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**Liveweight gain of sheep grazing lucerne, lucerne/grass mixes and  
lucerne supplemented with barley grain**

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A dissertation  
submitted in partial fulfilment  
of the requirements for the Degree of  
Bachelor of Agricultural Science with Honours  
at  
Lincoln University  
by  
L. A. Box

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Lincoln University

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Abstract of a dissertation submitted in partial fulfilment of the requirements for the Degree of Bachelor of Agricultural Science with Honours.

## **Liveweight gain of sheep grazing lucerne, lucerne/grass mixes and lucerne supplemented with barley grain**

by

L. A. Box

Animal production has proved superior from lucerne than other pastures in dryland situations. There is interest to include lucerne in a mix with grasses with complimentary growth patterns. Recently there has also been unpublished claims that liveweight gains on lucerne can be improved with grain supplementation. Experiment 1 was established at Ashley Dene in 2012/13 to compare liveweight production of sheep grazing lucerne, lucerne/brome and lucerne/cocksfoot mixes. In 2013/14 lucerne plus grain supplementation was added as Experiment 2. Over the 2013/14 season in Experiment 1, sheep grazing lucerne monocultures produced 808 kg LWT/ha, compared with 642 kg LWT/ha from lucerne/brome pastures and 605 kg LWT/ha from lucerne/cocksfoot pastures. In Experiment 1, 100% of the liveweight accumulated was from lambs. Spring liveweight production accounted for over half of the total annual production. Accumulated herbage dry matter yields were ~15 t/ha/y for all treatments in Experiment 1. All pastures used 837 mm of water at an efficiency of 18 kg DM/ha/mm and grew at 4.5 kg DM/ha/°Cd. Differences in lamb production in Experiment 1 were due to botanical compositions of the pastures which affected the energy available and consumed by animals. The lucerne component of lucerne/grass mixes reduced from an average 36.1% pre-grazing to 16.2% post grazing which was predominantly stalk. The grass component reduced from 33% pre grazing to 26% post-grazing which indicated a selection pressure towards lucerne. There was no difference in total annual ME produced by pastures among treatments. The selection towards lucerne shown in animals grazing lucerne/grass mixes resulted in a reduced intake of available ME due to less lucerne in the mixes (36%) than the monocultures (57%). This explained the differences in liveweight production. Animals grazing lucerne selectively grazed the leaf portion of the plant and avoided the stems which resulted in a build-up of dead material in all treatments. Using a second class of stock to follow after the lambs and graze the pastures to lower residuals could increase the utilisation of pastures and reduce the build-up of dead material. In Experiment 2, grain supplementation had no influence on lamb liveweight production, but advantages were seen in ewes. Ewes with access to barley grain gained 13 kg LWT/ha compared with ewes on the –grain treatment which lost 15 kg LWT/ha during the lactation phase. Over 80% of the grain fed occurred

before weaning which suggested ewes were consuming the majority of the grain. The lack of grain effect on the lambs was due to a lack of uptake of grain. Pastures on both grain treatments accumulated ~12 t DM/ha during the spring and summer when Experiment 1 occurred, this suggested no substitution occurred. Benefits may be seen in lambing from the ewes supplemented with grain due to increased condition at mating. Further measurements in the coming 2014/15 season are required, to confirm this.

**Keywords:** botanical composition, brome, *Bromus willdenowii*, cocksfoot, *Dactylis glomerata*, dryland, ewe, grazing brome, lamb, *Medicago sativa*, prairie grass, selection, water use.

# Table of Contents

1	INTRODUCTION .....	1
2	LITERATURE REVIEW .....	3
2.1	Pasture Species .....	3
2.2	Water Use .....	4
2.3	Dry matter production .....	6
2.4	Quality.....	9
2.5	Botanical Composition .....	11
2.6	Animal Requirements .....	13
2.6.1	Pasture allowance.....	13
2.6.2	Metabolisable energy .....	15
2.6.3	Protein.....	16
2.7	Animal production .....	17
2.8	Supplementation (of grain) to increase liveweight production.....	20
2.9	Grazing Behaviour .....	22
2.10	Conclusions .....	23
3	MATERIALS AND METHODS.....	24
3.1	Experimental Site .....	24
3.2	Site History.....	24
3.3	Soil fertility.....	25
3.4	Fertiliser .....	26
3.5	Meteorological data.....	26
3.6	Weed control .....	27
3.7	Experimental design.....	28
3.7.1	Experiment one.....	28
3.7.1.1	Livestock and grazing management.....	29
3.7.1.2	Measurements .....	30
3.7.1.2.1	Soil water budget.....	30
3.7.1.2.1.1	Potential soil water deficit.....	30
3.7.1.2.1.2	Soil water content (SWC).....	31
3.7.1.2.1.3	Water use efficiency .....	32
3.7.1.2.2	Dry matter measurements.....	32
3.7.1.2.2.1	Lucerne quality .....	35
3.7.1.2.2.2	Thermal time.....	35

3.7.1.2.3	Live weight measurements.....	36
3.7.1.3	Statistical Analysis.....	37
3.7.2	Experiment two.....	38
3.7.2.1	Livestock and grazing management.....	38
3.7.2.2	Grain supplementation.....	40
3.7.2.3	Measurements.....	41
3.7.2.3.1	DM measurements.....	41
3.7.2.3.2	Liveweight measurements.....	41
3.7.2.4	Statistical analysis.....	42
4	RESULTS.....	43
4.1	Experiment One.....	43
4.1.1	Animal production.....	43
4.1.1.1	Total animal production.....	43
4.1.1.2	Spring liveweight from ewes and lambs.....	44
4.1.1.3	Ewe liveweight.....	45
4.1.1.4	Rotational animal liveweight change.....	45
4.1.2	Pasture dry matter yield.....	47
4.1.2.1	Accumulated dry matter yield.....	47
4.1.2.2	Mean daily growth rates.....	48
4.1.2.3	Thermal time relationships.....	49
4.1.2.4	Botanical composition.....	50
4.1.2.4.1	Annual botanical composition.....	50
4.1.2.4.2	Rotation 1.....	51
4.1.2.4.3	Rotation 2.....	52
4.1.2.4.4	Rotation 3.....	53
4.1.2.4.5	Rotation 4.....	55
4.1.2.5	Nutritive yield.....	58
4.1.2.5.1	Metabolisable energy content.....	58
4.1.2.5.1.1	Annual.....	58
4.1.2.5.1.2	Rotation 1.....	59
4.1.2.5.1.3	Rotation 2.....	60
4.1.2.5.1.4	Rotation 3.....	60
4.1.2.5.1.5	Rotation 4.....	61
4.1.2.5.2	Nitrogen content.....	62
4.1.2.5.2.1	Annual.....	62

4.1.2.5.2.2	Rotation 1 .....	63
4.1.2.5.2.3	Rotation 2 .....	64
4.1.2.5.2.4	Rotation 3 .....	65
4.1.2.5.2.5	Rotation 4 .....	66
4.1.2.6	Soil water content .....	67
4.1.2.6.1	Available water .....	67
4.1.2.6.2	Water use and water use efficiency .....	69
4.2	Experiment Two .....	70
4.2.1	Animal production .....	70
4.2.1.1	Seasonal accumulated liveweight production .....	70
4.2.1.2	Spring liveweight from ewes and lambs .....	70
4.2.1.3	Ewe liveweight .....	71
4.2.1.4	Rotational liveweight gain .....	72
4.2.2	Pasture dry matter yield .....	73
4.2.2.1	Accumulated dry matter yield .....	73
4.2.3	Grain consumption.....	74
5	DISCUSSION.....	75
5.1	Experiment 1.....	75
5.1.1	Animal production .....	75
5.1.1.1	Liveweight production .....	75
5.1.1.2	Rotational liveweight gains.....	77
5.1.2	Pasture dry matter yield .....	78
5.1.2.1	Accumulated dry matter yield .....	78
5.1.2.2	Mean daily growth rates .....	79
5.1.2.3	Soil water budget .....	80
5.1.2.4	Thermal time.....	80
5.1.2.5	Botanical composition.....	81
5.1.3	Nutritive yield.....	82
5.1.3.1	Metabolisable energy .....	82
5.1.3.2	Nitrogen yield.....	84
5.2	Experiment 1 Conclusions.....	86
5.3	Experiment 2.....	87
5.3.1	Animal production .....	87
5.3.1.1	Liveweight production .....	87
5.3.1.2	Rotational liveweight gains.....	87

5.3.2	DM Production.....	88
5.3.3	Grain consumption.....	89
5.4	Experiment 2 Conclusions.....	90
6	GENERAL DISCUSSION.....	91
7	ACKNOWLEDGEMENTS.....	93
8	REFERENCES.....	94
9	APPENDICES.....	100

## List of tables

Table 2.1: Crude protein (g/g DM) and ME (MJ/kg DM) contents of herbage fractions (palatable, unpalatable and weed) and post-grazing residual of chicory, lucerne and red clover swards grown over five years. Values in parenthesis are standard errors for each mean calculated from five year's data. (Brown & Moot, 2004).....	10
Table 2.2: Annual metabolisable energy yield (GJ ME/ha) and N yield (kg N/ha) of lucerne monocultures, lucerne/ cocksfoot (Luc/CF) and lucerne/brome (Luc/Br) mixes at Ashley Dene, Canterbury (2012/13). Sown species yield is presented as the sum of the lucerne and sown grass yields (Coutts, 2013).....	11
Table 3.1: Species cultivar, sowing date, rate and drill type for paddocks C6E, C7W and C7E at Ashley Dene, Canterbury.....	25
Table 3.2: Soil test results from May/June 2011 for paddocks C6E, C7E and C7W at Ashley Dene, Canterbury. ....	26
Table 3.3: Summary of stock class, start and end date and plots grazed for each grazing rotation from 3/09/2013 to 30/04/2014 at Ashley Dene, Canterbury, New Zealand. Where E & L denotes ewes and lambs, WL denotes weaned lambs. ....	29
Table 3.4: Regressions used for DM calculations for lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes at Ashley Dene, Canterbury. ....	33
Table 3.5: Summary of timing of grazing rotations for lucerne monocultures, lucerne brome (Luc/Br) and lucerne/ cocksfoot (Luc/Cf) pastures at Ashley Dene, Canterbury. Grazing began on the 03/09/2013 and finished on the 09/05/2014. ....	35
Table 3.6: Summary of stock classes and measurements taken for grazing rotations from 13/09/13 to 30/04/2014. Where E & L denotes ewes and lambs, W L denotes weaned lambs, Ram Hgts denotes ram hoggets and Ewe Hgts denotes ewe hoggets. Measurements taken include dry matter yield (DM), animal liveweight gain (LWt), botanical composition (BC) and nutritive value (NU) and are indicated by a 'Y'. LWT period determines if the rotation was a 'production' or 'maintenance' period. Liveweight (LWT) rotation is when stock were weighed relative to grazing rotations.....	36
Table 3.7: Summary of stock grazing lucerne pastures with grain supplementation (+) and without grain supplementation (-) for either production or maintenance liveweight (LWT) from 13/09/2013 to 03/02/2014 at Ashley Dene, Canterbury. ....	39

Table 3.8: Barley grain allocated to Advantage feeders for the spring and summer period of the experiment at Ashley Dene, Canterbury. E&L denotes ewes and lambs, WL denotes weaned lambs.....	41
Table 4.1: Liveweight change (g/head/d) of ewes and lambs grazed on lucerne, lucerne/ cocksfoot (Luc/CF) or lucerne/brome (Luc/Br) mixes over liveweight Rotations 1, 2 and 3 from 03/09 to 02/12/13 at Ashley Dene, Canterbury, New Zealand. ....	46
Table 4.2: Liveweight gain (g/head/d) of lambs grazed on lucerne, lucerne/brome (Luc/Br) or lucerne/ cocksfoot (Luc/Cf) mixes over liveweight Rotations 4, 5 and 6 from 02/12/2013 to 03/02/2014 at Ashley Dene, Canterbury, New Zealand .....	46
Table 4.3: Liveweight gain (g/head/d) of ram hoggets grazed on lucerne, lucerne/ cocksfoot (Luc/CF) or lucerne/brome (Luc/Br) mixes over liveweight Rotation 7 from 24/03/2014 to 09/05/2014 at Ashley Dene, Canterbury, New Zealand .....	47
Table 4.4: Annual pre-grazing botanical composition of lucerne monocultures, lucerne/brome (Luc/Br) and lucerne/ cocksfoot (Luc/Cf) mixes from 19/09/2013 to 30/04/2014 at Ashley Dene, Canterbury.....	51
Table 4.5: Annual post-grazing botanical composition of lucerne monocultures, lucerne/brome (Luc/Br) and lucerne/ cocksfoot (Luc/Cf) mixes from 19/09/2013 to 30/04/2014 at Ashley Dene, Canterbury.....	51
Table 4.6: Pre-graze botanical composition of lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes for grazing Rotation 1 from 2/09 to 21/10/2013 at Ashley Dene, Canterbury.....	52
Table 4.7:Pre-graze botanical composition of lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes for grazing Rotation 2 from 21/10 to 3/12/2013 at Ashley Dene, Canterbury.....	52
Table 4.8: Post-graze botanical composition of lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes for grazing Rotation 2 from 21/10 to 3/12/2013 at Ashley Dene, Canterbury.....	53
Table 4.9: Dry matter (kg DM/ha) consumed by ewes and lambs of lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes for grazing Rotation 2 from 21/10 to 3/12/2013 at Ashley Dene, Canterbury. Negative values indicate an increase in DM of a component after grazing. ....	53

Table 4.10: Pre-graze botanical composition of lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes for grazing Rotation 3 from 3/12/2013 to 7/01/2014 at Ashley Dene, Canterbury. ....	54
Table 4.11: Post-graze botanical composition of lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes for grazing Rotation 3 from 3/12/2013 to 7/01/2014 at Ashley Dene, Canterbury. ....	54
Table 4.12: Dry matter (kg DM/ha) consumed by weaned lambs of lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes for grazing Rotation 3 from 3/12/2013 to 7/01/2014 at Ashley Dene, Canterbury. Negative values indicate an increase in DM of a component after grazing. ....	55
Table 4.13: Pre-graze botanical composition of lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes for grazing Rotation 4 from 7/01 to 23/03/2014 at Ashley Dene, Canterbury. ....	56
Table 4.14: Post-graze botanical composition of lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes for grazing Rotation 4 from 7/01 to 23/03/2014 at Ashley Dene, Canterbury. ....	56
Table 4.15: Dry matter (kg DM/ha) consumed by ewes and lambs of lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes for grazing Rotation 4 from 7/01 to 23/03/2014 at Ashley Dene, Canterbury. Negative values indicate an increase in DM of a component after grazing. ....	57
Table 4.16: Annual average pre-grazing metabolisable energy (MJ ME/kg DM) and total yield (GJ/ha) of lucerne monocultures, lucerne/brome (Luc/Br) and lucerne/ cocksfoot (Luc/Cf) mixes from 19/09/2013 to 30/04/2014 at Ashley Dene, Canterbury. ....	58
Table 4.17: Annual post-grazing metabolisable energy (MJ ME/kg DM) and corresponding average rotational yield (GJ/ha) of lucerne monocultures, lucerne/brome (Luc/Br) and lucerne/ cocksfoot (Luc/Cf) mixes from 19/09/2013 to 30/04/2014 at Ashley Dene, Canterbury. ....	58
Table 4.18: Pre-graze metabolisable energy (MJ ME) and ME yield (GJ/ha) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 1 from 2/09 to 21/10/2013 at Ashley Dene, Canterbury, New Zealand. ....	59

Table 4.19: Pre-graze metabolisable energy (MJ ME) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 2 from 21/10 to 3/12/2013 at Ashley Dene, Canterbury, New Zealand. ....	60
Table 4.20: Post-graze metabolisable energy (MJ ME) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 2 from 21/10 to 3/12/2013 at Ashley Dene, Canterbury, New Zealand. ....	60
Table 4.21: Pre-graze metabolisable energy (MJ ME) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 3 from 3/12/2013 to 7/01/2014 at Ashley Dene, Canterbury, New Zealand. ....	61
Table 4.22: Post-graze metabolisable energy (MJ ME) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 3 from 3/12/2013 to 7/01/2014 at Ashley Dene, Canterbury, New Zealand. ....	61
Table 4.23: Pre-graze metabolisable energy (MJ ME) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 4 from 7/01 to 23/03/2014 at Ashley Dene, Canterbury, New Zealand. ....	62
Table 4.24: Post-graze metabolisable energy (MJ ME) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 4 from 7/01 to 23/03/2014 at Ashley Dene, Canterbury, New Zealand. ....	62
Table 4.25: Annual pre-grazing nitrogen content (N%) and corresponding yield (kg N/ha) of lucerne monocultures, lucerne/brome (Luc/Br) and lucerne/cocksfoot (Luc/Cf) mixes from 19/09/2013 to 30/04/2014 at Ashley Dene, Canterbury. ....	63
Table 4.26: Annual post-grazing nitrogen content (N%) and corresponding average rotational yield (kg N/ha) of lucerne monocultures, lucerne/brome (Luc/Br) and lucerne/cocksfoot (Luc/Cf) mixes from 19/09/2013 to 30/04/2014 at Ashley Dene, Canterbury. ....	63
Table 4.27: Pre-graze nitrogen concentration (%) and N yield (kg/ha) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 1 from 2/09 to 21/10/2013 at Ashley Dene, Canterbury, New Zealand. ....	64
Table 4.28: Pre-graze nitrogen concentration (%) and N yield (kg/ha) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 2 from 21/10 to 3/12/2013 at Ashley Dene, Canterbury, New Zealand. ....	64

Table 4.29: Post-graze nitrogen concentration (%) and N yield (kg/ha) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 2 from 21/10 to 3/12/2013 at Ashley Dene, Canterbury, New Zealand. ....	65
Table 4.30: Pre-graze nitrogen concentration (%) and N yield (kg/ha) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 3 from 3/12/2013 to 7/01/2014 at Ashley Dene, Canterbury, New Zealand. ....	65
Table 4.31: Post-graze nitrogen concentration (%) and N yield (kg/ha) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 3 from 3/12/2013 to 7/01/2014 at Ashley Dene, Canterbury, New Zealand. ....	66
Table 4.32: Pre-graze nitrogen concentration (%) and N yield (kg/ha) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 4 from 7/01 to 23/03/2014 at Ashley Dene, Canterbury, New Zealand. ....	66
Table 4.33: Post-graze nitrogen concentration (%) and N yield (kg/ha) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 4 from 7/01 to 23/03/2014 at Ashley Dene, Canterbury, New Zealand. ....	67
Table 4.34: Water use (WU) of lucerne monocultures, lucerne/brome (Luc/Br) and lucerne/cocksfoot (Luc/Cf) mixes from 01/07/13 to 24/03/14 based on PET at Ashley Dene, Canterbury. ....	69
Table 4.35: Liveweight change (g/head/d) of ewes and lambs grazed on lucerne with grain supplementation (+grain) or without grain supplementation (-grain) over liveweight (LWT) Rotations 1, 2 and 3 from 13/09 to 02/12/13 at Ashley Dene, Canterbury, New Zealand .....	73
Table 4.36: Liveweight gain (g/head/d) of lambs grazed on lucerne with grain supplementation (+grain) or without grain supplementation (-grain) over liveweight (LWT) Rotations 4, 5 and 6 from 02/12/13 to 03/02/14 at Ashley Dene, Canterbury, New Zealand.....	73

## List of figures

Figure 2.1: Water extraction (mm) from each 0.1 m soil layer from 0-2.3 m depth for lucerne (circles) and grass based pasture (triangles) on a deep Wakanui silt loam (solid symbols) or a Lismore (A) very stony loam and Lismore (B) stony loam (open symbols) (Moot <i>et al.</i> , 2008). .....	3
Figure 2.2: Spring dry matter yield (t/ha) and water use (mm) for lucerne (WUE = 24 kg DM/ha/mm), perennial ryegrass/white clover (RG/Wc, WUE = 20 kg DM/ha/mm) and perennial ryegrass (RG, WUE = 13 kg DM/ha/mm) pastures at Lincoln, Canterbury between 29/9-9/12/1993 (Moot <i>et al.</i> , 2008). .....	5
Figure 2.3: Annual dry matter production in a) 2004/05 and b) 2005/06 of six dryland pastures grown at Lincoln University. Cf = cocksfoot, Cc = balansa clover, Sc =subterranean clover, Cc = Caucasian clover, Wc = white clover, Rg = ryegrass, Luc = lucerne. Bars represent one LSD. From Brown <i>et al.</i> (2006). .....	8
Figure 2.4: The total accumulated dry matter (DM) yield of lucerne monocultures (●), lucerne/brome (▽), and lucerne/cocksfoot (■) pastures from 1/07/2012 to 30/06/2013 at Ashley Dene, Canterbury, New Zealand. Grey area indicates the period when no measurements were taken due to low summer growth (Coutts, 2013). .....	9
Figure 2.5: Seasonal dry matter production of lucerne and sown companion grass (Cullen, 1965) ...	12
Figure 2.6: Botanical composition of lucerne and lucerne/prairie grass pastures under low, medium and high stocking rates. Low stocking rate (LSR), medium stocking rate (MSR) and high stocking rate (HSR) (Marsh & Brunswick, 1977). .....	13
Figure 2.7: Liveweight gain of suckling lambs during lactation at different pasture allowance (Rattray <i>et al.</i> , 1987) .....	14
Figure 2.8: Responses in lamb growth to pasture allowance varies depending on the pasture species offered (Jagusch <i>et al.</i> , 1979).....	15
Figure 2.9: Liveweight produced per hectare from six dryland pastures at Lincoln University. Cf = cocksfoot, Bc = balansa clover, Sc = subterranean clover, Cc = Caucasian clover, Wc = white clover, Rg = ryegrass, Luc = lucerne. Error bars represent one LSD above periods when production was different (Brown <i>et al.</i> , 2006). .....	18
Figure 2.10: Annual liveweight production of lucerne monocultures, lucerne/brome (Luc/Br) and lucerne/cocksfoot (Luc/CF) mixes over five liveweight production periods from 1/07/2012 to 30/06/2013 at Ashley Dene, Canterbury, New Zealand. Stacked bars represent spring	

liveweight gain with ewes and lambs(■), summer liveweight gain with weaned lambs (⊞) and autumn liveweight gain with ewe hoggets (■). The error bar is SEM for accumulated liveweight production (Coutts, 2013). .....	19
Figure 2.11: Major reasons for supplementary feeding in grazing systems (Dove, 2002). .....	20
Figure 3.1: Mean monthly air temperature (a) and rainfall (b) (bars) for the 2013/2014 growing season with long term means (lines) for the period 1975-2010 (air temperature) and 1980-2009 (rainfall). Data were obtained from Ashley Dene weather station (43°65'S,172°35'E). 27	
Figure 3.2: Stocking rate of ewes and lambs grazing on lucerne monocultures (●), lucerne/brome (□) and lucerne/ cocksfoot (▲) from the 19/09/2013 to the 09/05/2014 at Ashley Dene, Canterbury. ....	30
Figure 3.3: Potential soil moisture deficit (PSMD, mm) between 01/07/2013 and 15/05/2014 for paddocks C6E and C7E at Ashley Dene, Canterbury, New Zealand.....	31
Figure 3.4: Spring (a) and summer (b) linear regressions of lucerne height versus dry matter (DM) yield at Ashley Dene, Canterbury for old (○) and new (●) lucerne monocultures, old (□) and new (■) lucerne/brome pastures and lucerne/ cocksfoot (▲) pastures. Regressions used are given in Table 3.4. ....	34
Figure 3.5: Stocking rate of ewes and lambs from 13/09/2013 to 03/02/2014 on lucerne monocultures – grain (●) and + grain (▽) at Ashley Dene, Canterbury, New Zealand. ....	39
Figure 4.1: Annual liveweight production of lucerne monocultures, lucerne/brome (Luc/Br) and lucerne/ cocksfoot (Luc/CF) mixes over seven liveweight production periods from 3/09/2013 to 09/05/2014 at Ashley Dene, Canterbury, New Zealand. Stacked bars represent spring liveweight gain with ewes and lambs (■), summer liveweight gain with weaned lambs (⊞) and autumn liveweight gain with ram hoggets (■). ....	43
Figure 4.2: Spring liveweight production (kg LWT/ha) for Rotations 1 to 3 for lambs (a) and ewes (b) grazing lucerne monocultures (■), lucerne/brome (⊞) and lucerne/ cocksfoot (■) mixes at Ashley Dene, Canterbury, New Zealand. The error bar is SEM for lamb liveweight production across treatments. ....	44
Figure 4.3: Change in lactating ewe liveweight from 03/09 to 02/12/2013 (weaning) on lucerne monocultures (●), lucerne/brome (□) and lucerne/ cocksfoot (▲) mixes at Ashley Dene, Canterbury, New Zealand. ....	45

Figure 4.4: The total accumulated dry matter (DM) yield of lucerne monocultures (●), lucerne/brome (□), and lucerne/ cocksfoot (▲) pastures from 1/07/2013 to 30/04/2014 at Ashley Dene, Canterbury, New Zealand. Error bars are +/- SEM. ....	48
Figure 4.5: Mean daily growth rates of lucerne monocultures (●), lucerne/brome (□), and lucerne/ cocksfoot (▲) pasture mixes for regrowth cycles between 01/07/2013 and 30/04/2014 at Ashley Dene, Canterbury, New Zealand. Error bars are SEM for each harvest date. ....	49
Figure 4.6: Relationship between accumulated dry matter (DM) yield and accumulated thermal time (°Cd, Tb=0°C) for rates of lucerne monocultures (●), lucerne/brome (□), and lucerne/ cocksfoot (▲) pasture mixes from 01/07/2013 and 30/04/2014. Thermal time was accumulated using air temperature. The regression was: Yield = 4.5+0.21x – 430+494 (R <sup>2</sup> =0.98) .....	50
Figure 4.7: Soil water content of Plot 7 (top) and Plot 17 (bottom) in paddocks C6E and C7E, Ashley Dene, Canterbury. Where (●) is the upper limit and (○) is the lower limit for plant available water. ....	68
Figure 4.8: Accumulated dry matter yield (kg DM/ha) against accumulated PET (mm) which represented water used for lucerne monocultures (●), lucerne/brome (□), and lucerne/ cocksfoot (▲) pasture mixes from 01/07/13 to 24/03/14. Regression was: Yield = 18.0+0.75x + 2224+339 (R <sup>2</sup> =0.89). ....	69
Figure 4.9: Liveweight production of animals lucerne monocultures + or – grain supplementation over five liveweight production periods from 13/09/2013 to 03/02/2014 at Ashley Dene, Canterbury, New Zealand. Stacked bars represent spring liveweight gain with ewes and lambs (■), summer liveweight gain with weaned lambs (▣). The error bar is SEM for accumulated liveweight production from the summer period across treatments. ....	70
Figure 4.10: Spring liveweight production (kg LWT/ha) for Rotation 1 to 3 for lambs (■) and ewes (■) grazing lucerne monocultures + or – grain supplementation at Ashley Dene, Canterbury, New Zealand. The error bars are SEM for liveweight production from lambs across treatments. ....	71
Figure 4.11: Change in lactating ewe liveweight from 13/09 to 02/12/2013 (weaning) on lucerne monocultures – grain (●) and + grain (▽) at Ashley Dene, Canterbury, New Zealand. Error bars are SEM. ....	72

Figure 4.12: The total accumulated dry matter (DM) yield of lucerne monoculture pastures – grain (▽) and + grain (●), pastures from 1/07/2013 to 06/01/2014 at Ashley Dene, Canterbury, New Zealand. Error bars are SEM across treatments for each rotation..... 74

## List of plates

Plate 3.1: Map of experimental design showing paddocks C6E, C7W and C7E and plots 1-18. The total experimental area is 17.7 ha. At Ashley Dene, Canterbury. ◆ represents grain allocated plots. ....	28
Plate 3.2: Measurement of soil water content with a neutron probe (Troxler) in Plot 1 at Ashely Dene, Canterbury on 27/03/2014.....	32
Plate 3.3: Ewes and lambs with an Advantage grain feeder in Plot 13 at Ashley Dene, Canterbury on 01/11/2013. ....	40
Plate 4.1: Ewes grazing lucerne/ocksfoot pastures in Plot 2 showing the selection for lucerne, on the 11/05/2014 at Ashley Dene, Canterbury.....	57
Plate 2: Lucerne/brome pastures on 10/12/2013 at Ashley Dene, Canterbury, New Zealand. Reproductive stems are visible, highlighting the quality decline of the grass component. ....	59
Plate 3: Lambs seeking shelter under the Advantage grain feeder in Plot 16 on 22/01/2013 at Ashley Dene, Canterbury.....	74

## List of appendices

Appendix 9.1: Soil map of paddocks C6E, C7W and C7E at Ashley Dene, Canterbury, New Zealand.	100
Appendix 9.2: Detailed stock movements for grazing rotations on lucerne/brome at Ashley Dene, Canterbury, New Zealand from 3/09/2013 to 05/05/2014.	101
Appendix 9.3: Detailed stock movements for grazing rotations on lucerne/socksfoot at Ashley Dene, Canterbury, New Zealand from 3/09/2013 to 09/05/2014.	102
Appendix 9.4: Detailed stock movements for grazing rotations on lucerne monocultures at Ashley Dene, Canterbury, New Zealand from 3/09/2013 to 09/05/2014.	103
Appendix 9.5: Soil water content of Plot 1 (top) and Plot 2 (bottom) in paddocks C6E and C7E, Ashley Dene, Canterbury. Where (●) is the upper limit and (○) is the lower limit for plant available water.	104
Appendix 9.6: Soil water content of Plot 3 (top) and Plot 4 (bottom) in paddocks C6E and C7E, Ashley Dene, Canterbury. Where (●) is the upper limit and (○) is the lower limit for plant available water.	105
Appendix 9.7: Soil water content of Plot 5 (top) and Plot 6 (bottom) in paddocks C6E and C7E, Ashley Dene, Canterbury. Where (●) is the upper limit and (○) is the lower limit for plant available water.	106
Appendix 9.8: Soil water content of Plot 8 (top) and Plot 9 (bottom) in paddocks C6E and C7E, Ashley Dene, Canterbury. Where (●) is the upper limit and (○) is the lower limit for plant available water.	107
Appendix 9.9: Soil water content of Plot 10 (top) and Plot 11 (bottom) in paddocks C6E and C7E, Ashley Dene, Canterbury. Where (●) is the upper limit and (○) is the lower limit for plant available water.	108
Appendix 9.10: Soil water content of Plot 12 (top) and Plot 13 (bottom) in paddocks C6E and C7E, Ashley Dene, Canterbury. Where (●) is the upper limit and (○) is the lower limit for plant available water.	109
Appendix 9.11: Soil water content of Plot 14 (top) and Plot 15 (bottom) in paddocks C6E and C7E, Ashley Dene, Canterbury. Where (●) is the upper limit and (○) is the lower limit for plant available water.	110

Appendix 9.12: Soil water content of Plot 16 (top) and Plot 18 (bottom) in paddocks C6E and C7E, Ashley Dene, Canterbury. Where (●) is the upper limit and (○) is the lower limit for plant available water..... 111

# 1 INTRODUCTION

New Zealand's livestock production systems are based around outdoor pastoral systems. Maximising production on simple pastoral systems is a common goal in the industry. Perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.) are the predominant species sown. The species allow for simple production systems. However they have low productivity when soil moisture is limiting, especially in summer and autumn periods, due to their shallow root system which means they are unsuitable for dryland environments (Brown & Moot, 2004; Mills, Smith, Lucas, & Moot, 2008a). Furthermore there is often a reduction in herbage quality due to an increase in reproductive development in perennial ryegrass during the summer period.

An alternative pasture species for a dryland environment is lucerne (*Medicago sativa* L.). Lucerne has been promoted as a suitable legume for dryland systems in New Zealand for over 100 years (Moot, 2012). It is a leguminous plant which, if properly managed, grows longer in dry periods and recovers more quickly after rain than other species (Douglas, 1986; Moot, 2012). Lucerne has a deep tap root capable of extracting water at depths greater than 2.3 metres and has the ability to fix nitrogen due to its symbiotic relationship with rhizobia (Moot, Brown, Pollock, & Mills, 2008). Lucerne provides a source of summer feed on many dryland farms in east coast regions of New Zealand. A review by Douglas (1986) compiled 21 comparisons and found lucerne had an average 43% advantage over pasture under rainfed conditions. Lucerne was seen to have the capacity to produce 50% more dry matter (DM) but was frequently grown on potentially yield limiting soils with a pH of <6.0. In 2001 a survey by Kirsopp found 75% of dryland farmers in Canterbury grew lucerne and of these the average area on their farm was about 20%. Up to 10% of individual dryland farms in the Canterbury region grow lucerne for conserved feed to be used in summer droughts or feed during winter periods (Kirsopp, 2001).

Often lucerne is cut in spring for hay or silage with subsequent growth then used for grazing. Lucerne is also directly grazed in this area with some farmers growing  $\geq 30\%$  of their total property in lucerne to allow for this. Lucerne grown for sheep grazing in the central Canterbury area has declined due to the increase in dairy conversions (Moot, 2012). Lucerne can be used as a specialist forage crop for supplementary feed in dairy systems; however this is not readily taken up by dairy farmers due to a preference for perennial ryegrass pastures. Recent research by the Lincoln University dryland pastures group has aimed at encouraging the direct grazing of lucerne (Moot, Brown, Teixeira, & Pollock, 2003). The management requirements of lucerne have been more clearly

defined with the ability to use in grazing systems (Moot, 2009). The ability to graze lucerne *in situ* offers opportunity to increase animal production.

The predominant use of unirrigated, dryland farms is the production of sheep. To maximise returns liveweight production should be maximised. This can be achieved in dryland situations by using species of high quality (>11 MJ ME/kg DM) which are drought tolerant. Lambs grazing lucerne have shown superior liveweight gains over grass based systems (Mills, Smith, & Moot, 2008b). However the winter dormancy of lucerne and slow early spring growth limits its use (Tonmukayakul, Moot, & Mills, 2009). It is believed that this limitation can be overcome by sowing lucerne in a mix with species such as cocksfoot (*Dactylis glomerata* L.) and prairie grass (*Bromus willdenowii* Kunth.) which complement its growth (Fraser, 1982; Fraser & Rowarth, 1996). There has been increased interest in sowing lucerne as a mix with grasses. Lucerne/grass may offer the ability to reduce the weed content which can be a problem in pure swards (Cullen, 1965). There has been little research on the production achieved with lucerne/grass mixes.

A key goal in livestock production systems is to maximise animal production. In New Zealand this is generally achieved by using suitable pastures to maximise pasture availability. Supplementation in sheep grazing systems allows a farmer to manipulate the nutrient requirement of an animal at particular times of the year. Recently there has been unpublished commercial claims that grain has dramatically improved liveweight gains of lambs grazing lucerne with a 100% conversion of grain when using lick feeders. There has been no published evidence of this. Therefore, a second aim of this research was to compare animal performance on pure lucerne swards with and without grain supplementation.

Experiment 1 of this dissertation follows Coutts (2013) work which compared animal liveweight production from lucerne and two lucerne/grass mixes – lucerne/cocksfoot and lucerne/brome. Animal liveweight, pasture production and quality for 2013/14 were compared with the 2013/14 season. Pasture production and quality are used as explanatory variables for differences in liveweight production of animals grazing the treatments. Quantity of pasture produced is explained by water use and WUE efficiency of the pastures and related to thermal time accumulation. Quality of the pastures was determined by botanical composition and nutritive analysis of the components. Experiment 2 was superimposed in the lucerne portion of the Experiment 1 to quantify the effects of barley grain supplementation on animals grazing lucerne pre and post weaning.

## 2 LITERATURE REVIEW

### 2.1 Pasture Species

Lucerne (*Medicago sativa*) is a leguminous plant which, if properly managed, grows longer in dry periods and recovers more quickly after rain than other species (Douglas, 1986; Moot, 2009). Lucerne is typically used in dryland systems due to its ability to persist in moisture limiting conditions. Lucerne has a deep tap root capable of extracting water at depths greater than 2.3 metres (Moot *et al.*, 2008). It is able to fix nitrogen due to its symbiotic relationship with rhizobia (Brown, Moot, & Pollock, 2003; Brown, Moot, & Teixeira, 2005). These traits give lucerne the ability to increase productivity as the plant is able to extract more water from the soil profile (Figure 2.1). Moot *et al.* (2008) compared the water extraction of lucerne and ryegrass on two Canterbury soils. They found lucerne was able to extract 328 mm of water to a depth of at least 2.3 m on a deep Wakanui soil (Figure 2.1). On the same soil ryegrass extracted 243 mm of water to a depth of 1.5 m. On a stony Lismore soil, a ryegrass/clover pasture extracted 129 mm of water to a depth of 1.5 while lucerne extracted 131 mm of water to a depth of 2.3 m. This meant the advantage of lucerne for water extraction was most obvious on the deeper soil.

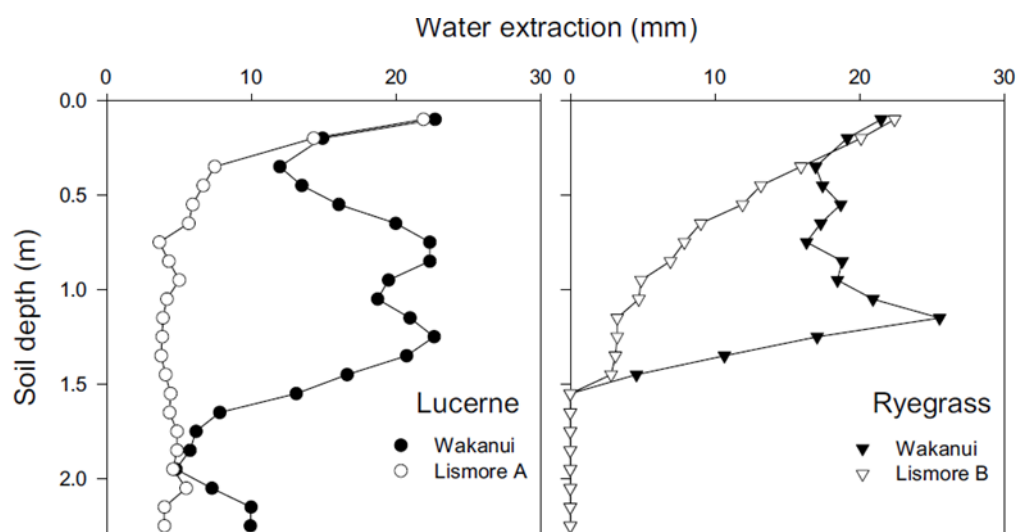


Figure 2.1: Water extraction (mm) from each 0.1 m soil layer from 0-2.3 m depth for lucerne (circles) and grass based pasture (triangles) on a deep Wakanui silt loam (solid symbols) or a Lismore (A) very stony loam and Lismore (B) stony loam (open symbols) (Moot *et al.*, 2008).

The use of lucerne has not always been popular with farmers having little success in correctly managing the plant until recently (Moot, 2009). Lucerne requires different management from perennial ryegrass and using rotational grazing is recommended to ensure high productivity and persistence. A lucerne pasture may not be grazed from July until at least mid-September which can

restrict its use during lambing (Moot *et al.*, 2003). Lucerne can be either grazed *in situ*, conserved or used under a cut and carry system. Many farmers also use grasses sown in conjunction with lucerne for grazing.

Cocksfoot is a tufted perennial grass species which has been shown to persist in moderate fertility and drought conditions (Norris, 1982). It is the second most commonly grown pasture species in New Zealand after perennial ryegrass, and often dominates pasture swards (Mills, Moot, & McKenzie, 2006). Cocksfoot, although slow to establish, shows aggressive growth enabling the plant to out-compete other species (Brown, Moot, Lucas, & Smith, 2006). Due to its competitive nature cocksfoot often out-competes companion clovers such as white clover resulting in a nitrogen deficient situation (Mills *et al.*, 2006). Over time cocksfoot/white clover pastures become cocksfoot dominant which results in a nitrogen deficient, unpalatable and unproductive pasture (Brown *et al.*, 2006). A legume more competitive than white clover is required to be sown in cocksfoot mixes for increased pasture productivity (Brown *et al.*, 2006). Lucerne is a more competitive perennial legume which may complement cocksfoot as a legume/grass pasture.

Prairie grass (*Bromus willdenowii* Kunth.) is a short-lived, large leaved, large tillered perennial originating from South America (Charlton & Stewart, 1999). It is drought tolerant with earlier winter/early spring growth than lucerne. Prairie grass is used as a special purpose pasture for winter and summer feed. Prairie grass requires free draining soils with a pH above 5.5. Grazing brome (*Bromus stamineus* Desv.) is closely related to prairie grass however it is finer leaved and tillered. Both cocksfoot and prairie grass are used in Experiment 1.

## 2.2 Water Use

Dry matter production of a pasture species is a result of water extraction and the efficiency of water use by the pasture. The water use efficiency (WUE) of a crop refers to the ratio of total dry matter (DM) accumulation relative to total water input in a system (Moot *et al.*, 2008) or the ratio of biomass produced to potential evapotranspiration (PET) (Martin *et al.*, 2006). Lucerne is able to extract more water than other species (Figure 2.1) and use that water more efficiently. Moot *et al.* (2008) found that dryland lucerne grown on a deep Wakanui silt loam soil had an annual WUE of 40 kg DM/ha/mm, and extracted 328 mm of water from a depth of at least 2.3 metres (Figure 2.1). When lucerne was grown on a stony Lismore soil with a low water holding capacity (WHC) it had an annual WUE of 16 kg DM/ha/mm and extracted 131 mm of water down to 2.3 metres. On the same soil types, ryegrass/clover pastures only utilised soil water to a depth of 1.5 metres and had a similar WUE to the lucerne on the Lismore soil with 16 kg DM/ha/mm produced. On the deep free draining

Wakanui soil the WUE of the ryegrass/clover pasture was lower at 18 kg DM/mm (Figure 2.2). The authors concluded that, where practical, deep rooting species, such as lucerne, should be sown on deep soils to utilise the full water holding capacity of the soil.

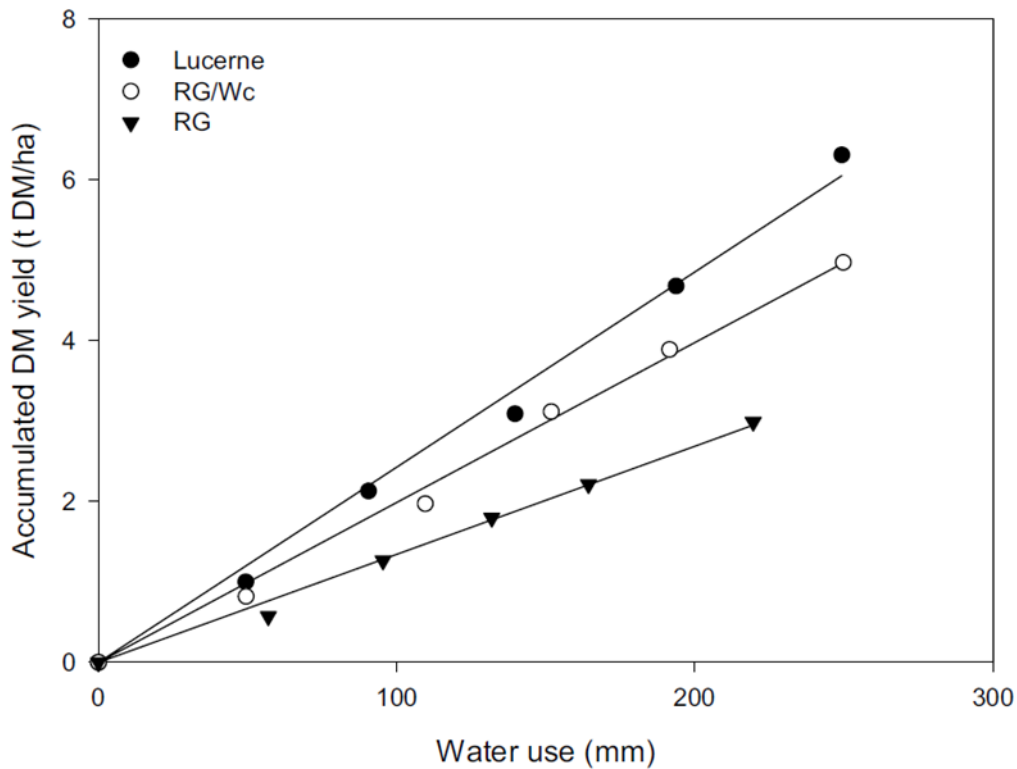


Figure 2.2: Spring dry matter yield (t/ha) and water use (mm) for lucerne (WUE = 24 kg DM/ha/mm), perennial ryegrass/white clover (RG/Wc, WUE = 20 kg DM/ha/mm) and perennial ryegrass (RG, WUE = 13 kg DM/ha/mm) pastures at Lincoln, Canterbury between 29/9-9/12/1993 (Moot *et al.*, 2008).

Lucerne in an intensive commercial pasture renewal programme in Central Otago had a WUE of 16.0 kg DM/ha/mm (Kearney, Moot, & Pollock, 2010). Browntop dominant pastures in similar conditions had a WUE of 3.5 kg DM/ha/mm. These values were found using rainfall data. The lower WUE compared with that found by Moot *et al.* (2008) was expected due to the limiting conditions faced in Central Otago environments and differences in data analysis.

Earlier experiments also found lower WUE than Moot *et al.* (2008). In an experiment by McKenzie, Gyamtsho, and Lucas (1990) the water use of lucerne and lucerne/prairie grass pastures in Canterbury was compared. The total water used did not differ between pasture types. Pure lucerne used 384 mm compared with 376 mm used by lucerne/prairie grass. Due to increased DM production lucerne had a mean water use efficiency (WUE) of 25 kg DM/ha/mm which was more ( $P < 0.05$ ) than 20 kg DM/ha/mm for lucerne/prairie grass for the period from November 1988 to

March 1989. This means at that point lucerne monocultures were able to produce more DM from the same amount of water as lucerne/prairie grass. After this period WUE did not differ ( $P>0.05$ ) between pasture type and ranged from 22 – 30 kg DM/ha/mm. The authors stated that the water use of lucerne could have been underestimated. Lucerne roots were found down to shingle, but neutron probe access tubes could not be installed that far down. Therefore, the lucerne could have been using water from between the shingle particles that was not accounted for.

Coutts (2013) found all pastures in the lucerne, lucerne/grass mix experiment had a WUE of  $22 \pm 0.11$  kg DM/ha/mm of water in spring 2012. This was comparable with the literature. This was the first year of the experiment. Whether or not lucerne/grass mixes will continue to have the same WUE as lucerne monocultures is not yet known.

The increased WUE of lucerne over other pasture species shows lucerne has the ability to produce dry matter at a greater quantity per unit water, especially in spring. It is able to access water deeper in the soil profile due to its long taproot and can use this water efficiently due to being high in N which results in higher photosynthetic rates (Peri, Moot, McNeil, Varella, & Lucas, 2002). Lucerne has also proven to be the most responsive species to summer rainfall (Mills *et al.*, 2008a).

### 2.3 Dry matter production

A review by Douglas (1986) of 21 comparisons found lucerne had an average 43% advantage in dry matter (DM) production over perennial ryegrass based pasture under rainfed conditions. Lucerne had the capacity to produce 50% more DM but was frequently grown on potentially yield limiting soils with a pH of  $<6.0$ . Unpredictable drought caused considerable variation in the annual yield of lucerne (Douglas & Kinder, 1973). However spring yield may be more consistent than grass based pastures (Stevens *et al.*, 2011).

Lucerne showed higher annual yields than ryegrass pastures in a nine year grazing experiment by Mills *et al.* (2008a). Peak dry matter yields were recorded in the first four years where lucerne produced 13.1-18.5 t DM/ha/yr. The ryegrass/white clover pasture yielded an average 9 t DM/ha/yr. Lucerne was able to maintain higher growth rates than ryegrass/white clover through the moisture limiting summer period giving it an advantage over grass pastures. In Years 6 (2007/08) and 7 (2008/09) of the experiment lucerne yielded 14.0 t DM/ha/yr showing the ability of lucerne to maintain an advantage over 7 years (Mills & Moot, 2010). Maximum growth rates were recorded in December 2007 when lucerne grew 92 kg DM/ha/d compared with 50 kg DM/ha/d for ryegrass/white clover. In non-limiting conditions lucerne has produced annual yields of up to 28 t DM/ha (Scott, 2003). Earlier experiments over a dry summer (270 mm rainfall from June to March)

showed lucerne produced more on deep (12.6 t DM/ha) than shallow (10.9 t DM/ha) soils (McKenzie *et al.*, 1990).

Dryland lucerne had an increased average yield (20 t DM/ha) over chicory and red clover (16 t DM/ha) in a five year experiment on Wakanui silt loam soil (Brown *et al.*, 2003). The advantage of lucerne was greatest at 6 t DM/ha in the final year of the experiment. This was when lucerne accounted for 94% of the sward compared with chicory which declined to 62% of its sward. Red clover had completely died out. The advantage of lucerne was due to higher growth rates in September and from December to May. Lucerne was able to extract more water than chicory and red clover and use that water more efficiently allowing for increased growth rates. These results are consistent with those from Mills *et al.* (2008) and Mills & Moot (2010).

Brown *et al.* (2006) compared cocksfoot with balansa clover (*Trifolium michelianum*) (Cf/Bc), cocksfoot with caucasian clover (*T. ambiguum*) (Cf/Cc), cocksfoot with subterranean clover (*T. subterraneum*) (Cf/Sc), cocksfoot with white clover (*T. repens* L. (Cf/Wc), ryegrass (*Lolium perenne* L.) with white clover (Rg/Wc) and lucerne (Luc) in the “Maxclover” experiment at Lincoln University. They found lucerne produced the most dry matter ( $P < 0.001$ ) in 2004/05 compared with other pasture mixes (Figure 2.3). In 2004/05 Cf/Sc and Cf/Wc were the most ( $P < 0.001$ ) productive grass based pasture mixes and Cf/Sc was the most ( $P < 0.001$ ) productive in 2005/06 (Figure 2.3). Growth rates of the grass-clover mixes ranged from  $< 10$  kg DM/ha/d during March-July up to a maximum of 60-105 kg/ha/d in October. The Cf/Sc pasture had a growth rate of 2.3 kg/ha/d in June, which rose to a maximum of 63 kg/ha/d in October. High pasture yields related to high liveweight gains.

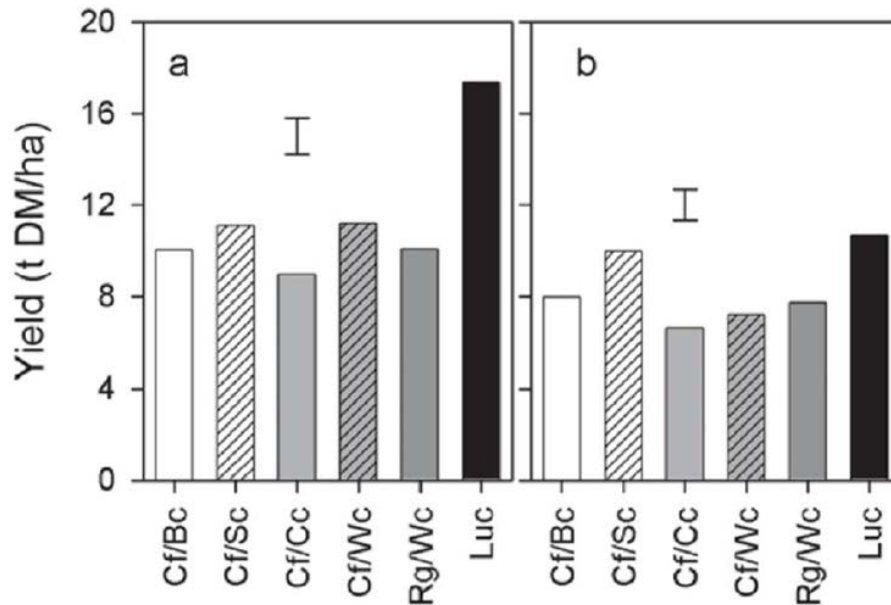


Figure 2.3: Annual dry matter production in a) 2004/05 and b) 2005/06 of six dryland pastures grown at Lincoln University. Cf = cocksfoot, Cc = balansa clover, Sc =subterranean clover, Cc = Caucasian clover, Wc = white clover, Rg = ryegrass, Luc = lucerne. Bars represent one LSD. From Brown *et al.* (2006).

Lucerne is commonly sown in mixes with grass companions. Growth of pure lucerne, lucerne/cocksfoot and lucerne/prairie grass was compared on a high fertility soil over three years by Cullen (1965). Lucerne/grass mixes out yielded pure lucerne stands in the first year. Lucerne produced 6250 kg DM/ha compared with 9580 for lucerne/cocksfoot and 12040 kg DM/ha for lucerne/prairie grass mixes (Cullen, 1965) (Figure 2.5). In the second and third years of the experiment yield differences became less pronounced.

Results from the previous season of Experiment 1 at Ashley Dene found no difference in accumulated DM (~12.5 t/ha) between lucerne monocultures, lucerne/cocksfoot and lucerne/brome pastures (Coutts, 2013). All pastures produced approximately 12.5 t DM/ha. The yields reported by Cullen (1965), were lower than many other lucerne pastures in Canterbury (Brown & Moot, 2004; Brown *et al.*, 2006; Mills *et al.*, 2006) due to the lower WHC of the soil at Ashley Dene.

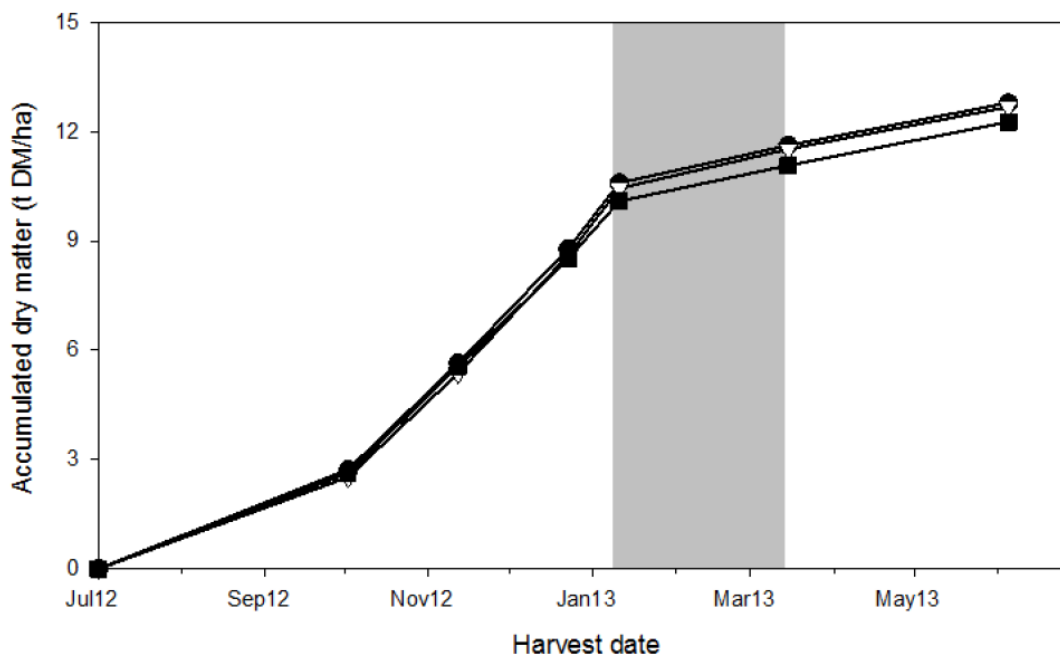


Figure 2.4: The total accumulated dry matter (DM) yield of lucerne monocultures (●), lucerne/brome (▽), and lucerne/socksfoot (■) pastures from 1/07/2012 to 30/06/2013 at Ashley Dene, Canterbury, New Zealand. Grey area indicates the period when no measurements were taken due to low summer growth (Coutts, 2013).

## 2.4 Quality

Pasture quality has a direct influence on the growth of grazing animals. Lucerne offers the potential to increase liveweight gains of sheep on dryland farms due to its superior ability to grow high quality herbage. Brown and Moot (2004) investigated the quality of lucerne, red clover and chicory over six years under irrigation at Lincoln. The ME of the palatable fractions of lucerne and chicory was high at 11.6 and 11.3 MJ ME/kg DM, respectively (Table 2.1). Lucerne has been seen to offer a higher metabolisable energy than perennial ryegrass. Mills and Moot (2010) reported on the annual ME yields of six pastures six and seven years after establishment in the 'Maxclover' experiment at Lincoln. Lucerne monocultures produced ~134 GJ ME/ha/yr which was higher than all other pastures. Ryegrass/white clover in the experiment produced ~18 GJ ME/ha/yr. Lucerne had an average ME content of 11 MJ/kg DM.

Superior ME production from lucerne resulted in greater ME intake. Brown *et al.* (2006) reported annual ME intake from lucerne (142-261 GJ/ha) to be greater than chicory (99-169 GJ/ha) and red clover (74-218 GJ/ha) for five regrowth seasons.

Table 2.1: Crude protein (g/g DM) and ME (MJ/kg DM) contents of herbage fractions (palatable, unpalatable and weed) and post-grazing residual of chicory, lucerne and red clover swards grown over five years. Values in parenthesis are standard errors for each mean calculated from five year's data. (Brown & Moot, 2004)

	Species	Palatable	Unpalatable	Weed	Residual
CP	Chicory	0.18 (0.011)	0.08 (0.013)	0.25 (0.011)	0.10 (0.010)
	Lucerne	0.29 (0.008)	0.12 (0.008)	*	0.12 (0.013)
	Red clover	0.25 (0.011)		*	0.20 (0.009)
ME	Chicory	11.3 (0.20)	9.4 (1.39)	11.4 (0.33)	8.6 (0.67)
	Lucerne	11.6 (0.13)	7.8 (0.42)	*	6.8 (0.55)
	Red clover	10.9 (0.21)		*	10.0 (0.09)

\* Weed fractions not analysed

Lucerne herbage produces high levels of protein, with reported accumulated protein yields of around 2000 kg/ha/year (Douglas, 1986). Crude protein (CP) and metabolisable energy (ME) in the palatable fraction of irrigated lucerne, chicory and red clover were compared by Brown and Moot (2004). Lucerne swards provided 30% greater CP and ME than chicory or red clover. Annual CP intake was 1.3 t CP/ha greater ( $P < 0.01$ ) for lucerne than red clover and 2.4 t/ha greater than from chicory. Similarly Brown *et al.* (2006) reported CP yield for lucerne (3.3-6.3 t/ha) was 1.0-3.6 t/ha greater than for chicory and red clover over five regrowth cycles. Throughout the duration of their five year experiment there was a decline in annual CP with lucerne CP decreasing from 6.3 t/ha to 3.4 t/ha.

Tonmukayakul *et al.* (2009) reported on the 'Maxclover' experiment for the 2008/09 season. Lucerne produced the highest N yield of 471 kg/ha/year. Cocksfoot /subterranean clover in the experiment produced 188 kg N/ha annually which was the next highest. The N content of lucerne was an average 3.9% compared with 3.5 and 4.3% for cocksfoot and subterranean clover respectively.

Waghorn and Barry (1987) reported that CP content of 0.27 g/g DM is likely to be above animal requirements. Crude protein is equal to the nitrogen content \* 6.25. Protein of any fresh pasture is approximately 70-80% soluble (Ulyatt, 1997). Around 90% of protein is degraded in the rumen in the first hour leading to losses of up to 50%. Due to these losses there may be an insufficient pass of protein to the duodenum leading to protein deficiencies even in high protein pastures. The protein and soluble carbohydrate contents of pasture differ throughout the year, so the diet is not always well balanced with respect to these nutrients.

In lucerne/grass mixes the proportion of grass in the mix likely effects the quality of the pasture. Coutts (2013) found no difference in annual ME and N yield between lucerne monocultures and lucerne/grass mixes at Ashley Dene, Canterbury. The ME and nitrogen yield of lucerne was greater in lucerne monocultures (88.3 GJ ME/ha and 286 kg N/ha respectively) than lucerne/ cocksfoot (65.8 GJ ME/ha and 213 kg N/ha) and lucerne/brome (58.8 GJ ME/ha and 189 kg N/ha) pastures which were not different (Table 2.2). Total ME and N yield did not differ between the treatments due to the contribution from the sown grasses in the lucerne/grass pastures.

Table 2.2: Annual metabolisable energy yield (GJ ME/ha) and N yield (kg N/ha) of lucerne monocultures, lucerne/ cocksfoot (Luc/CF) and lucerne/brome (Luc/Br) mixes at Ashley Dene, Canterbury (2012/13). Sown species yield is presented as the sum of the lucerne and sown grass yields (Coutts, 2013).

Pasture type	ME yield (GJ/ha)			N yield (kg/ha)		
	Lucerne	Sown grass	Sown species	Lucerne	Sown grass	Sown species
Lucerne	88.3a	-	88.3	286a	-	286
Luc/Cf	65.8b	23.6	89.4	213b	63.8	277
Luc/Br	58.8b	29.0	87.8	189b	68.4	257
P value	<0.001	0.121	0.758	<0.001	0.569	0.073

## 2.5 Botanical Composition

Maintaining adequate botanical compositions in both pure lucerne and lucerne/grass mixes can be difficult. Pure lucerne stands can be easily infested by weed populations affecting production and quality. However it can also be difficult to maintain a balance of both species in lucerne/grass mixes. Cullen (1965) investigated botanical composition of lucerne, lucerne/prairie grass and lucerne/ cocksfoot mixes over three years. In the first year the lucerne content of lucerne/grass mixes was low (7% in the lucerne/prairie mix) (Figure 2.5). Lucerne/grass mixes reduced the weed content of the pastures. About 50% of the species in pure lucerne stands were unsown species in the first year. In both of lucerne/grass mixes weed species comprised 25% of the sward. In the second and third years the lucerne content of the pastures increased. Cocksfoot made up 41% of the lucerne/ cocksfoot pasture in the third year, despite its aggressive growth pattern. Prairie grass was less persistent than cocksfoot and contributed just 12% of the annual yield in the third year (Figure 2.5). Cullen suggested that the defoliation interval was a key factor in determining whether cocksfoot or lucerne would dominate the sward. Frequent defoliation favoured cocksfoot growth,

while infrequent defoliation favoured lucerne growth. However, no specific details were provided in regards to the duration of frequent and infrequent defoliation periods during the experiment.

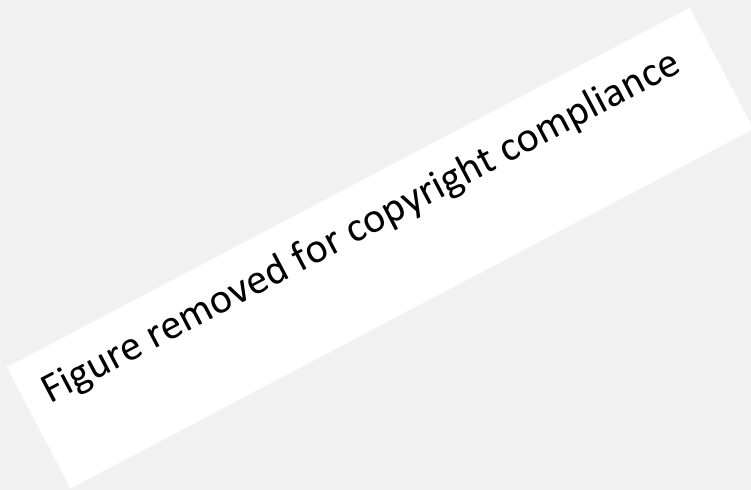


Figure 2.5: Seasonal dry matter production of lucerne and sown companion grass (Cullen, 1965)

The effects of stocking rate on the botanical composition of lucerne and lucerne/prairie grass mixes were investigated by Marsh and Brunswick (1977). High (10.0 cattle/ha), medium (6.67 cattle/ha) and low (5.0 cattle/ha) stocking rates were used. Dead material in both pastures decreased with increasing stocking rate due to the lower post grazing residual (Figure 2.6). Lucerne/prairie grass at a low stocking rate had a mean post-graze residual of 1815 kg DM/ha over four grazing rotations compared with 1270 kg DM/ha and 435 kg DM/ha for medium and high stocking rates, respectively. The grass component at a high stocking rate was lower than medium and low stocking rates (Figure 2.5). This suggests prairie grass in a mixture did not persist when grazed to low residuals. The weed content was lower in lucerne/prairie grass mixes with medium and high stocking rates compared with pure lucerne (Figure 2.6).




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Figure 2.6: Botanical composition of lucerne and lucerne/prairie grass pastures under low, medium and high stocking rates. Low stocking rate (LSR), medium stocking rate (MSR) and high stocking rate (HSR) (Marsh & Brunswick, 1977).

For the first year on this lucerne/grass mixes experiment at Ashley Dene, stocking rates were 15 SU/ha in spring, 8 SU/ha in summer and 6.5 SU/ha in autumn, which increased to 11 SU/ha due to increased feed availability (Coutts, 2013). Annually the lucerne monoculture in the experiment had at least 20% more lucerne than the lucerne/grass mixes. Unlike results from Cullen (1965), lucerne grass mixes maintained at least 40% lucerne in the mix. The lucerne component decreased as the season progressed and the sown grass component increased. This showed the selection that was occurring for lucerne and away from grass species. This was the first year of the experiment. The selection pressure on lucerne and lack of grazing of grass species may reduce the lucerne content over time. This shows the difficulties in managing lucerne/grass mixes, and the impact of year two is the focus of Experiment 1 in this dissertation.

## 2.6 Animal Requirements

### 2.6.1 Pasture allowance

The main source of feed for livestock in New Zealand systems is pasture. The amount of pasture on offer has an influence on the performance of grazing animals. For the first four to six months of a lambs life liveweight gain is primarily determined by the amount of milk obtained from its dam (Kenyon & Webby, 2007b). The lactation ability of the ewe depends on the condition in which she is

in and the quantity and quality of feed available to her. Rattray, Thompson, Hawker, and Sumner (1987) found ewes were able to maintain liveweight during lactation at a daily pasture allowance of around 4 kg DM/day. It was recommended to maximise lamb liveweight gain that ewes are offered 6 kg DM/day to ensure they eat 2-3 kg DM/day (Figure 2.7).

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Figure 2.7: Liveweight gain of suckling lambs during lactation at different pasture allowance (Rattray *et al.*, 1987)

In year 1 of Experiment 1, ewes with twin lambs were stocked at 15 SU/ha during the spring period (Coutts, 2013). Liveweight production from ewes and lambs was 570 kg LWT/ha for lucerne monocultures and 584 kg LWT/ha for lucerne/ cocksfoot mixes which was higher ( $P < 0.001$ ) than the 537 kg LWT/ha produced from lucerne/ brome mixes. In the second rotation of the spring period, ewes grazing lucerne monocultures grew at a maximum liveweight gain of 212 g/head/d which was greater than the 170 and 181 g/head/day seen in ewes grazing lucerne/ cocksfoot and lucerne/ brome pastures. Lamb liveweight gains were not different across treatments and had an average gain of 322 g/head/d. During this period animals consumed an average 1639 kg DM/ha. No difference between treatments and DM consumed was seen.

Weaned lamb growth rates reached a near maximum between 2-3 kg green DM/lamb/day when grazing legumes but needed 5-6 kg green DM/lamb/day on ryegrass or ryegrass/white clover (Jagusch, Rattray, Winn, & Scott, 1979). Lamb growth rates continued to increase with post-grazing herbage masses of up to 2000 kg DM/ha. However, high residuals can be wasteful of feed mainly because of trampling and the buildup of dead material. The best way to achieve this is to aim for post-grazing pasture residuals of not less than 1200 kg DM/ha. A grass based pasture cover of

around 5 cm equates to 1500 kg DM/ha. This may differ for lucerne compared with grass based pastures.

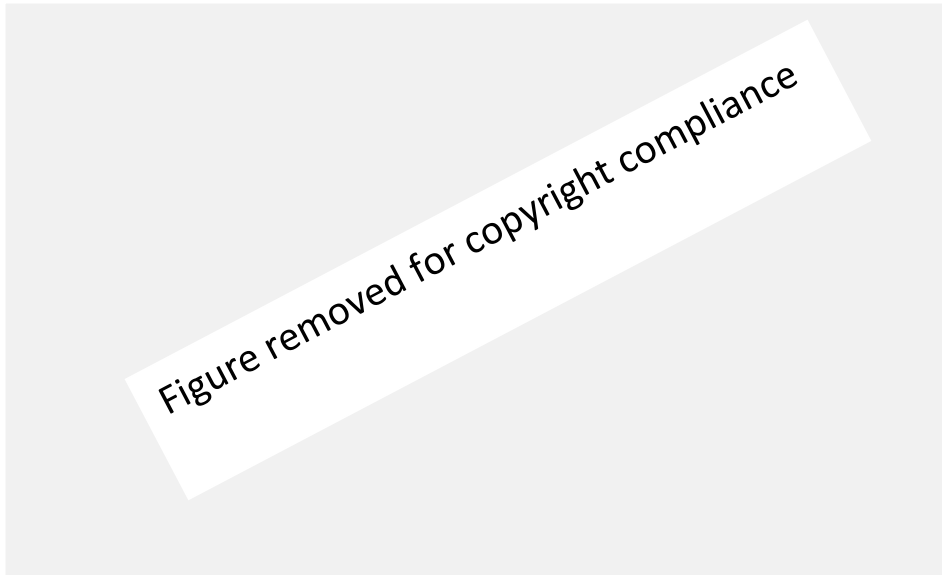


Figure 2.8: Responses in lamb growth to pasture allowance varies depending on the pasture species offered (Jagusch *et al.*, 1979).

### 2.6.2 Metabolisable energy

High pasture allowance is of little benefit if that pasture is poor quality. Pasture quality is key to ensure maximum growth rates are achieved. This is particularly important in a dryland situation to ensure lambs are grown out before drought occurs (Bywater, Logan, Edwards, & Sedcole, 2011). The energy requirement of an animal is expressed as the metabolisable energy (ME) requirement which is the sum of the requirement for maintenance as well as liveweight gain, pregnancy and lactation. Maintenance requirement is the ME required to keep the animal at a constant body weight. It includes the energy needs for animals to do this, plus the costs associated with harvesting and processing its maintenance requirements whilst grazing. Maintenance requirements are affected by species, liveweight, age, grazing environment, climate, feed quality and the physiological state of the animal. For a 60 kg ewe grazing a pasture with an ME of 10.5 MJME/kg DM on flat land, the requirement for maintenance is reportedly 9.0 MJ ME/day (Nicol & Brookes, 2007a). During pregnancy there is a further ME requirement that changes with the stage of pregnancy and lamb birth weight. For a ewe bearing twin lambs of 4 kg each two weeks out from birth, an additional 8 MJ ME/ewe is required to sustain the pregnancy. This can be calculated on a flock basis. For example, a flock scanned at 130% 14 days from lambing has a requirement above maintenance of 6.5 MJ ME/ewe/day. Requirements for lactation depend on the time from lambing and the weaning weight of lambs. For a ewe with 25 kg twin lambs at foot at 10 weeks, an additional 32 MJ ME/ewe/day is

required, provided the diet is 11.0 MJ ME/kg DM. The extra requirement of the ewe and her lambs for lactation is on average 45 MJ ME/kg lamb weaning weight. Once weaned, a lambs' requirement for maintenance and liveweight gain largely depends on the sex of the animal. Ram lambs have an average requirement for maintenance of 0.50 MJ ME/kg LW<sup>0.75</sup> compared with ewe lambs requirement of 0.45 MJ ME/kg LW<sup>0.75</sup>. At a weaning weight of 25 kg a ewe lamb would require 24 MJ ME/day and a ram lamb 27 MJ ME/day for maintenance.

Bywater *et al.* (2011) noted that to maintain high pasture quality, a high proportion of green leaf should be maintained with little dead matter and reproductive development. To achieve medium to high growth rates (200-300 g/day) the pasture should be green and leafy with a legume content for adequate energy (10 MJ ME/kg DM) and crude protein (above 20% crude protein) (Geenty, 1995). Increases in grazing pressure have led to the ability to keep pastures in an active growing state. With the use of high stocking rates (14 SU/ha), Bywater *et al.* (2011) found lamb growth rates could be improved by maintaining high quality pastures with a high clover content. The trial compared both a grass and legume system, both met target ME values of 11.5 MJ ME/kg DM through to the end of October proving increased grazing pressure can be used to improve pasture quality (ME).

Last season in Experiment 1 at Ashley Dene ME of lucerne and lucerne/grass pastures averaged ~11 MJ ME/kg DM (Coutts, 2013). Due to pastures having no difference in accumulated DM (Figure 2.4) or ME there was no difference in annual ME yield of the pastures. There was also no difference in herbage quality when compared with other literature (Brown *et al.*, 2006). Lucerne monocultures produced more ME yield (Table 2.2) from the lucerne component than lucerne/grasses but the contribution of grass to the ME yield, compensated for this. The highest ME yields of 27 GJ ME/ha were recorded for grazing rotation one of Experiment 1, when water was not limiting plant growth.

### **2.6.3 Protein**

The protein requirement for animals for liveweight gain depends on liveweight, mature liveweight and rate of gain. Protein is deposited at an increased rate for younger animals and decreases as the animal matures. For example, a young lamb of 20 kg liveweight requires 14 g crude protein per MJ ME compared with 6 g/MJ ME for the same lamb at 40 kg (Sykes & Nicol, 1983). Conversely metabolisable energy (ME) (and thus DM intake) requirement increases with maturity. A terminal sired ram lamb growing at 300 g/day grazing a pasture with an ME of 11.0 MJ ME/day has a metabolisable protein (MP) requirement of 93 g/day (Nicol & Brookes, 2007b). Of the protein ingested by ruminants grazing high quality forages, about 70% is degraded in the rumen and only 30% escapes to the small intestines for absorption (Waghorn & Barry, 1987). Sheep absorb protein

much more efficiently in the small intestine. Most pasture feeds are initially broken down in the rumen. The rumen provides relatively constant protein output through microbial protein. No matter what the protein levels of feed to an animal, rumen microflora convert it to about 13-14% protein. The rest is converted to ammonia, and eventually excreted as urea in the urine. In other words, the rumen bacteria waste a lot of potentially useful protein. The majority of protein lost to deamination is compensated by microbial protein synthesised. However the extensive protein degradation can result in insufficient amino acid absorption for maximising productivity in young growing and lactating animals.

Lambs fed traditional ryegrass–white clover pasture do not perform to their full potential because protein supply is sub-optimal. Fraser and Rowarth (1996) compared the liveweight gains of lambs grazing high and low protein pasture species. They used white clover and chicory to illustrate the effects of high protein diets on liveweight gain, with protein concentrations of 28 and 24.3% respectively and compared these to ryegrass with a protein content of 20.1%. Lambs were allocated 2 kg DM/day of the respective pastures. Over a 3 year period liveweight gains were greater from the high protein pastures. Lambs which grazed white clover had the greatest average liveweight gain (226 g/day), followed by chicory (192 g/day). Ryegrass pastures gave the lowest lamb liveweight gains across the 3 years with an average gain of 121 g/day. Results found support the view that protein supply limits the performance of animals grazing traditional ryegrass pastures.

Lucerne is a legume which generally has a high N content. Brown and Moot (2004) showed lucerne had a CP of 0.29 g/kg DM which was higher than the 0.18 g/kg DM in chicory (Table 2.1). This led to a 1.3 t CP/ha advantage of lucerne compared with chicory. The ability to maintain a high CP/N content pasture may improve the protein supply to lambs increasing liveweight gain. Currently there is limited literature on this. There is also no literature on the CP effects of sowing grasses with lucerne.

## 2.7 Animal production

New Zealand sheep systems are based on grazing pastures therefore production of liveweight is a factor of pasture allowance (dry matter produced by the pasture) and the quality of that pasture (Kenyon & Webby, 2007a). The ultimate proof of a high producing high quality pasture is in the production of the grazing animal. Animals grazing lucerne have shown increased liveweight production over other dryland pastures. The 'Maxclover' experiment at Lincoln University investigated livestock production from six dryland pastures over the 2004/05 and 2005/06 seasons (Brown *et al.*, 2006). The pasture treatments were cocksfoot with balansa clover (Cf/Bc), cocksfoot with Caucasian clover (Cf/Cc), cocksfoot with subterranean clover (Cf/Sc), cocksfoot with white

clover (Cf/Wc), ryegrass with white clover (Rg/Wc) and lucerne (Luc). Despite grazing commencing 40 days later than grass treatments, lucerne had the highest production for spring 2004 with 400 kg LW/ha produced (Figure 2.9). All grass treatments averaged 300 kg LW/ha in spring 2004 except Cf/Cc (200 kg LW/ha). Lucerne continued to produce the most liveweight in the summer period of 2004 with approximately 550 kg LW/ha. In spring 2005 lucerne had the lowest production (about 350 kg LW/ha) while Cf/Sc had the highest production (about 600 kg LW/ha). Lucerne produced the most dry matter in the 2004/05 season (Figure 2.3) which explained the increased liveweight production, since liveweight production is affected by quality and quantity of pasture available (Ratray *et al.*, 1987). In the 2005/06 season liveweight production advantages for lucerne were lost due to a dry winter (50 mm for June, July and August) meaning lucerne was unable to extract water from deeper in the soil profile via its taproot (Brown *et al.*, 2006).

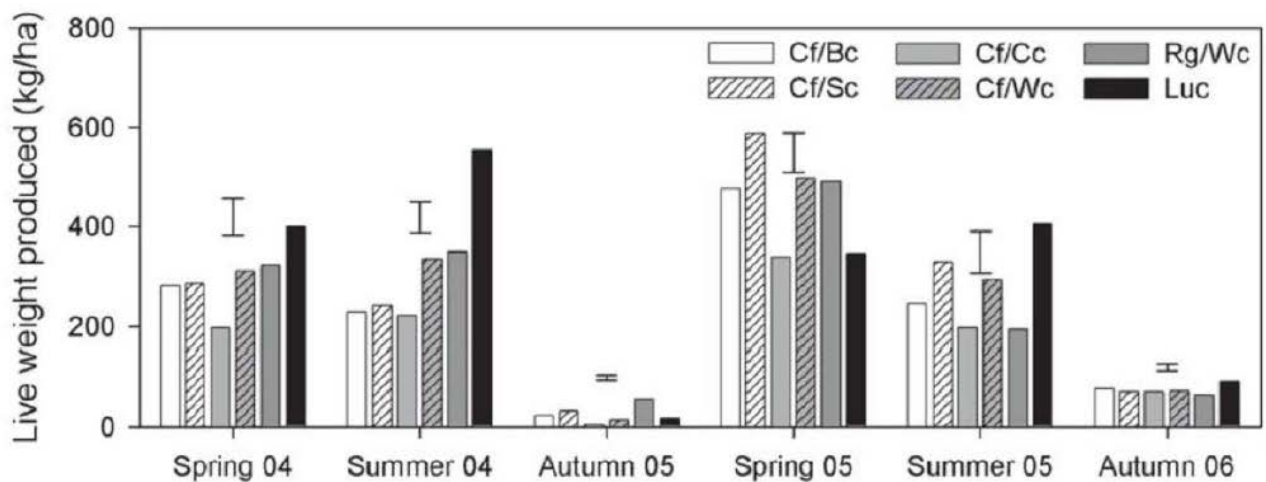


Figure 2.9: Liveweight produced per hectare from six dryland pastures at Lincoln University. Cf = cocksfoot, Bc = balansa clover, Sc = subterranean clover, Cc = Caucasian clover, Wc = white clover, Rg = ryegrass, Luc = lucerne. Error bars represent one LSD above periods when production was different (Brown *et al.*, 2006).

Mills *et al.* (2008b) also reported on the 'Maxclover' experiment but for five growing seasons from 2003/04 to 2007/08. Lucerne produced 33-42% more liveweight than grass based pastures in 2003/04, 2004/05 and 2006/07 whilst having a lower number of grazing days. Grazing days for lucerne were 1620 over the five seasons compared with 1266 for Cf/Sc and 1890 for Rg/Wc. This advantage was due to superior daily growth rates seen on lucerne. Hoggets on lucerne in spring had an average liveweight gain of 250 g/hd/day compared with 195 g/hd/day on Rg/Wc. In summer lambs, which grazed lucerne had an average liveweight gain of 160 g/hd/day while those lambs grazing Rg/Wc had an average liveweight gain of 65 g/ha/day. This showed the advantage lucerne had over ryegrass/white clover in spring and summer.

There has been little research into production from lucerne/grass mixes. One of the few published experiments compared beef production from lucerne and lucerne/prairie grass in Taupo (Marsh & Brunswick, 1977). This area is prone to drought due to the low water holding capacity of the pumice soils which dominate the region. Three stocking rates were used on each treatment which were low (5.0 animals/ha), medium (6.67 animals/ha) and high (10 animals/ha). Pasture DM yields were about 400 kg DM higher on the mixed sward but animal production was up to 89 kg LWT/ha greater on the lucerne only sward, particularly from December onwards. Increasing stocking rate tended to reduce herbage DM yield and per-animal production. The authors suggested difference in liveweight production were due to difference in herbage quality.

Coutts (2013) found annual liveweight production from the lucerne and lucerne/grass mix experiment at Ashley Dene to be 16% greater from lucerne monocultures and lucerne/socksfoot compared with lucerne/brome (Figure 2.10). Lucerne monocultures and lucerne/socksfoot mixes produced 865 kg LWT/ha compared with lucerne/brome mixes which produced 746 kg LWT/ha. Which was comparable with results from Brown *et al.* (2006). The highest liveweight production was during spring with approximately 70% of the annual liveweight production occurring for all three treatments. Spring dry matter production also accounted for ~50% of the accumulated total. This was expected as moisture was not limiting in the spring.

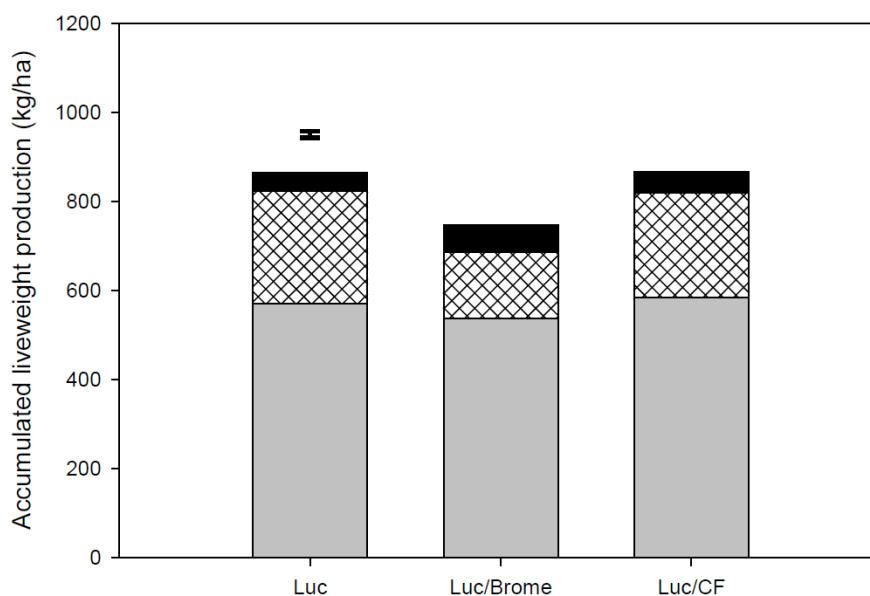


Figure 2.10: Annual liveweight production of lucerne monocultures, lucerne/brome (Luc/Br) and lucerne/socksfoot (Luc/CF) mixes over five liveweight production periods from 1/07/2012 to 30/06/2013 at Ashley Dene, Canterbury, New Zealand. Stacked bars represent spring liveweight gain with ewes and lambs (□), summer liveweight gain with weaned lambs (▨) and autumn liveweight gain with ewe hoggets (■). The error bar is SEM for accumulated liveweight production (Coutts, 2013).

## 2.8 Supplementation (of grain) to increase liveweight production

Supplementation of sheep in grazing systems allows a farmer to manipulate the nutrient requirement of an animal at particular times of the year. A supplement has been defined as 'something added to remedy a deficiency'. In general there are three reasons for adding a supplement to a diet (Figure 2.11). These are (1) to overcome a deficiency (2) to negate the effects of certain substances in a diet and (3) to contribute to energy and protein supplies. Most commonly a supplement is offered to increase the supply of a nutrient or total nutrient supply (e.g. supply of nitrogen to the rumen) or to improve the efficiency of nutrient utilisation in order for the animal to produce more. It can be difficult to determine exactly which nutrients are responsible for the response to the supplement if there is one.

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Figure 2.11: Major reasons for supplementary feeding in grazing systems (Dove, 2002).

Supplementation of grain is often used to increase the supply of carbohydrates relative to protein in an animal's diet. It is believed this should lead to increased production from that animal. An animal's response to increasing protein depends on the energy supply; the more energy the greater the response to protein (Chowdhury & Orskov, 1997). Protein supply and demand may be one of the reasons for poor post-weaning growth in lambs. In dairy situations, changing the ratio of crude protein relative to water soluble carbohydrates (WSC) improves the supply of energy to microbial populations. Edwards, Parsons, and Rasmussen (2007) found a WSC:CP ratio greater than 0.7 led to a reduction in the proportion of N excreted in urine and an increase in N intake excreted in useful products (milk). Using grain supplementation in situations where protein in the feed is high (above

18%) may lead to increased liveweight gains due to increased feed conversion efficiency as the capture of CP by microbes is increased.

True supplementation only occurs when the supplement is eaten and the intake of pasture is not reduced. This is the desired result but rarely occurs. Offering supplements often causes a reduction in pasture dry matter intake (Dove, 2002). Substitution rate (SubR) is describe as the reduction in pasture intake per unit increase in supplement intake. For example, if a daily supplement intake of 250 g DM reduces pasture intake by 150 g DM then the SubR is 60% ( $150 / 250 = 0.6$ ). Langlands (1969) found that even at low green pasture mass (650 kg DM/ha) a SubR of 0.38 was recorded for Merino ewes receiving 100-400 g wheat grain per day. When pasture mass was 2000 kg DM/ha SubR rose to 0.67.

Issues with introducing a grain component to an animal's diet can occur. Arnold and Maller (1974) identified sheep as either; shy feeders, moderate feeders or over-indulgers. This means although a supplement may be on offer the amount an animal will eat cannot be determined by simply dividing the amount of supplement by the number of animals. An Australian experiment used lupin grain marked with ytterbium (Yb) to estimate intakes of merino wethers when grain was either trailed on the ground or fed using stationary lick feeders (Holst, Curtis, & Hall, 1994). The variation in supplement intake was ~47% for supplement trail on the ground and ~78% for supplementation offered from a feeder. Animals were offered grain in the yards where low quality mature native grasses were available for grazing. It is likely the use of feeders in New Zealand would occur on higher quality pastures which may reduce the uptake of grain further.

In New Zealand the cost of grain often precludes its use for animal feeding in sheep grazing systems, except in crisis situations. Whole rather than processed grain should be fed to avoid acidosis. Where possible sheep should have prior exposure to grain or other supplements before as it can take some days for the ration to be acceptable to all sheep. Concentrates are not usually used in New Zealand to finish lambs due to the cost and availability of high quality forages which can be used (eg lucerne). To increase the economics of supplementation, feeders which reduce wastage, such as lick feeders, may prove beneficial. These feeders are generally placed on the opposite side of a paddock to a trough (Bowman & Sowell, 1996). Animals must use saliva to lick the supplement from groves. This limits intakes reducing the ability of animals to gorge themselves on the supplement.

Supplementation of animals grazing specialist forages is rare and there is little research in this field.

There is currently little literature on the liveweight gain effects of supplementation of grain to lambs on high quality forages such as lucerne. Unpublished claims of liveweight gain advantages to lambs grazing lucerne supplemented with barley grain have been made. There is a need for research in this

area to quantify any effects of supplementing grain to sheep grazing lucerne and this will be the basis for Experiment 2 in this study.

## 2.9 Grazing Behaviour

Grazing selection of livestock can influence the quality and botanical composition of a pasture. Sheep prefer to consume the leaf component of a plant compared with the stem. Arnold (1960) showed this to be true for lucerne. In his experiment lucerne stands contained 42% stem and 48% leaf prior to grazing with merino wethers. Four days after grazing, stem content had increased to 88% and leaf content had declined to 12%. This indicated that sheep selected the high quality (leaf) component of the diet. This was seen by Brown and Moot (2004) who observed 80% of total CP and 70% of total ME for a crop of 4300 kg/ha standing DM was selected by grazing sheep. Grazing preference of animals means that delayed grazing resulting in an increase of stem will not reduce potential stock production, unless stock are forced to graze to low residuals.

Nitrogen content of the pasture also causes grazing selection. Grazing sheep can distinguish between grass species, the level of nitrogen in grass leaves. Keogh (1986) stated that livestock select urine patches in preference to inter-urine patches. Higher intensity and more frequent defoliation of urine patches was observed. Edwards, Lucas, and Johnson (1993) applied calcium ammonium nitrate (26-0-0-0) at zero or 300 kg N/ha to old runout lucerne pastures overdrilled with seven grass species to investigate the effects of nitrogen applications on grazing selection. Plots were grazed by ewes with lambs at foot. Cocksfoot with 300 kg N/ha had a N content of 5.10% compared with 3.66% for cocksfoot with zero N applied. Grass height of cocksfoot plots with N decreased from 120 mm to 60 mm in the first day of grazing while plots with zero N applied remained constant at 60 mm. This indicated that sheep had a strong preference for plant species higher in N.

Grazing selection of livestock has the potential to change the dynamics of a pasture from legume dominant to grass dominant due to the strong preference for legume species. Furthermore what is available in a paddock before grazing may not actually be what is consumed during grazing. Therefore, pre-graze nutritive analysis may not be indicative of what was consumed. Post-graze nutritive analysis is required to allow determination of the exact quality of the diet selected by livestock.

## 2.10 Conclusions

- Lucerne is a perennial legume commonly sown as a monoculture but there has been increasing interest in using the species in a mix with grasses.
- Lucerne has an increased ability to extract water and a greater WUE than other species due to high N which enables increased photosynthetic rates. Lucerne/grass mixes appear to have a lower WUE however literature is limited.
- Lucerne has produced up to 50% more DM than traditional ryegrass based pastures in dryland situations.
- Lucerne has proven to produce superior ME and N yields than other species. There is little relevant data on the quality of lucerne/grass mixes. Previous work has shown lucerne/grass mixes can achieve the same ME production as monocultures.
- When lucerne is included in a mix with grass DM production is greater when infrequent grazing intervals are used.
- Inclusion of a grass species appears to reduce weed invasion.
- Pastures with a high proportion of green leaf should be utilised to meet animal ME requirements and maximise liveweight gains.
- Animals have shown a partial preference for legumes and species with high N contents. This may alter the botanical composition of lucerne/grass mixes under grazing.
- Supplementation generally results in substitution. Efficiency of grain utilisation was increased by using lick feeders rather than trailing grain.
- Previous experiments have found a lack of grain uptake by animals which has limited its use in pastoral systems.

### 3 MATERIALS AND METHODS

#### 3.1 Experimental Site

Both experiments are located on the Cemetery Block of Ashley Dene Research Farm, Canterbury, New Zealand (43°65' S, 172°32' E. 39 m a.s.l) in paddocks C6E, C7W and C7E (Appendix 9.1). The soil type is a mix of Lismore stony silt loam, Lowcliff stony silt loam and Ashley Dene deep fine sandy loam. Lismore stony silt loams have a water holding capacity (WHC) of 70-100 mm per metre of soil with excessive drainage. Stones are reached in the soil profile at a depth of 450-750 mm. Lowcliff stony silt loam soils are imperfectly drained with a WHC of 100-120 mm per metre of soil and 450-900 mm depth to stones. Ashley Dene deep fine sandy loams have the greatest depth to stones at over 900 mm (McLenaghan & Webb, 2012). The soil type is moderately to well drained and has a WHC of 100-160 mm per metre of soil.

#### 3.2 Site History

In December 2010 C6E was sown in kale (*Brassica oleracea* ssp. *acephala*) and C7E was sown in rape (*B. napus* ssp. *oleifera*). Both C6E and C7E were conventionally cultivated and lucerne, cocksfoot and brome were sown in November 2012 (Table 3.1). C7W has been 'Kaituna' lucerne since October 2006. Each species was sown in two different cultivars; 'Stamina 5' or 'Kaituna' lucerne, 'Safin' or 'Vision' cocksfoot and 'Bareno' grazing brome or 'Atom' prairie grass.

Fencing of the experimental area was completed in July/August 2011. C6E was divided into paddocks 1-6, C7W into 7-12 and C7E into 13-18. Poor establishment of the grass species meant re-sowing was necessary. Grass seed for reseeding was broadcast or drilled using a Fiona drill (Table 3.1). Lucerne in paddock C7E was resown with a Duncan drill due to poor establishment.

Table 3.1: Species cultivar, sowing date, rate and drill type for paddocks C6E, C7W and C7E at Ashley Dene, Canterbury.

Paddock	Sowing date	Species	Cultivar	Sowing rate (kg/ha)	Drill type	Method
C6E	18/11/2011	Cocksfoot	'Safin'	2	Triple disc	
			'Vision'	2	Triple disc	
		Brome	'Bareno'	10	Triple disc	
			'Atom'	10	Triple disc	
	19/11/2011	Lucerne	'Stamina 5'	8	Duncan	
	20/02/2012	Cocksfoot	'Safin'	3	Fiona	Broadcast
			'Vision'	3	Fiona	Broadcast
		Brome	'Bareno'	10	Fiona	Drilled
'Atom'			9	Fiona	Drilled	
C7W	13/10/2006	Lucerne	'Kaituna'	10	Commercial	
	20/02/2012	Cocksfoot	'Safin'	3	Fiona	Broadcast
			'Vision'	3	Fiona	Broadcast
		Brome	'Bareno'	10	Fiona	Drilled
			'Atom'	9	Fiona	Drilled
	C7E	18/11/2011	Cocksfoot	'Safin'	2	Triple disc
'Vision'				2	Triple disc	
Brome			'Bareno'	10	Triple disc	
			'Atom'	10	Triple disc	
19/11/2011		Lucerne	'Stamina 5'	8	Triple disc	
13/12/2011		Lucerne	'Stamina 5'	8	Duncan	
20/02/2012		Cocksfoot	'Safin'	3	Fiona	Broadcast
			'Vision'	3	Fiona	Broadcast
		Brome	'Bareno'	10	Fiona	Drilled
			'Atom'	9	Fiona	Drilled

### 3.3 Soil fertility

Soil samples were taken in May/June 2011. Results are show in Table 3.2. pH was the lowest in paddock C7E at 5.5 which is below the optimum for lucerne of 6-6.5. Sulphate sulphur was well

below the recommended 10-20 mg/kg in paddocks C6E and C7E where levels were 3 and 5 mg/kg, respectively.

Table 3.2: Soil test results from May/June 2011 for paddocks C6E, C7E and C7W at Ashley Dene, Canterbury.

Soil test	Optimum	C6E	C7W	C7E
pH	6-6.5	5.7	5.8	5.5
Olsen P	20-30	14	19	23
K (me/100g)	6-12	0.39	1.19	0.40
Ca (me/100g)	0.5-12	6.6	8.2	6.5
Mg (me/100g)	0.8-3.0	0.57	0.70	0.67
Na (me/100g)	0.1-0.5	0.12	0.13	0.12
CEC (me/100g)	20-25	15	15	14
Total base saturation	55-75	53	68	55
Sulphate sulphur (mg/kg)	10-20	3	18	5

### 3.4 Fertiliser

During September 2011 2 t/ha of lime was applied over all paddocks. In September 2012 Sulphur Super 15 (0,9,0,15) was applied to C6E at a rate of 250 kg/ha and 350 kg/ha in C7W and C7E.

On the 26 August 2013, 180 kg/ha of 20% sulphur superphosphate (0,9,0,20) was applied to all paddocks.

### 3.5 Meteorological data

Mean monthly air temperatures and monthly rainfall data were recorded at the Ashley Dene weather station located within the Cemetery Block, paddock C2 (43°65'S, 172°32'E). Rainfall was above average in October, December, March and three times greater than the average in April (Figure 3.1).

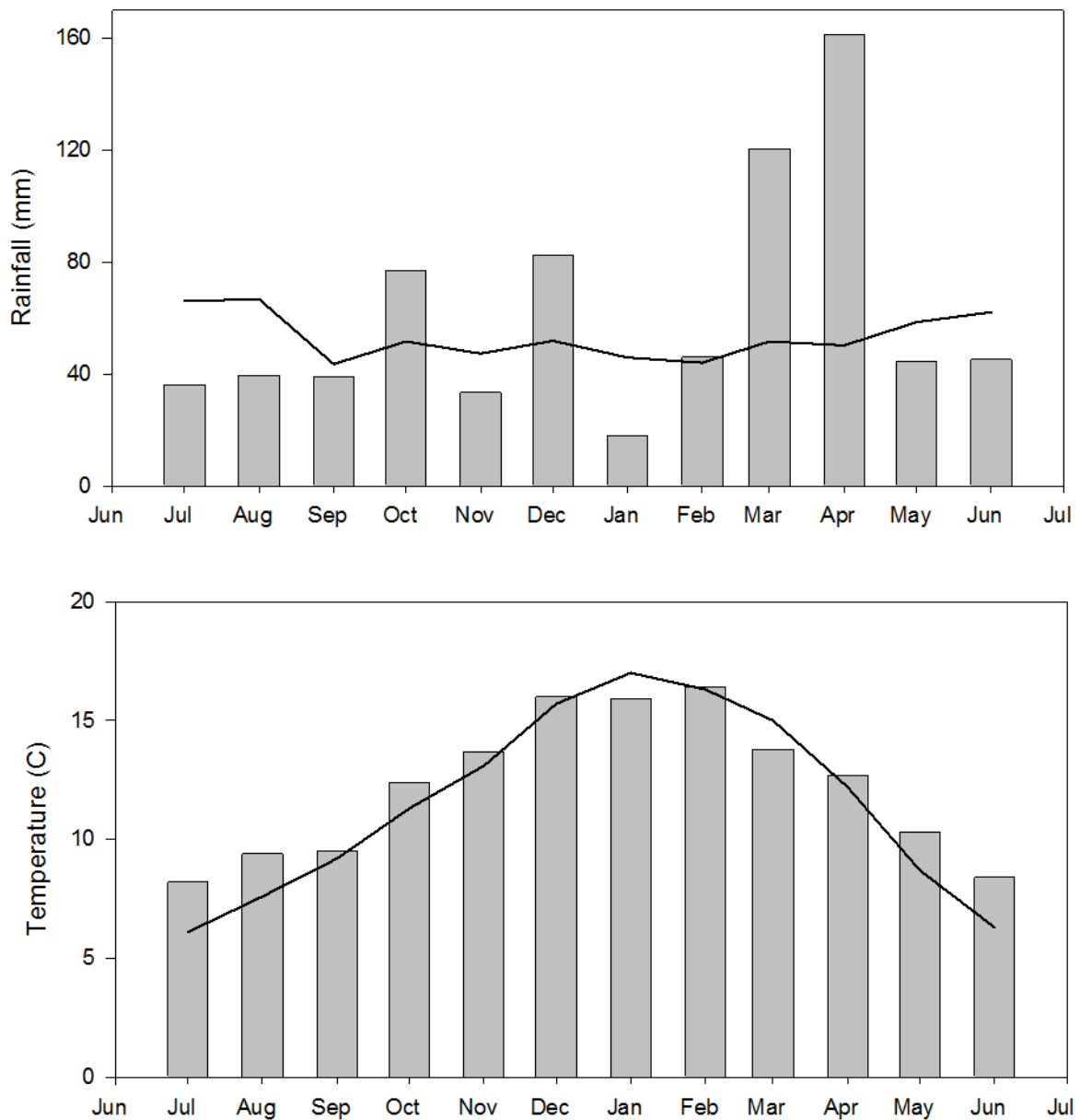


Figure 3.1: Mean monthly air temperature (a) and rainfall (b) (bars) for the 2013/2014 growing season with long term means (lines) for the period 1975-2010 (air temperature) and 1980-2009 (rainfall). Data were obtained from Ashley Dene weather station (43°65'S,172°35'E).

### 3.6 Weed control

Nodding thistles (*Carduus nutans*) were an issue in the older lucerne stands in C7W. The herbicide Velpar DF (active ingredient *Hexazinone* 240 g L<sup>-1</sup>) was sprayed in October 2011 and January 2012 at the recommended rate of 1.2 kg per 300 L water/ha for control of these. Velpar can suppress lucerne plants, therefore the stand was grazed severely before spraying to reduce the leaf area of lucerne plants, to minimize their herbicide uptake.

On the 14<sup>th</sup> January 2013 C7W (plots 7-12) were sprayed again with Velpar at the recommended rate (1.2 kg per 300 L water/ha). From October 2013 to January 2014 nodding thistles and horehound were hand removed as required from all plots.

### 3.7 Experimental design

Two experiments were carried out at the same experimental site. The main experiment (Experiment 1) was a complete randomised block design with six pasture replicates. A second grain experiment was superimposed on the lucerne monocultures in spring 2013. The lucerne replicates were split in half and a grain treatment was randomly allocated to each half.

#### 3.7.1 Experiment one

Experiment one involved 18 paddocks covering a total of 17.7 ha (Plate 3.1). There were three species replicates or six cultivar replicates. Each plot in the experiment is fenced with permanent net fencing. Small plastic troughs in each paddock supplied water to stock.

Ewes with twins were allocated to treatments from the 3<sup>rd</sup> September to the 18<sup>th</sup> September 2013 as they lambed, until total numbers required for the experiment were reached.

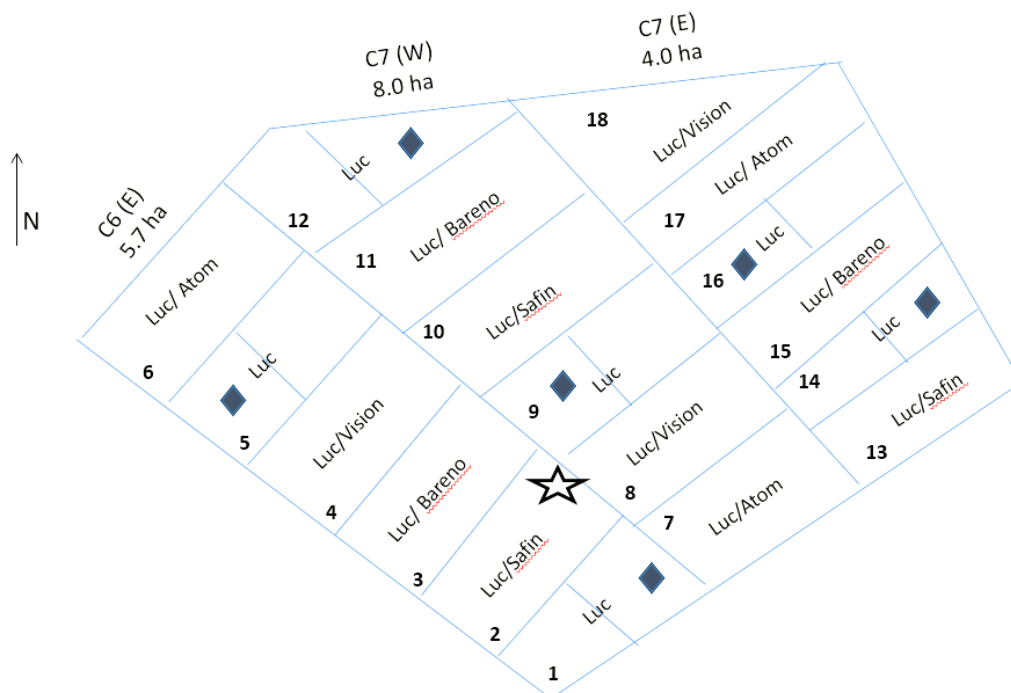


Plate 3.1: Map of experimental design showing paddocks C6E, C7W and C7E and plots 1-18. The total experimental area is 17.7 ha. At Ashley Dene, Canterbury. ◆ represents grain allocated plots.

### 3.7.1.1 Livestock and grazing management

Livestock were sourced from the Lincoln University Coopworth flock. Stock classes and rotation dates are summarised in Table 3.3. Detailed stock movements on a treatment and plot basis are given in Appendixes 7.2 to 7.4. Ewes with twin lambs began grazing the experiment from 3 September to 18 September as they lambed. Stock had access to salt licks at all times to avoid sodium deficiency which can occur when grazing lucerne (Sherrell, 1984). Three plots were grazed at once, with one from each treatment. Stock were shifted when desired residuals of approximately 1000-1500 kg DM/ha were met which was determined visually. The ewes and lambs completed two grazing rotations (three liveweight rotations) of the experimental site before being removed for weaning on 2 December 2013. Plots 10, 11 and 12 were hard grazed with ewe hoggets from the 24 September to the 01 October 2013 to simulate a hay crop (Table 3.3). This was because excellent early season pasture growth, and a slow start to lambing led to a surplus of feed. In a commercial situation such a surplus would lead to feed conservation.

Table 3.3: Summary of stock class, start and end date and plots grazed for each grazing rotation from 3/09/2013 to 30/04/2014 at Ashley Dene, Canterbury, New Zealand. Where E & L denotes ewes and lambs, WL denotes weaned lambs.

LWT Rotation	Stock Class	Start Date	End date	Plots grazed
1	E&L	13/09/2013	03/10/2013	1-3, 13-18
Cleanup	Ewe Hogs	24/09/2013	01/10/2013	10-12
2	E&L	3/10/2013	12/11/2013	1-9, 13-14, 16
3	E&L	13/11/2013	02/12/2013	6-9, 12, 15, 17, 18
4	WL	02/12/2013	16/12/2013	2, 3, 14
5	WL	16/12/2013	06/01/2014	4-9, 12-17
6	WL	06/01/2014	03/02/2014	1-18
7	Ram Hogs	24/03/2014	30/04/2014	1-18

Treatments were fully stocked on the 19/09/2013 (Figure 3.2). Ewes and lambs were weighed approximately monthly. Lambs were weaned and returned to the experimental site 02/12/2013. The stocking rate decreased from then on as lambs were removed for slaughter when they reached killable weights of 34 kg liveweight. The experiment was destocked on the 03/02/2014, due to low pasture growth. Restocking occurred on the 24/03/2014.

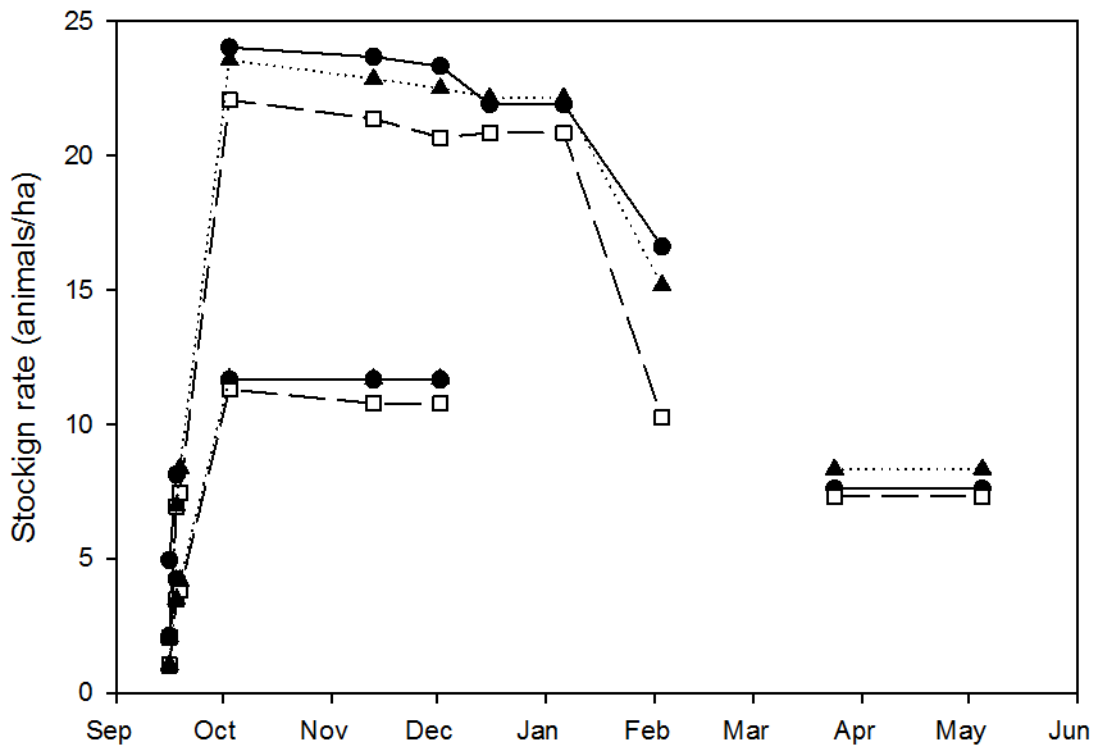


Figure 3.2: Stocking rate of ewes and lambs grazing on lucerne monocultures (●), lucerne/brome (□) and lucerne/cocksfoot (▲) from the 19/09/2013 to the 09/05/2014 at Ashley Dene, Canterbury.

### 3.7.1.2 Measurements

Annual measurements refer to the experimental period which occurs between 01/07/2013 to the 09/05/2014.

#### 3.7.1.2.1 Soil water budget

##### 3.7.1.2.1.1 Potential soil water deficit

Potential soil moisture deficit (PSMD) from the 01/07/2013 to 15/05/2014 is shown in Figure 3.3.

PSMD was set at zero on 1 July 2012 and accumulated from then on using Equation 1.

$$\text{Equation 1 Today's PSMD} = \text{Yesterday's PSMD} + \text{Today's Penman PET} - \text{Today's rainfall}$$

Negative PSMD values were not allowed to be returned. Rainfall and Penman potential evapotranspiration (PET) data were obtained from NIWA. PSMD increased from zero on 1 July 2013

to a maximum of 431 mm on 27 February 2013. PSMD is a calculated estimate based on climatic data, and is not an indication of the actual soil moisture deficit. This is found by examining the soil water content.

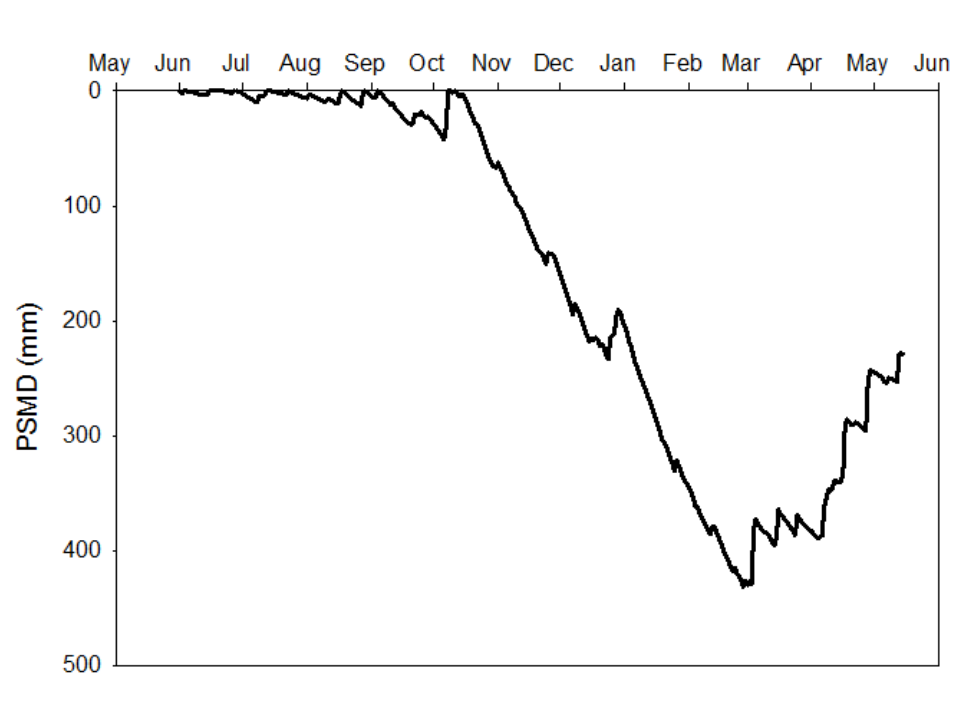


Figure 3.3: Potential soil moisture deficit (PSMD, mm) between 01/07/2013 and 15/05/2014 for paddocks C6E and C7E at Ashley Dene, Canterbury, New Zealand.

#### 3.7.1.2.1.2 Soil water content (SWC)

Volumetric soil water content was measured throughout the experiment. Measurements at 0-0.2 m were taken using a Time Domain Reflectometer (TDR) and a neutron probe (Troxler) was used for measurements every 0.2 m from 0.25-2.25 m. Data collected were used to calculate the soil water content (SWC) and plant available water.

Equation 2:  $Plant\ available\ water\ content = \Sigma(drained\ upper\ limit) - \Sigma(lower\ limit)$



Plate 3.2: Measurement of soil water content with a neutron probe (Troloxler) in Plot 1 at Ashely Dene, Canterbury on 27/03/2014.

#### 3.7.1.2.1.3 Water use efficiency

The water use efficiency (WUE) of the pastures was determined by calculating the amount of water used by the plants. This was done by calculating the accumulated potential evapotranspiration (PET) which represented a theoretical amount of water used by the pastures. PET was used rather than actual measured soil moisture as data collected were limited by missing values. DM produced for each treatment was plotted against PET and a regression calculated. The slope of the line represents the WUE of pastures.

#### 3.7.1.2.2 Dry matter measurements.

Sward height was measured using an automated sward stick with 50 measurements for lucerne and grass (in lucerne grass mixes) in each plot pre and post grazing. The average pasture height was determined using Equation 3.

$$\text{Equation 3: } \mathbf{Height (cm)} = \left( \frac{\text{Number of clicks}}{\text{Number of readings}} \right) / 2$$

Height measurements were then calibrated with three quadrat cuts to determine the dry matter yield. A rectangular 0.2 m<sup>2</sup> quadrat was placed across drill rows in an area representative of the entire paddock. Three destructive quadrat cuts of high, medium and low heights were taken for each plot. The height of lucerne and grass (in lucerne/grass mix paddocks) was measured. Plant material

within the quadrat was cut with hand shears and stored at 4°C in paper bags until the sample was sorted into botanical components. Approximately half of a sample was sorted into lucerne, grass (brome or cocksfoot), weeds and dead material. The remainder represented the ‘bulk’ of the sample, for total dry matter. The samples were then dried to a constant weight in a forced air oven at 60°C for a minimum of 48 hours. Following drying, samples were weighed using Mettler Toledo PB1502 and Sartorius 3716 electronic scales to determine the dry matter of the quadrat samples. Height and dry matter measurements were used to produce linear regressions of the relationship as a method of calculating dry matter yields (Figure 3.4). The height of each of the quadrat cuts was plotted against its corresponding DM yield and a linear regression was fitted based on the season and treatment. Spring regressions were based on lucerne height for monocultures, average height for lucerne/brome pastures and grass height for lucerne/cocksfoot. For the summer period there was a difference ( $P < 0.026$ ) in regressions for old and new lucerne in lucerne and lucerne/brome pastures. Lucerne monocultures and lucerne/brome pasture regressions were based on lucerne height and lucerne/cocksfoot regression based on average height for the summer period (Figure 3.4). In the autumn spring regressions were used as limited data available meant regressions could not be formed for this period. Calculated regressions are given in Table 3.4.

Table 3.4: Regressions used for DM calculations for lucerne monocultures, lucerne/cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes at Ashley Dene, Canterbury.

Pasture	Slope	Intercept	R <sup>2</sup>
<i>Spring/Autumn</i>			
Lucerne	93.4	74.5	0.82
Luc/Br	98.1	140	0.91
Luc/Cf	87.4	113	0.80
<i>Summer</i>			
Lucerne – new stand	89.3	319	0.70
Luc/Br – new stand	92.0	108	0.69
Luc/Cf	115.2	-11.7	0.71
Lucerne – old stand	63.3	285	0.75
Luc/Br – old stand	92.6	153	0.67

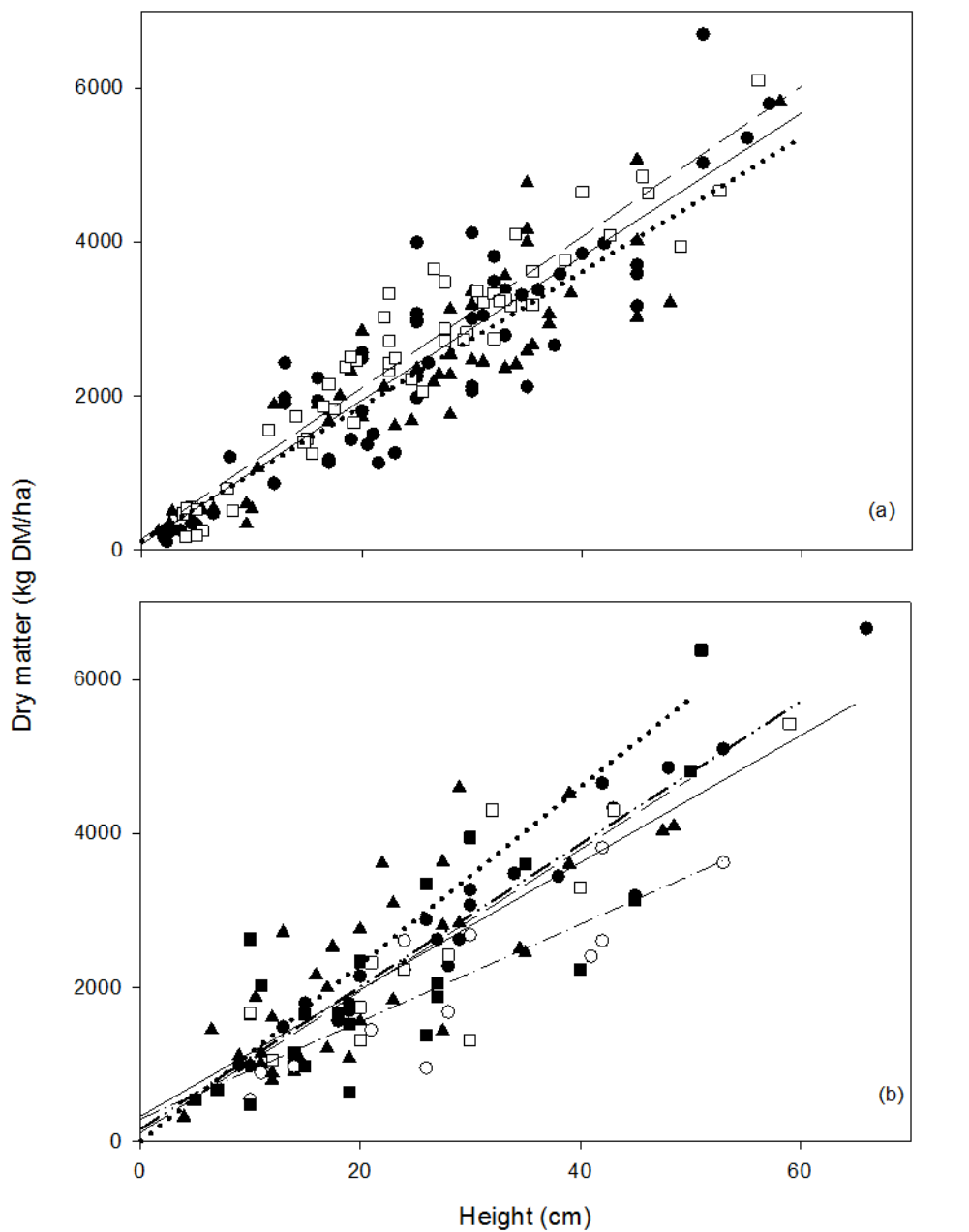


Figure 3.4: Spring (a) and summer (b) linear regressions of lucerne height versus dry matter (DM) yield at Ashley Dene, Canterbury for old (○) and new (●) lucerne monocultures, old (□) and new (■) lucerne/brome pastures and lucerne/cocksfoot (▲) pastures. Regressions used are given in Table 3.4.

DM were summarised for each grazing rotation. Grazing rotations did not always coincide with liveweight rotations and were different for each pasture.

Table 3.5: Summary of timing of grazing rotations for lucerne monocultures, lucerne brome (Luc/Br) and lucerne/ cocksfoot (Luc/Cf) pastures at Ashley Dene, Canterbury. Grazing began on the 03/09/2013 and finished on the 09/05/2014.

Treatment	Grazing Rotation	Start Date	End Date
Lucerne	1	03/09/2013	23/10/2013
Luc/Br	1	06/09/2013	27/10/2013
Luc/Cf	1	06/09/2013	25/10/2013
Lucerne	2	23/10/2013	30/11/2013
Luc/Br	2	27/10/2013	10/12/2013
Luc/Cf	2	25/10/2013	10/12/2013
Lucerne	3	30/11/2013	06/01/2014
Luc/Br	3	10/12/2013	17/01/2014
Luc/Cf	3	10/12/2013	17/01/2014
Lucerne	4	06/01/2014	03/02/2014
Luc/Br	4	17/01/2014	03/02/2014
Luc/Cf	4	17/01/2014	01/02/2014
Lucerne	5	24/03/2014	09/05/2014
Luc/Br	5	24/03/2014	09/05/2014
Luc/Cf	5	24/03/2014	09/05/2014

#### 3.7.1.2.2.1 Lucerne quality

Samples taken throughout the duration of the experimental period were analysed for nutritional quality. Pre-graze samples were obtained for grazing rotations 1-4 for lucerne monocultures and lucerne/brome pastures and Rotations' 2-4 for lucerne/ cocksfoot pastures. Post graze samples were obtained for grazing Rotations' 2-4. This meant annual data for post grazing was based on averages from Rotations' 2-4. The three destructive cuts were combined, into one sample which was then analysed by infrared spectrometry (NIRS) to determine the nutritive quality. Quality of sown grass, lucerne, weeds and a representative portion of the pasture which included all components were analysed.

#### 3.7.1.2.2.2 Thermal time

Thermal time was calculated to determine the relationship between yield and air temperature. Temperature data used were from Broadfields meteorological station. When moisture is not limiting, pasture growth rates can be related to thermal time (Tt) (also known as heat units or growing degree days ( $^{\circ}\text{Cd}$ )) (Tonmukayakul *et al.*, 2009). Thermal time is calculated as the mean

temperature minus the base temperature (Tb) below which no growth occurs (Equation 4) (Black, Moot, & Lucas, 2006). Both thermal time and base temperature are species dependent. A base temperature of 0°C was used. Thermal time allows for comparisons across pasture species to be made.

Equation 4: Thermal time (°Cd) =  $\sum \left[ \left( \frac{T_{max} + T_{min}}{2} \right) - T_b \right]$

### 3.7.1.2.3 Live weight measurements

Stock were weighed approximately monthly throughout the experiment using a Tru Test XR3000 system attached to a Prattley weigh crate. All animals were tagged with electronic identification tags.

The total number of graze days for the experimental period was derived by multiplying the number of stock by the duration of grazing. A summary of grazing and liveweight rotations with the stock class grazing and measurements taken is given in Table 3.6. Rotations were classified as either ‘production’ periods where liveweight gain was measured or ‘maintenance’ periods where clean up grazing occurred and animals were not measured but assumed to maintain a constant weight. LWT measurement periods did not always coincide with grazing rotations due to animals being weighed more than once in some rotations.

Table 3.6: Summary of stock classes and measurements taken for grazing rotations from 13/09/13 to 30/04/2014. Where E & L denotes ewes and lambs, W L denotes weaned lambs, Ram Hgts denotes ram hoggets and Ewe Hgts denotes ewe hoggets. Measurements taken include dry matter yield (DM), animal liveweight gain (LWT), botanical composition (BC) and nutritive value (NU) and are indicated by a ‘Y’. LWT period determines if the rotation was a ‘production’ or ‘maintenance’ period. Liveweight (LWT) rotation is when stock were weighed relative to grazing rotations.

Grazing Rotation	Plots Grazed	Stock Class	DM	LWT	BC		NU		LWT	
					Pre	Post	Pre	Post	Rotation	LWT Period
1	1-18	E&L	Y	Y	Y		Y		1	Production
1a	10-12	Ewe Hgts	Y						-	Maintenance
2	1-18	E&L	Y	Y	Y	Y	Y	Y	2-3	Production
3	1-18	WL	Y	Y	Y	Y	Y	Y	3-6	Production
4	1-18	WL	Y	Y	Y	Y	Y	Y	6	Production
5	1-18	Ram Hgts	Y	Y					7	Production

### 3.7.1.3 Statistical Analysis

Statistical analyses were carried out in Genstat 15 (Version 15, VSN International Ltd, Hemel Hempstead, UK). Data for individual plots were tested by one-way analysis of variance (ANOVA). For analysis of pasture mixes there were 5 replicates of 3 pasture mixes (d.f.=14). 5 replicates were used due to missing data in Rep 4. A tukey test was used to determine differences in annual and rotational yield and botanical composition.

Annual lamb liveweight production was analysed by one-way ANOVA using the plots as replicates. Ewe liveweight production was calculated using the entire experimental area which meant it was not analysed due to no replication. Mean ewe liveweight was compared using a one-way ANOVA. Rotational liveweight gain was analysed by one-way ANOVA using the animals as replicates. Differences in the standard error of the mean (SEM) between treatments for animal liveweight gains are due to there being different numbers of stock grazing each treatment.

Thermal time, WUE and height against dry matter were analysed by fitting linear regressions. Regressions and coefficients of determination ( $R^2$ ) values for spring thermal time and spring WUE were fitted in Microsoft Excel 2010, then the regression coefficients were analysed in Genstat by one-way analysis of variance in randomized blocks.

### **3.7.2 Experiment two**

Experiment two involved twelve lucerne plots. These were within the lucerne paddocks of Experiment 1 (Plate 3.1). Experiment two used six paddocks (1,5,9,12,14 and 16) of Experiment 1. Paddocks were divided using flexi nets to create 12 plots. There were two treatments of either lucerne or lucerne with grain supplementation. There were six replicates of each treatment. Experiment two finished in grazing Rotation 4 and liveweight Rotation 6.

#### **3.7.2.1 Livestock and grazing management**

Livestock for the experiment were sourced from the Lincoln University Coopworth flock. Stock classes and rotation dates are summarised in Table 3.3. Livestock followed the same grazing rotation and were managed in the same way as livestock in Experiment 1. Ewes with twin lambs at foot were allocated to treatments in the same manner as in Experiment 1. Treatments were fully stocked on the 18/09/2013. At this point there were 11.3 ewes/ha on the +grain treatment and 11.7 ewes/ha on the –grain treatment. Lambs on the 18/09/2013 were stocked at 21.9 lambs/ha on the +grain treatment and 23.0 lambs/ha on the –grain treatment. Stock were weaned and lambs returned to the experiment on the 2<sup>nd</sup> December 2013 at a stocking rate of 21 lambs/ha on the +grain treatment and 23 lambs/ha on the –grain treatment. From that point onwards stocking rate decreased as lambs reached killable weights of 32-34 kg.

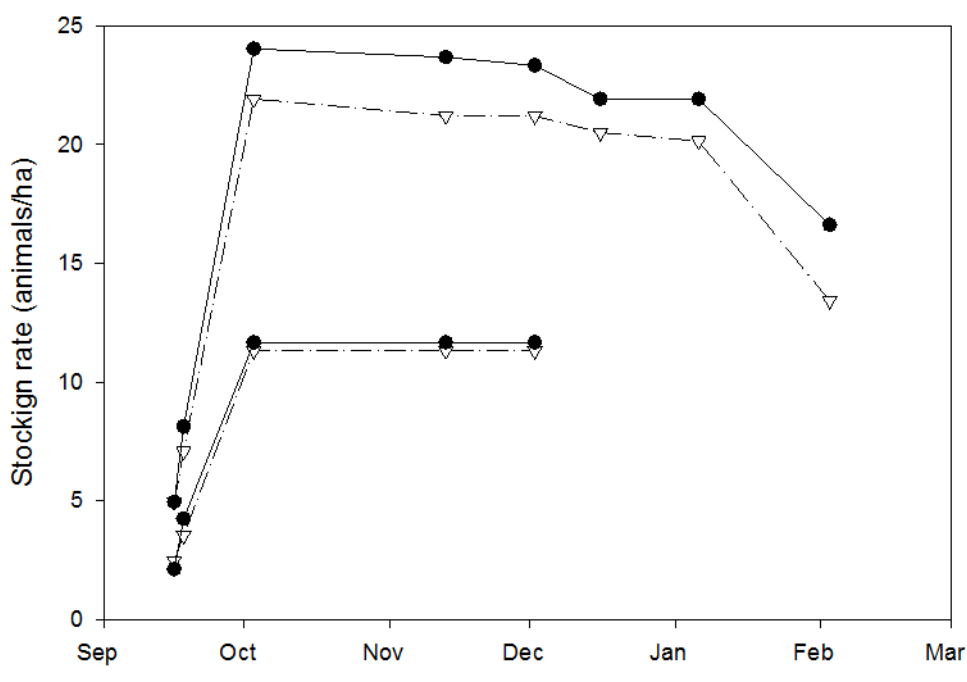


Figure 3.5: Stocking rate of ewes and lambs from 13/09/2013 to 03/02/2014 on lucerne monocultures – grain (●) and + grain (▽) at Ashley Dene, Canterbury, New Zealand.

Stock for both treatments were moved when lucerne on one treatment reached desired residual levels of approximately 1000-1500 kg DM/ha. Details of stock grazing each treatment are given in Table 3.7.

Table 3.7: Summary of stock grazing lucerne pastures with grain supplementation (+) and without grain supplementation (-) for either production or maintenance liveweight (LWT) from 13/09/2013 to 03/02/2014 at Ashley Dene, Canterbury.

Season	Treatment	LWT Rot	Production	Stock	Date on	Date off
Spring	+	1,2,3	Production	E&L	3/09/2013	2/12/2013
Spring	-	1,2,3	Production	E&L	3/09/2013	2/12/2013
Spring	+		Maintenance	Ewe hogs	24/09/2013	30/09/2013
Spring	-		Maintenance	Ewe hogs	24/09/2013	30/09/2013
Summer	+	4,5	Production	WL	3/12/2013	6/01/2014
Summer	-	4,5	Production	WL	3/12/2013	6/01/2014
Summer	+	6	Production	WL	6/01/2014	3/02/2014
Summer	-	6	Production	WL	6/01/2014	3/02/2014

### 3.7.2.2 Grain supplementation

Barley grain was fed to those ewes and lambs on lucerne plus grain plots (Plate 3.1). Two Advantage 'NGF800' feeders were used which were shifted (by towing) as required. Feeders were placed within the plots in the same position each time to contain any damage to pastures to small areas. The feeders had an adjustment system which involves two movable adjusters that slide perpendicular to each other. The design required stock to lick grain out of the groove. This restricted the ability of stock to gorge themselves with grain, as their saliva decreased with progressive licks. Ewe excluders were put in the feeders on the 17/10/2013. Grain was added to the feeders in 40 kg bags as required (Table 3.8). Bags were weighed prior to being put in feeders. At the end of the spring and summer grazing period there was an estimated 20 kg of barley grain left in the feeders.



Plate 3.3: Ewes and lambs with an Advantage grain feeder in Plot 13 at Ashley Dene, Canterbury on 01/11/2013.

Table 3.8: Barley grain allocated to Advantage feeders for the spring and summer period of the experiment at Ashley Dene, Canterbury. E&L denotes ewes and lambs, WL denotes weaned lambs

Date	Grain fed (kg)	LWT Rotation	Stock
13/09/2013	40	1	E&L
25/09/2013	37	1	E&L
1/10/2013	40	1/2	E&L
7/10/2013	41	2	E&L
11/10/2013	41	2	E&L
15/10/2013	38	2	E&L
21/10/2013	43	2	E&L
25/10/2013	37	2	E&L
30/10/2013	44	2	E&L
4/11/2013	38	2	E&L
8/11/2013	42	2	E&L
12/11/2013	41	2	E&L
13/11/2013	36	3	E&L
13/11/2013	37	3	E&L
21/11/2013	40	3/4	E&L
22/11/2013	39	4	E&L/WL
17/12/2013	39	4/5	WL
29/12/2013	41	5/6	WL
20/01/2014	37	6	WL
<b>TOTAL</b>	<b>750</b>		

### 3.7.2.3 Measurements

#### 3.7.2.3.1 DM measurements

In Experiment 2 50 height measurements were taken pre and post grazing in each lucerne treatment using an automated sward stick. Start and end values were recorded and used to calculate an average height for each plot using Equation 3. Height measurements were then calibrated with three quadrat cuts in the same manner as Experiment 1 (Section 3.7.1.2.2).

#### 3.7.2.3.2 Liveweight measurements

Stock were weighed in accordance with Experiment 1. The final liveweight measurement for Experiment 1 was carried out on the 3<sup>rd</sup> February 2014.

#### 3.7.2.4 Statistical analysis

Statistical analyses were carried out in Genstat 15 (Version 15, VSN International Ltd, Hemel Hempstead, UK). Dry matter and lamb liveweight production were analysed using a paired 't'-test with plots as replicates. Animal liveweight gains were analysed using a paired 't'-test with animals as the replicates.

## 4 RESULTS

### 4.1 Experiment One

#### 4.1.1 Animal production

##### 4.1.1.1 Total animal production

Animal production from the measured periods totalled 808 kg LWT/ha for animals grazing lucerne monocultures, 642 kg LWT/ha from lucerne/brome pastures and 605 kg LWT/ha from lucerne/socksfoot pastures (Figure 4.1). Spring liveweight production from ewes and lambs was 512 kg LWT/ha for lucerne monocultures, 420 kg LWT/ha for lucerne/brome mixes and 366 kg LWT/ha produced from lucerne/socksfoot mixes. Summer liveweight production from weaned lambs grazing lucerne monocultures was 229 kg LWT/ha compared with 158 kg LWT/ha for lucerne/brome mixes and 173 kg LWT/ha produced from lucerne/socksfoot mixes. Autumn liveweight production from ram hoggets was 66±1 kg LWT/ha for all three pasture.

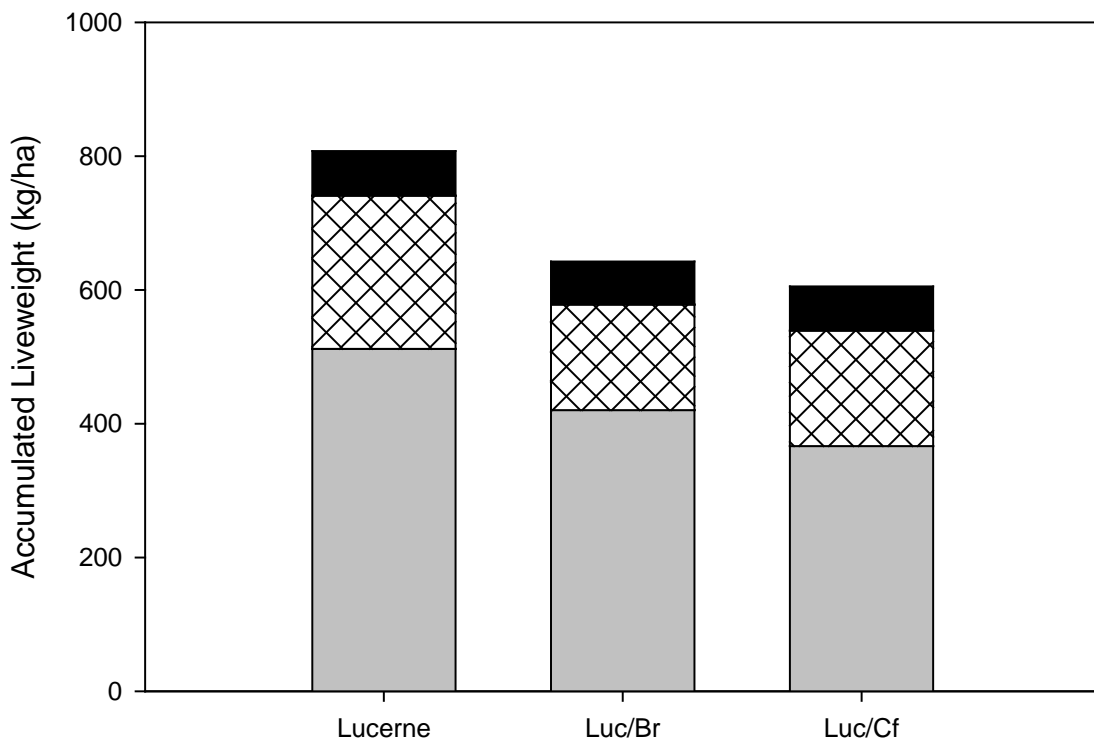


Figure 4.1: Annual liveweight production of lucerne monocultures, lucerne/brome (Luc/Br) and lucerne/socksfoot (Luc/CF) mixes over seven liveweight production periods from 3/09/2013 to 09/05/2014 at Ashley Dene, Canterbury, New Zealand. Stacked bars represent spring liveweight gain with ewes and lambs (■), summer liveweight gain with weaned lambs (▨) and autumn liveweight gain with ram hoggets (■).

#### 4.1.1.2 Spring liveweight from ewes and lambs

In the lactation phase during spring, 100% of the total liveweight gained was from lambs on all treatments. Ewes lost liveweight production during the spring period. Ewes on lucerne monocultures lost less liveweight (-15 kg/ha) than those on the lucerne/grass mixes (-87 kg/ha) during the spring period. Liveweight accumulated by lambs was not different ( $P < 0.487$ ) between treatments.

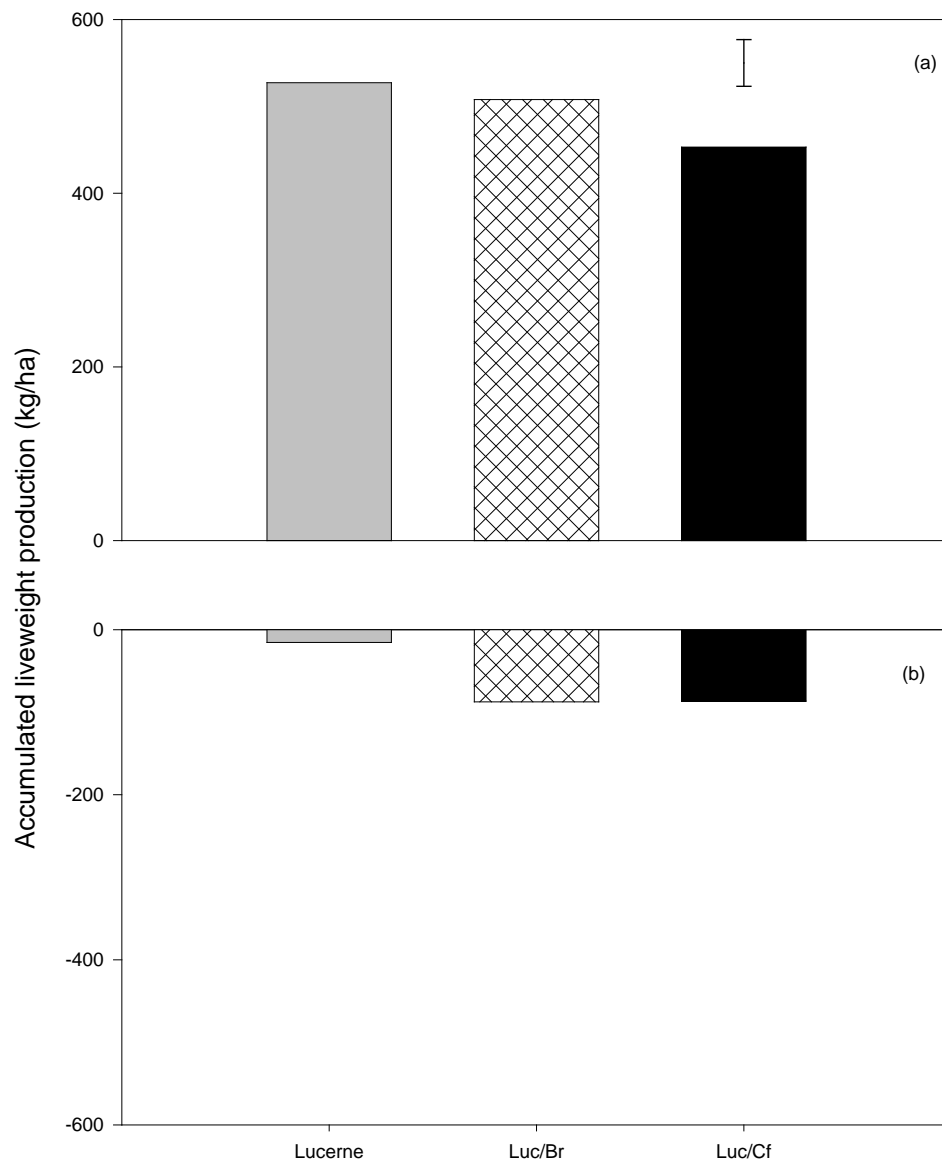


Figure 4.2: Spring liveweight production (kg LWT/ha) for Rotations 1 to 3 for lambs (a) and ewes (b) grazing lucerne monocultures (■), lucerne/brome (▨) and lucerne/cockfoot (■) mixes at Ashley Dene, Canterbury, New Zealand. The error bar is SEM for lamb liveweight production across treatments.

#### 4.1.1.3 Ewe liveweight

Ewes on lucerne/brome pastures initially weighed 69 kg/head which was more than ( $P<0.036$ ) the 63 kg/head for ewes on lucerne monocultures (Figure 4.3) while ewes grazing lucerne/cockfoot pastures (66 kg/head) were not different to the other treatments. At the end of lactation, ewes grazing lucerne/grass mixes had lost more ( $P<0.002$ ) weight (-7.7 kg/head for lucerne brome pastures and -5.3 kg/head for lucerne cocksfoot pastures) than those grazing lucerne monocultures (-1.2 kg/head).

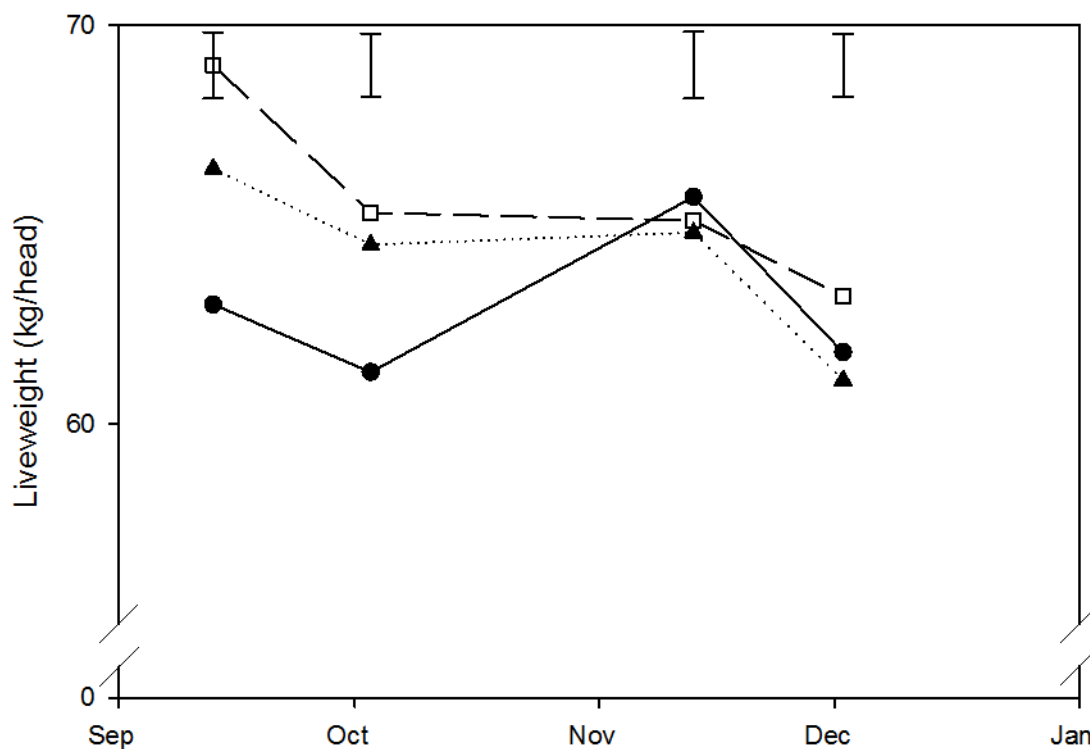


Figure 4.3: Change in lactating ewe liveweight from 03/09 to 02/12/2013 (weaning) on lucerne monocultures (●), lucerne/brome (□) and lucerne/cockfoot (▲) mixes at Ashley Dene, Canterbury, New Zealand.

#### 4.1.1.4 Rotational animal liveweight change

Rotation 1 liveweight losses were highest ( $P<0.001$ ) for ewes grazing lucerne/brome pastures (-237 g/head/d) and gains were lowest ( $P<0.001$ ) for lambs grazing lucerne/cockfoot pastures (248 g/head/d) (Table 4.1). In Rotation 2 ewes and lambs grazing lucerne monocultures had the greatest ( $P<0.001$ ) liveweight gains (107 and 242 g/head/d respectively). Liveweight gains of ewes and lambs grazing lucerne/grass mixes in Rotation 2 were not different. In Rotation 3 lambs on lucerne/cockfoot pastures continued to have the lowest liveweight gains ( $P<0.001$ ). Ewes on lucerne/brome pastures had the lowest liveweight loss in Rotation 3 of -118 g/head/d.

Table 4.1: Liveweight change (g/head/d) of ewes and lambs grazed on lucerne, lucerne/ cocksfoot (Luc/CF) or lucerne/brome (Luc/Br) mixes over liveweight Rotations 1, 2 and 3 from 03/09 to 02/12/13 at Ashley Dene, Canterbury, New Zealand.

Treatment	Rotation 1		Rotation 2		Rotation 3	
	LWT (g/head/d)	SEM	LWT (g/head/d)	SEM	LWT (g/head/d)	SEM
<i>Ewes:</i>						
Lucerne	-103a	31.2	108a	13.2	-205a	21.0
Luc/Br	-237b	28.0	5b	10.2	-118b	16.5
Luc/Cf	-134a	28.6	8b	8.7	-193a	14.8
<i>Lambs:</i>						
Lucerne	305a	6.5	242a	6.1	177a	6.5
Luc/Br	311a	6.5	203b	4.5	159a	6.5
Luc/Cf	248b	7.0	202b	4.0	111b	5.9

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests. For rotation details see Table 3.3.

In the summer period liveweight gains of weaned lambs on lucerne were 77 g/head/day in liveweight Rotation 4 which was lower ( $P<0.001$ ) than gains from lambs on lucerne/brome (131 g/head/d) pastures (Table 4.2). Lambs grazing lucerne/ cocksfoot pastures had the highest ( $P<0.001$ ) liveweight gains in Rotation 4 (174 g/head/d). In liveweight Rotation 5 lambs grazing lucerne/brome pastures had higher ( $P<0.001$ ) liveweight gains (108 g/head/day) than lambs grazing lucerne/ cocksfoot pastures (64 g/head/day). Lambs on lucerne monocultures had higher ( $P<0.001$ ) liveweight gains in liveweight Rotation 6 compared with lambs on lucerne/ grass mixes (179 g/head/d).

Table 4.2: Liveweight gain (g/head/d) of lambs grazed on lucerne, lucerne/brome (Luc/Br) or lucerne/ cocksfoot (Luc/Cf) mixes over liveweight Rotations 4, 5 and 6 from 02/12/2013 to 03/02/2014 at Ashley Dene, Canterbury, New Zealand

Treatment	Rotation 4		Rotation 5		Rotation 6	
	LWT (g/head/d)	SEM	LWT (g/head/d)	SEM	LWT (g/head/d)	SEM
Lucerne	77a	12.2	96ab	13.6	352a	11.3
Luc/Br	131b	13.2	108a	8.1	176b	8.9
Luc/Cf	174c	11.1	64b	8.1	182b	7.7

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests. For rotation details see Table 3.3.

In the autumn during liveweight Rotation 7, ram hoggets on lucerne/socksfoot pastures had the lowest ( $P<0.001$ ) liveweight gains of 186 g/head/day (Table 4.3). Liveweight of ram hoggets grazing lucerne monocultures and lucerne/brome pastures were not different at ~240 g/head/d.

Table 4.3: Liveweight gain (g/head/d) of ram hoggets grazed on lucerne, lucerne/socksfoot (Luc/CF) or lucerne/brome (Luc/Br) mixes over liveweight Rotation 7 from 24/03/2014 to 09/05/2014 at Ashley Dene, Canterbury, New Zealand

Treatment	Rotation 7 LWT (g/head/d)	SEM
Lucerne	246a	7.45
Luc/Br	241a	7.33
Luc/Cf	186b	5.53

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests. For rotation details see Table 3.3.

#### 4.1.2 Pasture dry matter yield

##### 4.1.2.1 Accumulated dry matter yield

At the end of the experimental period there was no difference ( $P<0.470$ ) in accumulated DM for all pasture types. From 01/07/2013 to 30/04/2014 all pastures had accumulated ~15 t DM/ha.

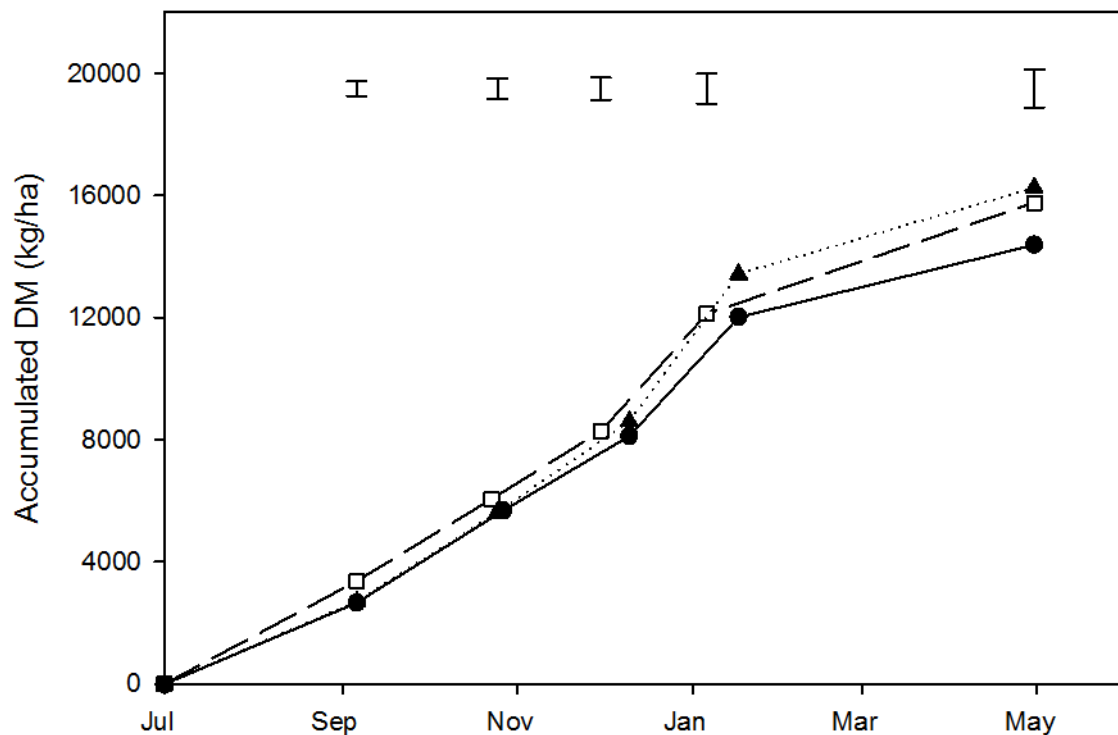


Figure 4.4: The total accumulated dry matter (DM) yield of lucerne monocultures (●), lucerne/brome (□), and lucerne/cockfoot (▲) pastures from 1/07/2013 to 30/04/2014 at Ashley Dene, Canterbury, New Zealand. Error bars are +/- SEM.

#### 4.1.2.2 Mean daily growth rates

For the period between the 01/07 and the 06/09/2013 all pastures ( $P < 0.081$ ) grew at 32 kg DM/ha/d (Figure 4.5). In grazing Rotation 2 from the 06/09/2013 to the 27/10/2013 there was no difference ( $P < 0.994$ ) in pasture growth rates (104 kg DM/ha/d) among pastures. In Rotation 3 all pastures ( $P < 0.219$ ) grew 95 kg DM/ha/d. In Rotation 4 from the 30/11/2013 to the 06/01/2014 for lucerne monocultures and 10/12/2013 to the 17/01/2014 for lucerne/grass mixes, lucerne monocultures had faster ( $P < 0.034$ ) growth rates (79 kg DM/ha/d) than lucerne grass mixes (54 kg DM/ha/d). During the autumn period all pastures ( $P < 0.091$ ) grew at 42 kg DM/ha/d.

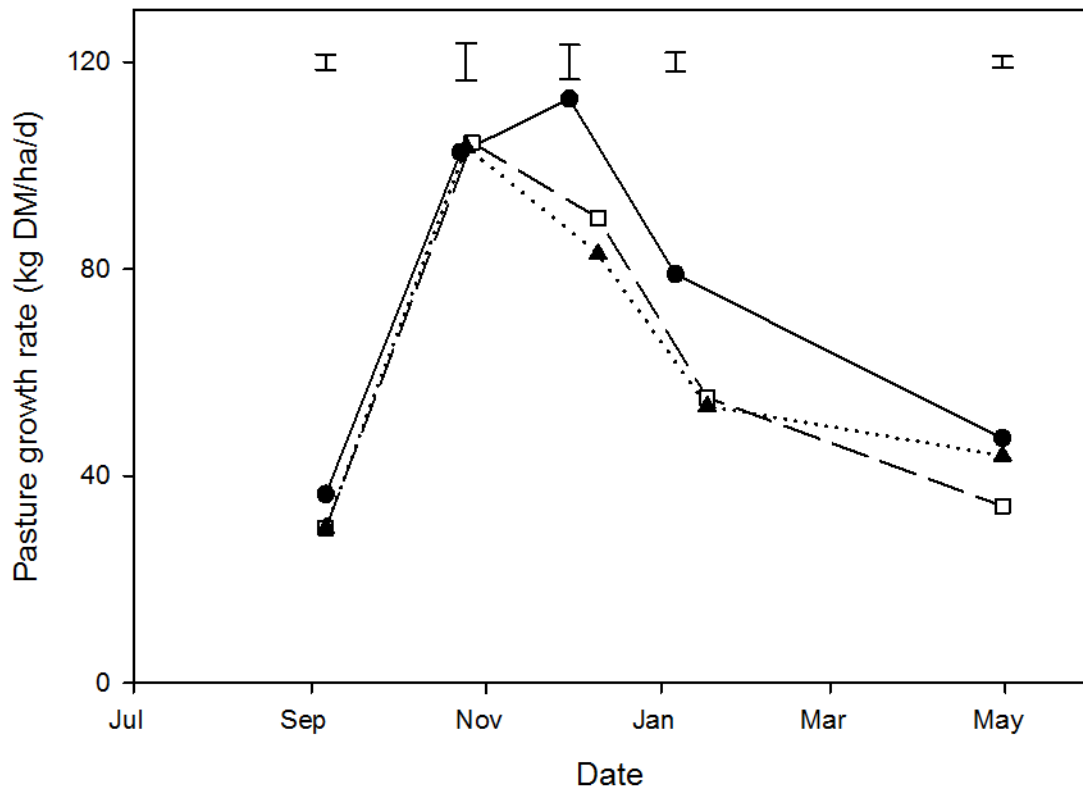


Figure 4.5: Mean daily growth rates of lucerne monocultures (●), lucerne/brome (□), and lucerne/cocksfoot (▲) pasture mixes for regrowth cycles between 01/07/2013 and 30/04/2014 at Ashley Dene, Canterbury, New Zealand. Error bars are SEM for each harvest date.

#### 4.1.2.3 Thermal time relationships

The relationship between thermal time and accumulated dry matter was linear for all pastures from the 01/07/2013 to 30/04/2014. All pastures ( $P < 0.302$ ) grew at  $4.5 \pm 0.21$  kg DM/ha/°Cd.

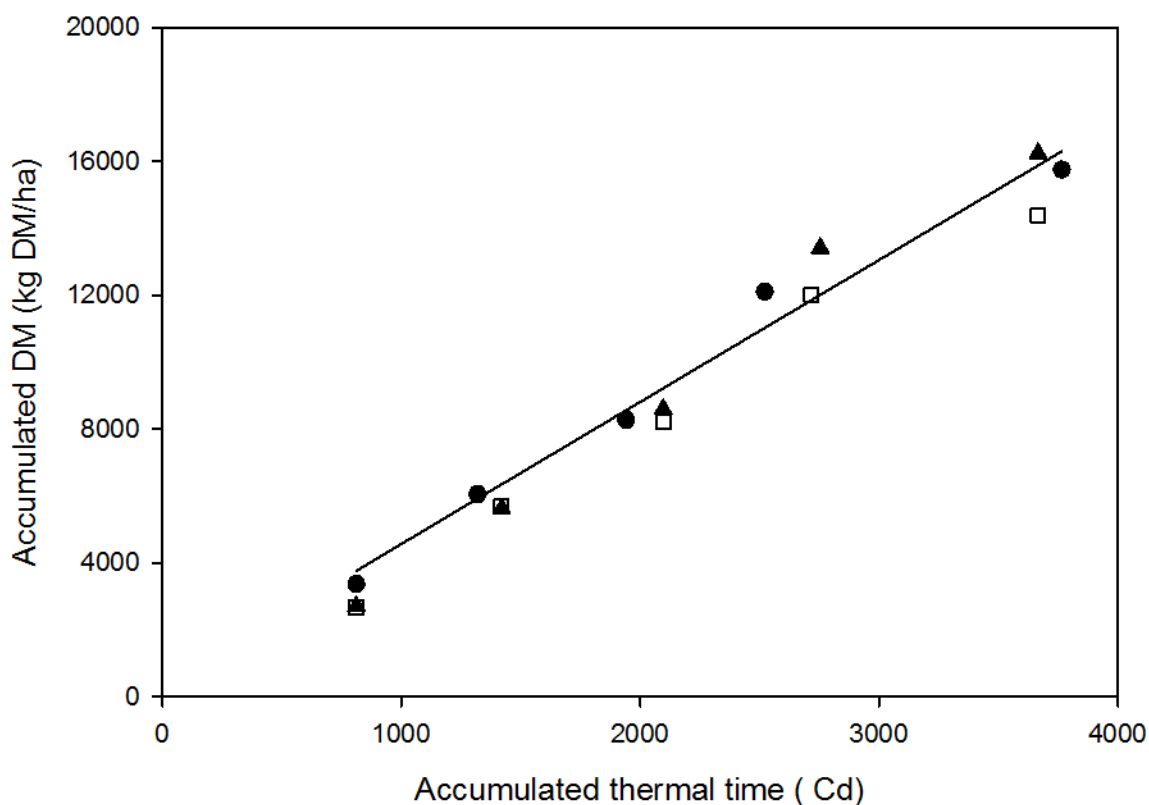


Figure 4.6: Relationship between accumulated dry matter (DM) yield and accumulated thermal time ( $^{\circ}\text{Cd}$ ,  $T_b=0^{\circ}\text{C}$ ) for rates of lucerne monocultures (●), lucerne/brome (□), and lucerne/cocksfoot (▲) pasture mixes from 01/07/2013 and 30/04/2014. Thermal time was accumulated using air temperature. The regression was:  $\text{Yield} = 4.5 \pm 0.21x - 430 \pm 494$  ( $R^2=0.98$ )

#### 4.1.2.4 Botanical composition

##### 4.1.2.4.1 Annual botanical composition

Prior to grazing, botanical composition of the lucerne component was highest ( $P<0.001$ ) in lucerne monocultures at 57.3% (Table 4.4). Lucerne monocultures also had the highest ( $P<0.001$ ) weed component (20.4%). The botanical composition was not different between the lucerne/grass mix treatments. Post-grazing the lucerne component had decreased to 33.6% for lucerne monocultures, 17.7% for lucerne/brome pastures and 14.7% for lucerne/cocksfoot pastures (Table 4.5). Lucerne monocultures maintained a higher ( $P<0.001$ ) lucerne and weed proportion post grazing compared with lucerne/grass mixes. The composition of the lucerne/grass mixes were not different post-grazing. Animals on all treatments ( $P<0.987$ ) consumed on average 41% of the pasture available.

Table 4.4: Annual pre-grazing botanical composition of lucerne monocultures, lucerne/brome (Luc/Br) and lucerne/cocksfoot (Luc/Cf) mixes from 19/09/2013 to 30/04/2014 at Ashley Dene, Canterbury.

Treatment	Lucerne %	Grass %	Weed %	Dead %
Lucerne	57.3a	-	20.4a	19.8
Luc/Br	35.0b	32.2	6.9b	25.5
Luc/Cf	37.3b	33.7	4.3b	23.6
Mean	43.2	33.0	10.5	23.0
SEM	1.55	1.91	2.63	1.16
P value	<0.001	0.700	<0.001	0.162

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests.

Table 4.5: Annual post-grazing botanical composition of lucerne monocultures, lucerne/brome (Luc/Br) and lucerne/cocksfoot (Luc/Cf) mixes from 19/09/2013 to 30/04/2014 at Ashley Dene, Canterbury.

Treatment	Lucerne %	Grass %	Weed %	Dead %
Lucerne	33.6a	-	20.8a	45.6
Luc/Br	17.7b	23.0	7.5b	51.1
Luc/Cf	14.7b	29.3	4.8b	51.8
Mean	22.0	26.15	11.0	49.5
SEM	1.75	2.45	1.37	1.55
P value	<0.001	0.225	<0.001	0.227

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests.

#### 4.1.2.4.2 Rotation 1

The lucerne component of the pre-graze pastures was 72.4% in the pure lucerne, 39.9% in lucerne/brome and 53.0% in lucerne/cocksfoot (Table 4.6). The dead component was highest in the lucerne/brome treatment (8%). There were no post grazing data available in Rotation 1. The weed component of all pastures ( $P<0.145$ ) was 16.8%. Weeds were predominantly grass weeds with some horehound and other broadleaf species. There were large patches of perennial ryegrass in some plots.

Table 4.6: Pre-graze botanical composition of lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes for grazing Rotation 1 from 2/09 to 21/10/2013 at Ashley Dene, Canterbury

Treatment	Lucerne %	Grass %	Weed %	Dead %
Lucerne	72.4a	-	23.9	3.7a
Luc/Br	39.9b	37.4	14.7	8.0b
Luc/Cf	53.0b	31.5	11.7	3.8a
Mean	55.1	34.5	16.8	5.2
SEM	2.40	4.10	2.43	0.53
P value	<0.001	0.349	0.145	0.01

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests. For rotation details see Table 3.5.

#### 4.1.2.4.3 Rotation 2

In grazing Rotation 2, pre-graze lucerne content of lucerne monocultures was 54.3% which was greater ( $P<0.001$ ) than the ~30.0% for lucerne/ cocksfoot and lucerne/brome pastures (Table 4.7). Lucerne monocultures had 30.2% weeds which was the highest ( $P<0.001$ ) of all treatments. Perennial ryegrass was the predominant weed in lucerne monocultures. The dead and sown grass components were not different in lucerne/ grass mixes.

Grazing generally resulted in an increase in weed and dead content for all treatments. Lucerne maintained the highest ( $P<0.001$ ) lucerne (34.6%) and weed (29.9%) proportion (Table 4.8). Sown grass proportions did not differ ( $P<0.831$ ) between lucerne/ grass treatments.

Table 4.7: Pre-graze botanical composition of lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes for grazing Rotation 2 from 21/10 to 3/12/2013 at Ashley Dene, Canterbury.

Treatment	Lucerne %	Grass %	Weed %	Dead %
Lucerne	54.3a	-	30.2a	15.5
Luc/Br	30.0b	45.5	9.0b	15.5
Luc/Cf	29.6b	46.8	7.7b	15.8
Mean	38.0	46.2	15.6	15.6
SEM	2.13	3.69	1.58	1.72
P value	<0.001	0.860	<0.001	0.995

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests. For rotation details see Table 3.5.

Table 4.8: Post-graze botanical composition of lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes for grazing Rotation 2 from 21/10 to 3/12/2013 at Ashley Dene, Canterbury.

Treatment	Lucerne %	Grass %	Weed %	Dead %
Lucerne	34.6a	-	29.9a	35.5
Luc/Br	14.3b	31.9	14.5b	39.4
Luc/Cf	16.8b	33.2	10.1b	39.9
Mean	21.9	32.6	18.17	38.3
SEM	1.70	3.02	1.80	2.20
P value	<0.001	0.831	0.001	0.671

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests. For rotation details see Table 3.5.

Ewes and lambs on lucerne monocultures consumed 3536 kg DM/ha which was more ( $P<0.083$ ) lucerne than those on the lucerne/grass mixes who consumed about 2000 kg DM/ha (Table 4.9). Ewes and lambs on lucerne/grass mixes consumed 2200 kg DM/ha of sown grass. Weed consumption was highest ( $P<0.033$ ) in lucerne monocultures. The total DM consumed by ewes and lambs did not vary between the pastures. Ewes and lambs on all treatments ( $P<0.084$ ) consumed 38.4% of the pasture available.

Table 4.9: Dry matter (kg DM/ha) consumed by ewes and lambs of lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes for grazing Rotation 2 from 21/10 to 3/12/2013 at Ashley Dene, Canterbury. Negative values indicate an increase in DM of a component after grazing.

Treatment	Lucerne	Grass	Weed	Dead	Total
Lucerne	3536a	-	905a	321	4441
Luc/Br	1990b	2145	-442b	-566	3693
Luc/Cf	2090b	2248	213ab	-804	4552
Mean	2539	2197	225	-350	4229
SEM	290.6	559.5	187.5	237.4	496.9
P value	0.083	0.928	0.033	0.160	0.749

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests. For rotation details see Table 3.5.

#### 4.1.2.4.4 Rotation 3

Pre-graze in Rotation 3 lucerne monocultures had a higher ( $P<0.014$ ) lucerne and weed component (52.8 and 18.3%, respectively) than lucerne/grass mixes (Table 4.10). The grass component of lucerne/grass mix pastures was not different for lucerne/ cocksfoot and lucerne/brome pastures.

Post grazing lucerne maintained the highest ( $P<0.016$ ) weed portion (15.6%) (Table 4.11). The lucerne component of the lucerne/ cocksfoot pasture was lower ( $P<0.009$ ) (12.7%) than that of the lucerne monoculture (30.7%). The lucerne component of lucerne/ brome pastures was not different from lucerne monocultures or lucerne/ cocksfoot pastures.

Table 4.10: Pre-graze botanical composition of lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/ brome (Luc/Br) mixes for grazing Rotation 3 from 3/12/2013 to 7/01/2014 at Ashley Dene, Canterbury.

Treatment	Lucerne %	Grass %	Weed %	Dead %
Lucerne	52.8a	-	18.3a	29.0
Luc/Br	34.4b	22.2	2.8b	40.5
Luc/Cf	35.4b	26.2	1.8b	36.5
Mean	40.9	24.2	7.63	35.3
SEM	2.47	2.45	1.82	2.06
P value	0.014	0.425	0.003	0.099

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests. For rotation details see Table 3.5.

Table 4.11: Post-graze botanical composition of lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/ brome (Luc/Br) mixes for grazing Rotation 3 from 3/12/2013 to 7/01/2014 at Ashley Dene, Canterbury.

Treatment	Lucerne %	Grass %	Weed %	Dead %
Lucerne	30.7a	-	15.6a	53.7
Luc/Br	18.5ab	15.3	3.2b	63.0
Luc/Cf	12.7b	28.4	1.8b	57.1
Mean	20.6	21.9	6.9	58.0
SEM	2.05	3.08	1.86	2.30
P value	0.009	0.600	0.016	0.281

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests. For rotation details see Table 3.5.

In Rotation 3 weaned lambs grazing lucerne/ cocksfoot consumed less cocksfoot than was growing resulting in a negative value for cocksfoot consumed (Table 4.12). There was no difference ( $P<0.663$ ) in the total consumption of DM among lambs on all treatments. Lambs on lucerne monocultures and lucerne/ cocksfoot pastures consumed about 2500 kg DM/ha of lucerne which was more ( $P<0.027$ ) than the 1643 kg DM/ha of lucerne consumed by lambs on lucerne/ brome pastures. ~34.3% of the pasture available on all treatments ( $P<0.249$ ) was consumed by lambs.

Table 4.12: Dry matter (kg DM/ha) consumed by weaned lambs of lucerne monocultures, lucerne/cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes for grazing Rotation 3 from 3/12/2013 to 7/01/2014 at Ashley Dene, Canterbury. Negative values indicate an increase in DM of a component after grazing.

Treatment	Lucerne	Grass	Weed	Dead	Total
Lucerne	2469a	-	1020a	392	3489
Luc/Br	1643b	957	312ab	285	2913
Luc/Cf	2491a	-675	-266b	-935	1550
Mean	2201	141	533	-86	2651
SEM	573.9	500.6	164.0	377.4	884.8
P value	0.027	0.134	0.020	0.309	0.663

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests. For rotation details see Table 3.5.

#### 4.1.2.4.5 Rotation 4

In Rotation 4 the grass component of lucerne brome pastures (12%) was lower ( $P<0.047$ ) than the 21% of lucerne cocksfoot pastures (Table 4.13). Weed and dead content was highest ( $P<0.027$ ) in the lucerne monocultures (11.7 and 30.8%, respectively). The lucerne content of lucerne monocultures was about 25% greater ( $P<0.011$ ) than the lucerne content of lucerne/cocksfoot pastures. There was no difference in the lucerne or weed contents of all pastures post-grazing (Table 4.14). The lucerne/cocksfoot pasture maintained the lowest ( $P<0.004$ ) dead component (45.3%) after grazing. After grazing the grass component remained higher ( $P<0.031$ ) in the lucerne/brome mixes than in the lucerne/cocksfoot mixes.

The proportion of dead material in the pastures had increased from an average 5.2% in Rotation 1 to 41% in Rotation 4. The sown grass component had also decreased in lucerne/grass mixes from 34.5% in Rotation 1 to 16.6% in Rotation 4. The amount of grass eaten in lucerne grass mixes had decreased from an average 2197 kg DM/ha in Rotation 2 to 1694 kg DM/ha in Rotation 4.

Table 4.13: Pre-graze botanical composition of lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes for grazing Rotation 4 from 7/01 to 23/03/2014 at Ashley Dene, Canterbury.

Treatment	Lucerne %	Grass %	Weed %	Dead %
Lucerne	57.5a	-	11.7a	30.8a
Luc/Br	39.6ab	12.0a	1.4b	47.0b
Luc/Cf	33.2b	21.2b	0.4b	45.2ab
Mean	43.4	16.6	4.5	41
SEM	2.96	1.99	1.55	2.38
P value	0.011	0.047	0.016	0.027

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests. For rotation details see Table 3.5.

Table 4.14: Post-graze botanical composition of lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes for grazing Rotation 4 from 7/01 to 23/03/2014 at Ashley Dene, Canterbury.

Treatment	Lucerne %	Grass %	Weed %	Dead %
Lucerne	20.1	-	8.1	71.8a
Luc/Br	17.0	11.0a	1.4	70.6a
Luc/Cf	33.2	21.2b	0.4	45.3b
Mean	23.4	16.1	3.3	62.6
SEM	2.75	2.02	1.37	3.04
P value	0.066	0.031	0.075	0.004

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests. For rotation details see Table 3.5.

In Rotation 4 lambs grazing lucerne monocultures consumed more ( $P<0.005$ ) lucerne than those grazing lucerne/grass mixes (Table 4.15). The amount of dead matter increased the most ( $P<0.030$ ) in lucerne monocultures (1518 kg DM/ha). Animals grazing all pastures ( $P<0.790$ ) consumed on average 49.4% of the pasture available in Rotation 4.

Table 4.15: Dry matter (kg DM/ha) consumed by ewes and lambs of lucerne monocultures, lucerne/ cocksfoot (Luc/Cf) and lucerne/brome (Luc/Br) mixes for grazing Rotation 4 from 7/01 to 23/03/2014 at Ashley Dene, Canterbury. Negative values indicate an increase in DM of a component after grazing.

Treatment	Lucerne	Grass	Weed	Dead	Total
Lucerne	2437a	-	242	-1518a	2679
Luc/Br	1319b	268	30	277ab	1617
Luc/Cf	1327b	522	13	307b	1861
Mean	1694	395	95	-311	2052
SEM	133.9	85.5	52.0	285.2	193.0
P value	0.005	0.169	0.169	0.030	0.095

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests. For rotation details see Table 3.5.



Plate 4.1: Ewes grazing lucerne/ cocksfoot pastures in Plot 2 showing the selection for lucerne, on the 11/05/2014 at Ashley Dene, Canterbury.

#### 4.1.2.5 Nutritive yield

##### 4.1.2.5.1 Metabolisable energy content

###### 4.1.2.5.1.1 Annual

Annual ME of lucerne pre-grazing was not different ( $P < 0.546$ ) between treatments (Table 4.16). The ME yield of lucerne available for grazing was greater ( $P < 0.001$ ) in lucerne monocultures (92.1 GJ/ha) than in lucerne/grass mixes (56.4 GJ/ha). However the total ME available for grazing for the entire experimental period did not differ ( $P < 0.305$ ) between pastures (147 GJ/ha).

Post-grazing the average rotational ME of the lucerne remaining was greatest ( $P < 0.002$ ) in lucerne monocultures (4.3 GJ/ha) (Table 4.17). The ME content (MJ ME/kg DM) of all components was not different among pasture types. The average rotational pasture ME yield after grazing (13.7 GJ/ha) was about half the pre-grazing ME yield (25.8 GJ/ha) and did not differ ( $P < 0.841$ ) among treatments.

Table 4.16: Annual average pre-grazing metabolisable energy (MJ ME/kg DM) and total yield (GJ/ha) of lucerne monocultures, lucerne/brome (Luc/Br) and lucerne/socksfoot (Luc/Cf) mixes from 19/09/2013 to 30/04/2014 at Ashley Dene, Canterbury.

Treatment	Lucerne ME	Lucerne ME yield (GJ/ha)	Sown grass ME	Sown grass ME yield (GJ/ha)	Pasture ME	Pasture ME yield (GJ/ha)
Lucerne	10.2	92.1a	-	-	9.6	151
Luc/Br	10.0	50.3b	10.1	46.8	9.3	133
Luc/Cf	10.3	62.4b	10.5	57.5	9.6	156
Mean	10.2	68.3	10.3	52.2	9.5	147
SEM	0.11	2.83	0.24	2.01	0.18	5.90
P value	0.546	0.001	0.410	0.065	0.795	0.305

Note: Treatment means followed by different letters are significantly different at  $\alpha = 0.05$  using least significant difference tests.

Table 4.17: Annual post-grazing metabolisable energy (MJ ME/kg DM) and corresponding average rotational yield (GJ/ha) of lucerne monocultures, lucerne/brome (Luc/Br) and lucerne/socksfoot (Luc/Cf) mixes from 19/09/2013 to 30/04/2014 at Ashley Dene, Canterbury.

Treatment	Lucerne ME	Lucerne ME yield (GJ/ha)	Sown grass ME	Sown grass ME yield (GJ/ha)	Pasture ME	Pasture ME yield (GJ/ha)
Lucerne	6.6	4.3a	-	-	7.1	13.1
Luc/Br	6.7	2.3b	9.5	5.2	7.3	13.1
Luc/Cf	6.5	2.1b	9.7	6.8	7.8	14.9
Mean	6.6	2.9	9.6	6.1	7.4	13.7
SEM	0.20	0.28	0.32	1.09	0.22	1.45
P value	0.546	0.002	0.821	0.491	0.370	0.841

#### 4.1.2.5.1.2 Rotation 1

The average ME (MJ ME/kg DM) of lucerne in Rotation 1 was not different ( $P < 0.886$ ) for all pastures (11.1 MJ ME/kg DM) (Table 4.18). The ME yield of the lucerne component of pastures was not different ( $P < 0.133$ ) between the lucerne monoculture (18.8 GJ/ha) and lucerne/grass mixes (12.5 and 17.0 GJ/ha for lucerne/brome and lucerne/ocksfoot respectively). The pasture ME yield available for grazing did not differ ( $P < 0.941$ ) between the pastures.

Table 4.18: Pre-graze metabolisable energy (MJ ME) and ME yield (GJ/ha) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 1 from 2/09 to 21/10/2013 at Ashley Dene, Canterbury, New Zealand.

Treatment	Lucerne ME	Lucerne ME yield (GJ/ha)	Sown grass ME	Sown grass ME yield (GJ/ha)	Pasture ME	Pasture ME yield (GJ/ha)
Lucerne	11.2	18.8	-	-	11.0	30.6
Luc/Br	11.2	12.5	11.2	14.6	11.1	29.7
Luc/Cf	11.0	17.0	11.0	9.1	11.0	32.1
Mean	11.1	16.1	11.1	11.9	11.0	30.8
SEM	0.14	1.95	0.21	2.42	0.15	2.74
P value	0.856	0.133	0.674	0.292	0.886	0.941

For rotation details see Table 3.5.



Plate 2: Lucerne/brome pastures on 10/12/2013 at Ashley Dene, Canterbury, New Zealand. Reproductive stems are visible, highlighting the quality decline of the grass component.

#### 4.1.2.5.1.3 Rotation 2

Pre-grazing the lucerne ME yield was greatest ( $P < 0.002$ ) in lucerne monocultures (17.8 GJ ME/ha) (Table 4.19). The grass component of lucerne/grass mixes was not different ( $P < 0.412$ ) and yielded an average 10.2 GJ ME/ha. The ME yield of all pastures did not differ ( $P < 0.845$ ) and averaged 33.4 GJ/ha. Post-grazing the quality of all components had reduced by more than half (Table 4.20). There was no difference in ME for all components for all treatments. Post-grazing the lucerne component of pastures had an average of 6.7 MJ ME/kg DM. The post-grazing ME yield of the lucerne component of the lucerne monoculture pastures (4.9 GJ/ha) was greater ( $P < 0.015$ ) than the ME yield of lucerne/grass mixes (average 2.6 GJ/ha).

Table 4.19: Pre-graze metabolisable energy (MJ ME) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 2 from 21/10 to 3/12/2013 at Ashley Dene, Canterbury, New Zealand.

Treatment	Lucerne ME	Lucerne ME yield (GJ/ha)	Sown grass ME	Sown grass ME yield (GJ/ha)	Pasture ME	Pasture ME yield (GJ/ha)
Lucerne	9.8	17.8a	-	-	9.7	32.5
Luc/Br	9.9	10.7b	10.0	14.6	9.5	34.7
Luc/Cf	10.1	9.5b	10.3	15.1	9.9	32.9
Mean	9.9	12.7	10.2	14.9	9.7	33.4
SEM	0.19	0.84	0.14	1.50	0.15	1.63
P value	0.861	0.002	0.412	0.868	0.604	0.845

Note: Treatment means followed by different letters are significantly different at  $\alpha = 0.05$  using least significant difference tests. For rotation details see Table 3.5.

Table 4.20: Post-graze metabolisable energy (MJ ME) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 2 from 21/10 to 3/12/2013 at Ashley Dene, Canterbury, New Zealand.

Treatment	Lucerne ME	Lucerne ME yield (GJ/ha)	Sown grass ME	Sown grass ME yield (GJ/ha)	Pasture ME	Pasture ME yield (GJ/ha)
Lucerne	7.0	4.9a	-	-	7.6	15.5
Luc/Br	6.4	2.5b	9.4	8.8	8.5	21.9
Luc/Cf	6.7	2.6b	8.9	6.7	8.3	17.5
Mean	6.7	3.3	9.2	7.8	8.1	18.3
SEM	0.26	0.32	0.13	1.66	0.18	1.70
P value	0.625	0.015	0.057	0.513	0.087	0.316

Note: Treatment means followed by different letters are significantly different at  $\alpha = 0.05$  using least significant difference tests. For rotation details see Table 3.5.

#### 4.1.2.5.1.4 Rotation 3

In Rotation 3, lucerne ME was similar ( $P < 0.512$ ) for all pastures with an average ME of 9.4 MJ ME/kg DM (Table 4.21). The ME yield of lucerne was 13.8 GJ ME/ha for lucerne monocultures which was not different ( $P < 0.241$ ) from lucerne/brome (8.5 GJ ME/ha) and lucerne/cocksfoot (11.4 GJ ME/ha)

pastures. Grass ME yield or content were not different ( $P < 0.941$ ) for lucerne/brome and lucerne/ cocksfoot pastures. Post-grazing the ME of lucerne was lower for all treatments (5.9 MJ ME/kg DM) compared with the average pre-grazing ME. ME of all sown components was not different between the treatments after grazing (Table 4.22). After grazing the ME yield of the sown grass component was higher ( $P < 0.036$ ) for lucerne/ cocksfoot pastures (11.2 GJ/ha) than lucerne/brome pastures (3.0 GJ/ha).

Table 4.21: Pre-graze metabolisable energy (MJ ME) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 3 from 3/12/2013 to 7/01/2014 at Ashley Dene, Canterbury, New Zealand.

Treatment	Lucerne ME	Lucerne ME yield (GJ/ha)	Sown grass ME	Sown grass ME yield (GJ/ha)	Pasture ME	Pasture ME yield (GJ/ha)
Lucerne	9.6	13.8	-	-	8.1	18.8
Luc/Br	9.2	8.5	10.0	7.2	8.2	11.1
Luc/Cf	9.5	11.4	10.1	10.0	8.2	17.9
Mean	9.4	11.2	10.1	8.6	8.2	15.9
SEM	0.14	1.22	0.19	1.36	0.33	3.06
P value	0.512	0.241	0.941	0.353	0.986	0.714

For rotation details see Table 3.5.

Table 4.22: Post-graze metabolisable energy (MJ ME) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 3 from 3/12/2013 to 7/01/2014 at Ashley Dene, Canterbury, New Zealand.

Treatment	Lucerne ME	Lucerne ME yield (GJ/ha)	Sown grass ME	Sown grass ME yield (GJ/ha)	Pasture ME	Pasture ME yield (GJ/ha)
Lucerne	6.2	4.4	-	-	6.9	9.9
Luc/Br	6.2	2.2	7.3	3.0a	6.4	10.9
Luc/Cf	5.4	1.7	9.9	11.2b	7.6	19.7
Mean	5.9	2.8	8.6	7.1	7.0	13.5
SEM	0.32	0.45	1.24	1.53	0.43	1.83
P value	0.559	0.055	0.325	0.036	0.587	0.105

Note: Treatment means followed by different letters are significantly different at  $\alpha = 0.05$  using least significant difference tests. For rotation details see Table 3.5.

#### 4.1.2.5.1.5 Rotation 4

In Rotation 4 the lucerne monoculture yielded the ( $P < 0.007$ ) most lucerne ME (11.3 GJ ME/ha) (Table 4.23). For all other measured components there was no difference in the ME content or yield between pasture types. Post-grazing the ME content of the lucerne component was on average lower by 3 MJ ME for all of the treatments. No difference in ME content of all of the measured components for all treatments was found post-grazing (Table 4.24). The total ME yield from lucerne monocultures was higher than the lucerne ME yield due to the contribution from weeds.

Table 4.23: Pre-graze metabolisable energy (MJ ME) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 4 from 7/01 to 23/03/2014 at Ashley Dene, Canterbury, New Zealand.

Treatment	Lucerne ME	Lucerne ME yield (GJ/ha)	Sown grass ME	Sown grass ME yield (GJ/ha)	Pasture ME	Pasture ME yield (GJ/ha)
Lucerne	10.2	11.3a	-	-	8.6	13.9
Luc/Br	10.0	5.9b	10.9	1.7	7.9	14.3
Luc/Cf	11.1	4.9b	10.8	2.0	8.1	13.5
Mean	10.4	7.4	10.9	1.9	8.2	13.9
SEM	0.33	0.71	0.14	0.61	0.26	1.08
P value	0.443	0.007	0.641	0.237	0.503	0.958

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests. For rotation details see Table 3.5.

Table 4.24: Post-graze metabolisable energy (MJ ME) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 4 from 7/01 to 23/03/2014 at Ashley Dene, Canterbury, New Zealand.

Treatment	Lucerne ME	Lucerne ME yield (GJ/ha)	Sown grass ME	Sown grass ME yield (GJ/ha)	Pasture ME	Pasture ME yield (GJ/ha)
Lucerne	7.1	1.5	-	-	5.8	10.3
Luc/Br	7.5	1.3	11.0	2.0	6.6	6.5
Luc/Cf	6.8	0.5	11.0	1.6	7.0	11.7
Mean	7.1	1.1	11.0	1.8	6.5	9.5
SEM	0.44	0.23	0.12	0.65	0.28	1.64
P value	0.824	0.341	0.980	0.801	0.293	0.451

For rotation details see Table 3.5.

#### 4.1.2.5.2 Nitrogen content

##### 4.1.2.5.2.1 Annual

Annual pre-grazing N% of the lucerne component of pastures was not different ( $P<0.769$ ) between treatments (3.3%) (Table 4.25). The lucerne component of lucerne monocultures yielded the most ( $P<0.001$ ) nitrogen (535 kg N/ha) pre-grazing. The N yield from the grass component of lucerne/grass mixes did not differ ( $P<0.700$ ) between the two lucerne/grass mixes (282 kg N/ha). The pasture N available for grazing was greater ( $P<0.006$ ) for the lucerne monoculture at 299 kg N/ha than for lucerne/grass mixes.

Post grazing the annual N content of lucerne was not different ( $P<0.714$ ) between pastures (Table 4.26). Lucerne monocultures maintained the highest ( $P<0.009$ ) N yield (11.2 kg N/ha) for the lucerne component of the pastures. The pasture N left after grazing (27.4 kg N/ha) was not different ( $P<0.479$ ) among pastures.

Table 4.25: Annual pre-grazing nitrogen content (N%) and corresponding yield (kg N/ha) of lucerne monocultures, lucerne/brome (Luc/Br) and lucerne/socksfoot (Luc/Cf) mixes from 19/09/2013 to 30/04/2014 at Ashley Dene, Canterbury.

Treatment	Lucerne N%	Lucerne N yield (kg/ha)	Sown grass N%	Sown grass N yield (kg/ha)	Pasture N%	Pasture N yield (kg/ha)
Lucerne	3.4	535a	-	-	2.8	299a
Luc/Br	3.2	245b	2.8	288	2.5	201b
Luc/Cf	3.3	256b	2.8	276	2.6	244b
Mean	3.3	345	2.8	282	2.6	248
SEM	0.08	15.2	0.11	14.3	0.10	10.1
P value	0.769	0.001	0.808	0.700	0.325	0.006

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests.

Table 4.26: Annual post-grazing nitrogen content (N%) and corresponding average rotational yield (kg N/ha) of lucerne monocultures, lucerne/brome (Luc/Br) and lucerne/socksfoot (Luc/Cf) mixes from 19/09/2013 to 30/04/2014 at Ashley Dene, Canterbury.

Treatment	Lucerne N%	Lucerne N yield (kg/ha)	Sown grass N%	Sown grass N yield (kg/ha)	Pasture N%	Pasture N yield (kg/ha)
Lucerne	1.7	11.2a	-	-	1.9a	33.9
Luc/Br	1.7	5.7b	2.0	8.9	1.4b	24.9
Luc/Cf	1.6	4.8b	1.7	12.0	1.5b	23.4
Mean	1.7	7.3	1.9	10.5	1.6	27.4
SEM	0.09	0.78	0.12	1.96	0.07	3.05
P value	0.714	0.009	0.286	0.445	0.038	0.479

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests.

#### 4.1.2.5.2.2 Rotation 1

In Rotation 1 the N yield of lucerne was not different between pastures ( $P<0.173$ ) with 76.7 kg N/ha produced from lucerne monocultures, 38.3 kg N/ha for lucerne brome pastures and 53.1 kg N/ha for lucerne/socksfoot pastures (Table 4.27). There was no difference ( $P<0.785$ ) in the pasture N% (3.0% N) of the pastures, and no difference ( $P<0.678$ ) in N produced (82.3 kg N/ha).

Table 4.27: Pre-graze nitrogen concentration (%) and N yield (kg/ha) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 1 from 2/09 to 21/10/2013 at Ashley Dene, Canterbury, New Zealand.

Treatment	Lucerne N%	Lucerne N yield (kg/ha)	Sown grass N%	Sown grass N yield (kg/ha)	Pasture N%	Pasture N yield (kg/ha)
Lucerne	3.6	76.7	-	-	3.0	81.1
Luc/Br	3.4	38.3	2.8	33.5	2.9	75.4
Luc/Cf	3.5	53.1	3.1	24.8	3.1	90.3
Mean	3.5	56.0	3.0	29.2	3.0	82.3
SEM	0.12	7.83	0.16	5.22	0.13	6.80
P value	0.797	0.173	0.332	0.427	0.785	0.678

For rotation details see Table 3.5.

#### 4.1.2.5.2.3 Rotation 2

The nitrogen content of the pastures and sown components in the pasture did not differ among treatments pre grazing (Table 4.28). The N yield of the lucerne component was higher ( $P < 0.020$ ) for lucerne monocultures (58.1 kg N/ha) compared with lucerne/grass pastures (32 kg N/ha). The grass component of lucerne/grass mixes was not different in N% or N yield ( $P < 0.948$ ) with an average yield of 38.9 kg N/ha. The pasture N yield did not differ across the treatments ( $P < 0.353$ ). The nitrogen content of all measured components was lower for all treatments after grazing. The pastures had an average N content of 1.7% N which was not different ( $P < 0.511$ ) across treatments (Table 4.29).

Table 4.28: Pre-graze nitrogen concentration (%) and N yield (kg/ha) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 2 from 21/10 to 3/12/2013 at Ashley Dene, Canterbury, New Zealand.

Treatment	Lucerne N%	Lucerne N yield (kg/ha)	Sown grass N%	Sown grass N yield (kg/ha)	Pasture N%	Pasture N yield (kg/ha)
Lucerne	3.2	58.1a	-	-	2.9	96.2
Luc/Br	3.1	33.2b	2.5	36.7	2.3	79.6
Luc/Cf	3.4	31.7b	2.5	41.1	2.4	78.5
Mean	3.2	41.0	2.5	38.9	2.5	84.8
SEM	0.24	3.78	0.28	5.17	0.19	5.46
P value	0.854	0.020	0.956	0.680	0.322	0.353

Note: Treatment means followed by different letters are significantly different at  $\alpha = 0.05$  using least significant difference tests. For rotation details see Table 3.5.

Table 4.29: Post-graze nitrogen concentration (%) and N yield (kg/ha) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 2 from 21/10 to 3/12/2013 at Ashley Dene, Canterbury, New Zealand.

Treatment	Lucerne N%	Lucerne N yield (kg/ha)	Sown grass N%	Sown grass N yield (kg/ha)	Pasture N%	Pasture N yield (kg/ha)
Lucerne	1.8	13.6a	-	-	1.8	35.2
Luc/Br	1.6	5.8b	1.6	13.3	1.6	37.2
Luc/Cf	1.7	6.2b	1.5	10.3	1.6	31.3
Mean	1.6	8.5	1.6	11.8	1.7	34.6
SEM	1.21	0.95	0.11	2.26	0.10	3.17
P value	0.511	0.010	0.613	0.529	0.437	0.763

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests. For rotation details see Table 3.5.

#### 4.1.2.5.2.4 Rotation 3

No difference in N content for all measured components across all treatments was found pre-grazing in Rotation 3 (Table 4.30). Lucerne had an average N content of 3.0% and yield of 33.4 kg N/ha for all treatments pre-grazing. The N yield from the pastures averaged 54.6 kg N/ha and was not different ( $P<0.763$ ) for all treatments. Post grazing, the N content of lucerne for all treatments was also not different ( $P<0.532$ ) (Table 4.31).

Table 4.30: Pre-graze nitrogen concentration (%) and N yield (kg/ha) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 3 from 3/12/2013 to 7/01/2014 at Ashley Dene, Canterbury, New Zealand.

Treatment	Lucerne N%	Lucerne N yield (kg/ha)	Sown grass N%	Sown grass N yield (kg/ha)	Pasture N%	Pasture N yield (kg/ha)
Lucerne	3.1	43.2	-	-	2.0	53.6
Luc/Br	3.1	23.7	2.4	13.5	2.4	55.3
Luc/Cf	2.9	33.4	2.6	26.7	2.1	54.9
Mean	3.0	33.4	2.5	20.1	2.2	54.6
SEM	0.09	4.88	0.32	3.70	0.17	6.92
P value	0.592	0.302	0.813	0.105	0.753	0.994

For rotation details see Table 3.5.

Table 4.31: Post-graze nitrogen concentration (%) and N yield (kg/ha) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 3 from 3/12/2013 to 7/01/2014 at Ashley Dene, Canterbury, New Zealand.

Treatment	Lucerne N%	Lucerne N yield (kg/ha)	Sown grass N%	Sown grass N yield (kg/ha)	Pasture N%	Pasture N yield (kg/ha)
Lucerne	1.6	11.5	-	-	2.1	30.1
Luc/Br	1.8	6.6	1.9	9.8	1.4	12.6
Luc/Cf	1.4	4.2	1.9	21.9	1.5	37.2
Mean	1.6	7.4	1.9	15.6	1.7	26.6
SEM	0.14	1.26	0.40	3032	0.12	4.02
P value	0.532	0.084	0.950	0.071	0.085	0.420

For rotation details see Table 3.5.

#### 4.1.2.5.2.5 Rotation 4

In Rotation 4 the pastures had a similar ( $P < 0.262$ ) N content (2.3%) and yield (40.0 kg N/ha) (Table 4.32). The N content of the lucerne component was not different ( $P < 0.700$ ) for all treatments with an average N content of 3.4%. The lucerne component of the lucerne monocultures had a higher ( $P < 0.006$ ) N yield (37.1 kg N/ha) than that of lucerne/brome pastures (15.9 kg N/ha) and lucerne/cocksfoot pastures (19.9 kg N/ha). The grass component of lucerne/grass mixes contributed 5.0 kg N/ha for lucerne/brome which was not different ( $P < 0.275$ ) from the 9.1 kg N/ha for grass from lucerne/cocksfoot pastures. Post grazing the N content of lucerne for all pastures was not different ( $P < 0.445$ ) and averaged 1.8% (Table 4.33). The grass component of lucerne/grass mixes was not different and had an average N content of 2.6% ( $P < 0.234$ ).

Table 4.32: Pre-graze nitrogen concentration (%) and N yield (kg/ha) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 4 from 7/01 to 23/03/2014 at Ashley Dene, Canterbury, New Zealand.

Treatment	Lucerne N%	Lucerne N yield (kg/ha)	Sown grass N%	Sown grass N yield (kg/ha)	Pasture N%	Pasture N yield (kg/ha)
Lucerne	3.4	37.1a	-	-	2.6	41.9
Luc/Br	3.2	15.9b	3.5	5.0	2.2	42.8
Luc/Cf	3.5	19.9b	3.4	9.1	2.1	35.4
Mean	3.4	27.0	3.5	7.1	2.3	40.0
SEM	0.12	2.29	0.24	1.69	0.13	5.55
P value	0.700	0.006	0.703	0.275	0.262	0.886

Note: Treatment means followed by different letters are significantly different at  $\alpha = 0.05$  using least significant difference tests. For rotation details see Table 3.5.

Table 4.33: Post-graze nitrogen concentration (%) and N yield (kg/ha) of lucerne monocultures, lucerne brome (Luc/Br) and lucerne cocksfoot (Luc/Cf) pastures for grazing Rotation 4 from 7/01 to 23/03/2014 at Ashley Dene, Canterbury, New Zealand.

Treatment	Lucerne N%	Lucerne N yield (kg/ha)	Sown grass N%	Sown grass N yield (kg/ha)	Pasture N%	Pasture N yield (kg/ha)
Lucerne	1.9	3.8	-	-	1.7	30.2
Luc/Br	1.9	3.4	2.8	3.5	1.4	16.4
Luc/Cf	1.5	1.1	2.3	3.9	1.2	19.0
Mean	1.8	2.8	2.6	3.7	1.4	21.9
SEM	0.14	0.73	0.18	1.15	0.12	4.22
P value	0.445	0.353	0.234	0.853	0.280	0.383

For rotation details see Table 3.5.

#### 4.1.2.6 Soil water content

##### 4.1.2.6.1 Available water

PAWC was not different between treatments ( $P > 0.393$ ), with a mean of 137 mm. However, the PAWC between plots was highly variable ranging from 195 mm in plot 7 to 107 mm from plot 17 (Figure 4.7). These values represent the highest and lowest total plant available water across all 18 plots. For other plots refer to Appendix 9.5 to Appendix 9.12. The amount of soil water available varied down the soil profile, due to the soil texture. In the top 0.2 m plot 7 had 35.9 mm of water available to lucerne and brome plants while plot 17 had 33.5 mm of water available. For plot 7, from 0.2 m to 2.05 m the profile plant available water ranged from 29.0 mm to 3.0 mm of soil compared with 19.9 mm of soil to 3.7 mm for plot 17. At the lowest recorded depth of 2.3 m, the plant available water was 5.0 mm for plot 7 compared with 2.3 mm of soil for plot 17.

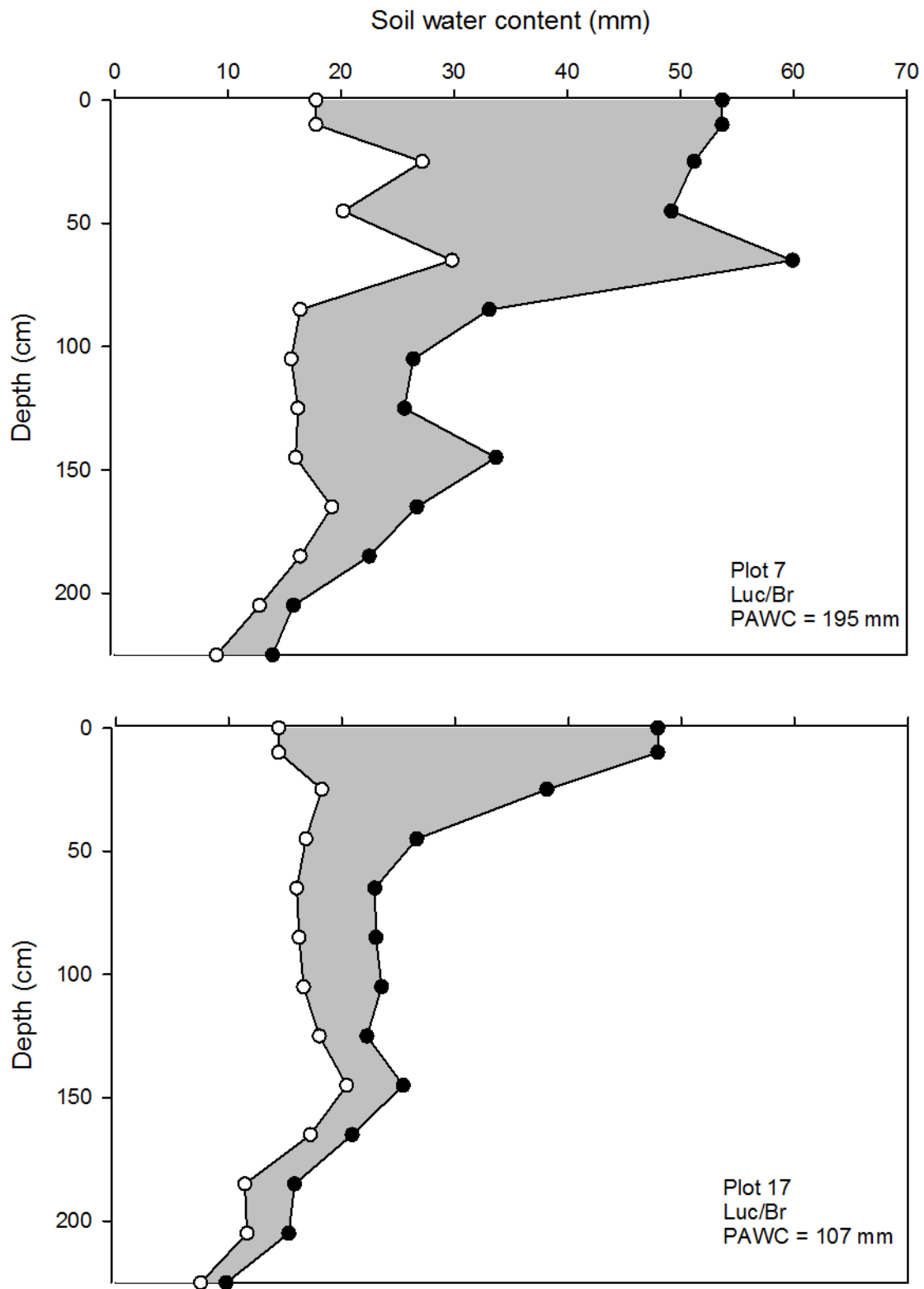


Figure 4.7: Soil water content of Plot 7 (top) and Plot 17 (bottom) in paddocks C6E and C7E, Ashley Dene, Canterbury. Where (●) is the upper limit and (○) is the lower limit for plant available water.

#### 4.1.2.6.2 Water use and water use efficiency

From the 01/07/2013 to the 24/03/2014 there was no difference in the amount of water used across treatments based on PET. All pastures used 837 mm of water.

Table 4.34: Water use (WU) of lucerne monocultures, lucerne/brome (Luc/Br) and lucerne/cocksfoot (Luc/Cf) mixes from 01/07/13 to 24/03/14 based on PET at Ashley Dene, Canterbury.

Treatment	Water Use (mm)
Lucerne	840
Luc/Br	835
Luc/Cf	835
Mean	837
SEM	4.2
P value	0.848

The theoretical WUE of lucerne monocultures, lucerne/brome and lucerne/cocksfoot mixes was calculated by plotting the cumulative dry matter against cumulative PET and fitting a linear regression. Theoretical WUE was not different ( $P < 0.345$ ) for lucerne monocultures and lucerne/grass mixes. From 01/07/13 to 24/03/14 all pastures had a WUE of  $18.0 \pm 0.75$  kg DM/ha/mm.

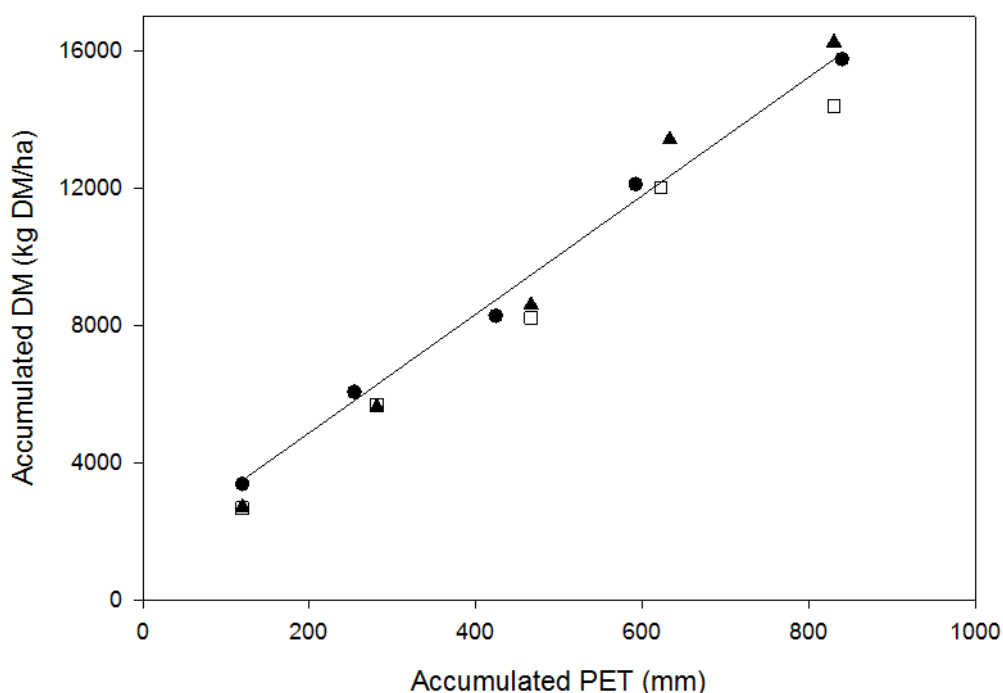


Figure 4.8: Accumulated dry matter yield (kg DM/ha) against accumulated PET (mm) which represented water used for lucerne monocultures (●), lucerne/brome (□), and lucerne/cocksfoot (▲) pasture mixes from 01/07/13 to 24/03/14. Regression was: Yield =  $18.0 \pm 0.75x + 2224 \pm 339$  ( $R^2 = 0.89$ ).

## 4.2 Experiment Two

### 4.2.1 Animal production

#### 4.2.1.1 Seasonal accumulated liveweight production

Animal production in Experiment 2 totalled 784 kg LWT/ha for lucerne + grain animals and 741 kg LWT/ha for – grain animals (Figure 4.9). Spring liveweight production was 546 kg LWT/ha from + grain animals and 512 kg LWT/ha from –grain animals. Summer liveweight production from weaned lambs was 238 kg LWT/ha for –grain lambs which was not different ( $P < 0.898$ ) from liveweight produced by +grain lambs (229 kg LWT/ha).

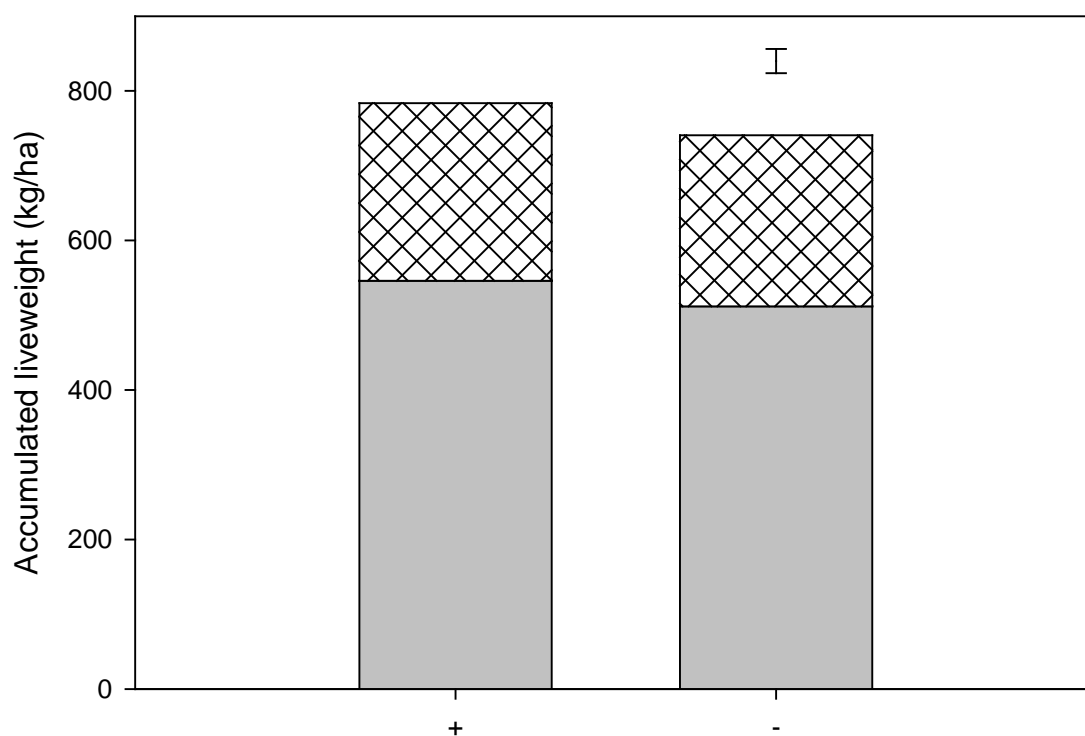


Figure 4.9: Liveweight production of animals lucerne monocultures + or – grain supplementation over five liveweight production periods from 13/09/2013 to 03/02/2014 at Ashley Dene, Canterbury, New Zealand. Stacked bars represent spring liveweight gain with ewes and lambs (■), summer liveweight gain with weaned lambs (▨). The error bar is SEM for accumulated liveweight production from the summer period across treatments.

#### 4.2.1.2 Spring liveweight from ewes and lambs

Liveweight accumulation from lambs in the spring period did not differ ( $P < 0.940$ ) between treatments. Ewes allocated to the +grain treatment gained 13 kg LWT/ha compared with those on the –grain treatment which lost 15 kg LWT/ha.

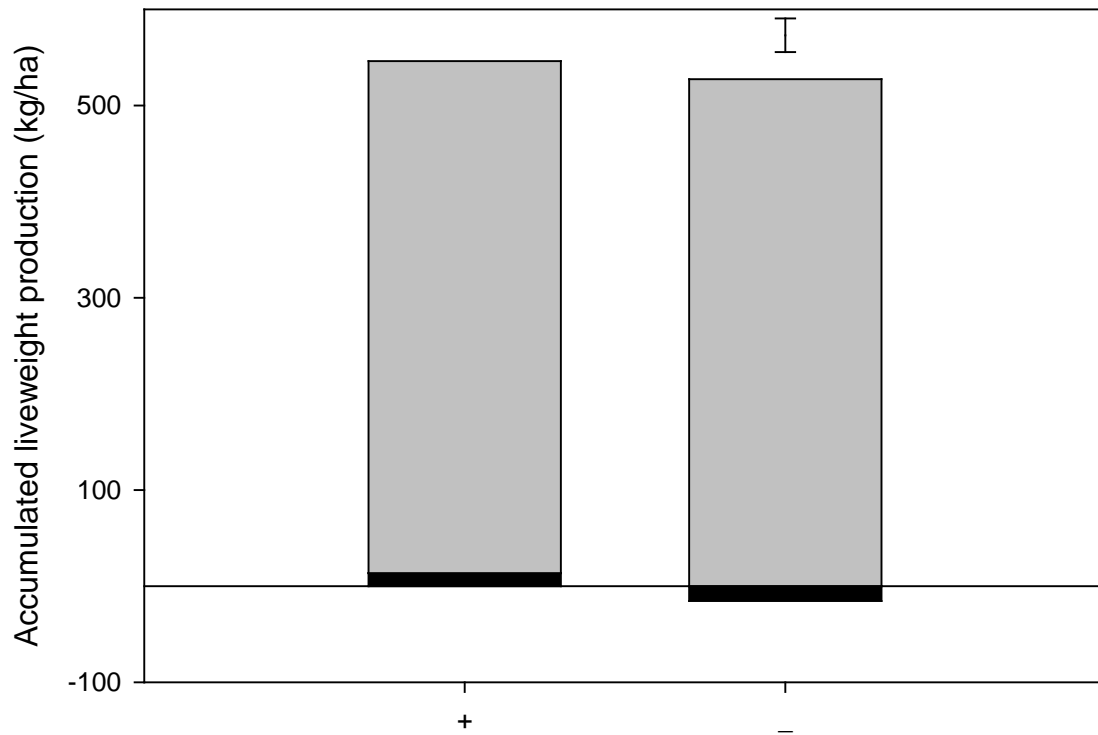


Figure 4.10: Spring liveweight production (kg LWT/ha) for Rotation 1 to 3 for lambs (■) and ewes (■) grazing lucerne monocultures + or – grain supplementation at Ashley Dene, Canterbury, New Zealand. The error bars are SEM for liveweight production from lambs across treatments.

#### 4.2.1.3 Ewe liveweight

Ewe liveweight of +grain ewes was initially 67 kg/head which was not different ( $P < 0.151$ ) from initial liveweight of –grain ewes (63 kg/head) (Figure 4.11). At the end of lactation ewes on the +grain treatment weighed 68 kg/head which was heavier ( $P < 0.020$ ) than those on the –grain treatment (62 kg/head). This resulted in ewes on the – grain treatment losing 16 kg LWT which was more ( $P < 0.095$ ) than ewes on +grain treatment who gained 14 kg LWT throughout the lactation phase.

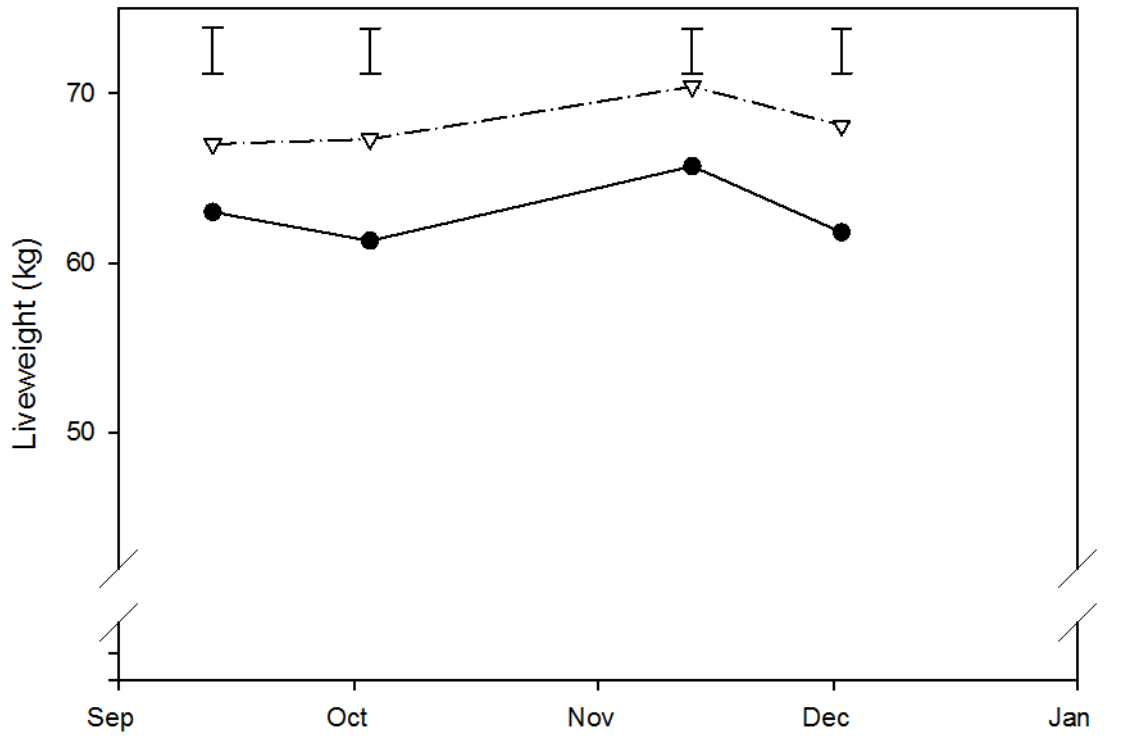


Figure 4.11: Change in lactating ewe liveweight from 13/09 to 02/12/2013 (weaning) on lucerne monocultures – grain (●) and + grain (▽) at Ashley Dene, Canterbury, New Zealand. Error bars are SEM.

#### 4.2.1.4 Rotational liveweight gain

In the first liveweight rotation ewes allocated to the +grain treatment had a liveweight gain of 17 g/head/d which was greater ( $P < 0.050$ ) than those on the –grain treatment which lost -103 g/head/d (Table 4.35). In liveweight Rotation 3, ewes from both treatments lost weight. The +grain ewes lost less ( $P < 0.046$ ) liveweight (-124 g/head/d) than the –grain ewes (-205 g/head/d). There was no difference ( $P < 0.641$ ) in lamb liveweight gains during the spring period.

Table 4.35: Liveweight change (g/head/d) of ewes and lambs grazed on lucerne with grain supplementation (+grain) or without grain supplementation (-grain) over liveweight (LWT) Rotations 1, 2 and 3 from 13/09 to 02/12/13 at Ashley Dene, Canterbury, New Zealand

	LWT Rotation 1		LWT Rotation 2		LWT Rotation 3	
	Ewes	Lambs	Ewes	Lambs	Ewes	Lambs
+ Grain	17a	314	77	238	-124a	175
- Grain	-103b	305	107	242	-205b	177
SEM	53.4	13.9	20.9	10.2	39.2	12.3
P Value	0.050	0.497	0.135	0.525	0.046	0.641

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$ . For rotation details see Table 3.3.

Weaned lambs on the + grain treatment had greater ( $P<0.007$ ) liveweight gains (140 g/head/d) than those on the -grain (77 g/head/d) treatment in Rotation 4 only (Table 4.36).

Table 4.36: Liveweight gain (g/head/d) of lambs grazed on lucerne with grain supplementation (+grain) or without grain supplementation (-grain) over liveweight (LWT) Rotations 4, 5 and 6 from 02/12/13 to 03/02/14 at Ashley Dene, Canterbury, New Zealand

	LWT Rotation 4	LWT Rotation 5	LWT Rotation 6
+ Grain	140a	130	320
- Grain	77b	96	352
SEM	19.3	21.8	22.5
P Value	0.007	0.077	0.107

Note: Treatment means followed by different letters are significantly different at  $\alpha=0.05$  using least significant difference tests. For rotation details see Table 3.3.

## 4.2.2 Pasture dry matter yield

### 4.2.2.1 Accumulated dry matter yield

In the first rotation pastures had accumulated 955 kg DM/ha. There was no difference ( $P<0.869$ ) in accumulated DM (Figure 4.12). At the end of the experimental period (06/01/2014) there was no difference ( $P<0.840$ ) in accumulated DM with both pastures having accumulated 12 t DM/ha.

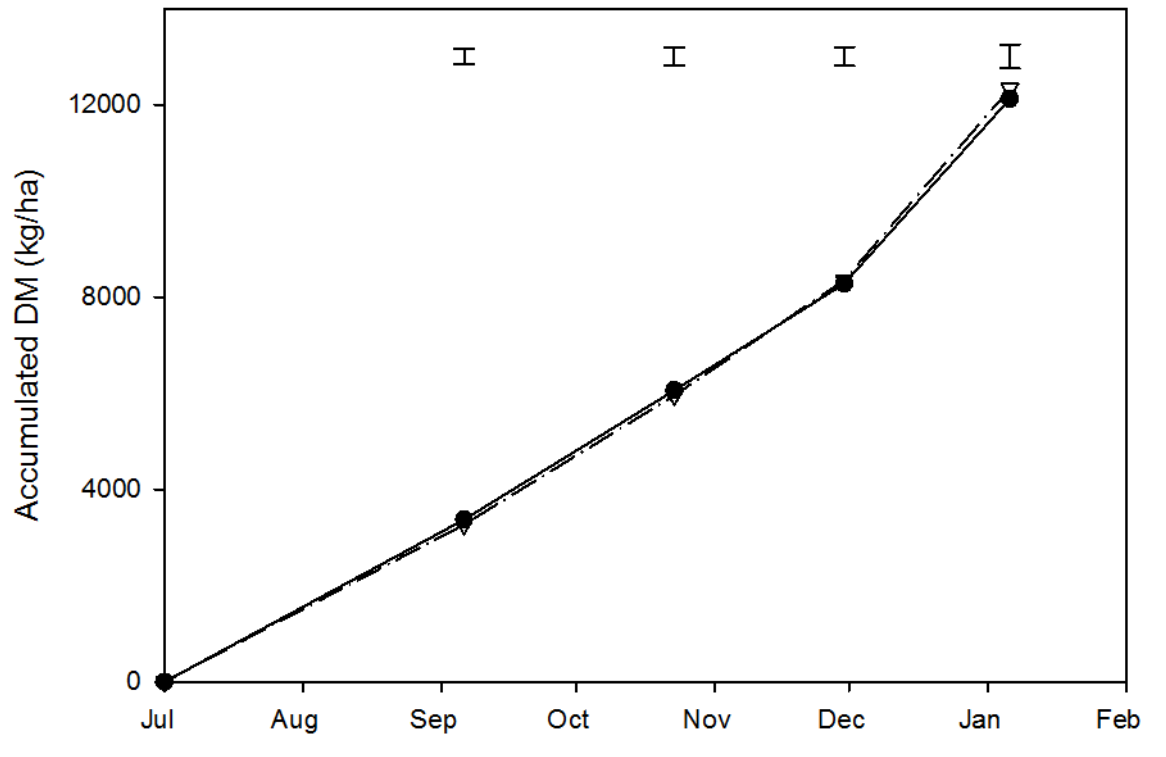


Figure 4.12: The total accumulated dry matter (DM) yield of lucerne monoculture pastures – grain (  $\nabla$ ) and + grain (●), pastures from 1/07/2013 to 06/01/2014 at Ashley Dene, Canterbury, New Zealand. Error bars are SEM across treatments for each rotation.

#### 4.2.3 Grain consumption

The amount of grain fed is given in Table 3.8. It was assumed that all grain fed was consumed. For the total period 750 kg of grain was consumed. From Rotation 1 to 3 during the lactation phase 633 kg of the grain was consumed, this was 84% of the total grain consumed. The remaining 16% of grain was consumed in Rotations 4, 5 and 6 which occurred after weaning.



Plate 3: Lambs seeking shelter under the Advantage grain feeder in Plot 16 on 22/01/2013 at Ashley Dene, Canterbury.

## 5 DISCUSSION

### 5.1 Experiment 1

#### 5.1.1 Animal production

##### 5.1.1.1 Liveweight production

Annually, lucerne monocultures produced 808 kg LWT/ha, lucerne/brome pastures produced 642 kg LWT/ha and liveweight from lucerne/socksfoot pastures totalled 605 kg LWT/ha. This was lower than the 865 kg LWT/ha produced by lucerne monocultures and lucerne/socksfoot pastures and 746 kg LWT/ha from lucerne/brome pastures last year (Coutts, 2013). Brown *et al.* (2006) showed annual liveweight production from lucerne to be 880 kg/ha. The difference in liveweight production was due to differences in animal performance as DM quality of pastures was similar and stocking rate had increased since last year. Poor animal production at Ashley Dene was occurring across the farm in the 2013/14 season. The reasons for this were not known. The farm uses a comprehensive drenching policy which means it can be assumed any intestinal parasite issues were not limiting animal production unless resistance was occurring.

Spring liveweight production was 512 kg LWT/ha for lucerne monocultures, 420 kg LWT/ha for lucerne/brome pastures and 366 kg LWT/ha for lucerne/socksfoot pastures. This means spring liveweight production accounted for over half of the total production from the experimental period. Last year spring production accounted for 70% of the total production (Coutts, 2013). Spring liveweight production was higher than the 400 kg LWT/ha produced in the spring period in an experiment by Brown *et al.* (2006). The spring period in the current experiment occurred from July to December. In the experiment by Brown *et al.* (2006) the spring period was from July to November. This meant animals in the current experiment had a longer period to grow. Differences in animal production may also have been due to differences in stocking rate which is a factor of pasture availability. Stocking rate used in their experiment was not specified. Pastures growing at faster rates can have greater stocking rates. On average 63% of the liveweight produced came from the spring period. This was the period when DM was most available with about 50% of total accumulated DM production coming from the spring period. These results were comparable with Mills *et al.* (2008b) who found an average 64% of the annual liveweight production occurred during spring. This was expected as during the spring period soil moisture is not limiting. All of the liveweight accumulated during the spring period was from the lambs.

During the spring period ewes on all treatments lost weight. This is expected as ewes will commonly mobilise their own body reserves to produce milk for their lambs (Nicol & Brookes, 2007a). A 60 kg ewe producing 3L of milk/day has a daily requirement of 27 MJ ME. A ewe has the ability to consume 3% of their liveweight/day. This means on a pasture of 11 MJ ME/kg DM she could

consume 1.8 kg which would give her 20 MJ ME. The shortfall is made up by the mobilisation of body reserves. During the spring period pre-grazing DM available was always above 2000 kg DM/ha. Animals grazed each paddock for about 7 days at a stocking rate of ~11.7 ewes/ha. This meant ewes with twin lambs had access to at least 10 kg DM/ha/day. Therefore DM availability was not limiting ewe liveweight gains just the ability to consume that DM. From a systems point of view this is not an issue provided ewes can gain condition coming into mating (Coop, 1996; Stevens, 1999).

Summer production was 229 kg LWT/ha for weaned lambs on lucerne monocultures compared with 158 kg LWT/ha for lambs on lucerne/brome mixes and 173 kg LWT/ha for those on lucerne/cocksfoot mixes. This was lower for all treatments than liveweight produced by weaned lambs in the summer of 2012/13. In the 2012/13 season summer (December-January) production was 252 kg LWT/ha for lucerne monocultures and 236 kg LWT/ha for lucerne/cocksfoot was higher than the 149 kg LWT/ha for lucerne/brome mixes. The lower liveweight production this year was not expected considering stocking rate for all treatments had increased by about 3 lambs/ha. This means differences were either due to differences in pasture quality, quantity or individual animal performance. In both years liveweight production was less than half the production of 550 kg LWT/ha for lucerne monocultures recorded by Brown *et al.* (2006) for summer (December-January). This large difference in liveweight production between the two experiments was not due to pasture availability since production was similar. Therefore differences were due to stocking rate or animal performance.

Autumn production averaged ~66 kg LWT/ha for all treatments. The autumn period was 46 days. At this time rainfall had occurred and all pasture had the same growth rate of 42 kg DM/ha/d. All treatments were stocked at ~8 lambs/ha. Autumn liveweight production in the 2012/13 season was 59 kg LWT/ha for lucerne/brome pastures, 43 kg LWT/ha for lucerne monocultures and 46 kg LWT/ha for lucerne/cocksfoot mixes. Differences were due to difference in pasture availability. The growth rate in the autumn period last year was less than half that of the current season at 16 kg DM/ha/d. The current season was wetter than average which allowed grazing in the autumn period to begin in March compared with May for the previous year. Animal performance would have also caused differences in liveweight production. In the current season ram hoggets were used to graze the treatments during the autumn period, last year the plots were grazed in the autumn by ewe hoggets. Rams tend to grow at greater rates than ewes (Geenty, 1995).

### 5.1.1.2 Rotational liveweight gains

Differences in liveweight gains are either a result of per head performance or stocking rate or a combination of the two. Both are affected by the availability and quality of pasture. During liveweight Rotation 1 lambs on lucerne and lucerne/brome pastures had an average daily liveweight gain of 308 g/head/day. In rotation 3, daily liveweight gain of lambs grazing lucerne and lucerne/brome pastures had dropped to 168 g/head/day. This was a result of a decline in milk from the ewe. At this period ewe liveweight losses were generally the highest for the lactation period. All pastures showed lower liveweight gains than those seen in the previous year from the experiment. In the 2012/13 season average pre-weaning liveweight gains of lambs were 300 g/head/day for Rotation 1, 2 and 3 (Coutts, 2013). The stocking rate increased this season to about 21 lambs/ha which was about 3 lambs/ha more than last year. It is generally accepted that an increase in stocking rate results in a decrease in per head performance. At this time most of the lambs intake is coming from the ewe. Ewes on all pastures had lost liveweight in Rotation 1 and 3. Last seasons' ewes were able to maintain liveweight during the lactation period (Coutts, 2013). Ewes on all treatments were losing the most liveweight in liveweight rotation 3. At this time ewes were using their own body reserves to produce milk for their lambs. Lambs were also beginning to graze the pastures resulting in a reduction in the available pasture for ewe maintenance. Even with adequate pasture availability a ewe is only able to consume 3% of her liveweight (Coop, 1996; Nicol & Brookes, 2007a; Stevens, 1999). This means to meet the 27 MJ ME/d requirement of a lactating ewes pastures must be high quality. In the current year the ME of the pastures were about 1 MJ/kg DM lower than the previous year. This coupled with increased stocking rate, explained the reduction in animal liveweight gain due to lower ME intakes.

After weaning in Rotation 4, lambs on lucerne/socksfoot pastures had the greatest liveweight gains at 174 g/head/d (Table 4.2). Liveweight gains of lambs on lucerne and lucerne/brome pasture had declined since weaning by about 100 g/head/d for lambs on lucerne and 15 g/head/d for lambs on lucerne/brome pastures. Contrary to this liveweight gains of lambs on lucerne/socksfoot pasture increased by about 60 g/head/d. At this time all pastures were producing the same quantity of pasture with no difference in quality (Table 4.22, Table 4.32). Animals were also all stocked at about 22 lambs/ha (Figure 3.2). This means pasture availability, quality or stocking rate cannot be used to explain the differences in liveweight gain observed on lucerne/socksfoot.

In liveweight Rotation 5, lambs on lucerne/brome pastures had an average 32 g/head/day liveweight gain advantage over those lambs grazing lucerne/socksfoot pastures. Liveweight gain of lambs grazing lucerne monocultures was not different from those grazing lucerne/brome or lucerne/socksfoot pastures. The liveweight gain of all animals had declined since Rotation 4 by >20

g/head/d. This was due to a reduction in the quantity and quality of pasture. Liveweight Rotation 4 occurred during grazing Rotation 3. In Rotation 3 the average ME yield of pastures had declined by almost half since Rotation 2 (Table 4.21).

In liveweight Rotation 6 weaned lambs grazing lucerne monocultures were gaining about twice as much as lambs on lucerne/grass mixes. The liveweight gains of all animals had increased by 250 g/head/d for lambs on lucerne monocultures, 68 g/head/d for lucerne/brome mixes and 118 g/head/d for lambs on lucerne/ cocksfoot mixes. At this time stocking rate had reduced to ~15 lambs/ha for lambs on lucerne and lucerne/ cocksfoot pastures and 10.3 lambs/ha for lambs on lucerne/brome pastures. This period also occurred just after a rainfall event where 83 mm fell (Figure 3.1). This means availability of high quality pasture also increased. The ME of lucerne had increased from 9.4 MJ ME/kg DM in grazing Rotation 3 to 10.4 MJ ME/kg DM in Rotation 4. Animals may have been showing a period of compensatory growth.

Results from the previous year found no difference in liveweight gain of lambs on all treatments. This year of the experiment showed lambs grazing lucerne/ cocksfoot pastures consistently had the lowest liveweight gains pre-weaning. Although cocksfoot pastures were producing at least as much DM as other treatments there tended to be a preference towards lucerne and away from cocksfoot which resulted in reduced intakes. This was shown by the increase in cocksfoot from Rotation 1 to Rotation 4.

## 5.1.2 Pasture dry matter yield

### 5.1.2.1 Accumulated dry matter yield

Accumulated dry matter yields were not different with 15 t DM/ha produced by all pastures (Figure 4.4). Therefore differences in animal liveweight production were not due to the availability of pasture. Although there was no difference in pasture production among treatments the components which contribute to yield had an influence on the liveweight gains of animals.

DM production was lower than other recorded values in Canterbury but more than the 12.5 t DM/ha produced from treatments in the previous season (Coutts, 2013). This was due to differences in water availability with over 200 mm more rainfall falling in the 2013/14 season than in 2012/13. Lucerne monocultures sown in Lincoln produced 19.5 t/ha and lucerne/brome pastures 19 t/ha (Fraser, 1982). Sowing date and rate were similar in both experiments. Differences in yield may be due to different soil types resulting in different availability of water. Soil types vary in terms of their soil water holding capacity and the amount of plant available water. The soil at Ashley Dene was

much stonier with a lower water holding and plant available water than that at Lincoln used for the experiment by Fraser (1982).

Furthermore differences between accumulated yields presented here and those by Fraser (1982) may be due to methodology used. This experiment used linear regression calculated based on height and weight of pasture samples from quadrat cuts. The regressions did not always fit the data well. Pre-grazing regressions had an  $R^2$  of at least 0.72, however post-grazing  $R^2$  values were as low as 0.29. There appeared to be no relationship between height and post-grazing DM. Tall thin stalks may have lower DM than many dense short stems. Taking representative quadrat cuts post-grazing rather than selecting high, medium and low areas in the paddock could prove useful. These could be used to calculate post-grazing DM by converting the per metre size of the quadrat to a per hectare value. This would eliminate the need for post-grazing regressions.

#### 5.1.2.2 Mean daily growth rates

All pasture grew at 32 kg DM/ha/d from the 01/07 to the 06/09/2013 then increased to a maximum of 104 kg DM/ha/d from the 06/09 to the 27/10/2013. This explains why DM yield was not different among treatments. From that point onwards the growth rate of pasture decreased. The only time there was a difference in pasture growth rates was in Rotation 4 when lucerne monocultures grew at 79 kg DM/ha/d compared with 59 kg DM/ha/d. Rotation 4 occurred at different times for the pastures. Lucerne monocultures were in Rotation 4 from the 30/11/2013 to the 06/01/2014 while Rotation 4 for the lucerne/grass mixes occurred from 10/12/2013 to the 17/01/2014. This meant differences in pasture growth rates were due to differences in climate as the rotations occurred at different periods. During December 83 mm of rain fell compared with 18 mm in January which meant the lucerne/grass mixes in Rotation 4 had less plant available water. This also explains why there was no difference in DM yield among treatments. Results in this experiment differed from results from last year. In the 2012/13 season a peak in growth rate occurred in November when lucerne brome grew at 98 kg DM/ha/d and lucerne cocksfoot at 89 kg DM/ha/d (Coutts, 2013). Despite differences in pasture growth rates they followed similar patterns. Results are comparable with daily growth rates recorded at Lincoln University. Brown *et al.* (2003) found mean daily growth rates of lucerne increased from 34 kg DM/ha/d in spring to 90 kg DM/ha/d in November/December and the declined from then on. Pasture growth rates were about 80 kg DM/ha/d for all treatments in early January. This was the period when liveweight Rotation 6 occurred. At this time stocking rate had decreased and animal liveweight gain per head rapidly increased. The relatively high growth rate of pasture may help to explain this as during this period there was the most pasture available at about 200 kg DM/lamb.

### 5.1.2.3 Soil water budget

The PAWC between plots was highly variable ranging from 195 mm in plot 7 to 107 mm from plot 17 which was the result of differences in soil type and texture. Plot 7 had more plant available water due to there being more sand and silt present in the lower part of the soil profile compared with plot 17 which had lots of stones, therefore little plant available water. The plant available water in the top 0.25 m of the soil profile was similar for plot 7 and 17. This could be due to organic matter and silt in the topsoil which is common to all plots. Despite these differences there was no difference in PAWC between treatments.

There was no difference in accumulated dry matter for all treatments. This was due to the fact that there was no difference in water use. The mean water use for all treatments was 837 mm. This was based on accumulated PET from NIWA. There was no difference in WUE of pastures throughout the measurement period which explains why there was no difference in annual accumulated DM. The fact that WUE remained linear from the 01/07/2013 to the 24/03/2014 indicates pasture was not limited by water. This was due to the wetter than average season with over 80 mm falling in December and 120 mm in March (Figure 3.1). The calculated relationship shows that pastures produced  $2224 \pm 339$  kg DM/ha before any water use occurred. In the 2012/13 season the mean WUE was the same for all treatments at 22 kg DM/ha/d (Coutts, 2013). Results from the two seasons are not easily compared. The current experiment used PET to calculate WUE of pastures compared with measured soil water used by Coutts (2013).

### 5.1.2.4 Thermal time

When pasture growth was calculated on a thermal time basis all pastures grew at a rate of 4.5 kg DM/ha/°Cd throughout the measured period. No difference in WUE or thermal time among treatments is expected as there was no difference in annual DM yield among treatments. This was different from rates last year when all pastures grew at 5.5 kg DM/ha/°Cd during spring then declined to 1.07 kg DM/ha/°Cd for lucerne/cocksfoot and 0.82 and 0.68 kg DM/ha/°Cd for lucerne monocultures and lucerne/brome respectively (Coutts, 2013). The difference was due to differences in water availability. The current season had greater rainfall through the summer period than the previous season (Figure 3.1). The fact that the relationship between accumulated DM and thermal time was linear for the entire experimental period showed there was a lack of moisture stress this season. This was unusual, Ashley Dene usually has a summer dry environment with drought occurring for a period in late summer. Measurements in the current season included the period between the 01/07/2013 to the 30/04/2014 compared with between the 11/08/2012 to 05/06/2013 for the 2012/13 season. It is likely growth rates in the current experiment were beginning to decline,

however plots were destocked before this occurred. Previous experiments which also used a base temperature of 0°C found spring growth rates of lucerne at Lincoln University were 4.9 kg DM/ha/°Cd and autumn growth rates of 1.1 kg DM/ha/°Cd (Tonmukayakul *et al.*, 2009).

#### 5.1.2.5 Botanical composition

Of the pasture available for grazing on average 41% was consumed. This meant over half the pasture was not utilised. This was due to the botanical composition, with some components being less palatable to grazing animals. Post grazing the proportion of lucerne reduced by about 15% for all treatments (Table 4.11). In the lucerne grass mixes the proportion of grass reduced by about 3%. The dead proportion increased after grazing. The change in botanical composition after grazing indicated a partial preference for lucerne. Ruminants have been shown to express a partial preference for legume content. Edwards *et al.* (1993) found when given the choice sheep will selectively graze 70% clover and 30% grass. Results showed that this was occurring in this experiment as lucerne was selected for rather than the grass species. Selection was particularly occurring in lucerne/ cocksfoot pastures. In Rotation 3 an increase in cocksfoot of 675 kg DM/ha occurred after grazing (Table 4.12). This showed not only the preference of animals to lucerne and away from grass but also the issues that can arise when trying to manage lucerne/grass mixes. No measurements of botanical composition were available after the 23/03/2014. Visual observations continued to show animals were selectively grazing lucerne and avoiding cocksfoot. Plate 4.1 shows ewe hoggets on lucerne/ cocksfoot in plot 4. The image was taken 4 days after animals began grazing. The image is dominated by cocksfoot with no lucerne visible. This shows the preference of lucerne that continued throughout the season.

Annually, lucerne monocultures had around 25-30% more lucerne and over twice as many weeds than lucerne/grass mixes pre-grazing. This shows the need for winter spraying of weed in lucerne swards. Winter spraying was not carried out on the plots. Winter annual weeds commonly fill available gaps after lucerne has self-thinned and gone dormant (Palmer & Wynn-Williams, 1976). It could prove valuable to spray plots in the coming winter to assist weed control. The use of paraquat is common but usually requires the addition of one of the Triazine family herbicides of atrazine, simazine or terbuthylazine, depending on weeds present and period of residual required in the soil. The predominant weeds in the experiment were grasses, thistles and some other broadleaf species. Paraquat with simazine or terbuthylazine would be most suitable for control of these weeds. Herbicides from the Triazine family should not be used on lucerne/grass mixes as grasses are susceptible to these herbicides. The compositions of lucerne/grass mixes were not different annually. The compositions in pastures here varied from those recorded by Cullen (1965) who

showed lucerne contents of 53% in lucerne monocultures, 20% in lucerne/ cocksfoot and 7% in lucerne/ brome pastures. This could be due to differences in pasture management.

In the first rotation before grazing of the experiment began the lucerne component of lucerne monocultures was 72% and around 45% for lucerne/ grass mixes (Table 4.6). In Rotation 2 this declined to 54% for lucerne monocultures and 30% for lucerne/ grass mixes (Table 4.7). This showed that ewes and lambs selected more lucerne than any other component. There was also an increase in the weed content. The competition between weeds and sown species reduced the contribution from sown species. This meant that the diet was highest in the first rotation when the most lucerne was on offer, however post graze cuts were not taken in Rotation 1. Ewes and lambs on lucerne monocultures also consumed more weeds than other treatments. The weed proportion of lucerne monocultures (30%) was higher than lucerne grass mixes (8%). The predominant weed during this period was perennial ryegrass. This again highlights the need for winter spraying.

Lucerne contents declined further in Rotation 3 (Table 4.10). In lucerne monocultures lucerne contents had gone from 72% in Rotation 1 to 53% in Rotation 3 and lucerne content of lucerne/ grass mixes from 45% to around 15%. Sown grass content had also reduced from 35% to 24%. This was due to an increase in the dead proportion of the pastures (from 5% to 35%). This was similar to previous year's results where a 50 kg DM/ha increase in dead material was noted (Coutts, 2013). This is common in lucerne pastures and again emphasizes the effect of diet selection. Animals selectively graze the leaves of lucerne leaving behind the stalk which resulted in an increase in dead material in the pastures.

### 5.1.3 Nutritive yield

#### 5.1.3.1 Metabolisable energy

All treatments produced 147 GJ ME/ha (Table 4.16). This meant liveweight was not affected by the amount of ME available for grazing. The sown species contributed around 100 GJ ME/ha and the remainder of ME production was from weeds. This was higher than the 88 GJ ME/ha produced from the sown species in the treatments last year (Coutts, 2013). In the current experiment the annual ME content was lower by about 1 MJ ME/kg DM than ME contents reported last year by Coutts (2013). The differences in ME yield were due to differences in DM yield. The issues with post grazing regressions may have meant an over-estimation of DM production and therefore ME production. This was due to the inability to correctly calculate post-grazing DM due to there being no relationship between height and DM. The lower ME content was due to lucerne being more advanced in growth at lambing than expected. This was due to earlier growth in September due to the mild 2013 winter which resulted in a higher proportion of stalk which was visually observed, no

separation of stalk and leaf proportions were carried out. Peak pasture growth rates occurred earlier in the 2013/14 period than the 2012/13 season which confirms this claim.

The lucerne component of monocultures produced 60% (92 GJ/ha) of the pasture ME yield, compared with about 40% (about 56 GJ/ha) for the lucerne component of lucerne/grass mixes. Sown grass contributed ~50 GJ/ha. Annual lucerne ME yields were lower than those reported by Mills and Moot (2010) who found lucerne could produce 134 GJ ME/ha seven years after establishment. The ME content of lucerne was 11 MJ ME/kg DM which was greater than the 10 MJ ME/kg DM in this experiment.

The fact that all pastures produced the same amount of metabolisable energy indicated that differences in liveweight production were not a result of the quality of the pasture (Table 4.16). However they may have been due to ME intakes. Animals on lucerne/cocksfoot showed a preference towards lucerne and away from cocksfoot. This means the ME intake was altered by selecting for more lucerne than grass. This is supported by the low ME yield (1.7 GJ/ha) of lucerne in lucerne/cocksfoot mixes left after grazing in Rotation 3 (Table 4.22). This would have reduced the liveweight production due to a lower ME intake as only ME from lucerne was consumed. Annually animals were utilising 41% of the pasture available to them. Botanical composition data showed that the proportion utilised was the green leaf. There was no separation of the palatable and unpalatable fractions of components. This meant the ME of the consumed components was higher than the ME of the analysed samples in the results. Annually the post grazing ME of lucerne in all treatments was 6.6 MJ ME/kg DM. This is low and represents the low quality stalk left behind, which means animals were utilising the high quality leaf of lucerne and leaving the stalk behind. Brown and Moot (2004) found the fraction of palatable lucerne herbage decreased linearly from 100% at 700 kg/ha standing DM to 57% at 4300 kg/ha standing herbage. Utilisation by grazing sheep was 70% of total ME for a crop of 4300 kg/ha standing DM. This meant although delayed grazing resulted in an increase in DM and decrease in fractions of palatable herbage the potential of stock production will not be reduced unless animals are forced to graze to low residuals. This is what would have been occurring in this experiment and is consistent with findings by Arnold (1960) who found low quality stem content had increased to 88% after grazing lucerne with merino wethers. It also can explain why a higher DM yield this year compared with the 2012/13 season did not relate to increased animal production. In mixed sheep and beef systems the stalky component left behind could be 'cleaned-up' by a lower class of stock i.e. cattle. This would increase the utilisation of the pasture and avoid build up of dead material.

During all grazing rotations there was no difference in pre or post grazing ME or ME yield from the treatments. Lucerne from lucerne monocultures generally produced more ME than lucerne from lucerne/grass mixes but the contribution from grass compensated for this. ME produced by the pastures reduced from ~30 GJ/ha in Rotations 1 and 2 to ~16 GJ/ha in Rotation 3 and 14 GJ/ha in Rotation 4. Lucerne ME after grazing was below 3 GJ/ha for Rotations 2, 3 and 4. No data for post grazing were available in Rotation 1. The ME of sown grass was more variable. In Rotation 2 the sown grass ME yield reduced by about 7 GJ/ha after grazing compared with a 1.5 GJ/ha reduction in Rotation 3 and no change after grazing in Rotation 4. This again shows the preference of sheep to lucerne and away from grass.

#### 5.1.3.2 Nitrogen yield

Annual nitrogen yield was 299 kg N/ha for lucerne monocultures and about 220 kg N/ha for lucerne grass mixes (Table 4.25). This was due to lucerne in lucerne monocultures producing over twice as much N as lucerne in lucerne/grass mixes. Grass produced ~280 kg N/ha which did not compensate for the lack of N from the lucerne component in lucerne/grass mixes. This coupled with the preference for lucerne meant that animals on lucerne monocultures had greater N intakes. Despite this, N levels do not explain the differences observed in liveweight production. Lambs at 20 kg have a requirement for 14 g CP/day (Sykes & Nicol, 1983). Crude protein is equal to the nitrogen content \* 6.25, which means the requirements is 87.5 g N/lamb/day. During the summer the lowest N yield occurred in Rotation 3 when all pastures produced 54.6 kg N/ha (Table 4.30). At this point the highest stocking rate that occurred was 22 lambs/ha and the longest amount of time spent in a paddock was 15 days. This means individual lambs had at least 165 g/N/day available for grazing. Therefore the supply of nitrogen was not limiting lamb growth on any treatment.

Previously all pastures on the experiment produced 286 kg N/ha (Coutts, 2013). This means the contribution of N from grass has reduced since the first year of the experiment. The proportion of grass has not declined since last year and DM yield has increased by about 3 t DM/ha/yr. This means the proportion of N supplied by the grass must have reduced in the 2013/14 season.

The increased N of lucerne monocultures compared with lucerne/grass mixes was due to a higher proportion of lucerne in the pasture. Lucerne consistently had the highest N content of all species present in the pastures. This explains why selection for lucerne was occurring. Nitrogen content of the pastures causes grazing selection (Edwards *et al.*, 1993). Grazing sheep can distinguish between grass species, the level of nitrogen in grass leaves. Keogh (1986) stated that livestock select urine patches in preference to inter-urine patches. Higher intensity and more frequent defoliation of urine

patches was observed. Urine patches cause an increase N content due to higher N uptake. This can explain some of the liveweight production differences as there was more of the favourable lucerne available to lambs on monocultures.

Nitrogen yield in this experiment was lower than the 471 kg N/ha/year produced by lucerne in an experiment at Lincoln University (Tonmukayakul *et al.*, 2009). The N content was slightly higher at 3.9% (compared with 3.3% in the current experiment) which would account for some of the difference. Differences were predominantly due to differences in pastures yield. Figures presented by Tonmukayakul *et al.* (2009) were from lucerne stands established on a Templeton silt loam which has a greater plant available water content than the stony Lismore soil at Ashley Dene. The experiment also showed N yield for a whole year compared with this experiment where N yield is from the experimental period only which does not represent the entire growing season of lucerne.

Similar to ME, the N yield of pasture declined over time. In Rotations 1 and 2 pastures were yielding ~84 kg N/ha. This dropped to 55 kg N/ha in Rotation 3 and 40 kg N/ha in Rotation 4 which was due to a reduction in the contribution from lucerne. The N yield of all pastures was generally halved after grazing. The lucerne N yield declined more than the N yield of the sown grass component of lucerne/grass mixes. This again indicated the preference towards lucerne and for the leafy high N component.

The nitrogen content of lucerne remained above 3% pre-grazing throughout Rotations 1-4 which is above the N content of 2.6% that indicated a severely compromised photosynthetic rate as shown by Peri *et al.* (2002). The sown grass N content was initially 3% for both grasses in Rotation 1. This declined to 2.5% by Rotation 2 and 3. This indicated the ability of lucerne to maintain a higher N content throughout the summer period. Sown grass species were going reproductive in Rotations 2 and 3 (Plate 2). This high N also helps to explain the high DM production observed.

## 5.2 Experiment 1 Conclusions

- Liveweight production was greater from lucerne monocultures than lucerne/grass mixes.
- No difference in water use, WUE or thermal time resulted in no difference in DM produced by all treatments.
- Lucerne content of all pasture declined throughout the experiment which indicated a selection preference towards lucerne and away from sown grass species, weeds and dead material.
- Grazing selection observed resulted in lower ME consumption by animals grazing lucerne/cockfoot pastures.
- N yield was greatest from lucerne monocultures. The N content of sown grass was lower than lucerne therefore did not compensate for the lower lucerne contribution in lucerne/pasture mixes.
- The increase in grass component in the lucerne/grass pastures showed difficulties in managing lucerne/grass mixes.
- A lower class of stock could prove useful in increasing utilisation of pastures.

## 5.3 Experiment 2

### 5.3.1 Animal production

#### 5.3.1.1 Liveweight production

From the 13/09/2013 to 03/02/2014 animal production totalled 784 kg LWT/ha for lucerne + grain animals and 741 kg LWT/ha for – grain animals. Liveweight production at 531 kg LWT/ha before weaning was not different between lambs offered barley grain and those without. This meant lamb liveweight produced before weaning was not increased by barley supplementation. This is expected as before weaning the majority of the lambs' intake is from milk produced by the ewes. Ewes on the +grain treatment produced 14 kg LWT/ha compared with ewes on the –grain treatment which lost 16 kg LWT/ha. The liveweight advantage of ewes with access to barley grain and the lack of lamb effect suggested that any grain consumed by the ewes was partitioned to maintaining condition rather than milk production.

After weaning, lamb liveweight gains were not affected by grain supplementation with both groups producing an average 223 kg LWT/ha from the 02/12/2013 to 03/02/2014. This indicated that offering grain had no effect on liveweight production. This was due to lack of uptake of grain by lambs.

Nearly all of the liveweight produced came from lamb liveweight production for both of the treatments. Liveweight production per hectare is a factor of either stocking rate or liveweight gain achieved by each animal. During the spring period when ~70% of liveweight production occurred, ewes and lambs on the +grain treatment were stocked at 11.3 ewes/ha and 21.9 lambs/ha compared with 11.7 ewes/ha and 24.0 lambs/ha on the –grain treatment. The lower stocked lambs on the +grain treatment meant per head performance was greater which produced more LWT/ha. This is a factor of the stocking rate model which states that as stocking rate increases per head production decreases and per hectare production increases.

#### 5.3.1.2 Rotational liveweight gains

Differences were seen in individual ewe liveweight gains per day in two of the three rotations. Before weaning ewes supplemented with grain maintained more liveweight than those with no supplementation. This was a result of the increased daily liveweight gains achieved when ewes were supplemented with grain. There was no difference in liveweight gains for lambs on either treatment pre-weaning. This suggests that ewe benefits were an increase in liveweight gain rather than any increase in milk production and subsequent lamb liveweight gains.

Differences in lamb liveweight gains only occurred in one rotation which occurred after weaning. In the first rotation after weaning (Rotation 4) lambs on the +grain treatment had liveweight gains of 140 g/head/d compared with 77 g/head/d for those on the –grain treatment. This increase in liveweight gain/head was due to individual animal performance which was affected by stocking rate and class/sex of stock rather than the grain. During Rotation 4 there were 16.6 lambs/ha on the –grain treatment and 13.8 lambs/ha on the +grain treatment. In addition to this the proportion of ewe lambs was ~10% higher on the –grain treatment than the +grain treatment. The lower stocking rate and higher proportion of ram lambs on the +grain treatment meant there was more pasture available to each animal and on average an increase in growth rate due to rams growing faster than ewe lambs. This is consistent with previous experiments which found ram lambs significantly grew faster than ewe lambs over several experiments (Fourie , Kirton, & Jury, 1970). The authors stated this was due to the fact that male animals laid down bone and muscle at a relatively faster rate and fat at a slower rate than females. The production of muscle is more efficient than fat resulting in faster growth rates. This was also seen by Butler-Hogg, Francombe, and Drans (1984) who found on average rams grew 28 g/day faster than ewes, and took on average 2 weeks less to achieve 35 kg live weight which is when animals can be slaughtered.

Therefore, grain supplementation did have an influence on liveweight gains of lambs. The benefit of grain supplementation was in the maintenance of ewe liveweight after lambing. The ability of ewes to maintain increased liveweight may have benefits in the following season. In a dryland environment stock with increased liveweight may have the ability to buffer liveweight during feed deficit months in the summer period. They may remain in higher condition coming out of the summer period and going into flushing and mating. This could lead to an increase in lambing % in the following season. Tracking ewes through the following season to see whether the difference in liveweight gain during the summer leads to any advantages in lambing would be beneficial.

### 5.3.2 DM Production

From 1/07/2013 to 06/01/2014 lucerne pastures accumulated 12 t DM/ha regardless of treatment (+ or – grain). The same DM production indicated the same intakes were achieved. Post grazing measurements were limited so sound conclusions to intakes could not be made. The same DM production suggested no substitution was occurring for animals on the grain treatment. This was unexpected as it is generally accepted that offering a supplement causes a reduction in pasture intake (Dove, 2002). In a previous experiment even at low green pasture mass (650 kg DM/ha) a SubR of 0.38 was recorded for Merino ewes receiving 100-400 g wheat grain per day, this increase to 0.67 when pasture mass was 2000 kg DM/ha (Langlands, 1969).

### 5.3.3 Grain consumption

Over 80% of grain fed was consumed prior to weaning. This indicated that the majority of grain was consumed by ewes rather than lambs. Ewe excluders were introduced to the feeders on the 17/10/2013. Visual observations indicated that these were not working and results support these observations. Whether or not the grain consumed by ewes was beneficial to the system is dependent on whether the increase in condition achieved translates to any increases in lambing % and subsequent lamb production in the following season.

The lack of effect of grain supplementation on lamb liveweight gains was due to a lack of lamb uptake to the grain. Lambs were attracted to the feeder as a source of shade/shelter (Plate 3) but were rarely observed consuming the grain. The main aim of grain supplementation is to increase lamb liveweight gains, which allows destocking to occur as early as possible with lambs reaching killable weights earlier. The challenge in achieving this with grain supplementation appears to be in enticing the lambs on to the grain. This is consistent with finding by Holst *et al.* (1994) who found variation in the uptake of lupin grain to be about ~78% which indicated issues on achieving grain consumption. Using a dye to determine how many lambs are consuming the grain and track their liveweight gains compared with lambs not consuming grain could provide information on the liveweight effects of grain on lambs which actually consume grain. If the number of lambs consuming grain is low methods of training lambs may need to be adopted.

Over the 80 day spring period 633 kg of grain was consumed. Observations suggested that only ewes were consuming grain. This meant on average individual ewes were consuming 25 g grain/day. In reality this is unlikely. Arnold and Maller (1974) identified sheep as either; shy feeders, moderate feeders or over-indulgers. This means although grain was on offer the amount which was consumed by ewes cannot be determined by simply dividing the amount of supplement by the number of animals. Again using a dye could determine how many ewes were consuming grain and help to determine daily grain intakes.

## 5.4 Experiment 2 Conclusions

- Supplementation of barley grain to animals grazing lucerne had no effect on lamb liveweight production.
- Ewes with access to barley grain gained 1.1 kg liveweight/ewe during the lactation period compared with those without supplementation who each lost 1.2 kg.
- Benefits in lambing % for ewes supplemented with grain may occur in the subsequent season. Further measurements are required.
- Lack of lamb effects appeared to be due to lack of uptake of grain.
- No substitution occurred.

## 6 GENERAL DISCUSSION

There are reasons other than production to consider planting lucerne in a mix with grasses. Lucerne has a high N content (Section 5.1.3.2, 4.1.2.5.2). High nitrogen diets result in high N returns to the soil in the urine of grazing livestock. Between 50-70% of the nitrogen ingested in the diet of ruminants is degraded by rumen microbes and excreted as urea in urine (Malcolm, Cameron, Di, Edwards, & Moir, 2014). This can contribute to leaching. With new environmental policies coming into place by 2017, utilising pastures which reduce leaching may be required. Sowing a companion grass with lucerne results in a greater utilisation of soil N. This is due to the grass uptake of N deposited on the soil in urine. This can reduce the soil N level, therefore reducing leaching. The N inputs via urine from livestock grazing high N pastures results in increased growth of other potentially N limited species which cannot fix their own N. This means sowing lucerne in a mix with grass species in dryland situations improves the production of grasses without the need for high urea applications. If it is economical to sow lucerne in a mixed pasture, production will not be sacrificed, as seen in Experiment 1 and leaching losses minimised which would increase the sustainability systems.

However sowing lucerne in a mix with grasses such as cocksfoot and prairie grass increases the complexity of grazing management. Lucerne requires different management to other common pasture plants such as perennial ryegrass. This is because the growing point of lucerne is situated at the top of the plant and not underground. The issues in managing lucerne/grass mixes became apparent in Experiment 1 when an increase in cocksfoot was seen post-grazing (Table 4.12). This meant cocksfoot was growing at a rate faster than it was being consumed. The elevated position of the growing point of lucerne means an infrequent rotational grazing management policy should be utilised. Cocksfoot has an aggressive growth pattern and requires frequent heavy defoliation. The grazing management policy utilised determines which species will dominate the sward. Since sheep have shown a preference to lucerne, management should favour lucerne growth. Frequent, heavy defoliation will favour cocksfoot growth, while infrequent defoliation will favour lucerne growth (Cullen, 1965). Therefore an infrequent grazing management policy should be used however frequent grazing in mid-summer to stop cocksfoot becoming clumpy would likely be necessary.

Continuing Experiment 1 in the 2014/15 season will allow for increased understanding of lucerne/grass mixes. In particular the long term effects on botanical composition will give a better idea of which grazing management policies should be used to maximise animal production. Weighing animals at the end of each grazing rotation where possible would be useful to determine liveweight production on a rotational basis which coincides with the physical grazing rotations

occurring. There is a need to more accurately determine post grazing DM. Height gave no relationship with DM after grazing. Cutting representative areas and weighing the DM may be best to determine post grazing rather than using height measurements. Caged areas to eliminate animal access to pasture within the case would allow measurement of any growth that occurs while animals are grazing paddocks. Separation of the palatable and unpalatable fractions would also give a better indication of ME and N consumption.

In Experiment 2 the potential increase in lambing for ewes supplemented with grain will only be beneficial to a system if the increased production results in greater income than the cost of grain required to achieve that production. This seems unlikely in low cost grazing systems which are predominantly used in New Zealand. A cost benefit analysis would prove beneficial to determine if the supplementation is justifiable to maintain ewe condition. The poor liveweight production seen in lambs across the farm at Ashley Dene in the 2013/14 season indicates the grain experiment should be continued for a second year. The grain treatments in the second year of the experiment should ideally be stocked at the same rate with the same class of stock where possible. This eliminates stocking rate effects on individual animal liveweight performance.

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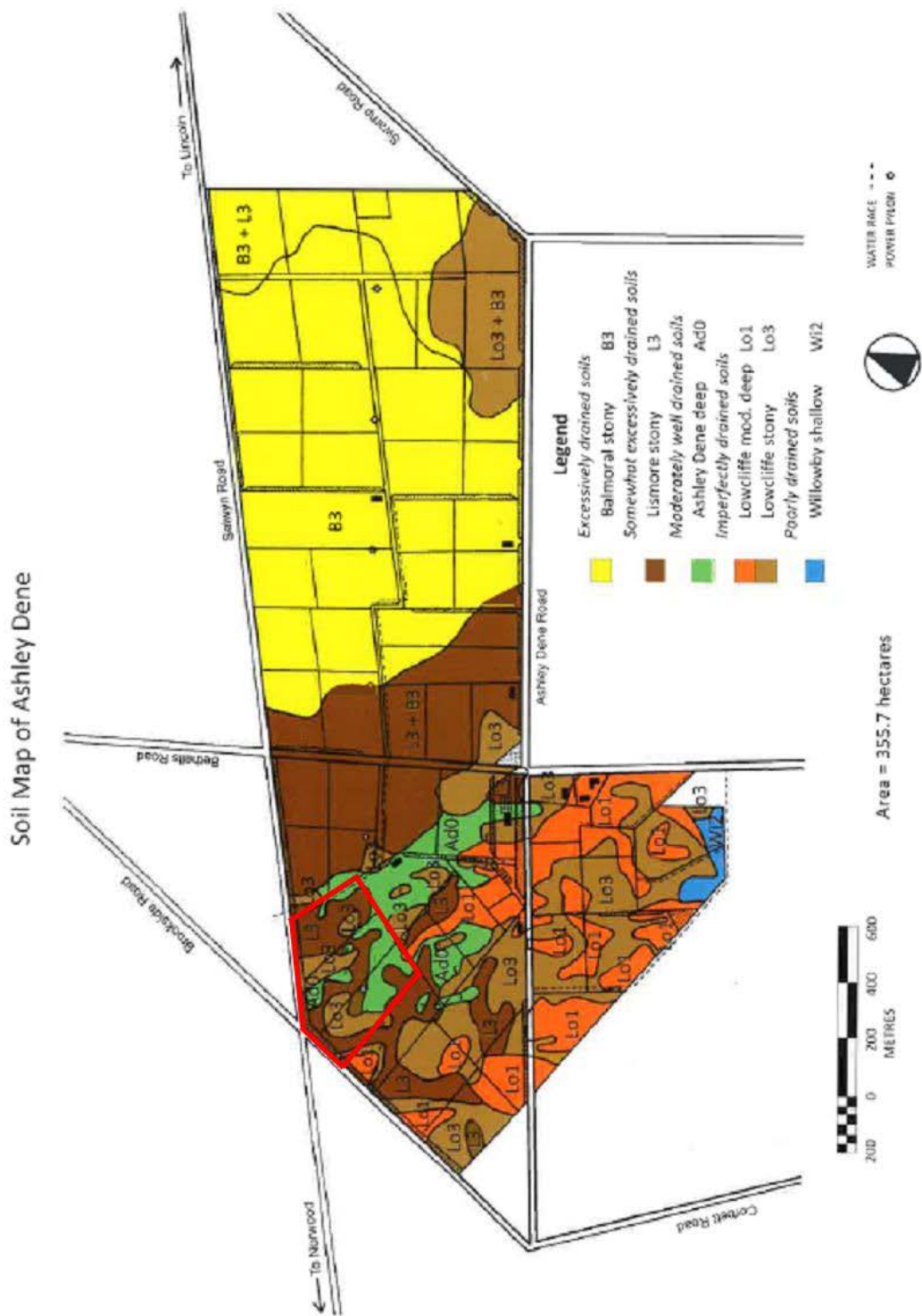
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# 9 APPENDICES



Appendix 9.1: Soil map of paddocks C6E, C7W and C7E at Ashley Dene, Canterbury, New Zealand.

Appendix 9.2: Detailed stock movements for grazing rotations on lucerne/brome at Ashley Dene, Canterbury, New Zealand from 3/09/2013 to 05/05/2014.

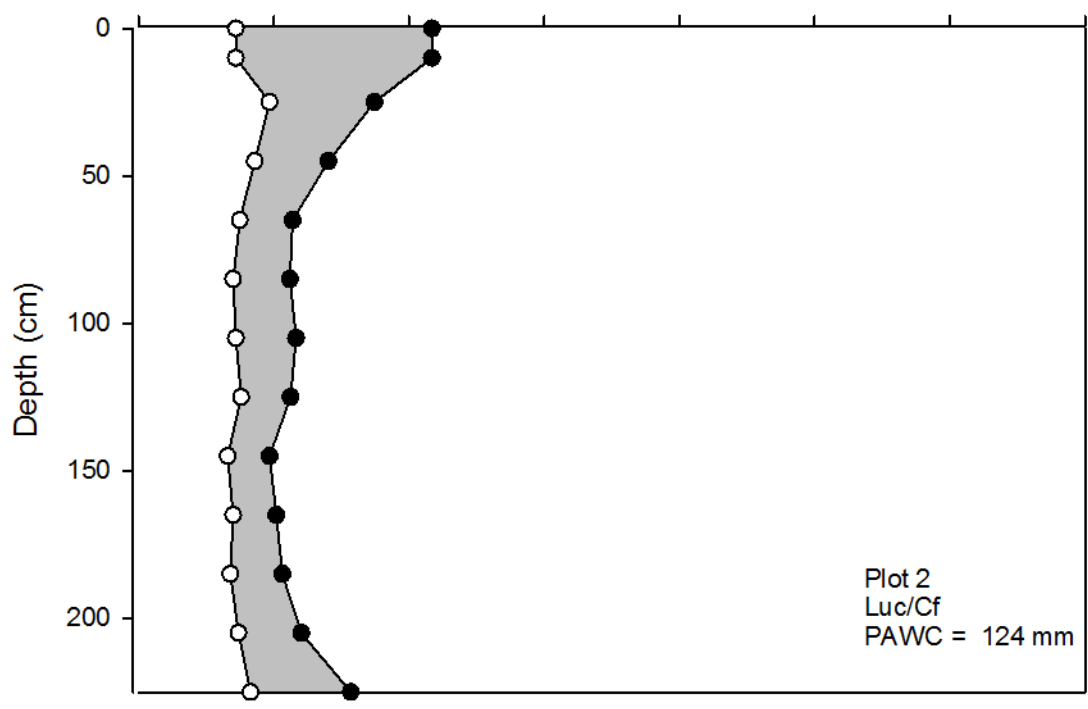
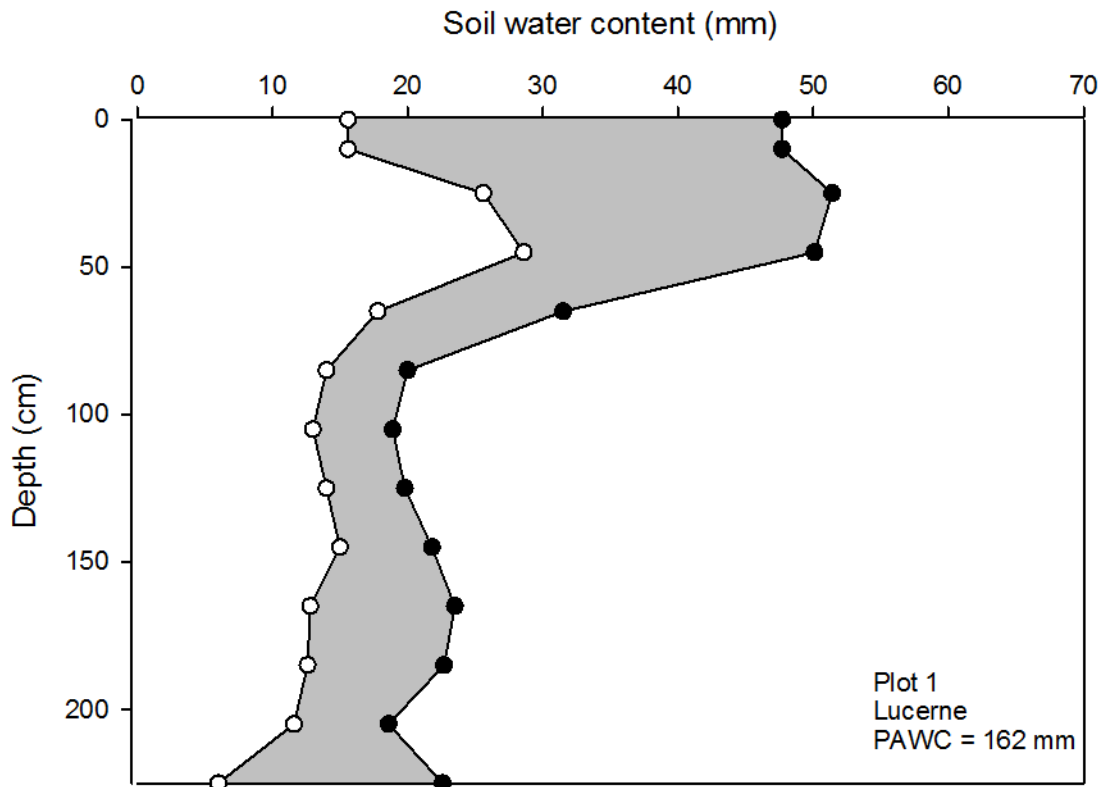
Plot	DM Rotation	LWt rotation	Stock	Date on	Date off
3	1	1	E & L	3/09/2013	1/10/2013
11	1		Hogs	24/09/2013	
15	1	1	E & L	24/09/2013	1/10/2013
17	1	1	E & L	30/09/2013	7/10/2013
6	1	2	E & L	7/10/2013	16/10/2013
7	1	2	E & L	11/10/2013	30/10/2013
3	2	2	E & L	21/10/2013	7/11/2013
15	2	3	E & L	7/11/2013	18/11/2013
6	2	3	E & L	13/11/2013	27/11/2013
17	2	3	E & L	14/11/2013	22/11/2013
7	2	3	E & L	25/11/2013	3/12/2013
11	2	3	Lambs	2/12/2013	10/12/2013
3	3	4	Lambs	10/12/2013	20/12/2013
15	3	5	Lambs	20/12/2013	28/12/2013
17	3	5	Lambs	24/12/2013	1/01/2014
6	3	5	Lambs	28/12/2013	2/01/2014
7	3	5	Lambs	2/01/2014	13/01/2014
7	4	6	Lambs	2/01/2014	13/01/2014
11	3	6	Lambs	13/01/2014	22/01/2014
3	4	6	Lambs	17/01/2014	21/01/2014
15	4	6	Lambs	21/01/2014	23/01/2014
17	4	6	Lambs	23/01/2014	27/01/2014
6	4	6	Lambs	30/01/2014	7/02/2014
3	5	7	Ram hogs	24/03/2014	1/04/2014
15	5	7	Ram hogs	1/04/2014	7/04/2014
17	5	7	Ram hogs	5/04/2014	11/04/2014
6	5	7	Ram hogs	11/04/2014	23/04/2014
7	5	7	Ram hogs	21/04/2014	30/04/2014
11	5	7	Ram hogs	28/04/2014	5/05/2014

Appendix 9.3: Detailed stock movements for grazing rotations on lucerne/cocksfoot at Ashley Dene, Canterbury, New Zealand from 3/09/2013 to 09/05/2014.

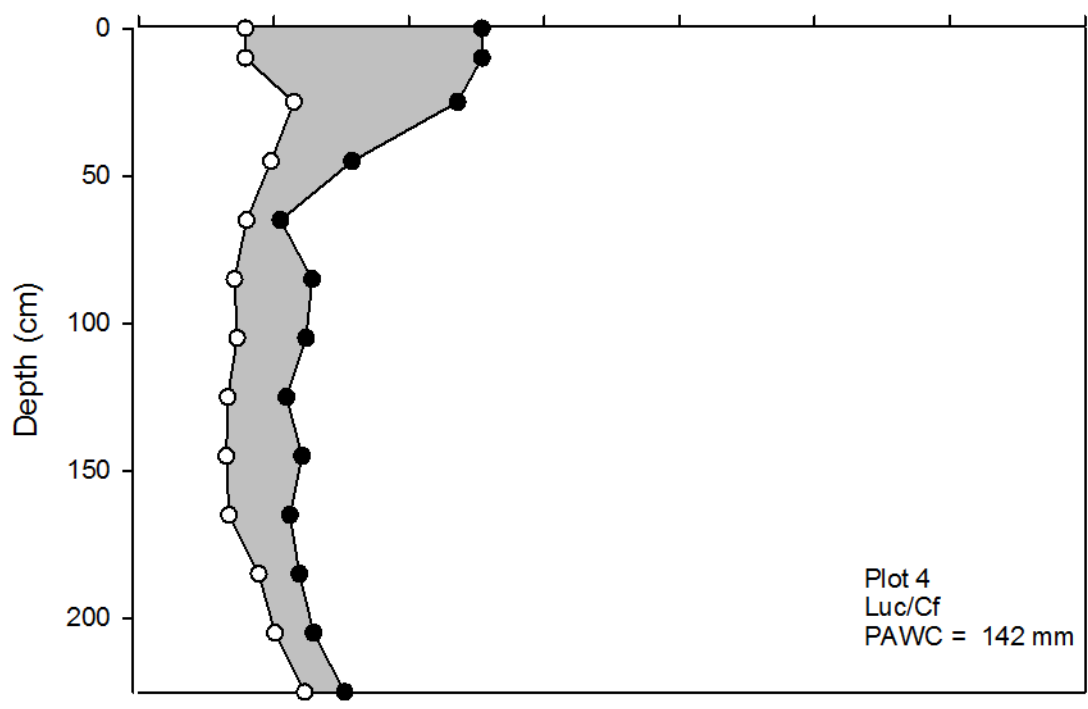
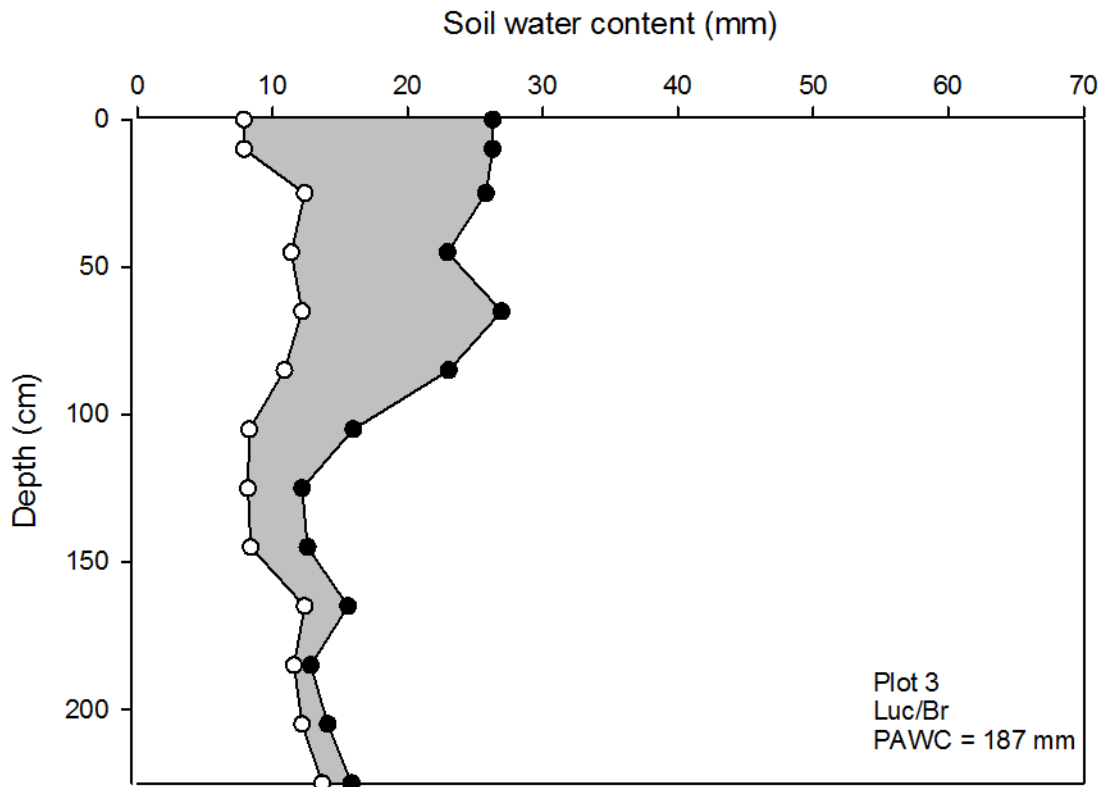
Plot	DM Rotation	LWt rotation	Stock	Date on	Date off
2	1	1	E & L	3/09/2013	1/10/2013
4	1	2	E & L	7/10/2013	16/10/2013
8	1	2	E & L	11/10/2013	30/10/2013
10	1		Hogs	24/09/2013	
13	1	1	E & L	24/09/2013	1/10/2013
18	1	1	E & L	30/09/2013	7/10/2013
2	2	2	E & L	21/10/2013	4/11/2013
4	2	3	E & L	18/11/2013	26/11/2013
8	2	3	E & L	26/11/2013	3/12/2013
10	2	3	Lambs	2/12/2013	10/12/2013
13	2	2	E & L	4/11/2013	11/11/2013
18	2	3	E & L	11/11/2013	18/11/2013
2	3	4	Lambs	10/12/2013	20/12/2013
4	3	5	Lambs	28/12/2013	2/01/2014
8	3	5	Lambs	2/01/2014	13/01/2014
10	3	6	Lambs	13/01/2014	22/01/2014
13	3	5	Lambs	20/12/2013	28/12/2013
18	3	3	Lambs	24/12/2013	1/01/2014
2	4	6	Lambs	17/01/2014	27/01/2014
4	4	6	Lambs	1/02/2014	4/02/2014
8	4	6	Lambs	2/01/2014	13/01/2014
13	4	6	Lambs	26/01/2014	29/01/2014
18	4	6	Lambs	29/01/2014	1/02/2014
2	5	7	Ram hogs	24/03/2014	1/04/2014
4	5	7	Ram hogs	11/04/2014	23/04/2014
8	5	7	Ram hogs	21/04/2014	30/04/2014
10	5	7	Ram hogs	30/04/2014	9/05/2014
13	5	7	Ram hogs	1/04/2014	7/04/2014
18	5	7	Ram hogs	5/04/2014	11/04/2014

Appendix 9.4: Detailed stock movements for grazing rotations on lucerne monocultures at Ashley Dene, Canterbury, New Zealand from 3/09/2013 to 09/05/2014.

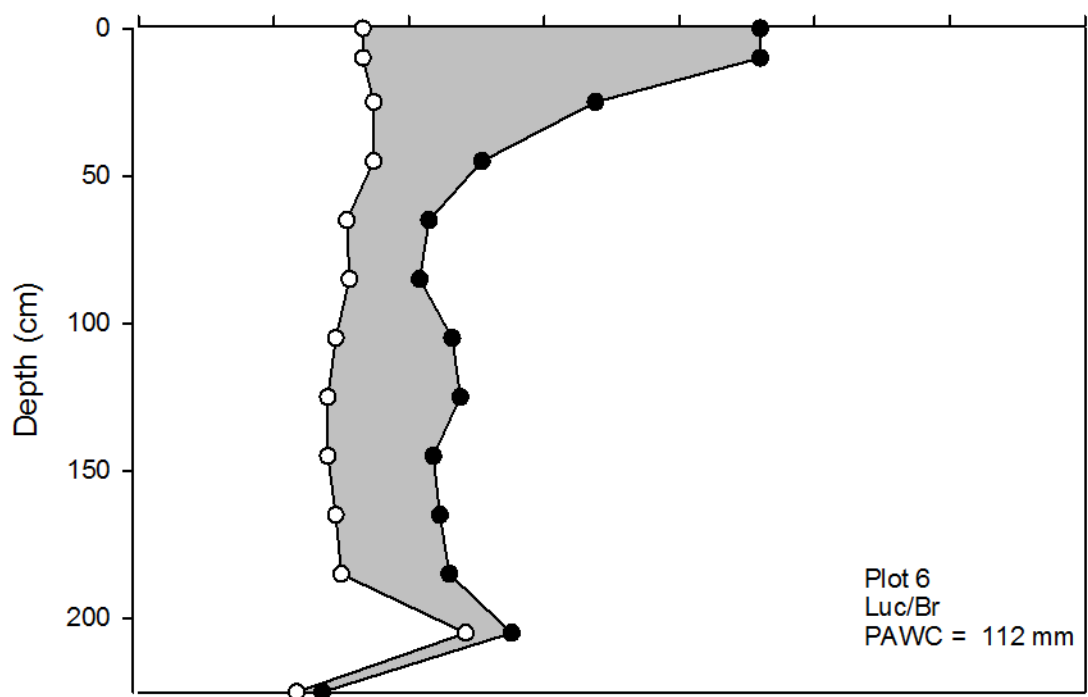
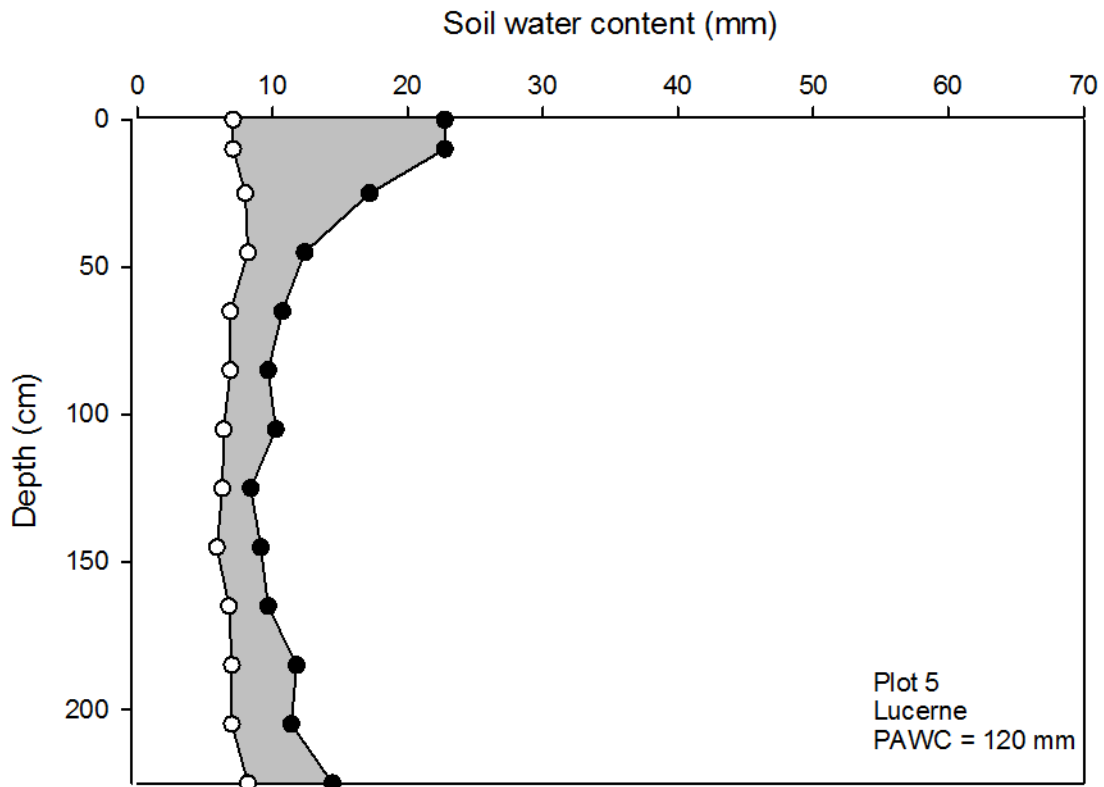
Plot	DM Rotation	LWt rotation	Stock	Date on	Date off
1	1	1	E & L	3/09/2013	1/10/2013
5	1	2	E & L	7/10/2013	16/10/2013
9	1	2	E & L	11/10/2013	24/10/2013
12	1		Hogs	24/09/2013	
14	1	1	E & L	24/09/2013	1/10/2013
16	1	1	E & L	30/09/2013	7/10/2013
1	2	2	E & L	21/10/2013	4/11/2013
5	2	3	E & L	8/11/2013	22/11/2013
9	2	3	E & L	11/11/2013	25/11/2013
12	2	3	E & L	25/11/2013	3/12/2013
14	2	2	E & L	31/10/2013	6/11/2013
16	2	2	E & L	4/11/2013	8/11/2013
1	3	3	Lambs	2/12/2013	12/12/2013
5	3	5	Lambs	19/12/2013	27/12/2013
9	3	5	Lambs	24/12/2013	29/12/2013
12	3	5	Lambs	29/12/2013	2/01/2014
14	3	4	Lambs	12/12/2013	16/12/2013
16	3	5	Lambs	16/12/2013	20/12/2013
1	4	6	Lambs	7/01/2014	22/01/2014
5	4	6	Lambs	23/01/2014	28/01/2014
9	4	6	Lambs	28/01/2014	7/02/2014
12	4	6	Lambs	31/01/2014	3/02/2014
14	4	6	Lambs	16/01/2014	20/01/2014
16	4	6	Lambs	20/01/2014	23/01/2014
1	5	7	Ram hogs	24/03/2014	4/04/2014
5	5	7	Ram hogs	17/04/2014	30/04/2014
9	5	7	Ram hogs	25/04/2014	6/05/2014
12	5	7	Ram hogs	6/05/2014	9/05/2014
14	5	7	Ram hogs	4/04/2014	10/04/2014
16	5	7	Ram hogs	10/04/2014	17/04/2014



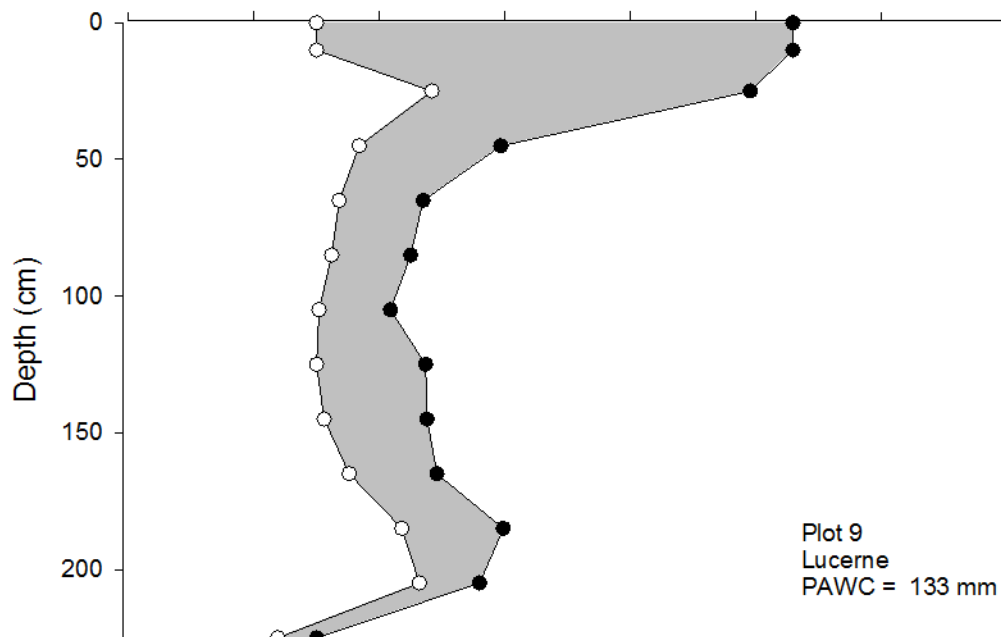
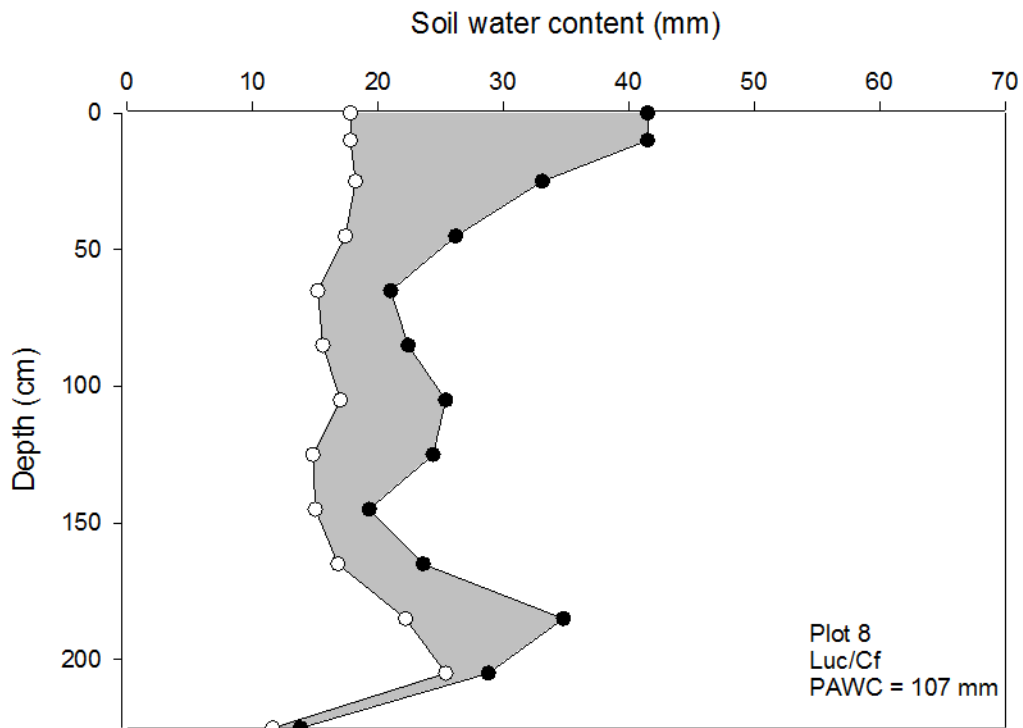
Appendix 9.5: Soil water content of Plot 1 (top) and Plot 2 (bottom) in paddocks C6E and C7E, Ashley Dene, Canterbury. Where (●) is the upper limit and (○) is the lower limit for plant available water.



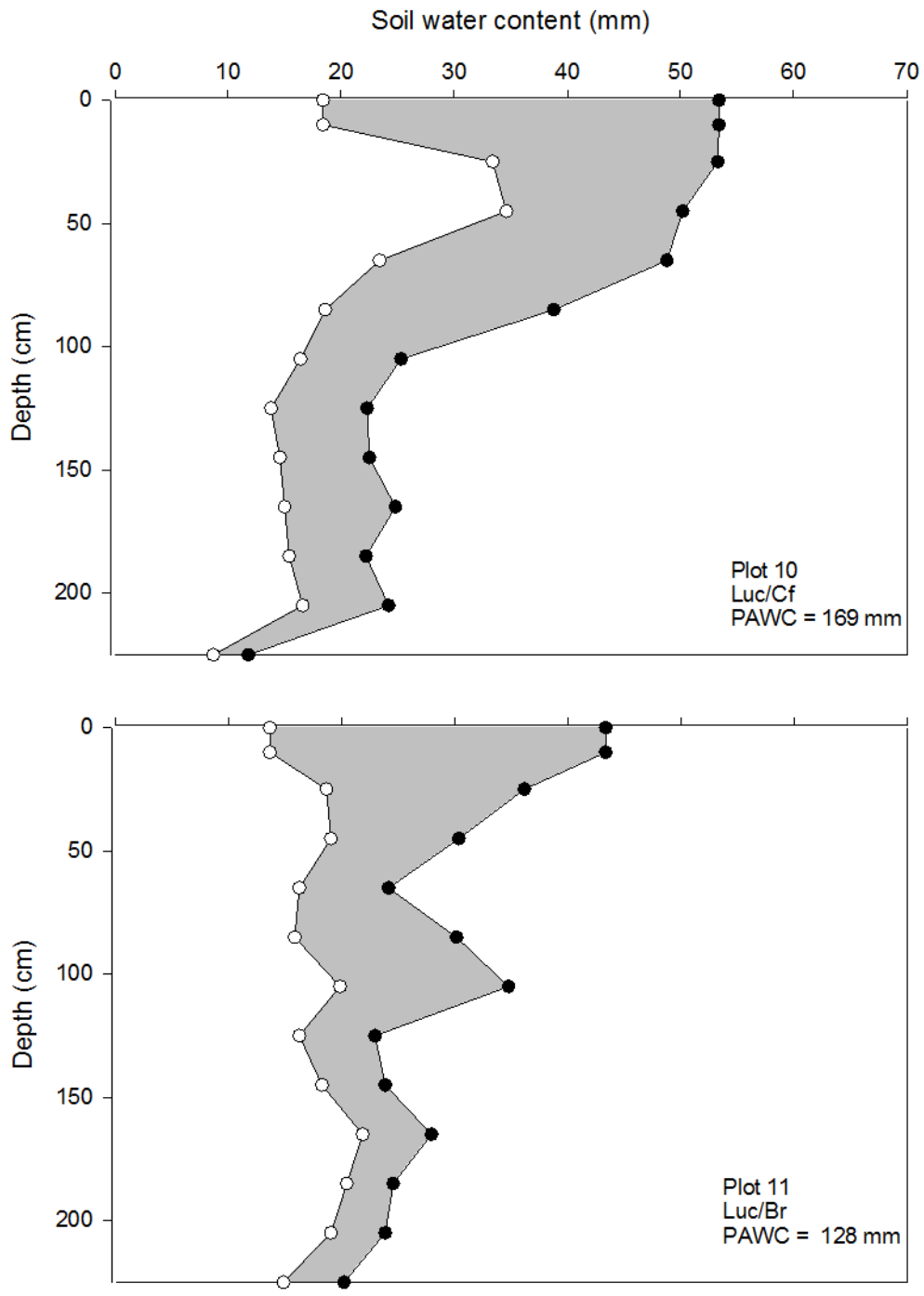
Appendix 9.6: Soil water content of Plot 3 (top) and Plot 4 (bottom) in paddocks C6E and C7E, Ashley Dene, Canterbury. Where (●) is the upper limit and (○) is the lower limit for plant available water.



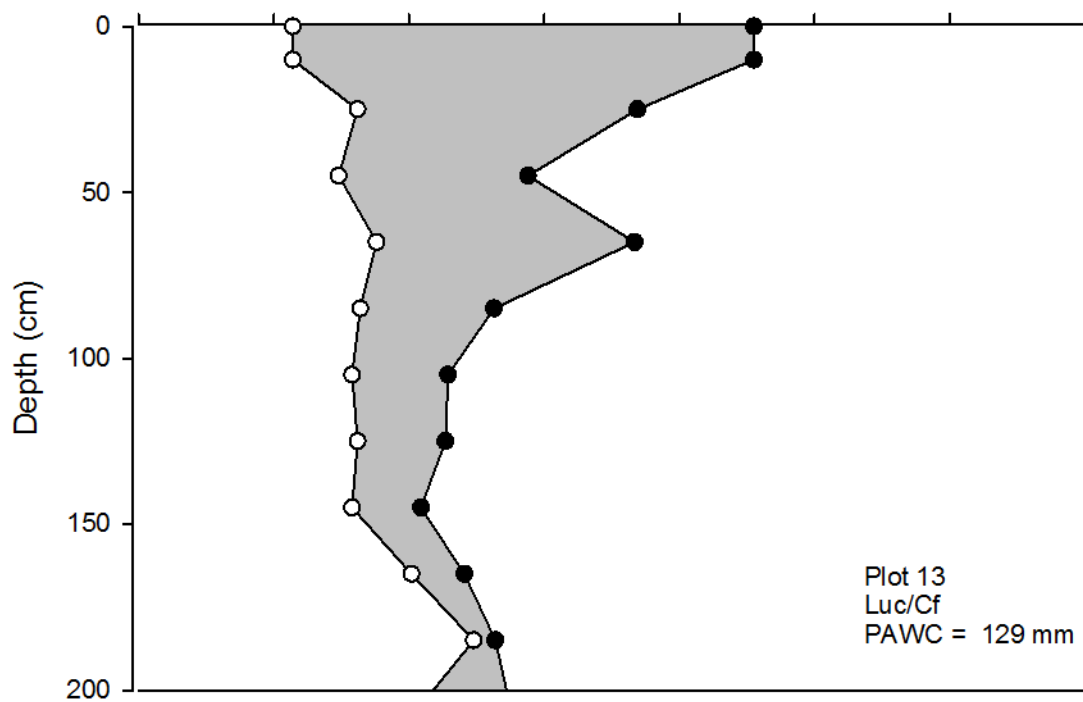
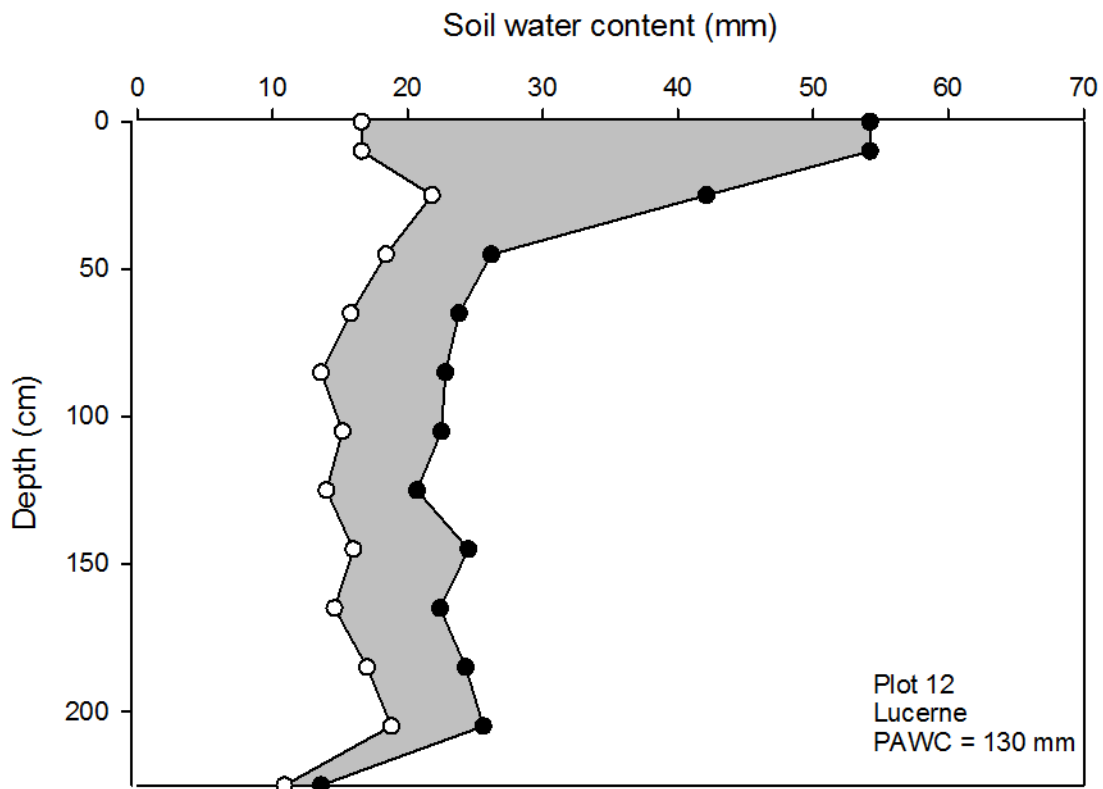
Appendix 9.7: Soil water content of Plot 5 (top) and Plot 6 (bottom) in paddocks C6E and C7E, Ashley Dene, Canterbury. Where (●) is the upper limit and (○) is the lower limit for plant available water.



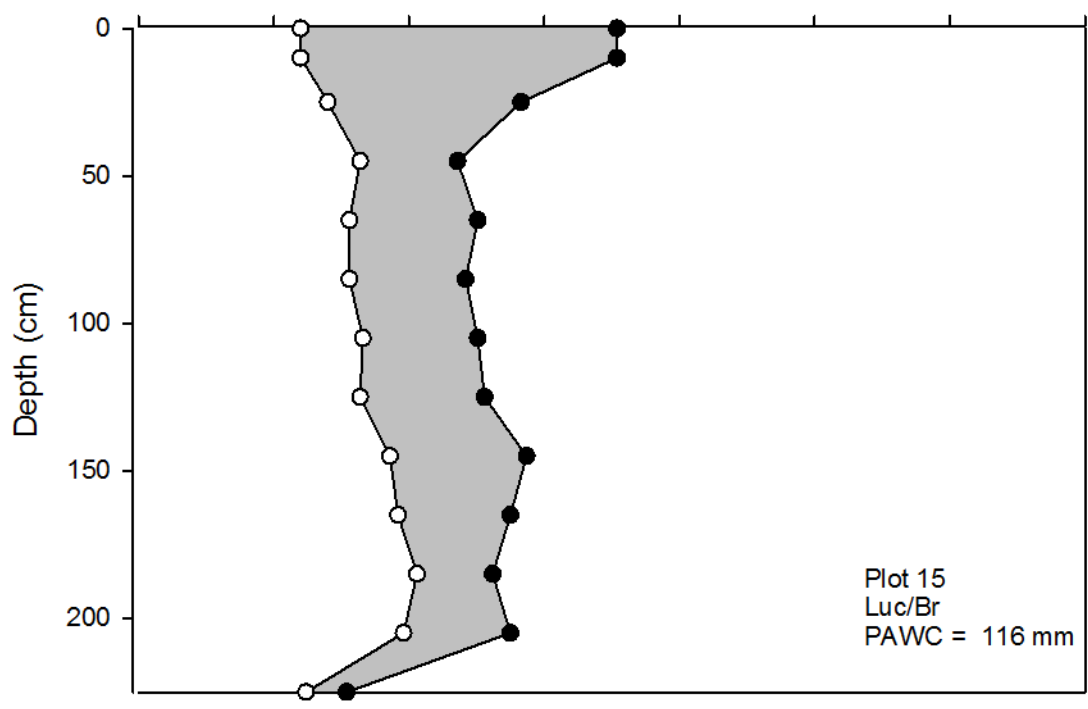
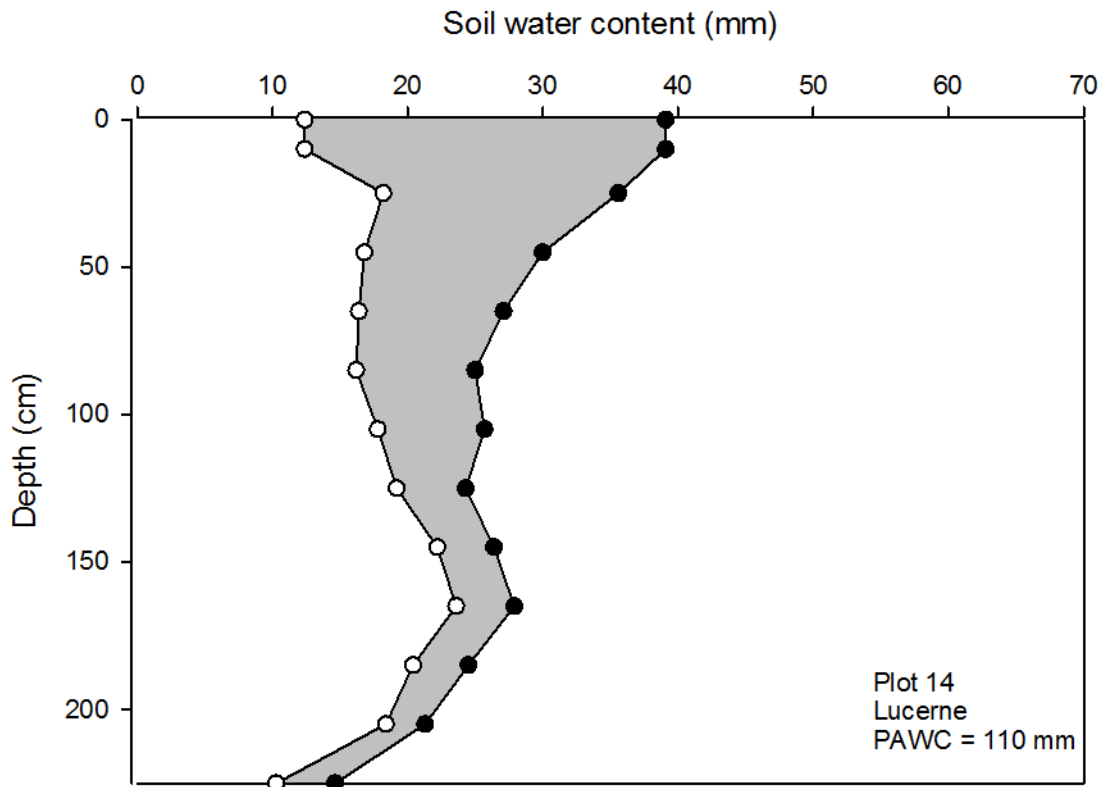
Appendix 9.8: Soil water content of Plot 8 (top) and Plot 9 (bottom) in paddocks C6E and C7E, Ashley Dene, Canterbury. Where (●) is the upper limit and (○) is the lower limit for plant available water.



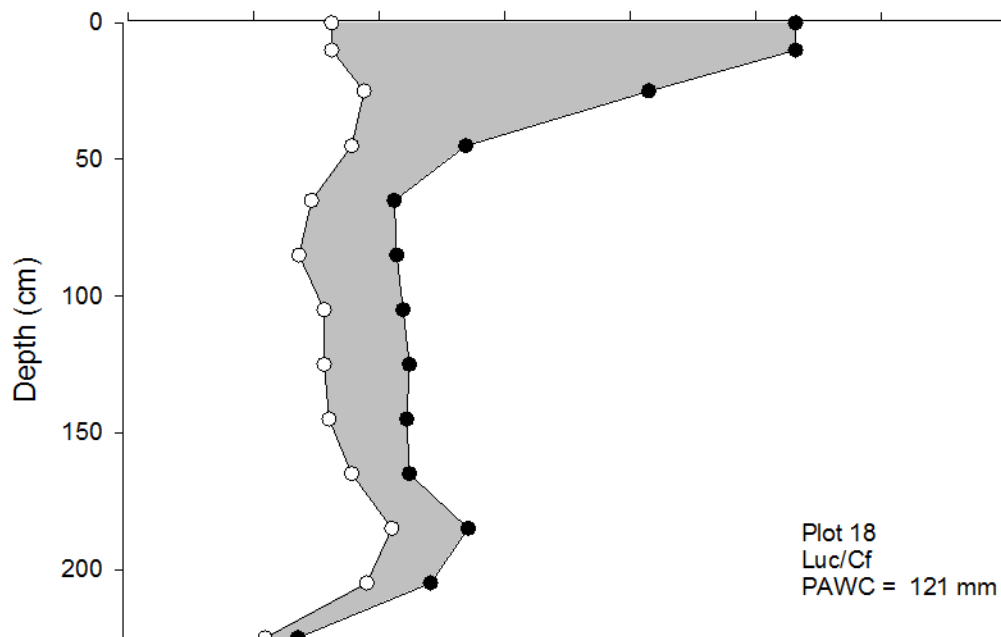
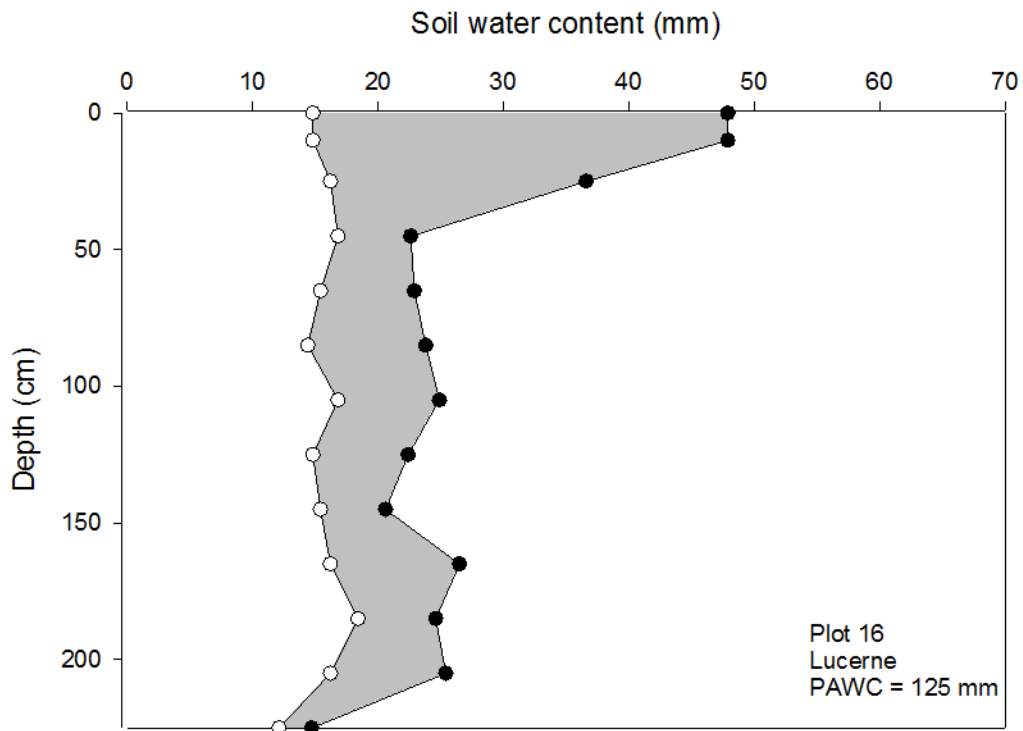
Appendix 9.9: Soil water content of Plot 10 (top) and Plot 11 (bottom) in paddocks C6E and C7E, Ashley Dene, Canterbury. Where (●) is the upper limit and (○) is the lower limit for plant available water.



Appendix 9.10: Soil water content of Plot 12 (top) and Plot 13 (bottom) in paddocks C6E and C7E, Ashley Dene, Canterbury. Where (●) is the upper limit and (○) is the lower limit for plant available water.



Appendix 9.11: Soil water content of Plot 14 (top) and Plot 15 (bottom) in paddocks C6E and C7E, Ashley Dene, Canterbury. Where (●) is the upper limit and (○) is the lower limit for plant available water.



Appendix 9.12: Soil water content of Plot 16 (top) and Plot 18 (bottom) in paddocks C6E and C7E, Ashley Dene, Canterbury. Where (●) is the upper limit and (○) is the lower limit for plant available water.