

THE DYNAMICS OF
LANTANA CAMARA (L.)
INVASION OF
SUBTROPICAL RAINFOREST
IN SOUTHEAST QUEENSLAND

A PH.D. SUBMITTED FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

BY

DANIEL STOCK BSc (HONS)

OCTOBER 2004

SCHOOL OF ENVIRONMENTAL AND APPLIED SCIENCES,
GRIFFITH UNIVERSITY, GOLD COAST CAMPUS, QUEENSLAND

Statement of Originality

The material presented in this thesis has not previously been submitted for a degree or diploma in any university and to the best of my knowledge contains no material previously published or written by another person except where due acknowledgement is made in the thesis itself.

Daniel H. Stock

Acknowledgements

Firstly, I sincerely thank Associate Professor Clyde Wild for his excellent supervision. Clyde has been, and will continue to be for the rest of my life, a great mentor in guidance, encouragement and motivation. His editorial comments and overall input into this thesis are more than just valuable. His eagerness to help, talks about anything and everything, and outward show of rapture towards our combined interest made studying 'our' weed a pleasure. I would also like to thank his dear wife Carmel and their children Francis and Seanan, who welcomed me invading their home, their rainforest and their lives.

I sincerely thank most of all my best friend and dearest wife, Michelle, whom without the encouragement, moral, comical, editorial and fieldwork support she provided would have made a trying time in our lives together even harder. Without her by my side, this thesis would certainly not have been possible. Thanks again for putting up with me over the years and pushing me in the right direction. You are my inspiration!

Sincere thanks must also be given to my other regular fieldwork volunteers Eric Chitra and Skye Page whom, along with Michelle, made long hours in the forest a joy. Eric and Skye were invaluable friends throughout my degree, with both a shoulder to complain on and eagerness to help me in the field: both heartedly supported me in my fieldwork mode and kept coming out for more punishment. Thanks also to the other fieldwork volunteers who occasionally accompanied me and found that a day in the forest was more than enough time spent with me in the wild. Also many thanks to the countless others members of the School of Environmental and Applied Sciences who have helped me and kept me laughing along the way, especially Simon Hodgkison, Pascal Scherrer, Jason Van de Merwe, Andrew Growcock, James Furse, Shoshana Fogelman, Leah Pischek, Michael Brickhill, Joanne Oakes and Carolyn Littlefair, as well as Rivkah, Dudley and Jessie.

Due thanks also go out to the rangers of Springbrook National Park, especially Mike Hall, the ranger in charge and his team who have opened both their park and their time for me over the years. Sincere thanks also go out to Dr Peter Mackey who evaluated the initial proposal and gave valuable feedback.

Finally, I would like to thank my parents, Victoria and Phillip, who have always encouraged me, over the years, to pursue my dreams and ambitions in both science and in all other aspects of my life. Again thank you both dearly, without you this thesis would not have been possible.

Abstract

Lantana *Lantana camara* L. is a highly aggressive exotic environmental weed that is well established throughout eastern Australia and is reportedly able to displace native vegetation under a range of conditions. Whether lantana is able to displace native vegetation in the absence of anthropogenic disturbance is subject of some disagreement in the literature. The question remains, however, as to what is the future for the Gold Coast hinterland rainforests in the face of invasion by lantana? This study is mainly directed at addressing the dynamics at the lantana/rainforest interface, especially lantana's capacity to invade and ability to compete with the wetter subtropical rainforests of the MacPherson Ranges of southeast Queensland, where the studies are centered on the Springbrook Plateau and the Springbrook and Lamington National Parks. The aims of this research are to determine: whether lantana can displace rainforest; whether rainforest can reclaim the space lost to lantana; and what are the mechanisms and processes involved.

To investigate these questions a conceptual framework was determined where key processes at the rainforest/lantana interface were determined and set in a logical context. A wide variety of possible processes whereby lantana could resist or displace rainforest or forest could resist or replace lantana were identified. The framework questions were addressed by observations made at lantana patches in Springbrook and Lamington National Parks in southeast Queensland.

These answers/conclusions indicate that lantana is not invading further into intact rainforest and is seemingly isolated to canopy gaps, suggesting that rainforest is *suppressing* further expansion of lantana. Even though lantana may not commonly occur thriving in subtropical rainforest, it was determined that the issues/interactions that need to be pursued via experimentation were as follows: (i) how common is lantana in the national parks of southeast Queensland; (ii) what limits lantana expansion (is it physical shading, processes attributable to biological effects, such as allelopathy or a combination of both) and; (iii) what physical/biological conditions suppress lantana health and aggressiveness.

Although some previous work has looked at the correlation between lantana density and tree cover in dry rainforest and savanna woodland, there have been no reported studies looking specifically at the quantity and abundance of lantana throughout a forest community. An extensive transect study in subtropical rainforest in southeast Queensland assessed habitat variables and the density of the lantana at numerous points along four transects running through rainforest and other mesic communities. The study was conducted in national parks to ensure that the typical disturbances present were, as much as possible natural rather than anthropogenic. From this study the extent of lantana infestation in particular forest types was determined and forest variables such as canopy density and canopy type were compared with

lantana density providing indications of the current extent of infestation and the types of forest especially prone to infestation by this environmental weed. The density of lantana in intact rainforest was low and only slightly more lantana was observed in secondary forest than in primary forest. These differences are however driven by the density of the forest rather than the nature of the forest. Finally, lantana appears to be disturbance-dependent in that there is significantly more lantana in disturbed areas than undisturbed areas of the forest: these differences were attributable to the more open canopies above disturbed sites, rather than the disturbance itself.

According to previous work the germination of lantana seeds is significantly reduced in low light conditions, such as occur under intact rainforest. A germination experiment investigated the contributions of shading and canopy type to the germination of lantana seeds. The experiment permitted the separation of shading and species-specific effects and the study of rainforest seeds under lantana. Seeds were bagged and placed under rainforest canopy trees and lantana, above and below the leaf litter for a six-month period or until maximum likely germination was achieved. The amount of germination was compared with the amount of shading, the position relative to leaf litter and the species of canopy they were placed under, to determine the relative contributions of shading, litter cover and canopy species. The results of this study show that native rainforest seeds germinate differently under rainforest canopies than under lantana with most showing a higher level of germination under rainforest canopies. This difference was found to be attributable to both the nature of the canopy (canopy species) and the changing level of shading (canopy openness). For most rainforest species, the difference attributable to the level of shading and nature of the canopy was indicative of greater germination capacity under the rainforest canopy than under lantana. Thus, lantana reduces the germination of natives and therefore, in this manner, reduces the forest's capacity to replace lantana. Lantana seed did not germinate in this study and thus their capacity to out-compete native species is, based on this work, unknown.

It appears that the competitive ability of lantana seedlings may give them the edge over rainforest seedlings when colonising canopy gaps. It is therefore important to examine the survival and growth of lantana seedlings compared to rainforest seedlings and the effect of canopy species and shade levels on lantana seedling survival, growth and thus competitive ability. Lantana and rainforest seedlings were planted under rainforest trees and lantana, and their survival and rate of growth over a period of 24 months compared. The survival and rate of growth was compared with the amount of shading and the species under which the seedlings were planted, to determine the contributions of shading and canopy species to survival and growth. The results of this study suggest that, as a seedling, lantana survival was greater under secondary forest canopies and lantana, than under the primary forest species. The growth of lantana seedlings was significantly different under different forest canopies, but differences in growth were not attributable to the different canopy openness ranges with each canopy species

and better explained by the actual canopy species themselves. This suggests that there are canopy specific differences in seedling growth beyond that explicable by canopy openness. As a canopy, lantana does not appear to suppress the survival and growth of rainforest seedlings and thus as a canopy, lantana may not prevent the establishment of native forest seedlings that were studied here.

In the rainforests of southeast Queensland, lantana is able to maintain large and dense patches apparently for long periods, leaving open the question of whether lantana in these forests is able to displace the forest or whether the rainforest displaces lantana. In this study, lantana was observed in a number of different locations in the border ranges between New South Wales and Queensland and there is little evidence of its capacity to displace forests in the absence of additional disturbances. The study here explored the reasons for the apparent inability of lantana to displace forest and focused particularly on the shading of lantana by the forest and the capacity of forest species to grow through patches of lantana. Lantana's inability to successfully expand its patch size, under intact rainforest, appears to be due to two main reasons: (i) the increased level of shade provided by the intact canopy of the rainforest compared to the open canopy of the disturbance; and (ii) the particular nature of (species in) the intact rainforest. The results suggest that lantana has little capacity to adapt to shading, only developing slightly larger leaves, longer petioles and longer thinner internodes in moderate shade. Conversely, there is a marked degradation of most health characteristics when lantana is growing in low light conditions. Where the canopy is denser than 75%, lantana will be unthrifty, probably unable to grow and certainly unable to flower. Therefore, maintaining at least 75% shading should prevent the successful encroachment of lantana and early achievement of this level of canopy density should be aimed at in revegetating disturbed sites.

This thesis suggests that lantana does not appear to have the ability to competitively displace rainforest. Conversely reclaiming the land taken over by lantana is very slow. More research is required to fully understand the rainforest's ability to recolonise lantana infestations. Although lantana thrives in the canopy gaps created by disturbances, it appears to be restricted (to these gaps) and seems unable to expand the patch beyond the canopy gap. If rainforest reclamation can be confirmed to take place at such a pace that gaps can be closed in an ecologically reasonable time, little active control of lantana maybe required. If active intervention is desired then control efforts should focus on the physical removal of the lantana from initially, small gaps, accompanied by the planting of fast growing rainforest species that can increase the shade at a disturbed site to prevent the reestablishment of the weed.

List of Publications Submitted and Accepted

- Stock, D.H. and Wild, C.H. 2002. The capacity of lantana (*Lantana camara* L.) to displace native vegetation. Pages 104-107 in Spafford Jacob, H., Dodd, J. and Moore, J.H. (Eds.) 2002. *13th Australian Weeds Conference: Papers and Proceedings*. Plant Protection Society of Western Australia, Perth, Western Australia.
- Stock, D.H. 2002. The dynamics of *Lantana camara* invasion of subtropical rainforest in Southeast Queensland. Pages 66-67 in Grice, A.C. and Setter, M.J. (Eds.) 2002. *Weeds of Rainforests and Associated Ecosystems*. Cooperative Research Centre for Tropical Rainforest Ecology and Management, Cairns.
- Stock, D.H. and Wild, C.H. 2003. The capacity of lantana (*Lantana camara* L.) to displace subtropical rainforest along the lantana/rainforest interface. Page 206 in Oliver, I., Kristiansen, P. and Silberbauer, L. (Eds.) 2003. *Ecological Society of Australia Ecology 2003 Conference: Abstracts*. University of New England, Armidale, New South Wales.
- Stock, D.H. 2005. (In Press). The Future Direction of *Lantana* Management in Eastern-Australian Subtropical-Rainforests. In Worboys, G.L., Lockwood, M. and DeLacy, T. 2005. *Protected Area Management: Principles and Practices (2nd edition)*. Oxford University Press, Melbourne.

List of Conference Presentations

- Thirteenth Australian Weeds Conference (2002): Weeds – Threats now and forever?
Perth, Western Australia.
- Weeds of Rainforests and Associated Ecosystems Workshop: A joint workshop of the Cooperative Research Centre for Tropical Rainforest Ecology and Management and the Cooperative Research Centre for Australian Weed Management (2002).
Cairns, Queensland.
- Ecological Society of Australia Ecology Conference (2003). Armidale, New South Wales.
- Cooperative Research Centre for Tropical Rainforest Ecology and Management Conference (2003). Cairns, Queensland

Statement of Originality	i
Acknowledgments	ii
Abstract	iii
List of Publications Submitted and Accepted	vi
List of Conference Presentations	vi
Table of Contents	vii
List of Tables	xii
List of Figures	xix
List of Appendices	xxiii
List of Abbreviations	xxiii
Glossary of Terms	xxiv
Preamble	xxv
1 General Background	1
1.1 Current Knowledge	3
1.1.1 Lantana in Rainforest	3
1.1.2 Lantana/Forest Dynamics	3
1.1.2.1 Rainforests in southeast Queensland	4
1.1.2.2 Lantana in Subtropical Rainforest	5
1.1.2.3 Lantana, Disturbance and Shading	6
1.2 Objectives	7
1.3 Thesis Outline	7
2 Literature Review	9
2.1 Terminology	9
2.2 Ecological Effects/Impacts of Weeds	10
2.3 Weeds in National Parks	11
2.4 The Role of Disturbances in Rainforest	11
2.5 Edge Effects in Relation to Invasibility	14
2.6 How Rainforest Resists Invasion by Weeds	16
2.7 <i>Lantana camara</i> L.	16
2.7.1 History	18
2.7.2 Genetics/ Polyploidy	19
2.7.3 Distribution	20
2.7.4 Ecology	21
2.7.5 Ecological Effects/Impacts of Lantana	24
2.7.5.1 Disruption of Succession	24
2.7.5.2 Soil Eutrophication	24
2.7.5.3 Changes to Fire Regimes	25
2.7.5.4 Allelopathy	25
2.7.5.5 Toxicity	27
2.7.6 Lantana Control	28
2.7.6.1 Physical Control	28
2.7.6.2 Chemical Control	29
2.7.6.3 Biological Control	29
2.7.7 Lantana in the Context of this Work	30

3	Conceptual Framework	31
3.1	Methods	31
3.1.1	Defining the Lantana Patch	31
3.1.2	Study Sites	33
3.2	Data collection	33
3.3	Results	34
3.3.1	Question 1. Can lantana displace rainforest?	34
3.3.2	Question 2. Can the rainforest reclaim space lost to lantana?	38
3.3.2.1	Question 2.1. Can rainforest displace lantana?	38
3.3.2.2	Question 2.2. Can rainforest grow through lantana?	39
3.4	Framework Conclusions	41
4	Factors Affecting Lantana Growth within the Forest	43
4.1	Introduction	43
4.2	Rationale	44
4.3	Objectives	44
4.4	Methods	44
4.4.1	Study Sites	44
4.4.1.1	Illinbah Circuit Track	45
4.4.1.2	Caves Circuit Track	46
4.4.1.3	Purlingbrook Falls Circuit Track	46
4.4.1.4	Warrie Circuit Track	47
4.4.2	Data Collection	48
4.4.2.1	Lantana Density	48
4.4.2.2	Forest Cover Density	49
4.4.2.3	Forest Cover Type	49
4.5	Data Analysis and Results	50
4.5.1	Lantana Presence/Absence	50
4.5.1.1	Analysis	50
4.5.1.2	Results	50
4.5.2	Lantana Density within Intact Rainforest	51
4.5.2.1	Analysis	51
4.5.2.2	Results	53
4.5.3	Effect of Disturbance on Lantana Density	56
4.5.3.1	Analysis	56
4.5.3.2	Results	56
4.6	Discussion	58
4.6.1	Overall Findings	58
4.6.2	Lantana Presence/Absence	59
4.6.3	Lantana Density within Intact Rainforest	59
4.6.4	Lantana Density in Intact Forest and Disturbed Areas	60
5	Factors Affecting Seed Germination	61
5.1	Introduction	61
5.2	Rationale	62
5.3	Objectives	63
5.4	Methods	64
5.4.1	Study Site	64
5.4.2	Study Species	65

5.4.3	Seed Collection	66
5.4.4	Seed and Seed Bag Preparation	66
5.4.4.1	Seed Preparation	66
5.4.4.2	Seed Bag Preparation	67
5.4.5	Placement	67
5.4.6	Germination Schedule	69
5.4.7	Data Collection	69
5.4.8	Data Analysis	70
5.4.8.1	Final Analytical Procedures	71
5.5	Results	73
5.5.1	Lantana Germination	73
5.5.2	Overall Germination	73
5.5.2.1	Canopy Openness Levels Under Different Canopies	73
5.5.2.2	Model with Canopy Species, Seed Species and Litter Position	74
5.5.2.3	Model with Canopy Species, Seed Species, Litter Position and Canopy Openness	77
5.5.3	Germination of Black Apple	78
5.5.3.1	Model with Canopy Species and Litter Position	79
5.5.3.2	Model with Canopy Species, Litter Position and Canopy Openness	81
5.6	Discussion	82
5.6.1	Lantana Germination	83
5.6.2	Native Rainforest Species Germination	83
5.6.2.1	Black Apple Germination	84
5.6.3	Summary	85
5.6.4	The Competitiveness of Lantana as both a Seed and a Canopy	86
6	Factors Affecting Seedling Survival and Growth	89
6.1	Introduction	89
6.2	Rationale	89
6.3	Objectives	90
6.4	Methods	90
6.4.1	Study Site	90
6.4.2	Study Species	90
6.4.3	Seedling Preparation	91
6.4.4	Transplanting Configuration	91
6.4.5	Watering of Plants on Initial Transplanting	92
6.4.6	Replanting and Establishment	93
6.4.7	Data Collection	94
6.4.7.1	Canopy Gap Fraction (CGF)	94
6.4.7.2	Overall Health of the Seedling	94
6.4.7.3	Total Above Ground Stem Height	94
6.4.7.4	Stem Width at Half the Stem Height	94
6.4.7.5	Total Number of Leaves	94
6.4.7.6	Total Approximate Area of the Three Largest Leaves	94
6.4.7.7	Total Number of Branches	95
6.5	Analysis and Results	95
6.5.1	Data Transformations	95
6.5.2	Lantana Seedling Survival	96
6.5.2.1	Lantana Seedling Survival Analysis	96
6.5.2.2	Lantana Seedling Survival Results	96
6.5.3	Lantana Seedling Growth	99

6.5.3.1	Lantana Seedling Growth Analysis	99
6.5.3.2	Lantana Seedling Growth Results	103
6.5.4	Overall Seedling Survival	119
6.5.4.1	Overall Seedling Survival Analysis	119
6.5.4.2	Overall Seedling Survival Results	120
6.5.5	Overall Seedling Growth	124
6.5.5.1	Overall Seedling Growth Analysis	124
6.5.5.2	Overall Seedling Growth Results	126
6.6	Discussion	144
6.6.1	Survival of Seedlings	145
6.6.1.1	Lantana	145
6.6.1.2	Native Rainforest Species	145
6.6.2	Seedling Growth	146
6.6.2.1	Lantana	147
6.6.2.2	Native Rainforest Species	149
6.6.3	Summary	151
6.6.4	The Competitiveness of Lantana as Seedlings	153
7	Comparison of Lantana Between Forest Clearings and Adjacent Forest	155
7.1	Introduction	155
7.1.1	Background	155
7.1.2	Objective	157
7.2	Methods	158
7.2.1	Study Locations	158
7.2.1.1	Purlingbrook Falls Circuit Track (Springbrook National Park)	158
7.2.1.2	Illinbah Circuit Track (Lamington National Park)	159
7.2.2	Data Collection	160
7.2.2.1	Number of Live and Dead Tips	161
7.2.2.2	Average Leaf Length, Leaf Width and Petiole Length	161
7.2.2.3	Average Leaf Length-to-Width Ratio	161
7.2.2.4	Average Leaf Area and Total Leaf Area	161
7.2.2.5	Average Number of Leaves and Average Percentage of Leaves Retained	162
7.2.2.6	Average Leaf Hue (Colour), Leaf Value (Lightness) and Leaf Chroma (Saturation)	162
7.2.2.7	Number of Internodes	162
7.2.2.8	Average Internode Length and Internode Width	163
7.2.2.9	Average Number of Green and Brown Internodes and Number of All Green and All Brown Stems	163
7.2.2.10	Average Percentage of Green Internodes	163
7.2.2.11	Average Length of Green Stem	163
7.2.2.12	Average Number of Living Branches	164
7.2.2.13	Average Number of Dead and Missing Branches	164
7.2.2.14	Average Number of Buds and Shoots	164
7.2.2.15	Average Number of Flowers	164
7.2.2.16	Canopy Gap Fraction (CGF)	164
7.2.2.17	Sub-sampling Site Classification	165
7.2.3	Data Analysis Procedures	166
7.2.3.1	Variables Elimination	166
7.2.3.2	Data Transformations	168
7.2.3.3	Analysis Procedures	169

7.3	Results	175
7.3.1	Leaf Characteristics	175
7.3.1.1	Average Number of Leaves	175
7.3.1.2	Average Percentage Leaves Retained	177
7.3.1.3	Average Leaf Area	179
7.3.1.4	Average Leaf Length-to-Width (L-W) Ratio	181
7.3.1.5	Average Petiole Length	183
7.3.1.6	Average Leaf Hue (Colour)	185
7.3.1.7	Average Leaf Value (Lightness)	187
7.3.1.8	Average Leaf Chroma (Saturation)	189
7.3.2	Stem Characteristics	193
7.3.2.1	Average Number of Green Internodes	193
7.3.2.2	Average Number of Brown Internodes	195
7.3.2.3	Number of All Green Stems	196
7.3.2.4	Number of All Brown Stems	197
7.3.2.5	Average Length of Green Stem	199
7.3.2.6	Average Internode Length	201
7.3.2.7	Average Internode Width	203
7.3.3	Health Characteristics	206
7.3.3.1	Number of Live Tips	206
7.3.3.2	Average Number of Living Branches	208
7.3.3.3	Average Number of Dead Branches	210
7.3.3.4	Average Number of Missing Branches	212
7.3.3.5	Average Number of Buds	214
7.3.3.6	Average Number of Shoots	216
7.3.3.7	Average Number of Flowers	218
7.3.4	Summary of Results	221
7.3.5	Transition Shade Levels	222
7.4	Summary of Overall Findings	223
7.4.1	Variables Which Did Not Differ Between Canopy Type	223
7.4.2	Variables Which Indicate a Response to Shading	224
7.4.3	Variables Which Indicate a Response to Canopy Type	227
7.4.4	Photosynthetic Capacity, Growth Potential and Flowering Capacity of Lantana Stems.	229
7.4.4.1	Photosynthetic Capacity of Lantana Stems	229
7.4.4.2	Growth Potential of Lantana Stems	231
7.4.4.3	Flowering Capacity of Lantana Stems	232
7.4.5	What Proportion of a Gap Will Contain Healthy Lantana?	234
7.5	Discussion	235
7.5.1	Is lantana responding to low light environments?	236
7.5.2	Is lantana's response to low light environments adequate to maintain healthy growth?	238
7.5.3	Implications for lantana invasion	239
8	Overall Discussion, Conclusions and Recommendations	241
8.1	Overall Discussion	241
8.2	Conclusions	244
8.3	Recommendations	245
8.3.1	Management Recommendations	245
8.3.2	Further Research	247
9	References	249

List of Tables**Page No.**

Table 1.1.	Characteristics of forest types	4
Table 3.1	Results of Question 1 (Are mature live or dead rainforest trees found within the perimeter of the lantana patch?)	35
Table 3.2	Results of Question 2 (Are the mature trees alive?)	35
Table 3.3	Results of Question 3 (Are fallen trees commonly found on the edge of the lantana patch?)	35
Table 3.4	Results of Question 4 (Can lantana ascend trees and pull them over?)	36
Table 3.5	Results of Question 5 (What is the spatial relationship between the trees and the surrounding forest?)	36
Table 3.6	Results of Question 6 (Are the dead trees concentrated on the edge of the patch?)	37
Table 3.7	Results of Question 7 (Is lantana found under the rainforest canopy alive and growing?)	37
Table 3.8	Results of Question 8 (Is the lantana healthy or struggling?)	37
Table 3.9	Results of Question 1 (Does dead lantana occur on the perimeter of live lantana patches?)	38
Table 3.10	Results of Question 2 (Are there young trees around the edge where dead lantana occurs?)	38
Table 3.11	Results of Question 3 (Are the dead patches below canopy of surrounding large trees?)..	39
Table 3.12	Results of Question 1 (Have some young rainforest plants “escaped” above the lantana canopy?)	39
Table 3.13	Results of Question 2 (Can the trees growing through the lantana grow until they produce a canopy over the lantana?)	40
Table 3.14	Results of Question 3 (Can the canopy reach such a density that it suppresses the lantana beneath it?)	40
Table 4.1	Percentage of lantana present between walking tracks	51
Table 4.2	Count of various forest types point between sites at each sampling	52
Table 4.3	ANOVA of lantana density predicted by forest type	53
Table 4.4	ANOVA of forest density predicted by site, forest type and their interaction	54
Table 4.5	ANOVA of lantana density predicted by forest density, site, forest type and the interaction between site and forest type	54
Table 4.6	ANOVA of lantana density predicted by forest density and forest type	55
Table 4.7	Mean lantana density between forest types when controlled for forest density	55
Table 4.8	ANOVA of lantana density predicted by site, disturbance and their interaction	56
Table 4.9	ANOVA of lantana density predicted by forest density, site, disturbance and the interaction between site and disturbance	57
Table 5.1	Germination Schedule	69
Table 5.2	Summary of germination analysis	70
Table 5.3	ANOVA of canopy openness predicted by canopy species	73
Table 5.4	Mean canopy openness under each canopy species	73

Table 5.5	Logistic ANOVA of total seeds germinated predicted by canopy species, seed species and litter position	74
Table 5.6	Planned comparisons of seed germination under different canopies	76
Table 5.7	Means of seed germination between different litter positions	76
Table 5.8	Logistic ANCOVA total seeds germinated predicted by canopy species, seed species, litter position and canopy openness	77
Table 5.9	Logistic ANOVA of total black apple seeds germinated at three and six months predicted by canopy species and litter position	79
Table 5.10	Planned comparisons of black apple germination under different canopies at three months and six months	80
Table 5.11	Means of black apple germination between different litter positions at three and six months	80
Table 5.12	Logistic ANOVA of total black apple seeds germinated at three and six months predicted by canopy species, litter position and canopy openness	81
Table 5.13	Black apple germination, at three and six months, under each canopy species	82
Table 5.14	Germination of seeds, partitioned by species, and by canopy under which they were grown	85
Table 5.15	Germination of seed species as measured under each canopy	86
Table 6.1	Table of total species initially planted and replanted	93
Table 6.2	Transformations applied to each variable	95
Table 6.3	Lantana seedling survival under different canopies	97
Table 6.4	Probit analysis of lantana seedling survival predicted by canopy species	97
Table 6.5	Probit analysis of lantana seedling survival predicted by canopy species and canopy openness	98
Table 6.6	ANOVA of canopy openness predicted by canopy species	103
Table 6.7	Mean canopy openness under each canopy species	103
Table 6.8	ANOVA of lantana seedling height increment (mm) predicted by canopy species	104
Table 6.9	Mean height increment (mm) for lantana seedlings under each canopy, compared between models without or controlled for canopy openness	105
Table 6.10	Planned comparisons of height increment (mm) for lantana seedlings under each canopy, compared between models without or controlled for canopy openness	106
Table 6.11	ANCOVA of lantana seedling height increment (mm) predicted by canopy species and canopy openness	106
Table 6.12	ANOVA of lantana seedling stem width increment (mm) predicted by canopy species	108
Table 6.13	Mean width increment (mm) for lantana seedlings under each canopy species	108
Table 6.14	Planned comparisons of width increment (mm) for lantana seedlings	108
Table 6.15	ANCOVA of lantana seedling stem width increment (mm) predicted by canopy species and canopy openness	109
Table 6.16	Regression of lantana seedling stem width increment (mm) on canopy openness	109
Table 6.17	ANOVA of lantana seedling leaf total increment predicted by canopy species	110
Table 6.18	Mean leaf total increment of lantana under each canopy, based on canopy species only model compared to when controlled for canopy openness	110
Table 6.19	Planned comparisons of leaf total increment for lantana seedlings, based on canopy species only compared to when controlled for canopy openness	110

Table 6.20	ANCOVA of lantana seedling leaf total increment predicted by canopy species and canopy openness	112
Table 6.21	Regression of lantana seedling leaf total increment on canopy openness.....	112
Table 6.22	ANOVA of lantana seedling leaf area (mm ²) predicted by canopy species	113
Table 6.23	Mean leaf area (mm ²) for lantana seedlings under each canopy species, based on canopy species only model compared to when controlled for canopy openness	114
Table 6.24	Planned comparisons of leaf area (mm ²) for lantana seedlings under each canopy, compared between models without or controlled for canopy openness	114
Table 6.25	ANCOVA of lantana seedling leaf area (mm ²) predicted by canopy species and canopy openness	115
Table 6.26	ANOVA of lantana seedling branch total increment predicted by canopy species	116
Table 6.27	Mean branch total increment for lantana seedlings under each canopy species	116
Table 6.28	Planned comparisons of branch total increment for lantana seedlings	117
Table 6.29	ANCOVA of lantana seedling branch total increment predicted by canopy species and canopy openness	118
Table 6.30	Regression of lantana seedling branch total increment on canopy openness	118
Table 6.31	Results of fitting all k-factor interactions, where k is the level of the interaction analysed	120
Table 6.32	Results of marginal associations	120
Table 6.33	Marginal table for seedling species by total survival	121
Table 6.34	Marginal table for canopy species by total survival	121
Table 6.35	Probit analysis seedling survival predicted by canopy and seedling species	121
Table 6.36	Probit analysis results with canopy and seedling species as the dependant variables and seedling survival as the response variable	123
Table 6.37	ANOVA of canopy openness predicted by canopy species	126
Table 6.38	Mean canopy openness under each canopy species	126
Table 6.39	ANOVA of seedling height increment (mm) predicted by canopy species and seedling species and their interaction	128
Table 6.40	ANOVA of seedling height increment (mm) predicted by canopy species and seedling species	128
Table 6.41	Mean height increment (mm) for seedlings under each canopy, compared between models without or controlled for canopy openness	128
Table 6.42	Mean height increment (mm) for each seedling species, compared between models without or controlled for canopy openness	128
Table 6.43	Planned comparisons of height increment (mm) for seedlings, based on canopy species only compared to when controlled for canopy openness	129
Table 6.44	ANCOVA of seedling height increment (mm) predicted by canopy species, seedling species and canopy openness	130
Table 6.45	ANOVA of seedling width increment (mm) predicted by canopy species and seedling species and their interaction	131
Table 6.46	ANOVA of seedling width increment (mm) predicted by canopy species and seedling species	132
Table 6.47	Mean width increment (mm) for seedlings under each canopy species	132
Table 6.48	Mean width increment (mm) for each seedling species	132
Table 6.49	Planned comparisons of width increment under different canopy species	132

Table 6.50	ANOVA of seedling leaf total increment predicted by canopy species and seedling species and their interaction	134
Table 6.51	ANOVA of seedling leaf total increment predicted by canopy species and seedling species	134
Table 6.52	Mean leaf total increment for seedlings under each canopy, compared between models without or controlled for canopy openness	134
Table 6.53	Mean leaf total increment for each seedling species, compared between models without or controlled for canopy openness	134
Table 6.54	Planned comparisons of leaf total increment for seedlings, based on canopy species only compared to when controlled for canopy openness	135
Table 6.55	ANCOVA of seedling leaf total increment predicted by canopy species, seedling species and canopy openness	136
Table 6.56	ANOVA of seedling total leaf area (mm ²) predicted by canopy species and seedling species and their interaction	137
Table 6.57	Mean leaf area (mm ²) for seedlings under each canopy, compared between models without or controlled for canopy openness	138
Table 6.58	Mean leaf area (mm ²) for each seedling species, compared between models without or controlled for canopy openness	139
Table 6.59	Planned comparisons of leaf area (mm ²) for seedlings, based on canopy species only compared to when controlled for canopy openness	139
Table 6.60	ANCOVA of seedling total leaf area (mm ²) predicted by canopy species, seedling species, their interaction and canopy openness	140
Table 6.61	ANOVA of seedling branch total increment predicted by canopy species and seedling species and their interaction	142
Table 6.62	ANOVA of seedling branch total increment predicted by canopy species and seedling species	142
Table 6.63	Mean branch total increment for seedlings under each canopy, compared between models without or controlled for canopy openness	142
Table 6.64	Mean branch total increment for each seedling species, compared between models without or controlled for canopy openness	142
Table 6.65	Planned comparisons of branch total increment, irrespective of seedling species	143
Table 6.66	ANCOVA of seedling branch total increment predicted by canopy species, seedling species and canopy openness	143
Table 6.67	Survival of seedlings, partitioned by species, and by canopy under which they were grown	151
Table 6.68	Growth of seedlings, partitioned by species, and as measured five variables related to growth or health	152
Table 6.69	Growth of seedlings, partitioned by the canopy species under which they were grown, and as measured five variables related to growth or health	152
Table 7.1	Stem and patch characteristics examined in lantana patches	160
Table 7.2	Final 23 variables (22 response, 1 predictor) selected for analysis and the transformations applied to achieve normality of distribution for each variable and the scale in which the results for each variable are reported	168
Table 7.3	ANCOVA of the average number of leaves per stem predicted by canopy type, canopy openness and their interaction	176

Table 7.4	ANCOVA of the average number of leaves per stem predicted by canopy type and canopy openness	176
Table 7.5	ANOVA of the average number of leaves per stem predicted by canopy type	176
Table 7.6	ANCOVA of the average percentage leaves retained per sub-sampling site predicted by canopy type, canopy openness and their interaction	178
Table 7.7	ANCOVA of the average percentage leaves retained per sub-sampling site predicted by canopy type and canopy openness	178
Table 7.8	ANOVA of the average percentage leaves retained per sub-sampling site predicted by canopy type	178
Table 7.9	ANCOVA of the average leaf area (mm ²) per sub-sampling site predicted by canopy type, canopy openness and their interaction	180
Table 7.10	ANCOVA of the average leaf area (mm ²) per sub-sampling site predicted by canopy type and canopy openness	180
Table 7.11	Regression of the average leaf area (mm ²) predicted by canopy openness	180
Table 7.12	Regression equation (linear) for the average leaf area (mm ²) against log(CGF)	180
Table 7.13	ANCOVA of the average leaf length-to-width ratio per sub-sampling site predicted by canopy type, canopy openness and their interaction	182
Table 7.14	ANCOVA of the average leaf length-to-width ratio per sub-sampling site predicted by canopy type and canopy openness	182
Table 7.15	Effects on average leaf length-to-width ratio per sub-sampling site of canopy type and canopy openness	182
Table 7.16	ANCOVA of average petiole length (mm) per sub-sampling site predicted by canopy type, canopy openness and their interaction	183
Table 7.17	ANCOVA of average petiole length (mm) per sub-sampling site predicted by canopy type and canopy openness	183
Table 7.18	Regression of average petiole length (mm) predicted by canopy openness	184
Table 7.19	Regression equation (linear) for average petiole length (mm) against log(CGF)	184
Table 7.20	ANCOVA of the average leaf Hue per sub-sampling site predicted by canopy type, canopy openness and their interaction	186
Table 7.21	ANCOVA of the average leaf Hue per sub-sampling site predicted by canopy type and canopy openness	186
Table 7.22	Effects on average leaf Hue per sub-sampling site of canopy type and canopy openness	187
Table 7.23	ANCOVA of average leaf Value per sub-sampling site predicted by canopy type, canopy openness and their interaction	188
Table 7.24	ANCOVA of average leaf Value per sub-sampling site predicted by canopy type and canopy openness	188
Table 7.25	Regression of average leaf Value predicted by canopy openness	188
Table 7.26	Regression equation (linear) for average leaf Value against log(CGF)	188
Table 7.27	ANCOVA of average leaf Chroma per sub-sampling site predicted by canopy type, canopy openness and their interaction	190
Table 7.28	ANCOVA of average leaf Chroma per sub-sampling site predicted by canopy openness and canopy type/canopy openness interaction	190
Table 7.29	Sigmoid curve equation for the average leaf Chroma against log(CGF)	191
Table 7.30	ANCOVA of the average number of green internodes per stem predicted by canopy type, canopy openness and their interaction	193

Table 7.31	ANCOVA of the average number of green internodes per stem predicted by canopy type and canopy openness	194
Table 7.32	ANOVA of the average number of green internodes per stem predicted by canopy type	194
Table 7.33	ANCOVA of the average number of brown internodes per stem predicted by canopy type, canopy openness and their interaction	195
Table 7.34	ANCOVA of the average number of brown internodes per stem predicted by canopy type and canopy openness	195
Table 7.35	Effects on the average number of brown internodes per stem of canopy type and canopy openness	196
Table 7.36	Means and standard deviations of average number of brown stems per stem.....	196
Table 7.37	Frequency of all green stems per sub-sampling site	197
Table 7.38	ANCOVA of the number of all brown stems per sub-sampling site predicted by canopy type, canopy openness and their interaction	198
Table 7.39	ANCOVA of the number of all brown stems per sub-sampling site predicted by canopy type and canopy openness	198
Table 7.40	ANOVA of the number of all brown stems per sub-sampling site predicted by canopy type	198
Table 7.41	ANCOVA of the average length of green stem (mm) per sub-sampling site predicted by canopy type, canopy openness and their interaction	200
Table 7.42	ANCOVA of the average length of green stem (mm) per sub-sampling site predicted by canopy type and canopy openness	200
Table 7.43	Effects on the average length of green stem length (mm) per sub-sampling site of canopy type and canopy openness	200
Table 7.44	ANCOVA of the average internode length (mm) per sub-sampling site predicted by canopy type, canopy openness and their interaction	201
Table 7.45	ANCOVA of the average internode length (mm) per sub-sampling site predicted by canopy type and canopy openness	202
Table 7.46	Effects on the average internode length (mm) per sub-sampling site of canopy type and canopy openness	202
Table 7.47	Regression equation (linear) for the average internode length (mm) against log(CGF) ...	202
Table 7.48	ANCOVA of the average internode width (mm) per sub-sampling site predicted by canopy type, canopy openness and their interaction	204
Table 7.49	ANCOVA of the average internode width (mm) per sub-sampling site predicted by canopy openness and the canopy type/canopy openness interaction	204
Table 7.50	Sigmoid curve equation for the average internode width (mm) against log(CGF)	205
Table 7.51	ANCOVA of the number of live tips per sub-sampling site predicted by canopy type, canopy openness and their interaction	206
Table 7.52	ANCOVA of the number of live tips per sub-sampling site predicted by canopy type and canopy openness	207
Table 7.53	ANOVA of the number of live tips per sub-sampling site predicted by canopy type	207
Table 7.54	ANCOVA of the average number of living branches per stem predicted by canopy type, canopy openness and their interaction	208
Table 7.55	ANCOVA of the average number of living branches per stem predicted by canopy type and canopy openness	208

Table 7.56	Effects on the average number of living branches per stem of canopy type and canopy openness	209
Table 7.57	Regression equation (linear) for the average number of living branches against log(CGF)	209
Table 7.58	ANCOVA of the average number of dead branches per stem predicted by canopy type, canopy openness and their interaction	210
Table 7.59	ANCOVA of the average number of dead branches per stem predicted by canopy type and canopy openness	211
Table 7.60	ANOVA of the average number of dead branches per stem predicted by canopy type ...	211
Table 7.61	ANCOVA of the average number of missing branches per stem predicted by canopy type, canopy openness and their interaction	212
Table 7.62	ANCOVA of the average number of missing branches per stem predicted by canopy type and canopy openness	212
Table 7.63	ANOVA of the average number of missing branches per stem predicted by canopy type	213
Table 7.64	ANCOVA of the average number of buds per stem predicted by canopy type, canopy openness and their interaction	214
Table 7.65	ANCOVA of the average number of buds per stem predicted by canopy type and canopy openness	215
Table 7.66	ANOVA of the average number of buds per stem predicted by canopy type	215
Table 7.67	ANCOVA of the average number of shoots per stem predicted by canopy type, canopy openness and their interaction	216
Table 7.68	ANCOVA of the average number of shoots predicted by canopy type and canopy openness	216
Table 7.69	Effects on the average number of shoots per stem of canopy type and canopy openness .	217
Table 7.70	ANCOVA of the average number of flowers per stem predicted by canopy type, canopy openness and their interaction	218
Table 7.71	ANCOVA of the average number of flower per stem predicted by canopy type and the canopy type/ canopy openness interaction	219
Table 7.72	Sigmoid curve equation for the average number of flowers against log(CGF)	219
Table 7.73	Summary of variables showing those that were initially removed through correlation and the final variables that had explanatory power	221
Table 7.74	Transition points from low to high light condition	222
Table 7.75	Estimated value of health variables explained by a canopy openness model	236
Table 7.76	Estimated value of health variables explained by a sigmoid model	236
Table 7.77	Differences in means of health variables between canopy types	238

List of Figures		Page No.
Figure 2.1	Botanical drawing of lantana and lantana in flower in the wild	17
Figure 2.2	The dispersal of lantana across the globe during the 19th and 20th centuries	18
Figure 2.3	The current distribution of <i>Lantana camara</i> in Australia	20
Figure 2.4	CLIMEX prediction model for the distribution of <i>Lantana camara</i> in Australia	21
Figure 2.5	<i>Lantana</i> in the subtropical rainforest of the Gold Coast hinterland	22
Figure 3.1	A cross section of a lantana patch in a canopy gap	32
Figure 3.2	Overhead view of the defined lantana patch	32
Figure 3.3	Map of Border Ranges showing the Illinbah Site at Lamington National Park and the Purlingbrook Site at Springbrook National Park	33
Figure 4.1	Location of the four field sites in southeast Queensland	45
Figure 4.2	Illinbah Circuit track map showing section of assessed track	45
Figure 4.3	Caves Circuit track map showing section of assessed track	46
Figure 4.4	Purlingbrook Circuit track map showing section of assessed track	47
Figure 4.5	Warrie Circuit track map showing section of assessed track	47
Figure 4.6	Schematic diagram depicting the sampling method used	48
Figure 4.7	Percentage of lantana across different sites	51
Figure 4.8	Lantana density between rainforest types	53
Figure 4.9	Forest density between rainforest types across different sites	54
Figure 4.10	Lantana density between rainforest types	55
Figure 4.11	Lantana density between disturbances	57
Figure 4.12	Lantana density between disturbances standardised for forest density	58
Figure 5.1	Location of field study site in relation to the Gold Coast hinterland, Queensland and Australia	64
Figure 5.2	Location of experimental canopy trees	67
Figure 5.3	The experimental layout of seed bags under one canopy tree species, each point represents both a buried and above litter seed bag	68
Figure 5.4	Canopy openness variation between different canopy species	74
Figure 5.5	Seed germination between different seed species under different canopies	75
Figure 5.6	Seed germination between different seed species above or below the leaf litter	75
Figure 5.7	Seed germination between different canopies at six months	76
Figure 5.8	Seed germination between different litter positions at six months	77
Figure 5.9	Seed germination between different seed species under different canopies	78
Figure 5.10	Total germination of black apple seeds under different canopy species	78
Figure 5.11	Black apple seed germination between different canopies at three and six months	80
Figure 5.12	Black apple seed germination between different litter positions at three and six months..	81

Figure 6.1.	Experimental layout of seedlings under a canopy tree and under a lantana patch	92
Figure 6.2	Rainfall and temperature during the first 12 months of the study compared to long term averages	92
Figure 6.3	Percentage survival of lantana seedlings under different canopy species	97
Figure 6.4	Percentage survival of lantana seedlings under different canopy species when canopy openness is allowed for	98
Figure 6.5	Diagrammatic of the steps taken to analyse the effect of canopy species and/or canopy openness on lantana seedling growth variables	101
Figure 6.6	Canopy openness variation between different canopy species where lantana seedlings were grown	103
Figure 6.7	Plot of 50% confidence inclusion ellipses for lantana height increment (mm) on canopy openness under each canopy species	104
Figure 6.8	Lantana seedling height increment (mm) under different canopies	105
Figure 6.9	Lantana seedling height increment (mm) compared with when controlled for canopy openness under different canopies	106
Figure 6.10	Plot of 50% confidence inclusion ellipses for lantana seedling stem width increment (mm) on canopy openness under each canopy species	107
Figure 6.11	Lantana seedling stem width increment (mm) under different canopies	108
Figure 6.12	Regression plot of lantana seedling stem width increment (mm) on canopy openness ...	109
Figure 6.13	Plot of 50% confidence inclusion ellipses for lantana seedling leaf total increment on canopy openness under each canopy species	110
Figure 6.14	Lantana seedling leaf total increment under different canopies	111
Figure 6.15	Lantana seedling leaf total increment compared with when controlled for canopy openness	112
Figure 6.16	Plot of 50% confidence inclusion ellipses for the leaf area of the three largest lantana seedling leaves (mm ²) on canopy openness under each canopy species	113
Figure 6.17	Lantana seedling leaf area (mm ²) under different canopies	114
Figure 6.18	Lantana seedling leaf area (mm ²) compared with when controlled for canopy openness under different canopies	115
Figure 6.19	Plot of 50% confidence inclusion ellipses for lantana seedling branch total increment on canopy openness under each canopy species	116
Figure 6.20	Lantana seedling branch total increment under different canopies	117
Figure 6.21	Regression plot of lantana seedling branch total increment on canopy openness	118
Figure 6.22	Survival of all seedlings under different canopies	122
Figure 6.23	Survival of different seedling species under all canopies	122
Figure 6.24	Survival of all seedlings under different canopies when canopy openness is allowed for.....	123
Figure 6.25a	Diagrammatic of the steps taken to analyse the effect of canopy species and/or canopy openness on overall seedling growth variables	125
Figure 6.25b	Diagrammatic of the steps taken to analyse the effect of canopy species and/or canopy openness on overall seedling growth variables	126
Figure 6.26	Canopy openness variation between different canopy species	127
Figure 6.27	Plot of 50% confidence inclusion ellipses for combined seedling residual height increment (mm) on canopy openness under each canopy species	127
Figure 6.28	Combined seedling height increment (mm) under different canopies	129

Figure 6.29	Height increment (mm) comparison, based on canopy species only model compared with the model controlled for canopy openness	130
Figure 6.30	Plot of 50% confidence inclusion ellipses for combined seedling residual stem width increment (mm) on canopy openness under each canopy species	131
Figure 6.31	Combined seedling width increment (mm) under different canopies	133
Figure 6.32	Plot of 50% confidence inclusion ellipses for combined seedling residual leaf total increment on canopy openness under each canopy species	133
Figure 6.33	Combined seedling leaf total increment under different canopies	135
Figure 6.34	Leaf total increment comparison, based on canopy species only model compared with the model controlled for canopy openness	136
Figure 6.35	Plot of 50% confidence inclusion ellipses for combined seedling residual leaf area (mm ²) on canopy openness under each canopy species	137
Figure 6.36	Seedling leaf area (mm ²) between different seedling species under different canopies.....	138
Figure 6.37	Combined seedling leaf area (mm ²) under different canopies	139
Figure 6.38	Seedling leaf area (mm ²) between seedling species under different canopies, statistically controlled for canopy openness	140
Figure 6.39	Seedling leaf area (mm ²) comparison, based on canopy–species–only model compared with the model controlled for canopy openness	141
Figure 6.40	Plot of 50% confidence inclusion ellipses for combined seedling residual branch total increment on canopy openness under each canopy	141
Figure 6.41	Combined seedling branch total increment under different canopies	143
Figure 6.42	Regression of seedling branch total increment on canopy openness	144
Figure 7.1	Map of Border Ranges showing the Illinbah section at Lamington National Park and the Purlingbrook section at Springbrook National Park	158
Figure 7.2	The location of field sites along the Purlingbrook circuit, Purlingbrook National Park ...	159
Figure 7.3	The location of field sites along the Illinbah circuit, Lamington National Park	159
Figure 7.4	Schematic sigmoid curve	170
Figure 7.5	Diagrammatic of the steps taken to analyse the effect of canopy species and/or canopy openness on lantana health variables	173
Figure 7.6	Schematic diagram of the logical	174
Figure 7.7	Scatter plot of the average number of leaves per stem	175
Figure 7.8	Means of the average number of leaves per stem between canopy types	177
Figure 7.9	Scatter plot of the average percentage of leaves retained of each sub–sampling site	177
Figure 7.10	Means of the average percentage of leaves retained per sub–sampling site between canopy types.....	179
Figure 7.11	Scatter plot of the average leaf area (mm ²) of each sub–sampling site	179
Figure 7.12	Regression plot of the average leaf area (mm ²) on canopy openness	181
Figure 7.13	Scatter plot of the average leaf length–to–width ratio of each per sub–sampling site	181
Figure 7.14	Scatter plot of the average petiole length (mm) of each sub–sampling site	183
Figure 7.15	Regression plot of the average petiole length (mm) on canopy openness	184
Figure 7.16	Scatter, and Box and Whisker plot of the average leaf Hue of each sub–sampling site with outliers highlighted	185
Figure 7.17	Final scatter plot of the average leaf Hue of each sub–sampling site	186
Figure 7.18	Scatter plot of the average leaf Value of each sub–sampling site	187

Figure 7.19	Regression plot of the average leaf Value on canopy openness	189
Figure 7.20	Scatter plot of the average leaf Chroma of each sub-sampling site	189
Figure 7.21	Separate slope plot of the average leaf Chroma on canopy openness	190
Figure 7.22	Sigmoid curve of the average leaf Chroma on canopy openness	191
Figure 7.23	Sigmoid curve of the average leaf Chroma on canopy openness with the outlier removed	192
Figure 7.24	Scatter plot of the average number of green internodes per stem	193
Figure 7.25	Means of the average number of green internodes per stem between canopy types	194
Figure 7.26	Scatter plot of the average number of brown internodes per stem	195
Figure 7.27	Scatter plot of the number of all green stems per sub-sampling site	196
Figure 7.28	Scatter plot of the number of all brown stems per sub-sampling site	197
Figure 7.29	Means of the number of all brown stems per sub-sampling site between canopy types ..	199
Figure 7.30	Scatter plot of the average length of green stem (mm) of each sub-sampling site	199
Figure 7.31	Scatter plot of the average internode length (mm) of each sub-sampling site	201
Figure 7.32	Regression plot of the average internode length (mm) on canopy openness	203
Figure 7.33	Scatter plot of the average internode width (mm) of each sub-sampling site	203
Figure 7.34	Separate slopes plot of the average internode width (mm) on canopy openness	204
Figure 7.35	Sigmoid curve the average internode width (mm) on canopy openness	205
Figure 7.36	Scatter plot of the number of live tips per sub-sampling site	206
Figure 7.37	Means of the number of live tips per sub-sampling site between canopy types	207
Figure 7.38	Scatter plot of the average number of living branches per stem	208
Figure 7.39	Regression plot of the average number of live branches on canopy openness	209
Figure 7.40	Scatter plot of the average number of dead branches per stem	210
Figure 7.41	Means of the average number of dead branches per stem between canopy types	211
Figure 7.42	Scatter plot of the average number of missing branches per stem	212
Figure 7.43	Means of the average number of missing branches per stem between canopy types	213
Figure 7.44	Scatter plot of the average number of buds per stem	214
Figure 7.45	Means of the average number of buds per stem between canopy types	215
Figure 7.46	Scatter plot of the average number of shoots per stem	216
Figure 7.47	Means of the average number of shoots per stem between canopy types	217
Figure 7.48	Scatter plot of the number of flowers per stem	218
Figure 7.49	Regression plot of the average number of flowers on canopy openness	219
Figure 7.50	Sigmoid curve of the average number of flowers on canopy openness	220
Figure 7.51	Visual representation of transition from low light condition to high light condition	222
Figure 7.52	The photosynthetic capacity of lantana stems on canopy openness under each canopy type	230
Figure 7.53	The growth potential of lantana stems on canopy openness under each canopy type	231
Figure 7.54	The flowering capacity of lantana stems on canopy openness under each canopy type ..	233
Figure 7.55	An estimation of the annual days of sunshine in a canopy gap	234

List of Appendices		Page No.
Appendix 1	Conceptual Frameworks	265
Appendix 2	Photographic Evidence for Conceptual Framework	267
Appendix 3	Raw data for Chapter 4 - Factors Affecting Lantana Growth within the Forest	271
Appendix 4	Canopy Gap Fraction Method	273
Appendix 5	A list of species of plants growing in lantana patches	275
Appendix 6	Raw data for Chapter 5 - Factors Affecting Seed Germination	277
Appendix 7	Lantana Seed Pre-treatment Germination Experiment for Chapter 5	287
Appendix 8	Tetrazolium-Chloride Seed Viability Test for Chapter 5	289
Appendix 9a	Raw data for Chapter 6 - Factors Affecting Seedling Survival and Growth	291
Appendix 9b	Raw data for Chapter 6 (summarized) - Factors Affecting Seedling Survival and Growth	311
Appendix 10	Raw data for Chapter 7 - Comparison of Lantana Between Forest Clearings and Adjacent Forest	313
Appendix 11	Sigmoid Curve Fitting Technique for Chapter 7	315

List of Abbreviations

ANECFCM	Australian and New Zealand Environment and Conservation Council and Forestry Ministers
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
ARMCAN	Agriculture and Resource Management Council of Australia and New Zealand
CGF	Canopy Gap Fraction
CRCAWM	The Cooperative Research Centre for Australian Weed Management
FC	Flowering Capacity
GP	Growth Potential
NCS	Nature Conservation Strategy
PC	Photosynthetic Capacity
QDNRM	Queensland Department of Natural Resources and Mines
QDNRM&E	Queensland Department of Natural Resources, Mines and Energy
QPWS	Queensland Parks and Wildlife Services
RSS	Residual Sum of Squares

Glossary of Terms

In the context of this thesis, the following terms have distinct definitions:

Aggressive — fast growing, tending to spread quickly and invade

Disturbance — a disturbance has been best defined by Sousa (1984) as “a discrete, punctuated killing, displacement, or damaging of one or more individuals (or colonies) that directly or indirectly creates an opportunity for new individuals (or colonies) to become established”

Economic weed — a weed whose impacts are, or are thought to be, detrimental to economic systems

Environmental weed — a weed whose impacts are, or are thought to be, detrimental to the environment and occur in relatively undisturbed and mostly native vegetation and are undesirable ecologically, but not always economically

Exotic plant/weed— a plant/weed existing in an area outside its native range

Forest canopy — as used here, is foliage that is wider than twice its height above the lantana

Healthy —showing signs of active growth, and lacking evidence of extensive disease or environmental stress (e.g. dead leaves)

Invasion — the arrival of an organism in regions beyond its natural range (Williamson 1996)

Invasive species — species that spread where they are not native

Lantana patch — as used here, is defined as the total area of lantana and may, or may not, extend under the rainforest canopy

Thrifty —healthy and in vigorous growth (i.e. thriving)

Unhealthy —showing extensive signs of disease or environmental stress

Unthrifty —showing evidence of succumbing to environmental stresses

Weed — a weed is a plant that grows where it is not wanted/a term that is used by the public, farmers and ecologists for the infestation of an unwanted plant into a garden, a paddock or a National Park

Preamble

“In nineteenth-century Europe a vegetable Frankenstein was created in hothouses by hybridising various Latin American shrubs. The monster so spawned, lantana (*Lantana camara*), went on to become one of the world’s worst weeds” (Low 2002).

It has long been recognised that exotic plant invasions represent a major threat to the integrity of natural ecosystems. Many studies have looked at the patterns and processes of invasive species. On the other hand, very few studies have looked at the mechanism of invasion in respect to the invaded community itself (Hobbs and Humphries 1995, Burke and Grime 1996, Prieur-Richard and Lavorel 2000).

The future of lantana *Lantana camara* L. (Lamiales: Verbenaceae) in the rainforests of central eastern Australia appears to be reliant on the interaction at the lantana/rainforest boundary (Fensham pers. comm. 2000). This work directly addresses these processes.

