. This ISPM recommends that packaging wood should be properly treated with appropriate methods such as use of methyl bromide, debarking or heat treatment to prevent wood borers from being moved globally. Other such ISPM include (i) ISPM No. 2 on Frame work for Risk Analysis, (ii) ISPM No. 11 on Pest risk Analysis for Quarantine pests including analysis of environmental risks and living modified organisms, (ii) ISPM No. 21 on Pest risk Analysis for regulated non-quarantine pests, and (iii) ISPM No. 3 on Guidelines for the export, shipment, import and release of biological control agents and other beneficial organisms. These relevant ISPM's are available on UN-FAO website (FAO, 2011, http://www.ippc.int/IPP/En/ispm.jsp).

Here too, there is a need for better training of relevant quarantine officers on how to implement relevant ISPM's. Regional government's should allocate and pool resources (funding) through regional blocks such as East Africa Community (EAC), Southern African Development Community (SADC), Economic Community Of West African States (ECOWAS) etc to offer regional training courses to the relevant officers.

Selection of resistant/tolerant host tree species genotypes

Historically, *Eucalyptus* forestry research programs worldwide have been aimed at breeding and selecting genotypes for rapid growth and site-matching for increased productivity, with minimum considerations of pest or disease resistance (Potts & Dungey, 2004; Oballa *et al*., 2010). The increasing numbers of invasive insect pests and their rapid spread is, however, changing the objectives of these research programs to consider pest resistance as one of the most important traits in the selection process (Dittrich-Schroder *et al*., 2012). Resistant hybrids specifically are increasingly being used as a strategy to mitigate the effects of invasive pests through breeding programs (Wingfield *et al*., 2013). Selected hybrids often show high vigour and maintain favourable parental traits, including pest and disease resistance, but must be clonally (vegetatively) propagated as further sexual reproduction tends to yield highly variable offspring. This strategy offers immense power to deal with pests, but requires constant vigilance and adaptation to remain ahead of newly arrived or adapted pest genotypes. *Eucalyptus* in its native range includes more than 700 species, growing in a wide range of habitats and ecological zones. This offers a substantial genetic diversity that can be exploited through selection and cross hybridization for pest resistance (Wingfield *et al*., 2008; Paine *et al*., 2011; Wingfield *et al*., 2013).

Variable levels of damage in the field have been reported for some of the recent invasive *Eucalyptus* pests. This suggests that there are good opportunities for selection and breeding for resistant planting material (Nyeko *et al*., 2010; Dittrich-Schroder *et al.*, 2012; Nadel *et al*., 2012). For example, preliminary field assessments for *L. invasa* revealed a wide range of damage between hybrid clones such as *E. grandis* x *E. urophylla* and *E. grandis* x *E. camaldulensis* genotypes in both Kenya and Uganda (Nyeko *et al*., 2010). Similar studies in South Africa also reported differences in susceptibility among genotypes of *Eucalyptus dunii, E. nitens, E. smithii, E. urophylla,* and *E. saligna* x *E.urophylla* to *L. invasa.* Results of these two studies (Nyeko *et al*., 2010; Dittrich Schroder *et al*., 2012) suggest that selection and planting of resistant or less susceptible *Eucalyptus* genotypes will be an important strategy to mitigate economic loss caused by an invasive pest species such as *L. invasa.* The challenge lies in combining the selection for resistance against *L. invasa* with that of other invading pest species such as *T. peregrinus, G. brimblecombei* and others.

Although the use of resistant hybrid clones is important for pest management, it has limitations. This strategy is expensive, has a long response time, and needs to be optimised against a wide range of pest species. The resulting selections may not perform well in certain climatic conditions (Wingfield *et al*., 2008; Eyles *et al*., 2010). The selection for pest resistance is also known to be a trade-off with growth, thus impacting potential productivity (Potts and Dungey, 2004). Furthermore, new pests are likely to continue to arrive and old ones will adapt to overcome resistance. These factors highlight the importance of integrating this strategy with other approaches, and not seeing breeding/ selection as the sole solution to pest problems.

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Increased international and regional collaboration on biological control and research tools and information

Establishment of international and regional collaborations to develop and implement appropriate mitigation and management measures would have huge benefits. Derived benefits include (i) reduced cost due to sharing of research facilities (e.g. quarantine and rearing units of biocontrol agent and DNA analysis and sequencing equipment), (ii) sharing of generated knowledge through various relevant research networks leading to reduction in duplication of research activities, (iii) utilization of the limited numbers of professionals in these fields to provide the best results in the shortest possible time frames, (iv) sharing of biocontrol agents obtained from different countries/regions where there are similar pest species, and (v) availability of large areas to conduct field research and release biological control agents for local adaptation and impact assessment. East Africa has much to gain from a more directed approach to international and regional collaboration to protect its growing resource of *Eucalyptus* plantation trees from the inevitable pest and pathogen threats.

In the eastern African countries, the success of regional collaboration is epitomized by the implementation of the successful regional classical biocontrol program to manage the invasive Cypress aphid, *Cinara cupressivora* Watson and Voegtlin (Hemiptera: Aphididae), a devastating pest of Mexican cypress *Cupressus lusitanica* (Cupressaceae) in eastern and central African region in the 1990’s (Ciesla, 1991; Watson *et al*., 1999; Day *et al*., 2003). In a regional collaboration project involving all affected countries, including Kenya, Uganda, Tanzania, Malawi, and Rwanda, a biocontrol agent *Pauesia juniperorum* (Stary) (Hymenoptera: Braconidae) was identified, screened, host specificity tests carried out, and mass reared in Kenyan and Malawian rearing facilities. The mass reared populations were distributed to throughout the region for releases (Day *et al*., 2003). This facilitated a rapid spread of the released of *P. juniperorum* in the cypress aphid across the infested region. It also reduced the cost of parasitoid mass rearing by centralising efforts and eliminating redundancy, sharing of research output across agencies, regions and countries was critical to the programme’s success.

The sharing of a recently released biological control agent of *T. peregrinus, Cleruchoides noackae* Lin and Huber (Hymenoptera: Mymaridae), in the infested countries such as Chile, Brazil and Kenya is another example that illustrates the benefits of a collaborative approach to management of invasive pests (Lin *et al*., 2007; Mutitu *et al*., 2013). In this regard, the establishment of the Biological Control of Eucalypt Pests (BICEP; www://bicep.net au) provides an apt example that could be used as a

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model on how to respond to future invasive species worldwide through a collaborative approach (Lawson *et al*., 2013). The latter program seeks to support and fast track the implementation of classical biological control program of *Eucalyptus* invasive pests through a search for and collection of potential biocontrol agents from the identified area of pest origin. Companies and countries in East Africa, and indeed globally, should seriously consider joining this program.

Conclusions and Recommendations

Invasive pests continue to increase and pose a serious threat to the success of the rising use of *Eucalyptus* in East Africa. These pests have both regional and global impacts, both moving into East Africa, but also using this area as a base from which to invade other areas. To deal with these threats effectively will require policy changes for the development and implementation of mitigation measures. Governments in East Africa need to change their approach to consider invasive pests as a key challenge to the future of plantation forestry. They must also significantly strengthen their abilities to prevent the entry of these pests. The application of DNA-base technologies, integrated and accessible databases, improved phytosanitary and quarantine measures, continuous selection and breeding for pest resistant genotypes of trees, and increased domestication of more tree species for plantation forestry worldwide are major processes that would need to be integrated to reduce economic loss due to increased invasive pest species.

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