Final Report to SFF
Grant No. 09/123

Dryland pasture persistence.

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Project Objectives

This trial site was initially was established to provide information on pasture/forage options suitable for intensification of hill and high country farm land (Years 1-3, SFF 06/067). This project covers Years 4-6 (SFF 09/123) which continued to monitor the experiments to quantify the longer term persistence of the species. This is important in hill and high country environments because pasture productivity is constrained by temperature giving a shorter growth season which can be further shortened by the development of water stress. Consequently, these farms tend to focus on store lamb and beef production by necessity and income is generally lower per hectare than that achieved in intensive lowland systems. Thus, more frequent pasture renewal is not feasible as it is not cost effective.

Approach to initial establishment

The Lees Valley Farmer's Group (LVFG) was formed in January 2005 to discuss agronomic issues related to the intensification of Lees Valley and similar farm types throughout the South Island. At this point scientists from Lincoln University were invited to discuss potential ideas for development. Together the LVFG sourced funding from the MAF Sustainable Farming Fund (SFF) to establish a trial site in the Lees Valley. Farmers within the group were surveyed about the issues relevant to them and ranked topics for demonstration on site and at their own properties. Issues most commonly identified were:

- Pasture species combinations
- Nitrogen on pasture
- Fertilizers and brassicas
- Caucasian clover establishment
- Annual clover establishment and management
- Sowing rates of pastures
- Lucerne grazing management
- Oversowing on steeper hill country

A weather station was installed 1 km from the trial site to measure soil and air temperature, soil moisture, rainfall, wind and solar radiation. Air temperature and soil temperature were also recorded. These data are used to relate pasture growth to the environment and compare Lees Valley weather conditions to other parts of Canterbury and the NIWA climate network.

Demonstration site background:

- Mt Pember Station has a total of 26 000 ha, of which 6 000 ha is flat land.
- The trial site is on elevated (400 m a.s.l.) flat land.
- Prior to the experiments it was dominated by fescue and blue tussock grassland, browntop and matagouri scrub.
- Main growth constraints are 120 day winters and prolonged summer soil moisture deficits of 60-100 days.

Weather summary for Lees Valley (LV), Canterbury

Table 1 Data summarized below are compared with data from Darfield and from ECAN rain records at Island Hill, due north from trial site, on the Ashley River.

	Air Temp. (°C)			Soil Temp. (°C)		Monthly Rainfall (mm)			
Month	**LV 1**	**LV 2**	**Darfield**	**LV 1**	**LV 2**	**LV 1***	**LV 2**	**LV (ECAN)**	**Darfield**
Nov-06	11.5		13.6	13.0		89.0		139.0	100.2
Dec-06	11.1		13.0	14.2		105.8		135.5	95.2
Jan-07	14.8		16.1	16.0		16.6		29.0	27.2
Feb-07	14.4		16.5	15.8		30.2		49.0	18.8
Mar-07	15.1		17.3	14.9		13.6		18.0	38.8
Apr-07	9.1	9.0	11.9	11.2	12.0	37.2		64.5	51.2
May-07	9.7	9.2	12.2	8.7	8.9	33.8		57.5	38.4
Jun-07	3.3	2.6	6.0	4.2	4.0	48.8		73.5	50.6
Jul-07	3.4	2.7	6.3	3.4	3.3	26.0		42.5	41.2
Aug-07	5.2	4.7	7.5	5.5	5.5	26.0		41.5	28.6
Sep-07	7.9	7.6	9.8	8.0	8.2	28.0		59.5	33.0
Oct-07	9.7	9.4	11.4	9.5	10.1	109.0		187.5	81.2
Nov-07	11.8	11.9	13.4	13.7	14.5	23.2		35.5	25.8
Dec-07	14.7	15.2	16.0	16.6	17.5	28.0		55.0	69.0
Jan-08	17.0	16.9	18.3	19.7	20.3	18.8		37.0	14.2
Feb-08	15.3	15.2	16.9	17.9	18.4	98.0		167.0	125.2
Mar-08	13.5	13.3	16.1	14.7	15.6	21.4		25.5	16.8
Apr-08	9.8	9.5	12.6	11.4	12.0	25.6		46.5	46.2
May-08	3.1	2.8	7.9	6.2	6.3	17.2		26.5	29.4
Jun-08	4.0	3.4	7.8	4.4	4.4	83.0		133.5	87.0
Jul-08	3.8	3.2	6.6	3.6	3.6	128.5		206.0	148.4
Aug-08	4.3	3.8	6.8	5.0	5.0	80.8		130.0	126.4
Sep-08	9.4	8.6	11.1	8.6	8.6	46.3		75.0	54.8
Oct-08	9.8	9.5	12.1	10.0	11.3	41.2		54.0	24.4
Nov-08	13.7	13.4	14.8	14.5	15.6	16.0		22.0	12.6
Dec-08	14.5	14.3	15.5	16.8	17.5	68.0		117.0	75.2
Jan-09	17.2	17.3	19.3	19.3	19.6	30.0		53.0	21.2
Feb-09	14.0	13.9	15.5	17.5	17.5	74.6		105.0	91.8
Mar-09	12.8	12.3	14.9	14.6	15.0	12.5		19.0	14.4
Apr-09	10.0	9.6	12.6	11.6	11.5	71.6		108.5	62.0
May-09	4.5	4.0	7.1	7.0	6.1	96.0		145.5	121.0
Jun-09	1.7	0.9	5.6	3.8	3.1	29.7		45.0	6.0

	Air Temp. (°C)			Soil Temp. (°C)		Monthly Rainfall (mm)			
Month	**LV 1**	**LV 2**	**Darfield**	**LV 1**	**LV 2**	**LV 1***	**LV 2**	**LV (ECAN)**	**Darfield**
Jul-09	3.0	2.5	5.6	3.0	2.9	70.0		106.0	52.0
Aug-09	7.9	7.4	9.7	5.4	5.9	46.2		70.0	65.2
Sep-09	7.9	7.5	10.5	6.9	7.8	43.6		66.0	31.4
Oct-09	7.1	**7.0**	9.5	7.9	9.4	79.2		120.0	88.6
Nov-09	11.6	11.6	13.1	10.2	13.6	16.2		24.5	14.0
Dec-09	13.7	13.6	15.1	12.8	16.2	32.3		49.0	38.0
Jan-10	14.5	14.4	16.1	14.7	17.3	45.2		68.5	84.0
Feb-10	15.8	15.6	17.5	15.4	19.4	16.2		24.5	28.6
Mar-10	13.8	13.3	15.8	13.8	15.7	36.6		55.5	23.2
Apr-10	11.6	11.1	14.3	11.3	12.0	17.5		26.5	19.0
May-10	7.4	6.7	9.8	9.0	8.6	133.7		202.5	189.8
Jun-10	3.6	2.9	6.6	5.0	4.2	71.0		107.5	84.2
Jul-10	2.4	1.7	6.1	3.3	3.1	62.6		88.5	63.4
Aug-10	5.9	5.5	8.0	5.3	5.9	109.6		138.5	97.6
Sep-10	8.6	8.3	10.7	7.2	8.0	56.4		97.0	74.6
Oct-10	9.6	9.5	11.4	9.1	11.1	25.2		45.5	43.8
Nov-10	13.8	13.9	15.1	12.4	15.0	52.6		65.5	57.0
Dec-10	16.0	15.9	17.6	15.5	18.0	49.4	62.0	74.0	54.3
Jan-11	15.1	15.5	16.8	16.2	18.9	51.0	62.6	82.0	72.1
Feb-11	15.4	15.8	17.3	15.6	18.6	47.6	69.8	65.5	57.1
Mar-11	13.2	13.1	15.7	13.9	15.2	37.2	50.6	57.0	58.4
Apr-11	8.9	8.9	12.2	10.5	10.5	64.4	64.4	70.5	73.2
May-11	9.1	8.8	11.6	9.1	8.5	87.4	99.0	102.0	61.9
Jun-11	5.7	4.9	8.1	6.7	5.5	36.0	52.0	45.5	42.1
Jul-11	3.8	3.0	6.0	3.8	2.9	56.4	80.8	98.0	27.4
Aug-11	3.9	3.2	7.3	3.2	1.0	30.4	46.6	44.5	44.2
Sep-11	7.3	6.8	8.7	6.3	6.4	28.8	37.4	42.0	29.4
Oct-11	9.8	9.5	10.6	9.1	10.3	96.0	139.6	116.5	109.2
Nov-11	11.6	11.6	13.0	11.4	12.6	67.8	89.2	99.5	80.4
Dec-11	14.2	14.2	15.1	13.6	17.7	58.0	79.6	94.3	103.8
Jan-12	14.8	14.9	15.6	14.4	18.4	30.2	38.4	64.5	64.4
Feb-12	13.8	13.7	15.2	14.4	16.4	43.8	58.0	69.5	76.4
Mar-12	11.9	11.7	13.1	12.7	13.8	56.0	85.0	87.5	58.4
Apr-12	9.0	8.9	12.3	10.3	11.1	30.2	41.6	42.5	40.4
May-12	6.2	5.9	8.7	7.4	6.7	23.2	37.0	41.8	18.6
Jun-12	3.1	2.3	5.3	4.5	3.2	66.2	92.2	102.6	74.0
Annual temperature means and rainfall totals for July 2007-June 2012 (5 years)									
Temp.	9.7	9.4	11.9	10.2	11.0				
Rain						768.3		1173.2	889.0

* LV 1 rain data, though highly correlated with the ECAN data (R^2 = 0.95), averaged only about 2/3 of the ECAN rain. A second rain gauge installed at the trial site recorded about 90% of the ECAN rain. Darfield data are courtesy of NIWA and ECAN rainfall data are from Environment Canterbury. Rainfall updates from the ECAN network are available by phone or their web page, http://ecan.govt.nz/pages/home.aspx

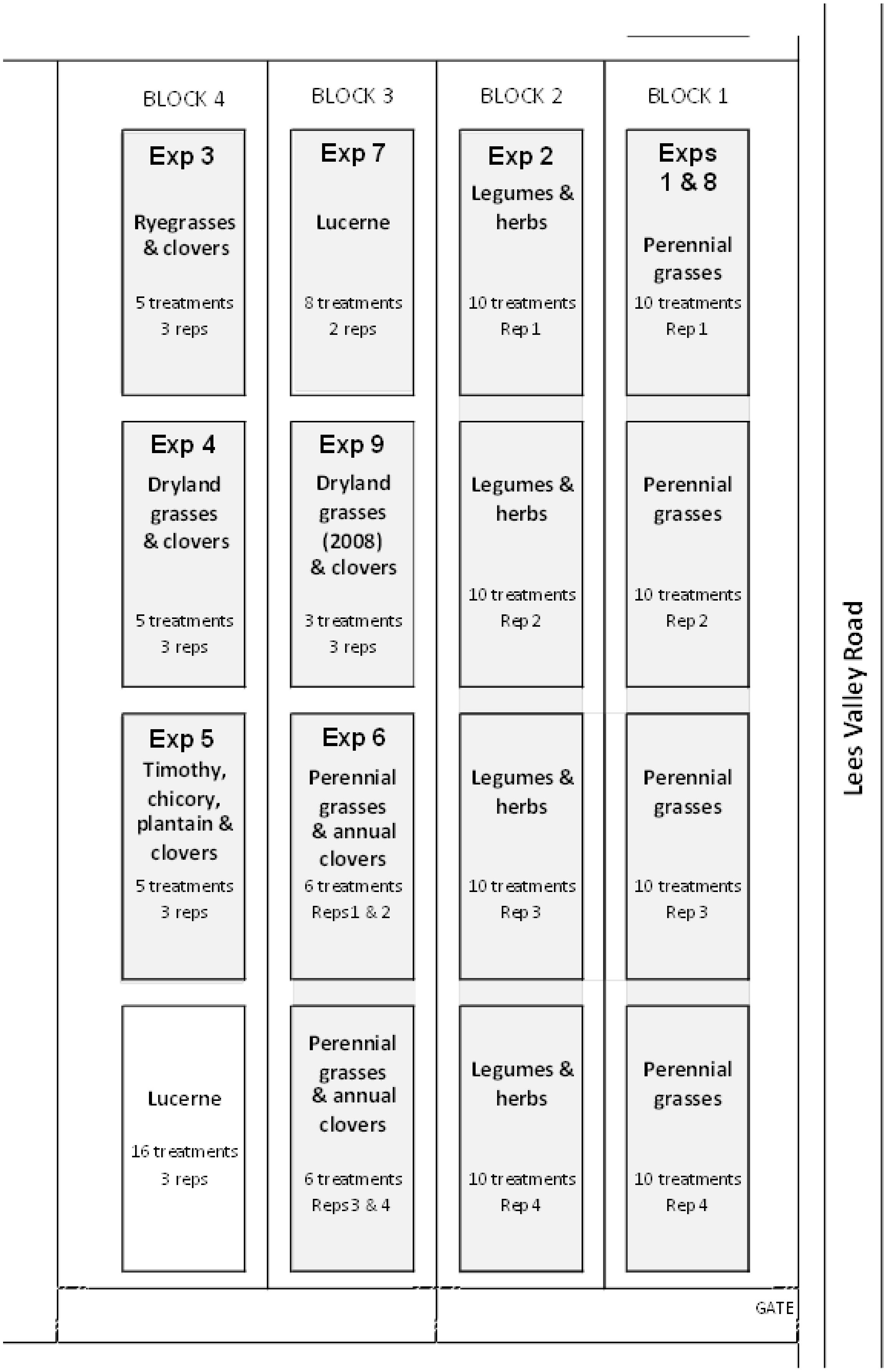

Figure 1 Site plan at the Lees Valley, Canterbury indicating location of the nine experiments reported in this final report.

Experiment 1: Perennial grasses

Table 2 Soil test results (0-7.5 cm) from the perennial grass block.

	pH	Olsen P	Ca	Mg	K	Na	Sulphate-S
Date	(H_2O)	(mg/L)		(MAF Quicktest units)			(mg/kg)
8/08/2007	6.1	16	9	8	9	2	9
19/05/2008	6.2	15	8	10	13	2	6
2/09/2009	6.2	15	7	7	7	2	5
11/08/2010	5.9	21	9	11	12	<2	-
31/08/2011	6.0	19	6	10	9	3	4

1.1 – Accumulated annual DM yields

1.1.1 Year 4 (2009/10)

- In Year 4 annual yields ranged from 1.9 t DM/ha from timothy pastures (Figure 2), which was less than all other pastures ($P<0.01$), to a maximum of 4.0 t DM/ha from ‘Aries’ HD established at 15 kg/ha.
- Yields from ‘Aries’ were similar regardless of 5, 10 or 15 kg/ha sowing rate and did not differ from the yield produced by the low endophyte ‘Cannon’.
- The 2.9±0.31 t DM/ha produced by the tall fescue and ‘Gala’ brome pastures was also less ($P<0.01$) than the 4.0 t/ha/yr produced by ‘Aries’ HD 15 kg/ha.

1.1.2 Year 5 (2010/11)

- In Year 5 the lowest ($P<0.01$) yield was again 1.9 t DM/ha from timothy pastures and the highest yield was 3.9 t DM/ha produced by the cocksfoot and ‘Revolution’ hybrid ryegrass pastures.
- The yields of ‘Aries’ pastures were similar to those of the low endophyte ‘Cannon’. However, the yield from the ‘Aries’ 5 kg/ha pastures (3.0 t/ha) was lower than the yield from the ‘Revolution’ hybrid ryegrass.

1.1.3 Year 6 (2011/12)

- Total annual yield was accumulated across three rotations in Year 6. To avoid confounding from spring N applications the yield was accumulated only using the control areas which did not receive N fertiliser during spring of Year 6.

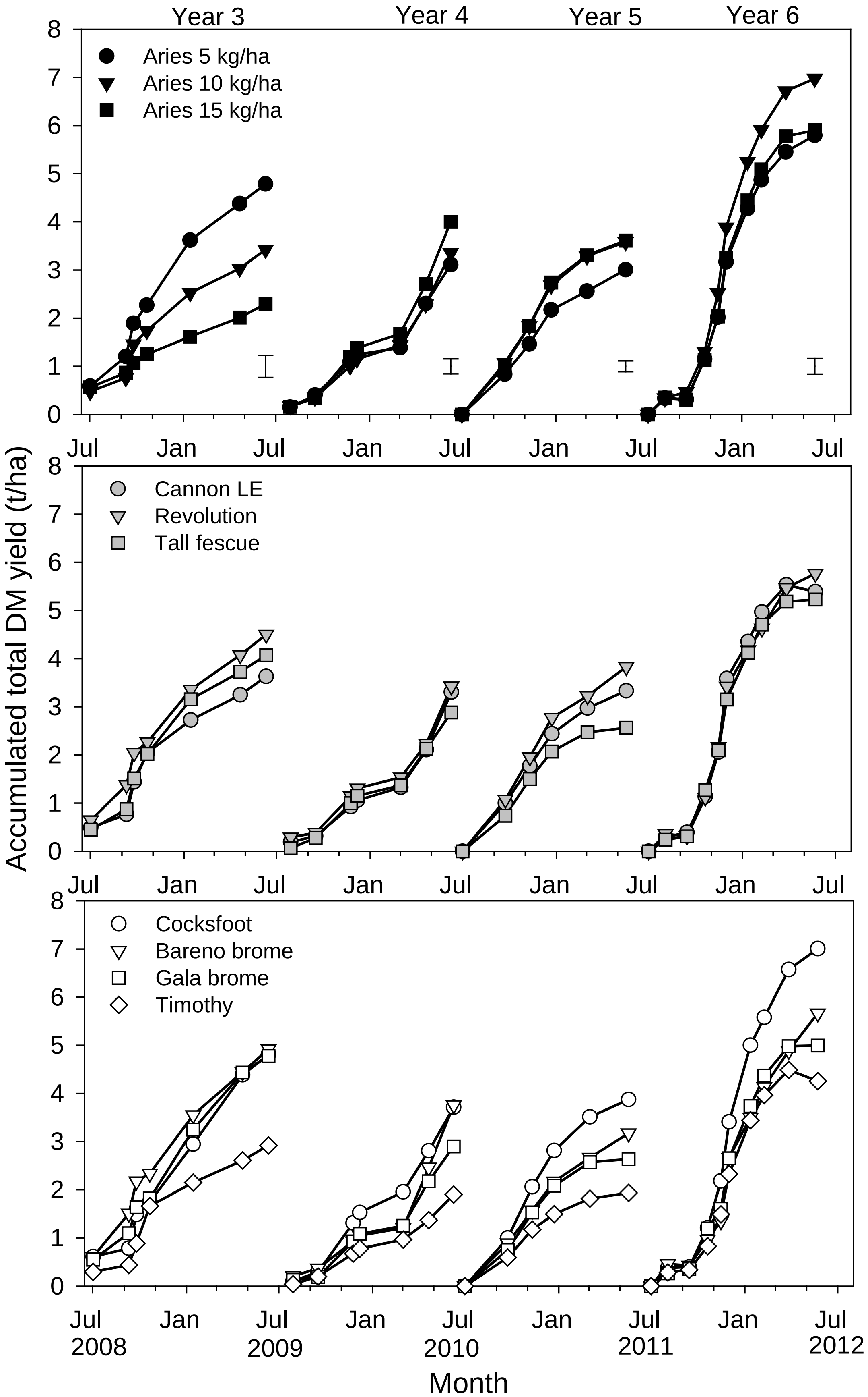

Figure 2 Accumulated total annual dry matter yields (t DM/ha) of 10 grass pastures in Year 3 (2008/09), Year 4 (2009/10), Year 5 (2010/11) and Year 6 (2011/12). Pastures were established as monocultures in 2006. Error bar is SEM for total annual yield.

- Total annual yield was highest ($P<0.001$) from cocksfoot and 'Aries' (10 kg/ha) pastures at 7.0±0.33 t/ha (Figure 2). Other pastures produced 5.5±0.32 t/ha but yield from 'Gala' brome was also similar to that from the timothy which produced the lowest yield (4.3 t/ha). Compared with previous years the spring production accounted for a lower proportion of total annual yields even though no N fertiliser had been applied. This was due to 228 mm of summer rainfall, that was most effectively used by the cocksfoot.
- Mean daily growth rate in the first rotation (14/7/2011-15/11/2011) ranged from 9-13 kg DM/ha/day. In the second rotation (22/11/2011-12/1/2012) it was 46-76 kg DM/ha/day and between 29/1/2012 and the final measurement on 23/5/2012 it ranged between 37 and 61 kg DM/ha/day.

1.1.4 Conclusions

1. Perennial ryegrass yields and persistence were unaffected by intitial sowing rates of 5, 10 or 15 kg/ha.
2. The survival of 'Cannon' LE indicates insect pest pressure (Argentine stem weevil) was minimal on-site.
3. Cocksfoot was able to maximise production from any summer rainfall.
4. Annual yields were dependant on rainfall from Nov-Mar.
5. Tall fescue and timothy were not competitive at establishment and this affected their pasture persistence.

1.2 Grass responses to spring N application (Experiment 8)

1.2.1 Spring DM yield and nitrogen response (Year 4)

- Total DM (Figure 3) yield in spring (10 Sep-24 Nov) of Year 4 was affected by pasture species and N application but there was no interaction. The Control (0 N) pastures produced 0.8 t DM/ha which was less ($P<0.001$) than half the 2.2 t DM/ha produced by pastures which received ~86 kg N/ha in early spring.
- For the main effect of pasture species the difference ($P<0.05$) in yields between the pasture species ranged from a minimum of 1.1 t/ha (tall fescue) to a maximum of 1.9 t/ha from 'Revolution' over 75 days of growth.
- The DM response was 10.4±2.63 kg DM/kg N applied (Table 3) and was similar for all 10 grass species.

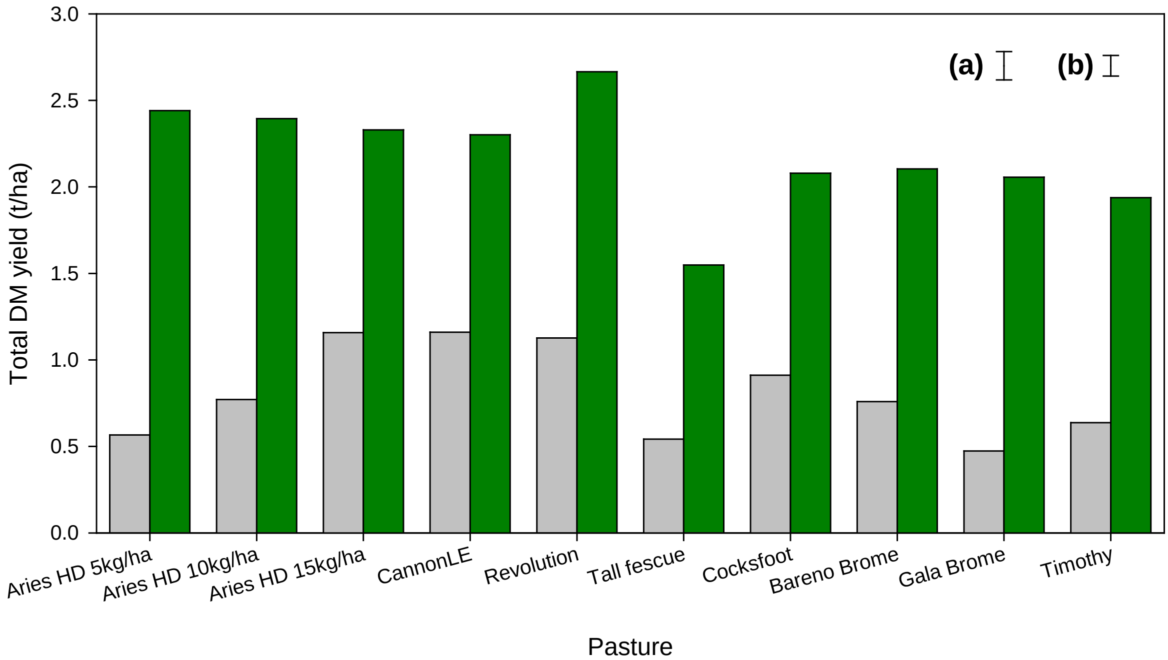

Figure 3 Total DM yield (kg/ha) of 10 perennial grass pastures established at Lees Valley, Canterbury in Year 4 (2009/10). Spring nitrogen was applied at 86 kg N/ha on 6/10/2009. The end of rotation yield was taken on 24/11/2009 and pastures were subsequently grazed two weeks later on 7/12/2009. Error bars are SEM for the main effects of (a) pasture species and (b) N application.

1.2.2 Effect of spring N application on yield (Year 6)

Spring N was applied as CAN (27% N) at 0, 50 or 100 kg N/ha on 14/9/2011. At the end of the rotation (16/11/2011) yields differed between pasture treatment ($P<0.001$) and by spring N application rate ($P<0.001$) but no interaction was observed. Figure 4 shows total spring DM yields ranged ($P<0.001$) from 1.9 t DM/ha ('Bareno' brome) to 2.9 t DM/ha from 'Aries' sown at 10 kg/ha. Yields from pastures initially established with 'Bareno' brome, 'Gala' brome and timothy were similar. Production by cocksfoot and 'Revolution' based pastures was similar to the highest yield measured in the 'Aries' 10 kg/ha pasture treatment.

Nitrogen fertiliser also affected spring DM yields which ranged from 2.0 t/ha from the control (0 kg N/ha) compared ($P<0.001$) with 2.5 t/ha when 50 kg N/ha was applied and the highest yield was 2.8 t DM/ha when 100 kg N/ha was applied (Figure 4).

The DM response to applied N was similar for both N fertiliser rates (50 or 100 kg N/ha) applied to the pastures resulting in the production of 9.9±1.04 kg DM/kg N applied (Table 4). This was comparable to the DM response of 10.4 kg DM/kg N measured in spring 2009 (Year 4).

Table 3 Dry matter response (kg DM/kg N applied) of 10 grass pastures established in 2006 at Lees Valley, Canterbury in spring of Year 4 (2009). Nitrogen was applied at 86 kg N/ha as CAN (27% N) on 6/10/2009 and yield was determined from whole plot pasture probe readings on 24/11/2009. Pastures were grazed two weeks later (7/12/2009).

Pasture		**Spring N response**
'Aries' HD ryegrass 5 kg/ha		13.5
'Aries' HD ryegrass 10 kg/ha		11.8
'Aries' HD ryegrass 15 kg/ha		11.1
'Cannon' LE ryegrass		13.5
'Revolution' hybrid ryegrass		9.6
'Advance' tall fescue		7.8
'Vision' cocksfoot		10.0
'Bareno' brome		9.3
'Gala' brome		7.5
'Viking' timothy		10.0
	Mean	10.4
	SEM	2.63
	P	ns

Note: level of significance is ns = non significant.

Table 4 Dry matter responses (kg DM/kg N applied) of 10 grass monocultures to application of 50 or 100 kg N/ha (CAN, 46% N) applied in spring of Year 6 (2011/12) at Lees Valley, Canterbury. Pastures were initially established in 2006.

Pasture	50 kg N/ha	100 kg N/ha
Aries HD 5 kg/ha	10.6	8.6
Aries HD 10 kg/ha	7.9	7.9
Aries HD 15 kg/ha	14.7	9.1
Cannon LE	11.9	8.3
Revolution	14.3	7.5
Tall fescue	-0.8	6.8
Cocksfoot	13.3	10.7
Bareno brome	8.9	11.5
Gala brome	14.4	5.7
Timothy	16.8	9.6
Mean	9.9	
SEM	1.0	
P	ns	

Note: ns = non significant.

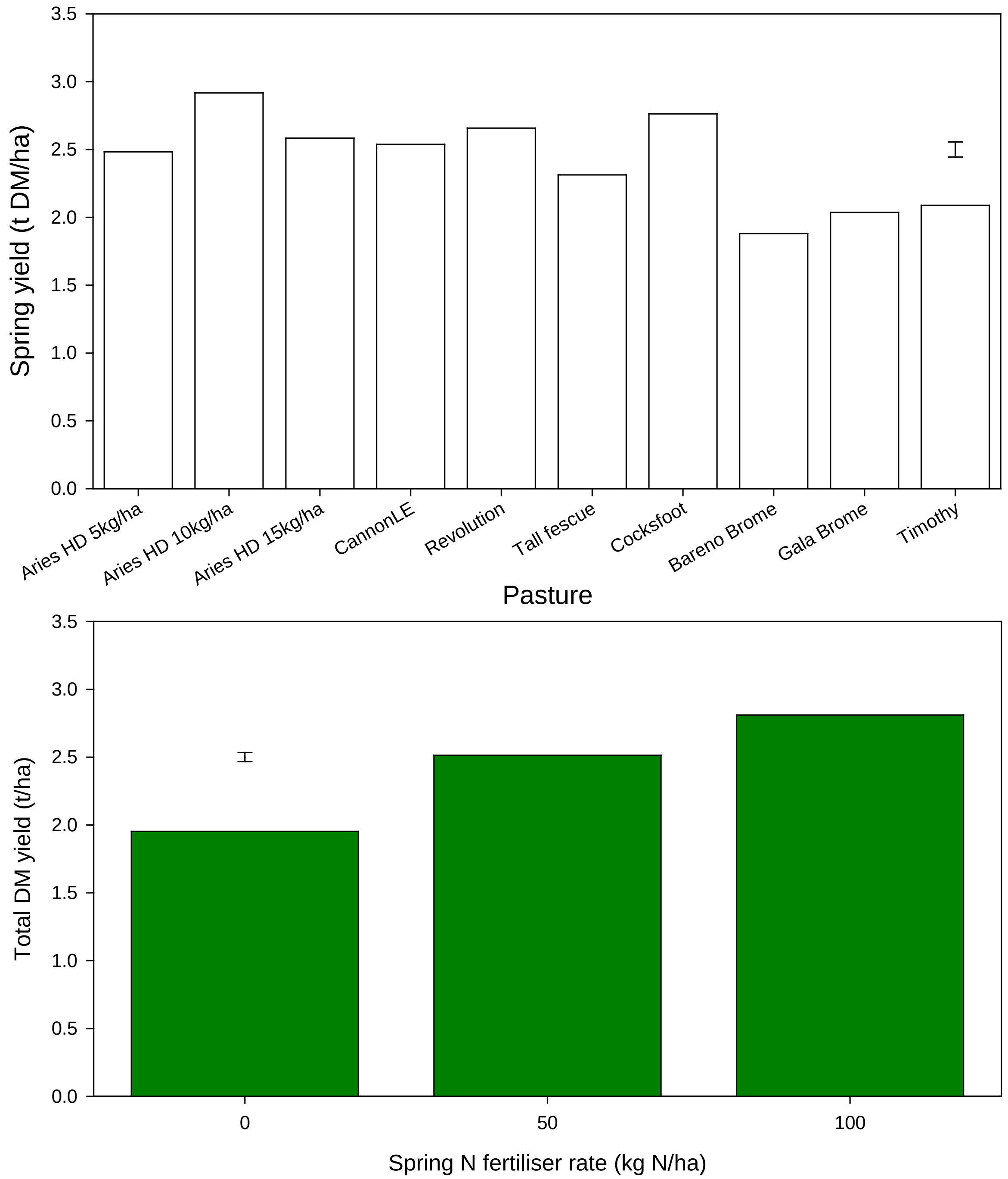

Figure 4 Total spring DM yield (t/ha) in Nov 2011 (Year 6) showing the effects of pasture type (top) and the effect of spring N (kg N/ha, bottom) on grass monocultures established at Lees Valley, Canterbury in 2006. Error bars are SEM for the effect of pasture type (top) and N fertilizer rate (bottom).

1.3 Botanical composition of improved grass monocultures

1.3.1 Year 4 (2009/10)

In Year 4 (2009/10) botanical composition was determined from destructive harvests made on 24/11/2009 and 9/6/2010. The first spring (24/11) evaluation occurred at the end of the first regrowth period on both the the Control pastures and which received 86 kg N/ha as CAN (27% N).

Section 1.2.1 reported the effects on pasture type and spring N on total DM yield in Year 4. Figure 5 shows that yields of the individual pasture components also differed between the species and N treatments in spring 2009.

1.3.1.1 Spring - Sown grass component

Nitrogen application increased (P<0.001) the mean yield of the sown grass component from 576 kg/ha (0 kg N/ha) to 1514 kg DM/ha (~86 kg N/ha).

As expected, sown grass yields also differed between pasture types. 'Gala' brome yielded minimal sown grass which was less (P<0.001) than from any other pasture. The highest yield from a sown grass component from 'Revolution' which yielded nearly double the grass yield from cocksfoot, timothy or tall fescue.

1.3.1.2 Spring - Unsown weed grasses

The only interaction (P<0.01) between pasture type and N fertiliser was for the unsown grass component. This component included the contribution from browntop. These unsown grasses which had invaded the improved grass monocultures yielded 1683 kg/ha in the 'Gala' brome pastures treated with 86 kg N/ha and this was more than the contribution of unsown species in any of the other grass pastures. The contribution of unsown species in the pastures were similar, except for the 487 kg/ha of unsown species in cocksfoot pastures which received 86 kg N/ha .

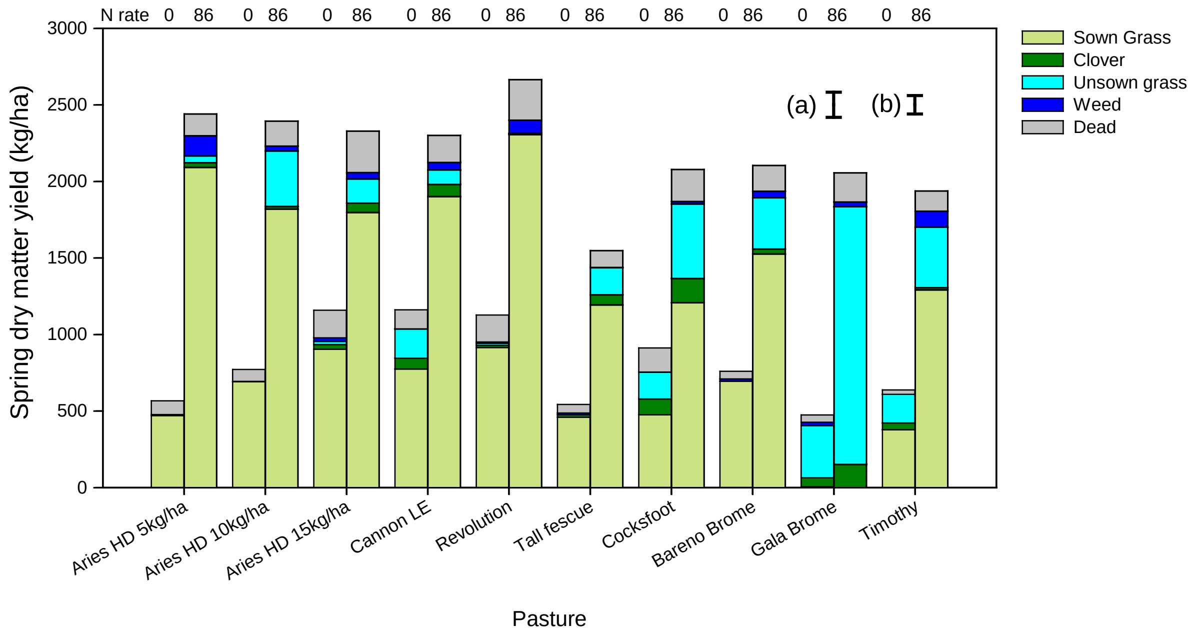

Figure 5 Spring dry matter yield of pasture components (24/11/2009, Year 4) of 10 grass species established in 2006 at Lees Valley, Canterbury. Error bars are SEM for the main effects of (a) species and (b) spring nitrogen (kg N/ha) application rate on total DM yield. Resident browntop was included in the unsown grass fraction.

1.3.1.3 Winter - Sown grass component

Figure 6 shows DM yields of pasture components in winter of Year 4 (9/6/2010). Total DM yields differed (P<0.01). The contribution from the 'Bareno' brome component was 396 kg/ha which was more (P<0.01) than the yield of the sown grass component in all other pastures except 'Revolution' (255 kg/ha).

1.3.1.4 Winter - Other pasture components

Yields from the volunteer clover, unsown grasses (which included browntop) and dicot weeds were similar in all 10 pastures. The dead material differed (P<0.05) between pastures with over half the total DM yield in the 'Bareno' brome pastures, or 924 kg DM/ha, contributed from dead material which was comparable to the amounts in 'Aries' established at 5 kg/ha and 'Revolution' pastures. The high dead content in all plots was a consequence of the common grazing management used across pasture species, which was controlled by the availability of stock. This prevented ideal timing and intensity of grazing for each individual species.

Post-graze residual were not quantified so we could not determine whether the cause of more dead material in 'Bareno', 'Aries' 5 kg/ha or 'Revolution' pastures was a result of senescence of material produced during regrowth or an inability to hard graze at the previous grazing, leaving a higher than desired residual biomass post-graze.

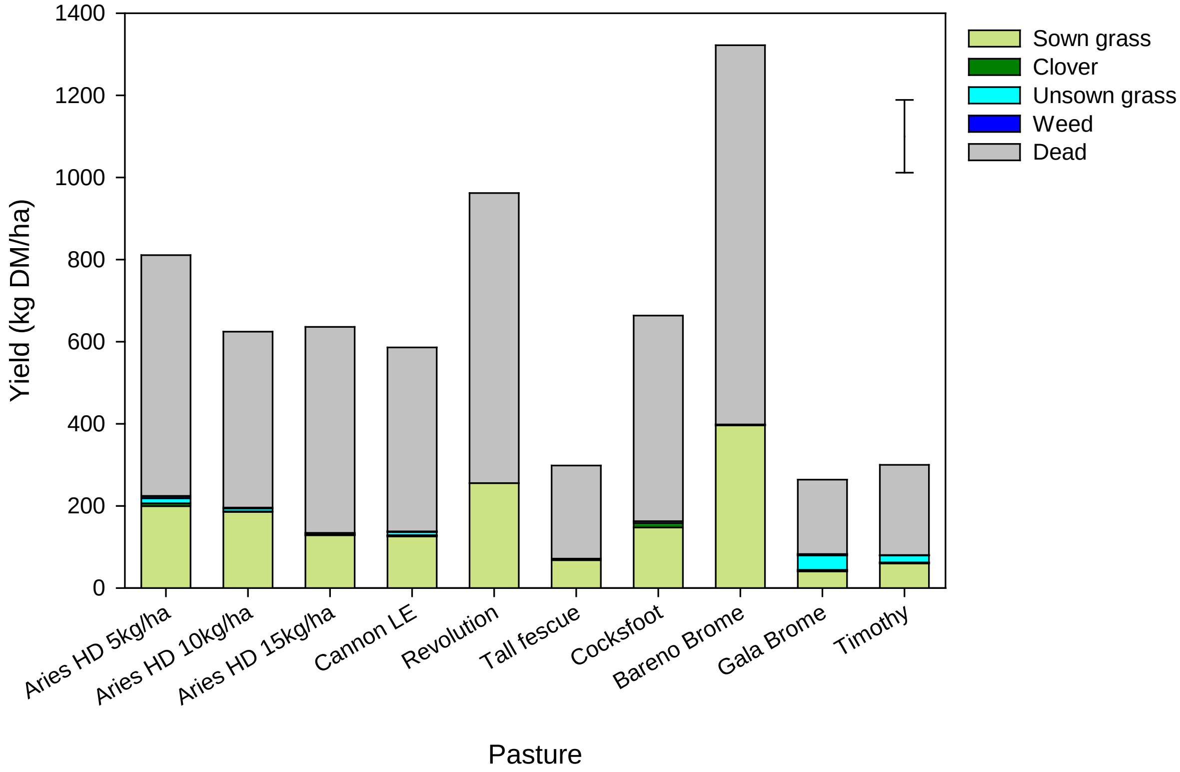

Figure 6 Yield of pasture components at the end of Year 4 (9/6/2010) for 10 pasture grass species established at Lees Valley, Canterbury in 2006. Error bar is the SEM for the effect of pasture type on total DM yield. Unsown grass included resident browntop.

1.3.2 Year 5 (2010/11)

1.3.2.1 Spring

Botanical composition of the grass pastures was determined twice in Year 5. On 10/11/2010 (spring, Year 5), visual estimates of botanical composition over the entire central area of each plot were made (Figure 7). Sown grass ranged ($P<0.001$) from a minimum of 0.5% ('Gala' brome) to a maximum of 83% ('Bareno' brome). There was 69±4.2% sown grass in 'Aries', 'Revolution' and cocksfoot pastures and no difference between the 5, 10 or 15 kg/ha sowing rates at which 'Aries' was initially established. As expected the low contribution from the sown grass component in tall fescue, timothy and 'Gala' brome pastures was less ($P<0.001$) than that found in all other pastures.

Volunteer clover (mainly white clover) ranged ($P<0.05$) from 3% ('Bareno') to 12% (tall fescue). Unsown grasses, mainly browntop which had re-invaded, accounted for >65% of pasture cover in tall fescue, timothy and 'Gala' brome pastures. All other pastures had <26% unsown grasses and were lowest ($P<0.001$) in the 'Bareno' brome (6%). There was no difference in the amount of dicot weeds (3±0.7%) or dead material (6±0.7%) observed in the pastures.

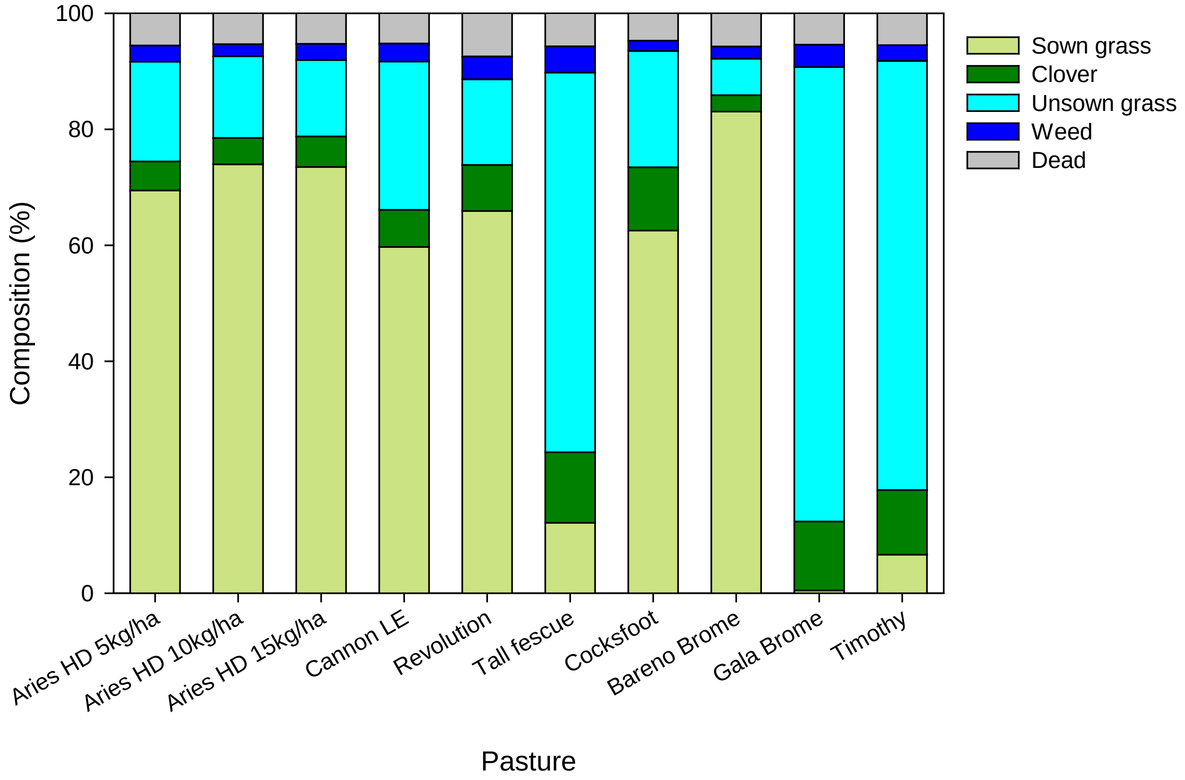

Figure 7 Composition of 10 perennial grass pastures from visual assessments made in spring of Year 5 (10/11/2010) at Lees Valley, Canterbury in 2006. Re-invasion by resident browntop at the site was included in the unsown grass fraction.

1.3.2.2 Autumn

In autumn of Year 5 (22/3/2011), BOTANAL evaluations (Jones & Hargreaves, 1979) showed sown grass from tall fescue, timothy and 'Gala' brome pastures accounted for 6±4.8% of pasture cover and this was less ($P<0.001$) than the contribution of sown grass from all other treatments (Figure 8). 'Bareno' brome retained the most sown grass (76%) followed by the 57% in cocksfoot pastures. The 64% sown grass in 'Revolution' pastures was intermediate and not different to the contribution in either pasture. 'Aries' and 'Cannon' ryegrasses contributed 36±4.8% of composition.

The summer rainfall was 222 mm. Thus, summer rainfall in Years 1, 2, 3, and 6 (214-275 mm) were comparable. Therefore, the decline in perennial ryegrass in Year 6 was not a consequence of a particularly dry summer.

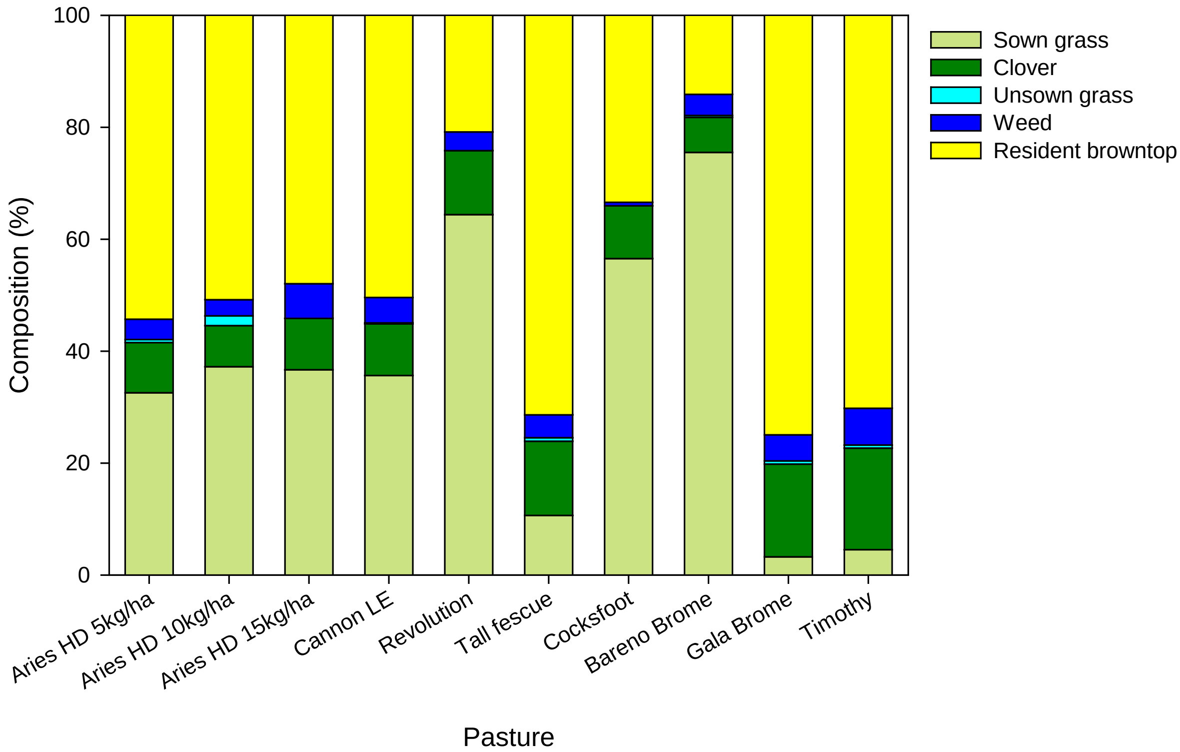

Figure 8 BOTANAL evaluations of botanical composition of 10 perennial grass pastures in autumn of Year 5 (22/3/2011), at Lees Valley, Canterbury. Pastures were established in 2006.

The clover content was lowest (P<0.001) in cocksfoot, 'Aries', 'Cannon' and 'Bareno' brome pastures (8±1.7%) and highest in timothy and 'Gala' brome pastures (17±1.7%). The encroachment of resident browntop back into the swards differed (P<0.001) and basically showed that the pastures where the improved grass had failed to establish (tall fescue, timothy and 'Gala' brome) had the most browntop (72±5.1%) compared with about 51±5.1% in 'Aries' and 'Cannon' ryegrass pastures. Browntop contributed 33-14% in the cocksfoot, 'Revolution' and 'Bareno' brome pastures. The contribution from other unsown grass species was minimal in all pastures. Similarly, there was no difference in the contribution of dicot weeds which was 4±1.9%.

1.3.3 Year 6 (2011/12)

1.3.3.1 Spring

In spring of Year 6, botanical composition of the perennial grass pastures treated with three levels (0, 50 or 100 kg N/ha) of spring applied N fertiliser (Figure 9) was evaluated.

Sown grass represented 35±1.4% of cover in pastures which received 0 or 50 kg N/ha in spring. This was more ($P<0.001$) than the 27% sown grass cover in pastures which received 100 kg N/ha. There was 21% volunteer clover in pastures treated with 50 kg N/ha which was less ($P<0.01$) than the 28±1.7% at the 0 or 100 kg N/ha rates.

Nitrogen rate affected ($P<0.001$) the contribution of browntop. Where no N was applied pastures contained 23% browntop compared with 32±1.8% when 50 or 100 kg N/ha was applied. Other unsown grasses (excluding browntop) contributed more ($P<0.05$) to pasture cover at 0 kg N/ha (10%) than the 5±1.4% when pastures receive 50 or 100 kg N/ha in spring.

There was an interaction ($P<0.05$) between pasture species and spring N application rate on the proportion of dicot weeds present. There were more weeds in 'Aries' 15 kg/ha, tall fescue, timothy, and 'Cannon' LE pastures which received 100 kg N/ha and 'Gala' brome with 50 kg N/ha than in the other pasture treatments.

1.3.3.2 Autumn

At the end of Year 6 (23/5/2012) a final BOTANAL evaluation was made. At this time the effects of spring applied N were no longer visible and the entire plot area was considered. Figure 10 shows there was a difference in the amount of sown grass present in the swards which ranged ($P<0.001$) from a minimum of 7±3.6% (timothy, tall fescue and 'Gala' brome pastures) to a maximum of 67±3.6% ('Bareno' brome and 'Revolution' hybrid ryegrass). The 56% cocksfoot was similar to the contribution of sown grass in 'Revolution' pastures. The contribution of the perennial ryegrasses ('Aries' and 'Cannon') was 41±3.6% regardless of endophyte level or initial sowing rate.

Volunteer clover content was highest ($P<0.001$) from pastures initially established with 'Revolution, timothy and tall fescue (18±1.7%) and lowest (9±1.7%) from cocksfoot, 'Bareno' brome and 'Cannon' LE pastures.

There was a difference ($P<0.001$) in the ability of the improved pasture grasses to supress the resident browntop. Specifically, in the tall fescue, timothy and 'Gala' brome pastures 68±4.0% was contributed by browntop (Figure 10) at the end of Year 6. In contrast, the least browntop (17±4.0%) was found in the 'Bareno' brome and 'Revolution' hybrid ryegrass pastures which also had the highest amount of sown grass present in their swards. There was 38±4.0% contributed from browntop in cocksfoot and 'Aries' pastures established at 10 and 15 kg/ha.

Other unsown grasses contributed 1±0.8% to cover and this was similar in all pastures. Similarly, dicot weeds represented 4±1.5% of BOTANAL determined composition and this level was unaffected by pasture species.

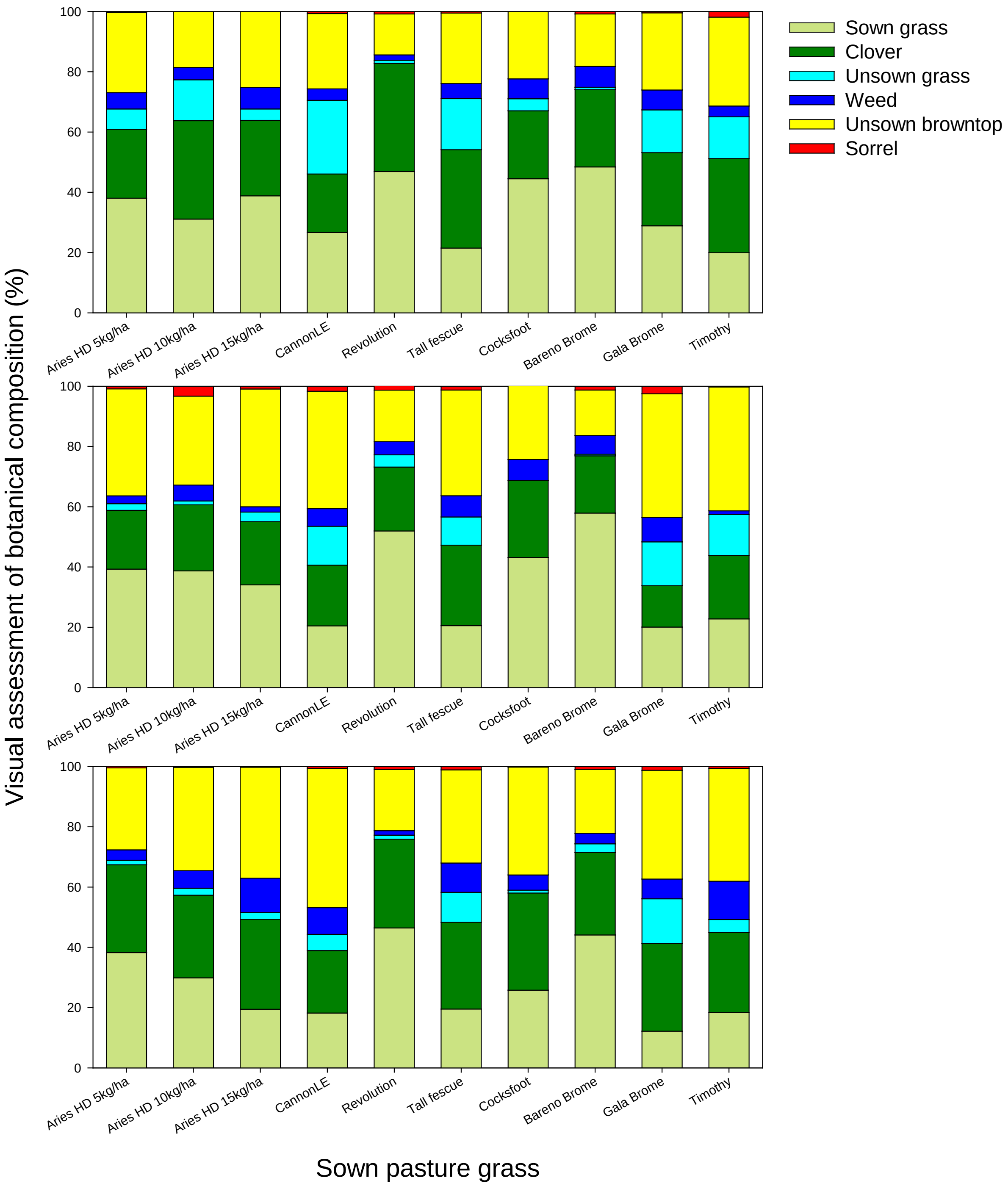

Figure 9 Pasture composition (%) at 0 (top), 50 (middle) or 100 kg N/ha (bottom) of 10 improved grass pastures at the end of the first spring rotation (15/11/2011) in Year 6 (2011/12). Pastures were initially established at Lees Valley, Canterbury in 2006. Evaluations were performed using the BOTANAL method.

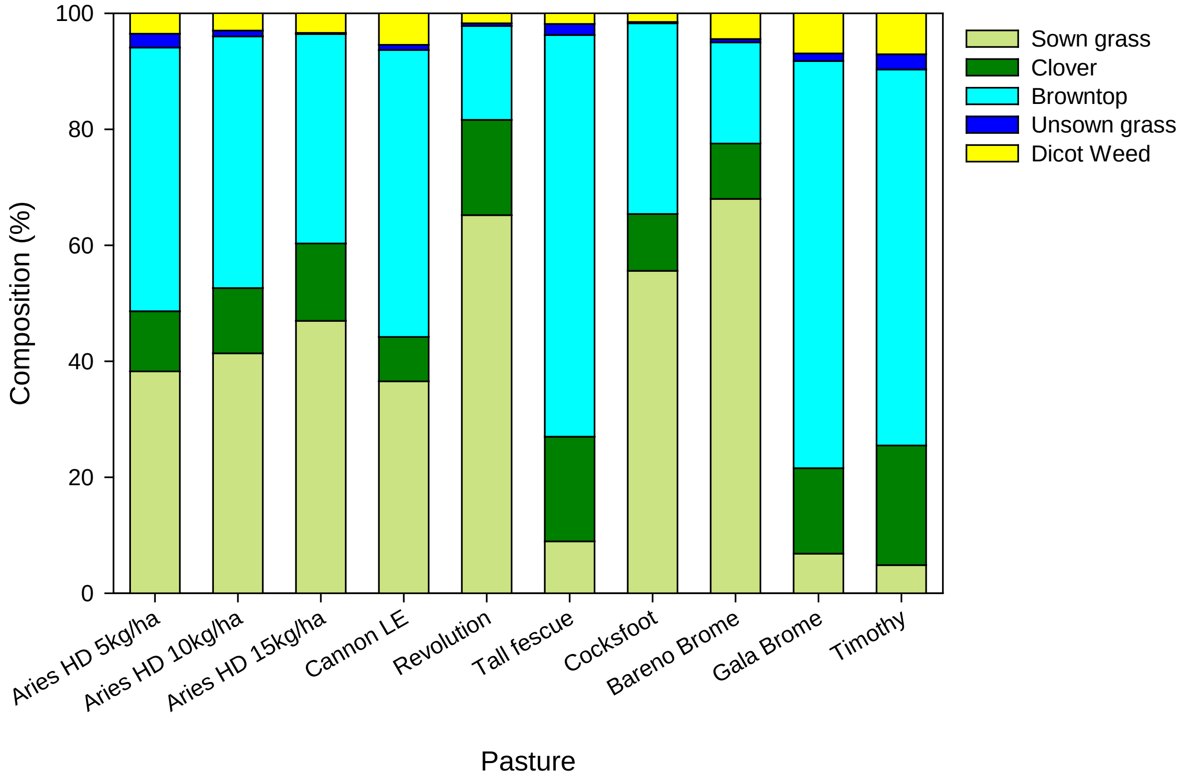

Figure 10 Botanical composition of pastures at the final evaluation on 23/5/2012 (Autumn, Year 6) from 10 perennial grass pastures at Lees Valley, Canterbury. Pastures were established in 2006 and the valuation made using the BOTANAL method.

1.4 Conclusions from the Perennial Grass block after six years:

Results after six years indicate that for the Lees Valley environment persistence was greatest from ‘Bareno’ brome and ‘Revolution’ hybrid ryegrass followed by cocksfoot. However, the ‘Bareno’ brome produced one of the lowest total annual DM yields while cocksfoot and ‘Aries’ (10 kg/ha) produced the most DM. Consequently, it is necessary to evaluate performance based on both production and persistence over time to gain an understanding of the attributes of each species.

Overall, as monocultures ‘Revolution’ and cocksfoot were most suitable and offered different seasonal growth patterns. The spring production from ‘Revolution’ hybrid ryegrass was consistent while summer active cocksfoot allowed production of feed when summer rainfall occurred. Tall fescue, ‘Gala’ brome and timothy were unsuitable species for initial development and intensification of these environments as they failed to establish. Resident browntop was able to re-establish with relative ease in the gaps that opened in these pastures. It is possible they may have a place in these systems but may need to be introduced as pasture renewal species later in the development process when resident browntop is no longer present, or under greater control.

Summer rainfall in Year 4 was 142 mm and this may have impacted on the ability of ryegrass to recover the following year when perennial ryegrasses contributed 36±4.8% of pasture cover in autumn of Year 5.

Experiment 2: The Legume Block

Total DM yields for Years 4-6 were not analysed because unexpected grazing events in summer/autumn meant yield accumulations underestimated actual DM production. No measurements were made in alsike, sub or balansa clover treatments in Years 4-6. Results therefore focus on botanical composition and yield of individual rotations from perennial clover plots where those data were valid.

Table 5 Soil test results (0-7.5 cm) from Experiment 2.

Date	pH (H_2O)	Olsen P (mg/L)	Ca	Mg	K	Na	Sulphate-S (mg/kg)
			(MAF Quicktest units)				
8/08/2007	6.0	17	7	10	11	2	8
19/05/2008	5.9	19	7	12	16	2	30
2/09/2009	6.0	20	6	10	11	2	6
11/08/2010	5.6	18	7	12	12	<2	-
31/08/2011	5.9	19	8	11	10	3	5

2.1 Spring DM yields (sown legume component)

2.1.1 Year 4 (2009/10)

- At 24/11/2009 the sown legume component of the pastures contributed 919±325 kg DM/ha and was not different (P=0.290) for all pastures (Figure 11). Spring (Sep-Nov, ECAN) rainfall totalled 211 mm (see Weather Summary, Table 1).
- Total annual DM yields (Figure 12) in Year 4 were about 3.1 t/ha and this was comparable to the previous three years.

2.1.2 Year 5 (2010/11)

- In November 2010 (spring) Caucasian clover yielded 906±165.2 kg DM/ha in the three pastures where it had been established. The lowest (P<0.05) legume yield in spring of Year 5 was 151 kg/ha from lucerne (Figure 11). Yields from red and white clovers were comparable to both groups. Sep-Nov (ECAN) rainfall totalled 208 mm (see Weather Summary, Table 1).
- Rainfall (ECAN) in summer (Dec-Feb) totalled 208 mm (see Weather Summary, Table 1).
- Lucerne plots continue to grow a significant weed component. Previously, lucerne represented <50% of total DM averaged over five measurements made in Years 1-3.

2.1.3 Year 6 (2011/12)

- In October 2011 (Figure 11) total sown legume was lowest from lucerne and Caucasian clover+chicory pastures (602±84.3 kg DM/ha) compared ($P<0.001$) with 1098±84.3 kg DM/ha from the legume component in the red, white, pure Caucasian and Caucasian/plantain treatments.
- Rainfall for spring (ECAN, Sep-Oct only due to timing of measurement) was 159 mm (see Weather summary, Table 1).
- Total accumulated DM yield in Year 6 averaged 9.4 t/ha which was the highest yield produced over the six years since the pastures were established (Figure 12) and 2-3 times more than total DM yields in the previous five years.
- The higher yield in Year 6, compared with other years, appeared to occur during the second regrowth cycle (20 Dec-12 Jan) when the mean daily growth rate averaged 103 kg DM/ha/day compared with 37 kg DM/ha/day in spring and about 15 kg DM/ha/day in the final measurement period.
- Summer rainfall (Dec-Feb in year 6 totaled 228 mm (ECAN) compared with 142 mm in Year 4 (Weather Summary, Table 1).

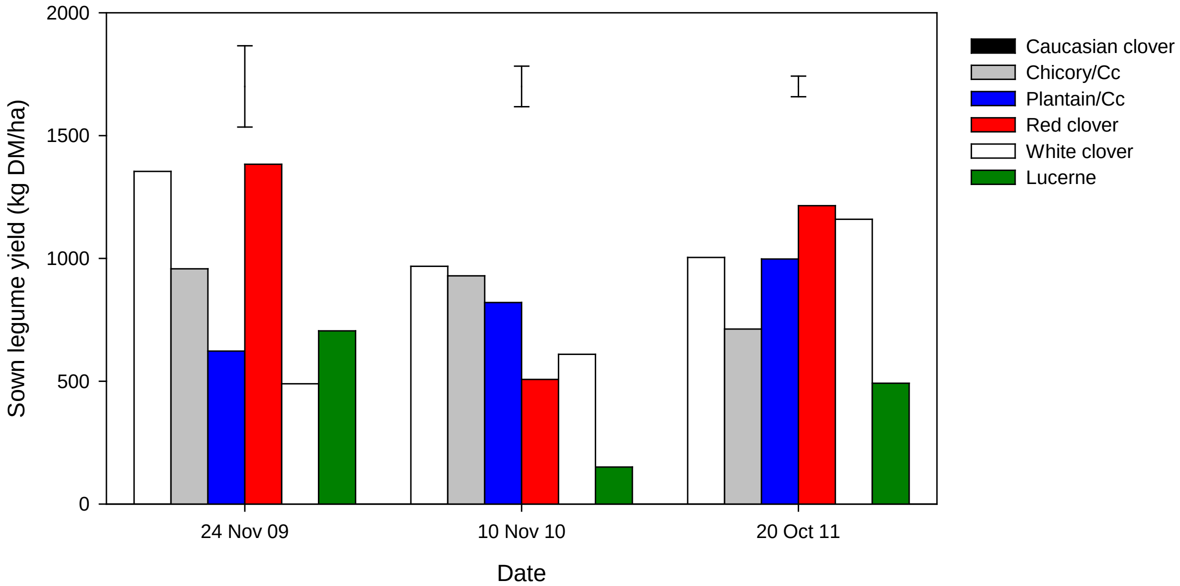

Figure 11 Dry matter production from the sown legume component in Experimental Block 2 (legume monocultures) present at the end of rotation evaluations in spring of Years 4 (Nov 09) 5 (Nov 10) and 6 (Oct 11) at Lees Valley, Canterbury. Error bars are SEM.

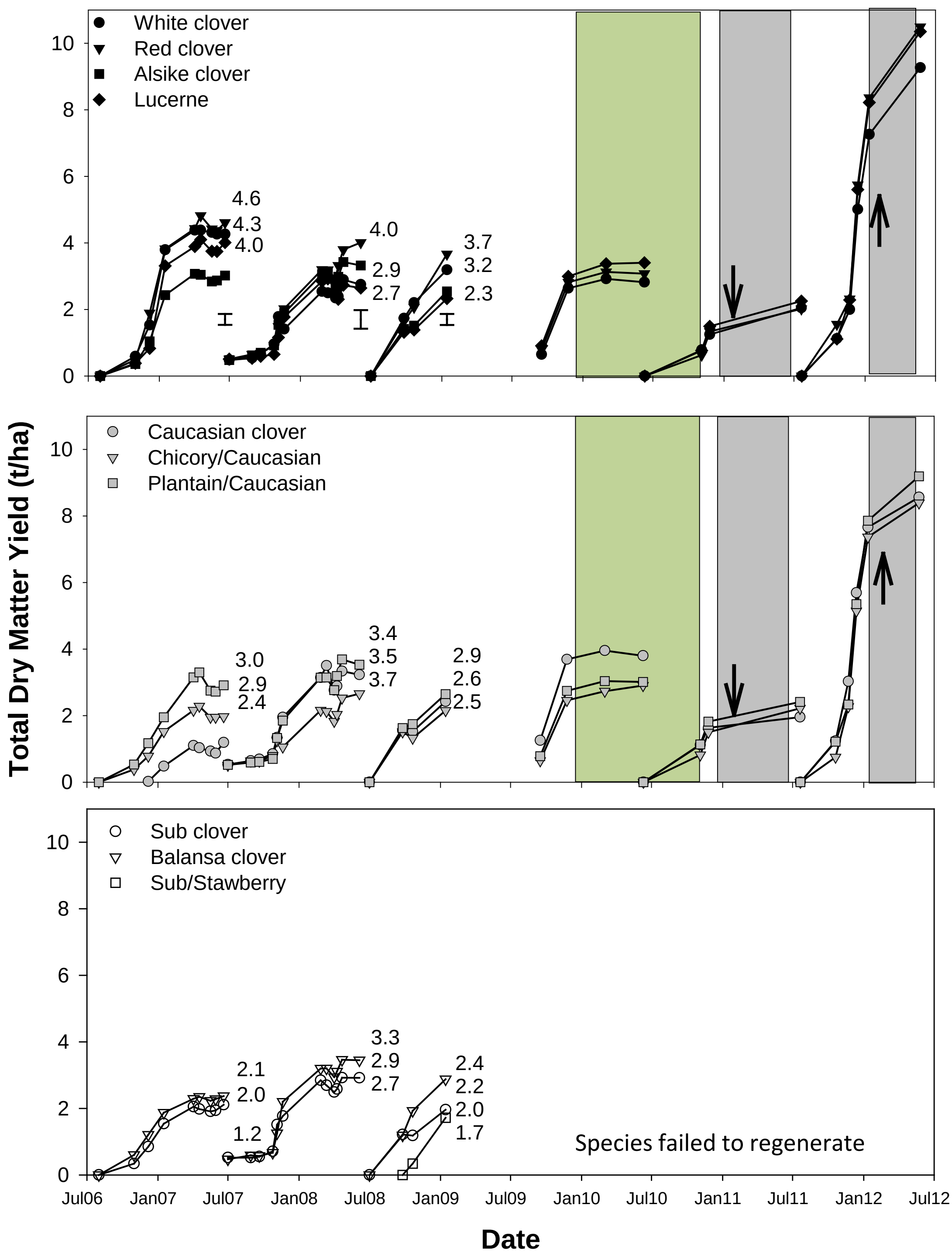

Figure 12 Accumulated total DM yield (t/ha) of legume pastures at Lees Valley, Canterbury over six years. Note: Grey areas indicate grazing (arrows) occurred between probe readings and there was no end of rotation DM yield measurement. Therefore, annual accumulations do not reflect actual DM produced. The green shaded area represents the 325 d period during which no grazing events were recorded in the legume block. This encompassed the end of a growth season so DM was partitioned between two mid rotation measurements. No measurements were taken in the alsike, sub or balansa clover treatments in Years 4-6. (Note: Data from Year 4-6 were not analysed because unexpected grazing events meant annual yields underestimate actual DM production).

2.2 Botanical composition

2.2.1 Year 5 (2010/11)

2.2.1.1 Spring

On 20/11/2010 (spring), visual evaluations of botanical composition were made in the legume block. These were matched with DM yields determined from pasture probe readings in the plots on 4/11/2010.

Results showed total DM yield was 1134±126 kg DM/ha in all pastures (Figure 13). However, composition differed between the pastures. Caucasian clover based treatments had the highest sown legume yield (906±165 kg DM/ha) which was more ($P<0.05$) than the 151 kg DM/ha produced by lucerne. Yields from red and white clovers were intermediate and similar to both groups.

The amount of unsown legume present ranged ($P<0.05$) from a minimum of 39 kg/ha in white clover monocultures to a maximum of 236 kg/ha in the lucerne monoculture. There was no difference in the amount of unsown clover (species not specified) in the white clover monoculture or that found in any of the Caucasian clover based treatments. The main volunteer clover species was white clover.

Plantain persisted ($P<0.001$) in the herb treatments more than chicory with spring yields in Year 5 of 204 and 44 kg DM/ha, respectively. Unsown grass contributed 79±15 kg DM/ha in all treatments. Dicot weed yield was highest ($P<0.001$) in lucerne (579 kg DM/ha) compared with 107±65 kg/ha from the other pasture treatments.

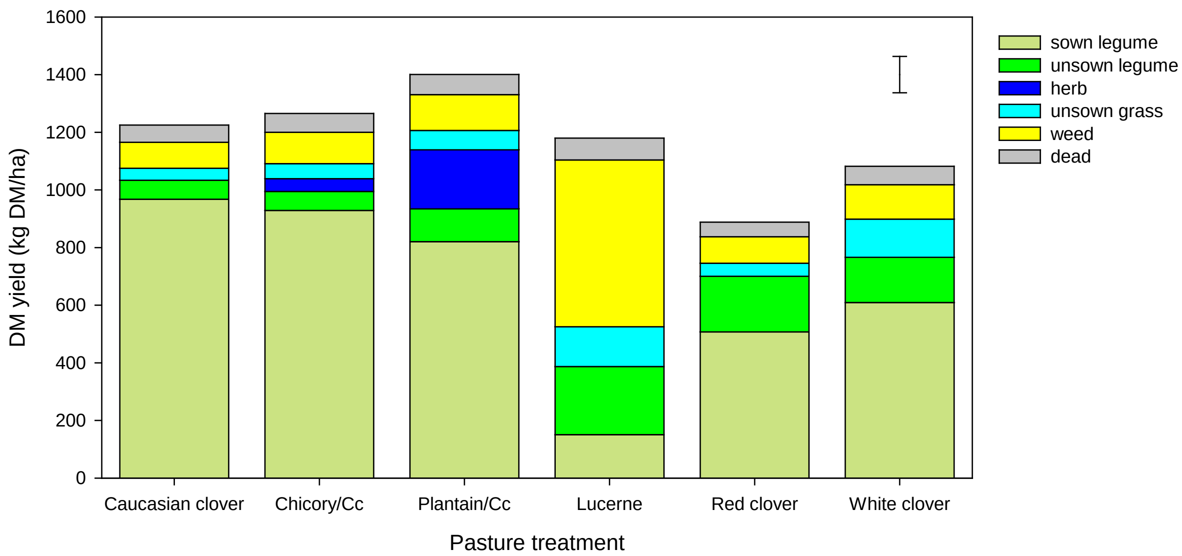

Figure 13 Yield (kg DM/ha) of pasture components from visual assessment on 10/11/2010 of six dryland legumes/herb pastures established in 2006 at Lees Valley, Canterbury. Total DM yield was determined from pasture probe readings taken on 4/11/2010. Error bar is the pooled SEM for total DM yield which was similar in all pastures.

2.2.2 Year 6 (2011/12)

2.2.2.1 Autumn

In autumn (23/5/2012) the amount of sown legume present was 21±6.1% in all treatments (Figure 14). No herbs (chicory or plantain) were present in the swards at the time of the evaluation (see Plate 1-Plate 4).

The contribution from unsown legumes (mainly unsown white clover) which had established over time differed ($P<0.001$) between the monocultures. Specifically, volunteer legumes were 18±2.5% of the composition in the lucerne and Caucasian/chicory swards which was more ($P<0.001$) than the 4±2.5% in the other legume monocultures.

Unsown grasses which had invaded the legume monocultures represented >50% of pasture cover at this time. Of this, browntop contributed 38±2.7% while other unsown grasses accounted for a further 15±2.3% of total composition. Total dicot weed content was 18±5.0%, which includes the contributions from catsear, dandelion, storksbill, woolly mullien, sorrel and hieracium. The invasion of weed species was expected over time and at no stage would pure legume swards, other than lucerne, be recommended.

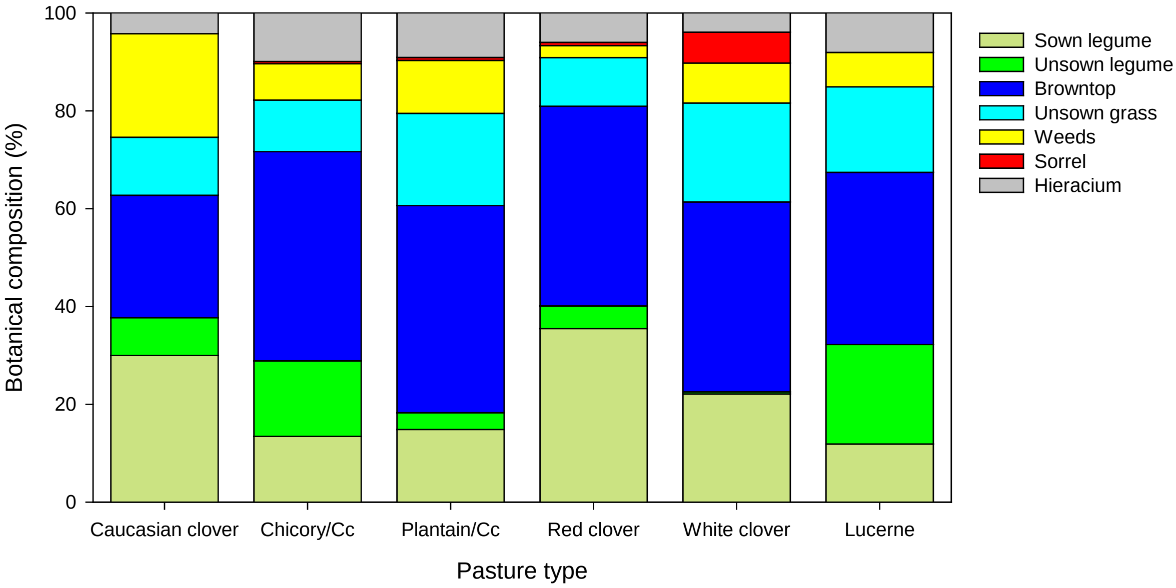

Figure 14 Composition of six legume/herb monocultures at Lees Valley, Canterbury evaluated by the BOTANAL method on 23/5/2012 (autumn, Year 6). Pastures were initially established in 2006.

Plate 1 Plantain and Caucasian clover pasture in the legume and herb experimental block on 20 Nov 2007 (spring, Year 2) at Lees Valley, Canterbury. Pasture was established in 2006.

Plate 2 Plantain and Caucasian clover pasture in the legume and herb experimental block on 20 October 2011 (spring, Year 6) at Lees Valley, Canterbury. Pasture was established in 2006.

Plate 3 Chicory and Caucasian clover pasture in the legume and herb experimental block on 20 Nov 2007 (spring, Year 2) at Lees Valley, Canterbury. Pasture was established in 2006.

Plate 4 Chicory and Caucasian clover pasture in the legume and herb experimental block on 2 February 2012 (Summer, Year 6) at Lees Valley, Canterbury. Pasture was established in 2006.

2.3 Conclusions

Caucasian and red clover were the most successful legumes introduced into this environment. At the end of the experiment red clover appears to be in decline.

The failure of sub and other annual legumes introduced to the site occurred from the second year (i.e. there was not a period of decline rather they failed to re-establish from seed). It is recommended that further research is conducted to identify the exact mechanism or environmental limitation responsible for this failure particularly as sub clover has persisted at an adjacent site where different establishment methods were employed.

Chicory and plantain content decreased over time with neither herb present in the swards when evaluated in the final autumn rotation of Year 6.

White clover production has varied with spring/summer rainfall. Visual observations indicate white clover had re-established from buried seed. Original plants died, in Year 2-3.

Lucerne production has been low in these plots in all years but total DM yield has been comparable. Unfortunately, this is because of production from less desirable weed species which have invaded the stands. Issues related to the lucerne failure are dealt with in Section 7.3.

Plate 5 Caucasian clover was the most persistent and productive clover on the Lees Valley trial site after six years.

Experiment 3: Ryegrass Mixes

3.1 Total DM yields

Total accumulated annual yield was 3.2±0.19 t/ha in Year 4 (2009/10) and was similar for all pastures (Figure 15).

In 2010/11 (Year 5), the yields ranged ($P<0.01$) from a minimum of 4.5 t/ha/yr, from high endophyte (HE) 'Cannon' ryegrass pastures, to a maximum of 5.4 t/ha/yr produced from 'Revolution' hybrid ryegrass established with cocksfoot.

In Year 6 the 8.8 t/ha produced by the 'Revolution'/cocksfoot mix was 24% more ($P<0.05$) than the 7.1±0.31 t/ha produced by the ryegrass monocultures which were all similar regardless of endophyte or initial sowing rate. The difference in total annual production resulted from summer/autumn productivity. In spring all pastures grew at about 28 kg/ha/day. During summer the 'Revolution'/cocksfoot mix grew at 72 kg DM/ha/d whereas the monocultures grew at 61 kg DM/ha/day. Further, in autumn, the 'Revolution' with cocksfoot continued to grow at a faster rate (18 kg DM/ha/day) than the monocultures (7 kg DM/ha/day).

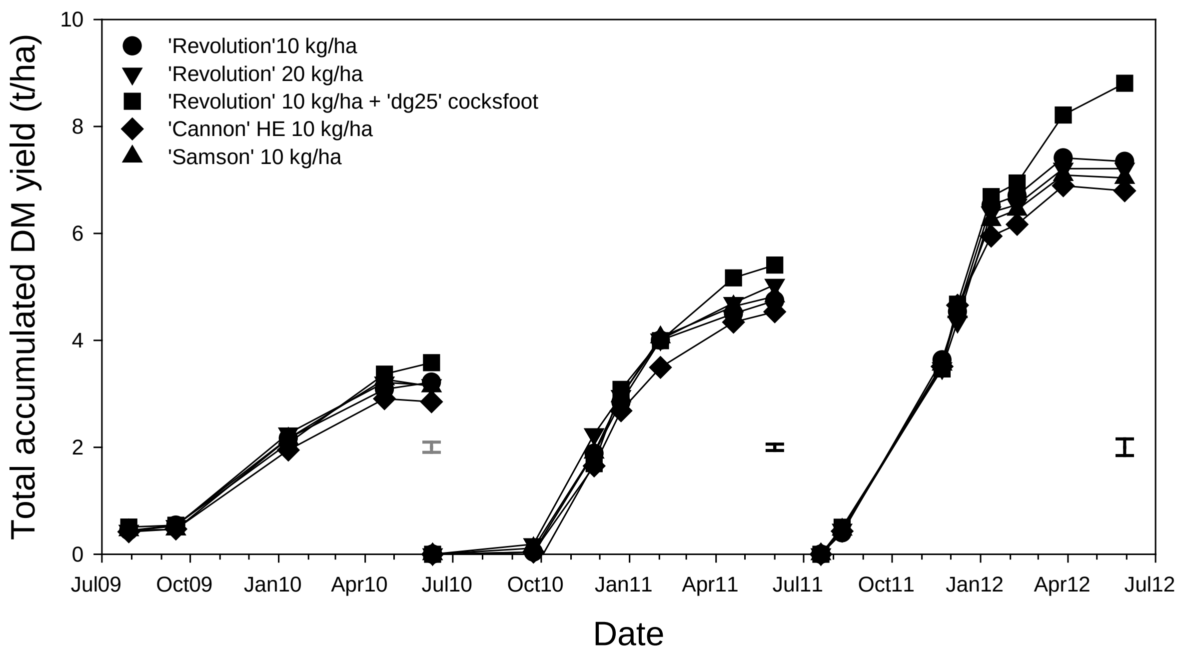

Figure 15 Total accumulated DM yield (t/ha) of ryegrass mixes (Experiment 3) established at Lees Valley, Canterbury in 2006. Error bars are for the total annual yield. Error bars in grey are pooled SEM associated with the grand mean (no observed effect of treatment) and black error bars are SEM for the effect of treatment when yields were different between pasture treatment.

3.2 Botanical composition

3.2.1 Spring Year 6 (2011/12)

On 22/11/2011 (Figure 16) there was no difference in the total DM produced in the spring regrowth period (3.5±0.1 t/ha). However, there was a difference in pasture composition. The yield of sown grass was highest (P<0.01) from the 'Revolution' established with cocksfoot which yielded 1.7 t/ha. This was almost double the 0.9±0.12 t/ha produced from the ryegrass in the other treatments. For the ryegrass component, the lowest yield (P<0.01) was from the 'Revolution' + cocksfoot pasture where 'Revolution' yielded only 0.2 t/ha compared with 0.9±0.1 t/ha from the other ryegrasses. There were no differences caused by initial sowing rate (10 vs. 20 kg/ha) nor were there any differences between cultivar or endophyte status. Cocksfoot, sown at an initial rate of 2 kg/ha, yielded 1.5 t/ha.

Total clover (basal white+sub) was 1.9±0.1 t/ha or about 54% of total yield and mainly white clover as the sub contribution was negligible. Unsown grasses, mainly browntop, accounted for about 15%, or 0.5±0.08 t/ha, of total DM.

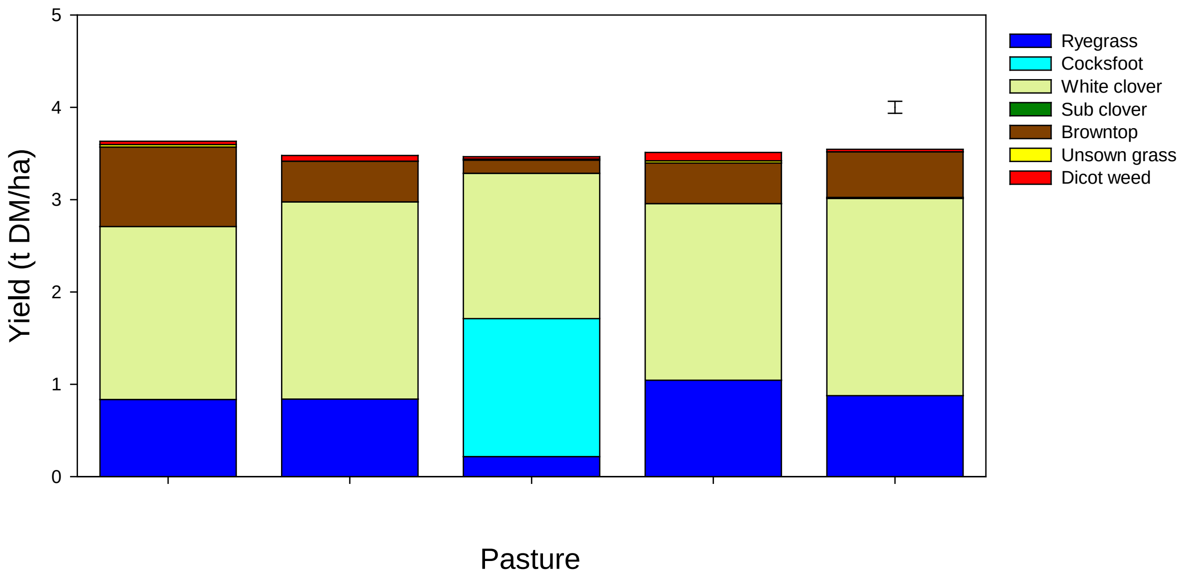

Figure 16 Yield of individual pasture components contributing to total DM yield in spring of Year 6 (22/11/2011) of the perennial ryegrass based pasture mixes established at Lees Valley, Canterbury in 2006. All pastures were established with basal white and sub clover. The error bar is the pooled SEM associated with the grand mean as there was no effect of treatment.

3.2.2 Autumn Year 6 (2011/12)

On 30/5/2012 the final evaluation of pasture composition was taken (Figure 17). At this time total sown grass content was 64±3.0% in all pastures. However, in the 'Revolution'+cocksfoot pasture 'Revolution' accounted for only 5% of pasture cover compared (P<0.001) with 61±5.3% from ryegrass in the other pastures. The difference was made up from cocksfoot which accounted for 72% of cover. As expected, given the aggressive behaviour of cocksfoot towards companion white clover, this treatment also had the lowest ($P<0.05$) basal white clover content (11%). White clover averaged 17 ±1.4% in the pastures established with 'Revolution' or 'Samson' as the only improved grass.

There was no effect of pasture treatment on the total amount of unsown grasses (browntop + other unsown grasses) which was 18±3.0% the majority of which was re-invasion by resident browntop. Total dicot weed cover (including contributions from Hieracium and sorrel) was 3±0.5% in all pastures.

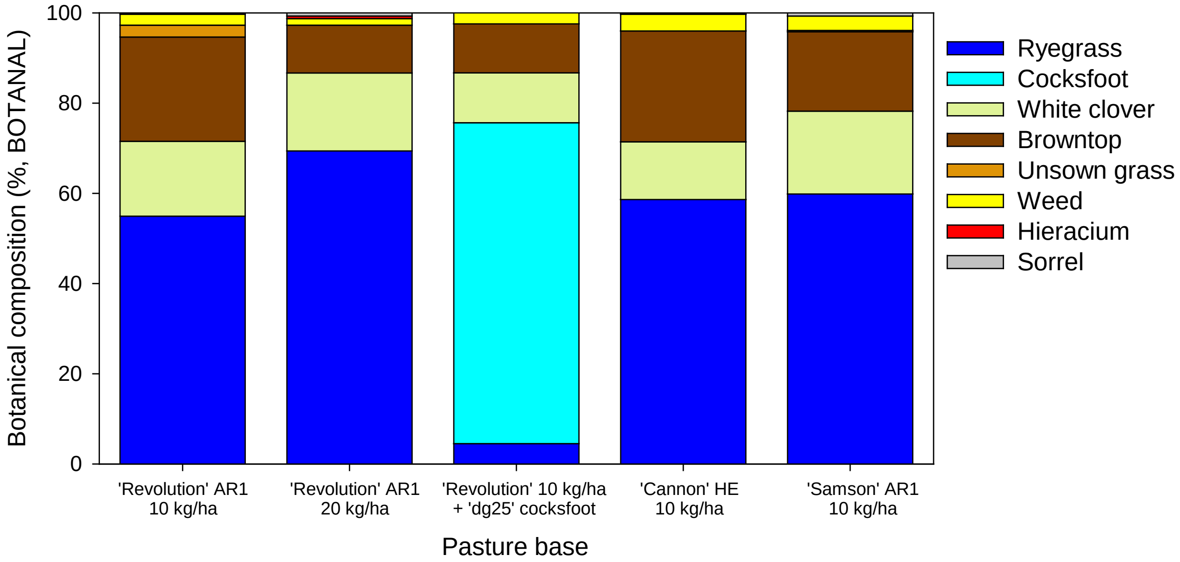

Figure 17 Botanical composition (%, BOTANAL) of perennial ryegrass based pasture mixes established with basal white and sub clover in autumn (30/5/2012) of Year 6. Pasture mixes were established at Lees Valley, Canterbury in experimental block 4 in 2006.

3.3 Conclusions

- Ryegrasses persisted, regardless or initial (10 or 20 kg/ha) sowing rate or endophyte status.

- The inclusion of cocksfoot with 'Revolution' increased total DM yields but suppressed the yield from the ryegrass and white clover components.

Experiment 4: Dryland Pasture Mixes

4.1 Total DM yields

For the dryland mixes (Figure 19) there were differences in yield in each year monitored (Years 4-6).

Total yield in Year 4 was highest (P<0.01) from the 'Bareno' and cocksfoot pastures which produced 4.0±0.20 t/ha compared with 1.8±0.20 t/ha from the tall fescue pastures.

In Year 5 (2010/11), the lowest yield was 2.4±0.18 t/ha/yr from the 'Bareno' and 'Advance' (MaxP) based pastures. The cocksfoot pastures (regardless of cultivar) produced the highest yield (5.0±0.18 t/ha/yr).

For Year 6, yields ranged from a minimum of 5.0 t/ha ('Bareno' brome) to a maximum of 8.5 t/ha by 'Ella' cocksfoot. In spring all dryland pastures grew at about 28 kg DM/ha/day and in autumn growth rates were 4-8 kg/ha/day. In summer mean daily grow rates for the period were between 40 ('Advance' MaxP) and 75 kg DM/ha/day ('Ella' cocksfoot).

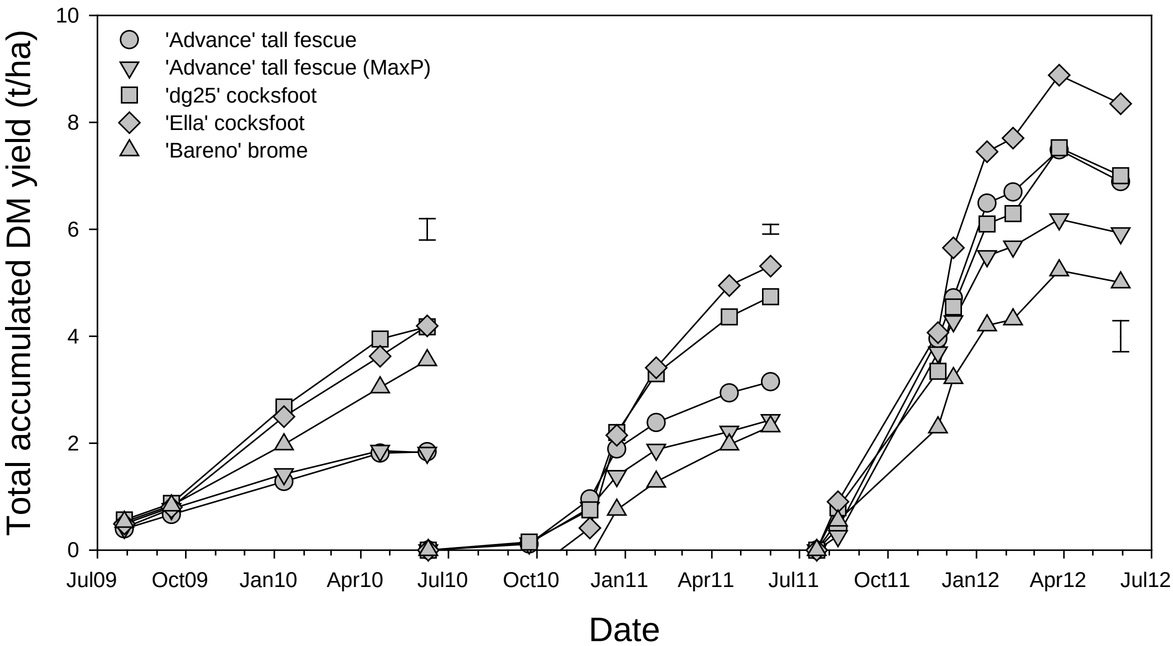

Figure 18 Total accumulated DM yield (t/ha) of dryland mixes (Experiment 4) established at Lees Valley, Canterbury in 2006. Error bars are SEM for the total annual yield.

4.2 Botanical composition

4.2.1 Spring Year 6 (2011/12)

Total yield on 22 Nov 2011 was lowest (P<0.01) from the 'Bareno' brome pastures at 2.3 t/ha (Figure 19). In contrast, the cocksfoot and tall fescue pastures yielded 3.8±0.3 t DM/ha. Cocksfoot yielded more (P<0.001) than the other improved grass bases. 'Ella' produced 3.0

t/ha, ‘dg25’ produced 2.4 t/ha compared with 0.5± t/ha from tall fescue and ‘Bareno’ grasses. For tall fescue, yields were not affected by endophyte status.

The contribution of basal white clover differed between pastures and was highest (P<0.01) in tall fescue pastures (2.4±0.4 t/ha) where it accounted for over half of the total DM yield produced in spring. As expected, white clover did not contribute as much in the cocksfoot based pastures (0.8±0.4 t/ha). White clover in the ‘Bareno’ based pastures was 1.4 t/ha and similar to that found in the cocksfoot and nil endophyte tall fescue. Sub yield was minimal and continued to support the previous evidence that all annual legumes established across the four experimental blocks had failed to produce or persist in this environment. The contribution of unsown grasses including re-invasion by resident browntop was lowest (P<0.001) in ‘Bareno’ and cocksfoot pastures (0.1±0.07 t/ha) and highest in nil endophyte tall fescue (1.3 t/ha). Dicot weed content was similar in all pastures (0.1±0.03 t/ha).

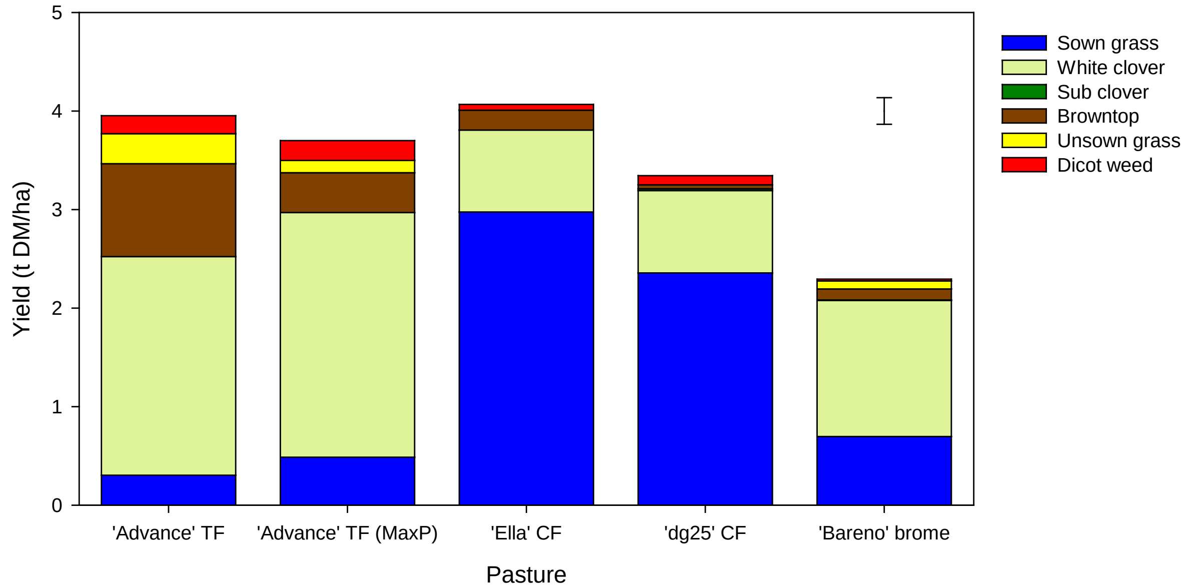

Figure 19 Yield of pasture components (t DM/ha) in spring of Year 6 (22/11/2011) in the dryland mix pastures established at Lees Valley, Canterbury in 2006. Error bar is the SEM for the difference in total DM yield between pastures.

4.2.2 Autumn Year 6 (2011/12)

The final assessment of botanical composition were made on 30/5/2012. Sown grass content was highest (P<0.001) in cocksfoot and ‘Bareno’ brome pastures where the improved grass accounted for 84±1.7% of cover compared with 19.6% in tall fescue infected with MaxP endophyte and 8% in endophyte free tall fescue (Figure 20). The 16% white clover in the endophyte free tall fescue pastures was higher (P<0.05) than the 9% white clover in cocksfoot and ‘Bareno’ brome pastures.

Total unsown grasses (browntop plus other unsown grass weeds) was highest (53%) in nil endophyte tall fescue and (P<0.001) lowest (5±2.4%) in cocksfoot and ‘Bareno’ brome. Total weed content (including hieracium and sorrel) was almost three times higher (P<0.01) in tall fescue compared with the 3±1.3% in all other pastures.

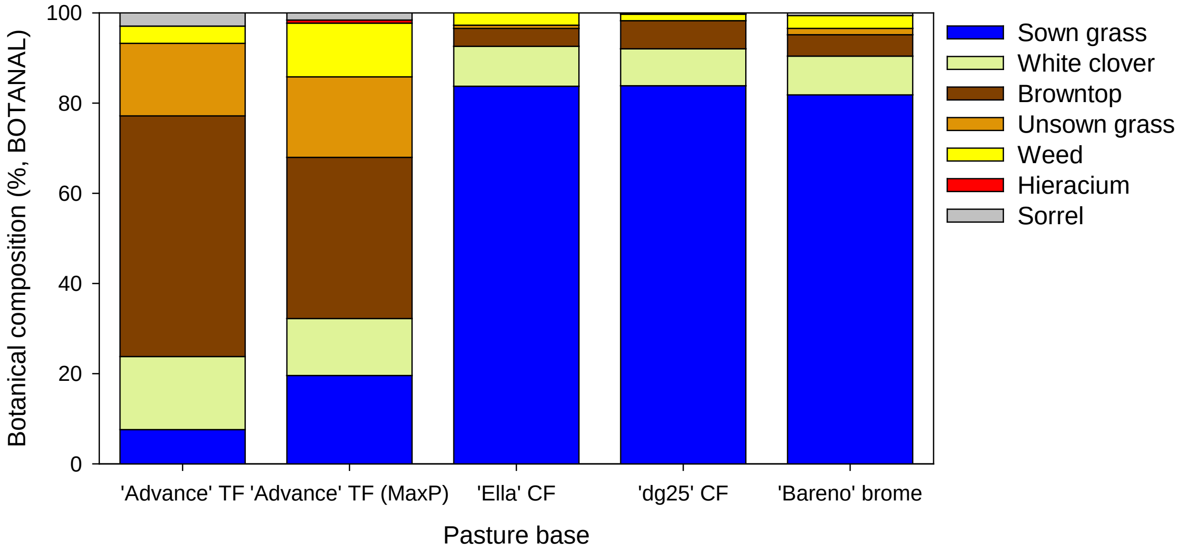

Figure 20 Botanical composition (%, BOTANAL) of dryland mix pastures in autumn of Year 6 (30/5/2012). Pastures were established at Lees Valley, Canterbury in 2006.

4.3 Conclusions

Similar to the grass monocultures in Experiment 1, tall fescue failed to persists and there was no consistent benefit in production of persistence gained from using endophyte infected cultivars. In this experiment, the tall fescue establishment was sufficient to provide productive swards. It failed to thrive after establishment and the sown area followed two years of annual cropping prior to establishment.

As with all other experiments where it was sown (Experiment 2 and 3), sub clover failed to persist when regenerating from the seed bank following initial sowing. It is likely that a combination of factors including, false breaks following intermittent autumn rainfall events, frost heave in winter and preferential grazing may have compounded the lack of success in this environment. In the previous project (Years 1-3) tests on hardseed showed levels comparable to those expected elsewhere and were therefore not considered an impediment here.

Experiment 5: Timothy Mixes

5.1 Total DM yields

In the timothy based pastures the total annual DM yield was 1.5 ±0.05 t/ha in Year 4 (Figure 21) and 0.8±0.05 t/ha in Year 5. Measurements ceased in spring of Year 6 as visual observations indicated minimal timothy remained.

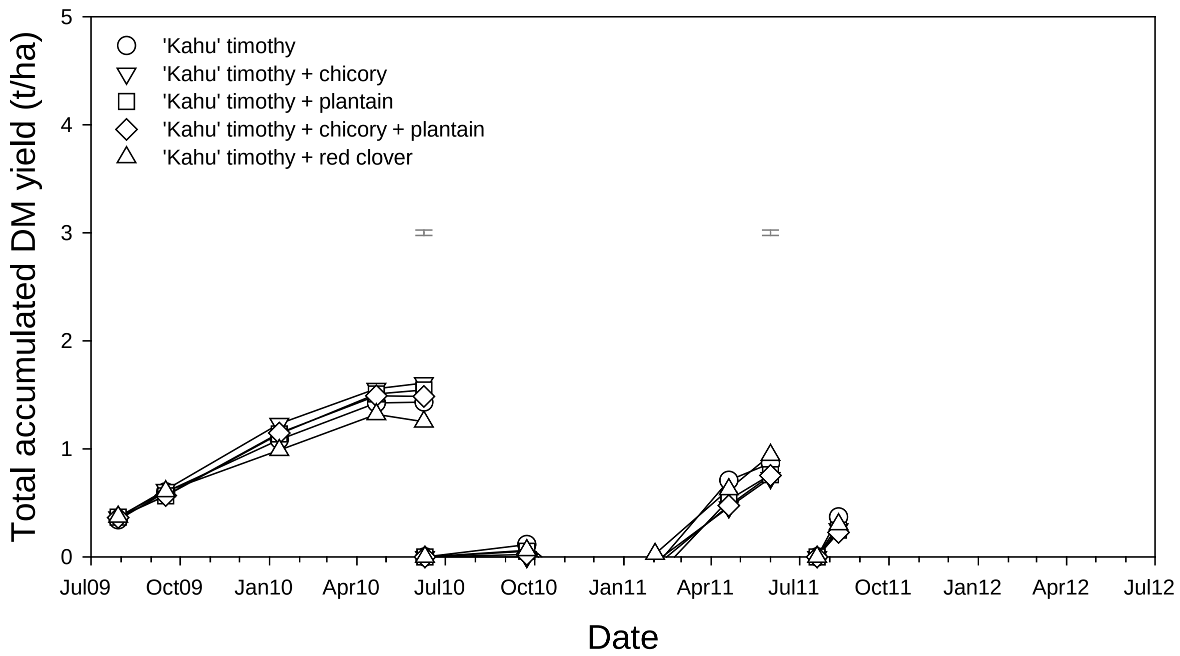

Figure 21 Total accumulated DM yield (t/ha) of timothy based mixes (Experiment 5) established at Lees Valley, Canterbury in 2006. Error bars are the pooled SEM associated with the grand mean.

5.2 Conclusion

In the timothy block, a combination of poor initial establishment, high grazing preference and the driest site, meant this species failed to produce and persist. It would have been interesting to see if timothy could survive and persist given more controlled grazing management and sowing in autumn following a fallow and autumn break rains.

Experiment 6: Perennial Grass Mixes with clovers

This block was established with either 'Bronsyn' AR1 perennial ryegrass or 'dg25' cocksfoot as the grass base with either arrowleaf, 'Denmark' sub, 'Leura' sub, red clover, Persian clover or 'Woogenellup' sub clover as the companion legume in 2008. This gave a total of 12 treatments which were replicated twice. 'Nomad' white clover was a basal addition to all treatments at sowing.

6.1 Total annual yields

Figure 22 shows there was no difference in accumulated annual DM yield of any of the treatments over the three years from establishment. Yields were 3.3±0.12 t/ha/yr in 2009/10, 2.7±0.13 t/ha/yr in 2010/11. The yield in 2011/12 was 7.6±0.40 t/ha which was more than double the yield measured in the previous two growth seasons.

These annual yields were comparable to the annual yields from Experiments 1 and 2 in Years 4 and 5. In 2011/12, total annual yield was greater than the average from the perennial grass block (Experiment 1) but less than was produced from the legume block (Experiment 2).

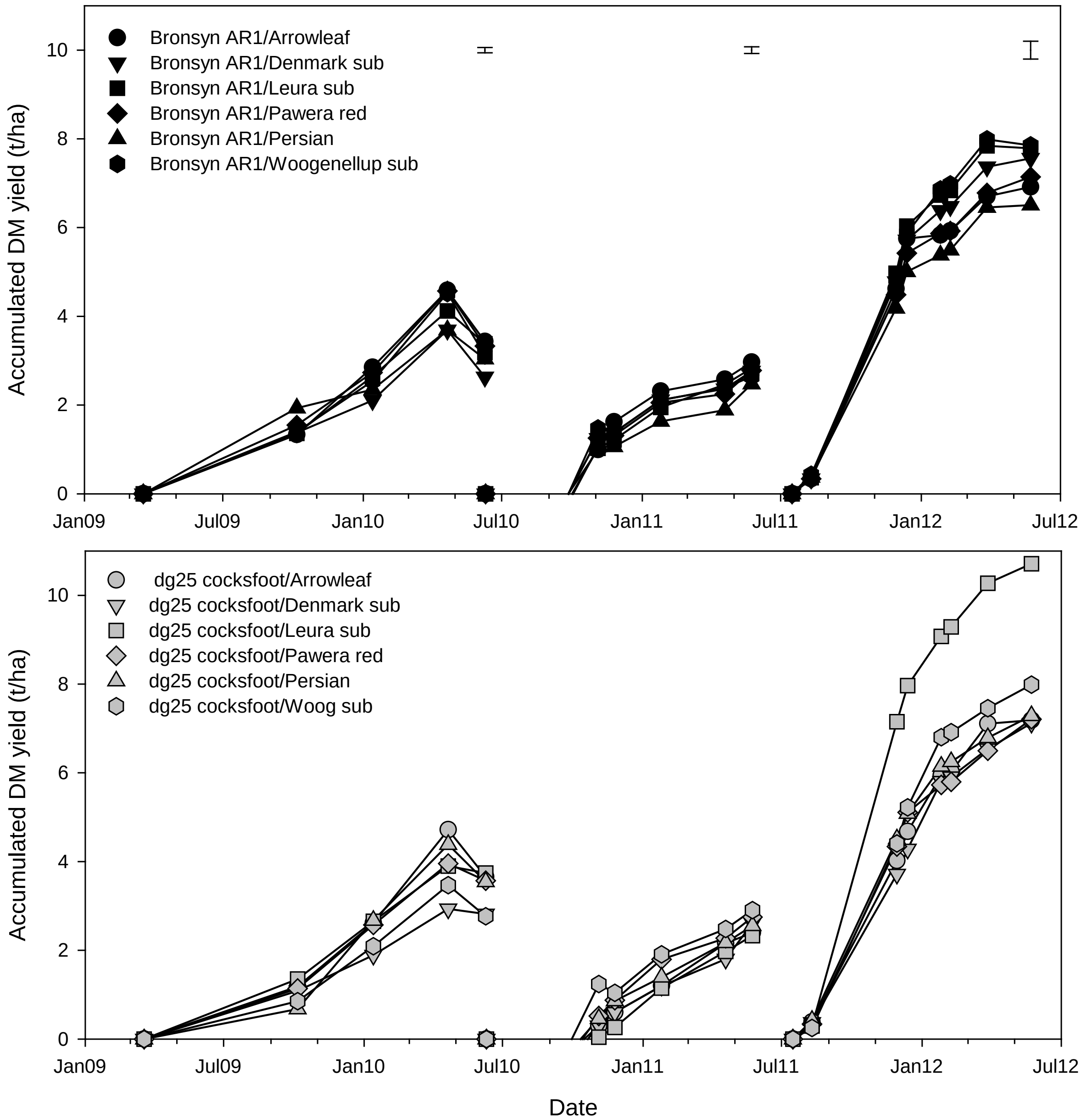

Figure 22 Accumulated DM yield (t/ha) of 12 perennial grass based pastures established with different companion clovers in experimental block 3 at Lees Valley, Canterbury. Error bars are the pooled SEM for the grand mean.

6.2 Botanical composition of perennial mixes (established 2008).

6.2.1 Spring Year 3 (2010/11)

Botanical composition was assessed visually on 25/11/2010 and applied to total biomass yield determined from a corresponding pasture probe reading (Figure 23). Total yield was unaffected by treatment at 1.8±0.08 t DM/ha. Of this, sown grass contributed 0.8±0.07 t/ha, basal white clover yielded 0.5±0.04 t/ha, unsown clovers yielded 0.08±0.01 t/ha, unsown weed grasses contributed 0.1±0.02 t/ha and dicot weeds 0.1±0.02 t/ha. There was no treatment effect on any of these components.

Apart from the white clover, red clover was most successful in maintaining a presence in the swards. There was 0.6 t/ha in the cocksfoot based pastures which was more ($P<0.001$) than the 0.4 t/ha in the ryegrass pastures. In all other pastures there was a similar low contribution from the sub, arrowleaf and Persian clovers.

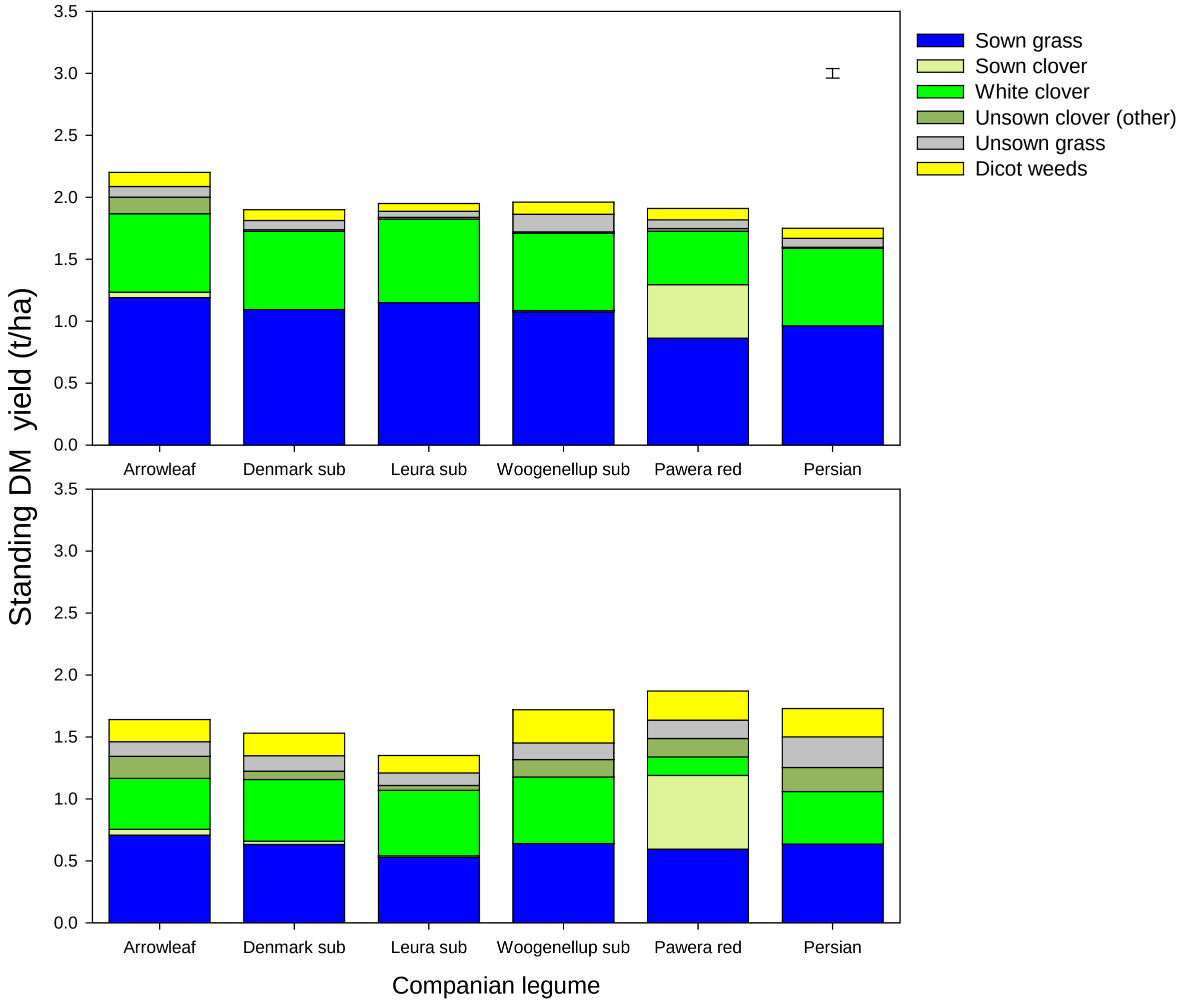

Figure 23 Botanical composition of pasture mixes, with 'Bronsyn' ryegrass (top) or 'dg25' cocksfoot (bottom) as the perennial grass, in spring 2011 (Year 3). Pastures were established with alternative companion legumes in 2008 at Lees Valley, Canterbury. The error bar is the pooled SEM for total DM yield.

6.2.2 Winter Year 3 (2010/11)

The final evaluation of pasture composition was made on 1/6/2011 by BOTANAL. Figure 24 shows there was no difference in the sown grass (59±1.7%), dicot weed (0.1±0.06%) or bare ground (20±1.6%) in winter.

Red clover was the only companion legume present in the pastures and was highest ($P<0.001$) in the 'Bronsyn'/red clover pastures (23%) compared with 19% in the cocksfoot/red clover pasture. Basal white clover varied between the pastures and was highest ($P<0.01$) in the pasture established with 'Bronsyn'/'Denmark' sub (22%) and lowest in the cocksfoot/red clover pasture (4%). Cover from sub, Persian and arrowleaf clovers was nil which indicated either germinating seedlings were lost due to a false break or frost heave or, alternatively, had failed to regenerate from buried seed following autumn breaks.

Encroachment of resident browntop was highest (10%) in the pastures established as cocksfoot/Persian clover and this was more than in any other pasture.

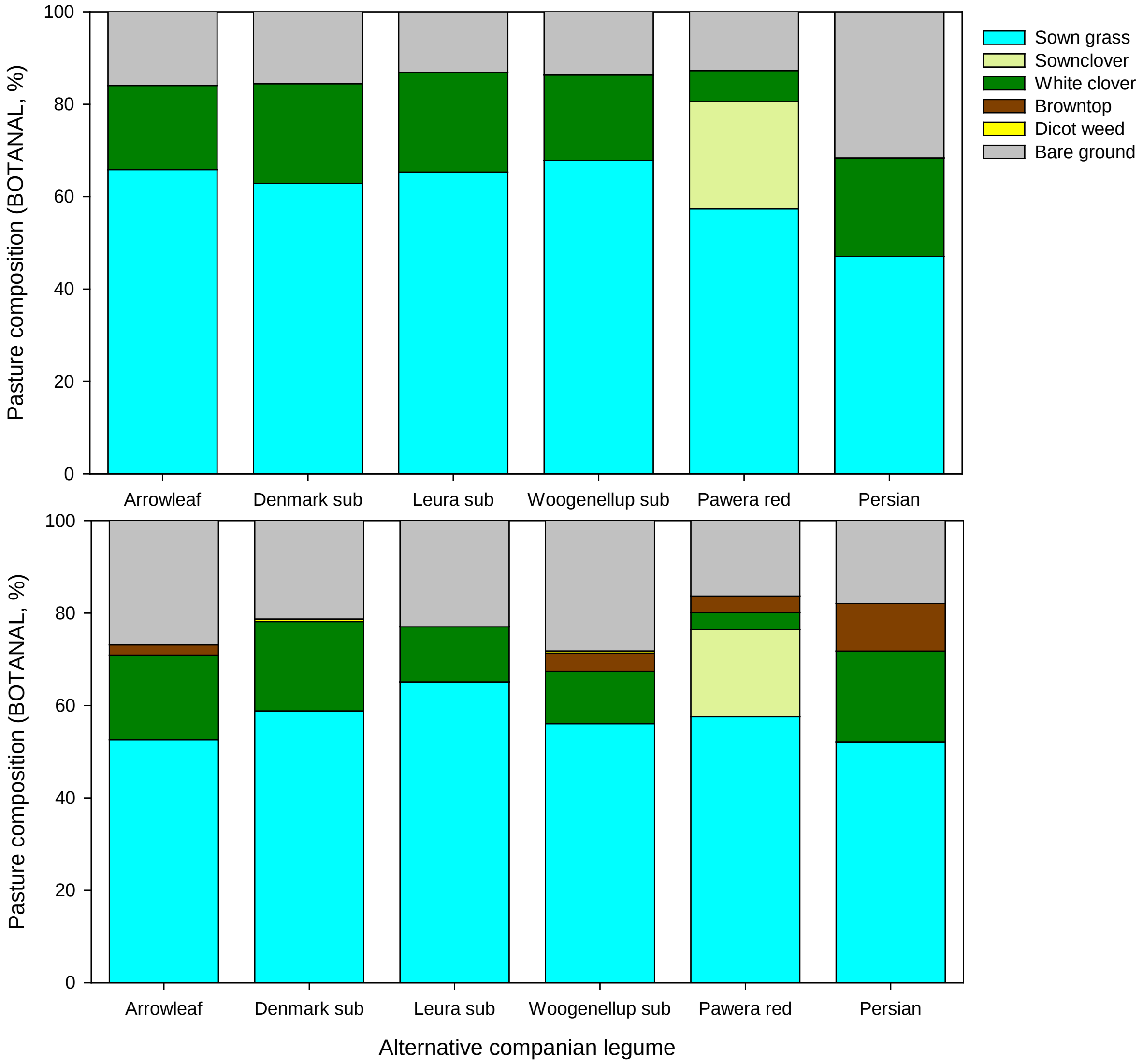

Figure 24 Pasture composition (%) in winter of Year 3 (2010/11) for 'Bronsyn' AR1 (top) and 'dg25' cocksfoot as the perennial grass bases. The pastures were established in Experimental block 3 at Lees Valley, Canterbury in 2008 with basal white clover included in all treatments.

6.3 Conclusions

Both perennial ryegrass and cocksfoot persisted for the three years since pastures were established (2008/09–2010/11). Botanical composition was not determined in Year 4 (2011/12).

Similar to the Legume/Herb block all annual companion clovers established with the ryegrass or cocksfoot grasses failed to persist.

Red and white clovers again showed their superiority in this environment.

The highest average yield was produced in Year 4 (2011/12) and averaged 7.6±1.48 t DM/ha ($P=0.857$). This was more than double the yields produced since pastures were established. This reflected the distribution of summer rainfall which maintained growth (Table 1, Weather Summary).

Experiment 7: Lucerne responses to lime

- The previous lucerne plots (Experiment 2) produced poor yields. Some plots showed horizontal root growth, suggesting aluminium toxicity.
- Previous studies (Edmeades *et al.* 1983) found a 50% reduction in DM yield of pastures when Aluminium levels were > 1 me/100 g of soil.
- Aluminium toxicity is more likely to occur in the subsoil than topsoil (Edmeades *et al.* 1983). Therefore, there is a need to lift pH at depth.

- A lime rate and type by lucerne experiment was established in 2008:
    - Lime applied March 2008 (AgLime or QuickLime; @ 0, 2, 4 or 8 t/ha).
    - Trial site sprayed out in Mid Nov 2008.
    - 'Grasslands Kaituna' lucerne sown in early Dec 2008 at 14 kg/ha).

Plate 6 Horizontal root growth of lucerne at Lees Valley, Canterbury, probably in response to aluminium in the subsoil.

7.1 Accumulated total DM yields

Figure 25 shows accumulated total DM production for 2009/10 was 2.3±0.08 t/ha and 3.4±0.09 t/ha for 2010/11. The yield in 2011/12 was 9.6±0.38 t/ha. Neither form of lime, rate of lime nor their interaction affected yields produced over the three years. However, it should be noted that in Year 3 (2011/12) total yield was 2-3 times greater than in previous years with a mean daily growth rate in the second rotation (Dec-Jan) of about 95 kg DM/ha/day compared with about 40 kg DM/ha/day in spring and autumn rotations.

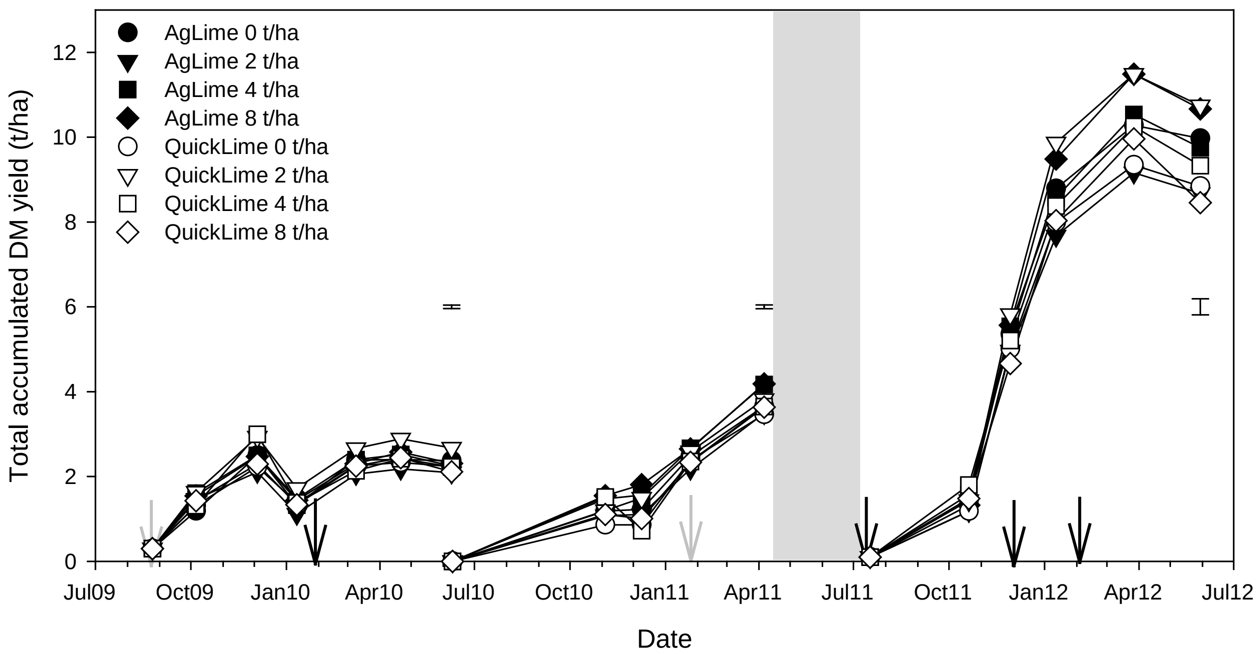

Figure 25 Accumulated total yield (t/ha) for lucerne with two forms of lime at four different rates prior to sowing. Grey arrows are dates the lucerne was mechanically topped and black arrows indicate grazing events. Grey areas indicate periods when no measurements were able to be taken. Error bars are the pooled SEM for the grand mean of total annual yield for 2009/10, 2010/11 and 2011/12 growth seasons.

7.2 Botanical composition

7.2.1 Spring Year 4 (2011/12)

BOTANAL evaluations on 20/10/11 (mid rotation) showed there was no effect of form or rate of lime on the volunteer white clover (28±3.2%), dicot weed (7±1.2%) or bare ground (12±2.4%) components of the lucerne stands (Figure 26).

However, the contribution of unsown grasses was more than double ($P<0.05$) in the AgLime treated lucerne (16%) compared with the 8% in the QuickLime treatment. Further, an interaction ($P<0.05$) between the rate and form of lime applied indicated the amount of lucerne cover was highest ($P<0.05$) in the 8 t/ha QuickLime (60%) and lowest in the 0 t/ha QuickLime swards (25%). All other lime rate and form combinations had 41±3.9% lucerne.

On the 29/11/2011, about 6 weeks later, composition of lucerne stands was evaluated again (i.e. no grazing occurred between these two evaluations). At this time, bare ground was not used as a category.

Lucerne contributed 50% more ($P<0.05$) to sward cover in the QuickLime amended swards compared with AgLime where 28% of cover was lucerne (Figure 27). Further the highest rates of lime (4 and 8 t/ha) had 45% lucerne which was more than double that in the control (0 t lime/ha). The contribution from volunteer white clover ranged from a minimum ($P<0.05$) of 25% (8 t lime/ha) to a maximum of 58% in the control (0 t lime/ha). There were more ($P<0.05$) unsown grasses in pastures amended with AgLime than those which received QuickLime but dicot weeds (5±1.2%) were similar in all treatments.

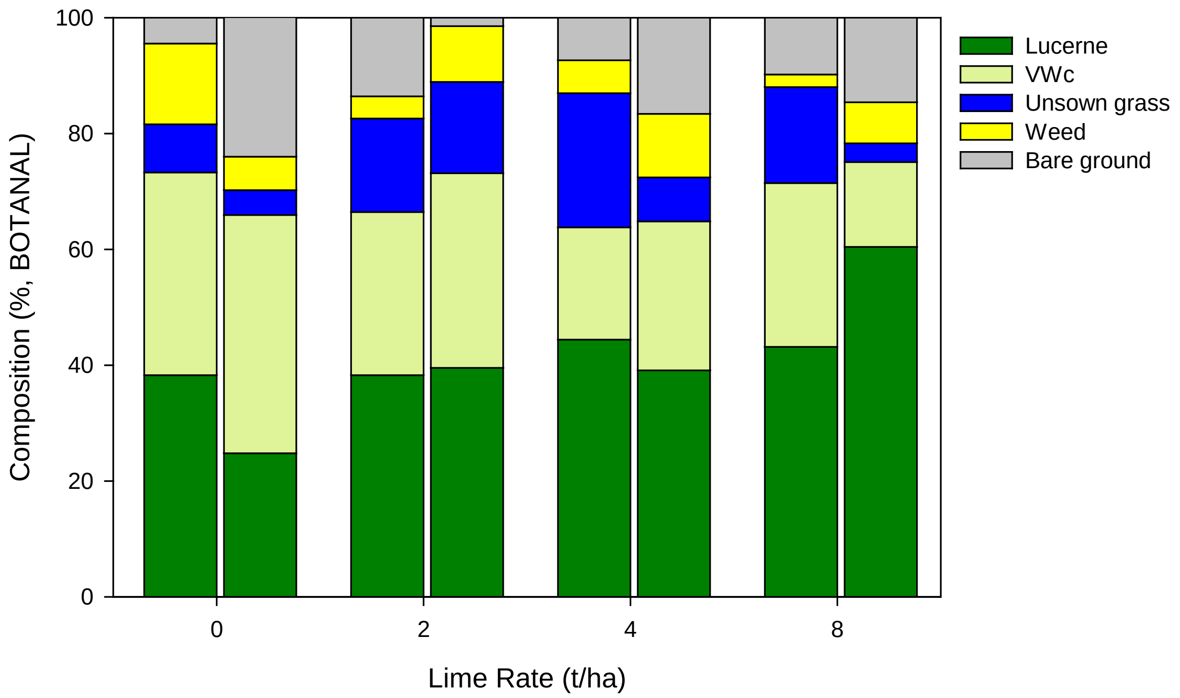

Figure 26 Botanical composition (%, BOTANAL) of lucerne on 20/10/2011 (spring Year 3) of lucerne swards established in 2008 at Lees Valley, Canterbury after soil amendment with AgLime (AgL) or QuickLime (QkL) at four different rates. Note: VWc is volunteer white clover.

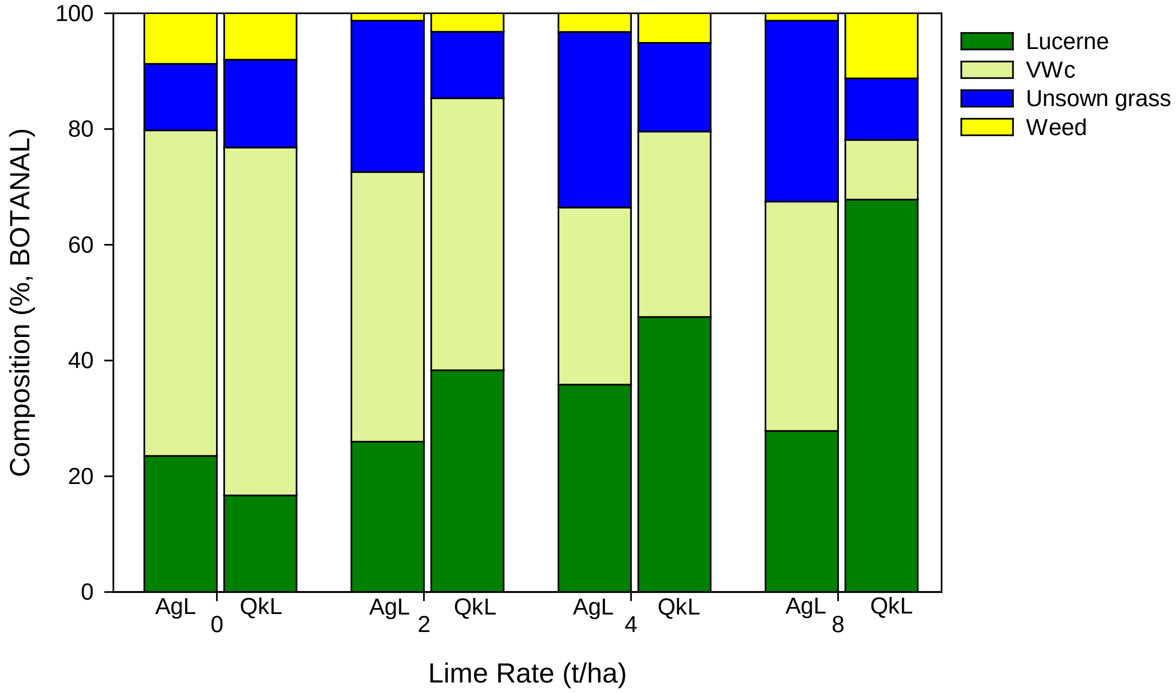

Figure 27 Botanical composition (%, BOTANAL) of lucerne on 29/11/2011 (spring, Year 3. Swards were established in 2008 at Lees Valley, Canterbury after soil amendment with AgLime (AgL) or QuickLime (QkL) at four different rates. Note: VWc is volunteer white clover.

7.3 Soil pH and Aluminium

7.3.1 Winter 2010/11

- Over all soil sampling depths and liming rates, soil pH was strongly related to soil plant-available aluminium (Figure 28).
- Soil exchangeable aluminium levels increased sharply below a soil pH of 5.8.
- At a soil pH of 5.8, exchangeable Al increased to 10 mg/kg or above. At this level, exchangeable Al is likely to reduce DM yield.

7.3.2 Winter 2011/12

- Soils were resampled at depths of 0-7.5, 7.5 to 15 and 15-30 cm in July 2012.
- pH and exchangeable Aluminium were unchanged from the late 2011 sampling.
- In most cases, soil pH increased with higher lime rates in the top 0-15 cm, but there has been little pH change observed below that depth. Exchangeable Al was dramatically reduced where soil pH was increased to 5.6 or above.
- Soil pH/Al levels positively influenced lucerne yield, although treatment differences were not significant at $P<0.05$ (refer Figure 25 and Figure 30).

7.3.3 How did the lime change soil pH and Al?

- Lime increased soil pH and lowered soil plant-available Al at the surface (top 7.5 cm of soil), especially for QuickLime at high rates (Figure 29).
    - The liming effect was small in the 7.5 – 15 cm depth, though significant for QuickLime at high application rates.
    - pH has remained low in the 15 – 30 cm depth, with soil Al remaining at high (toxic) levels in this horizon.
- In general, higher rates of lime resulted in higher soil pH and lower plant-available Al levels down the soil profile, though most pH change occurred in the 0 – 7.5 cm horizon.
- In the ‘medium term’ (now 3.5 years post lime application), QuickLime has been more effective at increasing soil pH at the high (8 t/ha) liming rate.

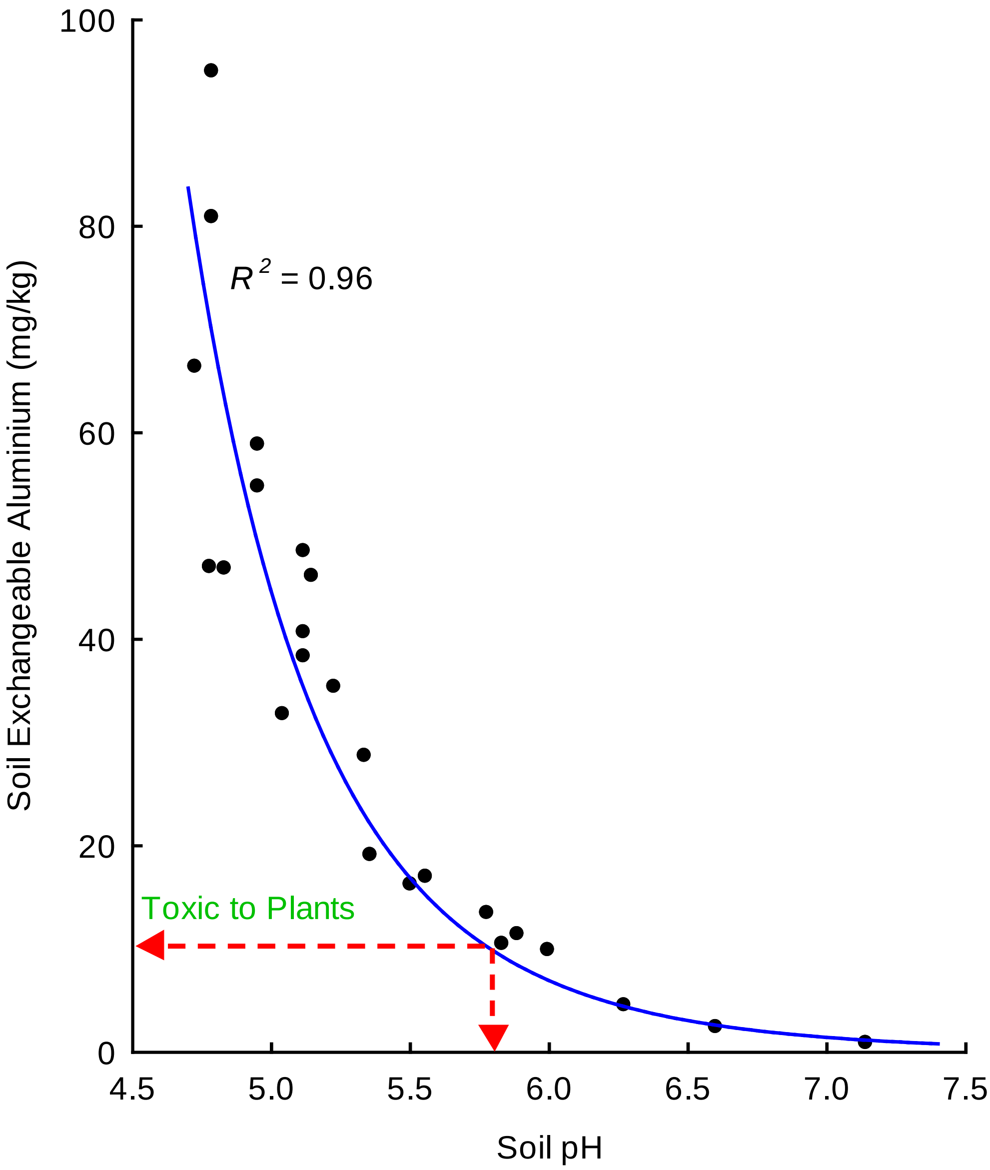

Figure 28 Relationship between soil aluminium and pH at Lees Valley, Canterbury. Soil samples were taken in Oct 2011.

7.3.4 Lime and lucerne yield

- DM cover (yield) is often low at this site and is soil moisture limited.
- Effect of lime/liming rate on yield has previously been unclear and is probably confounded by other factors.
- However, the full data set (mean values of many yield measurements) has now confirmed a yield response to liming at this site. Maximum yields were seen 4 – 8 t AgLime/ha, and 2 t QuickLime/ha (Figure 30).
- From results of our other research; it is possible that the higher soil pH at the 4 and 8 t/ha QuickLime rates limited soil phosphorus and/or trace element availability, which then limited yields for those treatments.

7.3.5 What other factors are currently influencing yield at this site?

- A comprehensive topsoil depth survey (depth to gravel at approx. 1.0 m intervals across the surface of the experimental area, Figure 31) has shown that topsoil depth is extremely variable, even over small distances (1–2 m). This results from soil deposition patterns from old braided river systems.
- Lucerne yields seem strongly related to topsoil depth/depth to gravel, and therefore the plant-available water storage capacity of the soil.

The failure of lucerne to thrive at this site due to high Al levels has led to further work to screen plants in glasshouse experiments using soil from the Lees Valley experimental area (Section 7.4).

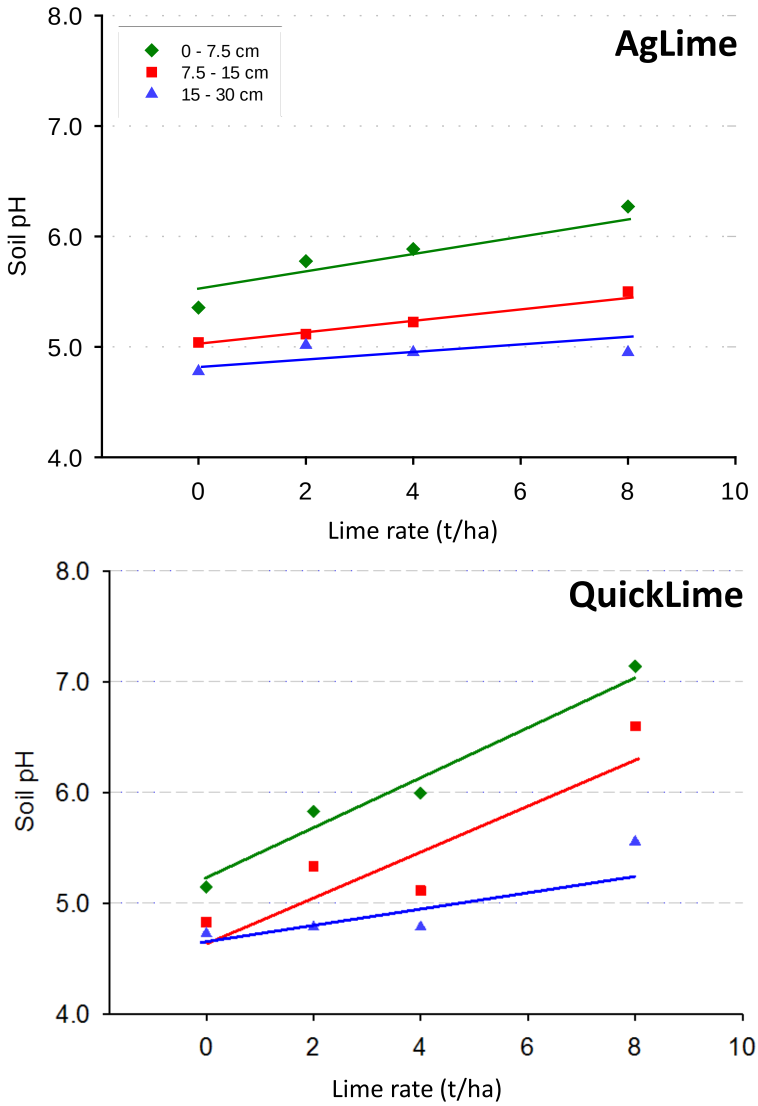

Figure 29 Change in soil pH in three soil layers after surface application of AgLime (top) or QuickLime (bottom). Soil samples were taken in Oct 2011 and lime was spread at 0, 2, 4 or 8 t/ha in March 2008.

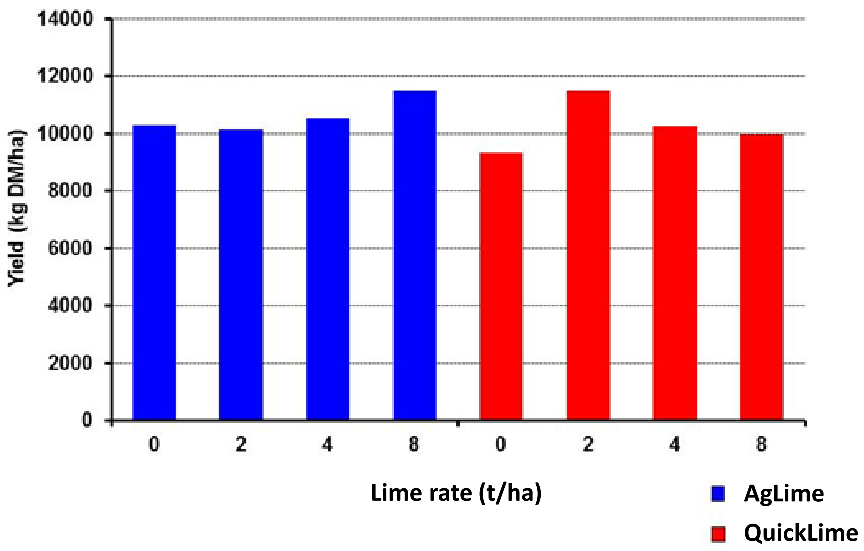

Figure 30 Lucerne yield in the final year (2011/12) after different forms and rates of lime were applied in March 2008.

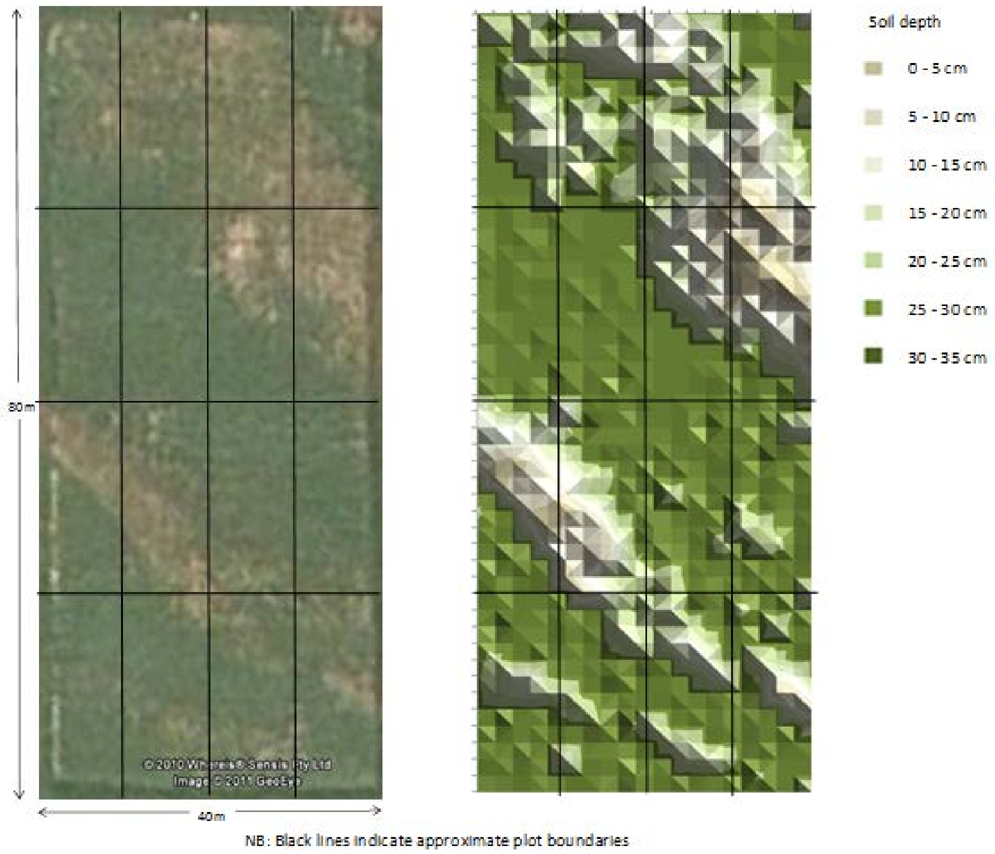

Figure 31 Depth of topsoil across the lucerne x lime experimental site at Lees Valley, Canterbury. The Google Earth satellite image (left, 25/11/2009) shows greener areas where soils are deeper, store more plant available water and allow lucerne growth to continue. The lighter, brown areas are shallower soils with stones nearer the soil surface (≤ 15 cm) and lower plant available water holding capacities. The figure on the right is measured soil depth across the experimental area.

7.4 Glasshouse Studies at Lincoln (2010/11)

- Current glasshouse studies at Lincoln University have focused on characterising potential high country legumes in terms of optimum soil pH and P requirements.
- Lucerne and Caucasian clover were grown in soil from the Lees Valley. Results show lucerne having a maximum yield between 4 and 6 t lime/ha, and Caucasian clover peaking at 3-4 t lime/ha (Figure 32).
- These results highlight the higher lime requirement of lucerne (which is consistent with the field trial results) and also indicate that Caucasian clover may have a higher tolerance of acid soil/high soil Al conditions.
- The depression in yield at high liming rates probably results from reduced soil P and trace element plant availability (at high soil pH).

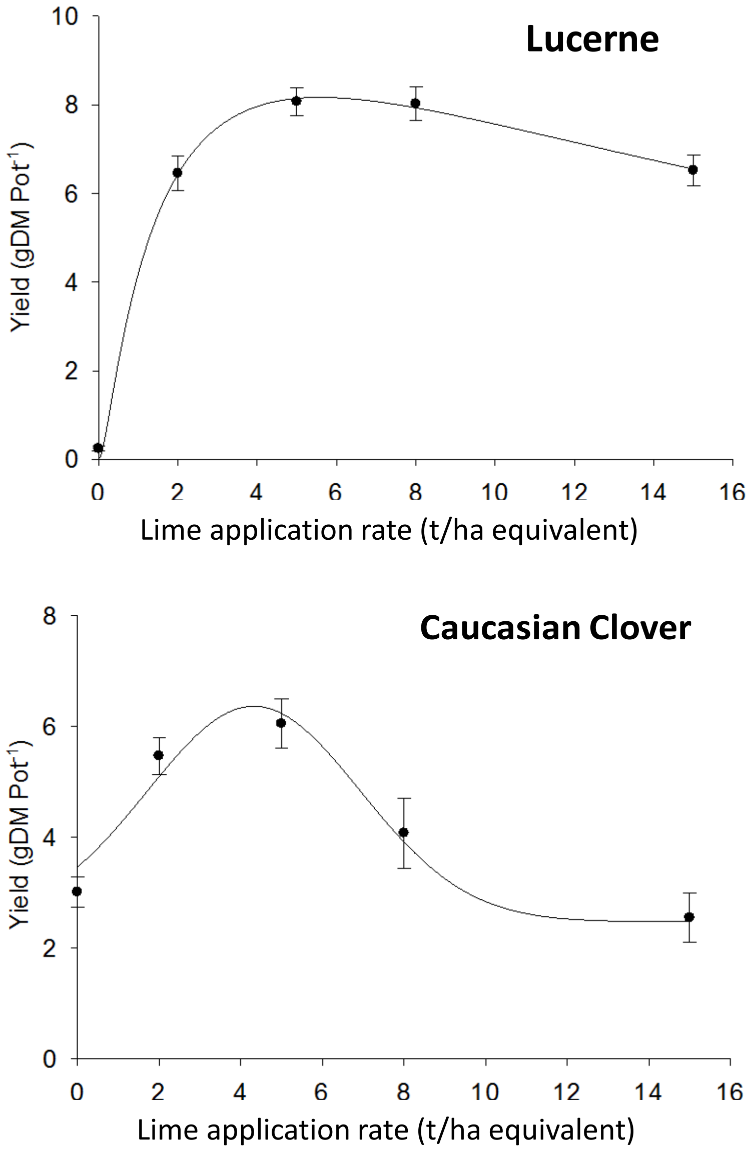

Figure 32 Dry matter yield (g DM/pot) of lucerne (top) and Caucasian clover (bottom) plants after different rates of lime were applied to soils from Lees Valley (Jordan 2011).

7.5 Conclusions

- Soil pH was strongly related to levels of plant-available aluminium.
- Lime increased soil pH and reduced plant-available aluminium in the short – medium term.
- Lime was most effective in the 0-7.5 cm horizon and much less effective at depth (15–30 cm). The pH and exchangeable Al in the 7.5–30 cm horizon remained at levels which would restrict lucerne growth, even for the limed treatments.
- Higher rates of lime were more effective at increasing soil pH. QuickLime showed an advantage over AgLime at the 8 t/ha rate in terms of penetration to the subsoil (7.5-30 cm). This response has not translated into a yield advantage to date.
- Soil pH/Al levels positively influenced lucerne yields. Extreme variability in depth of topsoil (micro-topography) and hence plant-available water storage have also influenced yields, especially in the first year of the trial.
- At this stage we recommend application of 2 t/ha QuickLime. Research is continuing.

Pasture Mixes (est. 2008) (Experiment 9)

This experiment was established in 2008 with a basal mix of ‘Nomad’ white clover and ‘Denmark’ sub clover included in all except the ‘Sonic’ short rotation ryegrass (monoculture). As with Experiment 6 because these pastures were established later (2008) than the other experiments the measurement Year (e.g. Year after establishment) differs from those reported elsewhere in the report.

9.1 Dryland Mixes 2008

9.1.1 Total annual yields

Total annual accumulated DM yields from the Dryland mixes experiment in Block 3 were highest from ‘dg25’ cocksfoot treatments in every one of the three years the pastures were monitored (Figure 33). In 2009/10, the 7.3 t DM/ha produced by ‘dg25’ cocksfoot was 53% more ($P<0.01$) than the 4.8±0.44 t/ha produced from ‘Bareno’ brome, ‘Sonic’ short rotation ryegrass or ‘Flecha’ tall fescue pastures. In 2010/11, there was an extra 1.2 t DM/ha produced from the cocksfoot compared ($P<0.05$) with the 3.2±0.25 t/ha from ‘Sonic’ or ‘Bareno’ pastures. However, the yield produced by ‘Flecha’ was not different to either group at 3.6 t/ha/yr.

In Year 6 total annual yield was the highest measured of the three years. Cocksfoot pastures produced12.3 t DM/ha which was 41% more ($P<0.05$) than the 8.7±0.6 t/ha from the three other pastures.

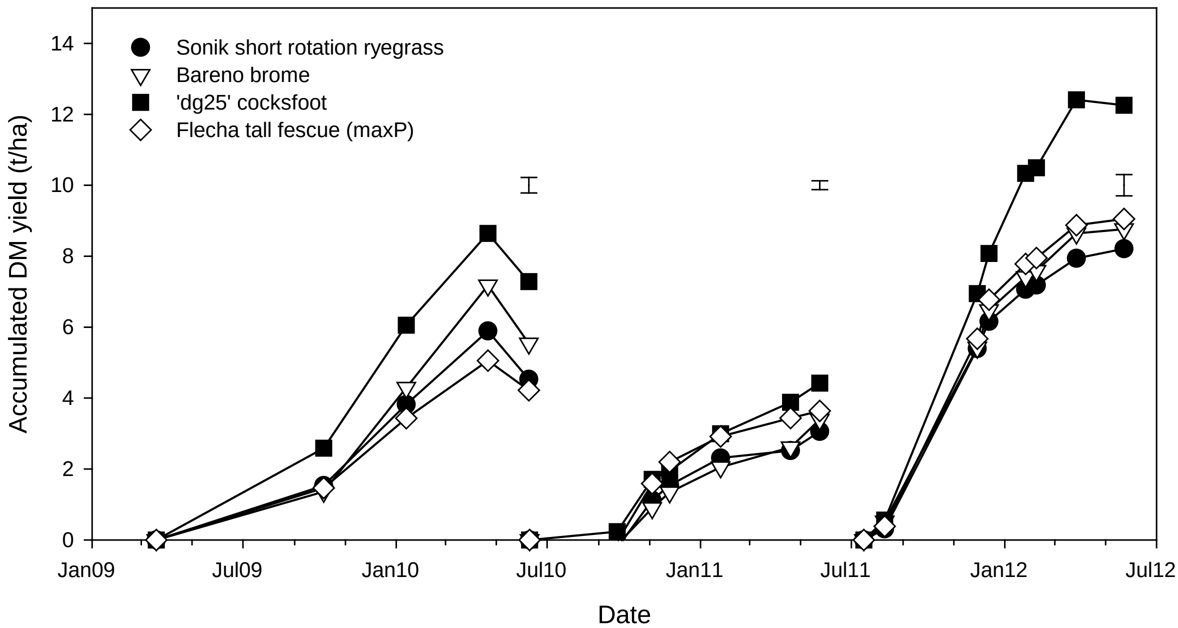

Figure 33 Accumulated DM yield (t/ha) of four dryland mix pastures in experimental block 3 at Lees Valley, Canterbury. Pastures were established in 2008. Error bars are SEM for the effect of treatment.

9.1.2 Botanical composition of Dryland mixes (established 2008).

9.1.2.1 Spring Year 3 (2010/11)

On 25/11/2010 visual estimates of pasture composition were made (Figure 34). These estimates were applied to total yield determined from a corresponding calibrated pasture probe measurement of standing dry matter yield. Total yield was 2.8±0.16 t/ha and similar for all pastures. There was more (P<0.01) sown grass in the cocksfoot (2.2 t/ha) mix than in the other pastures where sown grass yields were 1.3 ('Bareno') to 0.4 t/ha ('Sonic'). Sub clover yield was highest (P<0.001) in the 'Bareno' and tall fescue pastures (0.9±0.09 t/ha), compared with 0.5 t/ha in the cocksfoot pasture. No clover was sown with 'Sonic'.

White clover was highest (P<0.05) in the 'Sonic' short rotation ryegrass (1.0 t/ha) where no clover was sown (volunteer white clover). In contrast the other pastures where a basal rate of white clover was sown had 0-0.1 t/ha of white clover biomass and yields did not differ. The most unsown weed grasses were found in tall fescue and 'Sonic' pastures (0.9±0.16 t/ha) compared (P<0.05) with 0.1±0.16) t/ha in cocksfoot and 'Bareno' pastures. The amount of dicot weeds present in the swards at this time was unaffected by treatment (0.2±0.03 t//ha).

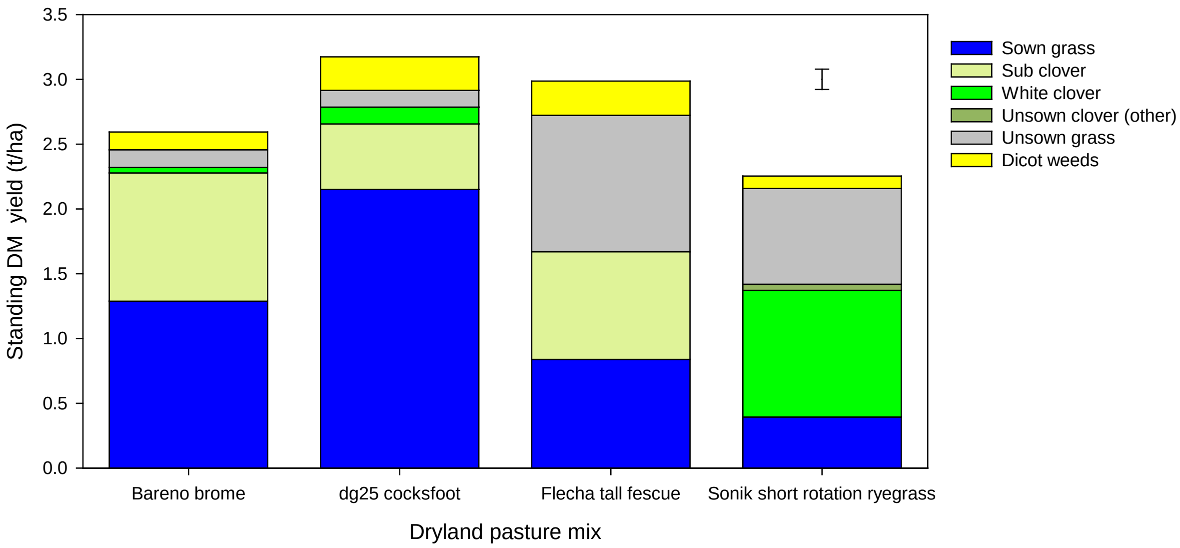

Figure 34 Botanical composition on 25/11/2010 (Spring, Year 3, established 2008) of mixed species pastures established in experimental block 3 at Lees Valley, Canterbury in 2008. Error bar is the SEM for total DM yield. White clover in the 'Sonic' pastures was unsown volunteer white clover whereas white clover in the other pastures was part of the seed mix sown.

9.1.2.2 Winter Year 3(2010/11)

The final evaluation of pasture composition was taken using the BOTANAL method on 1/6/2011. At this time no basal sub clover was present in any of the pastures indicating it had again failed to regenerate from the seed bank in autumn.

The 69% sown grass in the 'Bareno' brome pastures was more (P<0.05) than the 54% sown grass in the tall fescue pastures (Figure 35). Browntop re-invasion was highest (P<0.01) in the tall fescue pastures (16%) compared with 1±1.3% in the 'Bareno' and cocksfoot pastures.

There was no effect of treatment on basal white clover (18±1.8%), dicot weeds (0.5±0.5%) or bare ground (13±2.0%).

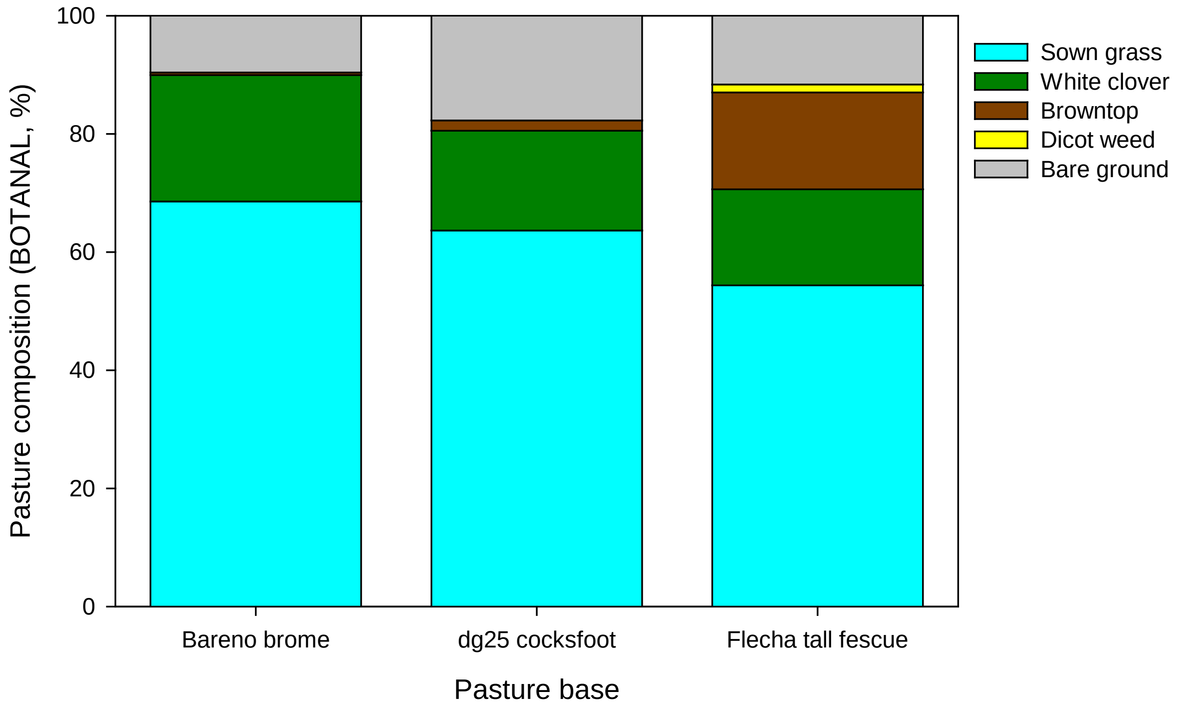

Figure 35 Botanical composition of dryland mixtures in winter (1/6/2011) of Year 3 from pastures established in experimental block 3 at Lees Valley, Canterbury in 2008. Sub and white clovers were basal to all treatments shown.

9.1.3 Conclusions from the Dryland Mixes (established 2008)

- Cocksfoot pastures produced the highest total DM yields in all three years.
- 'Bareno' and cocksfoot based pastures were the most effective at preventing the encroachment of browntop into the swards.
- Sub clover yield was lowest in cocksfoot pastures in spring 2009/10. No sub clover was present in winter 2010/11.
- Surprisingly, white clover appeared to contribute the most in spring as a volunteer component of the 'Sonic' pastures where it had not been sown. Buried white clover seed is ever present in most N.Z. soils.

10 References

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11 Acknowledgements & Sponsors

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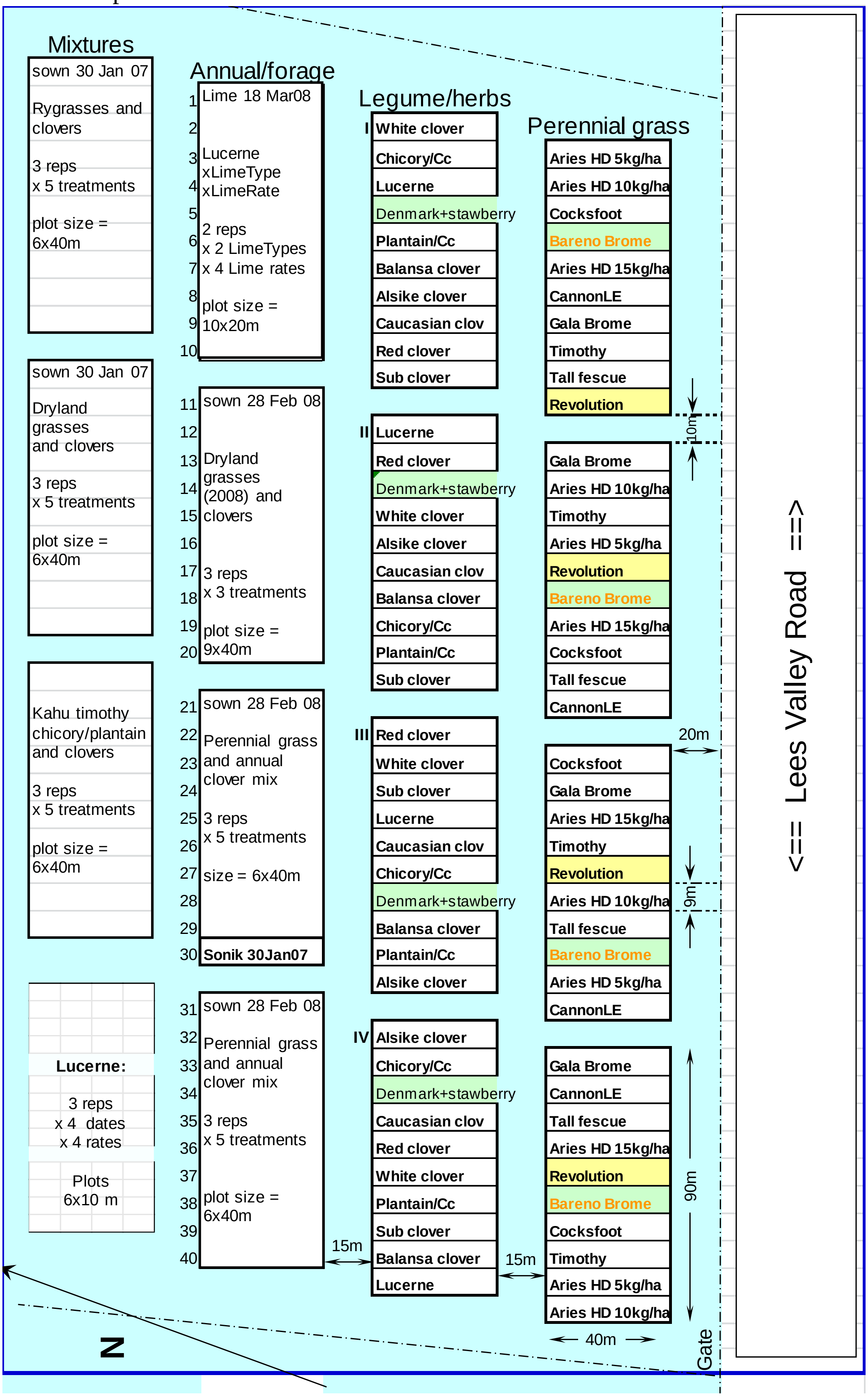
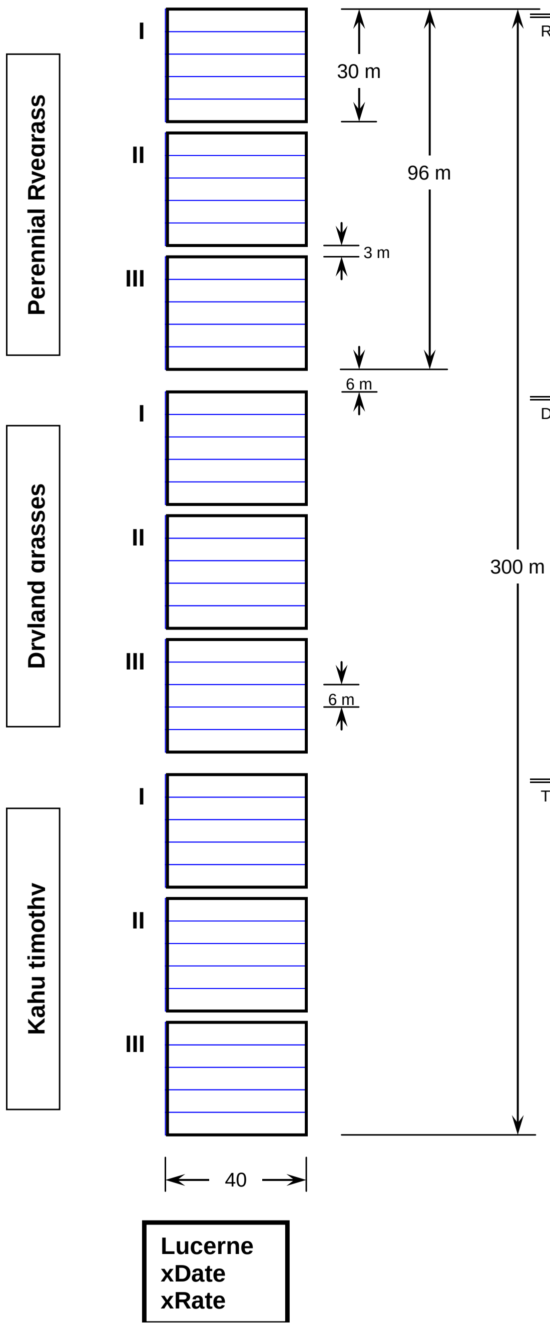
Appendix 1 Experimental area at Lees Valley Canterbury showing plot layout for Experiment 1 (perennial grasses) and Experiment 2 (Legume/herb block). Note: Experiment 8 (Grass responses to applied N fertiliser) was superimposed on Experiment 1



Appendix 2 Plot layout in Block 4 for Experiments 3 (perennial ryegrasses), 4 (Dryland grasses) and 5 (Timothy mixes).

Pasture mixtures: grass/clover/herbs



Experiment	Rep	Plot#	Trt#	Grass/forbs
Ryegrass	1	**1**	1	Revolution AR1 10kg
	1	**2**	3	Cannon HE 10kg
	1	**3**	5	Revolution 10 kg & Cf (dg25)
	1	**4**	4	Revolution AR1 20kg
	1	**5**	2	Samson AR1 10kg
	2	**6**	3	Cannon HE 10kg
	2	**7**	2	Samson AR1 10kg
	2	**8**	5	Revolution 10 kg & Cf (dg25)
	2	**9**	4	Revolution AR1 20kg
	2	**10**	1	Revolution AR1 10kg
	3	**11**	2	Samson AR1 10kg
	3	**12**	5	Revolution 10 kg & Cf (dg25)
	3	**13**	4	Revolution AR1 20kg
	3	**14**	1	Revolution AR1 10kg
	3	**15**	3	Cannon HE 10kg
Dryland mix	1	**16**	1	Advance Tf
	1	**17**	5	Ella Cf
	1	**18**	3	Bareno brome
	1	**19**	4	Agriseeds dg25 Cf
	1	**20**	2	Advance Tf +endophyte
	2	**21**	1	Advance Tf
	2	**22**	2	Advance Tf +endophyte
	2	**23**	5	Ella Cf
	2	**24**	4	Agriseeds dg25 Cf
	2	**25**	3	Bareno brome
	3	**26**	2	Advance Tf +endophyte
	3	**27**	5	Ella Cf
	3	**28**	1	Advance Tf
	3	**29**	4	Agriseeds dg25 Cf
	3	**30**	3	Bareno brome
Timothy	1	**31**	4	Kahu timothy & chic/pltn
	1	**32**	5	Kahu timothy & red clover
	1	**33**	3	Kahu timothy & plantain
	1	**34**	1	Kahu timothy
	1	**35**	2	Kahu timothy & chicory
	2	**36**	1	Kahu timothy
	2	**37**	3	Kahu timothy & plantain
	2	**38**	5	Kahu timothy & red clover
	2	**39**	4	Kahu timothy & chic/pltn
	2	**40**	2	Kahu timothy & chicory
	3	**41**	2	Kahu timothy & chicory
	3	**42**	1	Kahu timothy
	3	**43**	5	Kahu timothy & red clover
	3	**44**	4	Kahu timothy & chic/pltn
	3	**45**	3	Kahu timothy & plantain

Plus basal clover: Leura sub clover (10kg coated/ha) and Nomad white clover (2 kg/ha)

Appendix 3 Plot layout For Experiments 6 (perennial grasses with annual legumes) and Experiment 9(Dryland mixes est. 2008) in Block 3.

Plot layout for pasture mixes Lees Valley, Feb 08

Experiment	Rep	Plot#	Trt#	Grass/forbs
Dryland mix (2008)	1	1	1	Flecha Tall Fescue (maxP)
	1	2	3	Bareno brome
Basal =	1	3	2	dg25 cocksfoot
Denmark sub	2	4	3	Bareno brome
and Nomad wc	2	5	1	Flecha Tall Fescue (maxP)
				Existing Sonik short rotation ryegrass plot
	2	6	2	dg25 cocksfoot
	3	7	2	dg25 cocksfoot
plot size = 9 x 40 m	3	8	3	Bareno brome
	3	9	1	Flecha Tall Fescue (maxP)

	Rep	plot#	Grs#	Leg#	**Ryegrass clover headland**
Perennial grass + annual legs	1	1	1	1	Arrowleaf
	1	2	1	5	Woogenlup sub
	1	3	1	3	Denmark sub
Basal =	1	4	1	6	Pawera red
Nomad wc	1	5	1	4	Leura sub
oats	1	6	1	2	Persian
					New headland (9x40m) Bareno brome
with main plot	1	7	2	2	Persian
1= Bronsyn AR1 ryegrass	1	8	2	6	Pawera red
2=dg25 fine leaf cocksfoot	1	9	2	1	Arrowleaf
	1	10	2	5	Woogenlup sub
	1	11	2	3	Denmark sub
plot size = 6 x 40 m	1	12	2	4	Leura sub
					Existing Sonik short rotation ryegrass plot
					Existing Ryegrass clover headland
	2	13	2	5	Woogenlup sub
	2	14	2	4	Leura sub
	2	15	2	3	Denmark sub
	2	16	2	1	Arrowleaf
	2	17	2	6	Pawera red
	2	18	2	2	Persian
					New headland (9x40m) Bareno brome
	2	19	1	1	Arrowleaf
	2	20	1	6	Pawera red
	2	21	1	3	Denmark sub
					Existing Sonik short rotation ryegrass plot
	2	22	1	5	Woogenlup sub
	2	23	1	2	Persian
	2	24	1	4	Leura sub
					Existing Ryegrass clover headland

Appendix 4 Experimental design for Experiment 7 (lucerne by lime) in Block 3

Lucerne xLimeType xLimeRate (2008)

Plot Size = 10 x 20 m
with 3 m headlands
between ends of plots.
And a 4 m strip between
reps

Rep 1

Rep 2