

JCU ePrints

This file is part of the following reference:

Rangel, José Henrique de Albuquerque (2005)
Agroecological studies of Desmanthus – a tropical forage legume. PhD thesis, James Cook University.

Access to this file is available from:

<http://eprints.jcu.edu.au/17512>



Agroecological studies of *Desmanthus* – a tropical forage legume

Thesis submitted by

**José Henrique de Albuquerque RANGEL, BSc in Agronomic Engineering,
Universidade Federal Rural de Pernambuco, Brazil, MSc in Animal Nutrition
and Pasture, Universidade Federal de São Paulo, Brazil
in November 2005**

**for the degree of Doctor of Philosophy
in Tropical Plant Sciences
within the School of Tropical Biology
James Cook University**

ELECTRONIC COPY

I, the undersigned, the author of this work, declare that the electronic copy of this thesis provided to the James Cook University Library, is an accurate copy of the print thesis submitted, within the limits of the technology available.

Signature

Date

STATEMENT OF ACCESS

I, the undersigned, the author of this thesis, understand that James Cook University will make it available for use within the University Library and, by microfilm or other means, allow access to users in other approved libraries. All users consulting this thesis will have to sign the following statement:

In consulting this thesis I agree not to copy or closely paraphrase it in whole or in part without the written consent of the author; and to make proper public written acknowledgment for any assistance which I have obtained from it

Beyond this, I do not wish to place any restriction on access to this thesis.

José Henrique de Albuquerque Rangel

**STATEMENT ON SOURCES
DECLARATION**

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

José Henrique de Albuquerque Rangel

ABSTRACT

The use of forage legumes in tropical regions to improve the efficiency of animal production from grazing has been limited, largely because of the lack of economic incentives. There is a clear need, therefore, to investigate the existing gene pool of tropical forage plants to assess their potential for pasture improvement. Therefore, the present study evaluated the agronomic and ecological aspects of plant development in a set of genotypes of the genus *Desmanthus* and their relationships with the components of the surrounding environment, at different stages of growth, in a series of laboratory and field experiments.

Accessions of the genus *Desmanthus* formed permanent soil seed banks that ranged from 281 to 1303 seeds/m², with a large variation between genotypes, in experiments on a duplex soil on the Douglas Campus of James Cook University, Townsville. Genotypes originally collected in Argentina had larger seed banks than those of other tested genotypes, but a small number of surviving plants.

Fire increased seedling recruitment in almost all observed genotypes. Temperatures observed during controlled grass-fires reached a maximum of 300 °C at the soil surface, 80 °C at 10 mm depth, and around 30 °C at 30 mm depth suggesting that all seeds located at soil surface were killed, those at 10 mm depth were probably softened, and those at 30 mm or more in soil had no alteration in their seed-coat permeability.

Changes in strophliolar structure and germination, in response to the variation of oven temperatures ranging from 25 °C to 120 °C were observed in seeds of nine genotypes of *Desmanthus*. There were two groups with different patterns of responses: genotypes in which strophliolar structures were not significantly affected by temperatures below 80 °C; and genotypes with significant changes in the strophliolar structures when temperature rose to 60 °C.

Seedlings of 8 accessions of the *Desmanthus* complex, growing directly under trees in open savanna woodland had higher values of means for number of leaves/plant, height of plant, and number of plants surviving than seedlings growing between trees. Three years after sowing, all plants from the between-canopy environment had died, while many plants of accessions TQ88, CPI 79653, and CPI 91162 were thriving under the tree canopy.

Plants of *D. virgatus* CPI 78382 and *D. leptophyllus* TQ 88 growing in soils collected from under and between canopies had significantly increased their seedling emergence, by increasing shade levels and watering frequency. A low number of seedlings died in both genotypes, growing in soil from under the canopy but, plant deaths drastically increased in seedlings grown in soil from between the canopy. Growing in soil collected from under-canopies, plants allocated most of their dry matter to the production of aerial, rather than the underground parts, however, when grown in soil from between-canopies environment the largest proportion of the total dry matter was diverted to the underground parts. This diversified behaviour of biomass allocation for shoot and root in the two soils is thought to be controlled by the contents of nutrients in soil.

Seven accessions of the *Desmanthus* complex, sown into a pasture as seeds or seedlings, under two levels of competition with the natural vegetation, showed to have differentiated behaviour according the different treatments. Plant establishment and dry matter yields of plants sown by seed into unaltered vegetation were significantly reduced by competition.

The effect on liveweight changes and wool growth of Merino sheep of 200 g hay of four different forms of the *Desmanthus* complex included as a supplement to a diet of 600 g Mitchell grass (*Astrebla* spp.) was compared with 200 g hay of *Stylosanthes hamata* cv. Verano. Verano and *D. virgatus* CPI 79653 supplemented diets had the highest dry matter digestibility (46.52% and 44.94% respectively). All the legume-supplemented diets produced significantly more wool than the control. Clean wool growth was significantly correlated with nutritional parameters. The levels of nitrogen and sulphur present in some *Desmanthus* genotypes shows the potential of these plants in promoting wool growth.

ACKNOWLEDGEMENTS

I am most grateful to Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA, Brazil) for the financial support to carry out this research project.

I would like to express my gratitude to my supervisors Dr Robert L. Burt and Dr Ross Coventry, the first for his guidance and encouragements during the period the work was carried out and initially written, and the second by his wise and constructive suggestions in the final written work.

Grateful acknowledgments are made of the valuable help and advice given by members of the academic staff of the School of Tropical Biology of James Cook University. In particular I wish to thank my “Aussie brother” Chris Gardiner, for his help in field and laboratory work and in all my needs in Australia, and to Professor D. Griffiths for the accurate reading and precise suggestions on a draft of the manuscript.

I wish also to extend my sincere thanks to Dr J. Hogan of the CSIRO Davies Laboratory at Townsville, for providing facilities and advice in the first steps of my research program at CSIRO Landsdown Research Station.

I express sincere thanks to my friend Dr Peter Durr for his valuable help on numerous occasions.

Finally, I would forever thank the wonderful people of Australia for the friendship and affection given to myself and my family.

This thesis is dedicated in memory of my parents Fernando and Cely, and to my brothers Vital, Fernando, and Mario, my sister Catarina, my wife Salete, my sons Fernando, Andre, and José, and my daughter Jean, from whom I always had the greatest of the love and support.

TABLE OF CONTENTS	Page
Chapter 1 INTRODUCTION	1
1.1 Aim of this thesis	1
1.2 Role of legumes in pastures	2
1.3 <i>Desmanthus</i> for tropical pastures	4
1.4 Adaptation of <i>Desmanthus</i> to the semi-arid tropics	8
1.5 Seeds and soil seed bank, seed dormancy of <i>Desmanthus</i>	9
1.5.1 <i>The importance of seeds</i>	9
1.5.2 <i>Seeds of Desmanthus</i>	11
1.5.3 <i>Seed-coat dormancy in Desmanthus</i>	14
1.5.4 <i>Soil seed banks</i>	17
1.6 Regenerative strategies of <i>Desmanthus</i>	20
1.7 Environmental constrains to the growth of forage legumes	22
1.7.1 <i>Shade tolerance in tropical forage legumes</i>	22
1.7.2 <i>Soil water content in shaded habitats</i>	23
1.7.3 <i>Effect of trees on soil nutrients</i>	24
1.8 <i>Nutritional value of Desmanthus</i>	25
1.9 The approach of this thesis	26
1.10 Scientific papers and conference presentations arising from the present study	27
Chapter 2 MATERIAL AND METHODS	28
2.1 Morphological characteristics of the <i>Desmanthus</i> genus	28
2.2 Genotypes studied	29
2.3 The study area	34
2.3.1 <i>Location</i>	34
2.3.2 <i>Climate of the area</i>	34
2.3.3 <i>Vegetation of the study area</i>	38
2.3.3.1 <i>Nature of vegetation at JCU Douglas Campus</i>	38
2.3.3.2 <i>Vegetation of the experimental sites</i>	38
• <i>Site 1</i>	38
• <i>Site 2 and 3</i>	38
• <i>Site 4</i>	39
2.3.3.3 <i>Seasonality of growth</i>	39
2.3.4 <i>Soils of the study area</i>	41
<i>General soil type</i>	41
Chapter 3 BREAKING THE DORMANCY OF <i>Desmanthus</i> SEEDS	43
3.1 Viability of seeds in soil seed banks	43
3.1.1 <i>Materials and methods</i>	43
3.1.1.1 <i>The study area</i>	43
3.1.1.2 <i>Genotype selection</i>	43
3.1.1.3 <i>Selected genotypes and their previous seedling dynamics in the area</i>	45
3.1.1.4 <i>Seed recovery from the soil seed bank</i>	45

3.1.1.5	<i>Statistical analysis</i>	47
3.1.2	Results	47
3.2	Effects of heat on seed coat structure and germination of genotypes of the <i>Desmanthus</i> complex	49
3.2.1	Material and methods	50
3.2.1.1	<i>Heat treatments</i>	50
3.2.1.2	<i>Germination, hard seed and imbibed seed</i>	51
3.2.1.3	<i>Strophiolar structure</i>	51
3.2.1.4	<i>Statistical analysis</i>	52
3.2.2	Results	52
3.2.2.1	<i>Raised strophiole</i>	52
3.2.2.2	<i>Germination</i>	54
3.2.2.3	<i>Hardseededness</i>	59
3.3	Effect of fire on soil heating and seed coat dormancy	61
3.3.1	<i>Effect of fire on soil heating</i>	61
3.3.1.1	<i>Materials and methods</i>	61
3.3.1.2	<i>Results</i>	62
3.3.2	<i>Effect of fire on seedling recruitment</i>	62
3.3.2.1	<i>Materials and methods</i>	62
3.3.2.2	<i>Results</i>	64
3.4	Discussions	65
3.4.1	<i>Soil seed banks</i>	65
3.4.2	<i>Effects of heat on seed-coat structure and seed germination</i>	66
3.4.3	<i>Effects of fire on seedling recruitment from the soil seed-bank</i>	72
3.4.4	<i>Effects of fire on soil temperatures</i>	73
Chapter 4 EFFECTS OF SHADE ON EARLY GROWTH OF <i>Desmanthus</i>		74
4.1	Introduction	74
4.2	Materials and methods	76
4.2.1	<i>Location and site condition</i>	76
4.2.2	<i>Experiment layout</i>	77
4.2.3	<i>Seed sowing</i>	77
4.2.4	<i>Plant propagation</i>	80
4.2.5	<i>Environmental data collected</i>	81
4.2.5.1	<i>Tree density</i>	81
4.2.5.2	<i>Soil</i>	81
4.2.5.3	<i>Light interception</i>	81

4.2.6	<i>Plant observations</i>	82
4.2.7	<i>Experimental design and statistical analysis</i>	82
4.3	Results	84
4.3.1	<i>Soil</i>	84
4.3.2	<i>Tree density</i>	85
4.3.3	<i>Light irradiancy</i>	85
4.3.4	<i>Legume evaluation</i>	89
4.3.4.1	<i>Numbers of leaves per plant</i>	89
4.3.4.2	<i>Heights of plants</i>	90
4.3.4.3	<i>Plant survival</i>	95
4.3.4.3.1	<i>Under-canopy environment</i>	95
4.3.4.3.2	<i>Between-canopies environment</i>	98
4.4	Discussions	100
 Chapter 5 SEEDLING BEHAVIOUR OF TWO <i>Desmanthus</i> GENOTYPES UNDER DIFFERENT SOIL, LIGHT INTENSITY, AND WATERING FREQUENCY TREATMENTS		 105
5.1	Introduction	
5.2	Materials and methods	105
5.2.1	<i>Preliminary tests</i>	105
5.2.1.1	<i>Soil density and daily water balance in soil</i>	105
5.2.1.2	<i>Seed germination</i>	106
5.2.2	<i>Main trial</i>	107
	<i>Statistical analysis</i>	108
5.3	Results	109
5.3.1	<i>Preliminary tests</i>	109
5.3.1.1	<i>Soil density and daily water balance in soil</i>	
5.3.1.2	<i>Seed germination</i>	110
5.3.2	<i>Main trial</i>	111
5.3.2.1	<i>Actual water balance in soil</i>	111
5.3.2.2	<i>Seedling Emergence</i>	114
5.3.2.3	<i>Desmanthus plant survival</i>	114
5.3.2.3.1	<i>TQ 88</i>	114

5.3.2.3.2	<i>CPI 78382</i>	120
5.3.2.4	<i>Dry Matter Production (mg/plant)</i>	120
5.3.2.4.1	<i>Shoot Dry Matter (mg/plant)</i>	120
5.3.2.4.2	<i>Root Dry Matter (mg/plant)</i>	127
5.3.2.4.3	<i>Biomass allocation between shoots and roots</i>	129
5.3.2.4.4	<i>The interactive effect of treatments on shoot and root dry matter</i>	133
5.4	Discussions	138
 Chapter 6 PASTURE ESTABLISHMENT STRATEGIES FOR <i>Desmanthus</i> GENOTYPES		141
6.1	Introduction	141
6.2	Materials and methods	143
6.2.1	<i>Study site</i>	143
6.2.2	<i>Experimental design and procedures</i>	143
6.2.2.1	<i>Field methods</i>	143
6.2.2.2	<i>Statistical analysis</i>	145
6.3	Results	146
6.3.1	<i>Seedling emergence</i>	146
6.3.2	<i>Seedling survival</i>	147
6.3.3	<i>Shoot dry matter</i>	149
6.4	Discussions	150
 Chapter 7 STIMULATION OF WOOL GROWTH BY <i>Desmanthus</i> PASTURES		152
7.1	Introduction	152
7.2	Materials and methods	154
7.3	Results	156
7.3.1	<i>Diet components</i>	156
7.3.2	<i>Animal response to diets</i>	157
7.3.3	<i>Diet efficiency and the stimulation of wool growth</i>	160
7.4	Discussions	162
 Chapter 8 CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS		167
8.1	Conclusions	167

8.2	Future research direction	172
8.3	Possible application of this research	174
REFERENCES		175
9 APPENDICES		215
9.1	Appendix 1 - Meteorological data recorded at Townsville Airport and experimental sites	217
9.2	Appendix 2 - Statistical analyses of data collected in trials carried out in field and laboratory	223
9.2	Appendix 3 Scientific papers and conference presentations arising from the present study	237

LIST OF TABLES		Page
Table 1.1	Variation in size of some seeds of <i>Desmanthus</i> species.	12
Table 2.1	General characterization of the <i>Desmanthus</i> genotypes used in the study.	30
Table 2.2	Data of collection of the <i>Desmanthus</i> genotypes used in the study.	31
Table 2.3	Plant morphological characters of the <i>Desmanthus</i> genotypes used in the study.	32
Table 2.4	Plant anatomical characteristics of the <i>Desmanthus</i> genotypes used in the study.	33
Table 3.1	Plant survival and seedling recruitment of <i>Desmanthus</i> genotypes in three blocks at the experimental site.	46
Table 3.2	Soil seed bank of <i>Desmanthus</i> genotypes.	48
Table 3.3	Seed viability % of nine genotypes of <i>Desmanthus</i> by the Tetrazolium test.	49
Table 3.4	Percentage of raised seed strophioles of nine <i>Desmanthus</i> genotypes in function of the heat treatments (Control, 40 °C, 60 °C, 80 °C, 100 °C, and 120 °C).	53
Table 3.5	Percentage of germination in seeds of nine <i>Desmanthus</i> genotypes in functions of the heat treatments (Control, 40 °C, 60 °C, 80 °C, 100 °C, and 120 °C).	
Table 3.6	Percentage of seeds which remained hard after the germination test of nine <i>Desmanthus</i> genotypes submitted to heat treatments.	60

Table 4.1	Genotypes of <i>Desmanthus</i> used in the trial and germination %.	80
Table 4.2	Dates of data recording of field observations, time iweeks from thinning of seedlings, and rainfall.	83
Table 4.3	Soil Chemical Composition Under and Between Tree Canopies.	84
Table 4.4	Tree density at the experimental site at James Cook University.	85
Table 4.5	Photosynthetic photon flux (PPF, $\mu\text{mol}/\text{m}^2/\text{s}$) reaching soil surface at one position between-canopy and three positions under-canopy from 8:00 a.m. to 6:00 p.m. on September 1994.	87
Table 4.6	LSD pairwise comparisons of mean number of leaves/plant of legumes growing under-canopy by genotype at December 1992	90
Table 4.7	LSD pairwise comparisons of mean number of leaves of legumes growing between-canopies by genotype at December 1992.	90
Table 4.8	LSD pairwise comparisons of mean heights of legume plants at under- canopy sites by genotype at December 1992.	92
Table 4.9	LSD pairwise comparisons of mean heights of legume plants at between-canopies sites by genotype at December 1992.	93
Table 4.10	LSD pairwise comparisons of mean heights of legume plants at under-canopy sites by quadrant at December 1992.	93
Table 4.11	LSD pairwise comparisons of mean numbers of plants of surviving genotypes under-canopy sites.	96
Table 4.12	LSD pairwise comparisons of means of relative plant survival by quadrant in under-canopy sites.	97

Table 4.13	LSD pairwise comparisons of mean numbers of plants surviving by genotype and quadrant between-canopies sites.	100
Table 5.1	Water stress in soil according with the watering interval.	110
Table 5.2	Mean percentage germination of 3 replicates of 50 seeds of <i>D. leptophyllus</i> TQ88 and <i>D. virgatus</i> CPI 78382, from 3 September - 19 October 1994.	110
Table 5.3	LSD pairwise comparisons of means of seedling emergence (% of emerged seedlings from the sown seeds) by shade, soil, watering frequency, and genotype.	115
Table 5.4	LSD pairwise comparisons of means of seedling emergence (% of emerged seedlings from the sown seeds) for the interaction shade x genotype.	115
Table 5.5	Pairwise comparisons of means of individual dry weight of shoot (mg/plant) by shade, soil, watering frequency, and genotype by LSD ($p < 0.05$).	126
Table 5.6	Pairwise comparisons of means of individual dry weight of root (mg/plant) by shade, soil, watering frequency, and genotype by LSD ($p < 0.05$).	128
Table 5.7	LSD pairwise comparisons of means of individual shoot/root dry matter ratio by shade, soil, watering and genotype.	132
Table 6.1	LSD pairwise comparisons of means of germination (%) by genotype.	146
Table 6.2	LSD pairwise comparisons of means of shoot dry matter by the effects of vegetation management, establishment method, and genotype. Data subjected to $\sqrt{x+1}$ transformation before analysis.	150
Table 6.3	LSD pairwise comparisons of means of shoot dry matter by the interaction vegetation management x genotype. Data subjected to $\sqrt{x+1}$ transformation before analysis.	150

Table 7.1	Dry matter content of the diet components used in the wool growth experiment.	157
Table 7.2	Chemical compositions of diet components. Organic Matter, Neutral Detergent Fibre, Acid Detergent Fibre, Nitrogen and Sulphur contents expressed as percentage of the Dry Matter.	157
Table 7.3	The composition of different diets (Mitchell grass hay + supplement of hay of legumes as shown), and their effects on the nutritional parameters of Merino wethers over the period of the feeding trial.	159
Table 7.4	The effect of the different diets on the quantitative and qualitative parameters of wool. First growth period.	161
Table 7.5	The effect of the different diets on the quantitative and qualitative parameters of wool. Second growth period.	161
Table 7.6	Correlation coefficients between clean wool yield during the first wool growth period and nutritional parameters.	164
Table 7.7	Correlation coefficients between clean wool yield during the second wool growth period and nutritional parameters.	165

LIST OF FIGURES		Page
Figure 1.1	Variation among forms of <i>Desmanthus virgatus</i> complex, collected in Central and South America.	05
Figure 1.2	Aerial parts of a <i>Desmanthus</i> plant.	05
Figure 1.3	Circular model representing the environmental influences on a plant pasture in it different stages of life.	10
Figure 1.4	Diagram of a <i>Desmanthus</i> seed showing main structures.	13
Figure 2.1	Different parts of a <i>Desmanthus</i> plant.	28
Figure 2.2	Aerial view of James Cook University Douglas Campus with schools and divisions.	35
Figure 2.3	Experimental sites (1 to 4) at School of Biomedical and Tropical Veterinary.	35
Figure 2.4	Queensland long term rainfall map.	36
Figure 2.5	Townsville 100 year average monthly rainfall and experimental site monthly rainfall at the years of 1992, 1993, and 1994.	37
Figure 2.6	General view of the sites in February 1993.	40
Figure 2.7	General view of the sites in August 1993.	40
Figure 2.8	August 1993, plant of Chinee apple (<i>Ziziphus mauritiana</i>) killed by the drought on under-canopy site.	41
Figure 2.9	Queensland soil map	42
Figure 3.1	Experimental layout of 30 herbaceous forage legumes at the School of Biomedical and Tropical Veterinary by Suparto 1990.	44

- Figure 3.2** Effect of heat on the percentage of strophiole permeability (----Strophiole) and the percentage of germination (—Germination) in seeds of *Desmanthus* genotypes. Group of the “highly specific temperature for germination”. 56
- Figure 3.3** Effect of heat on the percentage of strophiole permeability (----Strophiole) and the percentage of and germination (—Germination) in seeds of *Desmanthus* genotypes. Group of the “intermediate specific temperature for germination”. 57
- Figure 3.4** Effect of heat on the percentage of strophiole permeability (----Strophiole) and on the percentage of germination (—Germination) in seeds of *Desmanthus* genotypes. Group of “indifferent in temperature for germination”. 58
- Figure 3.5** Soil temperatures during three experimental grassland fires at James Cook University. 63
- Figure 3.6** Maximum temperatures at different soil depths in three grassland experimental fires at James Cook University. 64
- Figure 3.7** Seedling recruitment in genotypes of *Desmanthus* genotypes after a grassland fire. 65
- Figure 3.8** Seed of *D. virgatus* (x 30) showing the pleurograme and hilum-strophiole structures. 69
- Figure 3.9** Impermeable flat-striped strophiole structure in seed of *D. virgathus* not submitted to heat treatment (x 100). 69
- Figure 3.10** Raised strophiole in seed of *D. virgatus* submitted to a temperature of 80 °C. Frontal view (x 100). 70
- Figure 3.11** Raised strophiole in seed of *D. virgathus* submitted to a temperature of 80 °C. Lateral view (x 100). 70

Figure 3.12	Effect of heat on the coefficients of correlation between germination and raised strophiole in seeds of <i>Desmanthus</i> genotypes.	71
Figure 4.1	Genotype distribution on the plots.	78
Figure 4.2	Under-canopy environment in March 1992.	79
Figure 4.3	Between-canopies environments in March 1992.	79
Figure 4.4	Mean of photosynthetic photon flux (PPF, $\mu\text{mol}/\text{m}^2/\text{s}$) reaching the soil surface registered from 8:00 a.m. to 6:30 p.m., for the under-canopy and between-canopies sites on 11 September 1994.	88
Figure 4.5	Photosynthetic photon flux (PPF, $\mu\text{mol}/\text{m}^2/\text{s}$) reaching soil surface at one point between-canopy and three points under-canopy, averaged for twenty two observations times in 11 September 1994.	88
Figure 4.6	Distribution of leaves per plant in genotypes of <i>Desmanthus</i> from February to December 1992 in two microenvironments, and actual monthly rainfall.	91
Figure 4.7	Progressive curves of plant height in genotypes of <i>Desmanthus</i> from February to December 1992 in two sites, under and between-canopies, plotted against rainfall in the same period.	94
Figure 4.8	Vigorous plants of <i>Desmanthus bicornutus</i> CPI 911628 and <i>D. leptophyllus</i> TQ88, under-canopy site in March 1995.	97

Figure 4.9	Kaplan-Meier cumulative survival curves of seven genotypes of <i>Desmanthus</i> at four locations under the tree canopy environment.	99
Figure 4.10	Kaplan Meier cumulative survival curves of seven genotypes of <i>Desmanthus</i> at four locations between the tree canopies environment.	101
Figure 5.1	Field distributions of shade cloth and pots.	107
Figure 5.2	Curves of decreasing water content (weight %) in soils collected from under and between tree canopies, submitted to treatments of 50 % shade and full sunlight.	110
Figure 5.3	Linear regression of the effects of 3, 6, and 12 day watering intervals on the water content in soils collected under and between tree canopies, averaged for the studied levels of 100%, 45%, 30% and 15% of full sunlight.	111
Figure 5.4	Linear regression for the studied levels of 100%, 45%, 30% and 15% of full sunlight on the water content in soil, averaged for soils collected from under and between tree canopies.	112
Figure 5.5	Linear regressions of water content in soil under 3, 6, and 12 day watering intervals, and different levels of sunlight.	113
Figure 5.6	Percentage of seedling emergence curves of <i>D. leptophyllus</i> TQ 88 in soil from under-canopies at four levels of light incidence, for different watering regime intervals.	116
Figure 5.7	Percentage of seedling emergence curves of <i>D. leptophyllus</i> TQ 88 in soil from between-canopies at four levels of light incidence, for different watering regime intervals.	117

- Figure 5.8** Percentage of seedling emergence curves of *D. virgatus* CPI 78382 in soil from under-canopies at four levels of light incidence, for different watering regime intervals. 118
- Figure 5.9** Percentage of seedling emergence curves of *D. virgatus* CPI 78382 in soil from between-canopies at four levels of light incidence, for different watering regime intervals. 119
- Figure 5.10** Percentage of seedlings survival curves of *D. leptophyllus* TQ 88 in soil from under-canopies, at four levels of light incidence, and three different watering regime intervals 121
- Figure 5.11** Percentage of seedlings survival curves of *D. leptophyllus* TQ 88 in soil from between-canopies, at four levels of light incidence, and three different watering regime intervals. 123
- Figure 5.12** Percentage of seedlings survival curves of *D. virgatus* CPI 78382 in soil from under-canopies, at four levels of light incidence, and three different watering regime intervals 123
- Figure 5.13** Percentage of seedlings survival curves of *D. virgatus* CPI 78382 in soil from under-canopies, at four levels of light incidence, and three different watering regime intervals. 124
- Figure 5.14** Linear regression for the effect of watering regime on the shoot and root dry matter yields of *Desmanthus*, averaged for four levels of shade, two soils, and two genotypes (n= 48). 127
- Figure 5.15** Scatter plot distribution of shoot and root dry matter of *D. leptophyllus* TQ 88, cultivated in soil from under and between tree canopies, in relation to total shoot or root dry matter. 130
- Figure 5.16** Scatter plot distribution of shoot and root dry matter of *D. virgatus* CPI 78382, cultivated in soil from under and between tree canopies, in relation to total shoot or root dry matter. 131
- Figure 5.17** Effect of watering intervals (3, 6, and 12 days) on the dry matter yield of shoot (mg/plant) of *D. leptophyllus* TQ 88 grown on soil from under and between-canopies, submitted to four levels of shade. 134

- Figure 5.18** Effect of watering intervals (3, 6, and 12 days) on the dry matter yield of root (mg/plant) of *D. leptophyllus* TQ 88 grown on soil from under-and between-canopies, submitted to four levels of shade. 135
- Figure 5.19** Effect of watering intervals (3, 6, and 12 days) on the dry matter yield of shoot (mg/plant) of *D. virgatus* CPI 78382 grown on soil from under and between-canopies, submitted to four levels of shade. 136
- Figure 5.20** Effect of watering intervals (3, 6, and 12 days) on the dry matter yield of root (mg/plant) of *D. virgatus* CPI 78382 grown on soil from under-and between-canopies, submitted to four levels of shade. 137
- Figure 6.1** Field spatial distribution of the applied treatments of vegetation management and introduction method on six *Desmanthus* genotypes. 144
- Figure 6.2** Kaplan-Meier cumulative survival curves of genotypes of *Desmanthus*, introduced by seed or by seedling into herbicide treated pasture (no competition) or into the natural grassland complex. 148
- Figure 71.** Location map of Australian central plain with the Mitchell grass country in green. 153

Glossary of Terms

Abscission scar or **hilum**. The scar at the point of attachment of the seed to a funicle (Cutler 1978; Raven *et al.* 1985).

Acid detergent fibre. The insoluble residue left from boiling a substance in a solution of acid detergent for 1 hour and filtering. Consists mainly of cellulose, lignin, and silica (Lassiter and Edwards 1982); the cellular wall components of forages (cellulose, lignin, and minerals) not soluble in acid detergent (Silva and Queiroz 2002).

Ad libitum. Applied to feeding animals meaning allowed feed in accordance with desire (Lassiter and Edwards 1982).

After-ripening. It is a process necessary for the completion of certain metabolic changes in seeds before germination is possible (Debenham 1971, Murdoch and Ellis 1992). It depends upon the environment and is usually accelerated at high temperatures (Gardener 1975).

Agroforestry system. It is a farming system that integrates crops and/or livestock with trees and shrubs (Sanchez 1999; Beetz 2002).

Alley-crop. It is a method of growing perennial species, usually shrub or tree legumes, together with annual crops (Stirzaker and Bunn 1996).

Bipinnate. Is said of a compound leaf when secondary leaflets (**pinnules**) arising along a secondary rachis (**rachilla**), the primary (compound) leaflets being termed **pinnae** (Debenhan 1971).

Boss. See Strophiole.

Brigalow. Country where brigalow, a species of acacia (*Acacia harpophylla*), is the main vegetation. "Extensive stands of Brigalow forests occurred on clay soils of

South West and Central West Queensland. Now mostly cleared for agriculture” (Griffith University 2005).

Browsing. When animals such as deer or goats browse, they feed on plants, especially on their young twigs or leaves, in an unhurried way (Sinclair 1988).

Caatinga. It is a type of Brazilian Northeast forest which is deciduous during the hot and dry season and includes a number of thorny species (Sinclair 1988).

Caudex, or flange. The perennial base of an otherwise herbaceous plant (Swartz 1971).

Cerrados. Is the name given to the Brazilian savanna. Around 85% of the large plateau of Brazilian central region was originally dominated by cerrados landscape, representing some thing like 1.5 to 2 millions of km², or 25% of the country surface (Pivello 2005).

Chartaceous. Of parchment or paper-like texture, usually devoid of green (Debenham 1971).

Clean wool. Processed wool, free of grease, soil particles, and vegetable matter (DPI 2004).

Cohabitant species. Mixtures of different plant species growing on the same patch of land (Happer 1977d).

Coated seed. Seed having an integument cover composed of layers (Swartz 1971).

Crown. The persistent base of a tufted grass (Swartz 1971).

Cuticle. A fatty and fat-derived layer of cutin in the seed outer wall, serving as a barrier to water and gas exchange but permeable to the diffusion of aqueous solutions through cracks and ridges to a limited degree (Debenham 1971, Cutler 1978); layer of wax or fat covering the external wall of epidermal cells (Raven *et al.* 1985).

Dorsi-ventrally flattened. Flat at both dorsal and ventral sides (Debenham 1971).

Endosperm. The multicellular food-storing tissue consisting chiefly of starches and oils, providing nutrient for the developing embryo formed inside a seed of flowering plants, following the double fertilization of the embryo-sac by the second sperm nucleus (Debenham 1971, Swartz 1971); a nutrient tissue formed within the embryo-sac of the spermatophyta (Cutler 1978).

Epidermal, Prism, or Malpighian cells. The outermost cells layer of primary tissues of the plant, sometimes comprising more than one layer (Cutler 1978). In the seed coats of certain plants (specifically in the legumes) a layer of radially elongated cells, which are palisade-like but devoid of intercellular spaces, may be present. These cells have been termed *Malpighian cells* after the investigator who first described them (Fahn 1974).

Evapotranspiration. The loss to the atmosphere of moisture from both the soil (evaporation) and its vegetative cover (transpiration) (Answer.com 2005) (Physical Geography 2004).

Falcate. With the shape of a lamina when flat and curved (like a reaper's hook, or sickle) (Debenham 1971).

Fire-recruitment syndrome or refractory seed syndrome. The condition by which certain seeds require the occurrence of a fire, for germination from the soil seed bank (Kelley 1991).

Flange. A projecting edge on an object used for strengthening it or for attaching it to another object (Sinclair 1988).

Forbs. Herbs others than grasses or sedges (Debenham 1971, Swartz 1971).

Funiculus. The stalk attaching an ovule to the placenta (Cutler 1978).

Greasy wool. Wool as it is shorn before washing or sorting (Wimburne 1982).

Hardseededness or seed-coat dormancy. The condition of having a seed coat that is impermeable to water (Fahn 1974).

Hilum, or abscission scar. The scar at the point of attachment of the seed to a funicle (Cutler 1978; Raven *et al.* 1985).

Hour-glass cells. A single layer of cells forms the hypodermis, which is also, called hourglass cells, pillar cells, osteosclereids or lagenosclereids, depending on their pattern of cell wall thickness and shape. They are usually larger than adjacent cell layers and are separated by wide intercellular spaces, except under the hilum cleft where they are absent (Souza and Marcos Filho 2001).

Hypocotyl. The short stem of an embryo seed plant, the portion of the axis of the embryo seedling between the attachment of the cotyledons and the radicle (Swartz 1971); the part of the axis marking the transition of root and stem development (Raven *et al.* 1985).

Innate dormancy, or primary dormancy. The physiological inhibiting mechanism of germination in the embryo; physiological dormancy (El-Keblawy 2006). The process of growth of an embryo to a stage fit for the germination process to occur, has not been completed while the embryo was still born on the parent plant (Haper 1977b)

In vivo dry matter digestibility. The apparent digestibility of the dry matter in animal fodder. The difference between the dry matter intake and its faecal excretion (Lassiter and Edwards 1982).

Lens, boss, or strophiole. See strophiole.

Llanos. Spanish American term for prairies, specifically those of the Orinoco River basin of North South America, in Venezuela and East Colombia. The llanos of the Orinoco are a vast, hot region of rolling savanna broken by low-lying mesas, scrub forest, and scattered palms. Elevation above sea level never reaches more than a few hundred feet. During the dry season (November to April) the land is sear, the grass

brown, brittle, and inedible; during the rainy season much of the area is inundated (Answers.com 2005).

Malpighian cells, palisade macrosclerid cells, epidermal, or prism. Plant cell on the surface of a leaf or other young plant tissue, where bark is absent. The exposed surface is covered with a layer of cutin (Biology Dictionary – Biology on Line 2005).

Metabolizable energy. The gross energy value of a food from which energy losses in faeces, urine, and gaseous products of digestion have been subtracted (Lassiter and Edwards 1982).

Micropyle. It is a structure located close to the hilum and represents the former passage for the pollen tube through the integument of the ovule (Tran and Cavanagh 1984); a small opening between the integuments at the free end of an ovule (Cutler 1978).

Mulga. A vegetation community of wide occurrence in the arid parts of Australia in which the shrub mulga (*Acacia aneura*) usually is a dominant (Debenham 1971).

Neutral detergent fibre. The cellular wall components of forages (cellulose, hemicellulose, lignin, protein, and minerals) not soluble in neutral detergents (Silva and Queiroz 2002); the part of a feed that is not soluble in boiling neutral detergent solution (3% sodium laurel sulfate); mostly cellulose, lignin, silica, and hemicellulose on the cell walls (Lessiter and Edwards 1982).

Obligate seeder. Group of plants that can regenerate only by the recruitment of seedlings from the soil seed bank (Bell 1985; 1994; Pate *et al.* 1990).

Palisade macro-sclereid cells. A layer of elongated cells in plant seeds set at right angles to the surface of the seed (Swartz 1971); because the shape and the thickness of the Malpighian cells they are also termed macrosclereids (Fahn 1974).

Papillate. Surface with superficial protuberances (Swartz 1971).

Parenchyma sclereid layer. A layer of tissue composed by cells with lignified, thick and pitted walls, involving the cotyledons of legume seeds (Swartz 1971; Van Staden *et al.* 1989).

Paripinnate. Is said of a pinnate leaf when there is no terminal leaflet of the rachis, i.e. the rachis ends in a leaflet-pair (Debenhan 1971).

Plant plasticity. The potential of plants to adapt to a large array of growth conditions and even to temporarily suspend active metabolism in order to withstand environmental conditions, not suitable for 'normal life'. The responsive adaptations of plant species to their environments lead to differences in growth rate and productivity and to differences in water or nitrogen use efficiency ('plant plasticity'). Ultimately adaptation will result in increased survival and reproduction (Experimental Plant Science 2005).

Pleurogram. A seed structure often present and complete in the Mimosaceae, rarely present and open in the Caesalpinaceae. It is visible in immature seeds as a localized area where the epidermal cells are shorter than the cells from other areas, and the area at the base of the shorter cells is filled in by parenchyma cells derived from periclinal division in the young hypodermal cells. In the mature seeds the pleurogram is visible as a fissure extending completely through the epidermis (Van Staden *et al.* 1989).

Prism, palisade macrosclerid cells, epidermal, or Malpighian cells. Plant cell on the surface of a leaf or other young plant tissue, where bark is absent. The exposed surface is covered with a layer of cutin (Biology Dictionary – Biology on Line 2005).

Residual hardseededness. Amount of hard seeds remaining after 21 days of germination test (the author).

Resprouters. Group of plants that regenerates from buds located in underground organs (Bell 1985; 1994; Pate *et al.* 1990).

Rugulate. With a wrinkled surface, marked by irregular raised or depressed lines (Debenham 1971, Swartz 1971).

Rugulate-papillate. Wrinkled surface with superficial protuberances (Swartz 1971).

Sclerid or sclereid. A unit of sclerenchyma, a cell with a lignified, thick and pitted wall and usually devoid of, or with very little protoplasm (Debenham 1971). A sclerotic or stone cell, a sclereid (FAO 2006)

Glossary [www-ididas.iaea.org/IDIDAS/w3.exe\\$GloSearch?ID=15462](http://www-ididas.iaea.org/IDIDAS/w3.exe$GloSearch?ID=15462)

Seed imbibition. The first step in seed germination is **imbibition**. In this process, water penetrates the seed coat and begins to soften the hard, dry tissues inside. The water uptake causes the grain to swell up. The seed/fruit coat usually splits open allowing water to enter even faster. The water begins to activate the biochemistry of the dormant embryo (Koning 1994).

Seed softening. Natural or enforced breakdown of seed-coat dormancy in legume seeds (Mott *et al.* 1981).

Seed-coat dormancy, or hardseededness. See hardseededness.

Seedling recruitment. Emergence of seedling from seeds stored on a soil seed bank, normally occurred after a fire event (Bebawi and Campbell 2002).

Sessile. Is said of a structure when borne without a supporting part, e.g. the petiole of a leaf, the filament of an anther, the pedicel of a flower (Debenham 1971).

Shade tolerance. Plant adaptation to reduced levels of incident sunlight (Benjamin *et al.* 2005) [http://www.aciar.gov.au/web.nsf/att/JFRN-6BN8Y2/\\$file/pr32chapter16.pdf](http://www.aciar.gov.au/web.nsf/att/JFRN-6BN8Y2/$file/pr32chapter16.pdf)

Silvipastoral system. A class of agroforestry system characterized by the presence of animals grazing between or under the canopies (Sánchez 1999).

Soil saturation. Wet soil in which all the pores are filled with water (Foth 1990).

Soil seed bank. Pool of seeds that, having some type of dormancy after release from the plant are incorporated into the soil and stay stored for undetermined periods (Grime 1979).

Strophiole, Boss, or Lens. An excrescence or appendage at or about the hilum of a seed, the caruncle (Swartz 1971); after the fertilization of the ovule, growths termed arils, develop on the surface of the seeds of certain plants. These growths, when they occur on the funiculus (e.g. *Euonymus* and *Acacia* spp.), are often termed *strophioles* and when occurring around the micropyle (e.g. *Ricinus*), are called *caruncles* (Fahn 1974).

Subcuticle. Under the cuticle, epidermis, or outer skin (Swartz 1971; Holmes 1985).

Suberecte. Almost erect, slightly erect or somewhat erect (Botanical Glossary 2005).

Suffruticose. The same as suffrutescent, slightly shrubby (Swartz 1971; Holmes 1985).

Tap-root. The primary persistent root typical of dicots and gymnosperms from which lateral roots are developed in acropetal succession (Debenham 1971); a water storage structure known as a 'xyllopode' (Burkart 1952; Carvalho and Mattos 1974).

Thermocouple. Thermocouples are pairs of dissimilar metal wires joined at least at one end, which generate a net thermoelectric voltage between the open pair according to the size of the temperature difference between the ends, the relative Seebeck coefficient of the wire pair and the uniformity of the wire-pair relative Seebeck coefficient (Temperature.com 2006). www.temperatures.com/tcs.html.

Testa or seed-coat. Represents the hardened integuments of the ovule. In seeds of the legumes it is covered by a very thick cuticle. This and another layer of the testa may prevent the passage of water and air as long as it is undamaged (Fahn 1974).

Water use efficiency. It is the relationship between plant production and water plant water uptake from soil below. Can be expressed as the ratio of plant dry matter yield and the plant water uptake in weight (Durr and Rangel 2003).

Xylopode. A more or less stony, hard, tuberous thickening of the roots and underground parts of shrubs in steppe regions in Brazil (Swartz 1971).