

Arrowleaf clover: potential for dryland farming systems in New Zealand

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Abstract

Arrowleaf clover (*Trifolium vesiculosum* L.) is a late maturing annual legume which has the potential to be used in a range of farming systems such as finishing lambs through to silage production and building soil fertility for future cropping. An experiment at Lincoln University, Canterbury, evaluated the performance of 'Arrotas' arrowleaf clover relative to white and subterranean clover from 23 May to 20 December 2007. By the 20/12/2007, 'Arrotas' produced 9800 kg DM/ha compared ($P < 0.001$) with 3370 kg DM/ha from subterranean and 1790 kg DM/ha from white clover. Metabolisable energy in late December was similar for all clovers. Results in Australia at similar latitudes and rainfall regimes to parts of the North and South Island of New Zealand suggest that 'Arrotas' could be successfully incorporated into local dryland systems.

Keywords: climate evaluation, *T. repens*, *T. subterraneum*, *T. vesiculosum*, dry matter yield

Introduction

In New Zealand dryland agricultural systems, arrowleaf clover (*T. vesiculosum*), a self regenerating annual clover native to the Mediterranean region, could play an important role. It has been cultivated in parts of the USA since the 1960s (Hoveland & Evers 1995) and in Australia since the 1980s (Wiley 1994). In Brazil, it increased animal liveweight when used in mixtures with oats (*Avena sativa*) or annual ryegrass (*Lolium multiflorum*) (Lobato *et al.* 1993).

Arrowleaf clover is an aerial seeding species suited to well drained sandy or clay soils with pH 5-7 (Evans 2006). The species is hard seeded and, because of its late flowering, extends the growth season by around 6 weeks when compared with other annual legumes such as subterranean clover (*T. subterraneum*) (Riffkin *et al.* 2001; Zhang & Evans 2004). In Australia, at latitudes similar to New Zealand, it persists in areas with 500-900 mm/yr rainfall. This indicates it may be suited to dryland areas of the east coast of New Zealand.

In this paper we examine the hypothesis that in areas with similar climatic conditions to those in which it has previously been tested (such as Launceston in Tasmania and Hamilton in Victoria, Australia) 'Arrotas' arrowleaf clover may contribute to local agricultural dryland systems.

Materials and Methods

An experiment comparing three legume species was established at Lincoln University, Canterbury on a Templeton silt loam soil of variable depth. In spring 2005, the site was used to grow lettuce (*Lactuca sativa*). On 27/12/2005, following soil tests, 400 kg/ha Nitrophoska (12,10,10,1) was applied to the experimental area. No fertilisers have been applied since this time. A high Olsen P (70) reflected the previous site use as the piggery and poultry unit for ~50 years up to the mid 1950s. In autumn 2006, 'Moata' short rotation ryegrass was sown. This was sprayed out with glyphosate (540 g/L ai) at 5 L/ha with Pulse as a surfactant on 2/5/2007. The site was ploughed, ditch harrowed and rolled on 10/5/2007 and 22/5/2007.

Experimental design

A randomised complete block (RCB) experiment, with four replicates, was drilled with an Øyjoord cone seeder on 23/5/2007. Treatments were monocultures of 'Nomad' white clover (*T. repens*) as a control, 'Leura', the latest maturing commercially available subterranean clover (*T. subterraneum*) and 'Arrotas' arrowleaf clover (*T. vesiculosum*) monocultures sown into 2.1 x 9.0 m plots at rates to achieve a target population of 333 viable plants/m² based on germination tests. The annual clovers were freshly inoculated with appropriate commercially available rhizobial strains prior to sowing. For white clover Group B inoculant (*Rhizobium leguminosarum* bv. *trifolii* TA1) was applied while subterranean and arrowleaf clovers were inoculated with Group C (*R. leguminosarum* bv. *trifolii* WSM1325).

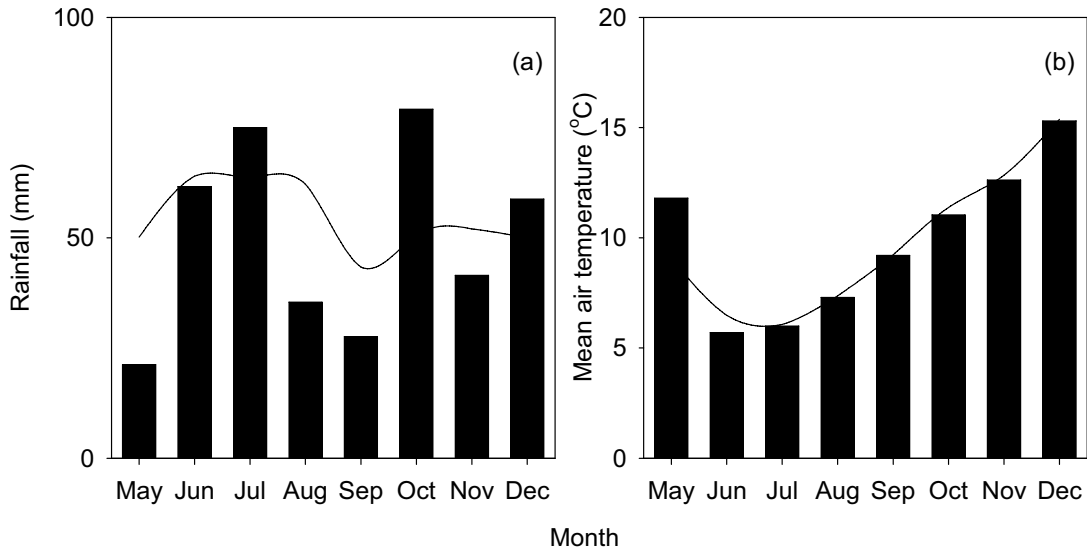
Environmental conditions

Monthly rainfall during 2007 (Fig. 1a) was less than the 1975-2002 mean (LTM), in May, August, September and November but was 30 mm above average in October. Mean monthly air temperature (Fig. 1b) followed the long-term seasonal pattern except it was 2.7°C warmer in May 2007 and 0.8°C cooler in June.

Measurements

Seedling emergence was measured from 2 x 1.0 m drill rows per plot on 26/6/2007. Dry matter (DM) production (kg/ha) was measured three times between sowing and the final harvest on 20/12/2007. On 12/9/2007, 30/10/

Figure 1 Monthly (a) rainfall (mm) and (b) mean monthly air temperature (°C) at Lincoln, Canterbury in 2007. Solid lines are long-term (1975-2002) monthly means. Data were recorded at the Broadfields Meteorological station located 2 km north of the experimental area.



2007 and 20/12/2007, yield was determined in each plot by cutting a 0.2 m² quadrat to ground level with a set of electric clippers. Subsamples were taken to determine yield of the sown clovers and samples were then dried to a constant weight. Sown clover samples, which included leaf, stem, petiole, flowers/buds, and dead material were then ground in a Cylotec mill and nutritional analysis of the bulk clover samples was conducted by near infra-red spectroscopy (NIRS). Plots were then grazed in common by ewes and the experiment was terminated before arrowleaf clover had fully matured and set seed.

On 3/12/2007, random samples were taken to ground level from one replicate to quantify the contribution of leaf, petiole, stem, flowers/buds and dead material to standing DM, but yield was not measured. Leaf, stem and petiole samples were ground and sent for nutritional analysis by (NIRS).

Climate comparisons

CLIMEX is a dynamic simulation model which enables the estimation of an animal or plant's geographic distribution and relative abundance as determined by climate variables (Sutherst *et al.* 2007). The model was first described by Sutherst & Maywald (1985), and the approach was used in plant breeding by Bennett *et al.* (1998) to match climatic similarities between areas in the Mediterranean basin and southern Australia.

This software was used to search the meteorological database contained within CLIMEX version 3 for locations with climates similar to that of a nominated location. The match index is the product of five parameters, which individually indicate the level of

similarity for average monthly maximum daily temperature, average monthly minimum daily temperature, average monthly rainfall, rainfall pattern and the relative humidity at 9 am and 3 pm. The total similarity between the specified location and any other location is calculated by averaging the similarity values of the five parameters. In this study we selected locations in New Zealand receiving less than 1000 mm of annual rainfall and compared them with locations in SE Australia where 'Arrotas' arrowleaf clover is well adapted.

Results

DM production

On 27/6/2007 (34 DAS) the plant populations were lowest ($P < 0.001$) for white clover (119 plants/m²) and highest (333 plants/m²) in the subterranean clover treatment. There were 228 plants/m² in arrowleaf clover plots. This indicated field emergence of 36% for white clover, 68% for arrowleaf and 100% for subterranean clover.

At the first harvest on 12/9/2007 (112 DAS), subterranean clover had produced 220 kg DM/ha which was 5-8 times greater ($P < 0.01$) than the 36±23.5 kg DM/ha produced by 'Arrotas' or white clover monocultures (Fig. 2). At 161 DAS (31/10/2007) both subterranean (3220 kg DM/ha) and arrowleaf (2120 kg DM/ha) clovers had higher yields ($P < 0.01$) than white clover (495 kg DM/ha). Between the first and second harvests mean daily growth rates were 62 kg DM/ha/d for subterranean and 42 kg DM/ha/d for arrowleaf clover and both were faster ($P < 0.01$) than the 10 kg DM/ha/d from white clover. At this time, 'Leura' had extensive

Figure 2 Dry matter production (kg DM/ha) between sowing (23/5/2007) and end of regrowth (20/12/2007) for 'Nomad' white clover, 'Leura' subterranean clover and 'Arrotas' arrowleaf clover at Lincoln University, Canterbury. Error bars are LSD ($P < 0.05$).

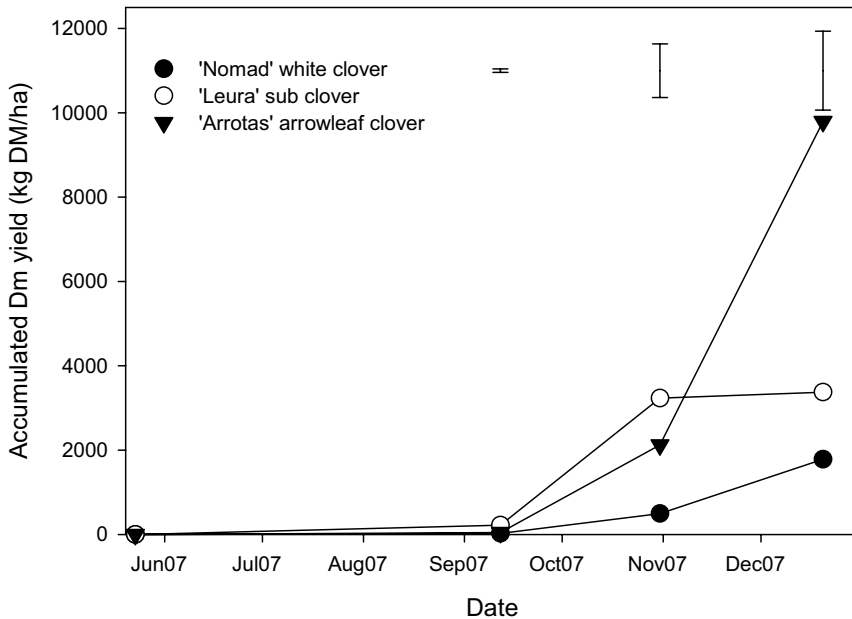


Table 1 Percentage (%) contribution to standing DM of leaf, petiole and stem material, neutral detergent fibre (NDF, g/kg DM), acid detergent fibre (ADF, g/kg DM), water soluble carbohydrate (CHO, g/kg DM), metabolisable energy (ME, MJ ME/kg DM) and nitrogen concentration (N%) from grab samples taken in Replicate 1 on 3/12/2007. Nutritive analysis was not conducted on flowers/buds or dead components.

Species	Component	%	NDF	ADF	WSC	ME	N%
Arrowleaf	Leaf	23	223	179	64	10.6	4.9
	Petiole	9	351	286	219	10.9	1.4
	Stem	64	449	326	381	10.6	1.2
	Flowers/buds	<1					
	Dead	3					
Subterranean	Leaf	21	198	178	139	11.1	3.8
	Petiole	27	309	275	277	11.5	1.4
	Stem	39	282	243	303	11.5	1.3
	Flowers/buds	6					
	Dead	7					
White	Leaf	31	192	164	114	12.1	5.1
	Petiole	31	300	279	256	11.8	2.0
	Stem	32	331	263	176	11.3	2.7
	Flowers/buds	6					
	Dead	0					

flower and burr formation whereas 'Arrotas' and 'Nomad' remained vegetative.

At the final harvest (20/12/2007, 211 DAS), arrowleaf clover yield of 9800 kg DM/ha was greater ($P < 0.001$) than the 3370 kg DM/ha produced by subterranean and the 1790 kg DM/ha from white clover. Figure 2 shows that DM production by subterranean clover reached a plateau between the second and third harvests as its life cycle ended and material began to senesce resulting in a net DM gain over a 50 d period of 140 kg DM/ha.

Between the second and third harvests, mean daily growth rate of arrowleaf was 153 kg DM/ha/d and higher ($P < 0.001$) than the 3 and 26 kg DM/ha/d from subterranean and white clover, respectively. 'Arrotas' had entered the reproductive phase and flowers were beginning to senesce by late December.

Random samples from the 3/12/2007 showed stem material represented 64% of arrowleaf, 39% of subterranean and 32% of white clover standing DM (Table 1). As expected, N% was highest (3.8-5.1%) in

Table 2 Neutral detergent fibre (NDF, g/kg DM), acid detergent fibre (ADF, g/kg DM), water soluble carbohydrate (CHO, g/kg DM), metabolisable energy (ME, MJ ME/kg DM) and nitrogen concentration (N%) from replicated bulk clover samples taken on 20/12/2007. Bulk clover samples contained leaf, stem, petiole, flowers/buds, and senesced leaves.

Species	NDF	ADF	WSC	ME	N%
Arrowleaf	386	295	231 ^a	10.4	1.6 ^c
Subterranean	346	280	126 ^b	10.4	2.1 ^b
White	317	229	94	11.1	3.6 ^a
Mean	349	268	150 ^b	10.6	2.5 ^a
SEM	17.7	16.6	17.1	0.9	0.1
Signif. ¹	NS	NS	**	NS	***

¹ NS – not significant; ** P<0.01; *** P<0.001

green leaf material compared with petiole and stems. The NDF of stem material of arrowleaf clover was 449 g/kg DM which was consistent with a highly lignified stem. Water soluble carbohydrate levels in the 'Arrotas' stem were 26% and 116% greater than those of stem material from subterranean or white clover, respectively. Metabolisable energy was reasonably consistent across species and components although leaf material of arrowleaf clover had a lower ME than that of white clover.

At the final harvest on 20/12/2007, ME of samples containing leaf, stem and reproductive material was 10.7±0.25 MJ ME/kg DM and similar for all clovers (Table 2). Water soluble carbohydrate levels in arrowleaf clover (231 g/kg DM) were greater (P<0.01) than those from subterranean (126 g/kg DM) and white clover (94 g/kg DM) and white clover had the highest (P<0.001) nitrogen content (3.6%) of the three species.

Climate evaluation

Two areas in Australia where 'Arrotas' showed excellent adaptation in a variety of different agricultural systems were Launceston, Tasmania, and Hamilton in SW Victoria. The best match to Launceston in New Zealand was Waipukurau (93%) and the closest location to Hamilton, Victoria was Blenheim with 91% fit. St Helens and Orford in Tasmania matched Blenheim well with fits of 91 and 92% respectively. Napier in New Zealand matched St Helens (Tas), Lakes Entrance (Vic) and Warrnambool (Vic) well with a fit of 92% for all three sites. Christchurch, close to the experiment reported here matched Launceston and Hamilton at 87 and 84% respectively.

Discussion

The results show 'Arrotas' has the ability to extend the growing season compared with the late flowering 'Leura' subterranean clover (Fig. 2). Mean daily growth rate of 'Leura' was 140 kg DM/ha/d between 12/9/2007 and 30/10/2007, when mean air temperature was 10.6°C. However, between 31/10/2007 and 20/12/2007, when mean air temperature was 13.8°C, arrowleaf had a mean daily growth rate of 153 kg DM/ha/d compared with 26

kg DM/ha/d by white clover and 3 kg DM/ha/d by subterranean clover. Specifically, arrowleaf clover had a longer lifecycle than subterranean clover and was able to utilise late spring/early summer rainfall which is variable and unpredictable (Fig. 1). This supports previous work that reported 'Arrotas' was late maturing and extended the growing season by several weeks compared with subterranean, balansa (*T. michelianum*) or Persian (*T. resupinatum*) clovers (Zhang *et al.* 2004). In Victoria, 'Arrotas' produced as much, or more, DM than the other annual legumes and over 60% of total production occurred from November onwards compared with 30% for the other annual legumes (Zhang *et al.* 2004). The extension of the growing season should result in improved animal performance through increased carrying capacity compared with white and subterranean clovers in late spring. Fresh stems of 'Arrotas' were grazed well by stock after the final harvest (visual observation) and preliminary results have suggested high levels of water soluble carbohydrates in the stems (Table 1) may contribute to grazing of lignified stems. The high proportion of stem material ensured that WSC levels in bulk clover samples at the final harvest remained higher than those of subterranean or white clovers. As expected, the annual legumes, which had begun to flower and senesce, had lower N content than perennial white clover which was still vegetative.

Holmes *et al.* (2005) demonstrated that 'Arrotas' extended the growing season by 4–6 weeks in Hamilton, Victoria, compared to 'Leura' subterranean clover and total lamb production from 'Arrotas' in late spring/early summer was 63% more than from 'Leura'. Inclusion of 'Arrotas' with perennial ryegrass, increased the utilisation of the low quality grass during early/mid summer by at least 1000 kg DM/ha (Thompson 2006) and lambs grew quicker on arrowleaf clover than expected from the quality of the feed on offer. It was hypothesised that tannin levels in the leaf between 2 and 5% (Hoveland *et al.* 1972) may have been a contributing factor.

In Australia, 'Arrotas' is adapted to pasture:crop rotations and shows excellent self regeneration in the year following cropping. In the third year of the rotation, 'Arrotas' had a

soil seed bank of 950 kg/ha, and in the fifth year it produced 12.8 t DM/ha (Evans *et al.* 2003; Zhang & Evans 2004; Zhang *et al.* 2004). High levels of hard seed and late seed set in summer precludes it from regenerating in the second year. Therefore, in New Zealand it may be necessary to direct drill an annual or perennial ryegrass in the second year following a pure stand that has been allowed to set seed. Alternatively, arrowleaf clover has performed well when direct drilled into hard grazed perennial grass pastures (Thompson 2006). It is important to establish a crop or grass in the second year to exploit the fixed N as arrowleaf clover with yields in excess of 10 t DM/ha will input 250 kg N/ha into the system (25 kg N/t DM) (Peoples *et al.* 1998). A third option is to leave the pasture ungrazed and, after seed set, use the crop as standing hay or cut for silage. Self regeneration will occur every year from its third season onwards (Zhang *et al.* 2004).

The close fit between a range of sites in Australia where the plant performs well and places in New Zealand where dryland agriculture is practised suggest that 'Arrotas' could be valuable in local pasture and pasture/crop rotation systems. Initial results are encouraging, and warrant further work to test this hypothesis.

Conclusions

- 'Arrotas' produced 9800 kg DM/ha between May and December and had a mean daily growth rate of 153 kg DM/ha/d between 31/10/2007 and 20/12/2007 when mean air temperature was 13.8°C.
- The longer lifecycle, relative to the later maturing commercially available subterranean clover cultivar, meant 'Arrotas' could utilise rainfall in late spring/early summer typical of dryland systems on the east coast of New Zealand.
- Climate suitability was >84% for a range of dryland east coast locations from Canterbury northwards.

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