Sub clover, cocksfoot and lucerne combine to improve dryland stock production

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Abstract
The temporal (seasonal) pattern of dryland pasture and stock production from four cocksfoot based pastures (mixed with balansa, Caucasian, subterranean or white clover), a ryegrass/white clover pasture and a pure lucerne crop were compared over 2 years (2004/05 and 2005/06). Subterranean clover with cocksfoot provided high legume content pasture giving higher stock production than other pasture mixtures from August to October. This complemented the high yields and stock production provided by lucerne from mid September to January in 2004/05. However, a dry winter followed by spring snow resulted in lucerne production similar to other pastures in 2005/06. Cocksfoot based pastures provided more maintenance feed than perennial ryegrass during a dry summer (2005/06) but ryegrass/white clover provided higher stock production in wet summer conditions (2004/05). These results suggest a range of pasture species are necessary to cope with the seasonal climate variability typically experienced in dryland farm systems.
Keywords: balansa clover, Caucasian clover, *Dactylis glomerata*, *Lolium perenne*, *Medicago sativa*, pasture growth rates, ryegrass, sheep production, *Trifolium ambiguum*, *Trifolium michelianum*, *Trifolium repens*, *Trifolium subterraneum,* white clover

Introduction
The most commonly used pasture mixture in New Zealand is ryegrass/white clover, which is productive under a wide range of management when water is adequate (Kemp *et al*. 1999). However, both species have shallow roots causing reduced production and persistence in dry conditions (Fraser 1994). Lucerne is a widely used alternative for dryland farms giving high plant and animal productivity from October to April (Brown *et al*. 2005). However, lucerne should not be grazed from July until at least mid September (Moot *et al*. 2003). This restricts the use of lucerne during lambing and means the area of lucerne on a farm is limited to 30-40% (White 1982). Thus, there is a need for a dryland pasture mixture that is productive during late winter and early spring and available during lambing, before lucerne grazing commences.

Cocksfoot is the pasture grass commonly grown in New Zealand to produce and persist in dry environments (Fraser 1994). However, mixing cocksfoot with white clover is seldom successful because they compete strongly for water during the summer (Moloney 1993). The loss of clover then reduces the N fixation in the pasture and consequently the N content of cocksfoot. Sheep prefer to graze high N herbage (Edwards *et al*. 1993) so will selectively graze white clover, adding to the competitive advantage of cocksfoot. Over time these factors usually result in cocksfoot-dominant pastures that are nitrogen deficient, unproductive (Peri *et al*. 2002) and unpalatable (Edwards *et al*. 1993). To improve cocksfoot pasture productivity, a more competitive legume is required that can provide high quality feed and fix N to increase the quality of the companion cocksfoot.

Annual clovers may be more suitable companion species for cocksfoot than white clover. Annuals grow actively during late winter and spring then die in the summer and re-establish from seed in the autumn (Smetham 2003). They avoid direct competition with cocksfoot during summer and may provide high quality feed from July to October (Hyslop *et al*. 2003). Subterranean clover is the most commonly used annual clover in New Zealand. Balansa clover (*Trifolium michelianum*) is a recently imported annual species that may be a suitable companion for cocksfoot. Caucasian clover is a perennial that has also been shown to be more competitive than white clover in dryland ryegrass pastures (Black and Lucas 2000). The aim of this experiment was to compare pasture and stock production from cocksfoot pastures in four combinations with balansa (Cf/Bc), Caucasian (Cf/Cc), subterranean (Cf/Sc), or white clover (Cf/Wc). The crucial periods of interest were when feed supply is frequently restricted on dryland properties, namely by temperature in early spring and moisture in summer. A ryegrass/white clover (Rg/Wc) pasture was included as the control and lucerne grown as a specialist summer forage.

Materials and Methods
Site, establishment and design
This experiment was a randomised complete block within a 1.46 ha paddock (H17) at Lincoln University on a Templeton silt loam soil with 0.85–1.45 m of fine material overlying gravels. The paddock was fenced into six blocks, each containing six individually fenced plots (22 × 23 m) opening onto adjoining laneways. Each block represented one replicate of six individually grazed

Table 1 Cultivar and bare seed sowing rate of species established in the dryland grazing experiment.

Species sown	Common name	Cultivar	Sowing rate
Trifolium michelianum	Balansa clover	'Bolta'	6 kg/ha
Trifolium ambiguum	Caucasian clover	'Endura'	8 kg/ha+
Trifolium subteraneum	Subterranean clover	'Denmark'	10 kg/ha+
Trifolium repens	White clover	'Demand'	3 kg/ha
Dactylis glomerata	Cocksfoot	'Vision'	4 kg/ha
Lolium perenne	Ryegrass	'Aries ARI'	10 kg/ha
Medicago sativa	Lucerne	'Kaituna'	8 kg/ha+

+ = seed was inoculated prior to sowing

pasture treatments (Cf/Bc, Cf/Cc, Cf/Sc, Cf/Wc, Rg/Wc and lucerne). Blocks 1–4 were established in the summer of 2001/02 with appropriate seeding rates (Table 1) in 150 mm drill rows on 18 February 2002. Blocks 5 and 6 were established in the following summer (2002/03). Livestock production measurements commenced from 13 August 2004 and were continued throughout 2004/05 and until March in the 2005/06 year.

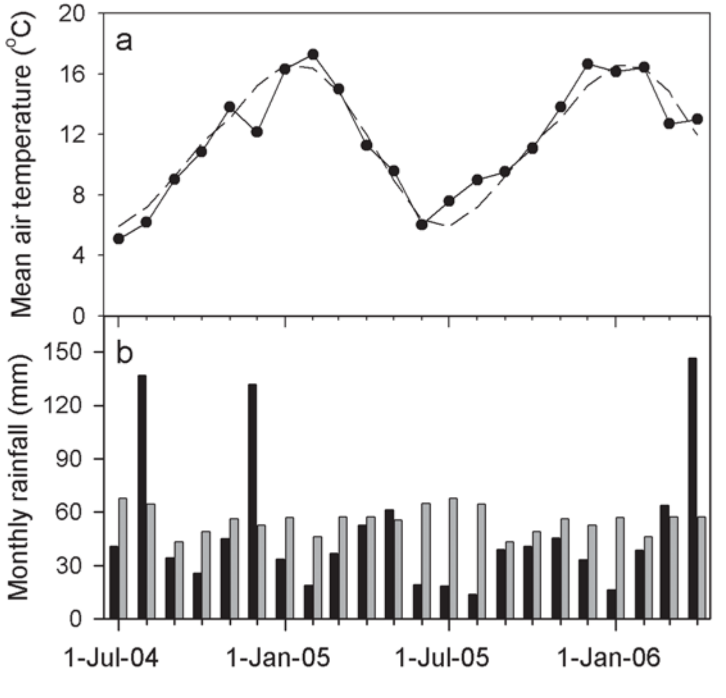
Weather

Data for temperature and rainfall are summarised in Figure 1. Of note the 2004/05 year was 1°C colder than average during July and August and 3°C colder than average in December with more than double the long-term average rainfall in August (136 mm) and December (131 mm). The spring of 2005/06 had temperatures 1.6°C warmer than average in July and August but there was a 100 mm snowfall on 19 September 2005. The winter of the 2005/06 had one third of the annual rainfall in June (19 mm), July (18 mm) and August (13 mm) and average to low rainfall for the growing season.

Management

Grazing management aimed to maximise stock production from each pasture treatment by using optimal grazing management for each pasture type. All treatments were rotationally grazed with either one mob of sheep grazing one plot and the other five plots spelled (long rotation), two mobs of sheep grazing separate plots and the other four plots spelled (medium rotation), or three mobs of sheep grazing and the other three plots spelled (short rotation). A "put and take" system was operated with a core group (5–10 animals) kept on each treatment throughout each grazing period to measure liveweight

Figure 1 a) Mean monthly temperature (—●—) and, b) rainfall (█) at Lincoln University from 1 July 2004 – 30 June 2006. Long term mean temperature (– –) and rainfall (▒) are also presented.



gain. "Spare" animals were put on or taken off treatments to match feed demand with supply throughout each period.

In 2004/05, hogget grazing began on 13 August for grass treatments and 22 September for lucerne. All treatments were grazed on a long rotation until 10 February 2005. The exception was the balansa clover pastures, which were spelled for a 6 week period at some stage between 3 November and 10 February to maximise flowering and establish seed reserves. This spell resulted in a large amount of low quality standing herbage and ewes were used to remove this. Weaned lambs were used to graze all treatments from 14 February – 11 May 2005. Annual clover seeds germinated following a wet week at the end of March 2005 (Fig. 1) and stock were removed from annual clover treatments from 2–28 April to allow seedlings to establish. Grazing finished on 11 May for all treatments

In 2005/06, grazing commenced on 11 August for pasture treatments and 30 August for lucerne with hoggets being grazed until 22 December 2005. Annual clover treatments (Cf/Sc and Cf/Bc) were grazed with short rotations at the start of 2005 but this suppressed clover growth in the Cf/Bc treatment so it was changed to a medium rotation from 23 September – 22 December 2005. The perennial clover treatments (Cf/Wc, Cf/Cc, Rg/Wc) were also grazed with medium rotations and lucerne was on a long rotation from August – December. Hoggets were removed from all treatments on 22 December 2005 because dry conditions had resulted in insufficient feed supply. Weaned lambs were put back on (excluding Rg/wc) on 18 January and grazed on a long rotation until 10 March when they were again removed to accumulate feed for autumn grazing and allow annual clovers to establish. Ewes were put into plots to clean up low quality pasture after lambs were removed throughout the last rotation (20 February – 10 March).

Measurements

Dry matter production and botanical composition of the five grass treatments were measured under cages in each plot. Caged areas were mown ($1m^2$) to 30 mm height prior to placement of cages and moved to a freshly mown area every 28 days. Dry matter cuts (0.2 m^2 quadrat) were taken when cages were moved and sub-samples were sorted into botanical fractions. Dry matter production of lucerne was measured by cutting five 0.2 m^2 quadrats from each plot on the day of grazing.

Liveweight gain was measured by weighing core animals prior to and following each grazing period (3–6 week intervals) throughout both years. Sheep were held overnight in a bare yard and weighed "empty" the following morning.

Analysis

Annual pasture production (t DM/ha/yr) was compared by summing total DM from each harvest within each year and analysed as a single factor ANOVA. Total DM growth rates and the growth rates of grass and clover components of the pastures were compared for each harvest using a single factor ANOVA. Lucerne data were not included in this analysis because it was harvested on different dates, but values are included in total dry matter figures for comparative purposes.

Liveweight gain (LWG, g/hd/d) was calculated for each measurement period (3–6 weeks) but could not be compared using ANOVA because they were confounded by the differing stocking rates and grazing durations imposed on treatments. To allow appropriate statistical comparisons of stock production, both years were separated into three seasons; spring (July–November), summer (December–February) and autumn (March–June). Liveweight production (LWP, kg/ha) was calculated from each plot by multiplying the grazing days during each season (core + spare animals) by the mean LWG of core animals from the corresponding treatment during the same season (assuming the same LWG in core and spare animals). This gave LWP data from each of the 36 plots, allowing comparison of spring, summer and autumn production between treatments using ANOVA.

Results

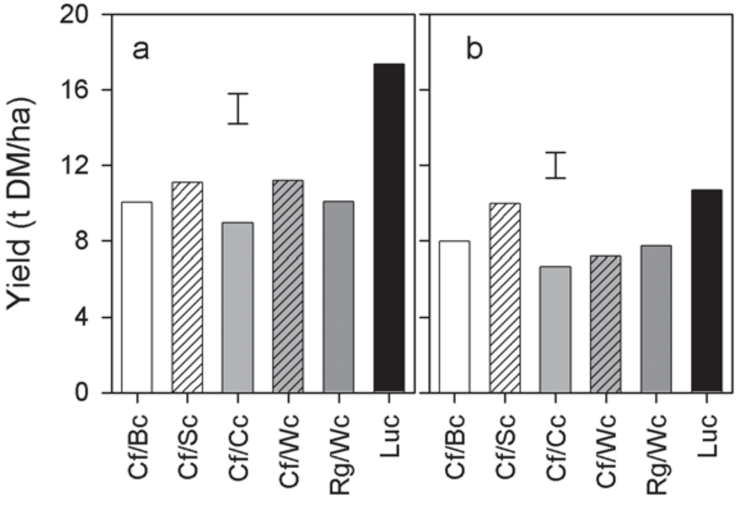
Pasture production

In the 2004/05 year the Cf/Sc and Cf/Wc treatments were the most ($P<0.001$) productive pasture mixtures followed by Cf/Bc, Rg/Wc and Cf/Cc (Fig. 2). The Cf/Sc was also the most ($P<0.001$) productive pasture in 2005/06 followed by Cf/Bc and Rg/Wc, Cf/Wc and Cf/Cc. Lucerne was the most ($P<0.001$) productive dryland pasture in 2004/05 but not in 2004/05.

All grass-clover pastures showed growth rates increasing from <10 kg/ha/d between March and July to a maximum of 60–105 kg/ha/d in October then decreasing during summer and autumn (Fig. 3a). The Cf/Sc pasture consistently had the highest ($P<0.05$) growth rates during the August to October period. There were few differences in total growth rates during the rest of the year except during the summer of 2006 (January and February) when all Cf based pastures had higher ($P<0.01$) growth rates than the Rg/Wc pasture. In 2004/05 lucerne growth rates were negligible during May–July and increased from September to November then decreased in December and January (Fig. 3a).

The growth rate of all clovers increased from June to a maximum in October in both years with the greatest ($P<0.05$) spring clover production in the Cf/Sc pastures (Fig. 3b). This was most apparent from June–October

Figure 2 Annual dry matter yields in, a) 2004/05 and b) 2005/06 of six dryland pastures grown at Lincoln University. Cf = cocksfoot, Bc, = balansa clover, Sc = subterranean clover, Cc = caucasian clover, Wc = white clover, Rg = ryegrass, Luc = lucerne. Bars represent one LSD.



2005 when the growth rate of sub clover in Cf/Sc pastures increased from 2.3 to 63 kg/ha/d. Balansa clover was the second most productive with growth rates increasing from 0.5–43 kg/ha/d over the same period. The perennial Cf/Wc and Cf/Cc had the least spring clover with production increasing from 0.5 kg/ha/d in June to 10–20 kg/ha/d in October. Clover production of Cf/Sc and Cf/Bc decreased to <5 kg/ha/d in January and February. By contrast the production of the clover component in the Cf/Wc, Cf/Cc and Rg/Wc pastures was 15–25 kg/ha/d in January and February in 2004/05. However, there was no difference in clover production of all treatments after December in 2005/06. There was no difference in spring growth rates of the grass components of pasture treatments in either year (Fig. 3c). However, the grass component of the Rg/Wc pasture had the lowest ($P<0.01$) growth from November–February in 2004/05 and from December–February in 2005/06.

Livestock production

In 2004/05, spring production averaged 300 kg LW/ha for all grass treatments except for the Cf/Cc treatment at 200 kg LW/ha (Fig. 4). Summer production during this year was greater ($P<0.001$) in the Cf/Wc and Rg/Wc treatments than the Cf/Sc, Cf/Bc and Cf/Cc treatments. Autumn production in the 2004/05 year was low, with Rg/Wc giving the greatest ($P<0.001$) production. Lucerne provided the greatest ($P<0.001$) stock production in the spring of 2004/05 with 400 kg LW/ha despite grazing commencing 40 days later than the grass treatments. Lucerne also gave the greatest ($P<0.001$) production during the summer of the 2004/05 year.

In 2005/06 the Cf/Sc treatment gave the greatest ($P<0.001$) spring production compared with the Cf/Bc, Cf/Wc and Rg/Wc treatments. Lucerne and Cf/Cc produced the least. During the summer lucerne again gave the greatest ($P<0.001$) animal production. The Rg/Wc and Cf/Cc treatments produced the least ($P<0.001$) during the 2005/06 summer.

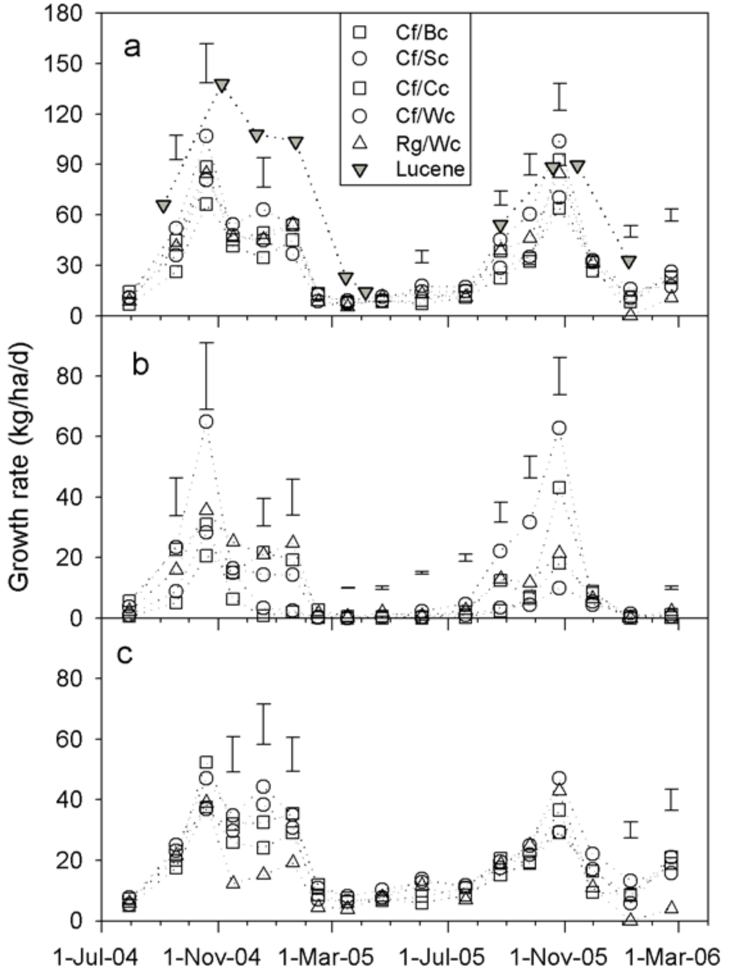
Discussion

No single pasture proved consistently superior throughout this experiment. However, individual pasture species demonstrated strengths at different times of the year and under different climatic conditions. The combination of species can be used to complement each other to improve annual stock production and cope with the climatic variability which is typical of dryland farming systems.

Seasonal complementarity

Spring is the most important period to maximise dryland production because moist soils and low evaporative demand minimise water stress and ensures reliable pasture growth. High stock growth rates are desired during this time to maximise lamb liveweight gain before the summer dry. During spring (July to November) sub clover-based pastures supported higher or equal stock production than other cocksfoot/clover mixtures and Rg/Wc pastures (Fig. 4). This was because sub clover pastures produced higher yields (Fig. 3a) and greater legume content (Fig. 3b) and therefore higher quality feed than other pasture treatments. The value of this spring feed quality can be demonstrated by comparing Cf/Sc pastures with Cf/Cc which had low legume content (Fig. 3b) and supported 100-250 kg LW/ha less stock production during spring

Figure 3 Daily growth rates of, a) total dry matter, b) legume and c) grass from six dryland pastures grown at Lincoln University. Cf = cocksfoot, Bc, = balansa clover, Sc = subterranean clover, Cc = caucasian clover, Wc = white clover, Rg = ryegrass, Luc = lucerne. Bars represent one LSD above periods when growth rates were different.



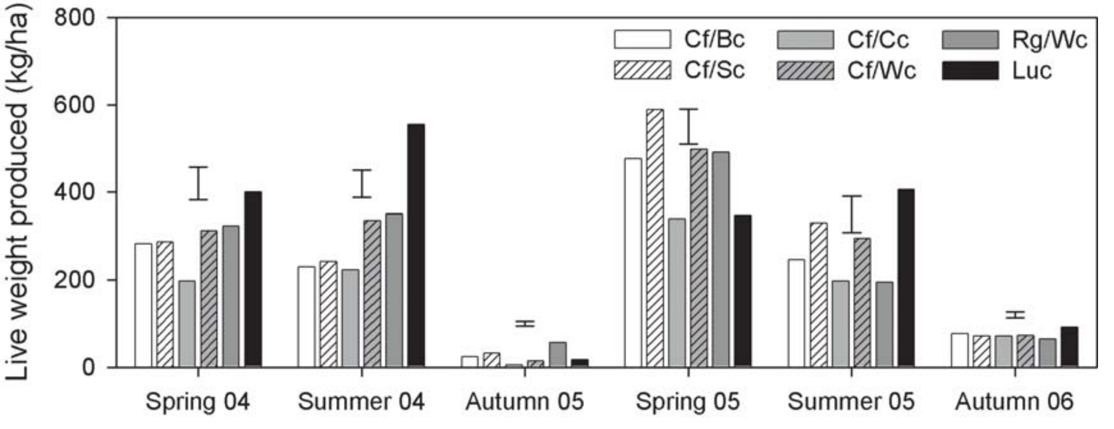
(Fig. 4). Low legume contents are typical of cocksfoot pastures on farms. Thus, it seems appropriate to use sub clover as the legume in pasture mixtures to improve dryland stock production during spring. Sub clover gave minimal summer legume production, even during wet summer conditions (Fig. 3b) and a complementary species is also needed to provide high quality feed during late spring and summer.

Lucerne gave the highest dry matter yields (Fig. 3a) and stock production (Fig. 4) during the summer (December to February) and was complementary to sub clover pastures when their production was low (Fig. 3). Lucerne also supported high stock production during spring in 2004 but spring production in 2005 was reduced by the dry winter (Fig. 1). This meant the sub soil was not rewetted and the advantage of lucerne having deep taproots was not expressed. This experiment highlights the complementarily of lucerne with sub-clover pastures which provide winter/early spring grazing. Lucerne and sub clover should not be grown in a binary mixture in the same paddock because they require different management to maximise production.

Cocksfoot pastures gave higher summer growth (Fig. 3c) and more stock production (Fig. 4) than the ryegrass pasture particularly during the dry 2005/06 summer. Cocksfoot-based pastures also maintained equal or higher production than ryegrass-based pastures during the spring when grown in a mixture with sub clover. This shows cocksfoot is complementary to sub clover and can be included in pasture mixtures to give its benefits of higher summer production without detriment to stock production throughout the spring.

Results suggest white clover would also be useful in dryland pastures as it responded to high summer rainfall

Figure 4 Liveweight produced per hectare from six dryland pastures at Lincoln University. Cf = cocksfoot, Bc, = balansa clover, Sc = subterranean clover, Cc = caucasian clover, Wc = white clover, Rg = ryegrass, Luc = lucerne. Bars represent one LSD above periods when production was different.



in 2004/05 (Fig. 1), producing high quality feed (Fig. 3) and supporting more stock production (Fig. 4) than annual clover based pasture. At this time sub clover had gone to seed so did not respond to high summer rainfall.

Management considerations

Gaining high production from a dryland farm system that uses sub clover/cocksfoot and lucerne pastures to complement each other requires appropriate management for each species. Consistent and persistent sub clover production requires managing for seed production in late spring and seedling survival in autumn (Costello & Costello 2003; Smetham 2003). Sowing up to 10 kg/ha seed of a productive cultivar (Widdup & Pennell 2000) in the autumn is the recommended way to establish a strong sub clover pasture. De-stocking this pasture for a 6–8 week period in the spring (around October) in the first year allows substantial seed production. In following years, lighter grazing or de-stocking for a period in October will encourage further seed production.

Ensuring high stock production from cocksfoot-based pastures requires high legume contents to maximise N returns to cocksfoot, to maintain its palatability (Edwards *et al*. 1993). Hard grazing was used in this experiment to maintain cocksfoot leaf in a vegetative (palatable) stage and to keep the pasture open so legumes remained productive (Lambert *et al*. 2000; Smetham 1990). A hard grazing was also imposed in late summer to remove low quality dead material and encourage tillering and short, leafy growth and open the pasture up for sub clover establishment. Spring grazings were frequent to keep cocksfoot short and leafy and a hard grazing was also imposed to keep pastures vegetative in October when reproductive stem extension was beginning.

Lucerne requires de-stocking from late June until about 0.2 m of growth has accumulated in spring which allows rotational grazing to commence (Moot *et al*., 2003).

Conclusions

- Sub clover gave the highest spring time legume growth and stock production.
- Cocksfoot increased production in dry summer periods without reducing spring production.
- Lucerne supported the greatest stock production during late spring and summer.

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