LEGUME ABUNDANCE IN NEW ZEALAND SUMMER-MOIST AND SUMMER-DRY HILL COUNTRY PASTURES

A thesis presented in partial fulfilment of the requirements

of the degree of

Doctor of Philosophy (PhD)

Institute of Natural Resources
Massey University
Palmerston North, New Zealand

Christian Hepp

2003

To Paulina, for her love, patience and constant support
To Nicolas, Benjamin, Vicente and 'Chumi', my dear boys
To my dear father who inspired me
To my mother for her unconditional love

... 'Immer wenn Du meinst, es geht nicht mehr, kommt von irgendwo ein Lichtlein her... '

ABSTRACT

The introduction of legumes has been a central factor in hill country pasture improvement in New Zealand since they are able to fix atmospheric nitrogen to contribute to pasture production and also improve pasture quality. However, at present legume content of hill swards has dropped to generally very low levels which will likely affect medium-long term sustainability of these pastoral ecosystems. This thesis is focussed on determining the relative importance of management and environmental factors that affect legume abundance in hill country swards. A series of field experiments were undertaken between May 2000 and April 2002 in contrasting summer-moist (Ballantrae; 40°19'S, 175°50'E) and summer-dry (Waipawa; 40°00'S, 176°23'E) hill country areas, including north aspects and south aspects at Waipawa, to evaluate the relative impacts of cutting height (targets of 3 or 7 cm), grass suppression by application of selective herbicide, soil-P status (high or low), autumn nitrogen application (0 or 50 kg N/ha), defoliation management (cutting, and rotational grazing with sheep), on legume abundance. A glasshouse experiment involved the effects of companion grasses and defoliation on individual white clover and subterranean clover plants grown in pots.

The suppression of grass competition caused the most marked changes in short-term sward composition, with an increase in legume abundance at all sites. Increasing soil-P status increased legume abundance, especially where white clover was present as a major botanical component. Altering pasture cutting height or applying nitrogen in the autumn had comparatively minor effects on legume abundance. Defoliation management (i.e. rotational grazing with sheep compared with cutting) played a secondary role in affecting legume abundance of swards, at least in the short term.

Residual effects of grass suppression resulted in an increase in legume abundance, which persisted for at least one year after treatment and affected legume species composition in the drier Waipawa north aspect. Pastures in the summer-moist areas showed a high degree of resilience and reverted quickly to the original grass dominance. Inter-annual and site contrasts in soil moisture patterns highlighted the relevance of soil moisture as a key factor in determining legume abundance and production, mainly in the summer-dry areas. In the glasshouse trial, severe defoliation had very strong effects, reducing plant size, leaf area, vegetative stem development and branching of individual legume plants. Moreover, root competition from grasses was seen to significantly limit clover shoot growth, this being more important than the shading effect.

From these experiments, it is suggested that the relative importance of factors affecting legume abundance in hill pastures is: soil moisture (if limiting, e.g. summer-dry hill country) > grass suppression > soil-P status > defoliation management > nitrogen application. However, some of these factors have been noted to interact, and relationships can acquire higher levels of complexity.

This study highlighted the relative importance of factors that influence legume abundance of hill country swards and showed that pasture composition can be dramatically modified and legume content increased, but also that these changes can be short-lived. Summer-dry hill country pastures strongly rely on highly variable non-manageable seasonal and inter-annual soil moisture profiles, and legume abundance is difficult to predict and less stable in time than in summer-moist conditions. However, a high potential of legume abundance is achievable with adequate soil moisture in summer, even at low soil-P status. In these dryland areas, the combination of limiting soil moisture, close-to-ground defoliation, and selective grazing, is likely to severely limit white clover growth and spread, and be aggravated by low soil-P status, as well as subterranean clover growth and seed set, therefore compromising legume abundance in the following season.

High tiller population density, combined with a high frequency and intensity of legume defoliation, will put legumes under stress from severe grass competition, ultimately affecting legume abundance. This is likely to be the case for many intensively set stocked hill country systems managed with sheep.

Keywords: Hill country pastures, legume abundance, white clover, subterranean clover, soil moisture, summer-dry, summer-moist, grass suppression, competition, cutting, rotational grazing, soil phosphorus status, nitrogen fertiliser.

ACKNOWLEDGEMENTS

I am deeply grateful to Professor John Hodgson (Institute of Natural Resources INR, Massey University) for his most generous support from our very first contacts from Chile to the completion of this degree. Prof's co-supervision, guidance, enthusiasm, encouragement, kindness, and permanent interest in my work, have been vital to me, and I am permanently indebted for it. I am still amazed at how fast and thorough he could speed through endless drafts of the thesis.

I would like to express my gratitude to Dr. Ian Valentine, Dr. Peter Kemp (INR, Massey University) and Dr. Allan Gillingham (Agresearch Grasslands) for their supervision, guidance and encouragement at different stages of the work, and especially through the process of revision of different versions and drafts of this thesis. Their advice, comments, support, friendly approach and help have made this work more motivating and fruitful.

Special thanks to Dr. Kerry Harrington (INR) for advice and help on herbicide use, Dr. Cory Matthew (INR) for setting up the root-washing facility, Dr. Alec Mackay (Agresearch) for support in the initial planning of the project, and Duncan Hedderley for statistical advice and his patience in responding my periodic enquiries.

Many thanks to a large group of people that helped at different stages of the experimental work: Mark Osborne, who provided much of the necessary gear and supplies, Bob Toes for his friendly help and teachings in the soil lab, Ian Furkert for pressure plate determinations and Ross Wallace for help with root washing. Brian Devantier (Agresearch) helped at the set-up stage and Phillip Budding with moisture sample processing at Ballantrae; Maurice Gray and Stuart Macmillan (Agreserach) cooperated with management of the experiments at the Waipawa site. Lindsay Sylva, Lesley Taylor and Ben Anderson (Plant Growth Unit, Massey) helped with the set-up

and management of the glasshouse experiment. Yvonne Gray, Hera Kennedy, Irene Manley, Pam Howell and Ruwan Dissayanake also helped and supported in different ways. A huge thank you to you all. Special thanks to my friend Roger Levy, who helped me in the set-up of experiments and with several sampling procedures. His skilled help, very special sense of humour, extensive communication skills and optimism made the difference in those long days of sampling in the otherwise lone and steep hills.

Sarah Hurst (Hortresearch), Elaine Fouhy (NZ MetService) and NIWA kindly provided climatic data, which is thankfully acknowledged. Dean Richards and Kevin Harris helped with all computing related support, and their assistance is deeply appreciated. Silvia Hooker and Dianne Reilly from the International Students Office offered permanent friendly support for which I am very grateful.

A special thank you to Bill Gates and Microsoft Inc. for its amazing creation, the 'Word' program. Only through a document of this magnitude have I been able to explore some of the endless possibilities of this instrument, which usually makes life so much easier.

The financial assistance of Instituto de Investigaciones Agropecuarias (INIA-Chile), that supported our family through a scholarship during our stay in New Zealand, is gratefully acknowledged. The help received through the Pastoral Science Scholarship (Massey University) is also thankfully recognised.

During my stay at Massey University I met many fellow students, some of whom became true friends and provided a highly diversified and pleasant working environment. Thanks to Walter Ayala, Juan Cañumir, Tara Pande, Andrew Wall, Jorge Zegbe, Dora Duarte de Carvallo, Wagner Beskow, Jose Rossi, Alvaro Romera, Alfredo Jimenez, Patricia Salles, Melissa Ercolin, Ignacio Lopez, Carlos Hug, Karin Timcke, Alejandra, Ignacio Donoso, Anita Kunz, and 'little' Sumanasena. Your friendship and support will not be forgotten.

We have spent wonderful moments in New Zealand, and we certainly will leave part of our hearts in this beautiful Island when we return to our Patagonian home. It was an extraordinary experience for our family to live three years in this amazing country in which we have learned to love the 'kiwi' approach and way of life. Thanks to many kiwi friends (an 'amazing race" of people) that have helped us in many ways and areas of daily life. The support of friends was vital to be able to go through difficult and sad moments, but it was wonderful to share the good and happy moments too. Special thanks to Patty and Juan, Roger and Paula, and Cornelia, amongst others.

A special thank you to my parents, whose love and support has been endless through many stages of my life. To my dear father, whom I embraced three years ago without realising that I would not embrace him again; I will never forget you.

Finally, my deepest and very special gratitude goes to my dear wife Paulina. Her willingness to embark in this 'crazy' and uncertain venture of crossing the Pacific Ocean for three years with a load of four boys aged between 1 and 10 is still a dilemma for me. It has been a hard time for her, but I have felt her love, support and commitment throughout this difficult time. Her help in the glasshouse and endless botanical separations is also 'endlessly' appreciated. Our sons Nicolas and Benjamin helped also at different stages of the experiments, while Vicente and Christian ('Chumi') have cheered me up and kept me going. Without the love and support of my family, I would not have been able to go through all this process.

Christian

Palmerston North, March 2003.

TABLE OF CONTENTS

LIST OF TABLES

Chapter 3:

Chapter 4:

Chapter 5:

LIST OF FIGURES

Chapter 3:

Chapter 4:

Chapter 5:

Chapter 6:

LIST OF PLATES