Annual dry matter, metabolisable energy and nitrogen yields of six dryland pastures six and seven years after establishment

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Abstract

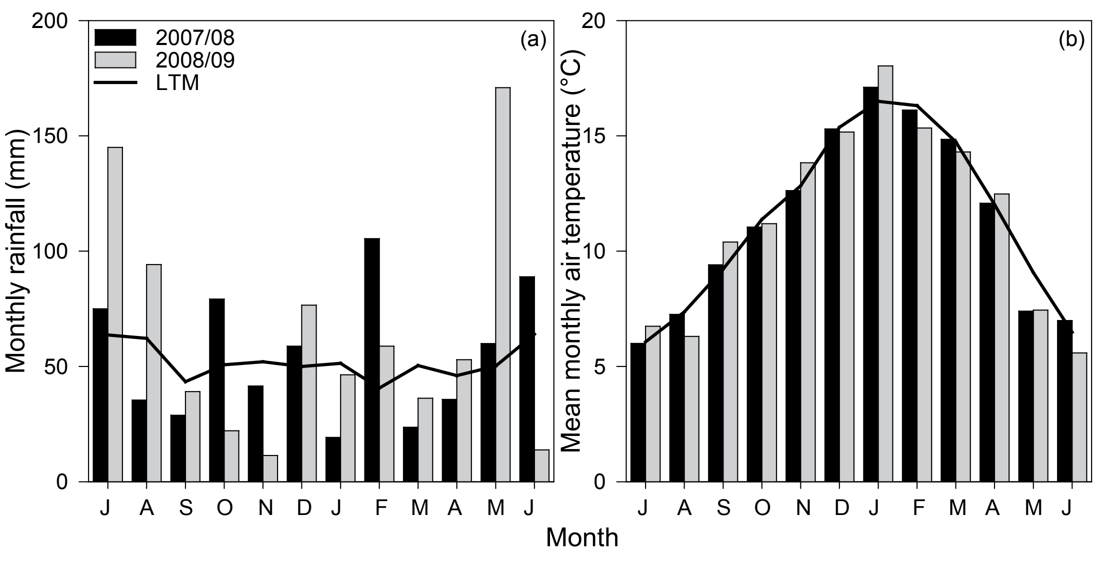
Dry matter (DM) yields, botanical composition, liveweight production and pasture quality of six grazed dryland pastures established in 2002 at Lincoln University, Canterbury, are reported for Years 6 (2007/08) and 7 (2008/09). Lucerne (*Medicago sativa*) yielded 14.0 t DM/ha/yr and sheep liveweight (LW) production totalled 903 (2007/08) and 1 141 kg/ha/yr (2008/09). Metabolisable energy (ME) on offer (~134 GJ/ha/yr) and N yield (>500 kg/ha/yr) from the lucerne exceeded those of grass-based pastures. Yields (9.8-11.2 t DM/ha/yr) and liveweight production (814-912 kg/ha/yr) from cocksfoot (*Dactylis glomerata*) pastures established with subterranean (*Trifolium subterraneum*) clover were greater than all other grass-based pastures. Annual ME was 79-96 GJ/ha and N yield was 269-316 kg/ha from the cocksfoot, subterranean clover and volunteer white clover (*T. repens*) components. For Year 7, the contribution of unsown weeds and grasses in cocksfoot-based pastures was ~28% of total annual yield compared with 55% in ryegrass (*Lolium perenne*)/ white clover pastures. Consequently, the ME and N yields from sown pasture components in ryegrass/white clover pastures were lower than those from cocksfoot-based pastures. These results indicate dryland farms with lucerne and/or cocksfoot/sub clover pastures can produce higher DM yields from more persistent pasture species. Persistence led to more ME and N on offer to grazing livestock, which resulted in higher liveweight production than from the ryegrass pastures.

Keywords: balansa clover, Caucasian clover, growth rates, pasture quality, *T. ambiguum*, *T. michelianum*

Introduction

To maintain the profitability of dryland farming systems exposed to periodic moisture stress it is important to use available resources efficiently within a narrow, but generally reliable, production window in spring. At this time temperatures are increasing and stored soil moisture is usually non-limiting to growth. Maximising dry matter (DM) and liveweight production allows priority stock to be sold in prime condition from the property by early summer. This can reduce the risk associated with maintaining production in summer/autumn when rainfall is more variable and unpredictable. To ensure long-term sustainability several criteria must be met 1)

Figure 1 Monthly (a) rainfall (mm) and (b) mean air temperature (°C) at Lincoln, Canterbury. Total annual rainfall was 651 mm in 2007/08, 767 mm in 2008/09. Long-term means (LTM) are for the period 1975-2001. Data are from the Broadfields meteorological site located 2 km north of the experiment site.



the quantity and quality of spring feed should meet stock demand during lambing/lactation 2) pastures must be able to efficiently use the "free" water resource stored in the soil and 3) pasture species must be able to survive, recover and persist through periods of water stress to reduce costs associated with frequent pasture renewal.

In Years 1-5 of the 'MaxClover' dryland grazing experiment total annual yields from lucerne monocultures (10.0-18.5 t DM/ha/yr) and sheep liveweight production (833-1 100 kg LW/ha/yr) were superior to grass-based pastures (Mills *et al.* 2008a; 2008b) in most years. However, winter production of lucerne was low and it must be rotationally grazed so high quality grass-based pastures are needed to complement its use particularly during lambing. Cocksfoot/subterranean clover pastures have previously been the most productive of the grass-based pastures. To quantify productivity differences, and allow comparison with other experiments, the DM yield, botanical composition, annual metabolisable energy (ME), nitrogen (N) yield and liveweight production from Years 6 (2007/08) and 7 (2008/09) of the 'MaxClover' grazing experiment are presented.

Materials and Methods

Full experimental details have been reported previously (Brown *et al*. 2006; Mills *et al*. 2008a). Briefly, four replicates of six dryland pastures were established on a variable depth Templeton silt loam soil at Lincoln University in autumn 2002. Pastures were 'Vision' cocksfoot (CF) established with 'Denmark' subterranean (CF/Sub), 'Bolta' balansa (*T. michelianum* (CF/Bal), 'Demand' white (CF/Wc) or 'Endura' caucasian (*T. ambiguum*; CF/Cc) clovers, an 'Aries HD' AR1 perennial ryegrass/white clover (RG/Wc) control and a 'Kaituna' lucerne (Luc) monoculture. Plots (0.05 ha) were individually fenced and gateways opened onto central laneways to facilitate movement of livestock. In 2003 an additional two replicates were established on an adjacent site. Thus, from the beginning of the third growth season, measurements were from six pasture treatments replicated six times.

Table 1 Harvest dates and regrowth duration (d) in 2007/08 and 2008/09 for the 'MaxClover' grazing experiment at Lincoln University, Canterbury, New Zealand. Harvest dates reported for lucerne monocultures, which were harvested before grazing, are the average harvest date of the six plots.

2007/08 (Year 6)				2008/09 (Year 7)			
Grass pastures		Lucerne		Grass pastures		Lucerne	
Date	(d)	Date	(d)	Date	(d)	Date	(d)
28/08	62	5/10	107	3/09	68	23/09	84
27/09	30	20/11	46	8/10	35	31/10	38
29/10	32	25/12	35	10/11	33	4/12	34
27/11	29	28/01	34	5/01	56	12/01	39
7/01	41	21/03	53	2/03	56	16/03	63
6/03	59	18/05	58	6/04	35	27/05	72
15/04	40	30/06	43	30/06	85	30/06	34
26/06	72						
Annual	365		376		368		364

Environmental conditions

Long-term mean (LTM) annual (Jul-Jun) rainfall is 624 mm/yr (1975-2001) and ranges from 41-64 mm/month throughout the year. Annual rainfall was 651 mm in 2007/08 and 767 mm in 2008/09 (Fig. 1a). In both 2007/08 and 2008/09 mean monthly air temperatures were above the average LTM in January.

Measurements

For the grass-based pastures there were eight rotations in 2007/08 and seven in 2008/09 (Table 1). At the start of each regrowth period an area was pre-trimmed to 25 mm and an exclosure cage placed to exclude grazing sheep. At the end of each 29-85 d regrowth period one 0.2 m^2 quadrat was cut to a residual height of ~25 mm. All grass pastures were harvested on the same day. Lucerne monocultures had seven rotations annually (33-107 days) and yield was measured from five 0.2 m^2 quadrats per plot. Each lucerne plot was harvested before sheep were moved to a new plot and the mean start date of harvests in the six lucerne plots is reported for simplicity.

Grazing commenced in the first lucerne paddock 24 days later than grass-based pastures in 2007/08 and 17 days later in 2008/09. Subsamples were taken to determine botanical composition (Cayley & Bird 1996). These were sorted into sown grass, sown legume, volunteer white clover (VWC), unsown species and dead fractions. Samples were dried at 65 °C until a constant weight. Sown grass and legume subsamples were retained and ground. Pasture quality on sown pasture components was determined by near infrared spectroscopy (NIRS) at the Analytical Laboratory Unit (Lincoln University). Annual metabolisable energy and N yields of sown pasture components were then calculated. For annual N yields the mean N% of white clover from the CF/Wc and RG/Wc pastures was applied to volunteer white clover recorded in Sub, Bal and Cc based pastures.

Annual liveweight production for Year 6 (2007/08) and Year 7 (2008/09) was determined as reported previously (Brown *et al*. 2006). To account for variations between animal demand and pasture supply, pastures were grazed with Coopworth hoggets which were replaced with weaned ewe lambs in late spring/ summer, using a 'put and take' system. Between 5 and

Table 2 Total grazing days/ha (Total) and "production" (P) grazing days/ha. The difference is grazing days by maintenance stock, where liveweight gain was assumed to be zero.

	2007/08		2008/09	
Pasture	Total	(P)	Total	(P)
CF/Sub	1812	1647	1807	1728
CF/Bal	1720	1557	1574	1495
CF/Wc	1815	1602	1557	1466
CF/Cc	1881	1674	1666	1573
RG/Wc	1590	1385	1418	1385
Luc	1448	1448	1614	1555

10 "core" animals were selected and assigned to one of the six pasture treatment groups. These animals were weighed "empty" before and after "production" grazing periods (Table 2). During "production" grazing periods treatment groups rotationally grazed the six replicates of their assigned pasture treatment. "Production" periods ended when there was insufficient growth to maintain grazing by "core" groups. Lucerne was rotationally grazed throughout active growth whereas grass-based pastures underwent simulated set stocking in early spring. For pasture established with annual clovers stock were removed in late spring to allow for reseeding. Pastures were de-stocked over winter (Jun-Aug) except for ewes that were used to "clean-up" all pastures.

Analysis

Data were analysed by one way ANOVA in Genstat 11 and, when significant, means were separated by Fisher's protected least significant difference (LSD) at the α=0.05 level. Data for DM production by lucerne stands were included in the analysis of annual production (35 d.f.) but, due to differences in the time of harvests, were excluded from analysis of individual harvest dates (29 d.f).

Results

DM production and growth rates

Lucerne yield was 14.0 t DM/ha in both years and exceeded ($P<0.001$) all grass-based pastures (Fig. 2). Yield of the CF/Sub pastures was 11.2 t DM/ha in 2007/08 and 9.8 t DM/ha in 2008/09. This was at least 24% more ($P<0.001$) DM than all other grass-based pastures in Year 6 and at least 40% more in Year 7 (2008/09). Over the two growth seasons mean daily growth rates ranged from 7 ± 2.1 kg DM/ha/d for grass-based pastures in winter (26/6/2008) to 92 kg DM/ha/d (25/12/2007) from lucerne (Fig. 3). Excluding lucerne, the mean daily growth rate of the CF/Sub pastures was greater than ($P<0.01$) other grass-based pastures in 7 of the 15 regrowth periods. In six rotations growth rates of the grass-based pastures were unaffected by treatment.

Botanical composition

By definition lucerne monocultures had the highest legume content (~13.1 t DM/ha/yr; Fig. 4). Of the grass-based pastures, sown species (grass + clover) in the CF/Sub pastures yielded 8.2 t/ha in Year 6 and 6.8 t DM/ha/yr in Year 7. These were greater ($P<0.001$) than sown

Figure 2 Total accumulated annual dry matter (DM) yield of six dryland pastures in 2007/08 (Year 6) and 2008/09 (Year 7) at Lincoln University, Canterbury. Error bars are SEM for total annual DM yield.

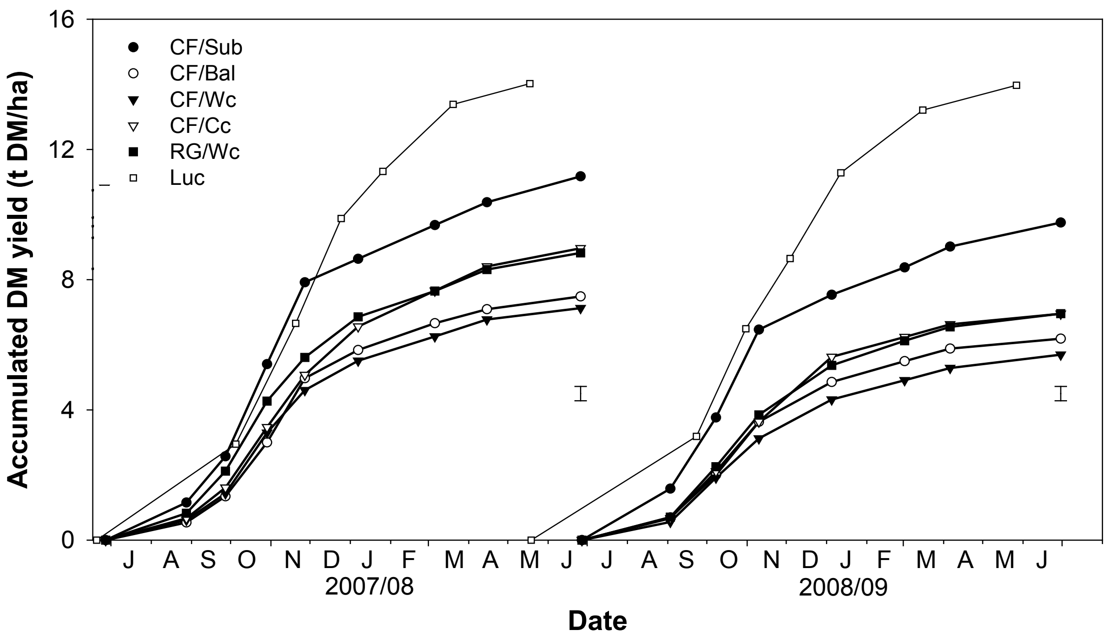


Figure 3 Mean daily growth rate (kg DM/ha/d) of dryland CF/Sub, CF/Bal, CF/Wc, CF/Cc, RG/Wc and lucerne pastures for 2007/08 (Year 6) and 2008/09 (Year 7) at Lincoln University, Canterbury. Lucerne was excluded from the analysis but is shown for reference. Error bars are SEM for rotations where treatment differences occurred.

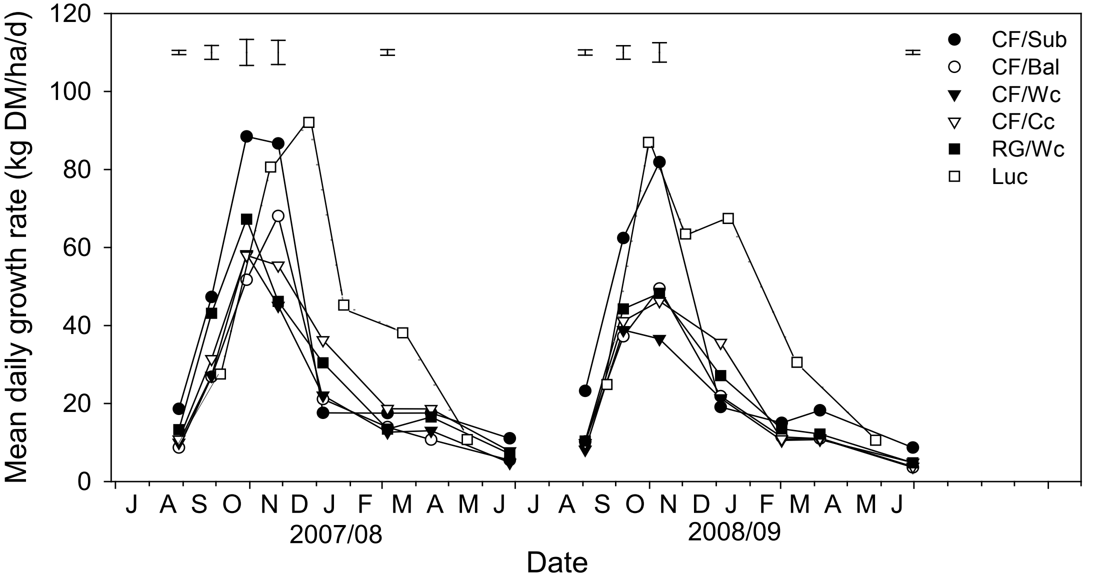
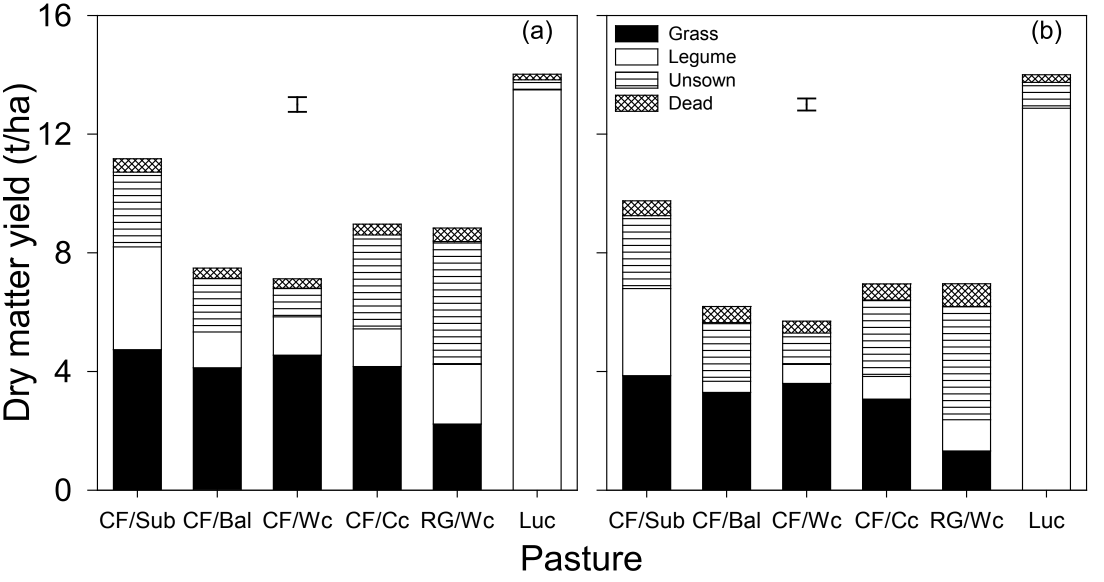


Figure 4 Annual contributions of sown grass, sown legume, unsown pasture components (volunteer white clover + dicot weed + unsown weed grasses) and dead material to total annual yield in 2007/08 (a) and 2008/09 (b). Error bars are SEM for total sown species (sown grass + sown legume).



species yields in all other pastures which were lowest at 2.4 t DM/ha/yr in RG/Wc pastures in Year 7. Sub clover yielded 3.5 and 2.9 t DM/ha/yr which was superior ($P<0.001$) to all other sown clovers in both years. In 2007/08, volunteer white clover contributed 1.3 t DM/ha/yr to the CF/Cc pastures compared ($P<0.01$) with 0.5 ± 0.17 t DM/ha in CF/Sub and CF/Bal pastures. In 2008/09, volunteer white clover was similar in the three treatments (0.5 ± 0.16 t/ha/yr).

Annual liveweight production

In Years 6 and 7 liveweight production from sheep

Figure 5 Nitrogen yield (kg N/ha/yr) of the sown grass, sown legume and volunteer white clover (VWC) components of six dryland pastures at Lincoln University, Canterbury in 2007/08 (Year 6) and 2008/09 (Year 7). Error bars are SEM.

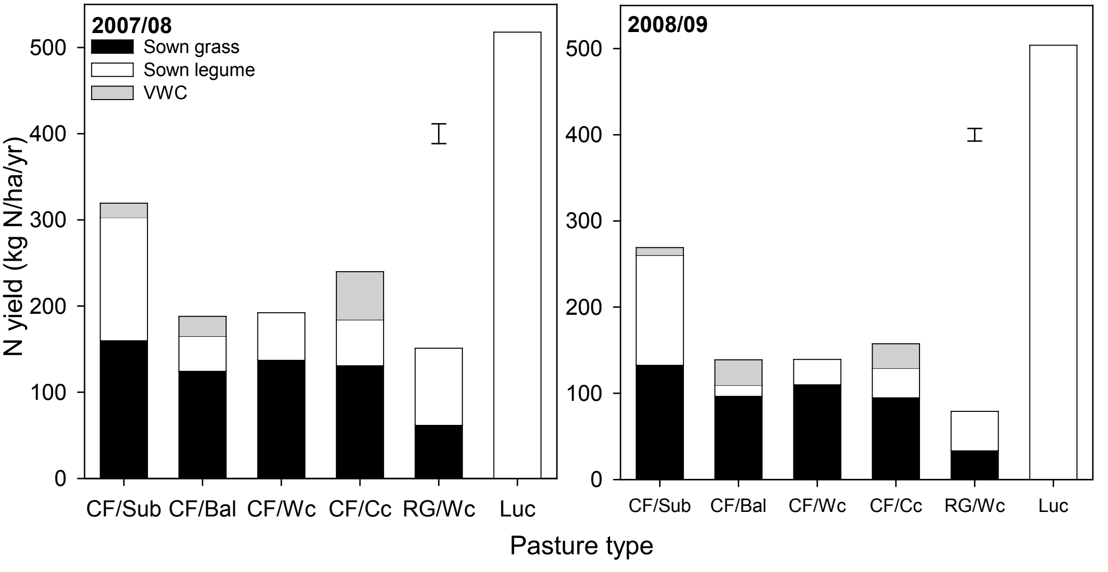


Table 3 Annual sheep liveweight production (kg/ha) from six dryland pastures in Year 6 (2007/08) and Year 7 (2008/09) at Lincoln University, Canterbury.

Pasture	2007/08	2008/09
CF/Sub	814 b	912 b
CF/Bal	543 de	702 c
CF/Wc	503 e	675 c
CF/Cc	655 c	719 c
RG/Wc	613 cd	711 c
Luc	903 a	1067 a
SEM	33.2	52.0
P value	***	***

Significance level ***=0.001

Table 4 Annual average ME (MJ/kg DM) of the sown pasture components of six dryland pastures in Year 6 (2007/08) and Year 7 (2008/09) at Lincoln University, Canterbury.

	2007/08		2008/09	
Pasture	Grass	Legume	Grass	Legume
CF/Sub	11.3 b	11.2 b	11.1 b	11.4 c
CF/Bal	11.3 b	11.4 b	11.1 b	12.0 a
CF/Wc	11.3 b	11.8 a	11.2 b	12.0 a
CF/Cc	11.3 b	11.3 b	11.2 b	11.8 b
RG/Wc	11.6 a	12.0 a	11.8 a	11.8 b
Luc	-	10.9 c	-	11.0 d
SEM	0.04	0.10	0.04	0.05
P value	***	***	***	***

Note:***=P<0.001

rotationally grazing lucerne was superior (P<0.001) to all other pastures (Table 3). In both years the CF/Sub pastures produced at least 24% more (P<0.001) LW than all other grass-based pastures.

Metabolisable energy content and ME yield

The average ME content of ryegrass was ~11.7 MJ/kg DM compared with ~11.2 MJ/kg DM for cocksfoot (P<0.001) (Table 4). Across individual harvests sown grass ME ranged from 9.8-12.4 MJ/kg DM (data not shown). Lucerne ME averaged ~11.0 MJ/kg DM which was lower than the clovers. The ME yield (GJ/ha/yr) of ryegrass was less than half (P<0.01) that on offer from cocksfoot in both years (Table 5). As expected, the ME yield of lucerne was greatest (~133.8 GJ/ha/yr), and that from Sub clover (~36.8 GJ ME/ha/yr) was almost double that of white clover in RG/Wc pastures (~18.0 GJ/ha/yr).

Nitrogen concentration and N yield

The N concentration of grasses ranged from 1.9-4.6% at individual harvests (data not shown). The annual average N% of ryegrass (2.7%) was less (P<0.001) than cocksfoot (3.0-3.5% N) in both years (Table 6). The N concentration of the cocksfoot with Sub (3.5%) was greater than from all other cocksfoot-based pastures in both years. Lucerne yielded 510 kg N/ha/yr (Fig. 5) which was superior (P<0.001) to all grass-based pastures. The sown species in the RG/Wc pastures yielded only 151 kg N/ha in Year 6 and 79 kg N/ha in Year 7.

Table 5 Accumulated annual metabolisable energy (ME) yield (GJ/ha) of sown grass, sown legume and volunteer white clover (VWC) in six dryland pastures at Lincoln University in 2007/08 (Year 6) and 2008/09 (Year 7).

	2007/08				2008/09			
Pasture	Grass	Legume	VWC	Total	Grass	Legume	VWC	Total
CF/Sub	51.3 a	39.8 b	4.7 b	95.9 b	43.0 a	33.8 b	2.5	79.2 b
CF/Bal	45.5 a	14.0 c	6.4 b	65.8 cd	36.5 a	4.0 c	8.1	48.6 c
CF/Wc	50.5 a	15.4 c	-	65.9 cd	38.8 a	7.8 c	-	46.4 c
CF/Cc	46.8 a	14.6 c	15.2 a	76.6 bc	33.9 a	7.7 c	7.7	49.3 c
RG/Wc	26.0 b	23.9 c	-	49.9 d	15.0 b	12.1 c	-	27.0 d
Luc	-	139.1 a	-	139.1 a	-	128.4 a	-	128.4 a
SEM	4.22	4.50	2.01	6.79	4.35	3.78	2.62	5.63
Significance	**	***	**	***	**	***	NS	***

Note: ** = P<0.01; *** = P<0.001; NS = non significant. Means followed by the same letter are similar at the P<0.05 level of significance. Volunteer white clover ME yields were determined using the average of white clover ME determined from the CF/Wc and RG/Wc pastures as VWC samples were not retained for analysis.

Table 6 Annual average nitrogen content (%) of the sown grass and sown legume components from six dryland pastures in Year 6 (2007/08) and Year 7 (2008/09) at Lincoln University, Canterbury.

	2007/08		2008/09	
Pasture	Grass	Legume	Grass	Legume
CF/Sub	3.4 a	4.2 b	3.5 a	4.3 b
CF/Bal	3.1 b	3.8 c	3.0 c	4.1 c
CF/Wc	3.1 b	4.2 b	3.1 bc	4.4 a
CF/Cc	3.2 b	4.3 b	3.2 b	4.6 a
RG/Wc	2.7 c	4.5 a	2.6 d	4.3 ab
Luc	-	4.0 c	-	3.8 d
SEM	0.05	0.08	0.05	0.09
P value	***	***	***	***

Note: *** = P<0.001

Discussion

High animal production from productive and persistent high quality pastures is the basis for dryland pastoral farming in New Zealand. Lucerne continues to show superior DM yields (Fig. 2), quality (Table 5 & Fig. 5) and sheep liveweight production (Table 3) in this experiment. This indicates that where lucerne can be grown it should be. Lucerne has been rotationally grazed to maintain long-term persistence, so it is recommended that lucerne stands are established on the deepest, well drained soils on flat to rolling land on a property that can be sub-divided. Exactly which environmental and soil conditions that will support lucerne production needs to be re-defined on-farm throughout the East Coast of New Zealand. Recent success in Marlborough (Avery *et al*. 2008) and Central Otago (Kearney *et al*. 2010, this volume) offer guidance for establishment and grazing management (Moot *et al*. 2003).

In contrast, the CF/Sub pastures have consistently been the most productive (LW and DM) of the grass-based pastures (Mills *et al.* 2008a; 2008b). In Years 6 and 7, they yielded 2-3 times more metabolisable energy than the sown species in the ryegrass/white clover pastures (Table 5) despite a lower absolute ME (Table 4). Pasture management that maintained the annual clover in these cocksfoot pastures (Fig. 4) led to superior N% and total N yield (Fig. 5) and has maintained high sheep liveweight gains (Table 3) over 7 years (Mills *et al.* 2008b). The success of this combination with subterranean clover, particularly in early spring (Brown *et al.* 2006) supports its use commercially (Costello & Costello 2003) and recommendations to overdrill Sub clover into existing grass-dominant pastures (Ates *et al.* 2010, this volume) to extend their productive life. These results suggest that in dryland environments, where perennial ryegrass and white clover have failed to persist, lucerne should be considered as the first pasture option followed by mixtures of cocksfoot and subterranean clover as a viable alternative if managed appropriately.

Overall, these results add to the growing body of literature (Ates *et al.* 2010, this volume; Brown *et al.* 2006; Brown *et al.* 2005; Kearney *et al.* 2010, this volume; Knowles *et al*. 2003; Mills *et al.* 2008a; 2008b; Tonmukaykul *et al.* 2009) that suggests ryegrass and white clover are inappropriate for dryland pasture production in low rainfall (<750 mm/yr) environments. The persistence of perennial ryegrass in this dryland experiment has been poor and it contributed only 19% of total DM in Year 7 (Fig. 4). The rate of decline over the 7 years has been disappointing given that the total annual rainfall (460-785 mm/yr) has been average, or above average, in five of the seven growth seasons. After a period of relative yield stability between Years 2-5 (Mills *et al.* 2008a), ryegrass yield has approximately halved. The invasion of unsown annual and perennial weed species compromised the productivity and quality of these pastures. The AR1 endophyte should have protected the perennial ryegrass from Argentine stem weevil (*Listronotus bonariensis*) but periodic drought and an inability to access soil moisture stored at >0.8 m soil depth (Tonmukaykul *et al*. 2009), plus the presence of other pasture pests (e.g. root aphids; *Aploneura lentisci*) may have contributed to its decline. Regardless of the reasons, perennial ryegrass has failed to persist and its continued use as the dominant grass sown in this and similar environments is questionable. Furthermore, the low N% (Table 6) of the ryegrass suggests available N from soil mineralisation or fixation from associated white clover was inadequate to maintain maximum photosynthesis rates (Peri *et al*. 2002) and water use efficiency (Tonmukaykul *et al*. 2009). This low leaf N will also limit leaf expansion, reducing light interception and consequently potential yield. The addition of N fertilisers may overcome some of this problem (Fasi *et al*. 2008) but is not usually viable across dryland farms.

Conclusions

Lucerne and subterranean clover with cocksfoot have shown superior animal and dry matter production over 7 years and should be promoted to improve production within dryland farming systems.

ACKNOWLEDGEMENTS

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