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

JCU
JAMES COOK UNIVERSITY

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 Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.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/m^2, 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 ºC at the soil surface, 80 ºC at 10 mm depth, and around 30 ºC 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 strophiolar structure and germination, in response to the variation of oven temperatures ranging from 25 ºC to 120 ºC were observed in seeds of nine genotypes of *Desmanthus*. There were two groups with different patterns of responses: genotypes in which strophiolar structures were not significantly affected by temperatures below 80 ºC; and genotypes with significant changes in the strophiolar structures when temperature rose to 60 ºC.

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.

AKNOWLEDGEMENTS

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 5 SEEDLING BEHAVIOUR OF TWO *Desmanthus* GENOTYPES UNDER DIFFERENT SOIL, LIGHT INTENSITY, AND WATERING FREQUENCY TREATMENTS **105**

5.1 Introduction

LIST OF TABLES

LIST OF FIGURES **Page**

Glossary of Terms

Abscission scar or h**ilum**. 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 km^2, 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 sed coat that is impermeable to water (Fahn 1974).

Hilum, or **abscssion 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, hemi-cellulose, 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 rhachis, 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 (Debenhan 1971). A sclerotic or stone cell, a sclereid (FAO 2006)
Glossary 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 (Debenhan 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

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