



An Australian Government Initiative



Growing Australian Red Cedar *and other Meliaceae species in plantation*

A report published by the RIRDC/Land
& Water Australia/FWPRDC/MDBC Joint
Venture Agroforestry Program

RIRDC publication number 04/135



"All living things are interrelated.
Whatever happens to the earth will
happen to all children of the earth".

Jefe Seattle 1785-1866

"It merely requires interest and effort,
so that one day there will be avenues,
small forests and garden cedars across
the length and breadth of the country;
and if they do take one hundred years
to mature, we can be sure that future
generations will be very pleased with us,
for 'Toona australis' is the most beautiful
of all cedars."

*John Vader (1987) in: Red Cedar, The Tree
of Australia's History*

© 2005 Rural Industries Research and Development Corporation, Canberra. All rights reserved.

ISBN 1 74151 043 0

ISSN 1440 6845

Publication number: 04/135

Growing Australian Red Cedar and Other Meliaceae Species in Plantation

The information contained in this publication is intended for general use to assist public knowledge and discussion and to help improve the development of sustainable industries. The information should not be relied upon for the purpose of a particular matter. Specialist and/or appropriate legal advice should be obtained before any action or decision is taken on the basis of any material in this document. The Commonwealth of Australia, Rural Industries Research and Development Corporation, the authors or contributors do not assume liability of any kind whatsoever resulting from any person's use or reliance upon the content of this document.

This publication is copyright. However, RIRDC encourages wide dissemination of its research, providing the Corporation is clearly acknowledged. For any other enquiries concerning reproduction, contact the Publications Manager on phone 02 6272 3186.

In submitting these reports the researchers have agreed to RIRDC publishing them material in edited form.

Researcher contact details:

Fyfe L. Bygrave and Patricia L. Bygrave
School of Biochemistry and Molecular Biology
Faculty of Science
Australian National University
Canberra ACT 0200

Phone: 02-6251 2269

Email: fyfe.bygrave@anu.edu.au

RIRDC contact details:

Rural Industries Research and Development Corporation
Level 1, AMA House
42 Macquarie Street
BARTON ACT 2600

PO Box 4776

KINGSTON ACT 2604

Tel: 02 6272 4819

Fax: 02 6272 5877

Email: rirdc@rirdc.gov.au

Web: www.rirdc.gov.au

On-line bookshop:

www.rirdc.gov.au/eshop

Printed in March 2005

Design, layout and typesetting by the RIRDC Publications Unit

Printed by Union Offset Printing, Canberra

Foreword

Red cedar is famed for its beautiful deep red, easy-to-work timber, and a history of logging associated with early Australian settlement. The timber is now so rare that it can fetch a high price, particularly once made into fine furniture. Many have tried to grow this tree in woodlots, often unsuccessfully, and it has been concluded, somewhat wistfully, that the species cannot be grown into a straight timber tree. This book, an initiative of the authors, explains the relationship that a number of cedar species worldwide have with the *Hypsipyla* shootborer, and outlines the current state of knowledge on the insect-cedar interaction and their chemistry. The authors demonstrate that they have successfully reared their red cedar woodlots to several metres in height, and show that with vigilance, this species can be grown.

Publication of this book was funded by the Joint Venture Agroforestry Program (JVAP), which is supported by the Rural Industries Research and Development Corporation (RIRDC), Land & Water Australia, and Forest and Wood Products Research and Development Corporation (FWPRDC), together with the Murray-Darling Basin Commission (MDBC). The R&D Corporations are funded principally by the Australian Government. Both State and Australian Governments contribute funds to the MDBC.

This book is an addition to RIRDC's diverse range of over 1,200 research publications and forms part of our Agroforestry and Farm Forestry R&D Sub-program which aims to integrate sustainable and productive agroforestry within Australian farming systems.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at www.rirdc.gov.au/fullreports/index.html
- purchases at www.rirdc.gov.au/eshop

Peter O'Brien

Managing Director
Rural Industries Research and Development Corporation

Preface

The rich resources of Australian red cedar (*Toona ciliata* var. *australis*), which European immigrants found as they displaced Aboriginal Australians along the northern two-thirds of Australia's east coast, catalysed the colonial exploration and exploitation of forests in this region. By the early 20th Century, red cedar had been exploited to economic extinction in much of its range, and the embryonic forest services in Queensland and New South Wales devoted effort in seeking to re-establish the species on a commercial scale. Their considerable efforts, then and subsequently, were defeated, almost without exception, by the cedar tip moth (*Hypsipyla robusta*).

Australian red cedar is one of many species world-wide within the commercially valuable tree family Meliaceae. During the 1980s and 1990s, increased interest in restoration of the resources of other Meliaceae, similarly depleted by forest conversion and unsustainable harvesting, prompted a higher level of activity in research on the Meliaceae and their pests.

Fyfe and Tricia Bygrave, who enjoy the joint delights of being both academics and farm foresters experimenting with red cedar, have contributed to this renewed research effort in the terms they describe in this book. Their efforts, reported here, should give us some hope that the cause of re-establishing Australian red cedar—with consequent benefits for both ecological restoration and commercial forestry—is an exciting challenge rather than a lost cause. We hope it will catalyse further work with this signature Australian tree.

Peter Kanowski

Professor of Forestry

The Australian National University, Canberra

About the authors

In 1980 Fyfe and Patricia Bygrave bought a run-down property on the mid-north coast of New South Wales located near the Nambucca River. In an attempt to reforest the property they began to plant eucalypt trees. Learning that Australian red cedar once had grown in the area, they then planted a stand of these beautiful trees. Soon after planting however they observed that the young trees had been attacked by the tip moth. This led to the commencement of a research program with members of the Forestry Department at the Australian National University. Their interest and challenge in successfully growing red cedar led to the writing of this book.

Fyfe and Patricia are academics now retired from their university careers. Fyfe, a biochemist, was a Professor at the Australian National University and Patricia, who has a PhD in Education/Psychology involving music, worked at the University of Canberra. Their reforestation and research programs have been fully self-funded.



Acknowledgments

This book was made possible by the research performed over many decades by a very large number of dedicated scientists. We especially acknowledge the following for discussions and for access to research documentation on various topics discussed in this book –

Dr Pieter Grijpma (then at Wageningen Agricultural College, The Netherlands), Professor Roger Leakey (then at Institute for Tropical Ecology, Edinburgh, Scotland), Dr Adrian Newton (University of Edinburgh), Dr Allan Watt (Institute for Tropical Ecology, Banchory, Scotland), Professor Jeffrey Burley (Plant Sciences Institute, Oxford University, United Kingdom), Dr Helga Blanco, Dr José Campos, Jonathan Cornelius, Dr Luko Hilje, Dr Francisco Mesen and Carlos Navarro (Centro Agronómico Tropical de Investigación y Enseñanza [Tropical Agricultural Research and Higher Education Center] CATIE, Turrialba, Costa Rica), Dr Charles Briscoe (Turrialba), Dr Maria Fatima das Gracias Fernandes da Silva (Departamento de Química, Universidade Federal de Sao Carlos, Sao Carlos, Brazil), the late Dr John Banks, Professor Peter Kanowski, Dr Jianhua Mo and Dr Mick Tanton (Forestry Department, Australian National University), the late Mr Doug Boland (Division of Forestry and Forest Products, CSIRO), Dr Saul Cunningham and Dr Rob Floyd (Division of Entomology, CSIRO), Dr Marianne Horak (Australian National Insect Collection, CSIRO), Dr Bill Foley and Dr Rod Peakall (Division of Botany and Zoology, Australian National University).

Dr Manon Griffiths (Queensland Department of Primary Industries - Forestry Research) kindly provided a copy of her PhD thesis and Ms Tess Heighes (Kangaroo Valley, New South Wales) provided copies of her field-work. Many of the healthy *Toona* seedlings we have grown over the years were obtained from Anika Farber (Possumwood Plants, Repton, New South Wales).

Sections of the book were written in Siena, Italy and we thank Professor Angelo Benedetti (Dipartimento di Fisiopatologia e Medicina Sperimentale, Università degli Studi di Siena) for kind hospitality during this period.

We particularly acknowledge with gratitude, Professor Peter Kanowski for introductions to key scientists, Dr Allan Watt and Professor Roger Leakey for kind hospitality at Banchory and Bush respectively, and Jonathan Cornelius also for kind hospitality and arrangements during our visit to CATIE, Turrialba, Costa Rica. These visits were made possible by approval from The Australian National University for FLB to undertake leave whilst this book was in preparation. The bulk of the writing was done during his tenure as a Visiting Fellow in the School of Biochemistry, Faculty of Science at the Australian National University in Canberra.

Professor Eric Bachelard (former Head of Forestry at the Australian National University) was kind enough to read an early draft and offered many helpful suggestions both to the format and some of the issues discussed. Dr Rosemary Lott (Rural Industries Research Development Corporation) provided numerous editorial suggestions that improved the flow and context of the various issues discussed. Others who provided useful comments were Professor Jack Elix (Chemistry Department, Australian National University), Dr Ross Wylie and Dr Manon Griffiths (Queensland Department of Primary Industries - Forestry Research) and David Carr (Greening Australia, Canberra). Our children, Drs Louise, Stephen and Lee Bygrave, also contributed with support over the years and with useful suggestions to the manuscript.

Contents

Foreword	iii
Preface	iv
About the authors	v
Acknowledgments	vi
Chapter 1: General Introduction	1
Chapter 2: Features of tropical forests	3
Current state of the world's tropical forests	3
Consequences of forest destruction	4
Exploitation of Australian red cedar (<i>Toona ciliata</i>)	4
Chapter 3: The timber trees of the Meliaceae family	6
Taxonomy	6
Geographic distribution of the species	7
Phenology	7
Wood and other uses	8
Chapter 4: The biology of the Meliaceae shootborer <i>Hypsipyla</i>	10
Taxonomy of <i>Hypsipyla</i>	10
Geographic co-location of Meliaceae and <i>Hypsipyla</i>	10
Life cycle of <i>Hypsipyla</i>	11
Chapter 5: Sex pheromones of <i>Hypsipyla</i>	15
General points	15
Pheromone chemistry	15
Chemical analysis of pheromones	15
Pheromone perception by the male	16
Chapter 6: The role of tree chemistry and physiology in insect/plant interactions	18
General points about insect/plant interactions	18
Secondary plant compounds as feeding stimuli	19
Chemical factors considered to induce <i>Hypsipyla</i> host preference	20
Chapter 7: Genetic studies on Meliaceae populations	22
Background	22
Technical approaches to identifying genetic variation in tree populations	22
DNA polymorphisms can establish genealogies	24
Evidence for genetic variation in Meliaceae populations	24
Evidence for genetic variation of <i>Toona ciliata</i> in Australia	25
Chapter 8: From natural forest to forest plantation	26
Establishing plantations of Meliaceae	26
Role of shade in relation to the incidence of attack	27
Chemical and biological control	28
Silviculture of Meliaceae	28
Chapter 9: Planting Australian red cedar (<i>Toona ciliata</i>)	30
Efforts to plant <i>Toona ciliata</i> and exotic species of Meliaceae in Australia	30
Current information and research in Australia on <i>Hypsipyla robusta</i> and <i>Toona ciliata</i>	31

Chapter 10: A successful plantation of <i>Toona ciliata</i> and <i>Cedrela</i> species in Australia	37
Planting sites	37
Species planted	37
Planting details	37
Growth of trees	38
Incidence of <i>Hypsipyla</i> attack	38
Research on our trees	38
Observations from the graft research	40
Chapter 11: Summary and conclusions	41
References	43
Glossary	53
Appendices	
Appendix 1. Rearing <i>Hypsipyla</i> in the laboratory	56
Appendix 2. Behavioural analysis of female sex pheromones	58
Appendix 3. Laboratory testing of plant secondary compounds on insects	59

Figures

Figure 1. Outline of the interrelating events involved in shootborer infestation of Meliaceae species	2
Figure 2. A chronology of the logging of <i>Toona ciliata</i> (Australian red cedar) on the east coast of Australia	5
Figure 3. Phenology of <i>Toona ciliata</i> located on the south coast of New South Wales, Australia	8
Figure 4. World distribution of Meliaceae and <i>Hypsipyla robusta</i> and <i>Hypsipyla grandella</i>	11
Figure 5. Outline of stages in the life-cycle of <i>Hypsipyla robusta</i>	12
Figure 6. Chemical structures of the pheromonal secretions of Ivory Coast virgin females of <i>Hypsipyla</i>	16
Figure 7. Diagrammatic representation of a sensillum	17
Figure 8. Manufacture of secondary compounds in plants	19
Figure 9. General chemical structures of secondary compounds isolated from Meliaceae sensitive to <i>Hypsipyla</i>	20
Figure 10. Application of molecular marker technology to the study of genetic variation in plants	23
Figure 11. Hypothetical dendrogram illustrating genetic variation between populations of a given species	24
Figure 12. Design of grafting experiment using Meliaceae species	39

Tables

Table 1. Rates of deforestation (1981-1990) of tropical forests in selected countries	3
Table 2. Principal timber trees of the Meliaceae family (subfamily – Swietenioideae)	6
Table 3. Abbreviated botanical descriptions of some of the Swietenioideae genera discussed in the text	9
Table 4. Outline of behavioural patterns of adult <i>Hypsipyla grandella</i> and <i>Hypsipyla robusta</i>	12

Chapter 1

General Introduction

Carefully examine a piece of antique furniture made from Australian red cedar or mahogany and what do you see? Generally we see only the beautiful grain and deep red colour of the timber. Little do we ponder the age of that timber and where it came from. Rarely do we ask why it is that the timber is now scarce or why it is not grown successfully in plantation both here in Australia or elsewhere in the world. Many in Australia appear unaware that red cedar trees, synonymous with the early history of Australia, now are difficult to find (see e.g. Jervis 1940; Vader 1987; McPhee *et al.* 2004), or that mahogany and related species of valuable timber may soon become extinct (Newton *et al.* 1993).

Species of mahogany and true cedar such as Australian red cedar and the cedrelas of Central and South America are among the most valuable timber trees found world-wide in tropical forests. They are members of the sub-family Swietenioideae within the family Meliaceae. The timber of all of these trees is much sought after because of its fine grain, colour and durability.

We know that in the appropriate climate they are fast growing. Mahogany and cedar trees can grow in height almost several metres a year and so by 25-30 years will have reached considerable height and diameter. Moreover, cedar seedlings, saplings and mature trees maintain the ability to survive damage from drought, fire and frost; they readily sprout from any affected parts. Only 200 years ago red cedar grew in great abundance along the entire east coast of Australia, from the Clyde River in southern New South Wales to far north Queensland, before being virtually wiped out through human intervention by early last century. So what is the impediment to regenerating these trees?

The underlying factor affecting regeneration is that the Meliaceae are attacked by an insect, a tipmoth or shootborer, that eats out the (apical) growing tip of the young tree. The female insect lays its eggs on the tree and the larvae that emerge burrow into the succulent sapwood, especially that of the dominant growing tip, thus rapidly destroying many centimetres of new growth. The tree compensates by pushing out shoots below this point of attack, resulting in a tree that is multi-branched and of little commercial value. Such attack has long been the major source of frustration to those who have endeavoured to grow and establish cedar and mahogany plantations world-wide.

Figure 1 outlines the close interrelationship between the insect shootborer¹ known as *Hypsipyla* and the Meliaceae host. The tree possesses specific chemicals, one (or more) of which are thought to serve as an attractant to the adult female insect, and one (or more) other chemicals that serve as a feeding attractant to the newly-emerged larvae. Thus underlying this interrelationship is a complex set of ecological interactions involving the biochemistry and physiology of *Hypsipyla* and their Meliaceae host (Grijpma 1974a, 1974b; Floyd and Hauxwell 2001; Newton *et al.* 1993; Whitmore 1976).

Over the past half-century or so, much research involving a number of scientific disciplines has been conducted in efforts to determine how the deleterious effects of the insect on the young tree might be understood and controlled. In this book we describe and collate these wide-ranging results to provide the interested reader and the professional scientist with a unique overview of the major points. It should serve also as a good general guide for the student of biology and ecology.

¹ The literature refers to the insect *Hypsipyla* either as 'tipmoth' or 'shootborer'. For consistency the latter term will be used hereafter in this book.

There are three broad practical aspects to the story:

The first (Chapters 1-3) is an overview of the state of tropical forests; their vital role in the ecology of this planet and the extent to which they are being destroyed by human activity. As well, a description is given of the important and endangered mahogany and cedar timber species that remain in these forests.

The second (Chapters 4-8) is a description of the biology of the shootborer and aspects of the chemistry and physiology of the Meliaceae trees. This information is central to understanding the insect/host interrelationship. The genetic aspects and the silviculture of the tree species are also discussed. This forms a basis to determining the best trees to plant and how to manage them.

The third (Chapters 9 and 10) is an account of the efforts being undertaken to plant areas of Australia with red cedar. In particular, the book concludes on a positive note - how, from the authors' own experience, it is possible to establish a plantation of Australian red cedar.

Relevant literature for each chapter is cited at the end of the book. To assist the reader, some of the scientific terms used are defined in an extensive glossary, also at the end of the book.

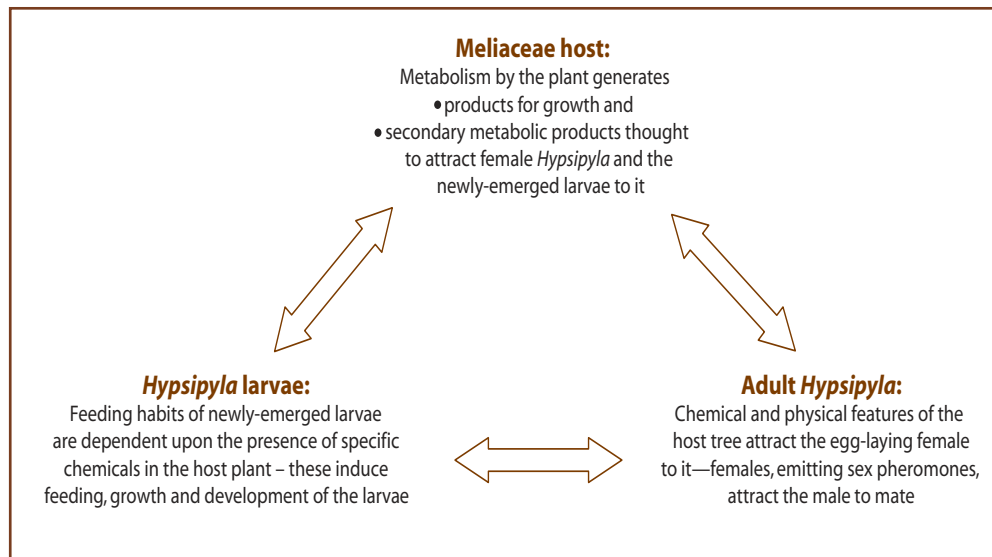


Figure 1. Outline of the interrelating events involved in shootborer infestation of Meliaceae species