A comparison of New Zealand and overseas white clover cultivars under grazing in New Zealand

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Abstract
A large number of white clover cultivars bred both in New Zealand and overseas are available for use by New Zealand pastoral farmers. Unfortunately, there is little published data on the merits of many of these cultivars under grazing in New Zealand. Data from a series of trials established in the Manawatu between 1996 and 2005 containing a range of cultivars from Europe, the Mediterranean, North and South America and New Zealand were used in a meta-analysis to assess the general adaptive yield and persistence potential of these contrasting cultivar types. All trials were maintained over 2 to 4 years, and revealed significant cultivar effects. Overall, New Zealand bred cultivars showed better adaptation than overseas cultivars. However, overseas cultivars containing Mediterranean germplasm, particularly from southern France, Italy and Syria exhibited beneficial features in the trials, and many recently bred New Zealand cultivars contain germplasm from these origins. In addition to using the appropriate parent germplasm when developing cultivars, it is equally important to evaluate and select under local conditions, in competition with grass, under grazing, over multiple environments and years. New Zealand farmers may benefit from an industry-wide benchmarking system for white clover cultivars, possibly by incorporation into the DairyNZ Forage Value Index.

Keywords: white clover, cultivars, germplasm, local, overseas, adaptation

Introduction
White clover (*Trifolium repens*) is the most widely used pasture legume in New Zealand. It provides plant-available nitrogen through symbiosis with *Rhizobia*, and improves animal intake and productivity in mixed swards (Caradus *et al*. 1996). Development of improved forage legumes has been a longstanding plant breeding goal in New Zealand (Cockayne 1918), although it was 1957 before 'Grasslands Huia', the first selected synthetic white clover cultivar, was released (Woodfield & Caradus 1994). Early breeding efforts in New Zealand focused on developing cultivars with broad adaptation, but in the last 25 years cultivars with more specific adaptation such as 'Grasslands Tahora' for moist hill country (Williams & Caradus 1979) and 'Grasslands Kopu' for dairy farming were developed. Since then, a proliferation of breeding and marketing efforts, supported by the statutory framework for protection of intellectual property in New Zealand and overseas, has seen hundreds of white clover cultivars bred and marketed to farmers worldwide (Woodfield & Caradus 1994).

The global and competitive nature of white clover breeding and marketing has led to sales of seed in international markets far beyond their breeding origins, raising questions of broad adaptation and suitability for the local environment of a wide range of cultivars available in New Zealand. In the absence of an industry benchmarking system such as the DairyNZ Forage Value Index provides for perennial ryegrass (Chapman *et al*. 2012), there is little peer-reviewed information on comparative performance of modern white clover cultivars available to New Zealand farmers.

Plant breeding principles indicate locally bred genetics are likely to be best adapted to the local environment, and genotype × environment interactions often constrain the adaptation of cultivars to specific production regions and pasture management regimes (Allard 1999). However, New Zealand has no native forage legumes and is wholly reliant on exotic forage germplasm sources, which are evaluated in and selected for agronomic performance in local conditions. This raises the question of how rapidly and successfully exotic germplasm has been adapted to New Zealand pastoral farming through local breeding programs which utilise grazing and grass competition to identify plant material. New Zealand breeders have routinely used overseas germplasm with desirable traits, for example Spanish germplasm providing winter growth in 'Grasslands Pitau' (Williams & Barclay 1975). However, these overseas germplasm have often required crossing with New Zealand derived-cultivars

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and ecotypes to provide good adaptation to local climate and farming conditions (Widdup & Boleyn 1986; Caradus *et al*. 1991).

The objective of this research was to examine historic small plot trial data to identify trends in adaptation for overseas and locally bred white clover cultivars, to gain insight into the relative agronomic merit of cultivars of local and international provenance under pastoral conditions typical of New Zealand.

Materials and methods

A range of white clover cultivars and experimental selections from New Zealand and overseas was established in perennial ryegrass based pastures in three experiments in the Manawatu between 1996 and 2005 (Table 1). The collection of clover cultivars included European and Mediterranean, USA, South American and New Zealand sources. The cultivars in Experiments II and III were common to both trials but different to those in Experiment I. The Europe-New Zealand group contained cultivars that had prior breeding and selection in New Zealand followed by final selection and testing in Europe before commercial release in Europe.

In the six months before each experiment the existing perennial ryegrass pastures were sprayed twice with the selective herbicide dicamba to remove any existing clover plants from the trial area. Fourteen-week-old glasshouse raised seedlings of all entries were then transplanted in late winter into small plots in these pastures. Plots consisted of ten plants established in a micro-plot, with plants 25cm apart. The plots were arranged in a randomised block design with up to six replications. The trials were rotationally grazed followed by topping to an even height if required, usually following a pattern of two defoliations in spring, summer and autumn and a single defoliation in winter.

Prior to grazing, plots were assessed for the proportion of clover herbage yield present on a 1–9 visual scale (1=lowest quantity, 9=highest quantity). For experiment I, after each visual scoring, a 0.5 m × 0.1 m quadrat of 25 plots representative of the 1–9 scale were cut and the clover and grass herbage dry matter (DM) yields was measured. A regression analysis between plot score and clover DM allowed a clover herbage yield (kg DM/ha) for all plots to be estimated. In Experiments II and III, plots were only visually scored for clover yield. Plots were also scored for leaf size in the first autumn of each trial.

The estimated clover yield data were analysed by ANOVA using Genstat version 16.

Results

In the three experiments there were summer moisture deficits in most years which will have induced stress on the clover (Table 1). The only exception was in year one of Experiment II when the Manawatu experienced an unusually wet summer. There were significant differences among the white clover cultivars for annual

Table 1 Site features and origin of white clover cultivars in each experiment

Trial Parameter	Experiment I	Experiment II	Experiment III
Site	Palmerston North	Aorangi, Manawatu	Palmerston North
Years	1996-99	2003-06	2005-08
Pasture Base	Samson AR1	Samson AR1	Samson AR1
Grazing Ruminant	Sheep	Cattle	Sheep
Cultivars*	UK (15)	Europe (10)	Europe (10)
	Coastal Europe (10)	Europe-NZ (15)	Europe-NZ (15)
	Northern Europe (18)	North America (11)	North America (11)
	Mediterranean (7)	South America (8)	South America (8)
	North America (14)	NZ cvs (15)	NZ cvs (15)
	South America (4)	NZ selns (7)	NZ selns (7)
	NZ cvs (16)		
Moisture Deficit (mm)			
Summer (Dec-Feb) Year 1	-137	106	-213
Summer Year 2	-144	-147	-212
Summer Year 3	-321	-213	-285

*Number of cultivars indicated in (), and includes these countries of origin: UK – Ireland, Wales; Coastal Europe – Denmark, Netherlands, France; Northern Europe – Czech Republic, Germany, Poland, Hungary, Sweden, Finland; Mediterranean – Israel, Greece, Italy; North & South America – USA, Argentina and Brazil.

mean DM yield within each experiment (P<0.05) (Tables 2 and 3).

Experiment I

The white clovers from Europe showed a clear relationship between latitude of origin and clover DM yield in New Zealand (Figure 1). Cultivars originating from high latitudes had the lowest median yield, while the highest yielding cultivars came from the Mediterranean region and Ireland (Figure 1). These Irish and Mediterranean cultivars were the closest in DM yield behind the New Zealand cultivars. The clover cultivars from South America were poor relative to their latitude of origin while USA cultivars showed wide ranging performance.

The performance of a representative set of more recent cultivars from different regions across Europe, USA and New Zealand is shown in Table 2. In the first 2 years there were few significant (P<0.05) differences among cultivars from all countries, except 'Crusader' which was the standout cultivar. In the third year, the

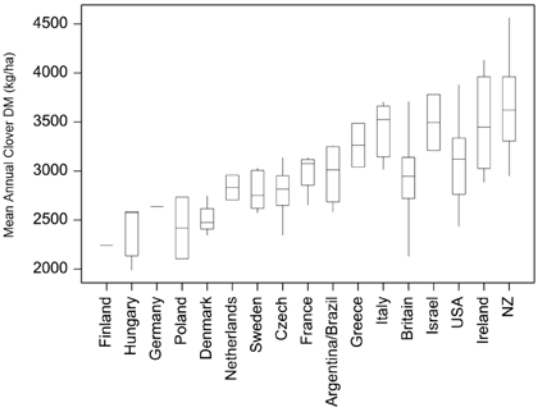

Figure 1 The estimated mean annual white clover DM yield (kg DM/ha/year) for cultivars bred in Europe, North and South America and New Zealand, using data from Experiment I over 3 years from 1996-99. For each country, the horizontal line in the box plot indicates the mean DM yield for the cultivars from that country, the box represents the middle 50% of variation, the vertical upper line covers the upper quartile of cultivars and the lower line covers the poorest quartile of cultivars.

Table 2 The relative mean annual white clover DM yields in Experiment I of the representative best performing cultivars from overseas and New Zealand origin including coastal Europe, UK, Mediterranean, USA and New Zealand under rotational sheep grazing. Data are relative to Grasslands Huia=100, which had estimated annual DM yields (kg/ha) of 3160, 3510 and 3265 in years 1, 2 and 3 respectively.

Cultivar	Country	Leaf size*	Year 1	Year 2	Year 3
Alberta	Denmark	M	84	75	67
Tregor	France	M	87	87	111
Riesling	Netherlands	ML	79	97	91
AberCrest	Wales	S	88	90	123
Avoca	Ireland	ML	97	90	74
Susi	Ireland	ML	101	117	156
AberHerald	Wales	L	94	98	104
Konitsa	Greece	ML	72	94	150
Tamar	Israel	L	73	100	169
Communalidi Rieti	Italy	L	96	109	131
Brown Loam	USA	L	55	92	130
SRVR	USA	L	73	107	115
Will	USA	L	81	111	143
Grasslands Tahora	NZ	S	98	98	162
Grasslands Prestige	NZ	SM	104	99	126
Crusader (Apex**)	NZ	M	121	145	147
Grasslands Kopull	NZ	L	79	120	179
F significance			P<0.001	P<0.001	P<0.007
LSD (5%)			16	24	59

*S=small, SM=small-medium, M=medium, ML=medium-large, L=large
**Crusader clover is marketed in New Zealand as Apex

coastal European and USA cultivars were inferior to the Mediterranean and New Zealand cultivars, with 'Tamar' (Israel) and New Zealand cultivars 'KopuII' and 'Tahora' exhibiting the highest yields. The summer in the third year was very dry (Table 1), and drought tolerance typical of Mediterranean germplasm such as 'Tamar' may have aided their performance.

Experiments II and III

There was a significant positive correlation (R=0.72**) for the estimated mean annual clover yield (based on visual scores) of cultivars under sheep grazing compared to the cultivars in cattle grazed pastures (Figure 2). In general, cultivars producing high clover yields performed well under both grazing managements. Poor cultivars were generally low yielding under both managements.

As in the first experiment, mean annual clover yield of a representative set of more recent cultivars from different regions was examined in greater detail (Table 3). The Europe-New Zealand group of cultivars and the New Zealand cultivars were the highest performers in these two experiments, although not significantly (P>0.05) different at the mean performance by country of origin level. Most of these cultivars produced significantly (P<0.05) greater yields than 'Grasslands Huia' under cattle grazing but similar to Huia under sheep grazing management. The standout cultivars were 'Barblanca' and 'Makuri', 'Tribute', 'KopuII' and 'Quest'. Overall, the modern cultivars from Europe, USA and South America were similar in performance to 'Grasslands Huia'. The exception was the Irish cultivar 'Aran' with significantly (P<0.05) greater yields under both grazing managements. The other notable Irish cultivar was 'Chieftain', which had higher yield under cattle grazing.

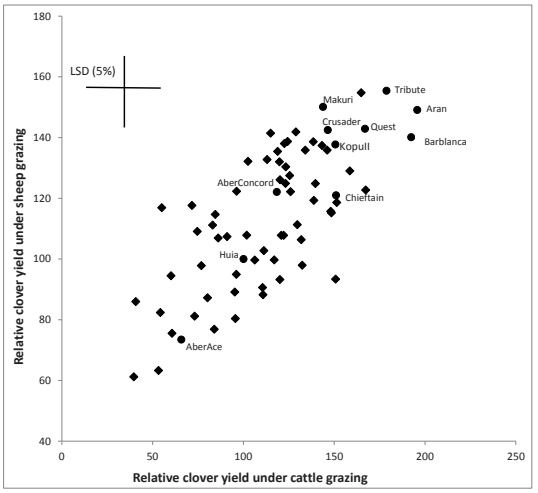

Figure 2 The estimated mean relative clover yield over three years (Grasslands Huia=100) for white clover cultivars under cattle (Expt II) and sheep (Expt III) grazing management at Aorangi and Palmerston North, respectively. All data points represent cultivars, the data points represented by circles are named cultivars likely to be of greater interest to New Zealand farmers than those indicatd by diamonds.

Table 3 The relative mean white clover yield in the third year of the best performing cultivars from Britain, Europe, North and South America and New Zealand under rotational cattle and sheep grazing management in Experiments II and III respectively. The clover herbage yield was estimated using a visual score from 1=poor to 9=very good and expressed relative to Grasslands Huia = 100.

Cultivar	Country	Leaf size*	Cattle	Sheep
AberAce	Wales	S	40	64
AberConcord	Wales	M	132	108
Chieftain	Ireland	ML	194	114
Aran	Ireland	L	240	156
Wanaka	Europe (NZ)	ML	176	94
Triffid	Europe (NZ)	ML	186	134
Barblanca	Europe (NZ)	ML	252	136
Makuri	Europe (NZ)	ML	174	140
Bounty	NZ	SM	128	110
Crusader (Apex**)	NZ	M	158	130
Tribute	NZ	ML	198	132
Quest	NZ	ML	198	140
KopuII	NZ	L	176	138
Durana	USA	S	86	96
Patriot	USA	M	86	90
Tillman II	USA	L	102	100
Goliath	Argentina	L	170	100
Kanopus	Uruguay	L	96	116
F Significance			P<0.001	P<0.001
LSD (5%)			77	43

*S=small, SM=small-medium, M=medium, ML=medium-large, L=large
**Crusader clover is marketed in New Zealand as Apex

Discussion

In most cases, cultivars bred overseas were less adapted than New Zealand bred cultivars across these three Manawatu experiments simulating New Zealand pastoral grazing systems. This fits the general paradigm of selective breeding and local adaptation published for perennial ryegrass in New Zealand (Rumball & Armstrong 1975).

Notably, when compared to overseas cultivars from a similar climate and pasture system such as Ireland, New Zealand bred clover cultivars as a group were not significantly (P>0.05) different. However, the New

Zealand cultivars had higher DM yield values, lending further support to the hypothesis of local breeding and adaptation are most likely to offer an assurance of high performance, even when environments are relatively similar, such as the case of New Zealand and Ireland.

The excellent performance in New Zealand experiments of the European cultivars bred in New Zealand is noted. These cultivars were first developed in New Zealand using germplasm with relevance to European conditions but with final evaluation and selection under European pastoral conditions (Caradus *et al.* 1990). The cultivars 'Barblanca', 'Makuri' and 'Triffid' are examples from these programmes and all have shown excellent agronomic potential in British and French cultivar testing trials (Woodfield *et al*. 2006). It seems there is an element of complementarity between the more temperate parts of Europe and New Zealand, and material can perform well in both regions when the early breeding evaluations are balanced across target environments. This suggests that while in general the location of the breeding and evaluation strategies is critical in determining adaptation to local conditions, that with appropriate strategies of multi-site evaluation that very wide adaptation bridging New Zealand and Europe can be achieved.

There was a clear trend for the high performing European clovers to originate from low latitude, particularly Mediterranean countries. There was a steady decline in the performance of clovers as the latitude of origin increased, with the lowest yielding clovers from the Scandinavian region. Caradus *et al*. (1991) reported a similar trend from earlier New Zealand trials and highlighted the high yielding potential of clovers originating from southern France, Syria and Italy. The Irish cultivars 'Aran' (originating from France and Israel), 'Chieftain' (from France) and 'Susi' (from Iran), performed well in the current experiments supporting the adaptive value of Mediterranean germplasm for New Zealand conditions. However, large leaved cultivars such as 'Aran' have shown less persistence under more intensive grazing pressure due to their relatively low stolon growing point density (Woodfield, unpublished data).

North and South American cultivars, although from lower latitudes, were generally poorly adapted in these New Zealand trials. This may be linked to the large leaved 'Ladino' based germplasm from northern Italy dominantly used in USA cultivars released prior to 2000. These had lower stolon densities and low cyanogenesis, which in previous trials showed poor persistence under New Zealand grazing conditions (Caradus *et al.* 1991). South American cultivars are dominated by early-flowering germplasm (Garcia 1993) with active winter growth and low summer growth, a trait with poor adaptation for New Zealand climatic conditions and grazing systems.

Use of overseas germplasm has been and continues to be vital to the success of clover breeding in New Zealand. Historic cultivars such as 'Pitau' and 'Kopu' relied on material imported from Spain and Italy, respectively, to introgress better winter growth and higher summer growth potential (Williams & Barclay 1975; Williams 1987). Recent agronomically superior New Zealand cultivars such as 'Crusader', 'KopuII' and 'Tribute' also have a large percentage of their parentage from overseas germplasm. 'Crusader' was developed from crosses between Syrian and French germplasm while 'KopuII' involved materials from sources including Italy, USA, Ireland and New Zealand (Woodfield *et al.* 2001). 'Tribute' incorporated Syrian and Southern French germplasm together with drought tolerant Australian ecotypes (Woodfield *et al*. 2003).

While not explicitly tested here, we propose that the successful development of adapted New Zealand cultivars is not only driven by good parent germplasm, but also by widespread evaluation of the material across sites. The evaluation strategy of using competition with grass and evaluating breeding populations under various grazing regimes over trials lasting at least 3 years to ascertain persistence is essential. These conditions ensure that during the selection process the material is tested in conditions relevant for New Zealand farmers. Even though the current trials were only from one region in New Zealand, a range of breeding sites and evaluation strategies play a key role in the development of clovers adapted to New Zealand pastoral conditions.

These experiments have highlighted the variability of the agronomic merit of a representative array of clover cultivars from overseas and New Zealand that are available to farmers. At present, there is no independent, consolidated information source for farmers to compare cultivars, and it would be beneficial to have an industry benchmarking system for white clover similar to the Forage Value Index (FVI) initiated by DairyNZ and the New Zealand Plant Breeding Research Association for ryegrass (Chapman *et al*. 2012). White clover continues to be the significant legume component in New Zealand pastures. Access to data on white clover cultivar performance will help ensure that New Zealand pastoral farmers are best able to select cultivars suitable for their environmental conditions on farm.

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