New challenges for lucerne in southern Australian farming systems – Identifying and breeding diverse lucerne germplasm to match these requirements

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Introduction to this thesis

This is a thesis by publication submitted to the University of Adelaide for the degree of Doctor of Philosophy. The thesis consists of an introduction and literature review followed by four journal publications that form a series of research chapters. The final chapter of general discussion draws the research chapters together and provides links to recent advances in the use of lucerne in southern Australian farming systems.

The first chapter is an introduction and literature review with 2 sections; (i) an introduction to the role of lucerne in southern Australian agriculture, and (ii) a published journal paper that identifies constraints to lucerne production and possible breeding strategies that may be employed to overcome these limitations. The research chapters include the characterisation of new germplasm (chapter 2), evaluation of this material across a broad range of environments (chapter 3), and the suitability of the germplasm in two farming systems (i) a pasture monoculture under persistent grazing (chapter 4), and (ii) a mixture of lucerne and wheat for grain and fodder production (chapter 5). The most suitable ideotpyes of lucerne (identified by winter activity and other characteristics) are discussed in relation to recommending lucerne for these new farming systems, and for the development of new lucerne cultivars.

Abstract

Lucerne is a deep-rooted perennial pasture that is promoted to land managers in southern Australia to mitigate the effects of dryland salinity, a problem of national significance caused by the replacement of native trees and shrubs with annual crops and pastures. In recent years, the acceptance of climate change has provided further rationale for increasing the use of perennial legumes in our farming systems. Perennial legumes have a role in offsetting $C0_2$ emissions by sequestering C and N in soil, and provide new, resilient options for future farming in a warmer and more variable climate. This research has focused on evaluating the diverse range of germplasm found in lucerne (*Medicago sativa spp.*) for a range of attributes in order to determine its compatibility with existing and future farming systems in southern Australia.

Regional field evaluation at 8 sites in southern Australia showed that lucerne is a broadly adapted and robust plant. After 3 years, plant density ranged from 2-55 plants / m^2 with differences in persistence attributed to tolerance to a combination of stresses including soil acidity, saline and sodic subsoils, drought conditions and persistent heavy grazing. Highly winter-active lucerne (class 9-10) was confirmed to be the most suitable group for short phase rotations in southern Australia, providing grazing is well managed. This germplasm was less persistent than other winter activity groups, but produces more total herbage yield in environments with winter dominant rainfall patterns. Highly winter-active lucerne has poor persistence under continuous grazing, but this may aid in its removal when used in rotation with crops. Winter-active germplasm (class 6-8) was more grazing tolerant and persistent, making it the

most suitable group for longer phase rotations (>4 years), or where more flexible grazing management practices are required (i.e. 35 days grazing followed by 35 days recovery). Individual grazing tolerant plants from this group were selected and randomly inter-mated to form new breeder's lines in the development of a grazing tolerant cultivar.

For the first time, the high water-use of a farming system involving wheat over-cropped into lucerne is presented. Lucerne over-cropped with wheat used an additional 43-88 mm of water in comparison to continuous wheat at Roseworthy and Katanning respectively. Over-cropping reduced wheat yield by 13-63%, but it can be more efficient in terms of land area to grow lucerne and wheat as a mixture than on separate parcels of land. Very winter-dormant lucerne (class 1-2) appears to be less competitive with winter cereal crops during wheat establishment. It may also be possible to reduce lucerne's competition with wheat at the critical stage of anthesis, with low spring yielding lucerne varieties identified in this research (SA37908). This group of plants provides excellent potential for the development of high water-use farming systems because they are grazing tolerant and persistent, and have summer forage production and sub-soil water extraction rates that are equivalent to winter-active lucerne.

The research has been used to identify the perfect ideotype for lucerne in phase farming and over-cropping systems, which can be used to set targets in future breeding programs. The research also highlights current opportunities for the integration of lucerne into southern Australian farming systems to help curb the spread of dryland salinity and reduce the impact of climate change.

Declaration

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

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

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Alan Humphries

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