Exploring lucerne germplasm diversity for Southern Cropping SYSTEMS

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Abstract

Renewed interest in lucerne (*Medicago sativa* L.) for the cropping regions have increased the requirement for a range of lucerne 'types' in the market place. Accordingly, a diverse array of lucerne germplasm from a number of germplasm centres has been assembled in order to target lucerne development specifically for the southern cropping zones. In the initial two years of the project, 434 'wild type' introductions have been characterised with collaboration from the Australian Medicago Genetic Resources Centre (AMGRC).

The accessions were first grown for 1-2 years at the Waite Institute, where their taxonomy was checked, seed increased and an initial assessment of characters with high heritability were made including habit, winter activity, production and quality. Subsets of the accessions have since been included in 10 field trials with the aim of selecting accessions that are persistent and high yielding, or with specific suitability for intercropping or phase farming.

Key words

Lucerne, genetic diversity, cropping rotation, water-use.

Introduction

Lucerne is expected to play an important role in future southern Australian cropping systems. Cereal production is under threat in southern and western Australia through declining soil fertility, deterioration of soil structure, rising saline watertables, and other problems such as herbicide-resistant weeds. Changes to the current farming systems are required for the long-term health of the cropping industries and one of the most promising options is the increased use of perennial legumes in the rotation (1). Lucerne has been identified as a key component of future cropping systems because it is a deep rooted herbaceous perennial legume capable of reducing recharge and lowering watertables (5). Lucerne also has high inputs to soil fertility through nitrogen fixation (4), a low ability to host many cereal diseases, and is competitive against major summer crop weeds.

Lucerne may either be grown as a phase in an annual crop rotation (3-6 years of lucerne followed by 3-6 years of annual cropping) or permanently in an intercropping situation (sowing an annual crop over a permanent background of lucerne). Breeding lucerne for the southern cropping zones will require a new approach with a broad germplasm focus to enable the selection of different lucernes as farming system requirements become apparent. The type of lucerne required in this evolving farming system is presently not clearly defined. For example, a winter dormant lucerne may be more suited to intercropping than traditional lucernes due to lower competition for water, light and nutrients during the growing season of the annual crop. With this in mind, a broad germplasm focus is being explored to determine the suitability of different plant types to a range of roles in the farming system.

A major challenge in breeding lucerne adapted to the environment in the southern cropping zones is improving its tolerance to acidic soils. Lucerne is best adapted to alkaline soils and is sensitive to acidic soils containing aluminium and manganese. Grazing tolerance will also be important, as broad acre cereal farmers have a limited ability to control grazing pressure with a smaller number of large paddocks. Other challenges in relation to breeding lucerne for the cropping districts are rhizobia compatibility, nitrogen fixation, seedling vigour and disease resistance. A broad germplasm focus is therefore required not only to match the role of the plant in the system, but also to provide variation for tolerance to a wide range of soil conditions and plant diseases.

This paper describes the efforts that have been made to acquire and evaluate a diverse germplasm base with regard to these challenges as part of a breeding program to develop lucerne specifically for the southern Australian cropping systems.

Results and Discussion

Acquisition and characteristics of genetic diversity

Lucerne germplasm has been acquired from the United States Department of Agriculture National Plant Germplasm System (USDA NPGS), and the Vavilov Institute in Russia. During the 1990's, the AMGRC gained control of the Australia's largest lucerne germplasm collection, consisting of some 2000 accessions. The AMGRC is now growing around 150 lucerne accessions each year for characterisation and seed regeneration. The function and methodology of the AMGRC is described in detail by Auricht *et. al.* (2). A total of 434 accessions have been characterised and regenerated in conjunction with the AMGRC in the years 1999/2000 and 2000/2001. The results for the first year are grouped by their centre of origin and presented in table 1.

Table 1. Origin, number of accessions and preliminary characterisation of lucerne germplasm.

Origin	No.	Flower Colour	Pod	Leaf Size	S:L	Habit	Forage Yield	Seed Yield (g)	YR 2000
Afghanistan	5	P	2-3	1-2	2-3	3-3	35-64	15-167	4
Algeria	2	P	1	2	2	4	45-71	13-55	3
Argentina	11	P,V	1-1	1-3	2-3	4	50-79	119-185	1
Canada	1	P,V,C	1	2	2	1-4	52	89	9
Chile	2	P	1-1	1-3	1-2	4	40-82	2-100	3
China	13	P,C	1-3	1-2	1-3	1-4	2-65	7-120	4
Egypt	2	P	1	3	1	4	32-55	1-220	2
France	5	P,C	1-1	2-3	2,3	4	51-77	59-124	2
Greece	2	P,C	1-1	1-3	2-2	1-4	16-51	3-37	5
India	8	P	1-1	2-3	2-3	3-4	49-76	57-124	20

Iran	8	P	1-2	1-2	1-3	3-4	26-60	1-144	16
Italy	7	P,C	1-2	1-2	1-3	1-4	23-70	25-155	1
Lebanon	2	P,V,C	1-1	1-2	3	3-3	41-46	40-68	
Morocco	9	P,C	1-2	1-3	2-3	1-4	25-61	38-135	14
Peru	3	P	1	2	3	4	45-79	23-98	9
Romania	3	P	1	2	1-2	4	23-47	13-77	2
Russia	91	P,C	1-3	1-3	1-2	1-4	3,64	1-117	8
Saudi Arabia	12	P	1-1	2-3	2-3	4	58-80	9-63	11
South Africa	6	P	1	2-3	1	4	43-73	16-94	
Spain	6	P,C	1-2	1-3	1-3	3-4	41-70	36-84	5
Tunisia	3	P,C	1-1	1-2	2-3	3-4	33-70	3-129	4
Turkey	3	P	1-2	1-2	2-3	3-4	35-48	13-57	5
USA	37	P,C	1-2	1-3	1-3	1-4	24-84	24-183	20
Other	21	P,V	1-2	2-2	1-3	4	45-75	51-173	9
Yemen	15	P	1	2-3	1-2	4	44-82	13-103	
Yr 1999 Total	277								
Yr 2000 Total									157

Flower colour: p=purple, v=variegated, c=cream
Pod (Shape): 1= tightly coiled, 2= semi-coiled, 3= straight
Leaf Size: 1= small, 2=medium, 3= large
S:L (visual Stem to Leaf ratio): 1= stemy, 3=leafy
Habit: 1=very prostrate, 2=semi-prostrate, 3=semi-erect, 4=erect and very erect
Forage Yield= total score of 7 visual measurements, correlated with a score of 10 given to Eureka for

each measurement.
YR 2000: Number of lines from each origin grown in the year 2000 for evaluation and seed increase.

The USDA NGPS has an internet database search engine that allows accessions with specific traits to be searched and selected. The germplasm characters selected for this project include seedling vigour, fall growth and recovery rates, crown width and depth, and root morphology characters such as tap-root dominant or fibrous rooting systems.

Sixty-two accessions were targeted with traits that relate to improved seedling vigour and mature plant growth, and grazing, acidity, waterlogging and salinity tolerances. The accessions have been grown in quarantine for a period of 12 months, which has allowed time for hand crossing for pure seed production and preliminary evaluation. Following release, these accessions have been grown for seed in the field to generate sufficient quantities for entry into field trials in 2001.

Four of the Russian accessions listed in Table 1 have been acquired from the Vavilov institute. Of particular interest is a waterlogging tolerant cultivar known as ‘Kometa’ that was developed by an unknown plant breeder in the Ukraine. While the waterlogging tolerance of Kometa needs to be confirmed under Australian conditions, the plant appears to have a semi-erect habit and moderate winter activity. The other three accessions are ‘water meadow’ ecotypes collected from Russian floodplains and appear to be considerably more dormant (observations are under glasshouse conditions).

Whilst some characters such as disease resistance and seed production will be important for all lucernes, others are closely related to the expected role of the plant in the cropping system.

Field adaptation and disease resistance

Field trials are designed to test the performance of the accessions in a range of environments in southern Australia. Accessions that are persistent and high yielding, or with specific suitability for intercropping or phase farming will be selected for further breeding and cultivar development.

The sites vary in soil type (sand-clay), pH (4.2-7.5, 0.1M $CaCl_2$), rainfall (325-475mm) and management. In 1999, trials were sown at Katanning and Borden in Western Australia and at Petersville and Melrose in South Australia. Preliminary field results (after 12 months) for average density and winter vigour of 26 accessions short-listed from preliminary characterisation are presented in table 2. This information is compared with glasshouse disease resistance results for each group of introductions.

Most of the ‘wild type’ introductions tested have particularly poor resistance to spotted alfalfa aphid (SAA). The exception was a pubescent introduction from Yemen, which is very winter active but poorly adapted to dryland conditions in southern Australia. Other accessions that have persisted well in the field trials require intensive breeding for resistance to one or more aphids.

Table 2. Field evaluation and disease resistance of a range of lucernes with different origins.

Origin	No.	Density	Winter vigour	BGA	SAA	Phytophthora	Anthracnose
Afghanistan	2	52.2	1.8-6.4	43.6	2.6	35.9	20.7
Argentina	2	55.2	3.7-8.4	47.4	0.0	42.5	12.1
Algeria	2	44.2-48.6	7.8-8.2	49-60	2.9-7.6	15-46	7.3-12

Egypt	1	45.9	9.5	59.9	0.0	10.8	17.6
Iran	1	48.0	2.4	43.7	3.9	44.0	11.5
Italy	1	47.3	2.6	58.3	9.6	50.5	19.6
Morocco	3	46.2-53.4	7.9-8.6	50-66	0.3-3.0	11.6-29	8.2-16
Peru	2	51.3-55.1	8.3-9.5	58-59	1.0-2.6	17-54	20-29
Russia	5	58.1-68.2	1.3-5.4	15-62	0.3-6.5	18-52	8.8-28
Saudi Arabia	1	31.2	8.8	48.9	1.6	42.2	22.3
USA	3	38.0-63.8	3.0-8.8	44.9	1.6	24.3	5.2
Yemen	1	12.9	9.8	44.3	50.7	17.0	7.3
South Africa	2	41.9-55.3	9.3	55.9	2.9	42.6	19.0
5% LSD	(t26)	11.1	6.5	17.3	11.9	22.5	11.6

No: Number of accessions tested from each country. Note: For Afghanistan, Argentina, USA and South Africa; only one accession has been tested for each disease.
Disease resistance scores are % resistance from glasshouse characterisation, BGA: blue green aphid, SAA= spotted alfalfa aphid.

These results show the range of genetic diversity available. Plants adapted to the cereal zone can be selected from this table, however they must also match the requirements of the farming system.

Matching plant morphology and winter activity with the farming system

Lucerne has been selected and bred to supply forage to animals. The primary role for lucerne in the cropping zone is to reduce recharge while maintaining annual crop yields in cropping rotation. These requirements of lucerne have pushed plant selection and breeding into new directions, and this will ultimately result in a new and unique cultivars.

Widespread changes in land use are required if the hydrologic balance is to be restored (3). Lucerne has at least two options for fitting into a cropping rotation with either a phase of lucerne (3-6 years of lucerne followed by 3-6 years of cropping) or permanent stands of lucerne that can be cropped over every year (intercropping). It is unlikely that the same type of lucerne will be used to achieve both of these options.

High yielding, winter active lucernes (often with a shorter lifespan) appear to be more suited to phase rotations of lucerne. The aim of a short lucerne phase is to have a plant using as much water as possible in a short period so that a quick return can be made to more profitable cropping.

The issue of which type of lucerne is suited for intercropping is not as clear. In some cases the lucerne would be sown with an economical cover crop, which is harvested for grain or foraged for hay. An autumn establishment clearly favours a highly winter active lucerne. Winter dormant lucernes suffer to a greater extent from competition with weeds (which in this case includes the cover crop) and insect damage due to their slow seedling growth. For this reason they are not usually sown at this time of year.

Once established however, a winter dormant lucerne appears to have many advantages over an active lucerne. Firstly they are not growing during the winter months and so are competing less with the annual crop during its growing season for moisture, light and nutrients. Winter dormant lucernes are also naturally more robust in terms of management. They have a far greater lifespan (which is important in permanent stands) and tend to be more grazing tolerant.

A winter dormant lucerne with a broader and deeper crown is more suited to direct drilling with narrow points, because individual plants can recover from seeding points removing part of the crown. A seeding point is likely to remove the whole crown of a narrow crowned plant, from which there is no recovery.

In order to match plant types with farming system, different management strategies are being used to assess the versatility of the different lucerne types and their suitability for use with intercropping. Three of the trials in Western Australia and South Australia are being cropped over to determine their suitability for intercropping. The measurements being recorded include the yield and quality of the crop, the ability of the plant to survive being cropped over, the yield of the lucerne at different times of the year and the effect of the lucerne on soil moisture content and nitrogen mineralisation.

CONCLUSIONS

A broad diversity of lucerne germplasm is available from gene-banks (Genetic Resource Centres) in the USA, Russia and Australia. They vary in many morphological and physiological characteristics (crown size, habit, winter vigour) as well as agronomic performance (persistence, productivity and disease resistance). Lucerne is a key plant that has been recognised for sustaining dryland agriculture in the cereal zone. This coupled with its broad range of genetic diversity has provided the opportunity for plant breeders to select well adapted types that are suited to specific roles within the cereal farming system.

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