QUANTIFICATION OF THE BELOWGROUND INPUTS OF ORGANIC CARBON BY THE ANNUAL PASTURE LEGUME BARREL MEDIC (*MEDICAGO TRUNCATULA* GAERTN.)

Michael Cameron Crawford

Thesis submitted for the degree of

DOCTOR OF PHILOSOPHY

in the

Faculty of Agricultural and Natural Resource Sciences

The University of Adelaide

Department of Soil Science

May 1997

TABLE OF CONTENTS

ABSTRACT

In the cropping soils of southern Australia, pasture phases based on the annual legume barrel medic (*Medicago truncatula* Gaertn.) provide significant inputs of organic matter and lead to improvements in soil structure and fertility. This thesis aimed to quantify the belowground input of carbon by barrel medic and the effect of defoliation on this input. This aids the development of simulation models of soil organic carbon, and has practical implications regarding rotation choice and grazing management.

The major belowground input of carbon in annual species is found as root production. Measurement of total root biomass production, using a technique that accounted for root death and decomposition, found that it was 1.6 to 2.9 times the maximum live root biomass. In a year of very low rainfall, root production was a lot less than in a year of average rainfall. However, the ratio of total root production to total shoot production was higher. In both years, the total root biomass production and root:shoot ratio of barrel medic were greater than faba beans but similar to barley grass.

Total root biomass production of a frequently defoliated barrel medic pasture was estimated using a ^{13}C dilution technique where swards were pulse labelled with ^{13}C. Root biomass production following labelling was estimated from the subsequent dilution in ^{13}C enrichment during the remainder of the season. Although live root biomass of cut pasture was less than that of uncut pasture, total root biomass production was similar. ^{13}C allocation data showed that this was due to greater allocation of carbon belowground by cut plants. It was concluded there must be greater turnover of root material under cut pasture.

The effect of defoliation on the amount of carbon released to the soil through rhizodeposition was estimated by growing plants in pots in a labelled atmosphere in a growth cabinet. Plants were grown in a ^{14}C-labelled CO_2 atmosphere, defoliated and then grown in a ^{13}C-labelled CO_2 atmosphere. Distribution of ^{14}C and ^{13}C in the plants was compared with uncut plants. Defoliation did not have a significant effect on belowground allocation of carbon. The proportion of labelled carbon allocated belowground was 24 and 28 % for cut and uncut plants respectively. Total input of carbon into the soil was estimated to be 1.70 (cut) and 1.65 (uncut) times the amount of carbon recovered in root biomass.

Applying these correction factors to results from the field experiments, total annual belowground input of carbon ranged from 700 to 1880 kg C/ha. As a proportion of carbon in above ground production, carbon input belowground ranged from 0.40 to 0.77. Defoliation at the frequency and level imposed in these experiments had no adverse effect on total belowground inputs of carbon.

DECLARATION

I declare that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

Michael Crawford Date

ACKNOWLEDGMENTS

My sincere thanks go to my principal supervisor, Dr Peter Grace, whose vision and enthusiasm helped to make this project achievable. Sincere thanks also go to my joint supervisors, Prof Malcolm Oades and Dr Bill Bellotti who both provided invaluable advice and support whenever necessary.

To the many people who provided assistance in the field, glasshouse and laboratory over the past three years, I also give thanks and acknowledgment. These people include Philip Clarke, Cliff Hignett, David Little, Colin Rivers, Bernie Swaby, Ian Trigg and Melissa Truscott. I would like to particularly thank Johan Swinnen, William Besz and Maurice Amato for their part in the construction of the controlled atmosphere growth cabinet and Maurice Amato for his assistance in performing ^{13}C analyses.

I am grateful to Jeff Baldock, Cameron Grant, Andrew Moore, Paul Nelson and Johan Swinnen for their advice and thought provoking discussion along the way. Thanks also go to members of the Department of Soil Science, the Cooperative Research Centre for Soil and Land Management and the CSIRO Divsion of Land and Water who provided support whenever necessary.

I would like to acknowledge the financial support of the Cooperative Research Centre for Soil and Land Management who provided me with a postgraduate scholarship, the Department of Natural Resources and Environment (Victoria) who granted me Study Leave Without Pay for three years and the Grains Research and Development Corporation and the Rural Industries Research and Development Corporation who both provided me with travel grants to assist me in presenting my work at international conferences.

Heartfelt thanks go to my parents for their support during my formative years and extra special thanks go to my wife and best friend, Linda, for diligently proof reading the entire thesis and for her constant support, encouragement and special advice.

PUBLICATIONS ARISING FROM THIS THESIS

Book chapters (refereed)

Crawford, M.C., Grace, P.R. and Oades, J.M. (1998). Effect of defoliation of medic pasture on below-ground carbon allocation and root production. In '*Management of Carbon Sequestration in Soil*'. (Eds. Lal, R., J.M. Kimble and B.A. Stewart). Chapter 26. pp. 381-389. CRC/Lewis Publishers, Boca Raton, Florida, USA.

Journal papers (refereed)

Crawford, M.C., Grace, P.R., Bellotti W.D. and Oades, J.M. (1997). Root production of a barrel medic (*Medicago truncatula*) pasture, a barley grass (*Hordeum leporinum*) pasture and a faba bean (*Vicia faba*) crop in southern Australia. *Australian Journal of Agricultural Research* **48** 1139-1150.

Crawford, M.C., Grace, P.R., Bellotti W.D. and Oades, J.M. (2000). Allocation of carbon to shoots, roots, soil and rhizosphere respiration by barrel medic (*Medicago truncatula*) before and after defoliation. *Plant and Soil* **227,** 67-75.

Conference proceedings (refereed)

Crawford, M.C., Grace, P.R., Bellotti W.D. and Oades, J.M. (1996). Below-ground inputs of carbon by crops and pastures. Proceedings of the 8th Australian Agronomy Conference, Toowoomba, Queensland. pp. 172-175.

Conference proceedings (non-refereed)

Crawford, M.C., Grace, P.R., Bellotti, W.D. and Oades, J.M. (1996). Root production of medic pastures. Proceedings of the 2nd Victorian Cropping Zone Conference, Rutherglen, Victoria. pp. 36-37.

Crawford, M.C., Grace, P.R. and Oades, J.M. and Bellotti, W.D. (1996). Effect of defoliation of medic pastures on below ground carbon allocation and sequestration. Proceedings of an International Symposium on Carbon Sequestration in Soil, Columbus, Ohio, USA.

Crawford, M.C., Grace, P.R. and Oades, J.M. (1996). Effect of defoliation of annual medic pastures on below ground ^{13}carbon allocation and on root growth. Proceedings of the 5th Symposium of the International Society of Root Research, Clemson, South Carolina, USA. p. 4.

Crawford, M.C., Grace, P.R. and Bellotti, W.D. (1996). Root production of crops and pastures - the effect of drought. Proceedings of the 1996 Farming Systems Conference, Adelaide, South Aust. pp. 135-136.

Crawford, M.C., Grace, P.R. and Bellotti, W.D. (1995). Root production of a faba bean crop, a barrel medic pasture and a barley grass pasture. Proceedings of the 1995 Tillage Workshop, Adelaide, South Australia. pp. 18-19.