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Smurfit Kappa
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IMPORTANT INSECT PESTS AND DISEASES of *Pinus* and *Eucalyptus* in Colombia

Carlos A.
Rodas Peláez

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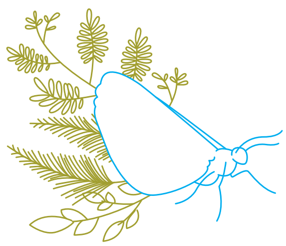

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FOREWORD

It gives me great pleasure to be invited to write the foreword to this ground-breaking book.

During my five years serving as the Forestry Division Manager of Smurfit Kappa Colombia, I have seen the important role that Research and Development has played in ensuring the sustainability of our company's investment in tree plantations. At the same time, I have witnessed the growing number of insect pests and microbial pathogens that threaten this key resource. This book provides a significant historical record of the health problems that Colombian *Eucalyptus* and *Pinus* tree plantations have experienced in the past. It also provides a foundation for the work needed to ensure their sustainability in the future.

According to the United Nations Food and Agricultural Organization, around 4 billion hectares (30%) of global continental land is tree cover. Of this, only 281 million hectares (7%) are commercial tree plantations, and only 54 million hectares (1.4%) of these are rapid-growing tree plantations. These highly productive plantations usually have yields of more than 5 m^3 per hectare per year, in cycles of less than 30 years. Moreover, they supply around 21% of the world's demand for wood.

Since its inception, Smurfit Kappa Colombia has invested heavily in providing key equipment and outstanding facilities for our own in-house capacity to study and manage insect pests and pathogens. Over the past 27 years, we have also supported a close working relationship with the Forestry and Agricultural Biotechnology Institute (FABI) at the University of Pretoria in South Africa. This has allowed us not only to understand the more important insect pests and pathogens, but also to study the biology and genetics of these organisms to a greater depth than is typically possible for a field-based protection program. This powerful association between field-based solutions and scientific research is made clear by the many studies referred to in this book. The challenge in the past has been how to communicate this knowledge effectively, enabling the people working in the field to convert this expertise into more productive plantations. Effective communication builds trust, promotes the credibility of research and produces tangible results. That's why in Smurfit Kappa we say that it's not just about forestry and tree research – it's also about the people who apply this knowledge.

Furthermore, the future of plantation forestry relies not only on research related to tree health, but also in tackling social and environmental issues such as climate change. In this regard, the global collaboration of which this book provides an outstanding example, becomes increasingly important.

We all know our world is rapidly changing, and in recent years governments and societies internationally have become increasingly committed to reducing all levels of plastic packaging. It is important to realize that this 'war' is not against plastics themselves, but about producing packaging that is both recyclable and sustainably sourced.

Smurfitt Kappa's new motto is 'Better Planet Packaging', allowing plastic to be replaced wherever possible with more sustainable options. This in turn will increase the demand for wood fiber packaging – 'sustainable wood for a sustainable world' – the provision of which requires expertise, knowledge, collaboration, dedication and talent. I see all these characteristics reflected in this book, and it is in this regard that I am grateful to Doctor Rodas and Professor Wingfield for sharing their knowledge with us.

I would also like to take this opportunity to thank members of the executive leadership of Smurfit Kappa Colombia for their support. I am fully aware that my predecessors, particularly Edgar Londono, Victor Giraldo and Rudolf Rhan have provided enthusiastic support for the work of Dr. Carlos A. Rodas and Prof. Mike Wingfield. Their roles in enabling the process that has led to the production of this book has been substantial and I thank them again for this.

Nicolás G. Pombo
Forestry Division Manager
Smurfit Kappa Cartón de Colombia

PREFACE

Colombia covers an area of approximately 114 million hectares (ha). Of this area, forests cover an estimated of 60 million ha, representing around 53% of the total land area. Approximately, 24.8 million ha (22%) of the territory is considered as forestry land suitable for commercial plantations.

In order to provide an alternative source of timber than that from natural forests, Colombian companies have planted approximately 568 769 ha with various species of *Pinus*, *Eucalyptus* and other native and non-native species. This clearly represents only a small proportion of the total area that might be used for forestry, which is set to increase in the future.

In general, trees established in plantations have been grown as monocultures. This allows substantial productivity within managed units. But these monocultures are also a homogeneous genetic resource that is highly susceptible to damage by insect pests and pathogens. It is consequently surprising that relatively little research has been conducted on pests and pathogens that negatively affect plantation forestry in Colombia. The information presented in this book represents the first comprehensive treatment of pests and diseases in *Pinus* and *Eucalyptus* plantations in the country. It is hoped this will form a basis for future management strategies and ensure the sustainability of plantation forestry in Colombia.

In this book, we provide an overview and historical background to the current pest and disease situation affecting the forestry sector in Colombia. This includes a summary of the main pests and diseases on commercially propagated non-native trees, especially species of *Pinus* and *Eucalyptus*. A wide range of sites occurring in Colombia were examined as a basis for this book, which includes all available information regarding the effects of different climatic conditions on the incidence and management of the various pests and diseases discussed. This book also includes brief descriptions of some serious pests and diseases not currently reported in Colombia, as they may represent significant future risks to the local forestry sector.

AUTHOR PROFILES

DOCTOR

CARLOS A. RODAS PELÁEZ

Doctor Carlos Rodas has worked on plantation tree pests and pathogens in Colombia since 1982 and has obtained global recognition for his knowledge and experience in this field. He is the founding Director of the Forest Health Protection Programme at Smurfit Kappa based in Colombia since 1988. Over the course of his career, he has established one of the world's most impressive in-company tree health programs focused on creating a world class center for the biological control of forest pests. He currently serves as Technical Advisor to the Pesticides Committee of Forest Stewardship Council (FSC), and Deputy Coordinator of the Diseases and Insects of Tropical Forest Trees Working Party at the International Union of Forest Research Organization, IUFRO.

He completed both M.Sc. and Ph.D. degrees at the University of Pretoria, prompted by collaborative research with Prof Mike Wingfield since 1993. Dr. Rodas has advised numerous post graduate students with M.Sc. and Ph.D. degrees. He has published various research papers on forest health and holds an extra-ordinary staff position with the Forestry and Agricultural Biotechnology Institute (FABI) at the University of Pretoria.

PROFESSOR

MICHAEL J. WINGFIELD

Professor Mike Wingfield, was the founding Director of the Forestry and Agricultural Biotechnology Institute (FABI) from 1998 to 2017. For more than thirty years, working in many countries throughout the world, Mike has conducted research on tree pests and pathogens, especially in regard to their global movement. He has published widely on the topic of tree health in more than 1000 research papers and seven books, and is regularly invited to present at prestigious conferences globally. He has also served in a range of meritorious offices based on his research.

He has received honorary doctorates from the University of British Colombia, Canada (2012) and North Carolina State University (2013), and in 2013 received the Kwame Nkrumah Scientific Award, the highest scientific award of the African Union. He was the President of the International Union of Forestry Research Organisations (IUFRO) from 2014-2019, and is currently serving as the IUFRO Immediate Past President. He serves as an advisor to the Executive of the University of Pretoria.

ACKNOWLEDGEMENTS

Material for this book has been collected over a period of approximately 30 years. During the majority of this time, we have worked together closely, visiting each other's laboratories regularly and seeking to better understand the pests and pathogens that threaten the sustainability of plantation forestry in Colombia. At the start of the project, most of the insects affecting plantations of *Pinus* spp. and some of those on *Eucalyptus* spp. were known to us. In contrast, very few pathogens were known to occur in these plantations. This situation has changed substantially over time, with numerous apparently native pathogens of *Eucalyptus* undergoing host shifts to infect these non-native trees.

New host specific pests and pathogens of both *Pinus* and *Eucalyptus* have also appeared in Colombia for the first time in recent years. As is true in other countries of the world, this is a trend that is set to continue. We have been privileged to have the opportunity to monitor this process and to undertake studies aimed at ensuring the sustainability of plantation forestry in Colombia. The impact of this work extends beyond Colombia given that pests and pathogens of plantation forestry are moving globally. In this regard, we appreciate the support and advice that we have gained from colleagues from many other parts of the world.

Studies that have contributed to the contents of this book have been supported financially by various institutions and we are grateful for this support. We especially thank Smurfit Kappa Colombia for their support of this work from the outset.

The Forest Health Protection Programme team has played an invaluable role by providing technical assistance over many years. Likewise, the work has been substantially supported by a wide range of members of the Smurfit Kappa research division as well as a passionate field staff without whom the project could not have been completed. We are also most grateful to the University of Pretoria, many members of the staff of the Forestry and Agricultural Biotechnology Institute (FABI), the National Research Foundation and members of the Tree Protection Co-operative Programme (TPCP) based at FABI in South Africa who have contributed in many different ways to making this book possible.

We dedicate this book to our families who have provided us with support, understanding and love, during the many hours spent in plantations compiling the material needed to complete this book. In this regard, we particularly thank our wives Claudia and Brenda, as well as our children Juliana and Laura (CR) and Anthony and Beverley (MW), who have patiently witnessed our passion for tree health issues over many years. In the process, our two families have become close friends, a privilege that we treasure deeply.

INTRODUCTION

The Latin American and the Caribbean regions have forest cover of approximately 46.4% of their total area, which represents around 23.4% of total global woodland cover. Peru, Colombia, Bolivia, Mexico and Brazil collectively comprise 80 % of the region's forested area, with Brazil having the largest share, amounting to 53% of the total (FAO, 2017). Commercial forestry plantations in Latin America and the Caribbean cover approximately 28.7 million hectares (ha). However, this represents only 14.3% of the world's total commercial forestry plantations (FAO, 2018).

Colombia has a surface area of 114.2 million ha, of which natural forest makes up 60 million ha. and 24,8 million ha. are considered as forestry land for commercial plantations (MADR, 2019). Approximately 568 769 ha (MADR 2019) are used for plantation forestry. From this area, *Pinus* species represent one of the most commonly grown non-native trees, with approximately 132 644 ha planted. This is followed by *Eucalyptus* species covering around 88 062 ha (Instituto Colombiano Agropecuario ICA), ICA- SPV-DTEVF-2020. Other native and non-native species occupy around 348 063 ha. In Colombia, protection of native forest has had a major influence on plantation forestry. Thus, in 2016, 10.8 million tons of timber, pulp and other forestry products were produced in the territory (DANE, 2018).

In order to develop a sustainable industry, Colombian forestry companies have focused on utilizing natural resources to satisfy the demand for wood products. Thus, in recent years, there has been an increase of approximately 200 000 ha of new plantations established. As an important consequence, the Colombian government has re-structured the forestry sector. This includes a long-term vision for woodland management and appropriate measures for sustainable industries, using reforestation to reduce negative impacts on the environment.

With its wide range of altitudes, weather conditions and soil qualities, the varied geography in Colombia offers many agro-ecological advantages for planting *Pinus* and *Eucalyptus*. This environment provides both tree species with optimal and varied conditions, allowing for rapid growth, adaptability and significant potential for increased yields. However, the variable climates in different regions of Colombia have also resulted in a wide range of tree pathogens and insects negatively affecting forestry resources. The very different climatic zones thus provide a wide range of conditions suitable for different pathogens and pests to damage different tree genotypes being propagated (Woods, Coates & Hamaan, 2005). In the case of diseases,

globalization has contributed to the spread of pests and pathogens, with dispersal barriers regularly being overcome (Watt et al., 2009; Wingfield, Slippers & Wingfield, 2010; Wingfield, Roux & Wingfield, 2011; Wingfield et al., 2011; Wingfield et al., 2013). Likewise, genetic uniformity within plantations has increased the risk of severe pest and pathogen damage.

Within their native environments, most pests and pathogens of *Pinus* and *Eucalyptus* do not cause substantial damage. However, when exotic tree species are cultivated in new environments, some insects and pathogens can cause severe loss (Burgess & Wingfield, 2017; Wingfield et al., 2001; Wingfield et al., 2015). For example, the *Cryphonectria* canker of *Eucalyptus*, was shown to have been caused by a suite of native pathogens that have adapted to infect non-native trees (Davison & Coates, 1991; Gryzenhout, Wingfield & Wingfield, 2009; Hodges, Alfenas & Cordel, 1986; Wingfield, 2003). Another classic case is the rust fungus *Austropuccinia psidii*, a native on Myrtaceae in South America that has adapted to infect *Eucalyptus* spp. and other members of the Myrtaceae (Coutinho et al., 1998; Glen et al., 2007; Granados et al., 2017; Rodas, Roux et al., 2015). Similarly, in Colombia, numerous species of *Chrysoporthe* and its relatives have been found on native members of Melastomataceae, and these fungi have also been shown to infect and cause cankers on non-native *Eucalyptus* spp. in plantations (Gryzenhout et al., 2006; Rodas et al., 2005; Wingfield, Rodas et al., 2001).

In Colombia, plantations of *Pinus* spp. have been severely damaged by insects in the Lepidoptera (Geometridae; Phasmatodea: Heteronemiidae and

Pinus maximinoi plantation defoliated by geometrid insects.

Pseudophasmatidae) and Hymenoptera (Formicidae) orders. Here, wide ranges of climate and altitude, in addition to a large diversity of hosts and the ready adaptability of insects, have contributed to a wide distribution of these pests in the country. This has resulted in severe outbreaks in a large number of areas, and in some cases caused tremendous financial loss.

Unlike the case with insect damage, commercial plantation forestry in Colombia has not been seriously affected by outbreaks of pathogens until relatively recently. In the 1980's, the plant pathogen *Diplodia sapinea* was first reported affecting *Pinus patula* plantations in the Eastern region, having caused substantial damage. This was in the altitude range between 1500 - 2000 m.a.s.l., an altitude not generally recognized as suitable for this particular tree species. Consequently, the use of *P. patula* as a planting stock has had to be eliminated in these areas (Hoyos, 1987; Rodas & Osorio, 2008).

Pinus spp. in Colombia are considered to be seriously threatened by new diseases and insect pests. For example, a major threat is pitch canker caused by *Fusarium circinatum*, which has appeared relatively recently, and affects *P. patula* (Steenkamp et al. 2012). Similarly, *Dothistroma septosporum*, which causes red band needle blight, is currently causing serious damage to *Pinus tecunumanii*, *Pinus kesiya* and *Pinus oocarpa* (Rodas et al., 2015). In tree nurseries, *Calonectria brassicae*, a fungus recently discovered and described, has caused serious damage to *Pinus* spp. (Lombard et al., 2009).

Eucalyptus spp. in Colombian plantations have likewise been severely damaged by pests and pathogens. For example, leaf-cutting ants (Hymenoptera:

Formicidae), sucking insects (Hemiptera: Miridae), wood borers (Lepidoptera: Hepialidae and Coleoptera Curculionidae) and defoliator insects, mainly in the Geometridae, have caused serious problems in some areas. These groups of insects are all native and have adapted to the wide range of environmental conditions in which *Eucalyptus* spp. have been planted.

Diseases of *Eucalyptus* have been caused by pathogens such as *Botryosphaeria ribis* that damages plantations where trees are stressed (Rodas et al., 2009). Similarly, basal canker, caused by *Chrysoporthe cubensis*, has resulted in substantial damage in some low altitude areas that have high humidity and temperature. In this case, the damage has been particularly severe to *Eucalyptus grandis* compared to *Eucalyptus* "*urograndis*", which is generally more tolerant to infection (Rodas, 2003). Diseases caused by *Calonectria* (asexual state *Cylindrocladium*) species have been reported in young plantations and also in nurseries (Crous & Wingfield, 1994; Lombard et al., 2010). In Colombia, *Calonectria spathulatum* was reported as being an important foliar pathogen in both young and mature plantations of *E. grandis* and *E.* "*urograndis*" (Rodas et al., 2005).

Relatively recently (2011), a new leaf and shoot disease has appeared in *Eucalyptus* plantations of Colombia; the pathogen being the rust fungus *A. psidii*. This pathogen was first reported as causing a commonly occuring disease on non-native trees such as *Syzygium jambos* and *Psidium guajava* (Glen et al., 2007; Granados et al., 2017; Rodas, Roux et al., 2015), but it has now apparently adapted to infect some *Eucalyptus* clones and seed sources, as well as *Corymbia citriodora* and *E.* "*urograndis*".

Between 1968 and 1993, the National Institute for Renewable Natural Resources and the Environment (Instituto Nacional de los Recursos Naturales Renovables y del Ambiente [INDERENA]) in Colombia, was responsible for forest protection, and developed the Sanitary Program for Forestry Plantations. Since 1994, forest protection in the country has been managed privately by independent forestry companies. In 2006, the Instituto Colombiano Agropecuario (ICA) assumed responsibility for forest health protection. More recently in 2014, prompted by the collaborative research department of Smurfit Kappa Colombia, various private forestry companies and the Universidad Nacional de Colombia, have been collectively developing the National Forest Protection Program, based in Medellin.

The primary aim of this book is to present a summary of current knowledge relating to the major pests and pathogens that affect the forestry industry in Colombia. The focus is on commercial forestry, based on non-native trees, particularly species of *Pinus* and *Eucalyptus* although many of the pests and pathogens affecting this resource have their origins in native forests of the country. Importantly, this book, which captures work conducted over a period of some 30 years, should provide a sound historical record of the emergence and management of key pests and pathogens. It also seeks to provide a foundation for the future work needed to ensure the sustainability of plantation forestry in Colombia.

PLANTATION FORESTRY IN COLOMBIA

The commercial forestry industry in Colombia comprises approximately 568 769 registered hectares (MADR, 2019). This is made up of approximimently 23.3% *Pinus* species, 15.5% *Eucalyptus* species and 61.2% other species. In general, commercial forestry is poorly developed, considering that there are nearly 24.8 million ha of land available for reforestation projects (MADR, 2019).

Commercial reforestation began in the 1940's with various *Cupressus* species, including *C. lusitanica* being planted. In addition, *Eucalyptus* species such as *E. globulus*, *E. viminalis*, and *E. citriodora* and some *Pinus* species such as *P. radiata*, *P. ponderosa* and *P. rigida* were introduced (Universidad Nacional de Colombia [UNAL], 1955).

By the 1960's, the species mainly used for commercial plantation purposes were *P. patula* and *Eucalyptus*. As areas committed to forestry expanded, various native insects began to adapt to feed on these introduced species. It has since become clear that, as in other countries, damage by pests and pathogens will inevitably rise, along with the consequent cost to exotic plantation forestry (Slippers, Stenlid & Wingfield, 2005; Wingfield, 2003; Wingfield et al., 2010; Wingfield et al., 2011; Wingfield, Slippers et al., 2011; Wingfield et al., 2013).

The plantation forestry area in Colombia has increased rapidly in recent years, in order to supply an increasing demand for wood products. The most important products from these plantations are solid wood (round logs and sawn timber) and pulp. This accounts for about 0.3% of worldwide production.

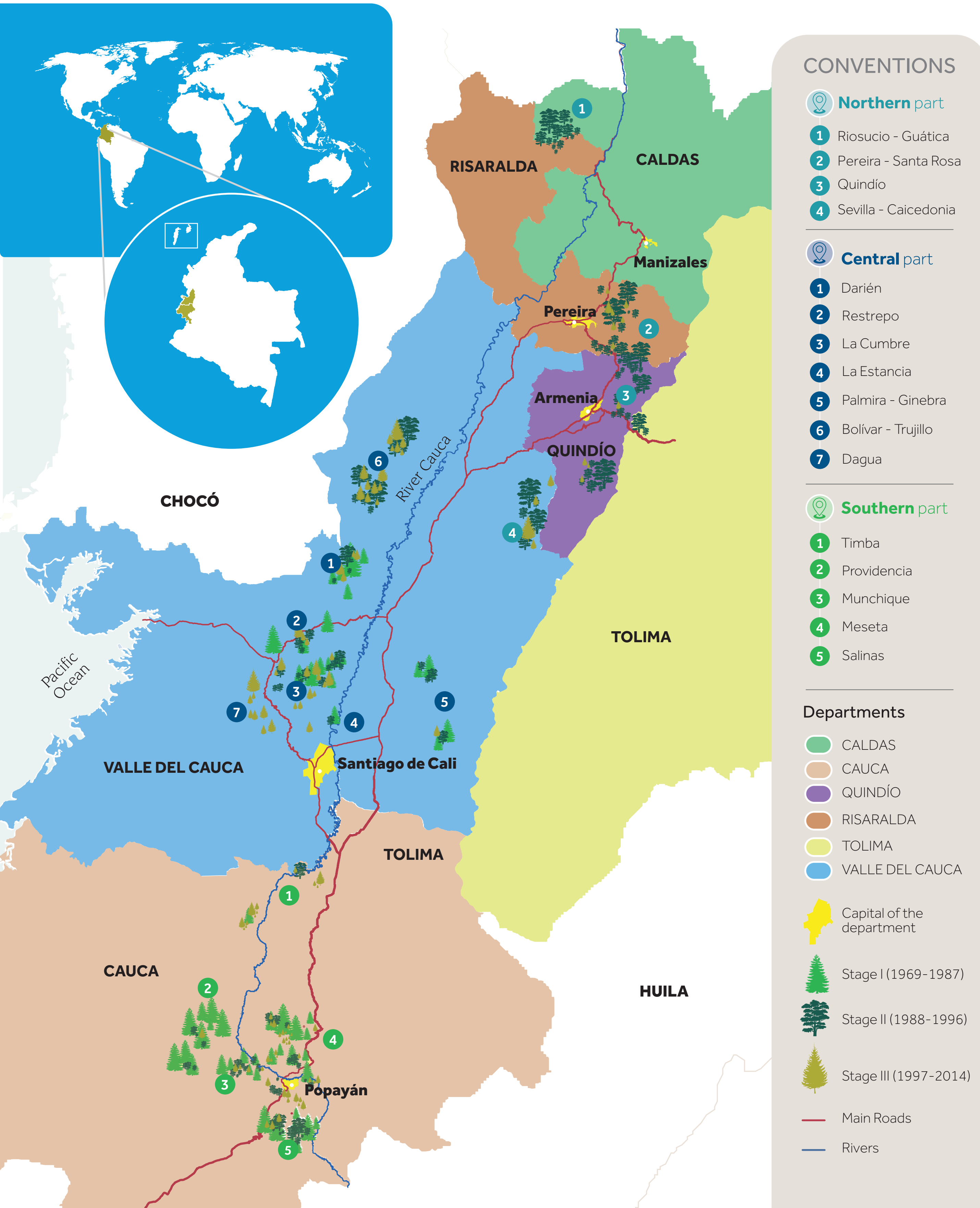
Most wood produced in Colombia is used locally. However, this situation is changing as new trade is growing with other countries, such as those in the Mercosur trade bloc (Brazil, Argentina, Paraguay and Uruguay). There is also increased trade with the United States, El Salvador, Guatemala, Honduras, Canada and some other European countries (MADR, 2006). While trade agreements and globalization are important trends, these also present increased opportunities for the introduction of new pests and pathogens (Liebhold, 2012; Wingfield et al., 2008; Wingfield et al., 2013), representing a serious threat to forestry in Colombia.

With increased demand, the application of biotechnology and appropriate control of pests and diseases becomes necessary in order to increase productivity and yields. Because *Pinus* and *Eucalyptus* plantation forestry is a prolonged business, these trees are continually being exposed to pathogens and insects, which may appear at any time. These pests and pathogens have therefore become of national concern, as they threaten not only the economic viability and long term sustainability of the forestry industry but also reforestation programs. It is for this reason, that UNAL (Medellín), Smurfit Kappa Colombia, various private forestry companies and ICA are collectively developing the National Forest Protection Program.

Pinus patula and *Eucalyptus* spp. are the most important elements of commercial plantation forestry in Colombia. *Pinus patula* was introduced into Colombia from Mexico in the 1960's for reforestation. The physiological characteristics of this species are well suited to the varying climate and soil conditions within the country and the total area now planted is approximately 132 644 ha (ICA, 2020).

Eucalyptus species were introduced from Australia into Colombia in 1868. Initially, *E. globulus* was used for ornamental purposes, but later commercial plantations of this species were established in the Central and Southern region in order to produce solid timber (Noguera, 1982). Currently, *Eucalyptus* species cover an area of approximately 88 062 ha (ICA, 2020). The most important planted species are *E. grandis* and its hybrids (Wright & Osorio, 1996). This is due to its superior capacity to adapt to a multiplicity of sites, its ease of vegetative propagation, which also enables hybridization with other *Eucalyptus* spp., its rapid growth and the high quality of its wood and pulp.

GEOGRAPHICAL DISTRIBUTION OF THE **FOREST AREA OF SMURFIT KAPPA**



Source: Smurfit Kappa

INSECT PESTS on *Pinus* species

As mentioned above, there are many insect pests that have caused damage to *Pinus* spp. in Colombia. A complete list is presented in Table 1. The following section treats only the most important examples and is based on the relatively limited available knowledge.

Melanolophia commotaria (Lepidoptera: Geometridae)

LEPIDOPTERA: **GEOMETRIDAE**

Oxydia vesulia.

Several members of the Geometridae are major forest pests (Triplehorn & Johnson, 2005). The first occurances of defoliator insects in Colombia were recorded in 1953 with the insect *Oxydia trychiata* being responsible for extensive damage to *C. lusitanica* plantations (Gallego, 1959). Since the 1960's, there have been other reports of Geometridae including the native *Glena bisulca*, *O. trychiata* (Vélez, 1972), *Cargolia arana* (Wiesner & Madrigal, 1983), and *Chrysomima semilutearia* (Rodas, 1994). More recently *Melanolophia commotaria* (CAR, n.d.) has damaged plantations of *P. patula*, *C. lusitanica*, *P. maximinoi*, *P. tecunumanii*, and *E. grandis*.

It is the larvae of the Geometridae that are responsible for the damage to trees and the economic loss that ensues. Fortunately, favorable environmental conditions usually result in the recovery of affected plantations. For example, rainfall can result in foliage regrowth. The main factor affecting the incidence of these native defoliators in Colombia is the lack of vegetation within forestry plantations that would normally provide habitats for their natural enemies. As a result, plantations older than six years are the most susceptible to infestation. But in some cases, younger plantations (under 6-year-old) that have had extensive exposure to herbicides become attractive to defoliators. The control of Geometridae is focused on early detection along with an early application of Integrated Pest Management (IPM) with the emphasis on biological control. All of these activities are interrelated and focus on reducing pest populations.

INTEGRATED PEST MANAGEMENT (IPM)

Integrated Pest Management for Geometridae in Colombia includes the evaluation of pest populations based on light-trap data. Silvicultural control includes thinning and pruning trees to increase their vigor. Biological control, using parasitoids, predators, and microbes, also represents a key component of pest management strategy. Here, food substrates such as honey, sugar and molasses are provided to increase predator and parasitoid populations. In Colombia, bacteria and fungi such as *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and a *Cordyceps* sp. (Bustillo, 1978; Bustillo & Drooz, 1977; Madrigal, 2003; Rodas, 1996), have been used to control populations of the most significant Geometridae species, which include *G. bisulca*, *O. trychiata*, *C. arana* and *C. semiluteraria* (Rodas, 1997). These insect pests are described individually below.

STEP 1 Monitoring, early detection and reporting.

STEP 2 Light traps are used to concentrate adult insects.

STEP 3 Release of the egg parasitoid *Telenomus alsophilae* (Hymenoptera: Scelionidae).

STEP 4 Larval control using *Bacillus thuringiensis* applications.

STEP 5 The larval parasitoid *Euplectrus* sp. (Hymenoptera: Eulophidae).

STEP 6 Pupal control with the entomopathogenic fungus *Beauveria bassiana* and pupal parasitoids.

STEP 7 Different sources of carbohydrate and proteins such as fish heads are used to feed parasitoids.

Siphoniomyia sp. (Diptera: Tachinidae) feeding on honey and water solution.

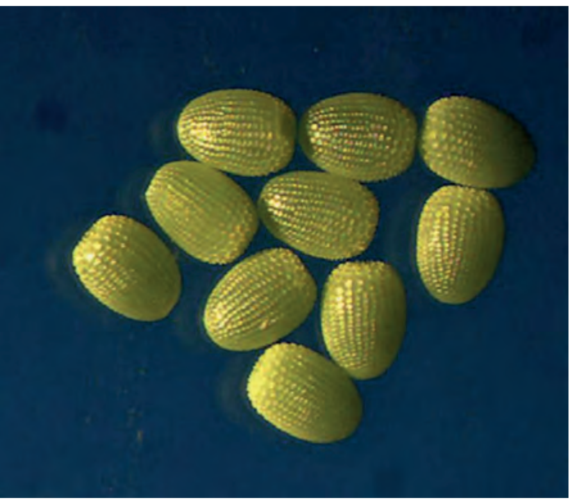
Cratichneumon sp. (Hymenoptera: Ichneumonidae) feeding on honey and water solution.

Siphoniomyia melaena. (Diptera: Tachinidae) feeding on protein such as fish heads.

Glena bisulca

(Lepidoptera: Geometridae)

Glena bisulca is one of the most frequently occurring and harmful species in *P. patula* plantations in Colombia (Bustillo, 1976a; Ladrach, 1992). Recently, this native insect has also affected other plantation tree species such as *Pinus tecunumanii*, *P. maximinoi* and various species of *Eucalyptus*. The larvae feed on foliage as they pass through five larval stages. The pupae concentrate among the litter at the base of trees. Adults orient themselves parallel to the tree bark on which females lay individual eggs in crevices, facilitating easy detection (Bustillo 1979; Drooz & Bustillo, 1972). As with many other forest pests, populations rise when there is poor plantation management or when environmental conditions, such as prolonged summers, adversely affect the population of their natural enemies.



Eggs.

Larva.

Pupae.

Adults in a typical position on stem.

Biological control agents

Biological control is best introduced immediately after early detection. The most useful insects for biological control of *G. bisulca* are the parasitoids of larvae such as *Cratichneumon* sp. (Hymenoptera: Ichneumonidae), *Elachertus* sp. (Hymenoptera: Eulophidae), *Rogas* sp. (Hymenoptera: Braconidae), *Siphoniomyia melaena* and other fly parasitoids (Diptera: Tachinidae). Predators of larvae in the Vespidae (Hymenoptera), such as *Parachartergus* sp., *Polybia* sp., *Polistes erythrocephalus* and the Pentatomidae (Hemiptera), including a *Podisus* sp., can also be effective.

Likewise, birds belonging to the families: Tyrannidae, Trogonidae, Momotidae, Parulidae, Turdidae (Madrigal, 2003), and microorganisms such as *B. thuringiensis*, *B. bassiana* and *Cordyceps* sp., can also reduce pest populations (Madrigal, 2003; Rodas, 1996). Most insects in the Tachinidae and Ichneumonidae families need to be provided with various sources of protein such as fish heads, and carbohydrates including sugar, honey and molasses, to ensure their sexual maturity.

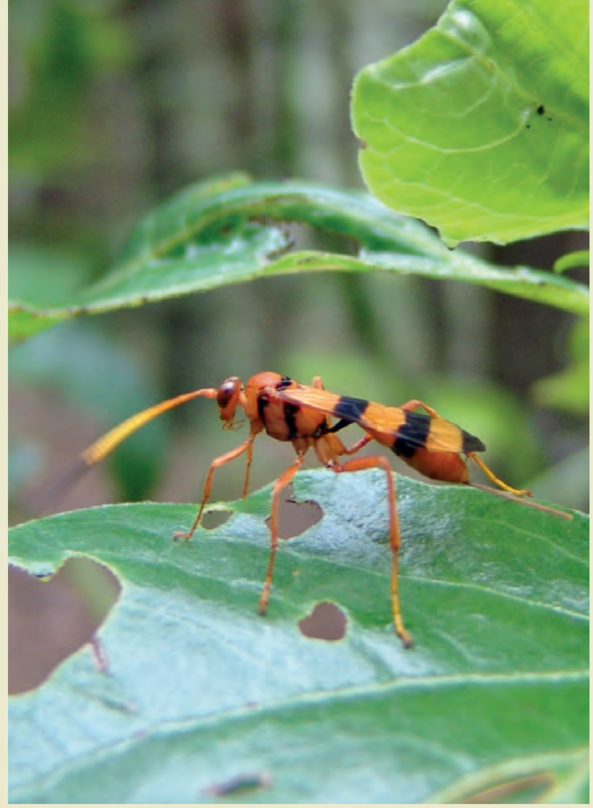
The larval parasitoid *Siphoniomyia melaena* (Diptera: Tachinidae).

Siphoniomyia melaena.

The larval parasitoid *Siphoniomyia* sp. (Diptera: Tachinidae).

Adults of S*iphoniomyia* sp. (Diptera: Tachinidae).

The pupal parasitoid *Cratichneumon* sp. (Hymenoptera: Ichneumonidae).



The larval parasitoid *Lanugo* sp. (Hymenoptera: Ichneumonidae).

The larval parasitoid *Elachertus* sp. (Hymenoptera: Eulophidae).

The larval, pupal and adult predator *Cyanocorax yncas* (Passeriformes: Corvidae).

Pupae infected by the fungal pathogen *Cordyceps* sp. (Hypocreales: Clavicipitaceae).

Eggs.

Larva.

Pupae.

Oxydia trychiata
(Lepidoptera: Geometridae)

This insect is widely distributed in most South American countries (FAO, 2007). In Colombia, it has continuously affected plantation trees since 1953, especially *P. patula*, which is the most susceptible host tree (Bustillo, 1976b; Gallego, 1959). *O. trychiata* is one of the most devastating insect pests found on *P. patula*, *P. tecunumanii* and *P. maximinoi*, with high levels of tree mortality being common. Moreover, this insect is also found causing damage to *Eucalyptus* spp., and coffee plants as well as to native tree species. The adult moths lay masses of eggs under *Pinus* foliage and on associated vegetation. The pupae can be found on the ground around infested trees and the adult insects commonly mimic the appearance of dried leaves (Madrigal, 2003).

In plantations where defoliators are problematic, silvicultural management is generally found to be poor. Weather also has a substantial influence on the presence and extent of damage, with infestations being most severe in dry seasons.

Adult female.

Adult male.

Biological control agents

Several biological control options are available for *O. trychiata*. Introduction of *B. thuringiensis*, is the most frequently used. In addition, parasitoids such as *Cotesia* sp. (Hymenoptera: Braconidae) and a species of *Xanthoepalpus* sp. (Diptera: Tachinidae) can be highly effective in infesting and destroying larvae (Madrigal, 2003). In Colombia, *Telenomus alsophilae* (Hymenoptera: Scelionidae) are propagated in large numbers on the eggs of *C. semiluteαria*. This small wasp was introduced from Virginia (USA) in 1975 for *O. trychiata* control (Bustillo, 1976b; Bustillo & Drooz, 1977; Drooz et al.,1977).

▲ The egg parasitoid *Telenomus alsophilae* (Hymenoptera: Scelionidae)

▲ The predator *Podisus nigrispinus*. (Hemiptera: Pentatomidae) feeding on larvae

▲ The larval parasitoid *Euplectrus* sp. (Hymenoptera: Eulophidae).

▲ A bird predator *Momotus aequatorialis* (Coraciiformes: Momotidae).

▲ Larva infected with *Bacillus thuringiensis*.

▲ A pupa infected by a *Cordyceps* sp. (Hypocreales: Clavicipitaceae).

Cargolia arana

(Lepidoptera: Geometridae)

Cargolia arana is found only in South American countries such as Colombia, Peru, Bolivia and Argentina (Covell, 1964). In Colombia, it is one of the most frequently encountered defoliators in forestry plantations (Madrigal, Wiesner & Arango, 1985; Wiesner & Madrigal, 1983). *C. arana* outbreaks were originally common in *C. lusitanica*, *P. patula* and *E. grandis* plantations. However, since 2004, newly established tree species including *P. maximinoi* and *P. tecunumanii* have also been seriously infested. This pest causes the same type of damage as other Geometridae, effectively cutting needles or parts of tree leaves. Adult moths lay egg masses on the bark of tree stems and branches and the pupae can also be found on tree trunks and branches.

Cargolia arana can be found solitarily or in groups with other insects such as *G. bisulca*, *O. trychiata*, *C. semiluteария*, *O. trychiata*, *Sabulodes glaucularia* (FAO, 2007; Madrigal et al., 1985). As is true for other Geometridae, outbreaks generally occur where management strategies have been breached, or where trees are densely planted or where thinning or pruning has been neglected.

▲ Eggs.

▲ Larva.

▼ Adult female.

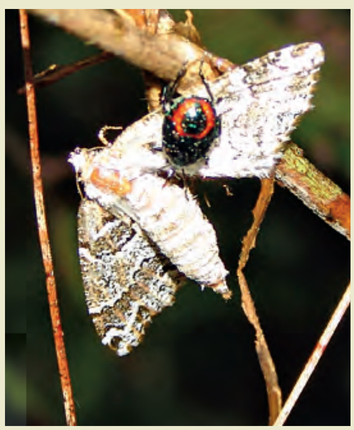
▼▶ Pupae.

Biological control agents

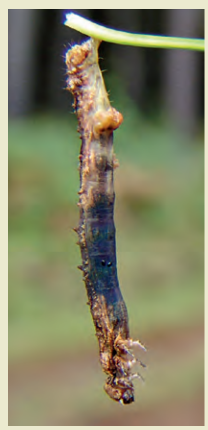
Natural enemies of *C. arana* include the egg parasites *T. alsophilae* (Hymenoptera: Scelionidae), and *Trichogramma* spp. (Hymenoptera: Trichogrammatidae), larval parasites such as *Cratichneumon* sp. and *Pimpla* sp. (Hymenoptera: Ichneumonidae) and predators such as *Podisus* sp. (Hemiptera: Pentatomidae) and the *Polistes* sp. (Hymenoptera: Vespidae) as well as some birds (Madrigal, 2003).

The larval and adult predator *Trogon collaris* (Trogoniformis: Trogonidae).

The larval and pupal parasitoid *Cratichneumon* sp. (Hymenoptera: Ichneumonidae).



The predator *Podisus nigrispinus*. (Hemiptera: Pentatomidae) predating on larva and adult.



Larva infected with *Bacillus thuringiensis*.

An Ichneumonidae parasitoid of pupae.

The egg parasitoid *Telenomus alsophilae* (Hymenoptera: Scelionidae).

Pupae infected with *Beauveria bassiana* (Hypocreales: Cordycipitaceae).

Chrysomima semilutearia

(Lepidoptera: Geometridae)

This insect pest was first detected in Colombia in 1991 causing severe damage to *P. patula* plantations (Rodas, 1994). *Pinus* spp. have the capacity to re-foliate after damage caused by *C. semilutearia*. In contrast, *C. lusitanica* cannot recover from an attack caused by any of the five instars of the larvae. This insect is also commonly found in both *Eucalyptus* plantations and in natural forests. The adults lay egg masses on tree trunks and branches and the pupae are found in the same place.

▲ Eggs.

▲ Larva.

▲▲ Pupae.

▼ Adult female.

▼ Adult male.

Biological control agents

The egg parasitoid *T. alsophilae* was first introduced as a biological control agent for *O. trychiata* and was quickly seen to be an excellent control agent for *C. semilutearia* as well. This small wasp has consequently been mass-reared for release and control (Bustillo, 1976a). Additionally, in Colombian *Pinus* and *Eucalyptus* plantations, the predator *Podisus* sp. (Hemiptera: Pentatomidae) and microorganisms such as *B. thuringiensis*, and *B. bassiana* have been used as alternative control measures (Rodas, 1994). Most of the control strategies for *O. trychiata* are also used to control *C. semilutearia*, although some methodological adaptations are normally required (Rodas et al., 2014).

Pictures illustrate some of the commonly encountered biological control agents in Colombia.

An Ichneumonidae parasitoid of pupae.

The egg parasitoid *Telenomus alsophilae* (Hymenoptera: Scelionidae).

Podisus nigrispinus (Hemiptera: Pentatomidae) feeding on a larva.

The pupae parasiotid *Palmistichus elaeisis* (Hymenoptera: Eulophidae).

The larval, pupa and adult predator *Psarocolius decumanus* (Passeriformes: Icteridae).

Pupae infected by the fungal pathogen *Beauveria bassiana* (Hypocreales: Cordycipitaceae).

Melanolophia commotaria
(Lepidoptera: Geometridae)

Melanolophia commotaria is a secondary defoliator with sporadic occurrence in a complex with other insects such as *G. bisulca*, *C. arana* and *O. trychiata*. Since 2013, the insect has been considered as a significant defoliator causing serious damage in old *P. patula* plantations in various geographic areas of Colombia. The adult moths lay eggs individually under the bark of tree trunks, branches and leaves. The larvae are green in color with two distinct white lateral bands along the body. The pupae are commonly found on the ground around infested trees, the pupae are similar to *G. bisulca* and the two are easily confused. The adult insects are nocturnal and are found on trunks and branches where they are well camouflaged during the day.

Eggs.

Larva.

Adult female.

Pupae.

Biological control agents

Integrated Pest Management strategies used for *M. commotaria* include using light-traps to concentrate the adult population, and the application of *B. thuringiensis* for larval control. An important larval parasitoid commonly known as "red fly" has also been found useful. This insect has been identified as *Adejeania* sp. (Diptera: Tachinidae) and it is considered the main control agent for *M. commotaria*. The entomopathogenic *Cordyceps* sp. has also been shown to provide effective control of the pupae.

Pictures illustrate some of the natural biological control agents encountered in Colombia.

The larval and adult predator *Turdus fuscater* (Passeriformes: Turdidae).

The parasitoid *Rogas* sp. (Hymenoptera Braconidae).

Pupae infected by the pathogenic fungus *Cordyceps* (Hypocreales: Clavicipitaceae).

The larval parasitoid "red fly" *Adejeania* sp. (Diptera: Tachinidae).

PHASMATODEA: **HETERONEMIIDAE**

Members of the Phasmatodea do not have enlarged hind femora and are incapable of jumping. They are commonly referred to as 'walking sticks' or 'stick insects' and are slow-moving, herbivorous and nocturnal. When their numbers are great, they can cause very serious damage to trees (Madrigal, 2003; Triplehorn & Johnson, 2005). In Colombia, members of all the Phasmatodea families are forest defoliators.

The first substantial populations of stick insects were found in Colombian plantations in 1975, but they were not considered a serious threat at the time (Madrigal, 2003). However, in the early 1980's, their populations exploded and they emerged as a significant threat to forestry (Rodas et al., 2017). Since 1986, there have been sporadic outbreaks in some *P. patula* plantations. The first of these was in the municipality of Pensilvania (Caldas, Colombia), where the insects *Planudes cortex* and *Libethroidea inusitata* appeared as pests (Madrigal, 1997; Madrigal & Abril, 1994).

Phasmatodea have a wide range of tree hosts, providing them with various food sources and the possibility of wider areas of colonization. When an outbreak occurs, the infestation may be associated with more than one species of this order. After emerging, phasmids cut and feed on the needles of *P. patula* and thus, both nymph and adult stages are responsible for damage. Eggs are dropped onto the soil and the nymphs emerge and climb trees to feed on the needles. These insects display both asexual and sexual reproduction (Bedford, 1978).

Outbreaks of Phasmatodea in Colombia are always associated with *Pinus* spp. in plantations over 8-year-old, usually in plantations where silvicultural best practices have been neglected. Pest management strategies to reduce Phasmatodea populations include physical controls, such as placing sticky bands on tree trunks to trap insects, and controlled burning. Optimal silvicultural conditions such as thinning and pruning also reduce population levels.

Defoliated area by *Litosermyle ocanae*.

The most representative species of Phasmatodea associated with forestry plantations in Colombia were identified for Smurfit Kappa Cartón de Colombia (SKCC), by Dr. David Nickle of The National Museum of Natural History of the Smithsonian Institution during the period 1990-1993. These included the following: Heteronemiidae: *L. inusitata*; *Litosermyle ocanae*; *Libethra strigiventrus*; *Libethra* sp.; *L. spinicollis*, *Ceroys quadrispinosus*; *Heteronemia striatus*. Pseudophasmatidae: *P. cortex*. Bacillidae: *Acanthoclina* sp.; *Acanthoclina* sp. near *hystrix* (Nickle personal communication). More recently in Colombia, 74 new species, in four new genera of stick insects, have also been discovered and described (Conle, Hennemann & Gutiérrez, 2011).

Litosermyle ocanae

(Phasmatodea: Heteronemiidae)

Since 1988, *L. ocanae* has been one of the most serious defoliators reported in Colombia. Several outbreaks have been recorded in *P. patula* plantations from different geographic areas including those in the Caldas, Antioquia, Quindío, and Cauca departments, resulting in substantial economic loss (Rodas et al., 2017). The total life cycle of *L. ocanae* under laboratory conditions showed an average of 225.8 days from eggs to adults. Egg incubation required an average of 65.8 days. The nymphal stage had a total of four instars with an average 121.6 days The adult stage lasts an average of 38.3 days (Rodas et al., 2017).

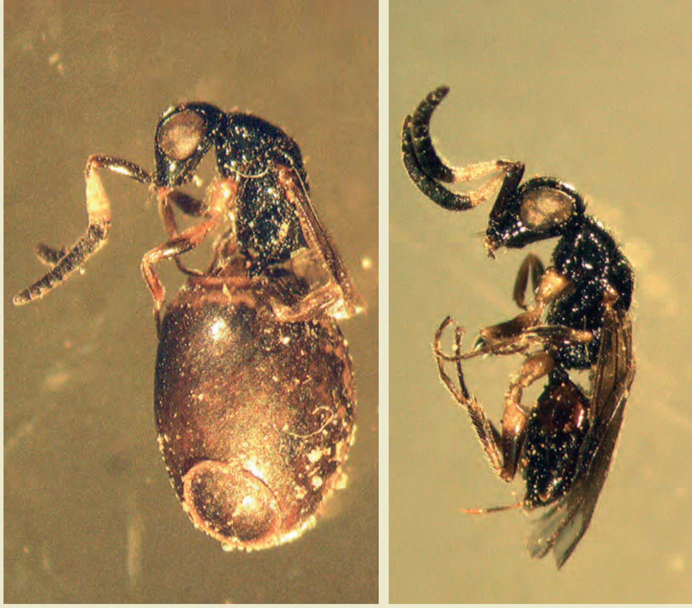
Eggs.

Nymph emerging from egg and nymphs.

Mating adults (male above female).

Biological control agents

Biological control remains the most important activity in reducing Phasmatodea populations in Colombia. Native plants are allowed to develop alongside plantations to encourage a build-up of parasitoid populations. The parasitoid *Adelphe* sp. (Hymenoptera: Chrysididae), identified by Dr. Carlos Sarmiento of the Universidad Nacional de Colombia (CES unpublished data), is one of the most effective egg parasites. Phasmids are best managed in the field by increasing parasitoid populations through the provision of food substrates such as molasses, sugar and honey. In addition, the insect pathogen *B. bassiana* has been used to reduce Phasmatodea populations (Rodas et al., 2017). Some birds such as *Tyrannus melancholicus* (Tyrannidae) are considered as important predators of *L. ocanae*.



A female parasitoid wasp *Adelphe* sp. (Hymenoptera: Chrysidadae) emerging from egg and emerged wasp.

An adult male emerging from egg.

An insect infected with the pathogenic fungus *Beauveria bassiana*.

A reduviid predator *Argylus gallus* (Hemiptera: Reduviidae).

Tyrannus melancholicus (Passeriformes: Tyrannidae) eating adult of *L. ocanae.*

Ceroys quadrispinosus

(Phasmatodea: Heteronemiidae)

Several outbreaks of *C. quadrispinosus* have been reported in *P. patula* plantations in Cauca, Quindío and Caldas departments.

Eggs.

Area defoliated by *C. quadrispinosus.*

Adult female.

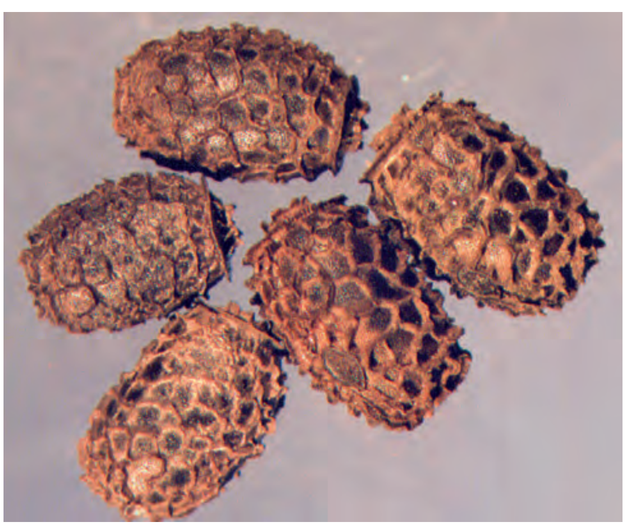
Adult female feeding on *Pinus patula* needles.

Adult male on the bark of stem of *P. patula*.

Planudes cortex

(Phasmatodea: Pseudophasmatidae)

Defoliation of *Pinus patula* by *P. cortex*.



Eggs.

Nymph.

Adult male showing wings.

Apterous adult female.

Biological control agents

Adults having died after applications of *Beauveria bassiana* (Hypocreales: Cordycipitaceae).

The predator *Podisus* sp. (Hemiptera: Pentatomidae) feeding on adult *Planudes cortex*.

The egg parasitoid wasp *Adelphe* sp. (Hymenoptera: Chrysidadae).

The nymph and adult predator *Psarocolius decumanus* (Passeriformes: Icteridae).

HYMENOPTERA: **FORMICIDAE**

Leaf-cutting ants are considered one of the five most serious pests in South American forestry plantations, particularly in Brazil (Camargo et al., 2006; Forti & Castellani, 1997). The economic repercussions of damage caused by these ants relate to a great extent on the age of the trees, and also to any environmental conditions contributing to secondary pest or disease agent development that may kill the trees (Mendes-Filho, 1981). The Formicidae are eusocial insects that include at least three castes; queens, males, and workers. The colony is therefore defined by the division of labor between physical castes (based on size and morphological differences) (Verza et al., 2007; Weber, 1972). Within the worker caste, polymorphism is high and relates to the form of labor that is performed (Camargo et al., 2006; Triplehorn & Johnson, 2005). In this regard, the ants make use of a symbiotic fungus that is cultivated on leaf tissue and which is the main food source for ant larvae (Camargo et al., 2006; Zanetti et al., 2003). The fungus *Leucoagaricus gongylophorus* forms a mutualistic relationship with both *Atta* and *Acromyrmex* ant genera, providing nutrition and energy for the development of healthy colonies (Camargo et al., 2008; Quinlan & Cherret, 1979; Silva et al., 2003; Weber, 1972).

In Colombia, both *Atta* and *Acromyrmex* genera are responsible for leaf-cutting in *Eucalyptus* and *Pinus* tree plantations as well as in other agricultural crops (Fernández et al., 2015). Four species of *Atta* are seen as the most serious pests. These include *A. cephalotes*, *A. colombica*, *A. laevigata* and *A. sexdens* (Mackay & Mackay, 1986). Species of *Acromyrmex* that cause damage include *A. aspersus*, *A. aspersus fuhrmanni*, *A. coronatus*, *A. echinatior*, *A. hystrix*, *A. landolti*, *A. nobilis*, *A. octospinosus*, *A. santschii*, *A. subterraneus*. The presence of *Acromyrmex* is geographically restricted to limited areas of the country, with consequent lower levels of tree and crop damage than that caused by *Atta* ants (Fernández et al., 2015).

Queen of *Atta cephalotes* (Hymenoptera: Formicidae) in her colony.

INTEGRATED PEST
MANAGEMENT (IPM)

Integrated pest management for leaf-cutting ants consists of a range of agricultural, mechanical, biological, microbial and chemical control strategies. These include the early detection of mating flights to prevent new nest formation, ant nest identification in the field, marking and measuring to calculate nest area, ant nest inventories and geo-referencing. Based on such information, chemical controls using toxic pellets and fog pesticides are usually applied.

▲ Ant nest inventory.

▲ Location and cleaning of ant nest.

▲ Marking of ant nest.

▼ Measurement of nest.

▼ Mapping and GPS inventory.

Other measures such as biological control by ant natural enemies are also important. These include the use of parasitoids such as *Eibesfeldtphora attae* (Diptera: Phoridae) (Uribe, 2012), predators such as *Vescia angrensis* (Hemiptera: Reduviidae), and other ants such as *Nomamyrmex esenbeckii* and *N. hartigi* (Hymenoptera: Formicidae). In addition, predators such as *Canthon virens* (Coleoptera: Scarabaeidae) and *Taeniolobus sulcipes* (Coleoptera: Carabidae) can also be useful.

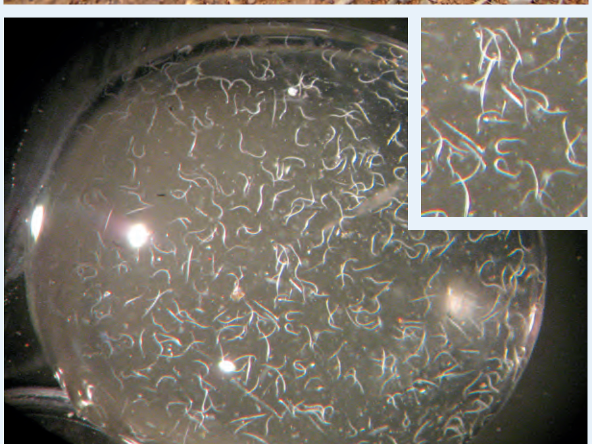
Birds like *Tyrannus melancholicus* (Tyrannidae) and *Pitangus sulphuratus* (Tyrannidae) amongst others, also provide means to reduce population levels (Madrigal, 2003).

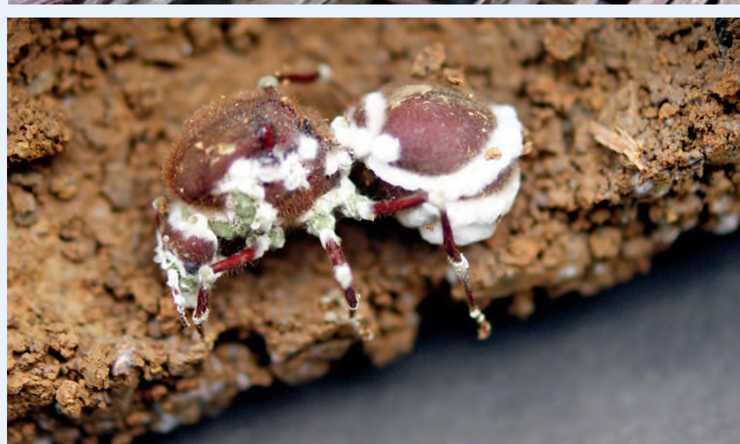
Fungi such as *M. anisopliae*, *Trichoderma harzianum* and *B. bassiana* are being investigated as possible control measures for ants (Ortiz, 1998; Ortiz & Guzmán, 2007). However, chemical control still remains the most effective and widely used approach to manage ant infestation, and this is generally achieved using toxic pellets (Sulfluramid, Fipronil) (Forti et al., 2007), as well as fumigation with Chlorpyrifos.

▲ Chemical control with thermo- fog.

▸▸ Chemical control with toxic pellets.

▸▸ Biological control using nematodes and entomopathogenic fungi.





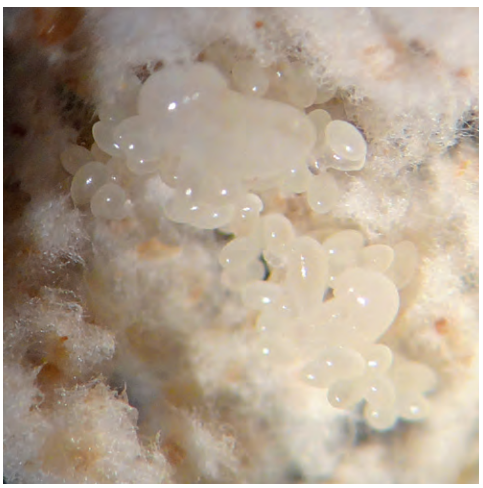
Atta cephalotes

(Hymenoptera: Formicidae)

In Colombia, the ant species causing the most serious damage to agricultural crops and forestry plantations is *A. cephalotes*. Effective silviculture and maintaining optimum conditions for healthy plantations (including the age of trees) are essential to keep damage to a minimum (Mendes-Filho, 1981). Nevertheless, *P. patula*, and some species of *Eucalyptus*, are often able to recover from three repeated defoliations without dramatically reduced productivity, although in some cases, partial or total defoliation can result in tree death (Camargo et al., 2006).

Unlike *Acromyrmex* spp., damage by *A. cephalotes* and other *Atta* species is generally limited to a maximum altitude of 2000 m.a.s.l. (Weber, 1972).

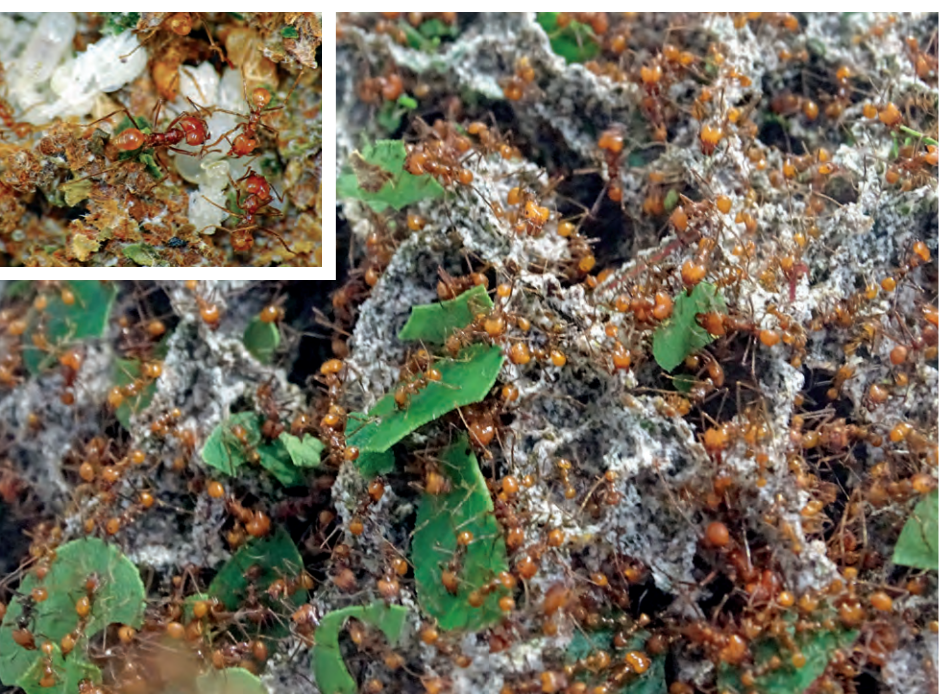
Biological stages



Egg.

Larva.

Pupae.



Gardener ant feeding larvae by trofalaxy.

Gardener caste.

Cutter caste.

Soldiers.

Carrier caste.

Cutter foragers and explorer caste.

New colony formation

▲ Winged adult male of *Atta cephalotes* (Hymenoptera: Formicidae).

▲ Winged adult female of leaf-cutting ants *Atta cephalotes*.

▲ Fertile queen establishing a new colony.

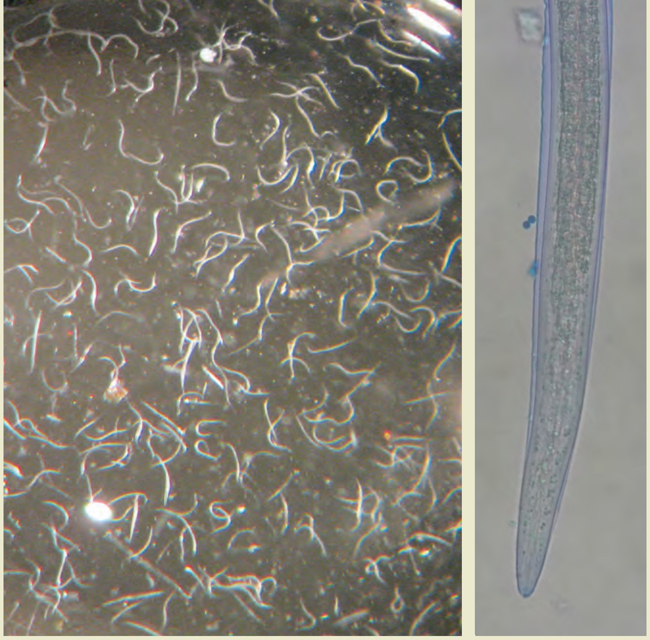
▲ Queen laying eggs and culturing the fungus *Attamyces bromatificus* (Agaricales: Agaricaceae).

▲ Ant nest showing chambers with *Attamyces bromatificus*.

Queen establishing a new colony. ▶

Biological control agents

In laboratory experiments, *A. cephalotes* have been infected with some strains of *M. anisopliae* and *T. harzianum*. Pellets which include the fungus are made with a mixture of orange juice, corn and wheat (Verza et al., 2006). The fungi thus introduced infect the fungal symbiont within the ant nest and compete with it for food. Parasitic nematodes as well as predatory ants and birds can be useful.



Parasitic nematodes used in biological control.

Queen infected by the entomopathogenic fungus *Beauveria bassiana* (Hypocreales: Cordycipitaceae).

Ant predators attacking an adult male.

The adult ants predator *Vanellus chilensis* (Charadriiformes: Charadriidae).

The predator *Pitangus sulphuratus* (Tyrannidae).

MINOR INSECT **pests in *Pinus* plantations**

There are various insects other than those mentioned above that are less serious in their effect, but that are still considered to be potential pests in terms of Colombian reforestation. They are usually controlled by broadly based Integrated Pest Management strategies, including biological control. These are presented in order of importance below.

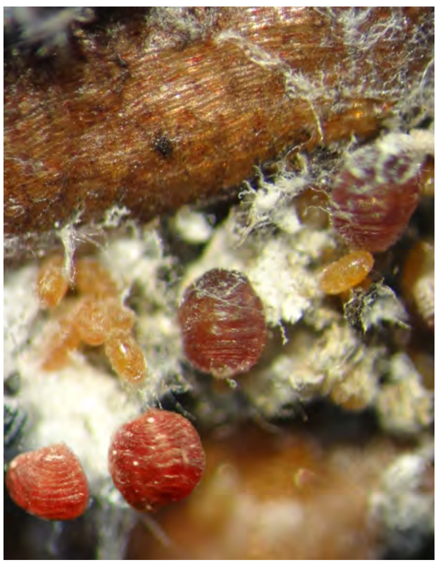
Pineus boerneri
(Hemiptera: Adelgidae)

Pineus boerneri was first detected in 2008, in various geographic regions of Colombia. The pest infests *P. kesiya*, *P. maximinoi* and *P. tecunumanii* and can cause severe defoliation, slowed growth and reduced productivity (Rodas, Serna et al., 2015).

Pinus kesiya plantation affected by *Pineus boerneri*.

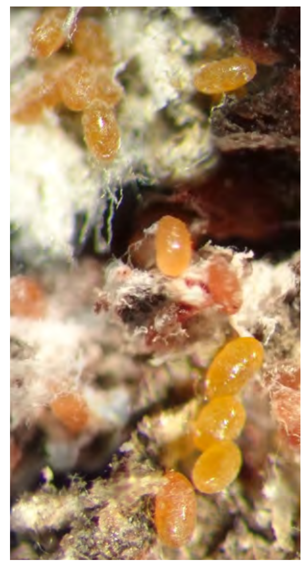

Low and high levels of white cottony tufts on tree bark.

Affected cones.



Adults on white woolly tufts.

Adults laying eggs.



Eggs.


First nymphal instar, showing long proboscis.

First nymphal instar emerging from an egg.

Fourth nymphal instar producing woolly tufts.

Biological control agents

Biological controls for *P. boerneri* include different species of the Chrysopidae, such as *Ceraeochrysa* and *Chrysoperla* species, and some of the Coccinelidae such as *Harmonia axyridis* (Brown et al., 2011) and *Cryptolaemus* sp. evaluated in laboratory studies (C. A. Rodas unpublished data).

Adult of *Ceraeochrysa* sp. (Neuroptera: Chrysopidae).

Eggs of *Ceraeochrysa* sp.

First larval instar emerging from the egg.

Last instar larvae of *Ceraeochrysa* sp.

Last instar larvae of *Ceraeochrysa* sp.

Cryptolaemus sp. (Coleoptera: Coccinellidae) feeding on *Pineus boerneri*.


▲▶ Adults of *Harmonia axyridis* (Coleoptera: Coccinellidae).


▲▶ Larvae of *Harmonia axyridis*.



▲▶ Larvae of *Chrysoperla* spp. (Neuroptera: Chrysopidae).

Glena sp.

(Lepidoptera: Geometridae)

The defoliator *Glena* sp. was reported for the first time in 1990 causing damage in *P. patula* in the Cauca zone at (2° 34′ 49″ N and 76° 78′ 17″ W) and elevations higher than 1770 m.a.s.l.

Adult male.

Adult female.

Larva.

Pupae.

Adult moths showing typical position on the stem.

Integrated Pest Managment and biological control agents

Pupae infected by the pathogenic fungus *Cordyceps* (Hypocreales: Clavicipitaceae).

Light traps for adult insect concentration.

The parasitoid *Rogas* sp. (Hymenoptera Braconidae).

The parasitoid *Casinaria* sp. (Hymenoptera Braconidae).

The larval and adult predator *Piaya cayana* (Cuculiformes: Cuculidae).

The larval and adult predator *Trogon collaris* (Trogoniformis: Trogonidae).

Cargolia pruna
(Lepidoptera: Geometridae)

The geometrid *C. pruna* has been found affecting *P. patula* at (2° 15′ 45″ N and 76° 36′ 19″ W) elevations higher than 2500 m.a.s.l.

Eggs.

Larvae on *Pinus patula* foliage.

Pupae.

Biological control agents

Chalcolepidius sp. (Coleoptera: Elateridae) predating larva of *Cargolia pruna*.

Pupae infected by the fungal pathogen *Beauveria bassiana* (Hypocreales: Cordycipitaceae).

The larval and adult predator *Trogon collaris* (Trogoniformis: Trogonidae).

Platycoelia nigrosternalis

(Coleoptera: Scarabaeidae)

The defoliator *P. nigrosternalis* is most commonly found affecting *Quercus*, a native host tree species. Since 2008, it has also been reported causing defoliation and considerable damage to *P. patula* plantations.

Adult emerging from the nest chamber.
Adult and eggs.

Adults feeding on *Pinus patula* needles.

Adult showing black spot typical of *nigrosternalis* species.

Larvae and eggs.

Biological control agent

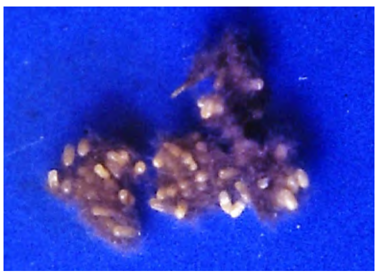
Larva infected with *Metarhizium* sp. (Hypocreales: Clavicipitaceae).

Mesoscia eriophora
(Lepidoptera: Megalopygidae)

In 1992, the defoliator *M. eriophora* was found causing severe defoliation on old *P. patula* trees in Pijao (Quindío department).

Adult female.

Eggs.



Larvae showing two different instars.

Larvae feeding on *Pinus patula* foliage.

Pupae on litter.

Biological control agent

The larval and pupal parasitoid *Lampocryptus* sp. (Hymenoptera: Ichneumonidae).

Oiketicus kirbyi
(Lepidoptera: Psychidae)

Oiketicus kirbyi frequently occurs on various host trees including *Pinus* species (Newman, 1980).

Adult males.

Adult female in nest.

Larva.

Larval nest.

Male pupa.

Pupal parasitoid *Spilochalsis* sp. (Hymenoptera: Chalcidiade).

Biological control agents

Pupae infected with *Beaveria bassiana* (Hypocreales: Cordycipitaceae).

Dirphia somniculosa
(Lepidoptera: Saturniidae)

Dirphia somniculosa can damage *P. patula*, *P. maximinoi* and *P. tecunumanii* with *Tibouchina lepidota* being the principal native tree host. The insect has many key natural enemies including *Cotesia* sp. (Hymenoptera: Braconidae), some unidentified flies: Diptera: Tachinidae, and some bacteria (*B. thuringiensis*), as well as the entomopathogen *B. bassiana*.

Adult.

Eggs.

Different larval instars.

Pupa.

Biological control agents

Larval stage infected by *Beauveria bassiana* (Hypocreales: Cordycipitaceae).

Tachinidae parasitoid of larvae.

Larva affected by *Bacillus thuringiensis*.

Other species

(Coleoptera: Curculionidae)
(Coleoptera: Melolonthidae)

Weevils in the Coleoptera: Curculionidae families, including *Compsus* sp., *Naupactus* sp. and *Macrostylus* sp. and *Anomala* sp. (Coleoptera: Melolonthidae) are often considered as potential pests in *Pinus* spp. plantations. Photographs illustrate different Coleoptera species found in *Pinus* and *Eucalyptus* plantations.

Different species of *Naupactus* sp. feeding on *Pinus* and *Eucalyptus* trees.

An adult of *Anomala pyropyga* (Coleoptera: Melolonthidae) feeding on *Eucalyptus* leaf.

Compsus sp. (Coleoptera: Curculionidae). feeding on *Pinus*,

Biological control

Compsus sp. infected by *Beauveria bassiana*.

INSECT PESTS ON *Eucalyptus* species

Eucalyptus plantations in Colombia have mainly been infested by defoliators such as those in the Geometridae. These include *Oxydia vesulia*, *Bassania schreiteri*, *Sabulodes caberata* and *Thyrinteina arnobia*.

Other insects including *Lichnoptera gulo* (Lepidoptera: Noctuidae) and *Selenothrips rubrocinctus* (Thysanoptera: Thripidae) also *Mites* (Acari: Trombidiformes) are commonly found at low elevations (900 - 1500 m. above sea level), and their presence can result in severe defoliation of 4 - 6 year-old trees.

Chalcophana sp.
(Coleoptera: Chrysomelidae)

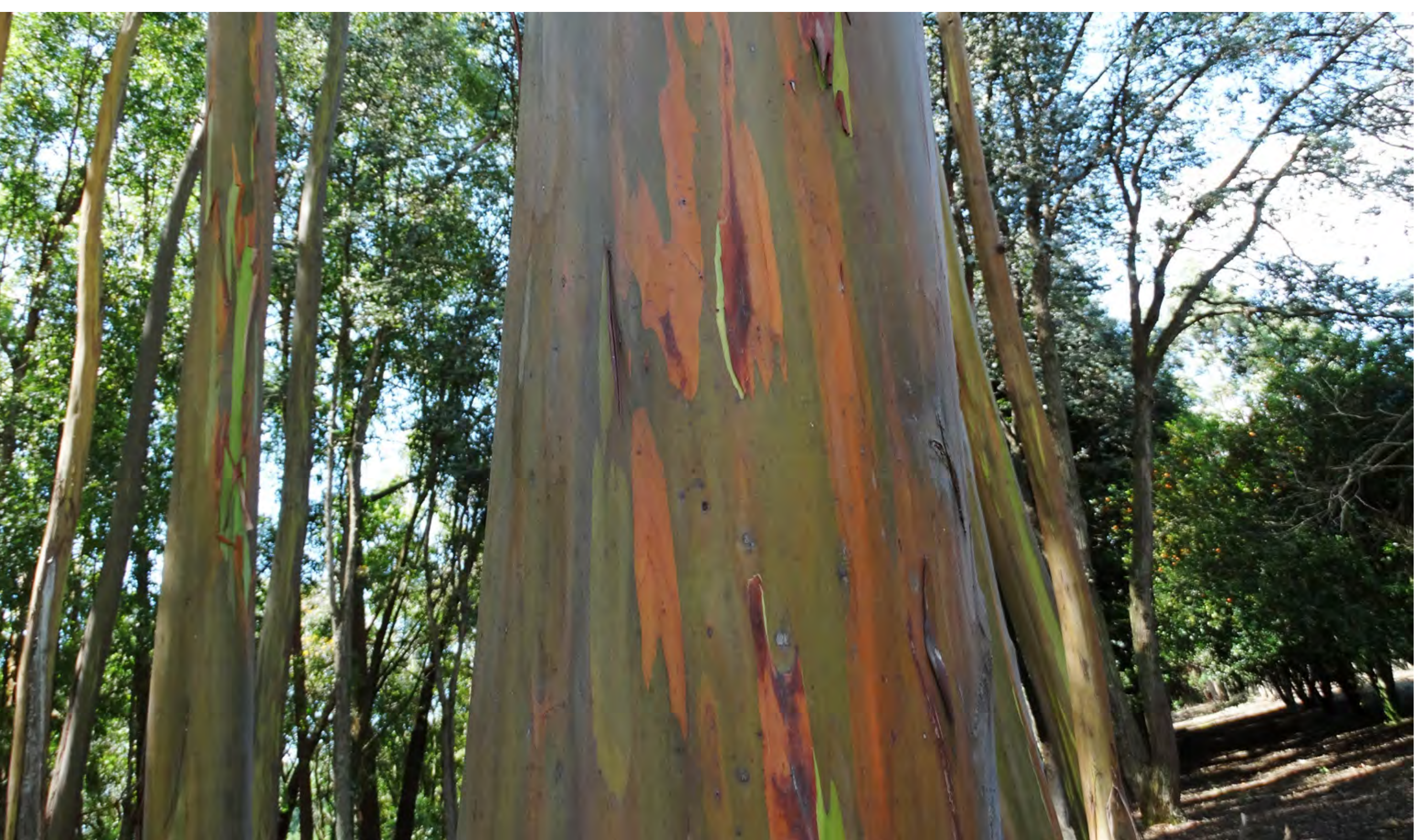
Insects in the Coleoptera, such as Chrysomelidae, Curculionidae, and Scarabaeidae, cause both foliar damage and also injury to the roots. Of these, the recent appearance of the non-native *Gonipterus platensis* in northern parts of Colombia is of great concern.

Since 2017, damage by different stem borers has been reported on clones and seed-derived trees of *Eucalyptus grandis* and hybrids of "*E. urograndis*" in Caldas, Quindío, Risaralda and Valle del Cauca departments. These insects include the family Curculionidae.

The non-native insect *Glycaspis brimblecombei* (Hemiptera: Psyllidae) has been recorded sporadically since 2005 and its damage has increased dramatically in recent years. *Monalonion velezangeli* and *Horciacisca signatus* (Hemiptera: Miridae) are among the most destructive sucking insects in young plantations.

Since 2016, three new pest insects have been reported causing significant damage to young as well as older plantations. They include *Euselasia pance* (Lepidoptera: Riodinidae), *Sarcina purpurascens* (Lepidoptera: Lymantriidae) and *Nystalea nyseus* (Lepidoptera: Notodontidae). An *Aepytus* sp. (Lepidoptera: Hepialidae) is a notorious wood borer in young plantations but is considered of minor importance.

In recent years, a substantial increase has been observed in the numbers of insects such as *Phobetron hipparchia* and *Sibine nesea* (Lepidoptera: Lymacodidae), the *Clastoptera* sp. (Hemiptera: Clastopteridae), and *Mimallo amilia* (Lepidotera: Mimallonidae), amongst others. Consequently, early detection and adequate control measures, including biological control, are key factors in maintaining a natural balance between insect populations and productive *Eucalyptus* plantations.



Oxydia vesulia

(Lepidoptera: Geometridae)

Oxydia vesulia is communly found causing defoliation on *Eucalyptus* plantations from 900 m.a.s.l.

Adult female.

Eggs.

Larva.

Pre-pupa and pupa.

Pupa.

Biological control agents

Adults of Tachinidae parasitoid of larvae.

The larval and adult predator *Trogon collaris* (Trogoniformis: Trogonidae).

Bassania schreiteri

(Lepidoptera: Geometridae)

The moth *B. schreiteri* is commonly found associated with other defoliators.

Adult.

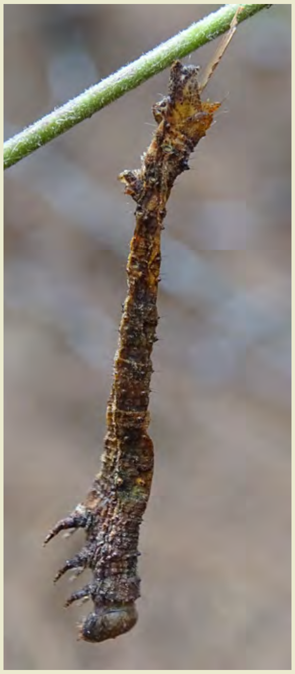
Eggs.

Larva.

Pupae.

Biological control agents

A predator *Podisus* sp. (Hemiptera: Pentatomidae) consuming larva.



Larva infected with *Bacillus thuringiensis*. (Bacteria: subsp. kurstaki).

Pupae infected with *Beauveria bassiana* (Hypocreales: Cordycipitaceae).

The larval, pupal and adult predator *Cyanocorax yncas* (Passeriformes: Corvidae).

Sabulodes caberata

(Lepidoptera: Geometridae)

Sabulodes caberata has been found causing damage to various species of *E. grandis* and *E. "urograndis"* from 900 to 1800 m.a.s.l.

Adult male.

Eggs.

Larva.

Pupae.

Pupa on foliage.

Adult female.

Biological control agents

Tachinidae parasitoid of pupae.

The larval and adult predator *Piaya cayana* (Cuculiformes: Cuculidae).

Thyrinteina arnobia

(Lepidoptera: Geometridae)

The moth *T. arnobia* is one of the most serious defoliator insects in *Eucalyptus* plantations in Brazil. Since 2019, the insect has been reported in Colombia for the first time causing severe defoliation of *E.* "*urograndis*" at Barranca de Upía, located at Latitude: 4°34'12.58"N and Longitude: 72°59'58.97"W in the Meta department.


Adult female.


Adult male.


Defoliation.


Eggs on branch.


Larva.


Eggs on bark.

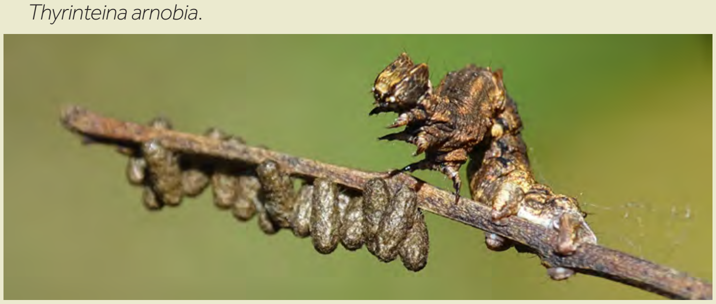
Larva.

Pupal cocoon.

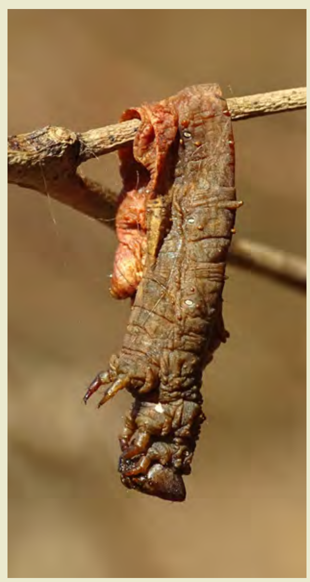
Pupa.

Biological control agents

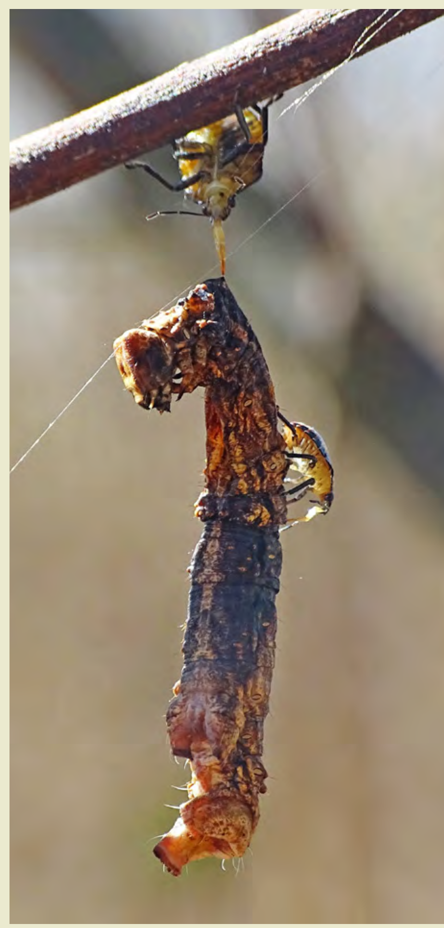
Podisus sp. (Hemiptera: Pentatomidae) predating eggs of *Thyrinteina arnobia*.



A Braconidae parasitoid of larvae.



Larva infected by *Bacillus thuringiensis*.



The predator *Podisus* sp. feeding on larva.

The predator *Podisus* sp. feeding adult.

A Tachinidae parasitoid of larvae.

Lichnoptera gulo

(Lepidoptera: Noctuidae)

The defoliator *L. gulo* causes extensive damage in mature plantations due to continuous defoliation that leads to the death of Eucalyptus trees.

Adult female laying eggs.

Eggs on bark.

Larva.

Pre-pupa.

Larva.

Pupae.

Biological control agents

The insect *L. gulo* has many natural enemies such as *Cotesia glomeratus* and *C. flavipes* (Hymenoptera: Braconidae) as well as some species of Diptera (Tachinidae).

Pupae of unknown parasitoid of larvae.

Larva parasitized by an unknown species of Braconidae (Hymenoptera).

Unidentified species of Tachinidae (Diptera) that results in high levels of parasitism of *Lichnoptera gulo* larvae.

Thrips: *Selenothrips rubrocinctus*

(Thysanoptera: Thripidae)

The thrips *S. rubrocinctus* are sucking insects that damage tree foliage of *Eucalyptus* spp. mostly during dry periods. Natural control of the insect occurs during the rainy seasons.

Significant damage caused by the sucking insect *Selenoptrips rubrocinctus* affecting the foliage of *Eucalyptus* trees.

Nymphs on leaves showing red bands important characteristic of the species.

Healthy and infested leaf.

Mites
(Acari: Trombidiformes)

Some Acari mites such as those in the Tetranychidae and Tenuipalpidae, have caused serious damage in *Eucalyptus* plantations where trees had been previously damaged by air pollution (Díaz & Ordóñez, 1975).

▲ Affected plantation.

▲ Individuals *Oligonichus* sp. on affected tissue.

▲ Microscopic characteristics of *Tenuipalpus* sp. (Acari: Tenuipalpidae) and *Oligonichus* sp. (Acari:Tetranichidae) respectively.

▲ Symptoms on young tissue.

◀▼ Leaf "burning" symptom.

Chalcophana sp.

(Coleoptera: Chrysomelidae)

In Colombia, the leaf beetle *Chalcophana* sp., commonly known as "Cucarrón Semanantero", is found every year between March and May. In some cases, it can cause *Eucalyptus* defoliation.

Adult.

Damage on *Eucalyptus*.

Eggs.

Adults.

Biological control agents

Management is by manual control, mainly when the affected areas are small and insect populations are low. Light-traps are useful to concentrate adults for removal, and the entomopathogen *B. bassiana* can also be used for adult control.

▲▲ Adults infected by *Beauveria bassiana* (Hypocreales: Cordycipitaceae).

Phyllophaga sp.
(Coleoptera: Scarabaeidae)

Damage, caused by a complex of Scarabaeidae, also referred to as June beetles, including *Ancognatha* sp., *Phyllophaga* sp., *Plectris* sp., and *Cymmela* sp., are common in young plantations, and is related to the consumption of young tree roots. The intensive herbicidal weed control provide favorable conditions to increase the insect population.

Affected young *Eucalyptus* tree.

Larvae.

Raster patterns on larva of *Phyllophaga* sp. are important for species identification.

Pre-pupa.

Pupa.

Adult of *Ancognata* sp.

Biological control agents

Pest management is focused on prevention, ensuring that trees have adequate nutrition. Light-traps can be used to concentrate adults for removal.

Entomopathogenic nematodes, as well as applications of the fungus *M. anisopliae* can, also provide effective control of larvae.

Larva infected by *Metarhizium anisopliae* (Hypocreales: Clavicipitaceae)

Gonipterus platensis
(Coleoptera: Curculionidae)

Damage to the foliar tissue.

Adult.

Species in the *Gonipterus* complex are commonly known as Eucalyptus weevils or Eucalyptus snout beetles, and they represent some of the most serious pests in *Eucalyptus* plantations world-wide. Their ability to adapt to new environments and feed on a wide range of *Eucalyptus* spp., has allowed these insects to cause considerable economic damage in plantations wherever they have been reported.

In the last decade, *Gonipterus* spp. have increased their areas of colonization, particularly in South America. They have now been reported in Argentina, Brazil, Chile and Uruguay, where they are becoming increasingly significant. In Colombia, in May 2016, a *Gonipterus* sp. was first detected by Prof. Alejandro Madrigal in the Antioquia region, causing the severe defoliation of *Eucalyptus* species at several locations (Madrigal, 2019).

Recent taxonomic and molecular research has shown that the genus *Gonipterus* represents a complex of cryptic species (Mapondera et al., 2012; Schröder et al., 2020). These species are found in 24 different countries, including New Zealand, Africa, Europe, and North and South America, where they can cause serious economic damage. The species occurring in Colombia has been identified as *G. platensis* by Dr. Rolf Oberprieler of the CSIRO, Australia.

The initial symptoms of infestation by *G. platensis* are defoliation of terminal buds with irregular perforations on leaf surfaces. Both adults and larvae of *G. platensis* are responsible for the damage, which affects the top third of trees, limiting their growth. Successive periods of defoliation give trees a stunted and "stag-head" appearance (Kliejunas et al., 2001) and can cause death.

The adults prefer to feed on leaf margins and the soft bark of young shoots. The larvae consume young shoots and feed over the whole leaf surface, leaving only the hard fibers (Fenilli, 1982; Rosado-Neto, 1993; Rosado-Neto & Freitas, 1982).

Adult laying eggs.

Egg capsules.

Capsule showing internal eggs.

Larvae.

Pupa.

Pupae in sand cocoon.

Mating adults.

Management and biological control agents

Chemical control of *Gonipterus* spp. should be considered as only a temporary control option. This approach can often be very expensive, provides only questionable results, and has the potential for further environmental damage. However, It can be recommended in specific small scale situations to reduce population build-up.

Worldwide, biological control has been one of the major means for management of *Gonipterus* spp. (Schröder et al., 2020) This has primarily been through using the egg parasite *Anaphes nitens* and more recently with *Anaphes inexpectatus* Hymenoptera: Mymaridae).

In the case of Colombia, a biological control program should be developed that includes the production and release of the parasitoids *A. nitens* and *A. inexpectatus*. The use of entomopathogenic fungi such as *B. bassiana* could also be useful, given the high humidity where plantations occur in the country.

The egg parasitoid *Anaphes nitens* (Hymenoptera: Mymaridae).

The larval predator *Apiomerus ochropterus* (Hemiptera: Reduviidae)

Adult infected with *Beauveria bassiana*. (Hypocreales: Cordycipitaceae).

Ambrosia beetles

Several reports of stem borers causing severe damages in *Eucalyptus* plantations have been made since 2017 in various geographic regions of Colombia, including Caldas, Quindío, Risaralda and Valle departments. The most significant insect affecting seed derived trees and clones of *E. grandis* include *Megaplatypus dentatus* (Coleoptera: Curculionidae). The occurrence of this insect is mostly on trees damaged by wind. Other wood boring insects reported include *Platypus* sp.; *Corthylus* sp.; *Euwallacea* sp. as well as *Xyleborus* sp. (Coleoptera: Curculionidae).

Megaplatypus dentatus

(Coleoptera: Curculionidae)

Plantation damaged by wind and infested by the borer *M. dentatus*.

Initial, intermediate and final damage caused by the borer in *Eucalyptus* stems.

▲ Initial hole.

▲ Tunnel associated with initial infestation.

▲ Adult.

▲ Borer emerging from a hole.

▲ Adult female.

▲ Adult male.

▲ Eggs in tunnel.

▲ Larvae and eggs in galleries.

▼ Larva.

▼ Galleries with larvae and adults.

Platypus sp.
(Coleoptera: Curculionidae)

Adult female initiating a tunnel.

Adult emerging from a hole.

Initial damage and galleries after adult entrance into the wood.

Galleries, hole in wood and associated fungi producing abundant kino gum.

Adult male .

Eggs in tunnel.

Larvae in galleries.

Corthylus sp.

(Coleoptera: Curculionidae)

▲ Adult.


▲▶ Signs of infestation on stems.

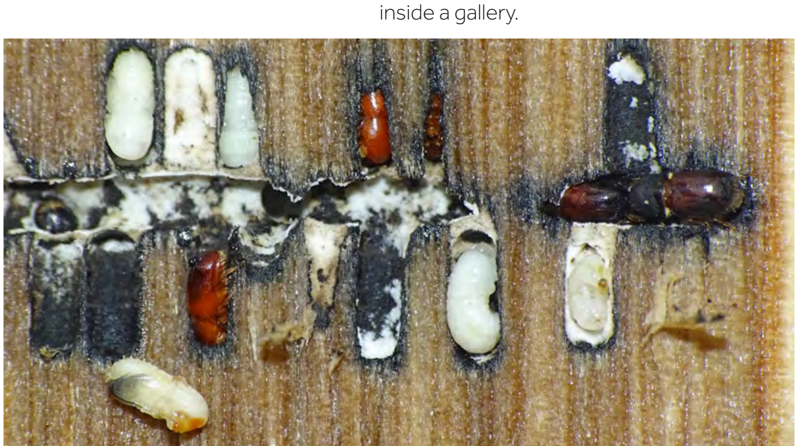

▲ Adults in tunnels.


▲ Galleries in the wood showing entry point of adults.


▲ Egg in tunnel


▲ Larva feeding on fungi and growing inside a gallery.

▶ Galleries showing larvae; pre-pupae; pupae becoming adults; and their nutritional fungi.



***Euwallacea* sp.** (Coleoptera: Curculionidae)

Adult.


External signs of infestation.


Initial damage.


Entrance hole with wood discoloration.


Eggs in tunnels.


Larva in tunnel.


Adult.

Galleries with pre-pupa, pupa and fungus food source.

***Xyleborus* sp.**
(Coleoptera: Curculionidae)

▼ Adults.

▲ Heavily infested stems showing exudation on bark surface and under bark lesions.

▲ Internal lesions showing the insect entrance points into the wood.

Glycaspis brimblecombei
(Hemiptera: Psyllidae)

In 2005, the lerp psyllid, *G. brimblecombei* was recorded for the first time on various *Eucalyptus* species in Colombia. It was first found by a private Forestry Company in Villanueva, Casanare where it was found infesting *E. tereticornis* and to a lesser extent *E. pellita* and *E. urophylla* (G. Gasca personal communication).

Since 2007, low levels of *Glycaspis brimblecombei* infestation have been recorded in young (6-month – 6-year-old) *E. "urograndis"* plantations, on the La Estancia Forestry Farm (3° 41' 31" N - 76° 32' 48" W), Yumbo (Valle del Cauca). The pest has also been recorded on 2 to 3-year-old *E. grandis* on the El Nogal Forestry Farm (4° 42' 60" N - 75° 36' 26" W) in Pereira (Risaralda).

The most recent collections of *G. brimblecombei* have been from 6-month-old *E. tereticornis* and *E. camaldulensis* in La Guamo (5° 48' 38" N - 75° 41' 02" W), La Pintada (Antioquia) where a severe infestation was recorded.

Currently recorded tree hosts of *G. brimblecombei* include *E. tereticornis*, *E. pellita*, *E. urophylla*, *E. "urograndis"*, *E. grandis*, and *E. camaldulensis* and the pest is now considered a serious threat to forestry in the country.

Glycaspis brimblecombei is characterized by a white lerp, composed principally of honeydew and wax, which protects the nymphs. At the adult stage, the wings are fully developed and the insects colonize new substrates. Damage is mainly to the foliage, shoots and branches of trees where sap-sucking on young tissues results in defoliation, and branch die-back. In cases of heavy infestation, trees can die. It is probable that defoliation and reduction in leaf area will also contribute to a decrease in wood production.

White lerps on leaves.

Lerps and nymphs.

Adults and eggs on leaf.

Adults mating.

Adults on stem.

Eggs.

White lerps.

Nymphs.

Biological control agents

The most viable option to reduce the impact of *G. brimblecombei* is classic biological control. This has been very effective when using the parasitoid *Psyllaephagus bliteus* (Hymenoptera: Encyrtidae), a host-specific parasitoid that has been used in biological control programs in other countries (Brennan et al., 1999; Dahlsten & Rowney, 2000; Paine et al., 2006).

In 2007, nymphs of *P. bliteus* were found in Yumbo, Valle del Cauca, in parasitic association with *G. brimblecombei* in a *E.* "*urograndis*" plantation (Rodas et al., 2014). This parasitoid is currently being bred in the Entomological Laboratories of Smurfit Kappa in Restrepo, Valle del Cauca, and released in affected *Eucalyptus* plantations within the Valle del Cauca area. Other predator insects that might be useful for biological control include those in the families Anthocoridae, Chrysopidae, Coccinellidae, Hemerobiidae and Syrphidae (Dahlsten & Rowney, 2000).

▲ Adult of *Ceraeochrysa* sp. (Neuroptera: Chrysopidae).

▶ Coleoptera: Meloidae.

▼ Adult of Hemiptera (Pentatomidae) eating nymphs.

▼ *Hypselonotus* sp. (Hemiptera: Coreidae)

A nymph of *Zelus* sp. (Hemiptera: Reduviidae) consuming adult insects.

Adult of *Photuris* sp. (Coleoptera: Lampyridae) predating nymphs.

The parasitoid *Psyllaephagus bliteus* (Hymenoptera: Encyrtidae).

A species of Chrysopidae (Coleoptera: Coccinellidae) consuming nymphs.

Monalonion velezangeli

(Hemiptera: Miridae)

Heavily damaged *Eucalyptus* plantation.

Adult of *M. velezangeli.*

Monalonion velezangeli (Hemiptera: Miridae) was first recorded on avocado in Colombia in 1984 and identified in 1988 (Carvalho & Costa, 1988). Its origin is believed to be Central and South America, where it is known on various crop plants (Vélez, 1997). In recent years, *M. velezangeli* has become a significant pest on a number of Colombian tree crops including avocado (Carvalho & Costa, 1988, Londoño & Vargas 2010a), coffee (Ramírez et al., 2007), guava and cacao (Giraldo et al., 2009; Londoño & Vargas, 2010b).

For about fifteen years, serious damage had been noted on young *Eucalyptus* trees in Colombian plantations, but the causal agent was unknown. During 2011, adults of a sap-sucking mirid were found in damaged plantations and these have now been identified as *M. velezangeli*.

The main damage is to young tissues such as buds and twigs, caused by sap-sucking. This results after an hour, in the rapid appearance of dark necrotic lesions, apparently due to the production of a toxic enzymatic saliva from the insect. Damage includes the loss of apical dominance, dried leaves, and decreased growth.

Careful observation has shown that the main damage to *Eucalyptus* occurs during the night, and it was this nocturnal behavior that resulted in *M. velezangeli* not being identified for many years. Both nymphs and adults are responsible for damage to young *Eucalyptus* species.

Severe damage has been observed

Adult male.

Lesions and severe damage.

Initial lesions and moderate damage.

on trees with relatively low levels of infestation by *M. velezangeli*. This is due to secondary infections by the fungal pathogen *Neofusicoccum ribis* (Rodas et al., 2009). This is consistent with observations of similar symptoms associated with damage due to *Helopeltis* spp. (Miridae) on *Eucalyptus*, where fungi in the Botryosphaeriaceae have been found causing secondary infections.

The first collections of *M. velezangeli* on *Eucalyptus* in Colombia were made in February 2011 from a young (27-month-old) *E. grandis* seedling plantation on the La Tigresa Forestry Farm (3° 49′ 44″ N - 76° 34′ 54″ W) near Restrepo (Valle del Cauca). In the same year, an 18-month-old *E. grandis* clone was seriously affected by both *M. velezangeli* and secondary *Botryosphaeria* infections, at La Mesa Farm (3° 43′ 59″ N - 76° 12′ 16″ W) near Palmira (Valle del Cauca).
The insect was also detected in a 6-month-old *E. grandis* seedling plantation on the Buenavista 2 Forestry Farm (2° 23′ 03″ N - 76° 35′ 02″ W) Salinas (Cauca). (Rodas et al., 2014).

Monalonion velezangeli is clearly an insect pest of emerging importance on *Eucalyptus* in Colombia. Damage is most severe on young trees growing in moist and shaded sites. While trees appear to recover from infestation as they become older, they can be seriously malformed and this is also related to secondary infections by *N. ribis* (Rodas et al., 2009). The fungus *Chrysofolia eucalypticola* (Crous et al., 2015) is consistently associated with damaged foliage and may also contribute to die-back of shoots.


Adult female laying eggs.


Third nymphal stage feeding on young leaf tissues.


Appendices of eggs inserted into branch tissue.


Egg showing the exposed appendices.

Management and biological control agents

There is good evidence to show that *Eucalyptus* clones differ in their susceptibility to damage by *M. velezangeli*, and this is linked to the differing susceptibility of clones to infection by *N. ribis* (Rodas et al., 2009). Thus, planting clones tolerant to infestation holds substantial promise. In addition, the use of the natural enemies of *M. velezangeli* is currently being investigated.


Adults infected with *Beauveria bassiana* (Hypocreales: Cordycipitaceae).

Horciacisca signatus

(Hemiptera: Miridae)

Horciacisca signatus is a serious pest in nurseries as well as in young *Eucalyptus* plantations. Nymphs and adults cause damage to leaves and buds, producing yellowish lesions due to the presence of a toxic saliva from the insect. The symptoms are thus similar to those caused by *M. velezangeli*.

Horciacisca signatus is usually associated with young *Eucalyptus* plantations. Management is preventative, through intensive herbicidal weed control, which eliminates the insect's natural vegetation hosts. This is crucial, as damage from *H. signatus* can often necessitate total replanting of affected areas.

▲ Adult female.

▲ Adult male.

▲ Adult female.

▲ Initial symptoms of damage on young *Eucalyptus grandis* tissue.

▲▼ Damage resulting in malformation of young trees, often necessitating replanting of stands.

Euselasia pance

(Lepidoptera: Riodinidae)

Damage to foliage of *Eucalyptus grandis*.

Typically gregarious larvae.

Euselasia pance was first reported in 1999 near the Pance River in the Cauca valley, Colombia, at 1200 m.a.s.l. (Callaghan, 1999). More recently (2016), *E. pance* was reported as a new defoliator causing damage in *Eucalyptus* plantations that were 1 to 3-year-old at Tortolas farm (3° 32' 31" N and 76° 40' 12" W), Dagua, Valle del Cauca. The trees included *E. grandis*, *E.* "*urograndis*" and *E. urophylla*. The insect has since been reported in various farms located in the Valle del Cauca, Caldas, Quindío, Risaralda and Cauca departments.

The larvae of *E. pance* are gregarious, and during the day can be found covering the entire leaves of trees in an organized pattern, or following each other in lines. Damage is produced by larvae feeding on foliage. The first instar larvae scrape the surfaces of the leaves and this results in defoliation. As the larvae approach the pupal stage, they seek out dried leaves on the ground below the infested trees, where pupation takes place. The pupae vary in colour from light red to dark brown, before the adults emerge as pale coloured butterflies, active during daylight. These adults lay masses of eggs under *Eucalyptus* foliage and also on the common guava, *Psidium guajava*, which is part of the native vegetation. As high numbers of adults and masses of eggs have been observed in native forests on *P. guajava* trees, this would suggest an initial migration from those plants to the *Eucalyptus* species.

Studies to determine the insect life cycle showed a total cycle of 75.1 days; 12 days for eggs, 37.5 days for larvae, 12.7 days for pupae and 12.9 days for adults (Rodas unpublished data).

Very little is known regarding *E. pance* as a tree pest in Colombian forestry.

Adult female laying eggs.

Eggs on *Eucalyptus* leaves.

Typically gregarious larvae on leaf.

Typically gregarious larvae on leaf.

Larvae in line on steam.

Pupae on leaf.

Biological control agents

Management strategies using biological control of *E. pance* could provide options to reduce the impact of this insect. Biological control using *B. thuringiensis* has resulted in some reduction of *E. pance* larvae. The egg parasitoid *T. alsophilae* and *Trichogramma* spp. have also been released as biological control agents. Another possible option for biological control is the predator stink bug *Podisus* sp. (Hemiptera: Pentatomidae), which has been observed feeding on all biological stages of *E. pance*, including eggs, larvae, pupae and adults.

▼Eggs of the predator *Ceraeochrysa* sp. (Neuroptera: Chrysopidae).

▼Larva of the predator *Chrysoperla* spp. (Neuroptera: Chrysopidae).

▲▲Nymphs of the *Podisus* sp. (Hemiptera: Pentatomidae) predating adults and eggs of *E. pance*.

▼An adult wasp (Hymenoptera: Vespidae) consuming larva.

Sarcina purpurascens

(Lepidoptera: Lymantriidae)

Affected *Eucalyptus* plantation.

Larva.

The saturniid moth, *S. purpurascens*, has a wide distribution in the south of Mexico, Central and South America, where they are considered as a major insect pest of *Eucalyptus* species. In Colombia, *S. purpurascens* is observed as an increasing threat of *Eucalyptus* species. It was recorded for the first time in 2016, causing severe defoliation of a 4-year-old *E. grandis* clone at La Trinidad farm (3° 39’ 20” N and 76° 46’ 24” W), Dagua, Valle del Cauca. Its presence was associated with the defoliator *O. trychiata*. Some months later, the same insect was reported with *E. pance* in the Quindío, Risaralda and Cauca departments.

The adult moths of *S. purpurascens* lay eggs in small groups on the leaves or bark of stems and branches. The eggs are white to yellow and dark in color, with a dark red band across their central area. The larvae are covered with abundant fine white hairs, and are commonly found in groups on the leaves and bark of the stems. The pupae are commonly covered with silk and residual hair, and found suspended on the stems or branches of infested trees as well as on associated vegetation. The adults are nocturnal and found during the day on stems, branches and leaves. They are grey in color, with banding across the wings.

Studies made to determine the life cycle of *S. purpurascens* indicate a total cycle of 87.6 days: 11.8 days for eggs, 54.1 days for larvae, 11.5 days for pupae and 10.2 days for adults (Rodas unpublished data).

Adult male.

▲ Adult female.

▲ Eggs.

▲ Typical position of larvae on the trunk.

▲▶ Pupae.

▼ *Tyrannus melancholicus* (Passeriformes: Tyrannidae) eating adult of *S. purpurascens.*

Biological control agents

The Integrated Pest Management (IPM) programs used for other defoliators are also useful for *S. purpurascens*. Light-traps are used to concentrate adults and reduce populations. *B. thuringiensis* applications are also used to reduce numbers of first instar larvae. Some key parasitoids that have been observed on *S. purpurascens* larvae and pupae are not yet identified, but are clearly species of either Diptera (Tachinidae) or Hymenoptera (Ichneumonidae). When the Moisture Index conditions are high, entomopathogens such as *B. bassiana* can also infect the insect pupae.

Birds such as *T. melancholicus* (Tyrannidae) among others are important predators of pupae and adults of *S. purpurascens*.

▲ Unknown pupal parasitoid of larva.

▲ Larva infected with *Bacillus thuringiensis.*

▲ Pupa infected with *Beauveria bassiana* .

▲ A larval parasitoid (Diptera: Tachinidae) emerging from pupae.

Nystalea nyseus (Lepidoptera: Notodontidae)

Damage to *Eucalyptus* plantation.

Larva feeding on *Eucalyptus* leaf.

The moth, *Nystalea nyseus*, commonly referred to as "Dragon larvae", is found in Central and South America including the Netherlands Antilles. There are at least 12 species and their main reported tree hosts are *E. grandis*, *E. urophylla*, *Psidium guajava*, *Psidium* sp. and *Eugenia stipitata*. These trees are all members of the Myrtaceae.

In Colombia, *N. nyseus* was first reported as a pest in 2016, causing severe defoliation in Tigresa farm (4° 01' 13" N and 76° 25' 23" W) and Cedral farm (3° 49' 45" N and 76° 34' 49" W) on 6-month-old *E. grandis* and 10-month-old *E. "urograndis"*. One year later in 2017, the insect was reported on *E. tereticornis* in Caucasia (Antioquia).

In November 2018, the first record of extensive defoliation caused by *N. nyseus* in Colombia was from a 183 ha, 30-month-old *E. "urograndis"* plantation in the La Berraquera farm (6° 44' 6" N - 74° 1' 11" W), Puerto Parra, Santander.

The adult moths of *N. nyseus* lay eggs individually on *Eucalyptus* leaves, and they are also found on stems where they mimic the appearance of the plant's tissues. They are nocturnal in habit and grey to dark grey in color. The eggs are spherical and darken from green to brown as they approach larval emergence. The larvae have distinct protuberances on their bodies, which gives them their 'dragon-larvae' appearance. The pupae are found on leaf margins, and are yellow capsules covered by a protective silk layer.

Adult.

Eggs on leaf.

First larval instar feeding on *Eucalyptus* leaf.

Pupal cocoon on leaf.

Management and biological control

Integrated Pest Management for *N. nyseus* mainly consists of light-traps to concentrate adults. Applications of *B. thuringiensis* are also used to control larvae, particularly for the first instars. The fact that this moth has only recently been observed damaging *Eucalyptus* implies that little is known regarding either its biology in relation to this tree host or its natural enemies that might be used in biological control.

Larva showing black spot typical of parasitism.

Pupae of *Cotesia glomerata* (Hymenoptera. Braconidae).

MINOR INSECT PESTS ON *Eucalyptus*

Aepytus sp.
(Lepidoptera: Hepialidae)

The wood borer, *Aepytus* sp. is considered to be a secondary pest in *Eucalyptus* plantations (Madrigal, 2003). Nevertheless, it can become a major problem whenever there is poor weed management. Visible symptoms of damage include galleries on trunk and stem surfaces. Entrance holes are covered with a silky, waxy material. The galleries can lead to a weakening of the trunks or stems that then become dry and are easily broken.

Management of this insect, as with other minor pests, is preventive. Removing all weeds from plantations can be very effective. The biological control fungus *B. bassiana* can be useful, although it can be difficult to apply in the case of this pest.

Damage on a *Eucalyptus grandis* stem with entrance hole covered with a waxy material.

Adult.

Stem deformation and larval entrance site.

Larva and damage to the central part of the stem.

Pupa.

Phobetron hipparchia

(Lepidoptera: Limacodidae)

Larva.

Larva.

Pupa.

Adult .

Clastoptera

(Hemiptera: Clastopteridae)

Nymph.

Adult.

Ctenarytaina eucalypti

(Hemiptera: Psyllidae)

▲ *C. eucalypti* on eucalyptus buds and leaves.

▲ Adults and eggs.

▲▶ Nymphs on leaves and buds.

Biological control agent

▼ The parasitoid *Psyllaephagus pilosus* (Hymenoptera: Encyrtidae).

Mimallo amilia

(Lepidotera: Mimallonidae)

Larva.

Adult moths.

Pupal cocoons on foliar area.

Larva of *M. amilia* preparing to pupate.

Pupa in cocoon.

Golofa porteri
(Coleoptera: Scarabaeidae)

The insect *G. porteri* can be a serious pest to young *Eucalyptus* trees. It commonly appears between March and May, in the Valle department in Colombia, and feeds on the bark of branches and stems, causing significant damage to *Eucalyptus* plantations.

▲ Damage caused on branch and stems of *Eucalyptus* trees.

▼ *G. porteri* adults on a *Eucalyptus* branch.

▲ Damage caused to branches and stems of *Eucalyptus* trees.

▲▶ Pupal stage of *G. porteri*.

Leaf rollers

Leaf rollers are now considered as insects causing serious damage in tree nurseries as well as in young *Eucalyptus* plantations. Some of those insects from Lepidoptera Totricidae.

▲ Larva in silk cocoon.

▲ Larva.

▼ Pupa in silk cocoon.

▲ Unidentified leaf roller.

▲▲ *Eucayptus* leaf package containing both larvae and pupae.

▼ Unidentified leaf roller.

DISEASES of *Pinus* species

Little is known regarding the diseases of *Pinus* spp. in Colombia (Table 2). As mentioned earlier in this book, for many years *D. sapinea* was the only pathogen known to cause damage in pine plantations.

More recently, other pathogens have been recognized and, while very little is known about them, brief descriptions are provided below.

Fusarium circinatum –Pitch Canker

Fusarium circinatum
–Pitch Canker

Fusarium circinatum is the causal agent of the serious pine disease known as Pine Pitch Canker (Wingfield et al., 2008). The pathogen can cause serious damage in nurseries, but is best-known for the cankers it causes on mature trees (Pérez-Sierra et al., 2007; Wingfield et al., 2008).

Fusarium circinatum was first discovered in Colombia in 2006. The most common symptoms associated with infection include foliar wilt, shoot and twig die-back, roots with small resin-soaked necrotic lesions and resinous cankers on trunks and branches.

Infected seedlings showing stem discoloration with drops of resin seeping from diseased tissue, die-back and dead seedlings.

Infected seedlings: showing difference between control (L) and infected plants (R) with die-back and dead seedlings.

Initial symptoms on a 2-year-old tree showing branch die-back.

Two-year-old tree, dead after severe infection.

Constricted root collar with copious resin exudation from infected tissues.

In Colombia, *P. patula* is the most susceptible species followed by *P. tecunumanii* (High Elevation). The species *P. maximinoi*, and *P. tecunumanii* (Low Elevation) have shown tolerance to infection and will therefore become increasingly important for commercial forestry in the future (Steenkamp et al., 2012).

Fusarium circinatum is significant due to its ability to infect seedlings in nurseries. This results in poor tree establishment in young plantations. In some countries such as South Africa and Chile, this pathogen has been reported as a major constraint to nursery propagation and to the establishment of new plantations (Mitchell et al., 2011; Viljoen, Wingfield & Crous, 1992; Wingfield et al., 2002; Wingfield et al., 2008). Efforts to find an effective control measure for Pitch Canker have been focused on screening for resistant *Pinus* spp. and nursery sanitation.

Trees that have died after inoculation.

Constricted root collar with copious resin exudation from infected tissues.

Internal lesions with resin impregnation of the wood.

Symptoms on 2-year-old trees after inoculation, showing resin exudation and internal lesions.

Symptoms on 2-year-old trees after inoculation, showing internal lesions.

Dothistroma septosporum
–Red band needle blight

The pathogen, *D. septosporum*, causes a disease known as Red Band Needle Blight. It is widely distributed and has spread to many of those parts of the world where non-native pines are grown in plantations (Barnes et al., 2004; Barnes et al., 2008; Gibson, 1972). Previously, the only pine needle blight pathogen recorded by Gibson in Colombia (1979; 1980) was *Scirrhia acicola*, which is the sexual state of *D. septosporum*. In this regard, it is important to recognize the taxonomic confusion between *D. septosporum* and *Dothistroma pini* (Barnes et al., 2004) at the time of this report.

Dothistroma septosporum was recently reported (2008) to cause a serious foliar disease in Colombia, when it resulted in severe damage and yield losses in plantations of *P. tecunumanii*, *P. oocarpa* and *P. kesiya* (Rodas, Wingfield et al, 2015). The damage is clearly related to the age of trees. They are most severely affected when they are 2 to 4-year-old and severe infection can cause death in trees of that age (Brown, Rose & Webber, 2003).

▲ Infected tree showing development of the disease from the bottom towards the top.

▼ Affected branches showing healthy current year needles, and severely affected needles from the previous infection period.

▼ Different levels of severity (left to right) from low to high.

Initial lesions on needles showing typical yellow to red bands.

Typical red bands at the start of sporulation.

Acervuli of the pathogen on the needles.

Pinus tecunumanii affected plantations by *Dothistroma septosporum*.

A high moisture index and high levels of precipitation provide favorable conditions for *D. septosporum* spores to germinate and penetrate through the stomata on needle surfaces (Brown et al., 2003). Because there are no distinct annual seasons in Colombia, infection appears to occur throughout the year. This is very different to the situation in, for example, New Zealand or Chile and it elevates the importance of the disease in Colombia.

The first symptoms of Dothistroma infection are the appearance of yellow bands on needles, which then become dark-red to brown, with fruiting bodies (acervuli) occurring at the centers of the lesions. The infection in the crowns progresses upwards from bottom to top, and from the inside of the crowns outwards. Key control strategies include screening for tolerant species, and silvicultural practices that can reduce humidity levels.

Diplodia sapinea

–Diplodia shoot blight

Shoot blight caused by *D. sapinea* was the first disease recorded in *Pinus* plantations in Colombia. It was first reported in the Cauca Valley in 1984, on *P. patula* in a 7-year-old plantation (Hoyos, 1987). However, since 2004 and more recently, 4-year-old pines have also been affected in many areas of the country (Rodas & Osorio, 2008).

At first in Colombia, Diplodia shoot blight was confused with symptoms of boron deficiency. Generally, the disease is most serious where *P. patula* has been planted in environments that are not conducive to growth

Affected *Pinus patula* trees in a plantation with the most severe damage.

Lesions at the base of needles showing fruiting bodies (pycnidia) of the pathogen.

Small cankers on young branches and growing tips, occuring in moist areas.

Defoliation caused by *Diplodia sapinea* in areas with high moisture levels.

Dead tips resulting in branch deformation.

(Hoyos, 1987). These areas are typically at low altitudes between 1500 to 2000 m.a.s.l., and in plantations older than 7-years. However since 2004, infections by *D. sapinea* have been observed affecting younger plantations (4-year-old), as well as at altitudes up to 2500 m.a.s.l. This situation has resulted in the reduced feasibility to continue planting *P. patula* in Colombia. Yet, *P. patula* plantations are wide-spread in Colombia, and the species has been planted at many different altitudes, often under stressful conditions. This has resulted in serious outbreaks of shoot blight caused by *D. sapinea* (Rodas & Osorio, 2008).

Initial symptoms of *D. sapinea* infection include die-back, cankers, deformed twigs and buds, blighted needles with the presence of black fruiting bodies (pycnidia) filled with spores that will then initiate new infections (Hoyos, 1987; Rodas & Osorio, 2008). Needles fall and are continuously replaced only if environmental conditions are favorable for growth. Where trees are stressed, they typically do not recover and die (Hoyos, 1987). To reduce the impact of the disease, silvicultural practices to reduce stress are required, but more importantly, appropriate sites need to be chosen for plantation establishment.

▲ Girdled stem of *Pinus* sp.

Calonectria species
–Death of *Pinus* cuttings in nurseries

A new disease, caused by the fungal pathogens *Calonectria brassicae* and *Calonectria brachiata*, was reported in nurseries in Colombia and first recognized in 2007. These fungi infect *P. tecunumanii*, and *P. maximinoi*, hedge plants, and young rooted cuttings in the nursery. Symptoms of infection include wilting, collar and root rot, die-back, and discoloration of the vascular tissue with accompanying abundant resin formation (Lombard et al., 2009). Disease management is focused on screening *Pinus* spp. for tolerance to infection. However in the nursery, sanitation to remove the source of the infection is of paramount importance.

▲ Exposed root collar showing tissue discoloration and resin exudation.

▲ Exposed pine seedling root collars showing girdling and discoloration of the cambium.

▲ Internal lesion after six weeks of inoculation.

Lecanostica sp. cf *L. acicola*
–Brown-spot needle blight

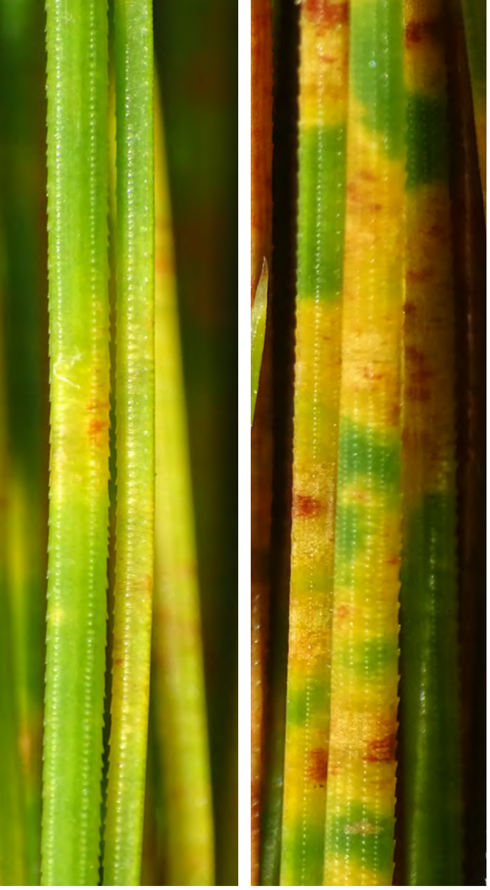
Since 2009, symptoms similar to those of red band needle blight have been observed in young *P. maximinoi* plantations, located in areas of high humidity in the departments of Quindío, Risaralda and Caldas. The symptoms were more severe in younger trees (less than 18-month-old), starting at the bottom of the canopy and ultimately infecting approximately 30% of the tree. Recently, the pathogen *Lecanosticta* cf *acicola* has been found on infected needles, in some cases resulting in severe defoliation of *P. maximinoi* and *P. tecunumanii* (high elevation provenance). The disease has also been found in *P. patula* but with relatively low impact. Recent studies (Van der Nest et al., 2019a; Van der Nest et al., 2019b) have shown that various species of *Lecanosticta* other than *L. acicola* occur on *Pinus* spp. in Latin America. The species associated with needle disease in Colombia has yet to be verified using DNA sequence data.

▲ Infected *Pinus maximinoi* plantation.

Medium-severe infection of *P. maximinoi* tree.

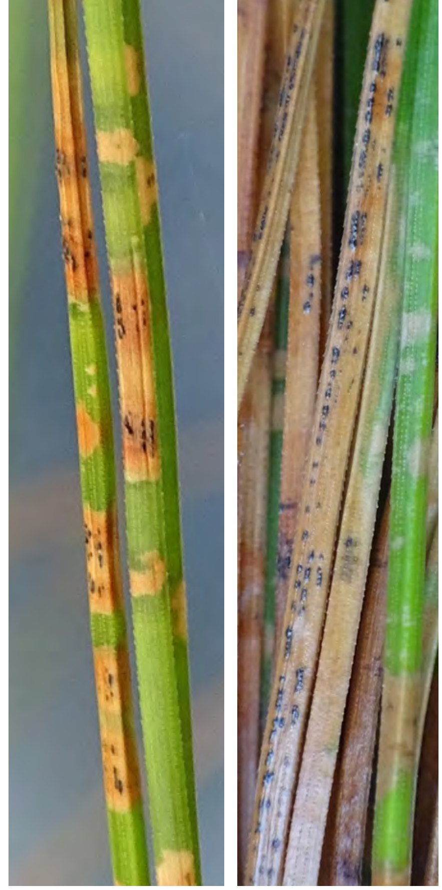
Severe infection showing needle damage moving from the base to the apex of trees.

P. maximinoi plantation, infected by *Lecanosticta* cf. *acicola*.



Initial lesions on needles showing yellow bands.

Red bands at the start of sporulation.



Fruiting bodies (acervuli) on needles.

Branch with typical infection, showing green tips and old red needles.

Young *P. maximinoi* tree showing initial infection.

Branches and needles infected by *Lecanosticta* cf. *acicola*.

DISEASES ON *Eucalyptus* species

Until the late 1990's, there had been very little research on *Eucalyptus* diseases in Colombia, when the first extensive establishment of *Eucalyptus* plantations took place. Some of the most damaging *Eucalyptus* diseases that have emerged in Colombian plantations are due to pathogens such as *Chrysoporthe cubensis*, which causes a serious canker disease (Rodas, Gryzenhout et al., 2005; Wingfield, Rodas et al., 2001), and *Botryosphaeria ribis*, which affects shoots, branches and stems. Both these diseases result in tree loss in plantations (Rodas et al., 2009).

Species of *Calonectria*, in particular the asexual form (previously referred to as *Cylindrocladium spathulatum*) are serious causal agents of defoliation and low wood productivity (Rodas, Lombard et al., 2005). In addition, the rust fungus *Austropuccinia psidii* has also recently appeared for the first time on *Eucalyptus* in Colombia (Rodas, 2013; Rodas, Roux et al., 2015).

These diseases are described briefly in the following section.

Chrysoporthe cubensis

–Basal stem canker

Chrysoporthe cubensis, first recorded as *Cryphonectria cubensis*, is one of the most serious pathogens in *E. grandis* plantations in the tropics and sub-tropics of Latin America. It is restricted to low altitude areas of Colombia, where average temperatures are over 25 °C and relative humidity (RH) is over 75%. The disease is known to cause a basal canker on *Eucalyptus*, and in some cases can result in tree death (Sharma, Mohanan & Florence, 1985; Wingfield, Rodas et al., 2001).

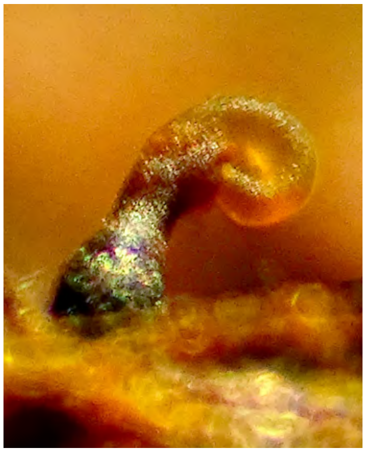
Infection due to *C. cubensis* in Colombia appears in plantations over 6-month-old. Common symptoms are the sudden die-back of isolated trees or trees in small patches, showing basal cankers that gradually increase in size on the stems (Rodas, 2003).

Similar symptoms have been observed on *Eucalyptus* plantations in other countries, for example in South Africa (Gryzenhout et al., 2004; Wingfield, Swart & Abear, 1989) and Brazil (Hodges et al., 1976; Seixas et al., 2004), but the species of *Chrysoporthe* involved are not all the same. The most effective management option is to plant disease resistant *Eucalyptus* clones and hybrids, and to ensure silvicultural practices that reduce the risk of tree wounds, which are key sites for infection (Alfenas et al., 2004; Van der Merwe et al., 2001; Rodas, 2003).

▲ Canker at the base of an *Eucalyptus grandis* stem.

▲ Internal symptoms in a cross section through a canker.

Cankers at the base and higher up on stems.



Typically pycnidia.

Abundant fungal fruiting bodies (pycnidia and perithecia) on the surface of the bark covering cankers.

Botryosphaeriaceae

–Shoot blight and stem canker

Species of Botryosphaeriaceae have a cosmopolitan distribution in the tropics and sub-tropics and are commonly associated with *Eucalyptus* diseases. The usual symptoms include stem and branch cankers, die-back, bleeding necrosis, coppice failure and seed capsule abortion (Alfenas et al., 2004; Barnard et al., 1987; Smith, Kemp & Wingfield, 1994; Smith et al., 2001; Webb, 1983).

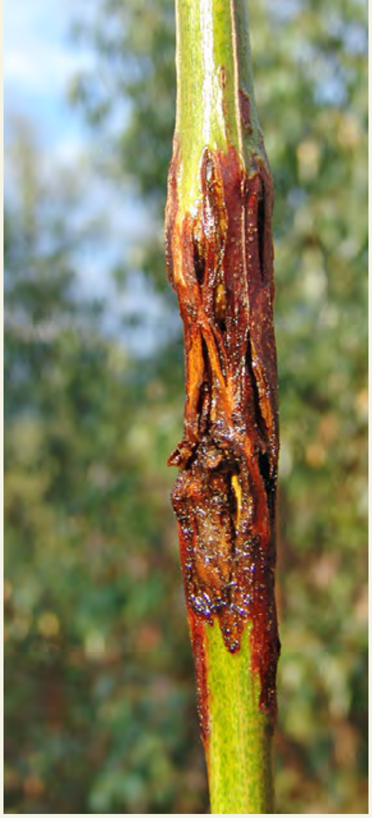
Eucalyptus spp. are infected through wounds, open stomata and lenticels. Botryosphaeriaceae fungi are opportunistic wound and stress-related pathogens, which can exist for long periods of time as endophytes in asymptomatic tissues (Luttrell, 1950; Schoeneweiss, 1981; Slippers & Wingfield, 2007; Slippers et al., 2009; Wene & Schoeneweiss, 1980).

Botryosphaeria canker has now been recognized as a substantial constraint to productivity in Colombian *E. grandis* plantations. Since the 1990's, disease caused by *Botryosphaeria ribis* has been recorded in high altitude zones with a high moisture Index, and frequent rainfall (Rodas et al., 2009).

▲ Infection of *Eucalyptus grandis* by the opportunistic pathogen *Botryosphaeria ribis*.

▼ Heavily affected *Eucalyptus* plantation.

▼ Shoot die-back and small cankers.



Cankers on the branches and main stem respectively.

Eucalyptus grandis plantations commonly affected by Botryosphaeriaceae range in age from 6 to 36-month-old, with the most susceptible trees being those between 18 and 26-month-old. Usual symptoms include small necrotic lesions on shoots at twig insertion points. These then develop into large irregular cankers causing die-back of the shoots. Cankers may also be located on branches and main stems. This gives rise to an abundant production of kino, which degrades wood quality, and can also weaken stems, which may break during strong winds or when harvesting (Rodas, 2003; Rodas et al., 2009).

Control strategies for canker caused by *B. ribis* and other Botryosphaeriaceae include planting an appropriate choice of disease tolerant *E. grandis* clones and hybrids. In addition, silvicultural practices contributing to tree vigor are important. This disease is also associated with tree stress, such as insect infestation (see the section on *M. velezangeli* above), and it is important to reduce stress whenever possible.

Extensive kino gum production and concomitant weakening of the stems.

Calonectria spp.
–Shoot and leaf blight

Calonectria spp., and their *Cylindrocladium* asexual states, are significant pathogens associated with diverse plant hosts in tropical and sub-tropical regions of the world (Crous & Wingfield, 1994; Crous 2002; Rodas, Lombard et al., 2005).

Calonectria spp. are associated with a wide variety of symptoms. These include damping off, root rot, crown canker, leaf spot, seedling and shoot blight, needle blight, wilt, fruit rot, tuber rot, cutting rot, die-back and stem lesions (Alfenas et al., 2004; Chen et al., 2011; Crous, 2002; Lombard et al., 2010; Old, Wingfield & Yuan, 2003; Schoch, 1999).

In Colombia, the main symptoms of infection by *Calonectria* spp. and particularly *C. spathulatum* in commercial *E. grandis* plantations normally include the necrosis of mature leaves on the lower branches of young trees. Defoliation develops upwards from the base of trees, and in severe cases tree death can occur (Rodas, 2003; Rodas, Lombard et al., 2005).

Defoliation in affected plantation.

Damage on leaves.

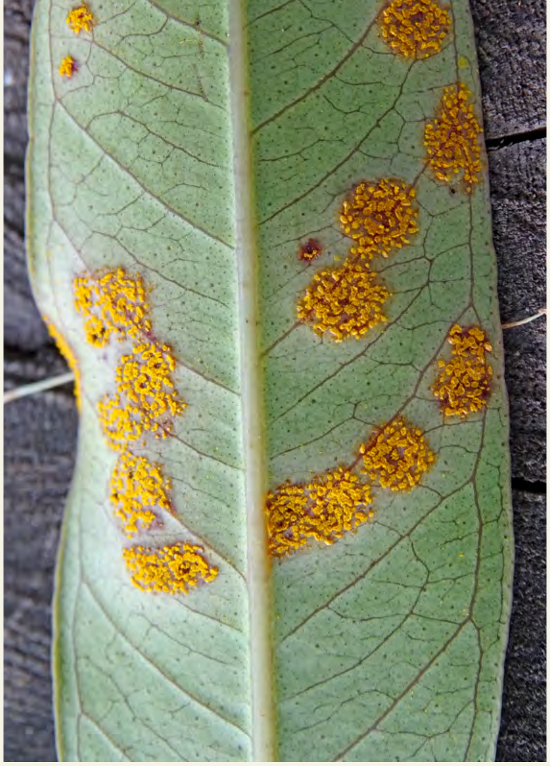
Symptoms of leaf blight caused by *Calonectria* spp. including *C. spathulatum.*

Outbreaks of the disease are usually associated with high humidity and frequent rainfall, which creates favorable conditions for infection by this group of fungi. Infections typically first appear when trees are 12-month-old, and where canopies are closed, leading to increased humidity and leaf wetness.

Austropuccinia psidii

–Myrtle rust

The disease caused by *A. psidii* is commonly referred to as Eucalyptus rust amongst plantation foresters. However, this name is misleading given that in South and Central America the pathogen is native, whereas *Eucalyptus* is an exotic species. Currently, the name more commonly used is Myrtle Rust. The disease is widely distributed in Central and South American countries, including Argentina, Brazil, Venezuela, Uruguay, Paraguay, Ecuador, Colombia and recently, also in Australia (Carnegie & Lidbetter, 2012; Coutinho et al., 1998; Glen et al., 2007; Old et al., 2003; Pérez et al. 2011; Rodas, Roux et al., 2015; Roux et al., 2013).



▲ Lesions on leaf of *Syzigium jambos* showing yellow uredinosporas.

▶▶ Lesions on leaves and tips of *Syzigium jambos*.

▼▶ Lesions on fruits and leaves of *Psidium guajava*.

Lesions and necrosis on the young growing tips and leaves of *Corymbia citriodora*.

Infected *Eucalyptus grandis* shoots and leaves.

The main symptom of *A. psidii* disease is the appearance of egg-yellow uredinia developing on the surface of both young leaves and shoots. This can lead to leaf deformation and shoot death (Alfenas et al., 2004; Old et al., 2003). *A. psiidi* also produces defoliation, die-back and stunted growth on trees (FAO, 2011). Young *Eucalyptus* trees are most susceptible and they remain highly susceptible until about two years of age, or until plantation humidity is reduced (Alfenas et al., 2004; Old et al., 2003; Pérez et al., 2011).

In Colombia, rust on Eucalyptus was unknown until 2011, although the pathogen was well-known on other Myrtaceae such as *S. jambos* and *P. guajava*. It is also known to occur on *Corymbia citriodora*, *E. grandis* and *E. "urograndis"* (Granados et al., 2017; Rodas, Roux et al., 2015). Control measures are focused on screening clones and hybrids for disease tolerance; a strategy commonly applied in Brazil (Alfenas et al., 2004; Glen et al., 2007).

Infected leaves of *E. grandis* after inoculation.

Ceratocystis neglecta
–Wilt disease

Wilt and die-back of young *Eucalyptus* trees was recorded in the 1990's in the Republic of Congo (Roux et al., 2000) and Brazil (Laia, Alfenas & Harrington, 1999; Roux et al., 2000). Later, in Uruguay, the disease was found in trees that had been recently pruned, and the pathogen was then identified as *Ceratocystis fimbriata sensu lato* (Barnes et al., 2003). This pathogen has also been found in South Africa, although intially this was in the absence of disease symptoms (Roux et al., 2004). The fungus on *Eucalyptus* has been described as *C. eucalypticol*a (Van Wyk et al., 2012).

In Colombia, *Ceratocystis* spp. are important pathogens of coffee and other fruit crop plants such as *Citrus*. In those cases, two species *C. colombiana* and *C. papillata* have been described as the causal agents (Marín et al., 2003; Van Wyk et al., 2010). Die-back and wilt of *Eucalyptus* has been associated with another *Ceratocystis* sp. described as *C. neglecta* (Rodas et al, 2008). The pathogen enters through wounds on the stems of trees and symptoms can include die-back, internal stem discoloration and the rapid death of affected trees.

Management is focused on the identification of disease tolerant *Eucalyptus* species and clones.

▲ Symptoms of *C. neglecta* infection on a young *Eucalyptus* tree with die-back and malformation of the root system.

▲ Typical Internal lesions associated with *C. neglecta* infection.

▲ External lesions on the root collar and root malformation.

Infected and dead *Eucalyptus grandis* trees in a plantation.

Typical lesions associated with infection by *Ceratosystis*.

Lesions, four months after inoculation, illustrating a high level of susceptibility.

Ralstonia solanacearum

–Bacterial wilt

The disease on *Eucalyptus* caused by *R. solanacearum* is commonly referred to as Bacterial Wilt. This disease caused by this bacterium has been reported from other countries of South America with tropical or sub-tropical climates. *Eucalyptus* hosts include *E. camaldulensis*, *C. citriodora*, *E. grandis*, *E. 'leizhou'*, *E. pellita*, *E. propinqua*, *E. saligna*, *E. urophylla* and *E. grandis* (Ciesla, Diekmann & Putter, 1996).

In Colombia, the disease was recorded in 2014 for the first time affecting 6-month-old *E. grandis* trees at the Vanessa Farm (76° 34' 32" W - 3° 05' 41" N) in Timba, Cauca. A second report, in which the disease was affecting *E. pellita* in the Vichada department, was made by the ICA in 2015 as *R. solanacearum*.

Symptoms of bacterial wilt in Colombia are the same as those attributed to the disease elsewhere in the world. Typical symptoms are death of branches on one side of a tree, the result of vascular tissue being blocked only on one side of the plant. In most cases, symptoms appear in trees that have previously suffered severe stress, usually from root strangulation. In all cases, bacteria exudes from infected tissues. This exudation, confirming the presence of the disease, is easily observed by cutting stem sections and observing exudation from vascular tissues.

There are two species of *Ralstonia* known to be associated with *Eucalyptus* tree wilt. These are *R. solanacearum* and *R. pseudosolanacearum*, which are only distinguishable from each other by

▲ Infected tree showing symptoms of *Ralstonia* infection.

▼ Dead eucalyptus trees associated with infection by *R. solanaceaurum.*

Base of the stem showing root knotting commonly associated with bacterial wilt.

Obstruction of the xylem vessels and phloem.

Abundant bacterial exudation in infected tissues.

Abundant bacterial exudation on infected tissues.

using molecular tools (Carstensen et al., 2017). The bacterium found in Colombia is *R. solanacearum*. The other species, *R. pseudosolanacearum* is associated with tree wilt also in Africa and Asia.

In all cases, where Bacterial Wilt is found, the disease is associated with previous severe stress to trees (Coutinho & Wingfield, 2017). This may be due to poor root development, infection by root pathogens or environmental stress.

This association of bacterial infection with stress has led to a view that on *Eucalyptus*, the bacterium is an opportunistic stress-related pathogen (Coutinho & Wingfield, 2017). Consequently, management of Bacterial Wilt should be focused on reducing tree stress. It is particularly important to ensure that all plants coming from a nursery have effective root systems. Any plants with poor root systems, which are then planted in hot, humid areas, are the most likely to display symptoms of the disease.

There is some evidence to suggest that tree clones can be selected for tolerance to Bacterial Wilt. However, this more likely indicates clones that have effective root systems in contrast to their having specific resistance to infection by bacteria.

MINOR DISEASES **on *Eucalyptus***

Several minor diseases on *Eucalyptus* have been found in nurseries as well as in plantations. Some include those caused by *Pantoea rodasii*, *Teratosphaeria epicoccoides*, *Botrytis cinerea* and *Coniella eucalypti*.

Pantoea rodasii

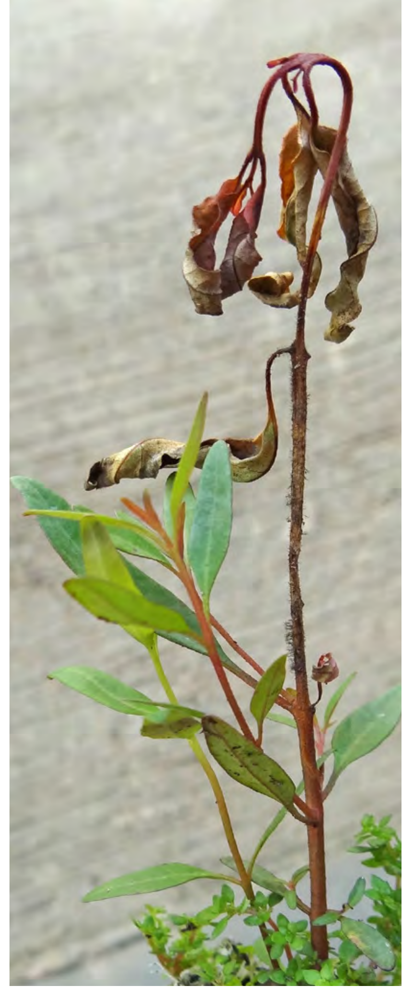
–Bacterial blight

Teratosphaeria epicoccoides

–Leaf disease

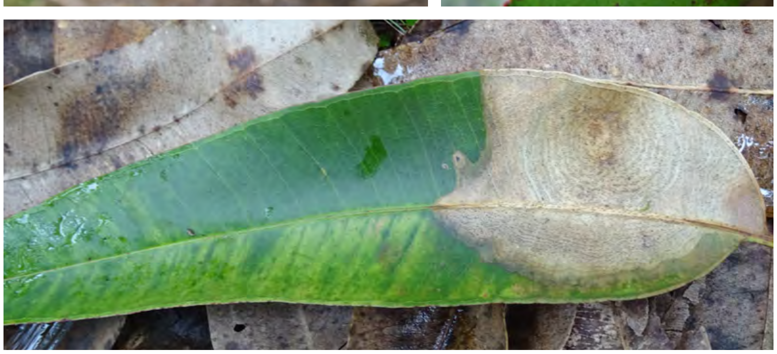
Botrytis cinerea
–Grey mold





Coniella eucalypti
–Leaf spot



HIGH RISK PESTS AND PATHOGENS not currently found in Colombia

The continual increase in new pest and pathogen problems in plantation forestry is a recognized global trend. This is particularly true for programs based on non-native species (Burgess & Wingfield, 2017; Wingfield et al., 2015). This also holds true in Colombia, and looks set to continue into the future. In the short term, those pests and diseases already present in neighboring countries will most likely gain entry to Colombia.

This is currently expedited by relatively porous border controls, and high levels of movement both in peoples and products.

Pests and pathogens from further abroad also pose a threat, although perhaps less so than those in closer proximity. Clearly, every effort must be made to prevent any accidental introduction of new pests and pathogens into the country.

The following examples of pests and pathogens are considered to present a high level of risk for Colombian forestry. While the list is far from extensive, it includes pests and pathogens that occur in other parts of Latin America and also those that are spreading globally, and found where *Pinus* spp. and *Eucalyptus* spp. are extensively propagated in plantations.

INSECTS ON ***PINUS***

Pissodes nemorensis

(Coleoptera: Curculionidae) -Pine weevil

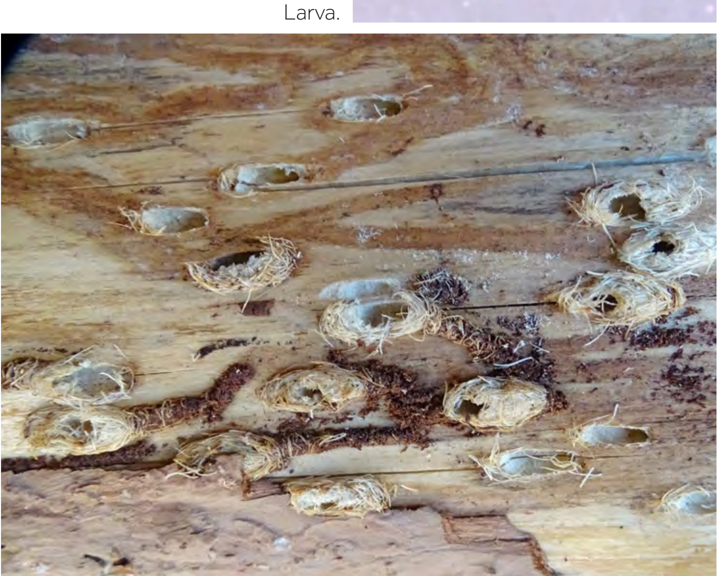
Adult and damage on *Pinus* shoot.

Damage on *Pinus* shoot with drops of resin exudation.

Adult feeding.

Larva.

Pre-pupa.



Chip cocoons containing pupae.

Sirex noctilio

(Hymenoptera: Siricidae) -Sirex wood wasp

Infestation of Sirex on *Pinus patula*.

Adult male and female.

Exit holes on bark.

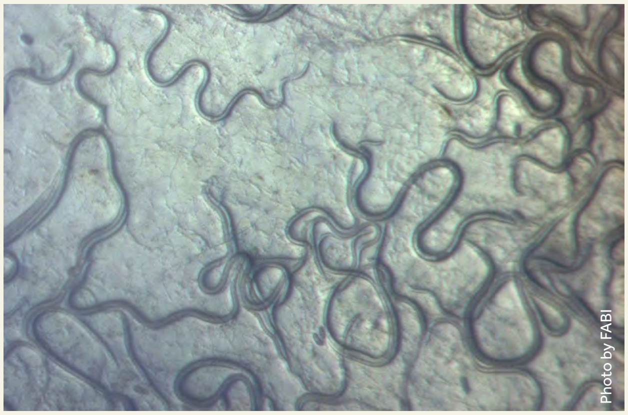
Larvae.

Pre-pupa and tunnel in wood.

Adult male.

Adult female ovipositing.

Biological control agents



The nematode *Deladenus siricidicola* (Tylenchida: Neotylenchidae).

Adult female of the egg parasitoid *Ibalia leucospoides*.

INSECTS ON *Eucalyptus*

Leptocybe invasa

(Hymenoptera: Eulophidae)
-Eucalyptus gall wasp


Photo by Barbara Puretz - LCBPF/UNESP

Adult of *Leptocybe invasa*.

Symptoms in an affected plantation.

Internal tissues with larvae.

Damage to young tissues showing heavy gall formation on the leaf midribs and young shoots. In some cases adult emergence holes are also obvious.

Internal tissues with pupae.

Biological control agent

Photo by Barbara Puretz - LCBPF/UNESP

Adult of the parasitoid *Selitrichodes neseri*.

Thaumastocoris peregrinus

(Hemiptera: Thaumastocoridae) -Bronze bug

Infested trees.

Typical bronze color of infested leaves.

Eggs on leaves.

Adults.

Adults and nymphs on leaves.

Ophelimus maskelli
(Hymenoptera: Eulophidae) -Gall wasp

Adult.

Infested *Eucalyptus* trees.

Adult female.

Galls displaying different levels of severity on leaf laminas.

Adults on leaves.

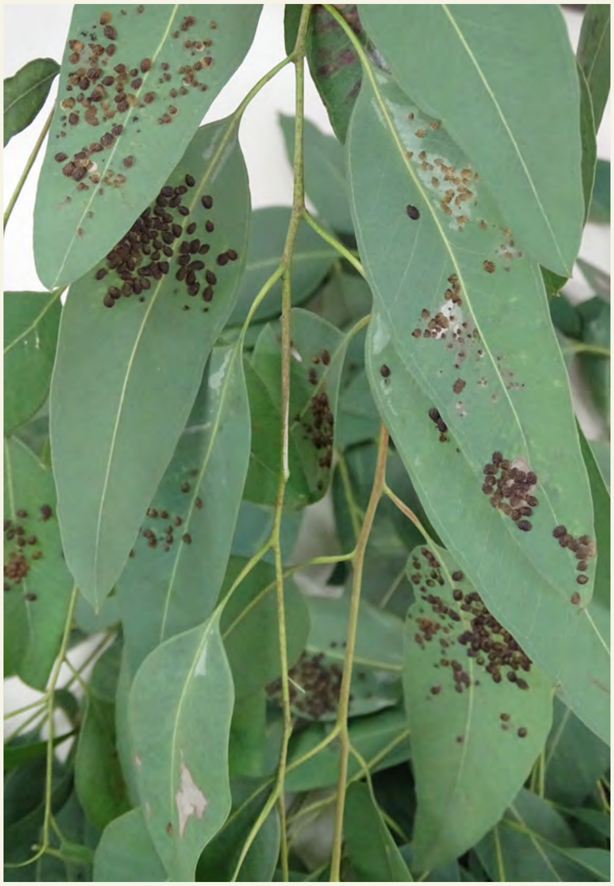
Damage on leaves.

Biological control agent

Adult of *Closterocerus* sp. (Hymenoctera: Eulophidae).

Spondyliapsis sp.

(Hemiptera: Psyllidae)
-Shell lerp psyllid



▲ Eucalyptus leaves infested with *Spondyaliapsis* sp.

▲▲ Adults.

▲▶ Heavily infested leaves.

Eggs.

First instar nymphs.

Last instar nymphs and adults.

DISEASES ON *Eucalyptus*

Teratosphaeria destructans

–*Eucalyptus* shoot and leaf blight

▲ Symptoms associated with infection by *Teratosphaeria destructans*.

▼▶ Different levels of infection of leaves showing upper and lower leaf surfaces.

High level of infection and necrotic leaf tissues.

Initial and advanced levels of infection.

Sporulation on the lower side of a leaf.

Teratosphaeria zuluensis
–Eucalyptus stem canker

Heavily infected trees in a Eucalyptus plantation.

Typical lesions on the bark.

Lesions on stem with fruiting bodies.

External and internal lesions on trunk.

Lesion with small fruiting bodies (pycnidia) on the surface.

Different lesion forms on the bark of *Eucalyptus* trees.

Teratosphaeria pseudoeucalypti

–*Eucalyptus* leaf spot

▲ Defoliation of Eucalyptus trees.

▼▶ Chlorotic spots typical of initial lesions.

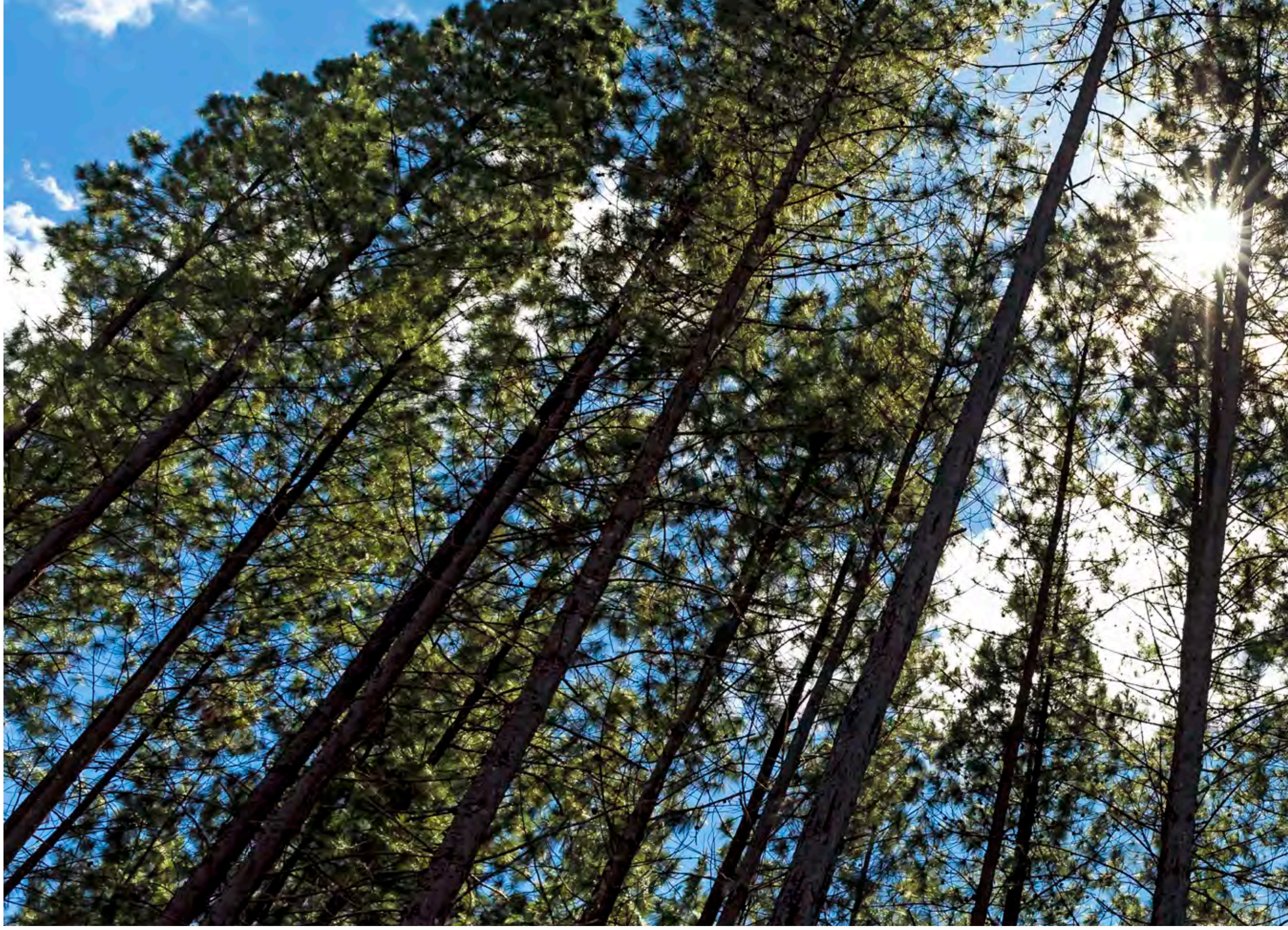
Necrotic lesion with fruiting bodies on leaf.

Symptoms on lower and upper surface of leaves.

Quambalaria eucalypti
–Leaf spot and shoot blight

Lesions and sporulation typical of infection.

Necrotic lesions on shoots after inoculation.

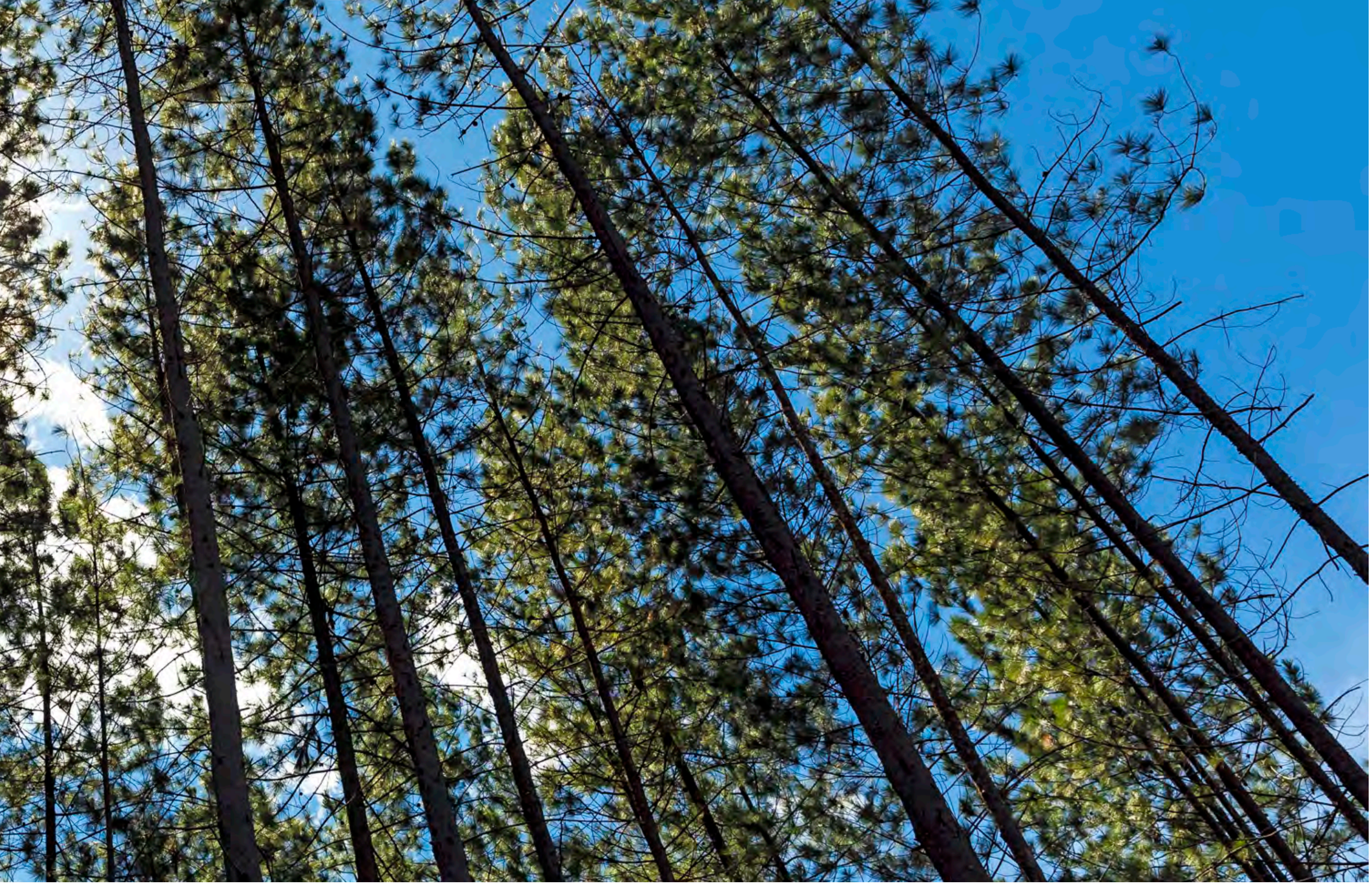


FUTURE PROSPECTS

Until relatively recently, very little was known regarding pests and pathogens of *Pinus* spp. and *Eucalyptus* spp. in Colombia. Nevertheless, these agents of disease and tree death have gradually increased in their significance. They now represent a serious and growing threat to future plantation productivity. This understanding, alongside the fact that plantation forestry is set to increase substantially in Colombia, strongly suggests that substantial investment in confronting this threat is essential to the future sustainability of the industry.

In the case of pest insects, Geometridae are the principal defoliators causing economic loss in *Pinus* and *Eucalyptus* plantations. Amongst the most important of these pests are *G. bisulca*, *O. trychiata*, *C. semilutearia* and *C. arana*. However in recent years, damage and economic loss has been considerably reduced due to effective Integrated Pest Management strategies, with the emphasis on biological control.

Stick insect (Phasmatodea) populations are now being effectively managed with the egg parasitoid *Adelphe* sp. and *B. bassiana* as biological control agents.



Source: Smurfit Kappa

Leaf cutting ants (*Atta* spp.) still remain a serious threat to tree plantations, as there are few options for ant control other than chemicals. In this regard, the use of chemicals is being increasingly prohibited due to their toxic effects. The development of safer alternative control measures should be a high priority.

The negative consequences of diseases such as those caused by the pathogen *D. sapinea*, *D. septosporum*, *Lecanosticta* cf *acicola*, *F. circinatum* and *Calonectria* spp. on *Pinus* spp. and *C. cubensis*, *B. ribis*, *C. spathulatum*, *A. psidii*, *C. neglecta* and *R. solanacearum* on *Eucalyptus* spp. have now been recognized as of serious economic importance. Preventative strategies are largely focused on the selection of disease tolerant planting stock. However, silvicultural techniques that maintain plantation conditions unfavorable to infection by disease are also considered significant and are being actively pursued.

Two of the most important strategies to reduce plantation tree loss are risk assessment and continual monitoring. These ensure an understanding of potential impact and early detection of any new pest and disease problems that may threaten plantation forestry. These strategies form an integral part of the Integrated Pest and Disease Management program in Colombia.

In order to reduce losses in the future, research into tree plantation pests and diseases must be advanced. This should include field-based studies underpinned by a deep understanding of the biology of the pest and disease agents. This knowledge should strongly inform the development of pest and disease management strategies. Ultimately, pest and disease research should be an ongoing priority for all forestry companies, as well as for the Colombian government.

Table 1

IMPORTANT **INSECT PESTS** ON FORESTRY plantation species in Colombia

Order: Lepidoptera

Family	Species	Year of detection	Damage	Life cycle (days)	Host	Report by
Geometridae	*Glena bisulca* Rindge	1968	Defoliation	90-120	Pp, Pt, Pm, Cl, Eg	Bustillo 1970, Drooz and Bustillo 1972, Vélez 1972
	Glena sp.	1990	Defoliation	81	Pp, Pt	Rodas 1996[1]
	Oxydia trychiata	1953	Defoliation	120	Pp, Pm, Cl, Eg	Gallego 1959
	Cargolia arana	1979	Defoliation	74-95	Pp, Cl, Pt, Pm	Wiesner & Madrigal 1983
	Cargolia pruna	1992	Defoliation	--	Pp, Cl	Madrigal 2003
	Chrysomima semilutearia	1990	Defoliation	94	Pp, Cl, Pt, Pm, Eg	Rodas 1994[1]
	Melanolophia commotaria	1982	Defoliation	--	Eg, Eu, Es	Madrigal 2003
	Oxydia vesulia	1997	Defoliation	--	Pp, Eu,Eg	Madrigal 2003
	Sabulodes caberata	1997	Defoliation	--	Eg, Eu, Es	Madrigal 2003
	Bassania schreiteri	1979	Defoliation	98	*Pinus* spp., Eg	Wiesner & Madrigal 1983
	Thyrinteina arnobia	2020	Defoliation	--	Eu	Manuel Luke, personal comunication 2020
Hepialidae	*Aepytus* sp.	1992	Borer	--	*Eucalyptus* spp.	Madrigal 2003
Megalopygidae	*Mesoscia eriophora*	1992	Defoliation	--	*Pinus* spp.	Rodas 1992[2], Madrigal 2003
Mimallonidae	*Mimallo amilia*	2010	Defoliation	--	*Eucalyptus* spp.	Madrigal 2003
Noctuidae	*Lichnoptera gulo*	1971	Defoliation	103	Pp, Eg, Cl	Bustillo 1975
Notodontidae	*Nystalea nyseus*	2016	Defoliation	--	Eg, Euro, Pg, Es	Rodas 2016[2] Sanabria & Cano 2017[3]
Lymacodidae	*Phobetron hipparchia*		Defoliation	55-65	*Eucalyptus* spp.	Madrigal 2003
Lymantriidae	*Sarcina purpurascens*	2016	Defoliation	88	Eg	Rodas 2016[2]
Saturniidae	*Dirphia somniculosa*	1980	Defoliation	1 year	*Pinus* spp., Tl	Wiesner & Madrigal 1983
Riodinidae	*Euselasia pance*	2016	Defoliation	75	Eg, Eu, E	Rodas 2016[2]
Psychidae	*Oiketicus kirby*	1991	Defoliador	1 year	*Pinus* spp., Eg	Madrigal 2003

Order: Hemiptera

Adelgidae	*Pineus boerneri*	2008	Sucking	66	*Pinus* spp.	Rodas et al. 2015
Clastopteridae	*Clastoptera* sp.	2005	Sucking	--	Eg	Madrigal 2003
Miridae	*Monalonion velezangeli*	2009	Sucking	61	Eg, Eu	Rodas et al. 2015
	Horciacisca signatus	1995	Sucking	--	Eg, Eu, Es	Rodas 1995[2], Madrigal 2003
Psyllidae	*Glycaspis brimblecombei*	2005	Defoliation	--	Et, Ec, Eg	Rodas et al. 2015

Order: Hymenoptera

Formicidae	*Atta cephalotes*	1958	Defoliation	177	*Pinus* spp., Cl, *Eucalyptus* spp.	Mackay & Mackay 1986

Order: Coleoptera

Family	Species	Year of detection	Damage	Life cycle (days)	Host	Report by
Chrysomelidae	*Chalcophana* sp.	--	Defoliation	--	*Eucalyptus* spp.	Madrigal 2003
Scarabaeidae	*Phyllophaga* sp.	--	Roots	1 year	*Eucalyptus* spp.	Madrigal 2003
	Platycoelia nigrosternalis	2008	Defoliation	--	Pp	Rodas 2013
	Golofa porteri	2003	Bark removal	--	Eg, Eu	Rodas 2003[2]
Curculionidae	*Compsus* sp.	--	Defoliation	--	*Pinus* spp.	Madrigal 2003
	Gonipterus platensis	2016	Defoliation	-	*Eucalyptus* spp.	Madrigal 2016[4]
	Megaplatypus dentatus	2017	Borer	-	Eg, Eu	Rodas et al. 2017[2]
	Platypus sp.	2017	Borer	-	Eg, Eu	Rodas et al. 2017[2]
	Corthylus sp.	2017	Borer	-	Eg, Eu	Rodas et al. 2017[2]
	Euwallacea sp.	2017	Borer	-	Eg, Eu	Rodas et al. 2017[2]
	Xyleborus sp.	2017	Borer	-	Eg, Eu	Rodas et al. 2017[2]
Melolonthidae	*Anomala* sp.	--	Defoliation	1 year	*Pinus* spp., Eg	Madrigal 2003

Order: Phasmida

Heteronemiidae	*Litosermyle ocanae*	1988	Defoliation	199	Pp	Rodas et al. 2018[5]
	Ceroys quadrispinosus	1997	Defoliation	--	Pp	Rodas et al. 2017[5] Madrigal 2003[5]
Pseudophasmatidae	*Planudes cortex*	1987	Defoliation	192	Pp	Rodas et al. 2017[5] Madrigal 2003[5]

Order: Thysanoptera

Thripidae	*Selenothrips rubrocinctuns*	1997	Sucking	--	Pp	Madrigal 2003

Order: Acari

Tetranychidae	*Tenuipalpus* sp. *Oligonichus* sp.	2015	Defoliation	--	Eg, Eu	Rodas et al. 2015[2]

Ec: *E. camaldulensis*
Eci: *E. cinerea*
Eg: *E. grandis*
Egl: *E. globulus*
Es: *E. saligna*
Epu: *E. pulvurulenta*
Et: *E.tereticornis*
Euro: *E. urophylla*
Eu: *E. urograndis*
Pp: *P. patula*
Pk: *P. kesiya*
Po: *P. oocarpa*
Pt: *P. tecunumanii*
Pe: *P. elliottii*
Pm: *P. maximinoi*
Cl: *Cupressus lusitanica*
Tl: *Tibouchina lepidota*
Es: *Eugenia stipitata*
Pg: *Psidium guajava*

1. Identification made by Dr. Douglass Ferguson, Taxonomic Services Unit of the Systematic Entomology Laboratory, PSI, USDA.
2. Internal Report Smurfit Kappa - Unpublished data.
3. Reference report: "Estudios biológicos de *Nystalea nyseus* (Lepidoptera: Notodontidae) en *Eucalyptus tereticornis* en Caucasia (Antioquia)".
4. Reported by Alejandro Madrigal 2016, presented in XLVI Congreso Sociedad Colombiana de Entomología, Memorias. Julio 2019, p. 13.
5. Identification was made through C.A. Rodas in 1990, by Dr. David Nickle, Research entomologist, Systematic Entomology Laboratory, PSI, USDA.

Table 2 IMPORTANT **PATHOGENS** ON SPECIES of *Pinus* and *Eucalyptus* in Colombia

Family	Pathogen	Year of detection	Age of trees	Host	Reported by
Nectriaceae	*Fusarium circinatum*	2005	From Nursery	Pp, Pm, Pt	Steenkamp et al. 2012
	Calonectria spp.	2007	From Nursery	Pm, Pt	Lombard et al. 2009
	Calonectria spathulatum	1995	From 1 year	*Eucalyptus* spp.	Rodas et al. 2005
Mycosphaerellaceae	*Dothistroma septosporum*	2008	From 3-month-old	Pt, Pk, Po, Pm	Rodas et al. 2015
	Lecanosticta sp. cf *L. acicola*	2009	From 1 year	Pm, Pp, Pt	Rodas et al. 2009[1]
Botryosphaeriaceae	*Diplodia sapinea*	1984 -2004	From 4-year-old	Pp, Pt	Hoyos 1987, Rodas & Osorio 2008
	Botryosphaeria ribis	1991	From 6-month-old	Eg, Eu	Rodas et al. 2009
Cryphonectriaceae	*Chrysoporthe cubensis*	1995 - 2003	From 6-month-old	Eg, Eu	Wingfield, Rodas et al. 2001, Rodas 2003
Sphaerophragmiaceae	*Austropuccinia psidii*	2011	From Nursery until 2-year-old	Eg, Eu	Rodas et al. 2015, Granados et al. 2017
Ceratocystidaceae	*Ceratocystis neglecta*	2008	From 6-month-old	Eg, Eu	Rodas et al. 2008
Ralstoniaceae	*Ralstonia solanacearum*	2014	From 1-year-old	Eg, Eu	MJW and CAR unpublished data
Erwiniaceae	*Pantoea rodasii*	2012	From Nursery until 2-year-old	Eg, Eu	Brady L. et al. 2012
Teratosphaeriaceae	*Teratosphaeria epicoccoides*	--	From Nursery	*Eucalyptus* spp.	--
Sclerotiniaceae	*Botrytis cinerea*	--	From Nursery	*Eucalyptus* spp.	--
Schizoparmeaceae	*Coniella eucalypti*	--	From 6-month-old	*Eucalyptus* spp.	--

Pp: *P. patula*
Pk: *P. kesiya*
Po: *P. oocarpa*
Pt: *Pinus tecunumanii*
Eg: *E. grandis*
Eu: *E. urograndis*
Pm: *P. maximinoi*

1. Internal Report Smurfit Kappa - Unpublished data.

REFERENCES

Alfenas AC, Valverde AE, Gonçalves R, Francisco de Assis T. 2004. *Clonagem e Doenças do Eucalipto*. Viçosal: Universidade Federal de Viçosa.

Barnard EL, Geary T, English JT, Gilly SP. 1987. Basal cankers and coppice failure in *Eucalyptus grandis* in Florida, USA. *Plant Disease* 71:358-361.

Barnes I, Crous PW, Wingfield BD, Wingfield MJ. 2004. Multigene phylogenies reveal that red band needle blight of *Pinus* is caused by two distinct species of *Dothistroma*, *D. septosporum* and *D. pini*. *Studies in Mycology* 50:551-565.

Barnes I, Kirisits T, Akulov A, Chhetri DB, Wingfield BD, Bulgarov TS, Wingfield MJ. 2008. New host and country records of the Dothistroma needle blight pathogens from Europe and Asia. *Forest Pathology* 38:178-195.

Barnes I, Roux J, Wingfield BD, O'Neill M, Wingfield MJ. 2003. *Ceratocystis fimbriata* infecting *Eucalyptus grandis* in Uruguay. *Australasian Plant Pathology* 32:361-366.

Bedford G. 1978. Biology and Ecology of the Phasmatodea. *Annual Review of Entomology* 23:125-149.

Brennan EB, Gill RJ, Hrusa GF, Weinbaum SA. 1999. First record of *Glycaspis brimblecombei* (Moore) (Homoptera: Psyllidae) in North America: Initial observations and predator associations of a potentially serious new pest of eucalyptus in California. *Pan-Pacific Entomologist* 75:55-57.

Brown A, Rose D, Webber J. 2003. Red Band Needle Blight of Pine. *Forestry Commission Information Note (FCIN)* 49:1-6.

Brown PMJ, Thomas CE, Lombaert E, Jeffries DL, Estoup A, Handley L-JL. 2011. The global spread of H*armonia axyridis* (Coleoptera: Coccinellidae): distribution, dispersal and routes of invasion. Bio*Control*. 56:623-641. doi: 10.1007/s10526-011-9379-1

Burgess TI, Wingfield MJ. 2017. Pathogens on the move: A 100-year global experiment with planted eucalypts. *Bioscience* 67:14-25.

Bustillo AE. 1970. Gusano defoliador del ciprés. ICA Regional 4. *Boletín de Divulgación* 31, 1-12.

Bustillo AE. 1975. Estudios del gusano rojo peludo. *Lichnoptera gulo* Herrich-Schaeffer (Lepidoptera: Noctunidae), plaga del pino y del ciprés. I Biología y Ecología. *Revista Colombiana de Entomología* 1:15-20.

Bustillo AE. 1976a. Diferencias en el ciclo de vida e incidencia en el número de instares de *Glena bisulca* (Lepidoptera: Geometridae) a diferentes temperaturas ambientales. *Revista Colombiana de Entomología* 2:99-103.

Bustillo AE. 1976b. Estudio biológico del medidor gigante *Oxydia trychiata*, plaga de coníferas en Colombia. *Revista Colombiana de Entomología* 2:41-61.

Bustillo AE. 1978. Manejo integrado de plagas forestales en Colombia. In *Seminario sobre Manejo de Plaguicidas y Manejo del Ambiente* (February 13-17). Bogotá, Colombia.

Bustillo AE. 1979. ¿Qué causa los brotes de *Glena bisulca¿* Recomendaciones sobre su manejo. In *Seminario sobre Plagas Forestales en Colombia - Socolen* (September 6-7). Medellín, Colombia.

Bustillo AE, Drooz AT. 1977. Cooperative establishment of a Virginia (USA) strain of *Telenomus alsophilae* on *Oxydia trychiata* in Colombia. *Journal of Economic Entomology* 70:767-770.

Callaghan CJ. 1999. New taxa of Neotropical Riodinidae (Lepidoptera. *Revista Brasileira de Zoologia* 16(4):1045-1064.

Camargo RS, Forti LC, Lopes JFS, Matos CA. 2008. Growth of Populations and Fungus Gardens of *Atta sexdens rubropilosa* (Hymenoptera, Formicidae) Response to Foraged Substrates. *Sociobiology* 52:1-11.

Camargo RS, Forti LC, Lopes JFS, Nagamoto NS. 2006. Studies on Leaf-cutting ants, *Acromyrmex* spp. (Formicidae, Attini): Behaviour, reproduction and control. *Recent Research Developments in Entomology* 5:1-21.

Carnegie AJ, Lidbetter JR. 2012. Rapidly expanding host range for *Puccinia psidii* sensu lato in Australia. *Australasian Plant Pathology* 41:13-29.

Carstensen GD, Venter SN, Wingfield MJ, Coutinho TA. 2017. Two *Ralstonia* species associated with bacterial wilt of *Eucalyptus*. *Plant Pathology* 66:393-404.

Carvalho JCM, Costa LAA. 1988. Mirídeos Neotropicais, CCXCVII: Duas Novas Espécies do Gênero *Monalonion* Herrich-Schaeffer (Hemiptera. *Revista Brasileira de Biologia* 48:893-896.

Chen SF, Lombard L, Roux J, Xie YJ, Wingfield MJ, Zhou XD. 2011. Novel species of *Calonectria* associated with *Eucalyptus* leaf blight in Southeast China. *Persoonia* 26:1-12.

Ciesla WM, Diekmann M, Putter CAJ. 1996. *Eucalyptus* spp. technical guidelines for the Safe Movement of Germplasm 17, Rome: FAO/IPGRI.

Conle O, Hennemann F, Gutiérrez Y. 2011. The stick insects of Colombia. Norderstedt, Germany: Books on Demand.

Coutinho TA, Wingfield MJ. 2017. *Ralstonia solanacearum* and *R. pseudosolanacearum* on *Eucalyptus*. Opportunists or primary pathogens? *Frontiers in Plant Science* 8:3. Doi. 10.3389/fpls.2017.00761.

Coutinho TA, Wingfield MJ, Alfenas AC, Crous PW. 1998. Eucalyptus rust: A Disease with the Potential for Serious International Implications. *Plant Disease* 82:819-825.

Covell Jr CV. 1964. A new species of *Cargolia* (Geometridae: Ennominae) from Mexico, with transfers of species. *Journal of the Lepidopteristis' Society* 18:111-115.

Crous PW. 2002. Taxomony and pathology of *Cylindrocladium* (*Calonectria*) and allied general. Minnesota: The American Phytopathological Society.

Crous PW, Groenewald JZ, Wingfield MJ, Rodas-Peláez CA. 2015. Fungal Planet description sheets: 320–370. *Persoonia* 34:167-266.

Crous PW, Wingfield MJ. 1994. A monograph of *Cylindrocladium*, including anamorphs of *Calonectria*. *Mycotaxon* 55:341-345.

Dahlsten DL, Rowney DL. 2000. The Red Gum Psyllid, a new pest of *Eucalyptus* species in California. University of California at Berkeley, College of Natural Resources, Center for biological Control. (In *Proc. the 48th Annual Meeting of the California Forest Pest Council*. November 18-19, 1999). Sacramento, California.

Davison EM, Coates DJ. 1991. Identification of *Cryphonectria cubensis* and *Endothia gyrosa* from eucalypts in Western Australia using isozyme analysis. *Australasian Plant Pathology* 20:157-160.

Departamento Administrativo Nacional de Estadística [DANE]. 2018. Boletín Técnico. Cuenta ambiental y económica de flujos de productos del bosque 2015-2016. Cuenta Satélite Ambiental (CSA). Bogotá.

Díaz T, Ordóñez E. 1975. Reporte preliminar de insectos, ácaros y hongos relacionados con los bosques colombianos. Medellín: Inderena.

Drooz AT, Bustillo AE. 1972. *Glena bisulca*, a serious defoliator of *Cupressus lusitanica* in Colombia. *Journal of Economic Entomology* 65:89-93.

Drooz AT, Bustillo AE, Fedde GF, Fedde VH. 1977. North American egg parasites successfully controls a different host genus in South America. *Science* 197(4301):390-391.

Fenilli, R. 1982. First record of *Gonipterus platensis* Marelli, 1926 and *Gonipterus gibberus* (Boisduval, 1835) (Coleoptera, Curculionidae, Gonipterinp) in the State of Santa Catarina, Brazil. *Anais da Sociedade Entomológica do Brasil* 11(2):293-294.

Fernández F, Castro-Huertas V, Serna F. 2015. Hormigas cortadoras de hojas de Colombia: *Acromyrmex & Atta* (Hymenoptera: Formicidae). In Fauna de Colombia - Monografía No. 5. Bogotá D.C.: Instituto de Ciencias Naturales, Universidad Nacional de Colombia.

Food and Agriculture Organization of the United Nations [FAO]. 2007. Forest Health & Biosecurity Working Papers. Overview of Forest Pest: Colombia. Forestry Department. Working Paper FBS/14E. Rome: FAO.

Food and Agriculture Organization of the United Nations [FAO]. 2011. Guide to implementation of phytosanitary standards in forestry. FAO Forestry Paper 164. Rome: FAO.

Food and Agriculture Organization of the United Nations [FAO]. 2017. Estado de los bosques y el sector forestal en la región. Comisión Forestal para América Latina y el Caribe. Trigésima Reunión Tegucigalpa, Honduras. Nota de Secretaría. FO:LACFC/2017/2.

Food and Agriculture Organization of the United Nations [FAO]. 2018. FAOSTAT statistics database. Rome. [Accessed February 12, 2019] http://www.fao.org/faostat/en/#data

Forti LC, Castellani MAP. 1997. Formigas cortadeiras: Biologia, Ecologia, Danos e Controle. Botucatu: FCA/UNESP.

Forti LC, Pretto DR, Nagamoto NS, Padovani CR, Camargo RS, Andrade APP. 2007. Dispersal of the delayed action insecticide sulfluramid in colonies of the leaf-cutting ant *Atta sexdens rubropilosa* (Hymenoptera: Formicidae). *Sociobiology* 50:1-15.

Gallego FL. 1959. Gusano Geometridae (medidor) de los pinos. *Revista Facultad Nacional de Agronomía Medellín* 19(53):59-62.

Gibson IAS. 1972. *Dothistroma* blight of *Pinus radiata*. *Annual Review of Phytopathology* 10:51-72.

Gibson IAS. 1979. Pests and Diseases of Pines in the Tropics. *European Journal of Forest Pathology* 9:126-127.

Gibson IAS. 1980. Two Pine Needle Fungi New to Colombia. *Tropical Pest Management* (26):38-40.

Giraldo M, Acevedo FE, Benavides P, Villegas C. 2009. Evaluación morfológica y molecular de insectos del género *Monalonion* spp. (Hemiptera: Miridae) alimentándose de cultivos de café, guayaba, cacao y aguacate. In *Resúmenes XXXVI Congreso Sociedad Colombiana de Entomología - Socolen*. Medellín, Colombia.

Glen M, Alfenas AC, Zauza EAV, Wingfield MJ, Mohammed C. 2007. *Puccinia psidii*: a threat to the Australian environment and economy - A review. *Australasian Plant Pathology* 36:1-16.

Granados GM, McTaggart AR, Barnes I, Rodas CA, Roux J, Wingfield MJ. 2017. The pandemic biotype of *Austropuccinia psidii* discovered in South America. *Australasian Plant Pathology* 46:267-275. doi: 10.1007/s13313-017-0488-x.

Gryzenhout M, Myburg H, Van der Merwe NA, Wingfield BD, Wingfield MJ. 2004. *Chrysoporthe*, a new genus to accommodate *Cryphonectria cubensis*. *Studies in Mycology* 50:119-142.

Gryzenhout M, Rodas CA, Mena-Portales J, Clegg P, Wingfield B.D, Wingfield MJ. 2006. Novel host of the *Eucalyptus* canker pathogen *Chrysoporthe cubensis* and a new *Chrysoporthe* species from Colombia. *Mycological Research* 110:833-845.

Gryzenhout M, Wingfield BD, Wingfield MJ. 2009. Taxonomy, phylogeny, and ecology of bark-inhabiting and tree-pathogenic fungi in the Cryphonectriaceae. Minnesota: The American Phytopathological Society.

Hodges CS, Alfenas AC, Cordel CE. 1986. The conspecificity of *Cryphonectria cubensis* and *Endothia eugeniae*. *Mycologia* 78:334-350.

Hodges CS, Reis MS, Ferreira FA, Henfling JDM. 1976. O cancro do eucalipto causado por *Diaporthe cubensis*. *Fitopatologia Brasileira* 1:129-170.

Hoyos C. 1987. Determinación del agente causal de la muerte descendente del *Pinus patula* en el Valle del Cauca (tesis de pregrado. Universidad Nacional de Colombia, Medellín, Colombia. [Accessed October 17, 2012] http://www.cnr.berkeley.edu/biocon/dahlsten/rglp/Dahlsten-handout_rglp.pdf

Instituto Colombiano Agropecuario [ICA]. 2020. (ICA- SPV-DTEVF-. Bogotá: Subgerencia de Protección Vegetal - Dirección Técnica de Epidemiología y Vigilancia Fitosanitaria. Programa Fitosanitario Forestal.

Kliejunas JT, Tkacz BM, Burdsall Jr HH, DeNitto GA, Eglitis A, Haugen DA, Wallner WE. 2001. Pest risk assessment of the importation into the United States of unprocessed Eucalyptus logs and chips from South America. General Technical Report, Forest Products Laboratory, USDA Forest Service, No. FPL-GTR-124. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. https://doi.org/10.2737/FPL-GTR-124.

Ladrach WE. 1992. Plantation establishment techniques in tropical America. *Tree Planters' Notes* 43:25-132.

Laia ML, Alfenas AC, Harrington TC. 1999. Isolation, detection in soil, and inoculation of *Ceratocystis fimbriata*, causal agent of wilting, die-back and canker in *Eucalyptus*. In L. Morin (Ed.). Proclamations of the Biennial Conference. 12th Australasian Plant Pathology Society. (September 27-30). Canberra, Australia.

Liebhold AM. 2012. Forest pest management in a changing world. *International Journal of Pest Management* 58:289-295.

Lombard L, Rodas CA, Crous PW, Wingfield BD, Wingfield MJ. 2009. Calonectria (*Cylindrocladium*) species associated with dying *Pinus* cuttings. *Persoonia* 23:41-47.

Lombard L, Zhou XD, Crous PW, Wingfield BD, Wingfield MJ. 2010. *Calonectria* species associated with cutting rot of *Eucalyptus*. *Persoonia* 24:1-11.

Londoño ME, Vargas HH. 2010a. *Monalonion velezangeli* Carvalho y Costa (Hemiptera: Miridae. ¿Por qué es una plaga de importancia en cultivos de aguacate? In VII Seminario Internacional de Frutas Tropicales - Agroindustria e Innovación (July 22-23), Medellín, Colombia.

Londoño ME, Vargas HH. 2010b. Avances en la identificación de hospederos de *Monalonion velezangeli* (Hemiptera: Miridae. In Resúmenes XXXVII Congreso Sociedad Colombiana de Entomología - Socolen. (June 30 - July 2). Bogotá, Colombia.

Luttrell ES. 1950. *Botryosphaeria* stem canker of elm. *Plant Disease Reporter* 34:138-139.

Mackay W, Mackay E. 1986. Las hormigas de Colombia: arrieras del género *Atta* (Hymenoptera: Formicidae). *Revista Colombiana de Entomología* 12:23-30.

Madrigal A. 1997. Los fásmidos como plaga potencial de la reforestación en Colombia. In Resúmenes XXIV Congreso de la Sociedad Colombiana de Entomología. (July 16-18). Pereira, Colombia. pp. 225-249.

Madrigal A. 2003. Insectos forestales en Colombia. Biología, hábitos, ecología y manejo. Universidad Nacional de Colombia. Medellín, Colombia: Marín Viecco.

Madrigal A. 2019. *Gonipterus platensis* Marrelli (Coleoptera: Curculionidae) nueva plaga de importancia forestal en Colombia. En: 46 Congreso Sociedad Colombiana de Entomología. Desafíos entomológicos en la ocupación del territorio. Memorias & Resúmenes. Medellín, Colombia, 17, 18 y 19 de julio de 2019. p. 303-313.

Madrigal A, Abril G. 1994. Biología y hábitos del insecto-palo (*Libethroidea inusitata* Hebard) defoliador del *Pinus patula* en Antioquia. *Crónica Forestal y del Medio Ambiente* 19:25-36.

Madrigal A, Wiesner RL, Arango EMI. 1985. *Oxydia platypterata* guenée, *Sabulodes glaucularia* (Snellen) y medidor campanita, tres nuevos defoliadores de importancia forestal en Colombia. *Revista Colombiana de Entomología* 11:21-26.

Mapondera TS, Burgess T, Matsuki M, Oberprieler RG. 2012. Identification and molecular phylogenetics of the cryptic species of the *Gonipterus scutellatus* complex (Coleoptera: Curculonidae: Gonipterini), *Australian Journal of Entomology* 51(3): 175-188.

Marín M, Castro B, Gaitán A, Wingfield BD, Wingfield MJ. 2003. Relationships of *Ceratocytsis fimbriata* isolates from Colombian coffee-growing regions based on molecular data and pathogenicity. *Journal of Phytopathology* 151:396

Mendes-Filho JM de A. 1981. Técnicas de combate ás formigas. In Mariconi F de AM, Mendes JM de A, Filho-Moraes TS de A (eds.) Reunião Técnica sobre: Formigas Cortadeiras em Povoamentos Florestais. *Série* Técnica-*IPEF Piracicaba 2*(7):1-29.

Ministerio de Agricultura y Desarrollo Rural [MADR]. 2019. Colombia: Minagricultura actualiza información estadística sobre plantaciones forestales en el país. Bogotá, Colombia.

Mitchell RG, Steenkamp ET, Coutinho TA, Wingfield MJ. 2011. The pitch canker fungus, *Fusarium circinatum:* implications for South African forestry. *Southern Forest* 73:1-13.

Newman D. 1980. Susceptibilidad de algunos árboles al ataque defoliador del gusano canasta (Oiketicus kirbyi Guilding) en el Valle del Cauca. Cali, Colombia: Smurfit Kappa Cartón Colombia.

Noguera A. 1982. Colombia bajo la sombra de sus árboles. Colombia: Fondo Cultural Cafetero - Corporación Nacional de Investigación y Fomento Forestal.

Old KM, Wingfield MJ, Yuan ZQ. 2003. A Manual of Diseases of Eucalyptus in South-East Asia. Canberra: Center for International Forestry Research.

Ortiz A. 1998. Selección y evaluación de una cepa de *Trichoderma* o *Gliocladium* para el control de *Atta cephalotes* en condiciones de laboratorio (tesis de posgrado en Entomología. Universidad Nacional de Colombia. Medellín, Colombia.

Ortiz A, Guzmán GE. 2007. Las hormigas cortadoras en el departamento de Antioquia. Medellín, Colombia: Universidad de Antioquia, Secretaría de Agricultura de Antioquia, Gobernación de Antioquia, Universidad Nacional de Colombia.

Paine TD, Dreistadt SH, Garrison RW, Gill RJ. 2006. Eucalyptus Redgum Lerp psyllid. *Pest Notes*, 7460:1-4. [Accessed October 17, 2012] http://www.ipm.ucdavis.edu/PDF/PESTNOTES/pneucalyptusredgumpsyllid.pdf

Pérez-Sierra A, Landeras E, León M, Berbegal M, García-Jiménez J, Armengol J. 2007. Characterization of *Fusarium circinatum* from *Pinus* sp. in Northern Spain. *Mycological Research*. 111(7):832-839.

Pérez CA, Wingfield MJ, Altier NA, Simeto S, Blanchette RA. 2011. *Puccinia psidii* infecting cultivated *Eucalyptus* and native myrtaceae in Uruguay. *Mycological Progress* 10:273-282.

Quinlan RJ, Cherret JM. 1979. The role of fungus in the diet of the leaf-cutting ants *Atta cephalotes* (L). *Ecological Entomology* 4:151-160.

Ramírez HJ, Gil ZN, Benavides P, Bustillo AE. 2007. Estudio de los insectos asociados a un nuevo disturbio en café denominado Chamusquina. Universidad de Nariño. *Revista de Agronomía* 24:63-75.

Rodas CA. 1994. *Chrysomima semilutearia* (Felder & Rogenhofer) Nuevo defoliador de plantaciones forestales en Colombia. Informe de Investigación *- Smurfit Cartón de Colombia Investigación Forestal* 164:1-7.

Rodas CA. 1996. Una nueva especie de *Glena* (*Glena* sp. Lepidoptera: *Geometridae*) defoliador de *Pinus patula* en Colombia. Informe de Investigación *- Smurfit Kappa Cartón de Colombia Investigación Forestal* 172:1-7.

Rodas CA. 1997. Manejo de defoliadores en plantaciones forestales. Informe de Investigación *- Smurfit Kappa Cartón de Colombia Investigación Forestal* 185:1-14.

Rodas CA. 2003. Diseases of *Eucalyptus* in Colombia (M.Sc. Thesis). University of Pretoria, Pretoria, South Africa.

Rodas CA. 2013. Important pests and diseases of plantations grown *Pinus* and *Eucalyptus* in Colombia and their control (Ph.D. Thesis). University of Pretoria, Pretoria, South Africa.

Rodas CA, Gryzenhout M, Myburg H, Wingfield BD, Wingfield MJ. 2005. Discovery of the *Eucalyptus* canker pathogen *Chrysoporthe cubensis* on the *Miconia* (Melastomataceae) in Colombia. *Plant Pathology* 54:460-470.

Rodas CA, Hurley B, Bolaños M, Granados G, Wingfield MJ. 2017. Biology of *Litosermyle ocanae* in Colombian *Pinus patula* plantations. Southern Forests: a Journal of Forest Science, 80:3, 279-284. doi: 10.2989/20702620.2017.1334175

Rodas CA,, Lombard L, Gryzenhout M, Slippers B, Wingfield MJ. 2005. *Cylindrocladium* blight of *Eucalyptus grandis* in Colombia. *Australasian Plant Pathology* 34:143-149.

Rodas CA, Osorio E. 2008. *Segundo informe: Afección de* Diplodia *en plantaciones de Pinus patula*. Colombia: Smurfit Kappa Cartón Colombia.

Rodas CA, Roux J, Maier W, Granados G, Bolaños M, McTaggart R, Wingfield MJ. 2015. First report of *Puccinia psidii* on *Corymbia citriodora* and *Eucalyptus* in Colombia. *Forest Pathology* 45(6):534-536.

Rodas CA, Roux J, Van Wyk M, Wingfield BD, Wingfield MJ. 2008. *Ceratocystis neglecta* sp. nov, infecting *Eucalyptus* trees in Colombia. *Fungal Diversity* 28:73-84.

Rodas CA, Serna R, Bolaños M, Granados G, Wingfield MJ, Hurley B. 2015. Biology, incidence and host susceptibility of *Pineus boerneri* (Hemiptera: Adelgidae) in Colombian pine plantations. *Southern Forests: a Journal of Forest Science* 77(3):165-171. doi: 10.2989/20702620.2014.1001662.

Rodas CA, Serna R, Hurley B, Bolaños M, Granados G, Wingfield MJ. 2014. Three new and important insect pests recorded for the first time in Colombian plantations. *Southern Forests: a Journal of Forest Science* 76(4):245-252. doi: 10.2989/20702620.2014.965983.

Rodas CA, Slippers B, Gryzenhout M, Wingfield MJ. 2009. Botryosphaeriaceae associated with *Eucalyptus* canker diseases in Colombia. *Forest Pathology* 39:110-123.

Rodas CA, Wingfield MJ, Granados G, Barnes I. 2015. Dothistroma needle blight: an emerging epidemic caused by *Dothistroma septosporum* in Colombia. *Plant Pathology* 65:1-11.

Rosado-Neto GH. 1993. Gonipterinae dos eucaliptos: primeiro registro de *Gonipterus scutellatus* para o Estado de São Paulo, Brasil, e algumas considerações sobre *G. gibberus* (Coleoptera: Curculionidae. *Revista Brasileira de Entomologia* 37:465-467.

Rosado-Neto GH, Freitas S. 1982. Description of immature forms of the eucalyptus weevil *Gonipterus gibberus* Boisduval, 1835 (Coleoptera, Curculionidae. *Revista Brasileira de Biologia* 42:467-471.

Roux J, Greyling I, Coutinho TA, Verleur M, Wingfield MJ. 2013. The Myrtle rust pathogen, *Puccinia psidii*, discovered in South Africa. *International Mycological Association* 1:155-159.

Roux J, Van Wyk M, Hatting H, Wingfield MJ. 2004. *Ceratocystis* species infecting stem wounds on *Eucalyptus grandis* in South Africa. *Plant Pathology* 53:414-421.

Roux J, Wingfield MJ, Bouillet JP, Wingfield BD, Alfenas AC. 2000. A serious new wilt disease of *Eucalyptus* caused by *Ceratocystis fimbriata* in Central Africa. *Forest Pathology* 30:175-184.

Sanabria SA, Cano M. 2018. Estudios biológicos de *Nystalea nyseus* (Lepidoptera: Notodontidae) en *Eucalyptus tereticornis* en Caucasia (Antioquia). En: 44 Congreso Sociedad Colombiana de Entomología; Bogotá, D.C.: Socolen. p. 348.

Schoch CL. 1999. Phylogenetic relationships and population dynamics of Calonectria. (Thesis Ph.D. Agric.). University of Stellenbosch, South Africa.

Schröder ML, Slippers B, Wingfield MJ, Hurley BP. 2020. Invasion history and management of Eucalyptus snout beetles in the *Gonipterus scutellatus* species complex. *Journal of Pest Science* 93:11–2. https://doi.org/10.1007/s10340-019-01156-y

Schoeneweiss DF. 1981. The role of environmental stress in diseases of woody plants. *Plant Disease* 65, 308-314.

Seixas CDS, Barreto RW, Alfenas AC, Ferreira FA. 2004. *Cryphonectria cubensis* on an indigenous host in Brazil: a possible origin for eucalyptus canker disease? *Mycologist* 18, 39-45.

Sharma JK, Mohanan C, Florence EJM. 1985. Disease surrey in nurseries and plantations of forest tree species grow in Kerala. Kerala Forest Research Institute. *KFRI Research report* 36.

Silva A, Bacci M, Siqueira CG, Bueno OC, Pagnocca FC, Hebling MJA. 2003. Survival of *Atta sexdens* workers on different food sources. *Journal of Insect Physiology* 49:307-313.

Slippers B, Burgess T, Pavlic D, Ahumada R, Maleme H, Mohali S, Rodas C, Wingfield MJ. 2009. A diverse assemblage of Botryosphaeriaceae infecting Eucalyptus in native and non-native environments. *Southern Forest* 71:101-110.

Slippers B, Stenlid J, Wingfield MJ. 2005. Emerging pathogens: fungal host jumps following anthropogenic introduction. *Trends in Ecology and Evolution* 20:420-421.

Slippers B, Wingfield MJ. 2007. Review: Botryosphaeriaceae as endophytes and latent pathogens of woody plants: diversity, ecology and impact. *Fungal Biology Reviews* 21:90-106.

Smith H, Crous PW, Wingfield MJ, Coutinho TA, Wingfield BD. 2001. *Botryosphaeria eucalyptorum* sp. nov, a new species in the *B. dothidea*-complex on Eucalyptus in South Africa. *Mycology* 93:277-284.

Smith H, Kemp GHK, Wingfield MJ. 1994. Canker and die-back of Eucalyptus in South Africa caused by *Botryosphaeria dothidea*. *Plant Pathology* 43:1031-1034.

Steenkamp E, Rodas CA, Kvas M, Wingfield MJ. 2012. *Fusarium circinatum* and pitch canker of *Pinus* in Colombia. *Australasian Plant Pathology* 41:483-491.

Triplehorn CA, Johnson NF. 2005. Borror and DeLong's introduction to the study of insects. Belmont, CA: Thomson Brooks/Cole.

Universidad Nacional de Colombia [UNAL]. 1955. Apuntes sobre reforestación en Antioquia. *Revista Facultad Nacional de Agronomía* 47:5-65.

Uribe S. 2012. Identificación de los dípteros (Diptera: Phoridae) parasitoides y asociados al hábitat de hormigas cortadoras de hojas (*Atta cephalotes* y *Acromyrmex octospinosus*) y algunos aspectos de su biología (M.Sc. Thesis). Universidad Nacional de Colombia, Colombia.

Van der Merwe NA, Myburg H, Wingfield BD, Rodas C, Wingfield MJ. 2001. Identification of *Cryphonectria cubensis* from Colombia based on rDNA sequence data. *South African Journal of Science* 97:295-296.

Van Wyk M, Roux J, Kamgan G, Wingfield BD, Wingfield MJ. 2012. *Ceratocystis eucalypticola* sp. nov. from *Eucalyptus* in South Africa and comparison to global isolates from this tree. *IMA Fungus* 3:45-58.

Van der Nest A, Wingfield MJ, Janoušek J, Barnes I. 2019a. *Lecanosticta acicola:* A growing threat to expanding global pine forests and plantations. *Molecular Plant Pathology* 20:1327-1364. doi:10.1111/mpp.12853.

Van der Nest A, Wingfield MJ, Ortiz P, Barnes I. 2019b. Biodiversity of *Lecanosticta* pine-needle blight pathogens suggests Mesoamerican Centre of origin. *IMA Fungus* 10, 2. (2019). Doi:10.1186/s43008-019-0004-8.

Van Wyk M, Wingfield BD, Marin M, Wingfield MJ. 2010. New *Ceratocystis* species infecting coffee, cacao, citrus and native trees in Colombia. *Fungal Diversity* 40:103-107.

Vélez RA. 1972. El defoliador del ciprés *Glena bisulca* Ringde. *Revista Facultad Nacional de Agronomía* 29:7-8.

Vélez RA. 1997. Plagas agrícolas de impacto económico en Colombia: bionomía y manejo integrado (2a ed.). Medellín: Universidad de Antioquia.

Verza SS, Forti LC, Lopes JFS, Camargo RS, Matos CAO. 2007. Influence of physical and chemical factors during foraging and culture of the symbiont fungus in *Atta sexdens rubropilosa* (Hymenoptera: Formicidae). *Insect Science* 14:295-300.

Verza SS, Forti LC, Matos CAO, García MG, Nagamoto N. 2006. Attractiveness of citrus pulp and orange albedo extracts to *Atta sexdens rubropilosa* (Hymenoptera: Formicidae). *Sociobiology* 47:1-9.

Viljoen A, Wingfield MJ, Crous PW. 1992. Fungal pathogens in *Pinus* and *Eucalyptus* seedling nurseries in South Africa: A Review. *Suid-Afrikaanse Bosboutydskrif* 161: 45-51.

Watt MS, Kriticos DJ, Alcaraz S, Brown AV, Leriche A. 2009. The host and the potential geographic range of Dothistroma needle blight. *Forest Ecology and Management* 257: 1505-1519.

Webb RS. 1983. Seed capsule abortion and twig die-back of *Eucalyptus camaldulensis* in South Florida induced by *Botryosphaeria ribis*. *Plant Disease* 67:108-109.

Weber NA. 1972. *Gardening ants, the* Attinae. Philadelphia: American Philosophical Society.

Wene EG, Schoeneweiss DF. 1980. Localized freezing predisposition to *Botryosphaeria dothidea* in differentially frozen woody stems. *Canadian Journal of Botany* 58:1455-1458.

Wiesner RL, Madrigal CA. 1983. Principales plagas del ciprés, *Pinus patula* y eucalipto en Colombia. In Primer Seminario Internacional sobre Manejo de Plagas Forestales Socolen-Fundef. Medellín, Colombia. pp. 1-33.

Wingfield MJ. 2003. Daniel McAlpine Memorial Lecture: Increasing threat of diseases to exotic plantation forests in the Southern Hemisphere: lesson from *Cryphonectria* canker. *Australasian Plant Pathology* 32:133-139.

Wingfield MJ, Brokerhoff EG, Wingfield BD, Slippers B. 2015. Planted forest health: The need for a global strategy. *Science* 349:832-836. 10.1126/science.aac6674.

Wingfield MJ, Hammerbacher A, Ganley RJ, Steenkamp ET, Gordon TR, Wingfield BD, Coutinho TA. 2008. Pitch canker caused by *Fusarium circinatum* - a growing treat to pine plantations and forests Worldwide. *Australasian Plant Pathology* 37:319-334.

Wingfield MJ, Jacobs A, Coutinho TA, Ahumada R, Wingfield BD. 2002. First report of the pitch canker fungus, *Fusarium circinatum*, on pines in Chile. *Plant Pathology* 51:397.

Wingfield MJ, Rodas C, Myburg H, Venter M, Wright J, Wingfield BD. 2001. Cryphonectria canker on *Tibouchina* in Colombia. *Forest Pathology* 31:297-306.

Wingfield MJ, Roux J, Slippers B, Hurley BP, Garnas J, Myburg AA, Wingfield BD. 2013. Established and new technologies reduce increasing pest and pathogen threats to Eucalypt plantations. *Forest Ecology and Management* 301:35-42.

Wingfield MJ, Roux J, Wingfield BD. 2011. Insect pest and pathogen of Australian acacias grown as non-natives - An experiment in biogeography with far-reaching consequences. *Diversity and Distributions* 17:968-977.

Wingfield MJ, Slippers B, Roux J, Wingfield BD. 2001. Worldwide movement of exotic forest fungi, especially in the tropics and the Southern Hemisphere. *Bioscience* 51:134-140.

Wingfield MJ, Slippers B, Roux J, Wingfield BD. 2011. Fifty years of tree pest and pathogen invasions increasingly threatening world forests. In Richardson DM (ed.). *Fifty years of invasion ecology*. *The legacy of Charles Elton* (pp. 89-99). Oxford: Wiley-Blackwell.

Wingfield MJ, Slippers B, Wingfield BD. 2010. Novel associations between pathogens, insects and tree species threaten world forests. *New Zealand Journal of Forest Sciences* 40 Suppl:95-103.

Wingfield MJ, Swart WJ, Abear B. 1989. First record of *Cryphonectria* canker of *Eucalyptus* in South Africa. *Phytophylactica* 21:311-313.

Woods A, Coates KD, Hamaan A. 2005. Is an unprecedented Dothistroma needle blight epidemic related to climate change? *Bioscience* 55:761-769.

Wright JA, Osorio LF. 1996. Comparison of *Eucalyptus urophylla* provenance performance at half-rotation in Colombia and hybrid strategies with *Eucalyptus grandis*. *Forest Ecology and Management* 88:117-122.

Zanetti R, Zanuncio JC, Mayhé-Nunes AJ, Barros AG, Souza-Silva A. 2003. Combate sistemático de formigas-cortadeiras com iscas granuladas, em Eucaliptais com cultivo mínimo. Sociedade de Investigações Florestais. *Revista* Árvore 27(3):387-392.

Insect pests and pathogens increasingly threaten the world's forests. This threat is both to trees in natural woody ecosystems and in planted forests. In terms of planted forests, commercial forestry in Colombia represents an important and growing industry that depends on fast-growing plantations of mainly of non-native species of *Pinus* and *Eucalyptus*. As is true in other parts of the world, the future sustainability of this resource will depend on an ability to manage the growing number of insects and microbes that reduce their viability and productivity.

During the course of the last almost three decades, the authors, Carlos A. Rodas Peláez and Michael J. Wingfield, have collaborated in efforts to identify and manage the most important insects and microbes damaging commercial forest plantations in Colombia. In so doing, they have accumulated a substantial body of knowledge that is fundamentally important to the sustainability of not only Colombian forestry but also forests of South America and globally. This book summarizes the most important available knowledge regarding the identity, biology and management of insect pests and microbial pathogens found on species of *Pinus* and *Eucalyptus* in Colombia. Importantly, it provides the most comprehensive historical record of the topic to have been produced. But equally so, it sets a foundation for future research and innovation that must ensure the sustainability of plantation forestry in the future.

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