White clover breeding for dryland sheep and cattle pastures in Australia

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Abstract

Despite the potential value of white clover for Australian pastures in the high rainfall zone, there is a lack of adapted cultivars, especially for dryland environments where hot dry conditions in summer limit persistence. A joint NZ AgResearch – NSW Agriculture breeding project is evaluating key groups of world-sourced white clover germplasm characterised by specific criteria; medium leaf/early flowering, high nodal root frequency, taprootedness, stoloniferous/medium leaf and drought tolerance. Results in the first growth cycle indicated that plant spread and herbage yield were associated with these criteria. Results over three growth cycles will be used to identify elite parent genotypes for polycrossing and testing in target dryland environments.

Keywords: breeding, drought tolerance, dryland pastures, persistence, *Trifolium repens*, white clover

Introduction

White clover (*Trifolium repens* L.) was introduced to Australia by the early European settlers. Dutch white clover was included in a list of non-indigenous plants compiled in 1803 and a vegetation survey in 1892 showed white clover to have naturalised widely in the high rainfall zone of eastern Australia (Davidson & Davidson 1993). From the 1930s, Departments of Agriculture in Australia recommended pasture improvement based on white clover with ryegrass, cocksfoot or phalaris (Moodie 1934). White clover continues to be recommended as the main legume component of permanent pastures in the high rainfall zone (Lowien et al. 1991). In New South Wales, there are currently only two cultivars recommended for dryland environments; Grasslands Huia for high rainfall districts and Haifa for low rainfall districts; Grasslands Tahora and Kopu are provisionally recommended for high rainfall districts. Other cultivars such as Prop, El Lucero, Ladino and uncertified ecotypes are not on the recommended list but may be commercially available.

The Australian white clover zone

The white clover zone in Australia extends over some 6 million hectares predominantly in south-east Australia (Table 1). The zone of adaptation corresponds to the temperate perennial grass zone where rainfall conditions are favourable; (i) where average annual rainfall exceeds 700 mm in the south and 750 mm in the north, (ii) where the length of the growing season is protracted due to evenly distributed rainfall, (iii) where summers are mild and moist (Moore 1973; Paton & Hosking 1973). Under irrigation, white clover extends beyond the boundaries of the temperate perennial grass zone to the perennial grass/annual legume zone, the Mediterranean zone and the subtropics.

Table 1: The significance of white clover for wool, sheep and beef cattle in dryland Australian pastures (Ayres unpublished – data sourced from the Australian Bureau of Statistics and survey in the white clover zone).

	Area (ha × 10^{-6})	GVP† ($m p.a.)	Δ GVP ‡ ($m p.a.)
NSW	3.8	424	54.6
Victoria	1.0	385	38.6
Tasmania	0.9	48	6.8
S. Australia	0.03	3.7	0.6
W. Australia	(-)	(-)	(-)
Queensland	0.34	(-)	(-)

† Gross value of production from white clover based pastures
‡ Expected increase in gross value of production from new white clover cultivars
(-) Trace

In New South Wales, white clover is the most widely sown perennial pasture legume with presence over some 6% of the total pasture area; about 20% of the New South Wales pasture base is sown pasture (Archer 1995). The contribution of white clover-based pastures to wool, sheep and beef production in the dryland pasture zone of Australia is estimated to be about $860 million per annum and the potential increase in gross value of production from breeding more persistent white clover cultivars in the dryland zone is predicted to be about $100 million per annum (Table 1).

Constraints to white clover performance

The major problem with current white clover cultivars in Australia is that herbage yield fluctuates widely from year to year. This lack of reliability, particularly in marginal environments is largely due to poor survival through summer moisture deficit (Robinson & Lazenby 1976; Gillard et al. 1989). Factors such as pests and diseases (Allen et al. 1987; Garret 1991), edaphic constraints (Wolfe & Lazenby 1973), intolerance of grass competition and close grazing (Curll et al. 1985; Curll & Wilkins 1985), and lack of winter activity in cold environments (Lazenby & Lovett 1975; Hill 1989) all have influence on the contribution of white clover to sward performance. Management factors that impact severely on persistence of white clover are declining levels of phosphate fertiliser use and inappropriate grazing management.

Current breeding projects

White clover improvement in Australia operates under the Australasian Perennial Legume Improvement Program and comprises two subprograms; "Improvement of white clover for high rainfall/irrigated dairy pastures", and "Improvement of white clover for dryland beef and sheep pastures". The first subprogram is centered at Hamilton (Agriculture Victoria) and the second at Glen Innes (NSW Agriculture). Previous white clover improvement work at Glen Innes has included three major projects; (i) a project that established a world-sourced white clover collection and germplasm resource centre, characterised the collection and undertook national field testing of a large and diverse set of cultivars, (ii) a project that examined the significance of genotype-environment interactions for breeding strategies, and (iii) a project that produced a summer rainfall ecotype collection and examined the concept of ecotype development. The project described in this paper is aimed at identifying heat/drought-tolerant germplasm for the development of new cultivars for dryland environments.

Table 2: White clover lines under field evaluation categorised on morphological and physiological features.

	Criteria	Source of lines	No. of lines
1.	Medium leaf/early season flowering	Mediterranean introductions & lines selected on local characterisation data	39
2.	High nodal root frequency	Lines selected on local characterisation data	19
3.	Tap root	Tap root selections	6
4.	Stoloniferous, medium-leaf size	Lines selected on local characterisation data	15
5.	Drought tolerance	Australian summer rainfall ecotypes, drought selections & low rainfall lines	37
6.	Novel characteristics	Virus resistant lines, experimental breeding lines, cultivar and ecotype reselections, stoloniferous/medium leaf lines, small and large leaf types	24
7.	Cultivar standards	G. Huia, G. Kopu, G. Tahora, G. Demand, G. Prestige, Prop, Haifa, Siral, El Lucero, Irrigation	10

Table 3: Plant spread and yield of white clover for lines categorised on morphological and physiological features.

	Plant spread (cm)		Yield score (0–9)	
	Summer	Winter	Summer	Winter
Medium leaf/early flower	45	31	4.4	5.7
High nodal root frequency	47	32	4.9	5.8
Taprootedness	45	22	4.7	4.6
Stoloniferous/medium leaf	46	29	4.3	5.3
Drought tolerance	40	26	3.7	5.0
SEM	1.8	2.0	0.18	0.19

Methods

Field evaluation of germplasm

A set of 140 lines plus 10 cultivar standards were chosen for field evaluation. The lines were chosen on the basis of criteria that are important for persistence and agronomic performance in the Australian dryland temperate pasture zone. The criteria used were; medium-large leaf with early flowering, high nodal root frequency with medium leaf, tap rootedness, high stolon density with medium leaf, drought tolerance and novel features. The novel lines include small and large leaf types, dense growth habit combined with leafiness, virus resistant lines, experimental crosses, and cultivar and ecotype reselections (Table 2).

Seedlings were propagated in the glasshouse and transplanted into a tall fescue (cv. Demeter) sward free of indigenous legumes in spring 1994. The site has a basalt soil type and was fertilised with superphosphate to maintain medium soil phosphate status. The experimental design consisted of 150 lines with 5 reps. Each plot consisted of 10 plants in a 1 m row with 1 m between plots. The trial was grazed with sheep to include six grazings per annum and will continue for three years.

Measurements

Plots were assessed every eight weeks prior to each grazing. Each assessment included a visual score of clover biomass per plot area on a 0–9 linear scale and a measurement of row spread at three fixed points. Visual scores were calibrated to DM yield by scoring and harvesting 15 quadrats (75 × 100cm). Yield and row spread results in the first growth cycle are presented in this report.

Statistical analysis

To compare lines, the statistical model accounted for spatial variability induced by within-site factors such as fertility and moisture gradients (Cullis & Gleason, 1991). Within-site variability was removed and the predicted yields were adjusted for those error effects.

Results and discussion

Data are presented in Table 3 for summer and winter row spread and herbage yield for five groups of lines (Group 1: medium leaf/early flowering, Group 2: high nodal root lines, Group 3: tap rooted lines, Group 4: stoloniferous/medium leaf lines, Group 5: drought tolerant lines). Data are not presented for Group 6 (novel types) because these lines represent diverse characteristics and do not form a cohesive group. Likewise, data are not presented for the 10 cultivar standards. Comment is made, however, on the relative performance of Haifa and Huia because of their significance as recommended cultivars for dryland environments.

In summer, lines selected on the basis of high nodal root frequency (Group 2) were highest yielding and drought tolerant lines (Group 5) were lowest yielding. High nodal root lines, medium leaf/early flowering lines and stoloniferous/medium leaf lines showed best winter activity. Plant spread in summer was comparable for all groups but following very dry autumn conditions, plant spread of tap root lines was markedly reduced.

Haifa was ranked 6th (among 150 lines) and 5th for row spread in summer and winter respectively, and was significantly better than Huia (45th and 128th). There were no significant differences between cultivars in either summer or winter herbage yield; Haifa was ranked 61st and 26th, and Huia was ranked 22nd and 62nd for summer and winter herbage yield respectively.

These results are for the first growth cycle. Although preliminary, the data suggest that agronomic performance was associated with the criteria used to select germplasm entries. Field evaluation of these lines will continue for a further two growth cycles to identify superior material for polycrossing and testing in target dryland environments.

Acknowledgements

This project is a component of the Australasian Perennial Legume Improvement Program and is partly funded by the Meat Research Corporation. The authors acknowledge the contribution of ideas and support from colleagues, especially Dr Warren Williams, Dr John Hay (NZ AgResearch) and Dr Ken Archer (NSW Agriculture).

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