[ƛǿŜ weight gain of ewes and lambs grazing subterranean clover-based pastures

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Abstract of a Thesis submitted in partial fulfillment of the requirement for the Degree of Masters of Agriculture Science

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The performance of four dryland pastures grown at Ashley Dene, Canterbury, was compared over the last two years of the five-year 'MaxAnnuals' grazing experiment. The pastures were sown in March 2013 with cocksfoot with sub clover, or a ryegrass/fescue hybrid with sub clover, both with and without balansa clover. 'MaxAnnuals' follows on from the previous 'MaxClover' experiment which found cocksfoot with subterranean clover was persistent and high yielding over the nine years. There was limited live weight gain data from 'MaxClover', so this paddock scale experiment was initiated. Ryegrass or plantain were also included in with clover in this 'MaxAnnuals' experiment to extend the range of species tested. Balansa clover was added to the subterranean clover-based pastures to see if the overall animal and pasture yields and clover content could be increased by the inclusion of a second legume.

Each of the four pasture types were assigned a mob of ewes and lambs during spring and weaned lambs during summer, when pasture growth allowed. Grazer ewes were used to 'clean-up' pastures in autumn. The main measurement period was the live weight gain of ewes and lambs in spring. Differences between years or among treatments were related to seasonal pasture yield, composition, and feed intake.

The total live weight production was not different among treatments of each year, but there were differences between years. Live weight gain averaged 511 kg/ha in 2016 and 635 kg/ha in 2017. During 2016, there was both spring and summer live weight production periods, but soil water deficits in late spring 2017 did not allow grazing over summer. Thus, the live weight production achieved solely from the spring of 2017, was greater than the 2016 spring and summer periods combined.

During spring, ewe live weight decreased by 6 kg/ha across all treatments in 2016, but increased by 61 kg/ha in 2017. Lamb live weight gain averaged 402 kg/ha in spring 2016 which was less than the 574 kg/ha in 2017. The higher live weight gain in spring 2017 is due to the differences in clover content between years. The average clover content at the beginning of spring was 5% in 2016, and 75% in 2017, which led to 90% greater intake.

Thus, the higher content of the winter-active sub clover meant that pasture growth was greater and began 281 °C days earlier in 2017 resulting in opening spring pasture covers of 2065 kg DM/ha, more than double that of the 931 kg DM/ha achieved at the start of spring 2016. The lower clover content in 2016 meant that spring pasture accumulation averaged 6.4 kg DM/ha/°C day, which was less than the 10.4 kg DM/ha/°C day in spring 2017.

Across both springs, yields from plantain pastures averaged 5021 kg DM/ha, which was higher than the average of 4284 kg DM/ha from cocksfoot pastures. Although lower yielding, cocksfoot pastures were the most persistent with an average weed content of only ~1% at the end of the experiment. The poorer persistence of ryegrass in the initial mix meant that plantain took advantage and increased its presence in the ryegrass pastures so they were referred to as plantain pastures. Throughout the last two years, the weed content of the plantain pastures increased from ~4% to ~38% of the sward. This suggests plantain pastures may be an option for short-term (3-4 years) in dryland environments, but weed invasion is likely to compromise their production and persistence.

The addition of balansa clover did not increase live weight gains, but did increase total clover content. Across both springs, clover content averaged ~37% from sub clover, which was lower than the ~45% from sub clover plus balansa pastures. Balansa together with subterranean clover in the mix caused management complications because the top flowering balansa needed time to reseed when ewes and lambs were grazing. Thus, it is recommended to concentrate on the management of the most dominant legume in any pasture to maximise clover content.

Keywords: *Trifolium subterraneum* L., *Dactylis glomerata* L., grazing, *Plantago lanceolata* L., sheep live weight, *Lolium perenne* L., *Trifolium michelianum* L., dryland pastures.

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ABBREVIATIONS

Acronym	Description
ADF	Acid detergent fibre
CF	Cocksfoot
CP	Crude protein
DM	Dry matter
DMD	Dry matter digestibility
DS	Destocked
DUL	Drained upper limit
GD	Graze day
LAF	Lambs at foot
LL	Lower limit
LWG	Live weight gain
ME	Metabolisable energy
N	Nitrogen
NDF	Neutral detergent fibre
NIRS	Near infra-red spectrometry
PAR	Photosynthetically active radiation
PAWC	Plant available water holding capacity
PET	Potential evapotranspiration
PL	Plantain
PSWD	Potential soil water deficit
S + B	Sub clover and balansa
S.E.M.	Standard error of the mean
TDR	Time domain reflectometer
TP	Trigger point
WL	Weaned lambs
WUE	Water use efficiency

1 INTRODUCTION

Dryland farming systems in New Zealand rely on rainfall as the sole moisture input for pasture production. Rainfall is variable and unreliable with most dryland areas receiving 800 mm or less annually. There is a narrow, but generally reliable production window in spring. This is when temperatures are increasing, but the stored soil moisture is usually non-limiting to growth (Mills and Moot, 2010). In dryland pastures, this narrow period is 100-130 days in which a lamb born at ~5 kg has to reach ~35 kg, to be sold prime. Hence, emphasis needs to be put on maximising the live weight production as efficiently as possible to achieve a minimum pre-weaning growth rate of 300g/hd/d.

Utilising pasture species that grow in late winter/early spring is the key to take advantage of winter stored soil moisture in dryland environments. Sufficient early spring pasture production will provide the required feed for lactating ewes and lambs, allowing priority stock to be sold prime by early summer. This reduces the risk associated with maintaining production in summer/autumn when rainfall is variable and unpredictable (Mills and Moot, 2010).

White clover (*Trifolium repens* L.) and perennial ryegrass (*Lolium perenne* L.) have long been the standard pasture mix choice in New Zealand. However, they are susceptible to drought and lack the persistence required to survive in New Zealand dryland pastures (Woodfield and Caradus, 1996). Subterranean (*Trifolium subterraneum* L.) and balansa (*Trifolium michelianum* L.) clovers, are winter annual legumes that can offer high dry matter production in dryland farming systems and provide early spring growth for lactating ewes and lambs (Ates *et al*., 2010; Mills *et al*., 2015b). An advantage of legumes is that they also provide nitrogen that is the most limiting pasture growth factor in the spring.

The live weight production off a pasture is the main indicator of its performance. In a dryland environment, a pasture needs to be high yielding in early spring, and have an adequate proportion of legume and grass to match as closely as possible the dietary preference from sheep of ~70% legume, and ~30% grass (Nicol and Brookes, 2007b; Rutter, 2006). Higher intake is associated with higher legume content (Cosgrove and Edwards, 2007), but the 30% of grass is still necessary to balance out any costs associated with consuming a high legume diet (Ulyatt *et al*., 1988). Thus, using companion grass species that tolerate low soil moisture and do not out-compete subterranean or balansa clover have been shown to generate high animal live weight production (Mills *et al*., 2015a).

The main aim of this research was to quantify the live weight production of sheep off annual clover-based pastures at Ashley Dene, Canterbury. The experiment compared the effect of annual clovers on live weight gain of ewes and lambs, and quantified the influence of sown pasture species for the fourth and fifth years of the 'MaxAnnuals' grazing experiment on pasture production. 'MaxAnnuals' aimed to see if the addition of balansa to sub clover-based pastures enhanced the legume content in spring and then whether this affected the total live weight gain of sheep in spring and summer. There were four dryland pastures assessed in the 'MaxAnnuals' experiment. They were cocksfoot (*Dactylis glomerata*) and subterranean clover, with and without balansa clover, and a ryegrass/fescue hybrid (Ultra Enhanced®) and subterranean clover, with and without balansa clover. Plantain (*Plantago lanceolata*) was also included in all pastures. 'MaxAnnuals' follows on from previous research in the 'MaxClover' experiment which found cocksfoot with subterranean clover (CF/Sub) pastures to be a persistent and high yielding mix in dryland pastures. However, 'MaxClover' did not have strong live weight gain data due to the 0.05 ha grazing plots being too small to evaluate stock performance accurately. There was also no ryegrass or plantain included in any of the mixes with subterranean clover, and only one legume was included in each mix. Thus, in the 'MaxAnnuals' grazing experiment, each treatment occupied two hectares so more animals could be used and the accuracy of live weight gain data improved. Ryegrass and plantain were included and balansa clover was added to the subterranean clover-based pastures to see if the overall animal and pasture yields, and clover content could be increased.

The null hypothesis for this experiment was that there would be no live weight gain differences from ewes and lambs off subterranean clover-based pastures in the final two years of the 'MaxAnnuals' experiment.

This thesis begins with a review of the literature in Chapter 2 to provide background information to understand the experimental concepts. Chapter 3 describes the materials and methods. Chapter 4 focusses on soil water and discusses water use efficiency among the treatments and identifies periods of soil water deficits during the last two years. This is used to interpret the animal and pasture results in Chapters 5 and 6. Chapter 7 provides a general discussion of the experiments, and any implications for animal and pasture performance in dryland regions.

2 LITERATURE REVIEW

The review outlines the need for early spring feed, and provides general information on the pasture yield, quality, and animal performance off subterranean clover-based pastures. It also gives descriptions of the legumes and other companion species used in the experiments in this thesis.

2.1 Dryland farming

Dryland pastures receive less than 800 mm of rainfall annually and experience significant soil moisture deficits in late spring and/or during summer (Brown and Green, 2003). In New Zealand, the majority of these at-risk pastures are situated along the east coast in the shadow of the main divide. These areas remain consistently dry during summer when potential evapotranspiration rates are high and rainfall is limited. This slows or halts pasture growth, adversely affecting animal productivity and farm profitability. Profitability must be maintained in dryland farming systems by aligning lactation with the narrow, but generally reliable production window in spring (Mills and Moot, 2010). During this period, temperatures are beginning to increase, but stored soil moisture is still adequate for growth. Climate change scenarios predict these areas will become drier with greater variability in future (Salinger, 2003).

2.2 Early spring feed

Farming dryland areas can prove to be particularly challenging. Summer drought-prone farms should aim to have spring lambs up to weight and sold before the onset of summer moisture stress. Assuming a 5 kg/hd birth weight (Nicol and Brookes, 2007a), a lamb needs to gain 286 to 333 g/hd per day to reach a prime weight of 33 kg/hd in ~100 days.

Carrying lambs into the summer in a dryland farming system with unreliable rainfall increases the financial risk (Avery *et al*., 2008). As summer develops, soil water deficits increase and the rate of pasture growth declines. Pasture quality deteriorates, and the quantity of feed on offer cannot meet stock demand. This results in a decrease in lamb live weight gain and can expose the farmer to additional costs such as buying supplementary feed and/or having to sell stock at discounted prices as ‘store’ rather than ‘finished’ lambs (Mills *et al*., 2015b). Therefore, utilising the spring period as early as possible to maximise lamb live weight gains, and selling them prime or as heavy store lambs before the onset of summer is the key to profitable farm systems (Anderson *et al*., 2014; Avery *et al*., 2008).

The selection of dryland pasture species that peak in production during the narrow window in spring is essential to provide early spring feed. The availability of feed early in spring can lead to maximised live weight gains and ensure lambs are finished before summer-dry conditions begin to negatively affect pasture quality and production (Grigg *et al*., 2008; Mills and Moot, 2010).

2.3 Subterranean (sub) clover in dryland systems

White clover has been the most commonly sown legume in New Zealand as it offers high quality feed (Brock and Hay, 2001). Farmers heavily rely on a 'traditional' mix has with perennial ryegrass, but in dryland areas both species fail to persist (Fraser, 1994). White clover initially produces a taproot, but this dies after about 18 months (Widdup *et al*., 2003). Therefore it requires a monthly minimum rainfall of 40 mm to survive, and at-least 20 mm per month more is required for growth over summer (Brock, 2006). Knowles *et al*, (2003) showed dryland systems fail to meet these moisture demands from white clover, which severely affects its ability to persist. Substituting white clover for a legume with greater persistence and adaptation to dryland areas, such as subterranean clover, has advantages for pasture and animal production (Brown *et al*., 2006; Mills *et al*., 2008b).

Subterranean clover is a winter annual legume adapted to suit Mediterranean-type climates with mild winters and hot, dry summers (Smetham and Wu Ying, 1991). Sub clover growth is optimal in environments with an annual rainfall of 250-600 mm, which falls mainly in autumn, winter and spring (Smetham, 2003). This has meant successful sub clover establishment in the dry east coast regions of New Zealand (Smetham, 2003). It is active over winter preferably after an autumn sowing. Sub clover growth accelerates during early spring (September-October) then sets seed and dies in late spring/early summer (Figure 2.1). It remains dormant until germination again with autumn rain (Chapman *et al*., 1986; Scott, 1971). Peak herbage growth in early spring makes it a suitable candidate to fit in the 'narrow production window' in dryland farming systems.

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Figure 2.1: White and subterranean clover seasonal growth rates (Brown *et al*., 2006).

The biomass production from sub clover under dryland conditions during winter and early spring is superior when compared with other common legumes. This production contrasts from perennial species such as lucerne (*Medicago sativa*) and red clover (*Trifolium pratense*), which can offer feed later in the spring/early summer due to access to any moisture at depth in the soil (Brown *et al*., 2003).

Many dryland pastures may already have sub clover present, particularly 'Mt Barker', due to a surge in over-sowing of the species during the 1950s. Some farmers have managed the resident sub clover in their pastures and have seen an increase in clover content without sowing any additional seed (Grigg *et al*., 2008). However, for pastures where the existence of sub clover is limited, the clover content cannot be increased without first adding to the seed bank. This is not always straight forward as a lot of New Zealand dryland is hill country that is incapable of being drilled over. Often, the only method of adding to the seed bank is by over-sowing, but there is limited information on the success of over-sowing clover into existing pastures. Falloon and Charlton (1984) stated the over-sowing of perennial ryegrass ('Ruanui') into hill country was unreliable and uneconomical without the addition of a pesticide treatment. Only ~32% of untreated 'Ruanui' seeds successfully germinated, compared with ~78% of coated and pesticide treated seeds, when over-sown into a dry hill pasture.

There are a number of sub clover cultivars available with different flowering times to suit a range of farm systems (Nichols *et al*., 1993). Selecting a cultivar that is able to flower and set sufficient seed before soils reach wilting point is the aim for dryland farms. However, determining the best cultivar can be difficult as there is a lack of New Zealand based data on the performance of different cultivars. This has meant that choice of a cultivar is reliant on data obtained from Australia. More research is needed on the performance of sub clover cultivars in New Zealand to increase levels of confidence when choosing a cultivar. This is not a focus of this thesis.

There are also limitations in the sub clover cultivars available in New Zealand. All subterranean clover seed is imported from Australia, thus the range of cultivars available to New Zealand farmers is influenced by their availability. In the 1930s, work by Levy and Gorman (1936) discussed the high dry matter yields from 'Mt Barker' and 'Tallarook', but these were the only two commercially available cultivars during that time. This also explains the widespread over-sowing of 'Mt Barker' across the country between the 1930s and 1960s (Smetham, 2003). Relying on seed imported from Australia also comes with New Zealand biosecurity issues with weed seed and soil contamination (Lucas *et al*., 2015). More research is required to commercialise sub clover strains in New Zealand, but this is not likely to be a fast process, and it is not part of this study.

2.3.1 Germination and Establishment

Subterranean clover grows optimally in soils with a pH above 5.6. High acid soils will impact the plant-rhizobium relationship, negatively affecting growth of the legume (Lucas *et al*., 2016). Phosphorus and sulphur are important for promotion of vigorous legume seedling growth. Molybdenum is also an essential trace element required for nitrogen fixation.

Following germination, the seedling will initially depend upon seed reserves for growth. Providing moisture levels are adequate, seedling leaf appearance is driven by the accumulation of thermal time (Tt) or degree-days (°Cd) (Black *et al*., 2002). Moot *et al*. (2003a) studied the thermal time requirements of five sub clover cultivars and found that the first trifoliate leaf appeared at around 230±20.0°Cd with a phyllochron (period between emergence of successive leave on a shoot) of 68°Cd.

Different sub clover cultivars have differing responses to temperature. Hampton *et al*. (1987) found that 'Woogenellup', was slower to germinate than 'Mt Barker' and 'Tallarook'. At 5°C after only 9 days, when 'Mt Barker' and 'Tallarook' had reached close to 100% germination. Whereas 'Woogenellup' took approximately 22 days to reach a maximum of only 75% germination. This indicates the adaptation of sub clover to germinate in the autumn with rain and cooler temperatures, but also that there are differences among cultivars (Askin, 1990).

As with most legumes in a legume/grass pasture, sub clover must be given priority during its establishment phase (Lonati *et al*., 2009) so it is not out competed by the grass component. Moot *et al*. (2003a) stated that the ultimate success or failure of sub clover depends on the number of seedlings that establish each autumn. If managed correctly, the more seedlings that are able to establish, the higher yield herbage and seed set (Ates *et al*., 2010).

2.3.2 Pasture yields

Mills *et al*. (2015b) assessed the dry matter (DM) yields of six grazed dryland pastures. Of the six pastures, the most successful grass-based pasture was cocksfoot/sub clover (CF/Sub). The pastures were established in 2002 at Lincoln University, Canterbury. Figure 2.2 shows that total annual yields from the CF/Sub in Years 6-9 ranged from 8.7-11.2 t ha/yr, which was ~20%- 40% more than all other grass-based pastures (Mills *et al*., 2015b). Over the whole 9 years of the experiment, CF/Sub yields decreased from 12 t/ha to 8.7 t/ha. The subterranean clover component represented 26-32% of the total annual production with an annual rainfall averaging ~600 mm throughout the experiment, which shows the suitability of sub clover in the environment.

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Figure 2.2: Annual rainfall and total annual accumulated dry matter yield (t DM/ha/yr) of dryland CF/Sub (cocksfoot/sub clover), CF/Bal (balansa), CF/Wc (white clover), CF/Cc (Caucasian clover), RG/Wc (ryegrass/white clover) and lucerne pastures for nine years from 2002/03 to 2010/11 at Lincoln University, Canterbury. Error bars are SEM for total annual accumulated dry matter yield (Mills *et al*., 2015b).

Further work by Ates *et al*. (2010) supports the suitability of sub clover in dryland environments to increase overall yield. Cocksfoot and ryegrass pastures with sub clover (CF + AC; RG + AC) and without sub clover (CF – AC; RG – AC) were measured over two years (2006-2008) at Ashley Dene, Canterbury. Figure 2.3 shows that in spring 2007/08, yields produced from pastures including sub clover were 34-45% higher than those without. This shows the ability of sub clover to provide additional dry matter. The improved yields from inclusion of sub clover is likely to be the result of additional nitrogen input (Tonmukayakul *et al*., 2009) from the legume. Mills *et al*. (2006), suggested this may be especially noticeable in cocksfoot pastures, where annual dry matter production is limited more by nitrogen than water, in Canterbury.

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Figure 2.3: Total accumulated dry matter (DM) production of ryegrass (RG) and cocksfoot (CF) pastures with (+AC) and without (-AC) annual clovers grown in C9(A)S at Ashley Dene, Canterbury from 2006 to 2008. Error bars are SEM for total annual DM yield (Ates *et al*., 2010).

2.3.3 Nutritive value

Subterranean clover provides an easily digestible feed of high metabolisable energy and crude protein. As with most pasture species, the nutritive value of a plant generally decreases during the change from the vegetative to reproductive state. For example, subterranean clover matures late spring/early summer and changes in the nutritive value of the legume can be observed as a result of this. This is supported by research from Walsh and Birrell (1987) who found that the nutritive value (crude protein and dry matter digestibility) of subterranean clover decreased rapidly after flowering as summer approached.

Changes in maturity within the plant can also affect the quality of the plant components. For example, as sub clover matures, the stems and petioles tend to become less palatable. Ru and Fortune (2000) studied the nutritive value of 26 different sub clover cultivars during the vegetative phase and at the conclusion of the flowering phase. They found that the leaves of all cultivars had a similar dry matter digestibility (DMD) (~75%) to the stems (~74%) and petioles (~75%) at the vegetative stage. Whereas, at the end of the flowering phase, the DMD of the leaves remained similar (~70%), but the stems (~59%) and petioles (~63%) were greatly reduced.

2.3.4 Grazing management

Grazing management is vital during establishment of sub clover. If used correctly, grazing can increase germination, seedling emergence and survival rates.

Subterranean clover is classed as a "near-ruderal" species, meaning that it cannot tolerate competition (Grime *et al*., 1990). The establishment of seedlings in mixed swards can result in competition for moisture, especially from the grass component. Therefore, for success of the legume, it is vital to minimise such competition during establishment and reestablishment each year (Smetham, 2003). On hill country, Emmersen (1980) recommended that to decrease the level of competition and control companion grasses, hard, clean-up grazing around a small number of paddocks should be carried out. This should be done in summer and autumn and repeated once every three years.

Defoliation of newly germinated seedlings should not be too close. Grazing below the junction of the stem and the two cotyledons can result in death of the seedling (Smetham, 2003). Silsbury and Fukai (1977) recommend new seedlings be spelled from grazing for 3-5 weeks after germination. Moot *et al*. (2003a), showed subterranean clover seedlings had greater post-grazing survival rates after they had produced 6 leaves. Resisting grazing until this stage allows a greater leaf area to build up for the plant to become self-sufficient and have a higher tolerance for grazing. Care should also be taken in terms of grazing intensity at this time as the need to remove competition is balanced with the need for sub clover to anchor itself in the soil. Heavy grazing can have detrimental effects on seedlings in the first spring following establishment, so grazing management should be lax (i.e. about 2000 kg DM/ha) using lower stocking rates than usual (Lucas *et al*., 2017).

It is deemed 'safe' to continue grazing sub clover from the 6-leaf stage until the onset of flowering. The number of flowers produced directly relates to the amount of seed set and this will have an impact on seed bank yields (Ates *et al*., 2013). Ideally, stock should be removed, or stocking rates greatly reduced when sub clover is flowering. This is supported by Rossiter (1961) who found that continued defoliation from the 6 leaf stage until first flower appearance increased seed production by up to 30%. Whereas, continued defoliation after first flower appearance reduced seed yield. More recently, Ates *et al*. (2013) found that pastures that were grazed by sheep until early December had 50% fewer seedlings in the following autumn, compared with pastures that were taken out of grazing from mid-October before the onset of flowering.

2.4 Animal performance

Enhanced animal production is achieved from high pasture quality, productivity and persistence. Increasing the legume percentage is a strategy to improve live weight gain. Sub clover is generally evaluated on a dry matter yield performance. There are a limited number of sub clover-based grazing experiments in New Zealand that have reported live weight gain data. In the 'MaxClover' experiment, (Mills *et al*., 2008a; Mills *et al*., 2008b), five grass-based pastures were evaluated (Table 2.1). The subterranean clover-based pasture was consistently the most productive in terms of live weight (and dry matter) produced. The study ran over seven years and higher sheep live weight gains were maintained over this time. The persistence of subterranean clover in the dryland environment led to more ME and N on offer to grazing livestock, which resulted in superior live weight production (e.g. 814 and 912 kg/ha in 2007/08 and 2008/09 respectively). Cocksfoot and white clover pastures only produced 503 kg/ha (2007/08) and 675 kg/ha (2008/09) or 38% and 26% less than the annual live weight produced from the CF/Sub pastures. These highlight the suitability of sub clover to maximise live weight gain from dryland pastures.

Table 2.1: Annual sheep live weight production (kg/ha) form six dryland pastures in Year 6 (2007/08) and Year 7 (2008/09) at Lincoln University, Canterbury (Mills and Moot, 2010). 'CF/Sub' refers to cocksfoot + subterranean clover treatment, 'CF/Bal' refers to cocksfoot + balansa, 'CF/Wc' refers to cocksfoot + white clover, 'CF/Cc' refers to cocksfoot + Caucasian clover, 'RG/Wc' refers to ryegrass + white clover, and 'Luc' refers to the lucerne treatment.

Pasture	**2007/08**	**2008/09**
CF/Sub	814 $_{b}$	912 $_{b}$
CF/Bal	543 $_{d\,e}$	702 $_{c}$
CF/Wc	503 $_{e}$	675 $_{c}$
CF/Cc	655 $_{c}$	719 $_{c}$
RG/Wc	613 $_{c\,d}$	711 $_{c}$
Luc	903 $_{a}$	1067 $_{a}$
SEM	33.2	52.0
P value	**0.001**	**0.001**

The 'MaxClover' experiment used plots of 22 x 23 m (0.05 ha) which meant only a few animals grazed each plot. To validate the animal performance data, the 'MaxAnnuals' dryland experiment with sub clover-based pastures was established in 2013 and continued until summer 2017. The aim of the experiment was to quantify the feed available in early spring for set-stocking, and determine if the clover content could be enhanced by using two annual clovers in combination. Specifically, sub clover, and either a ryegrass/fescue hybrid or cocksfoot, with or without balansa clover. Mean daily lamb live weight gain (g/hd/d) results from 2015 (year 3 of the trial) were all over 300 g/hd/d (Black *et al*., 2015) which supports the suitability of subterranean clover as the basis for early spring feed.

2.5 Companion species

Pasture species that can survive soil water deficits are required to complement the sub clover. Thus, the drought-tolerant capabilities of cocksfoot and plantain in the 'MaxAnnuals' experiment were also investigated. A ryegrass/fescue hybrid grass was also used in the 'MaxAnnuals' pastures, but its presence in the sward diminished over the five years of the experiment which meant there was little ryegrass/fescue remaining in the pastures in the last two years, that this study reports on.

2.5.1 Balansa clover

Balansa clover is a winter-active annual legume, also originating from the Mediterranean region with rainfall predominantly ranging from 350 – 600 mm (Craig and Ballard, 2000). Balansa follows a similar life cycle to sub clover with germination in autumn following rainfall and growing until seed set in late spring/early summer.

Balansa is thought to compliment sub clover (Monks *et al*., 2008) due to its ability to inhabit different soil pH and types within a pasture (Dear *et al*., 2002). However, it may struggle to compete with sub clover seedlings during the initial establishment stage due to its slower growth rates under cool temperatures. This is supported by Dear and Coombes (1992) & Dear *et al*. (2002) who found that balansa clover seedlings could be easily out-competed by sub clover seedlings, even while producing more than 3000 seedlings/m^2.

As with subterranean clover, successful regeneration of balansa requires careful management around flowering to promote substantial seed production. Monks *et al*. (2008) studied the grazing management and productivity of balansa clover as part of the larger 'MaxClover' experiment (Brown *et al*., 2006). The mix was sown with 3.5 kg/ha of 'Bolta' balansa clover, 10 kg/ha of 'Denmark' sub clover, and 4 kg/ha of cocksfoot. Their results found that if balansa was well managed in its first year of establishment, it could offer a minimum of 4 t DM/ha/year (36%) to a dryland cocksfoot pasture in its second year from only a low sowing rate of 3.5 kg/ha. This suggests that the incorporation of a low rate of balansa with sub clover into a dryland pasture mix may result in increased dry matter yields, and clover content.

2.5.2 Ryegrass/fescue hybrid

The high yielding attributes of perennial ryegrass were paired with the high-quality traits of meadow fescue to create the ryegrass/fescue hybrid ("Ultra-enhanced®") grass (Cropmark, 2013) used in the 'MaxAnnuals' experiment. The grass is described as fine-leaved with dense tillers, and can be sown in either autumn or spring. It is reported to have exceptional growth during late winter/early spring, which makes it a suitable candidate for dryland pastures (Cropmark, 2013).

The ryegrass/fescue proportion of the sward became less with every year of the 'MaxAnnuals' experiment. In year 2016 of the 'MaxAnnuals' experiment, mid-spring cage cuts found that only 4-13% ryegrass/fescue grass remained in the sward. This is likely due to persistence issues so its ability to cope with regular soil water deficits during summer is questionable. Due to the reduction of the ryegrass/fescue hybrid grass in 2016, there was a marked increase in the plantain component of the pastures (55-68% of sward). This suggests that the hybrid grass may also have had a limited ability to deal with competition.

2.5.3 Cocksfoot

Cocksfoot is a productive and persistent grass that dominates New Zealand dryland (Fraser, 1994). Compared with other pasture species, cocksfoot is said to be less digestible (Barker *et al*., 1993). However, it is very competitive for moisture during summer (Moloney, 1993) making it a suitable species for drought-susceptible soils, and regions.

The ability of cocksfoot to persist in a dryland environment is well known. Tozer *et al*. (2011) looked at the persistence of chicory (*Cichorium intybus*), cocksfoot, red clover and plantain. 'Old' pastures that were sown with chicory, cocksfoot, red clover, or plantain more than 7 years ago were assessed. Of the total number of paddocks sown with the species, 87% still had cocksfoot present, and 75% had plantain, while chicory and red clover only persisted in 34% and 36% of paddocks respectively. This highlights the ability of cocksfoot to persist in the sward for long periods.

Studies have found that sheep have a strong preference to graze high N herbage (Edwards *et al*., 1993), which means legumes are often selectively grazed, reducing the pressure on cocksfoot. To maximize production and cope under conditions where cocksfoot is likely to be abundant, a legume is required that can tolerate competition, provide high-quality livestock feed, and potentially improve the quality of the companion grasses (i.e. cocksfoot) by fixing N and making it available each year when it dies. The early growth of subterranean clover is complimented well with the slower spring growth of cocksfoot (Ates *et al*., 2010). The majority of cocksfoot yield is produced in autumn and summer rather than spring (Kemp *et al*., 1999). This allows sub clover to become well established in the sward without being dominated by cocksfoot.

2.5.4 Plantain

Plantain, also known as ribwort, is an erect perennial herb originating from temperate regions. *Plantago lanceolata* has high winter and summer growth, with a medium number of branches and very large, erect leaves (Stewart, 1996). The herb is also distributed across subtropical regions due to its ability to cope under drought conditions. This makes it a suitable herb species for dryland pastures.

Studies have suggested that lambing and/or finishing lambs on plantain/legume pasture mixes have resulted in higher feed values, and increased milk (Hutton *et al*., 2011) and lamb production. Research by Kemp *et al*. (2010) & Kemp *et al*. (2013) found that lambs were finished faster on a mix of plantain, chicory, red and white clover pastures compared with traditional perennial ryegrass and white clover pastures.

Plantain is highly palatable in its vegetative state, but previous research has found the palatability of plantain decreases during late summer/early autumn (Fraser and Rowarth, 1996; Moorhead *et al*., 2002; Robertson *et al*., 1995). This is probably due to a change from the vegetative to reproductive state. When plantain is in its reproductive phase, the leaves age and the seed head comprises 60% of the available DM, which reduces its palatability (Cave *et al*., 2015; Fraser and Rowarth, 1996). However, the palatability issues may not affect lamb growth rates during this time as Kemp *et al*. (2013) reported lamb daily growth rates of ~210 g/hd/d over summer when offered plantain monocultures, and 223-336 g/hd/d when offered plantain in a mix with perennial clovers.

2.6 Pasture intake

Daily pasture intake was defined by Allden and Whittaker (1970) as: *intake rate (g DM/min) * grazing duration (min/day)*. The rate of intake is dependent upon bite rate and bite mass. There is a strong relationship between bite mass and pasture height – the greater the sward height, the greater the bite mass (Cosgrove and Edwards, 2007). Potential daily intake is also impacted by animal live weight. Court *et al*. (2010) stated that ruminants have a potential appetite of ~4% of their live weight. Thus, a ewe with a live weight of 60 kg will have a maximum pasture intake of approximately 2.4 kg DM per grazing day (GD).

Intake rates will differ among animal species. For example, when grazing the same pasture, cattle will usually exhibit higher intake rates due to a larger bite size compared with sheep. The larger the bite mass, the lower the associated prehension bite rate, resulting in less time required to ingest (Cosgrove and Edwards, 2007). For example, the larger intake from cattle means that less time is spent on prehension and mastication compared with sheep (Parsons and Chapman, 1998).

Pasture type can also have an effect on prehension and mastication time. Penning *et al*. (1995) found that total handling costs for ewes were 5000 seconds/kg DM for grass, which was higher than the 2000 seconds/kg DM for clover. These results supported earlier work by Newman *et al*. (1994) & Parsons *et al*. (1994b) who also found that less handling time per unit bite mass was required for clover than grass.

2.6.1 Intake by lambs

A lamb's rumen is fully developed and able to digest pasture approximately three weeks after birth (B+LNZ, 2010). However, in the first six weeks of age, it is milk intake that will have the biggest influence on lamb growth rates. Thus, milk production from ewes must be at optimum during this time. Ewe milk production can be affected by ewe genotype, number of lambs, and the health of the ewe throughout its pregnancy and during the lactation period (Judson *et al*., 2009).

As lambs begin to graze, their daily energy intake coming from the pasture will increase with time, especially for twins (Judson *et al*., 2009). This means it is important to have both quantity and quality of feed on offer as both daily pasture allocation and quality of forage are the main drivers of lamb growth rates.

2.6.2 Selective grazing

When calculating intake in a grazing system, there is a difference between the feed on offer, and what is eaten by the animal. The capability of an animal to selectively graze depends on its bite width. The smaller the bite, the greater its ability to select within a pasture (Cosgrove and Edwards, 2007). This means sheep are more selective than cows, and sheep are used in this study.

The selectivity of a diet is impacted by three main factors – palatability, accessibility, and availability of species in the sward. In mixed pastures, the botanical composition offers more choice, and livestock will selectively graze if pasture allocation allows it. Generally, younger stock will select a higher protein, lower fibre diet compared with mature stock (Hughes *et al*., 1984). Animals will also selectively graze plant components. For example, leaf is preferred over stem, and green material is selected over dead material. Grazing these 'high quality' portions of the plant can mean that the actual ME intake is higher than the estimated ME content for the overall pasture. If the quality of the pasture is poor, selective grazing increases. This can lead to lower intake and poorer animal performance. For example, if only a small proportion of green leaf and/or legume remains in the pasture, animals are faced with the increased costs associated with having to locate the desirable components (Chapman *et al*., 2007; Edwards *et al*., 1996).

When unrestricted, stock will select a mixed diet (Parsons *et al*., 1994a) of approximately 70% legume, 30% grass (Cosgrove and Edwards, 2007). Mixed swards in comparison to monocultures can be beneficial in that they allow stock to preferentially select more palatable plants and/or specific plant parts in order to better meet their nutritional needs throughout the seasons (Cave *et al*., 2015). However, the preference for 70% legume in the diet can mean the legume portion of a sward can rapidly become diminished if over-grazed. It can be expected that if a pasture is highly stocked, or the time spent grazing a pasture increases, that selective grazing decreases due to less choice. In comparison, research by Cave *et al*. (2015) found that grazing intensity had no effect on diet selection.

In early spring, Cave *et al*. (2015) noticed that when ewe lambs grazed a herb and legume mix, there was a greater preference and selection for chicory and plantain, rather than red and white clover. However, the botanical composition of the pasture during this period was predominantly chicory and plantain. Thus, the selection of chicory and plantain was due to ease of access and availability in the sward, rather than a preference. This was consistent with previous research from Concha and Nicol, (2000) using perennial ryegrass and white clover, where the species that was of a greater height and more accessible was consistently selected.

Research by Corkran (2009) suggested that preference also changes among seasons. This is probably due to changes from the vegetative to reproductive stages of individual pasture species. For example, during summer, weaned lambs grazed a mixed pasture of red clover, chicory and plantain. Plantain was the least preferred species – due to low palatability as a result of reproductive development of the plant (Swainson and Hoskin, 2006).

2.6.3 Pasture allocation & utilisation

The more pasture allocated, the greater the intake up until an asymptote (Penning, 1986). Research by Rattray *et al*. (1982) determined pasture allocation needs to be at least 8 kg DM/ewe before pasture intake no longer increased. Thus, a paddock set-stocked at 10 ewes/ha need an allocation of 80 kg/hd/day.

Utilisation is generally higher if grazing intensity is higher and thus pasture allocation is lower. If grazing intensity is low and pasture allocation high, pasture intake will increase, but utilisation will decrease, and the preferred species will be actively selected.

The botanical composition of a pasture can also effect utilisation. For example, as a pasture matures, or soil water deficits occur, the proportion of dead or unpalatable material often increases. This results in a reduced amount of palatable feed available to be consumed from the pasture allocated, and thus a lower pasture utilisation rate.

2.6.4 Estimating pasture intake

Feed intake directly relates to livestock performance but estimating this accurately can be difficult. There are two main methods in which intake can be estimated. The first involves measuring the difference in pasture between a pre-graze and post-graze period. The second uses energy requirement calculations from Nicol and Brookes (2007b) to estimate the pasture that should be consumed to meet the energy requirements necessary for that class of animal, to have maintained or gained the measured live weight. Both of these methods will be used in this thesis.

2.6.4.1 Pasture disappearance

Determining pasture intake by measuring the disappearance of pasture can be unreliable. It requires accurate sampling that is representative of the paddock. However, maintaining a high level of accuracy can prove difficult when dealing with the variability in pasture mass from grazing experiments. Non-uniformity of pasture easily arises due to factors such as selective grazing by stock, and the change in botanical composition of a sward over time.

Using pasture disappearance as a method to determine intake is likely to become less accurate with an increase in the size of grazing experiments. i.e. more pasture area to attempt to accurately estimate results in the increased risk of inaccuracies.

2.6.4.2 Energy requirement

Metabolisable energy intake also has an influence on livestock performance (Waghorn *et al*., 2007). Thus, a more accurate method of estimating pasture intake uses the ME requirements for livestock calculated using information from Nicol and Brookes (2007b). The ME required for different stock classes to meet maintenance, growth, and lactation can be calculated. This is then divided by the average ME content of the pasture to give an estimate of required feed intake.

Although this is maybe a more accurate approach than the pasture disappearance method, it still has some challenges. The primary issue is with stock and selective grazing of the pasture. Stock will selectively graze legumes over grasses or more palatable portions of a plant. This means the ME content of the pasture intake is probably higher than the average ME content of the overall pasture. To cope with this, a maximum ME value of approximately 12 MJ ME/kg DM could be used. It is unlikely for the ME content of intake to be higher than this value (Nicol and Brookes, 2007b). This allows the minimum pasture intake to be calculated that would be required to meet livestock maintenance, growth and lactation.

2.7 Summary

The research for this research project focusses on maximising the live weight production of ewes and lambs off subterranean clover-based pastures. Any differences in live weight will be explained in terms of dry matter production, botanical composition, and pasture intake. The data collected and analysed completes Years 4 and 5 of the 'MaxAnnuals' grazing experiment.

3 MATERIALS AND METHODS

As noted in Chapter 2, this research consisted of 2 years of data following on from Years 1-3 of the 'MaxAnnuals' grazing experiment, with the aim to quantify the effect of annual clovers on live weight gain of ewes and lambs.

This chapter outlines the materials and methods used.

3.1 Experimental site

Experiment 1 was measured from September 2016 to November 2017 within the 'MaxAnnuals' experiment in paddocks C9A(N) and C9B(N) of Lincoln University's dryland research farm in Canterbury, New Zealand – Ashley Dene (43°38′ S, 172°19′ E, 39 m a.s.l.). The site is located 14 km from the campus. It is bounded by pine trees (*Pinus radiata*) on the northern boundary and a water race on the western boundary. The total area of 8.04 ha was split into 16 paddocks. Each paddock was ~0.5 ha in size, except paddocks 1 (0.6 ha) and 9 (0.3 ha), which gave a total grazed area of two hectares per treatment.

3.2 Soil characteristics

The alluvial soils at the site are classified as 75% Lismore silty loam (Typic Dytrustept, USDA taxonomy), and 25% Balmoral silty loam. Lismore soils are well-drained pallic firm brown soils with a water holding capacity of ~80 mm in the top 1.0 m. These soils are moderately stony with moderate P retention (43%). Balmoral soils are well drained acidic orthic brown soils with a low water holding capacity of 55 mm in the top 1.0 m. These soils are very stony with a medium P retention (36%) (S-MAP, 2018).

3.3 Paddock history

3.3.1 Prior to 'MaxAnnuals'

Since 1985, a fixed rotation of 2 years of autumn sown winter forage, primarily consisting of turnips (*Brassica rapa*), 'Moata' Italian ryegrass (*Lolium multiflorum*), or oats (*Avena sativa*), was sown following a summer fallow to assist with weed control and soil moisture accumulation. Spring sown lucerne followed for 5-7 years, with a 2.5 t/ha application of lime prior to sowing. Annual sulphur superphosphate was applied at rates of 150 – 200 kg/ha. Winter herbicide applications were used every 2 years during the lucerne phase to control weeds. In January 2012, the paddock was sown in forage rape (*Brassica napus*). This was grazed the following winter before a cultivated summer fallow, and the establishment of the current experiment in 2013 (Section 3.8).

3.3.2 Years 1-3 of the ‘MaxAnnuals’ grazing experiment

The first year of the ‘MaxAnnuals’ experiment was aimed at generating a seed bank for regeneration of annual clover for the following 3-4 years. This meant balansa and subterranean clover were well managed and left to flower, with hoggets only used for maintenance grazings during spring 2013. Ewes and lambs began grazing in spring 2014 (Year 2) and the first set of live weight production data was collected.

Grazing for the 2015/16 season (Year 3) did not begin until the 20th August 2015 on ryegrass pastures. This is because the originally sown ryegrass did not survive due to drought, and so additional ryegrass was sown in autumn of Year 2 and spelled over winter. Grazing for cocksfoot pastures began 21 days later on the 10th September 2015. This was due to less feed being available as a result of winter grazing in June and July 2015. Winter grazing was necessary to open up the cocksfoot pastures, as the young sub clover seedlings were becoming suppressed by the tall cocksfoot growth. Weaned lambs were returned to the plots in late summer from 7th January to 20th February 2016. This was followed with a ‘clean-up’ graze by hoggets in Paddocks 1-4 and 9-12. Ewes were then used for an autumn graze from 7th to 26th of April 2016. This was the last grazing event before plots were set-stocked with ewes in lambs in spring 2016, and the beginning of the two-year experimental period for this research began.

3.4 Soil fertility

Soil tests were taken from every plot (and combined into C9A(N), C9B(N), or by treatment) annually in either May or June from 2011-2017 (Table 3.1). Results showed that C9A(N) had an Olsen P of 13 in 2013, and 11 in 2014. Whereas, C9B(N) had an Olsen P of 20 and 14, respectively. Therefore, 350 kg/ha (C9A(N)) and 180 kg/ha (C9B(N)) of 20% sulphur super (0, 8, 0 ,20) were applied in August 2013 and August 2014 to lift the Olsen P and SO_4S levels. Identical applications of 200 kg/ha of superphosphate (0, 9, 0, 10) were used in July 2015, and September 2016. Olsen P levels took until 2017 to register an increase.

Table 3.1: Recommended soil fertility values for pasture growth (Hills, 2018) and mean soil fertility levels measured in winter prior to each year from 2011-2017 at Ashley Dene, Canterbury.

Treatment		Year	pH	Olsen P (mg/L)	K me/100g	SO_4S (MAF)	Ca me/100g	Mg me/100g	Na me/100g
Recommended	**Low:**		**5.8**	**20**	**0.50**	**10**	**6.0**	**1.00**	**0.20**
value range	**High:**		**6.3**	**30**	**0.70**	**12**	**12.0**	**3.00**	**0.40**
Combined C9A(N)		2011	5.8	20	0.57	10	7.3	0.71	0.11
		2012	5.9	25	0.68	14	7.3	0.76	0.11
		2013	5.8	13	0.45	4	8.2	0.56	0.09
		2014	5.7	11	0.40	6	7.3	0.45	0.09
Combined C9B(N)		2011	6.0	22	0.68	10	7.3	0.61	0.09
		2012	6.4	25	0.68	10	10.0	0.76	0.13
		2013	5.9	20	0.68	6	7.3	0.56	0.09
		2014	5.7	14	0.57	5	6.4	0.50	0.09
Cocksfoot/sub clover		2015	5.7	19	0.68	34	8.2	0.71	0.16
		2016	5.4	19	0.96	24	7.3	0.61	0.11
		2017	5.8	35	0.96	9	7.3	0.71	0.09
Cocksfoot/sub clover/balansa		2015	5.7	20	0.45	28	8.2	0.61	0.13
		2016	5.6	16	0.68	15	6.4	0.56	0.11
		2017	5.8	37	0.90	14	7.3	0.81	0.13
Ryegrass/sub clover		2015	5.5	17	0.57	36	7.3	0.61	0.13
		2016	5.5	20	0.74	23	7.3	0.56	0.16
		2017	5.8	26	0.57	10	8.2	0.61	0.13
Ryegrass/sub clover/balansa		2015	5.5	22	0.62	47	7.3	0.61	0.16
		2016	5.4	22	0.62	27	7.3	0.56	0.16
		2017	5.8	28	0.57	12	7.3	0.61	0.13

3.5 Herbicide application

Prior to establishment of the four experimental pastures in 2013, mallow (*Malva parviflora*) was the dominant broadleaf weed when the area was sprayed with 6 L/ha of glyphosate (Roundup ®) to create a stale seedbed. There were no herbicides used during the 'MaxAnnuals' experiment, but hand grubbing of nodding thistles (*Carduus nutans*) took place when required.

3.6 Meteorological data

The meteorological data during the experimental period from March 2016 – November 2017 are shown in Figure 3.1-Figure **3.4**. Rainfall and air temperature data were collected daily on site at Ashley Dene. Daily penman evapotranspiration (PET) and solar radiation data were collected from the Broadfield Meteorological Station (14 km north east of the experimental site). Long term mean (LTM) monthly data for Broadfield's are the average of 40 years from 1975 to 2015. The long term mean annual rainfall is 627 mm and the total annual PET is 1014 mm. The annual mean temperature ranged from 6.1 °C in the coldest month of July, to 16.6 °C in the warmest month of January. The annual mean temperature was 11.4 °C.

3.6.1.1 Rainfall and evapo-transpiration

The ‘spring’ measurement period was defined as from 1 July to 30 November in two years. The ‘summer’ period covered 1 December to 28 February, and ‘autumn’ events were in the period between 1 March and 30 June in both years. The rainfall pattern in Canterbury is usually described as erratic with potentially high (100 mm) rainfall in one month and very low (10 mm) rainfall the next. It generally does not follow the long-term mean (LTM) pattern, of ~50 mm per month.

The 2016 calendar year was drier than average, receiving 108 mm less annual rainfall than the LTM of 627 mm. Autumn 2016 was classed as a dry season. Specifically, March received below average rainfall with the first autumn rains not falling until 15th and 16th March 2016 (7.1 mm and 18.9 mm respectively). April was also drier than average, with only 8.4 mm of rain recorded, 16% of the LTM of 51.6 mm. A further 104 mm fell in May, followed by only 25 mm in June leading to a drier than normal autumn which received 52 mm less than the LTM of 225 mm.

Total rainfall was then also 60% lower than the LTM in spring 2016. The ‘spring’ period started dry, with only 4 mm of rain in July, which was 47 mm less than the monthly LTM (Figure 3.1). Rainfall was also well below average for the remainder of spring until October which saw slightly higher than average monthly rainfall. Thus, rainfall in 2016 was below the LTM in all months except March, April, and October.

Summer 2016/17 rainfall was below the LTM across all months, with rainfall in February totaling 2.6 mm, or 6% of the LTM of 41.1 mm. The following autumn months from March through till June were wet, receiving a combined total rainfall of 265 mm – or 40 mm more than the LTM.

Total rainfall in spring 2017 (months July to November) was 264 mm and was almost identical to the LTM (265 mm). However, the mean monthly rainfall in July 2017 was double (127 mm) the monthly LTM (61 mm), but November received only 0.4 mm. Thus, the spring growth period was shortened by the lack of in season rainfall and low water holding capacity of the stony soil.

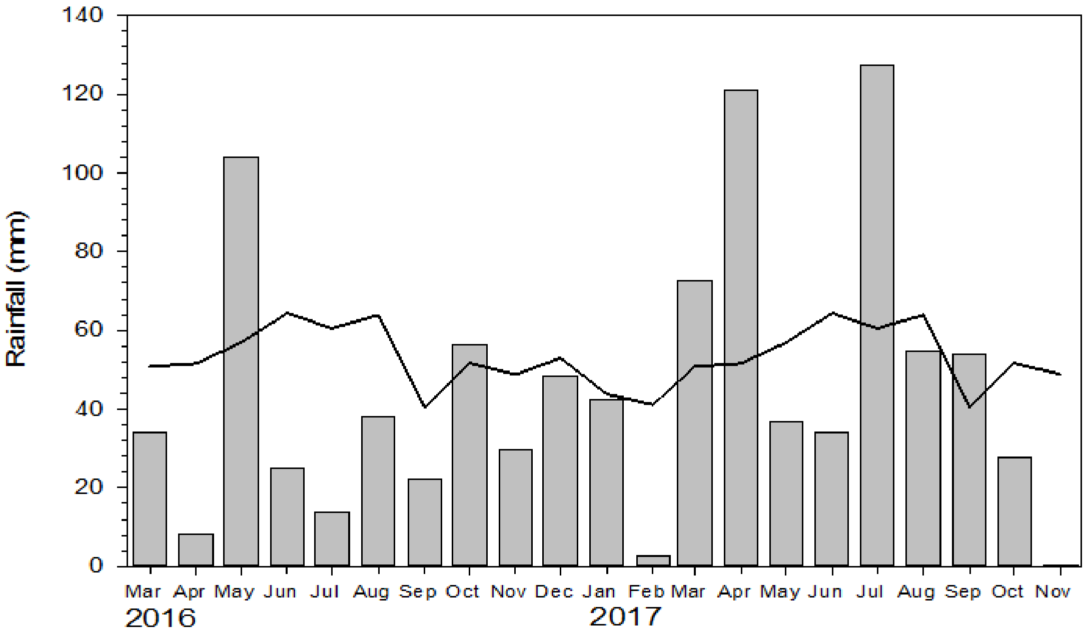


Figure 3.1: Monthly rainfall (mm) from 1 March 2016 to 30 November 2017 collected on site at Ashley Dene. The long-term mean (-) is of 40 years from 1975 to 2015 from Broadfields Meteorological Station located 14 km north east of the experimental site.

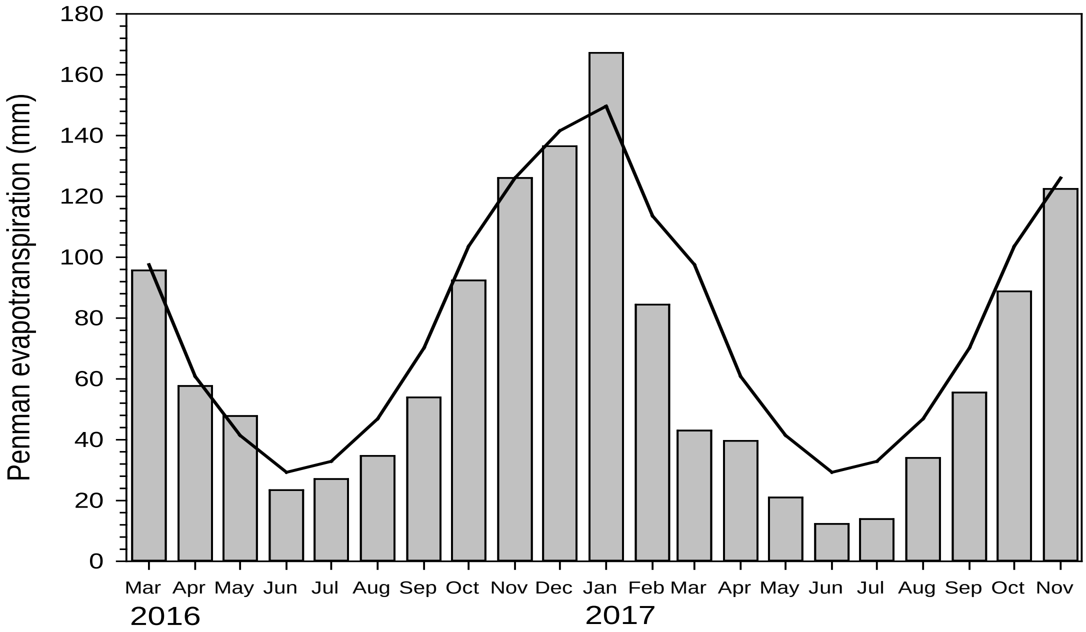


Figure 3.2: Monthly potential evapotranspiration (PET) (mm) from 1 March 2016 to 30 November 2017. The LTM is of 40 years from 1975 to 2015 (-) collected from Broadfields Meteorological Station located 14 km north east of the experimental site.

Penman evapotranspiration (PET) in 2016/17 was 20% below the LTM. PET during the spring period was also below the LTM in both years. In 2016 it was 46 mm and in 2017 it was 65 mm below the LTM (Figure 3.2). The minimum monthly PET in June 2016 was 12 mm, while the maximum was in January 2017 (167 mm).

3.6.1.2 Temperature and solar radiation

The mean monthly temperatures and mean monthly solar radiation were similar to the LTM in both years (Figure 3.3). Mean monthly temperatures were below average in August 2016, and March and May 2017. The highest monthly mean temperature during the experimental period was 16.8 °C in both January and February 2017. The lowest monthly temperature was 6.2 °C in July 2017. Mean monthly total photosynthetically active radiation (PAR) ranged from 4.8 MJ m^2 in July 2017 to 23.4 MJ m^2 in November 2017 (Figure 3.4).

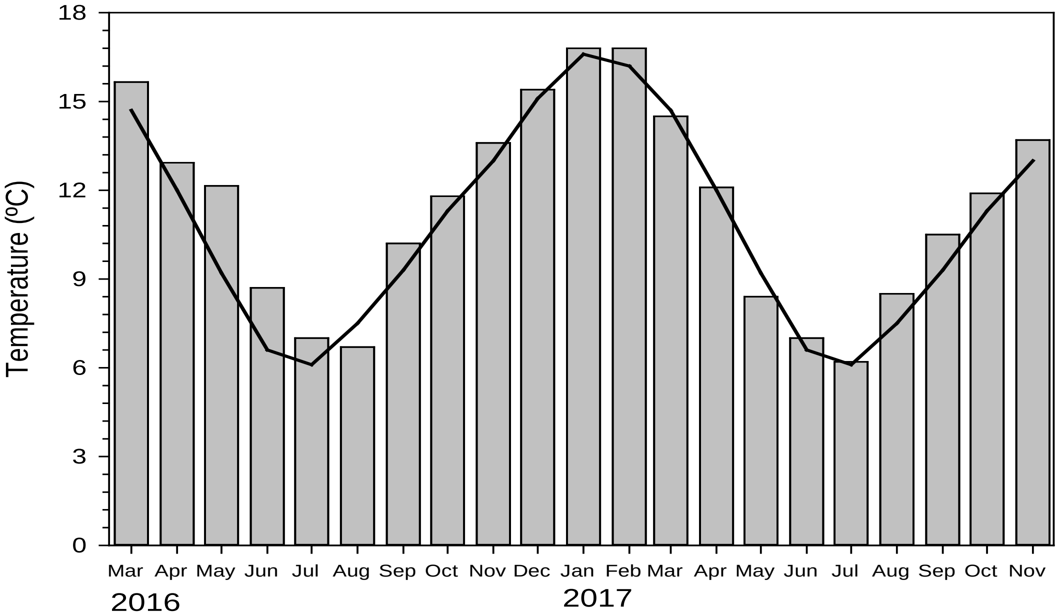


Figure 3.3: Mean monthly temperatures (ºC) from 1 March 2016 to 30 November 2017. The LTM is of 40 years from 1975 to 2015 (-) from Broadfields Meteorological Station located 14 km north east of the experimental site.

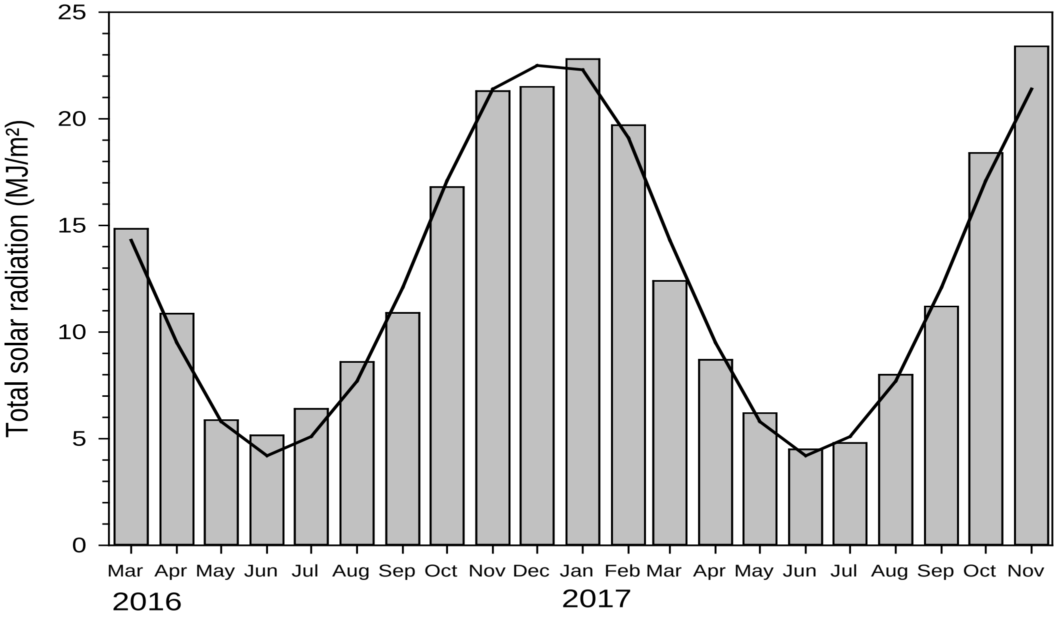


Figure 3.4: Mean monthly total solar radiation (MJ/m²) from 1 March 2016 to 30 November 2017. The LTM is of 40 years from 1975 to 2015 (-) from Broadfields Meteorological Station located 14 km north east of the experimental site.

3.7 Soil Moisture

Soil moisture content was recorded between 2 and 6 week intervals throughout the duration of the experiment. Each plot had a 2.3 m neutron probe (Troxler™ and InstroTek™) which was used to take measurements every 20 cm from 0.25-2.25 m. In the top 0.2 m of the soil profile, measurements were collected using Time Domain Reflectometer (TDR) (Soil Moisture Equipment™).

3.7.1 Water use

The maximum depth of water extraction was determined by observing water extraction patterns in individual soil layers from the TDR and neutron probe data. In most cases, the drained upper limit (DUL) was calculated as the mean of the 2nd and 3rd highest soil water content readings per layer, while the lower limit (LL) was from the 2nd and 3rd lowest readings per layer. In some cases, where drainage events were captured by soil water observations, these were excluded from the calculation of DUL (again based on visual observation of soil water data collected). The actual soil water measurements (TDR and neutron probe) were not used to determine the actual soil water use because there was an indication that the different neutron probes were giving different soil moisture readings and this resulted in some abnormal patterns of water extraction. The use of two different machines occurred because of the Troxler was out of commission for an extended period after it had initially been used for all measurements.

3.7.2 Plant available water capacity (PAWC)

The potential soil water deficit assumes that actual evapotranspiration equals potential evapotranspiration (Penman PET) when the soil moisture is 0-50% of potential. When the soil moisture deficit is 50-100% of PAWC, then PET is reduced proportionally as the extent of the deficit increases (Moot *et al.*, 2012). At this site, it is assumed that PAWC was equal to 150 mm, so PET would be reduced when the soil water deficit was >75 mm (half the PAWC). However, in this research, plot specific PAWC were able to be used instead of the estimated PAWC of 150 mm.

3.7.3 Soil water deficits

Actual (ASWD) and potential soil water deficits (PSWD) were calculated for each year from Penman's PET measured at Broadfield weather station, and rainfall measured on-site at Ashley Dene. The potential soil water deficit was set to zero and accumulated from 1st July each year. The actual soil water deficit was calculated using:

Equation 1: $ASWD\ today = Yesterdays\ ASWD + PET - Rainfall$

When the ASWD was equal to half the calculated PAWC, this was labeled the ‘trigger point’ (TP). This is the point when water stress would first occur, and usually results in a loss of leaf area, then stomatal closure and wilting.

3.8 Pasture establishment

Four pastures, replicated four times, were initially established in a randomized complete block design (Figure 3.5) between 26th March and 16th April 2013. Two replicates were sown on each date. The pastures were drilled using a Duncan Renovator II triple disc drill, followed by a Cambridge roller.

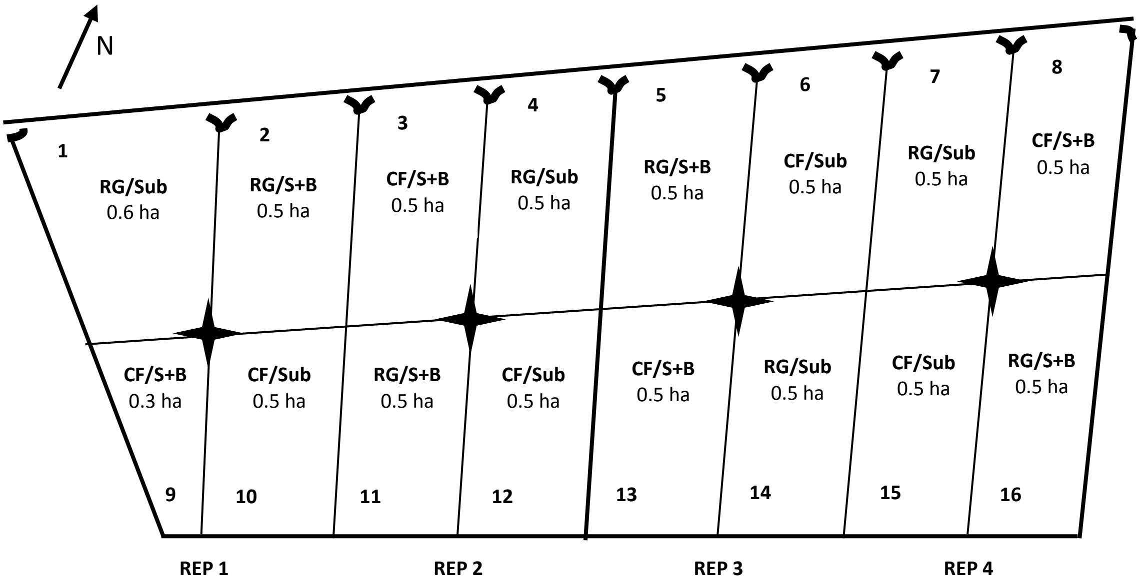


Figure 3.5: Experimental area for Experiment 1 (‘MaxAnnuals’) clover-based pastures showing plot numbers and pasture treatment at Ashley Dene. ’CF/Sub’ relates to cocksfoot/sub clover, ‘RG/Sub’ relates to ryegrass/sub clover, ‘CF/S+B’ is cocksfoot/sub clover/balansa clover, and ‘RG/S+B’ is ryegrass/sub clover/balansa clover.

Table 3.2 lists the sown pastures which included either cocksfoot (CF; 2kg/ha of ‘Greenly’) or a ryegrass x fescue hybrid (RG; 10kg/ha, breeders line) established with or without balansa clover (Bal; 0 or 4 kg/ha of ‘Bolta’). Basal pasture components, sown with all treatments, were 10 kg/ha of sub clover (5 kg/ha ‘Denmark’ + 5 kg/ha ‘Rosabrook’), white clover (0.5 kg/ha ‘Nomad’) and plantain (0.5 kg/ha *Plantago lanceolata,* ‘Tonic’).

Table 3.2: Sowing rates (kg/ha) of species and cultivars used in Experiment 1 of the 'MaxAnnuals' dryland pastures established in C9N(A) and C9N(B) at Ashley Dene in March/April 2013.

	Subterranean clover		White clover	Plantain	Balansa	RG X TF hybrid	Cocksfoot
Pasture	Rosabrook	Denmark	Nomad	Tonic	Bolta	Ultra Enhanced	Greenly
CF/Sub	5	5	0.5	0.5	0	0	2
CF/S+B	5	5	0.5	0.5	4	0	2
RG/Sub	5	5	0.5	0.5	0	10	0
RG/S+B	5	5	0.5	0.5	4	10	0

The focus of this thesis is on Years 4 and 5 of the experiment. By this time the initial sown species had changed. The sub-clover seed bank was thought to be near empty at the end of the 2016/17 season because of two 'false strikes' during the summer. Ryegrass pastures were predominantly plantain-based by 2015, so for the remainder of this thesis, the original RG/Sub and RG/S+B pastures will be referred to as plantain pastures – PL/Sub and PL/S+B.

3.9 Livestock management

The grazing management throughout Experiment 1 aimed to optimize the quantity and maintain the quality of herbage to maximise pasture and animal production in spring, and to encourage the persistence of sub clover. A detailed list of grazing periods can be found in Appendix 1Appendix **4**. Stocking rates were adjusted when necessary using the 'Put and Take' method to match feed on offer.

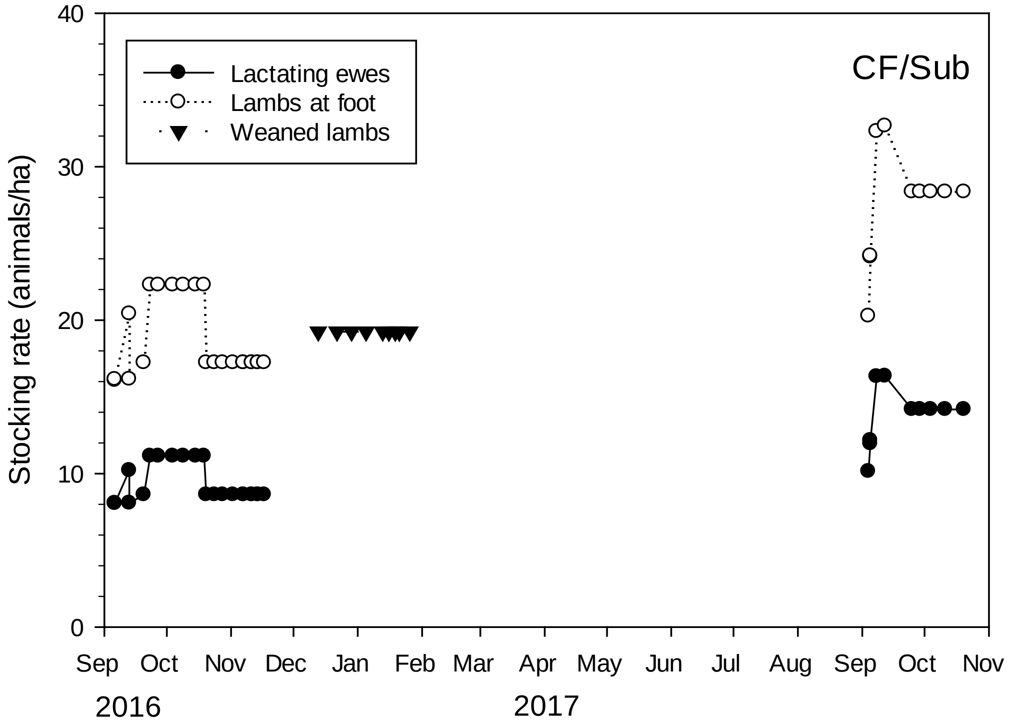
In 2016 of the 'MaxAnnuals' Experiment 1, lactating ewes and lambs at foot grazed the pastures during the spring period until they were replaced by the same weaned lambs during early summer of 2016/17 as more feed came on offer again following rainfall in December and January (Figure 3.1). The ewe weights at the beginning of the spring live weight period were variable (Appendix 5) due to the initial stocking process. Ewes and lambs were placed in the trial plots as they became available from the main flock. Time was a limiting factor and it was not an option to wait until lambing had finished to then sort all the ewes into similar weight groups, before placing them on the plots.

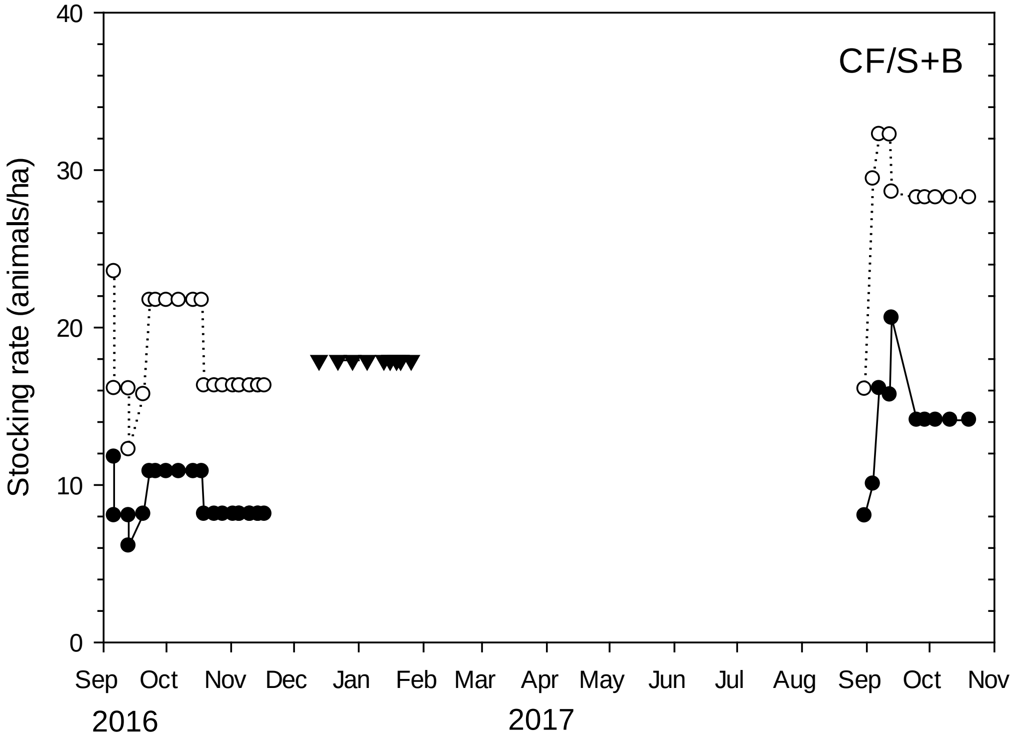
Ewes were used for 'clean-up' grazing events in autumn 2016, summer 2016/17 following the removal of weaned lambs from the pastures, and again in mid-autumn 2017 following above average rainfall (Figure 3.1). This grazing was consistent with on-farm practices that are required to condition the pastures, so the quality remains high, but also maintains ewe weights.

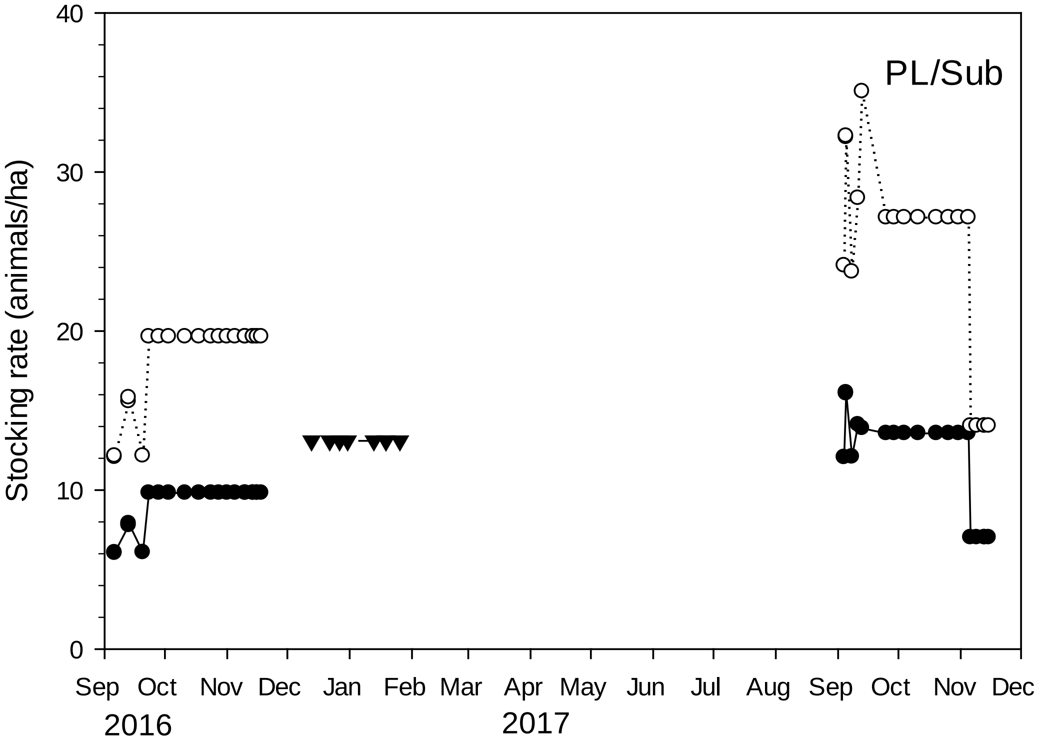
Figure 3.6 shows the stocking rates and duration of productive grazings on the four different pasture treatments in 2016/17 and 2017/18. The final grazing before spring 2016 was a clean-up graze by ewes from the 7th April to 26th April. Introduction of stock to the treatments began with set-stocking on the 6th September in 2016 (Appendix 6). The set-stocking period lasted 8 days with all treatments from Reps 3 and 4 stocked on the 6th September, and the remaining Rep 1 and 2 treatments stocked on the 13th September. Ewes and lambs remained set-stocked on their pasture treatments until 20th October 2016. Four groups of ewes and their twin lambs then began rotationally grazing within the four replicates of each pasture treatment. The ewes and lambs remained in their four treatment groups and were rotationally grazed until being removed on the 18th November 2016 when there was no feed available. If a ewe or lamb died, they were removed from the group and replaced with another ewe and set of twin lambs. Following sufficient rainfall for pasture growth to continue, weaned lambs were able to graze the pastures again from 13th December until 26th January 2017.

In summer 2017, a mob of 185 grazer ewes were used for a 'clean-up' across all reps over a 7-day period. This mob started in rep 1 (paddocks 1, 2, 9, and 10) on 21st February 2017 and finished in rep 4 (paddocks 7, 8, 15, and 16) on 28th February 2017. The high stocking rate was used to remove low quality herbage, and to reduce pasture mass and dead material in the dry, grass-dominant summer swards. This is standard practice in dryland pastures (Grigg *et al*., 2008) to allow sub clover seedlings to have space to germinate and establish with autumn rain. No live weight gain measurements were taken for these grazer ewes.

A second mid-autumn graze was carried out to keep the grass component of the pastures short to enable sub clover to come through with limited competition. This took place across all 16 paddocks, starting in Paddocks 1 and 9 on the 19th April 2017, and finishing in Paddocks 8 and 16 on the 2nd May 2017. The maintenance ewe stocking rates and duration of grazings are not shown in Figure 3.6 so that the important treatment effects can be seen easier during spring and summer production grazings.


Stocking rate (animals/ha)
0
10
20
30
40
Lactating ewes
Lambs at foot
Weaned lambs
CF/Sub
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
2016
2017


Stocking rate (animals/ha)
0
10
20
30
40
CF/S+B
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
2016
2017



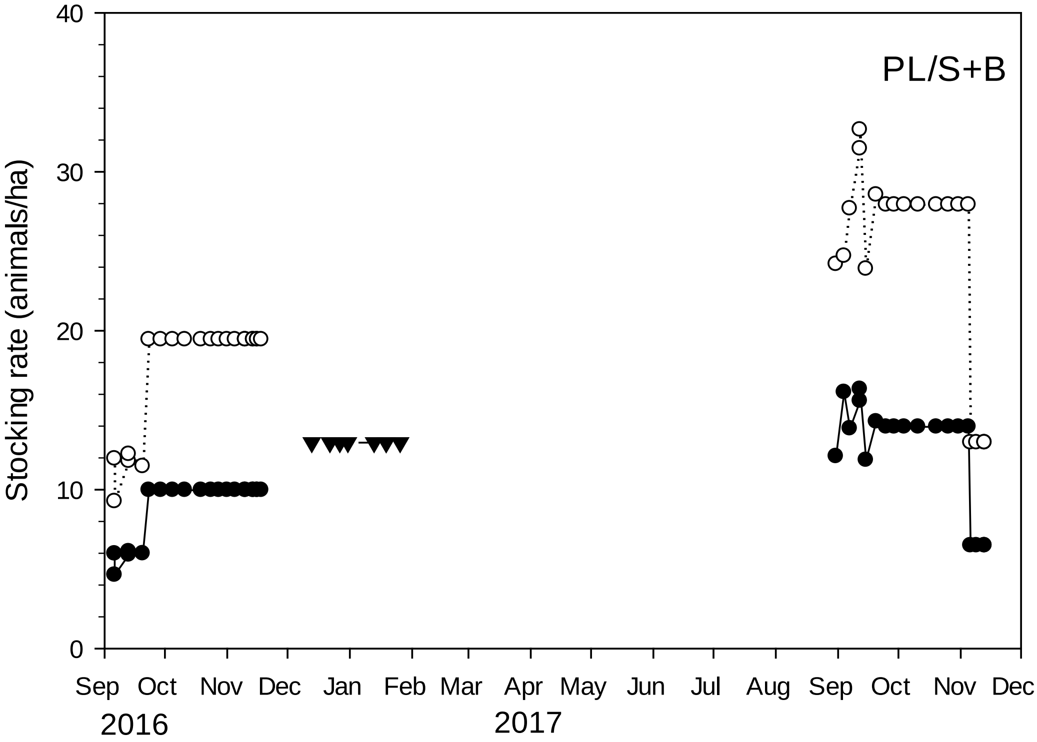


Figure 3.6: Stocking rate and duration of production grazings of four dryland pastures from autumn 2016 to spring 2017.

All paddocks were spelled from the beginning of May 2017 until lambing when all paddocks were set-stocked again from the 31st August 2017 – six days earlier than in spring 2016. The set-stocking period in 2017 was more staggered with paddocks (starting from the Rep 4 end) stocked as soon as sufficient ewes and lambs became available from the main commercial flock. Paddocks 8 (CF/S+B) and 16 (PL/S+B) were the first to be stocked on the 31st August, while Paddocks 1 (PL/Sub) and 9 (CF/S+B) were the last to be stocked on the 13th September. The four groups of ewes and their twin lambs then began rotationally grazing from the 25th September to 15th November 2017 when the feed supply diminished and all stock were removed from the plots.

Plate 1: Ewes and lambs grazing paddock 5 (PL/S+B) on the 1st November 2017. Feed supply quickly diminished in early November. All stock had to be removed from the treatments by the 14th November 2017.

3.9.1 Grazing days

Grazing days (GD) were calculated per hectare by multiplying the number of days each plot was grazed by the stocking rate per plot, by the plot size (ha). Given the differences in stock classes, the grazing days for ewes were calculated separately to lambs.

3.10 Animal health

Prior to mating, ewes were vaccinated with Toxovax® and Campyvax® to immunize against abortion and perinatal loss from toxoplasmosis and campylobacter. Pre-lambing, ewes were vaccinated with Eweguard 6 in 1® to give control of Ostertagia and Barber's Pole worm and a minimum 7 days control of Trichostrongylus. Lambs were not drenched while on the experiments. Regular monitoring for foot rot or foot scald took place, and livestock were treated with zinc sulphate as required.

3.11 Measurements

Coopworth ewes and twin lambs were selected for the experiments from the main flock at Ashley Dene as they became available over lambing. A random mixture of ewe and ram lambs were used in the experiment. Any ewes or lambs with obvious health issues, or twin lambs substantially different in size were not selected. Ewes and lambs were set-stocked across all 16 paddocks for approximately one month to begin with. Stock were not placed in a paddock until there were sufficient ewes and twin lambs available to match the feed on offer in that paddock (i.e. all animals were placed in their paddock and began grazing at the same time).

Each group was weighed prior to entering the paddock. After set-stocking, the stock were combined into one of four treatment groups based on the treatment they had been grazing. They were then rotationally grazed around those same pasture types. Ewes and lambs were rotated every 2-7 days based on feed available per paddock. All treatment groups were weighed monthly in 2016/17 and every two weeks in 2017/18 until all animals were removed.

3.11.1 Live weight

Live weight gain measurements were collected during the production grazing periods (ewes, lambs, and weaned lambs) in spring 2016 and 2017, and summer 2016/17 (Figure 3.6).

All stock were weighed full as they entered and left the experimental area with Tru Test XR 3000 scales in a Prattley weigh crate. After weighing, ewes and lambs remained in their treatment groups and were returned to their treatment paddocks.

A seasonal weighted live weight gain (g/hd/day) was calculated for animals in each stock class in spring and summer where applicable. The live weight production from each plot was calculated for data analysis. This was carried out by multiplying the seasonal weighted live weight gain (g/hd/day) by total production graze days (total number of stock x days grazing) (Brown *et al.*, 2006).

3.11.2 Herbage mass/dry matter availability

A rising plate meter was used to measure herbage mass pre- and post-grazing per plot. Each time, 50 plate meter readings were taken across the whole paddock. The plate meter readings were calibrated to cuts using 0.2m^2 quadrats. Plate meter readings (CPH, cm) were plotted against dry matter (DM, kg/ha) and a linear regression fitted (Figure 3.7) for the quadrat cuts made in spring and summer in 2016/17 and for spring 2017/18. Regression analysis for linear models was completed for each of the seasons using Genstat (v.18, VSN International). Determining a relationship between CPH and DM enabled an estimation of plot pasture mass. A plate meter reading could be inserted into the 'x' function of the linear regression equation to obtain an estimated dry matter (kg/ha) value.

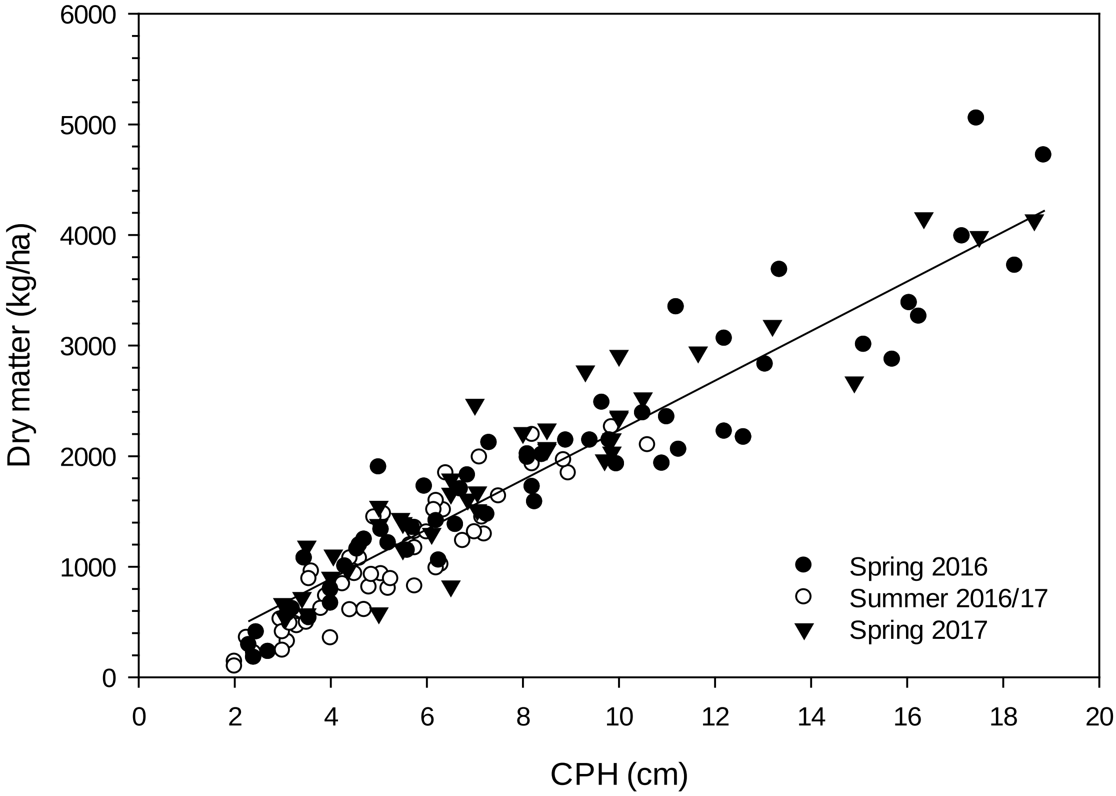


Figure 3.7: Dry matter yield (kg/ha) and associated plate meter readings (CPH, cm) for calibration cuts made in spring and summer 2016/17, and spring 2017/18, at Ashley Dene, Canterbury. The regression equation is $y=228x+79.5$ $R^2=0.89$.

3.11.3 Herbage on offer and nutritive value

Moveable exclosure cages were also used to measure pasture production in all 16 paddocks over both years of the experiment. The use of moveable exclosure cages meant that measurements could be taken independently of the grazing of paddocks (Roberts and Thomson, 1984). The method used was similar to the 'rate of growth' technique described by (Lynch, 1960) and (Radcliffe, 1974). In 2016/17, only one cage (720mm x 1100mm at the base, 415mm high) was placed in each of the 16 paddocks, whereas two exclosure cages were used in 2017/18. The cages were placed on areas of pasture that were representative of the paddock. Before placing the cages, the pasture was trimmed using a mower to a uniform height 5 cm above ground level. After approximately six weeks during spring and 12 weeks during summer and autumn, the area under the cages were harvested to 5 cm above ground level again and the cages were then moved to a new area and pasture trimmed in readiness for the next rotation.

Cage harvest subsamples were taken for botanical composition. Each plot sample was sorted into sub or balansa clover, sown grass (ryegrass/cocksfoot), plantain, weed grass, dicot weeds, and dead. These were then dried in a forced air oven at 60ºC for at least 72 hours, before the dry weights were measured. The dry sub clover, balansa, ryegrass, cocksfoot and plantain sorted samples were then ground in a mill to pass through a 1 mm stainless steel sieve (Cyclotec Mill, USA) in preparation for NIR analysis. Any replicate samples that had insufficient material for analysis were combined. NIR was used at Lincoln University to test for the metabolisable energy (ME; MJ ME/kg DM), crude protein (CP; %DM) neutral detergent fibre (NDF, %DM), and acid detergent fibre (ADF; %DM) of the sown pasture components.

The nutritive value of the herbage on offer was also measured additionally by snip samples. On the 14th September 2017, near the beginning of the 2017/18 spring live weight period, 30 snips per plot were collected at the same height that the animals were grazing to. The samples were random, but representative of what the stock were eating i.e. unpalatable weeds were avoided. Each plot sample was sub-sampled and sorted for botanical composition using the same processes as for the cage cuts. No snip samples were collected in 2016/17.

Pre-graze quadrat cuts and associated botanical compositions were also collected during the 2017/18 spring period in addition to the snip samples. These were carried out under my supervision by Lincoln University 3rd year plant science students on the 24th and 28th July, and the 8th, 13th and 14th of September. Their data were included in analysis for this thesis.

The main weed species in the experiments were chickweed (*Stellaria media*), vulpia hair grass (*Vulpia bromoides* L.), and dock (*Rumex obtusifolius* L.)

3.11.4 Intake and feeding preference

Pasture intake and feeding preference were determined by pasture disappearance. This method assumed that the difference in pre-grazing and post-grazing pasture mass and composition was consumed by livestock over the duration of the grazing period. This assumed that there was no pasture growth within the grazing period.

Plate 2: A five meter transect, permanently marked out with pegs during the spring period when ewes and lambs grazed. Visual pasture estimates were recorded at every meter along the string (marked with coloured ties) using 0.1 m^2 round quadrats.

Transect lines and quadrats were used to monitor the pasture disappearance and preference. One 5 m transect was set up and marked with pegs (Plate 2) in each paddock, in Reps 3 and 4. At every meter along the transect, a 0.1 m^2 round quadrat was placed (Plate 3), and a visual estimate of the cover (%) of the pasture components was completed. Each of the five quadrats per paddock was assessed seven times each throughout the spring period: three pre-grazing events, three post-grazing events, and one final assessment before all stock were removed from the experiment.

Plate 3: One of five 0.1 m^2 quadrats placed along a transect line to visually score the pre-graze botanical composition from Paddock 15 at Ashley Dene, Canterbury.

3.12 Statistical analysis

3.12.1 General

Statistical analysis was performed using GenStat (Version 16.1, VSN International Ltd, 2013). Split plot analysis of variance was used to compare treatments between years. Treatment was used as whole plots and year as the sub plot. One-way analysis of variance was used to anaylse among treatments and when there was only data available from one year to analyse e.g. weaned lambs live weight production data. Fishers protected least significant difference tests identified differences in means at the X=0.05 level. Any results where P 0.05 ≤ 0.10 were reported as trends.

‘t’-tests were carried out for live weight production from each treatment mob and stock class, during each live weight rotation. For example, ewes in live weight Rotation 1 in spring, grazing CF/Sub versus ewes in live weight Rotation 1 in spring, grazing PL/Sub. The six different treatment combinations were tested for each stock class in each live weight rotation and results were analysed for any differences in live weight production (g/hd/d).

Orthogonal contrasts with one-way analysis of variance were used to compare plantain pastures with cocksfoot pastures, and sub clover pastures with sub + balansa pastures across the two years. The orthogonal contrast matrix used for statistical analysis is shown in Table 3.3.

P-value results for between year comparisons are shown in all tables. Significant and trend p-values are bolded.

Table 3.3: Orthogonal contrast matrix used for statistical analysis with one-way analysis of variance. 'CF/Sub' refers to the cocksfoot and sub clover treatment, 'CF/S+B' refers to the cocksfoot and sub clover + balansa treatment, 'PL/Sub' refers to the plantain and sub clover treatment, and 'PL/S+B' refers to the plantain and sub clover + balansa treatment. 'CF v PL' refers to cocksfoot vs. plantain pastures, and 'S v S+B' sub clover vs. sub clover + balansa pastures.

Contrast	**CF/Sub**	**CF/S+B**	**PL/Sub**	**PL/S+B**
CF vs PL	1	1	-1	-1
S vs S+B	1	-1	1	-1

3.12.2 Livestock

A single mob of sheep was assigned to each of the four treatments during each season. Thus, there was no independent live weight data collected within years. To allow analysis within years, live weight gain during each live weight gain rotation within a treatment group, was distributed among replicates in relation to the number of days stock were grazing.

For example, for a live weight rotation of 20 days and an increase in total live weight of 100 kg for a group of weaned lambs, it was assumed that live weight gain increased equally each day by 5.0 kg across all replicates. Therefore, during this rotation, a mob of lambs spending 7 days on Replicate 1 was assumed to have grown 35 kg, 5 days on Replicate 2 grew 25 kg, and 4 days each on Replicates 3 and 4, was assumed to have grown 20 kg. The live weight gained from each replicate was then divided by the area of the replicate to give LWG/ha.

3.12.3 Grazing days

Grazing days were calculated for each paddock and analyzed by dry matter (DM) rotation. This allowed any differences to be analyzed due to more feed on offer (indicated by more grazing days) or if not due to feed, then differences were a result of differences in live weight gain/hd (although sometimes both factors may have caused differences in total live weight/ha).

3.12.4 Nutritive value

Seasonal averages from the four reps of each of the four pastures for spring, summer and autumn were calculated for neutral detergent fibre (NDF; %), metabolisable energy (ME; MJ ME/kg DM), crude protein (CP; %), and nitrogen concentration (N; %) of the sown pasture components.

Total spring ME, CP, NDF and ADF yields on offer were calculated by multiplying the measured total average spring pasture yield by the measured average ME, CP, NDF and ADF contents of each plot.

Typical ME values of a pasture range from 8-12 MJ/kg DM (Lambert and Litherland, 2000). The ME content of a pasture is normally determined as the most limiting to animal performance

The average CP content of New Zealand pastures ranges from 10-30% (Lambert and Litherland, 2000). The CP content directly relates to the nitrogen (N) content of pastures as the average N content of proteins is equal to approximately 16%. Thus, the CP content divided by 6.25 (1/0.16 = 6.25) will equal the N content. This means that pasture components with high CP will also have high N content.

ADF is used as a predictor of feed quality also by measuring the fibre content of a pasture (including the poorly digested cell wall portions of a pasture, such as cellulose and lignin). Higher ADF values suggest a lower quality pasture. Pastures with an ADF content less than 35% are considered high quality (Van Saun, 2018).

For legume forages, NDF content below 40% is considered high quality (Van Saun, 2018). Higher NDF values are often associated with a decline in dry matter intake, but an increase in chewing due to decreased digestibility and thus, greater gut fill.

4 SOIL WATER

4.1 Introduction

At some point in a summer dry environment, a lack of soil moisture limits production. Therefore, to interpret pasture and animal responses, it is important to quantify the timing and amount of water deficits. This is done through defining the soil water profile of each plot. To do this the drained upper limit (DUL) is used to quantify the maximum amount of water the soil can hold. The lower limit (LL) occurs when no further moisture can be extracted. The difference between DUL and LL quantifies the plant available water content. Ideally this should not differ between treatments. However, the variability of soils means this needs to be confirmed to enable valid comparisons of pasture growth, water used, and water use efficiency among treatments. This chapter reports on the soil water analysis of all 16 plots to ensure any treatment differences were not caused by differences in soil water holding capacity.

The objectives of Chapter 4 are:

- Quantify the soil profile properties in terms of drained upper limits, lower limits, plant available water capacity, and the maximum depth of water extraction among pastures.
- Quantify spring water use and the spring water use efficiency among pastures.
- Quantify soil water deficits and the water use from individual plots and relate these back to potential evapotranspiration.

4.2 Soil profile

The calculated drained upper (DUL) and lower limits (LL) did not differ among treatments. Figure 4.1 shows an example of the PAWC from Plot 3 as representative of all plots due to the lack of differences between pastures. The DUL, or maximum amount of water available after drainage has occurred averaged 241 mm (P=0.953) across all treatments (Table 4.1). The LL represents the soil water content when pastures are unable to extract any more. This averaged 118 mm (P=0.684) among the different pastures (Table 4.1). The difference between the DUL and LL is equal to the actual plant available water content (PAWC) (Table 4.1). The value of 123 (±8.4) mm confirms the principal that ~50% of the total water content is readily available to plants.

Table 4.1: Drained upper limit (DUL, mm), lower limit (LL, mm), plant available water content (PAWC, mm), maximum depth of water extraction (m) calculated from soil water readings from 1st July 2016 to 24th November 2017 from four dryland pastures at Ashley Dene, Canterbury.

Treatment	DUL	LL	PAWC	Water extraction depth
CF/Sub	243	115	128	1.40
CF/S+B	236	111	125	1.40
PL/Sub	248	127	122	1.50
PL/S+B	237	121	116	1.45
Year mean	241	118	123	1.44
S.E.M.	17.2	9.7	8.4	0.89
P-value	0.953	0.684	0.793	0.830

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

Among the 16 plots, the PAWC ranged from 92 – 163 mm. This large range is due to the variability in soil type and depths from plots in the experimental area. However, the random nature of the variability and randomization of treatments meant there was no treatment effect so average values could be used for all plots.

A one-way analysis of variance also found no differences (P=0.830) in the maximum depth of water extraction (Table 4.1). Neutron probes were measured to a depth of 2.3 m, but the maximum depth of extraction appeared to be 1.44 (±0.89) m across all treatments. This is determined as the point where DUL=LL which indicates roots are not extracting water. Figure 4.1 shows the measured LL below 1.4 m actually increased, and there was minimal difference between LL and DUL. This suggests there was water available to plants below 1.4 m, but the roots had not extracted it. Indeed, the 28% moisture content for LL at 2.0 m suggests water would be available, but only to deep rooted species.

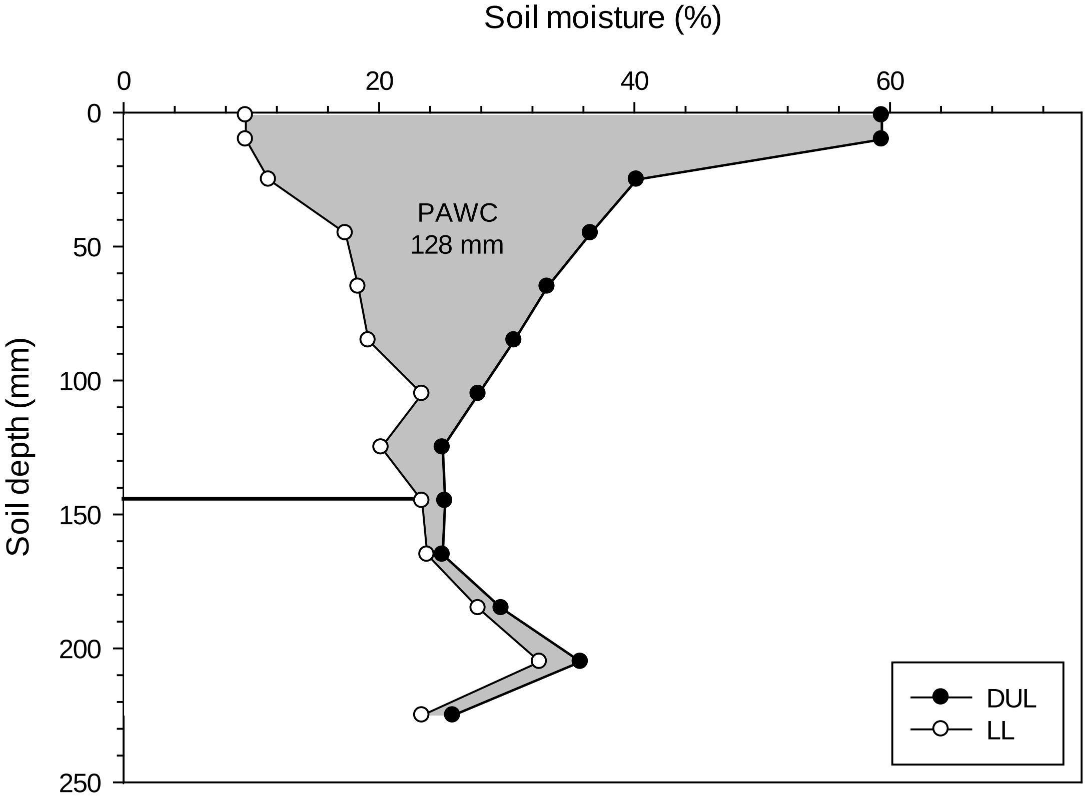


Figure 4.1: Plant available water holding capacity (PAWC) (%) from Plot 3, being the difference between drained upper limit (DUL) and lower limit (LL), measured to a depth of 2.3m from 2016-2017 at Ashley Dene, Canterbury. The solid horizontal line at 144 mm represents the maximum depth of extraction.

4.3 Water use

Annual water use could not be compared between for the full calendar years because in 2016 we had water use data for the whole year whereas, 2017 only had water use data for spring. Table 4.2 lists the timing of limiting soil water deficits calculated in Julian days and thermal time. The date in which the ASWD was >62.5 mm was not different among treatments, but was different between years ($P<0.001$). Spring 2016 reached this point at 291 Julian days which relates to 17th October, while spring 2017 was 12 Julian days later on the 30th October. Spring water use from of each year was compared (Table 4.3). Water use was accumulated form the 1st July until the time of destocking for each year. Destocking occurred on the 18th November 2016, and the 15th November 2017. During these periods, water use averaged 240 mm in 2016, which was higher ($P<0.001$) than the 228 mm used in 2017. Although statistically showing more water was used in 2016, in practice it only represented 12 mm which is three days growth at an actual evapotranspiration of 4 mm/day. So in practical terms, its unlikely to have made a difference. As expected, water use was similar among treatments in 2016 ($P=0.795$) and 2017 ($P=0.822$).

Table 4.2: Time of limiting soil water deficit in Julian days, and ºC days after 1st July by 'break point' of four dryland pastures during 2016 and 2017 at Ashley Dene, Canterbury.

Treatment	**Julian days**		**°C days**	
	2016	**2017**	**2016**	**2017**
CF/Sub	292	303	521	585
CF/S+B	291	303	518	584
PL/Sub	291	303	518	584
PL/S+B	291	303	518	584
Mean	291 $_b$	303 $_a$	519 $_b$	584 $_a$
S.E.M.	0.04		0.22	
P-value	**<0.001**		**<0.001**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

Table 4.3: Spring water use (mm) accumulated from 1st July to the time of destocking for each year, from four dryland pastures during 2016 and 2017 at Ashley Dene, Canterbury**.**

Treatment	**2016**	**2017**
CF/Sub	242	230
CF/S+B	241	230
PL/Sub	238	227
PL/S+B	235	224
Mean	240 $_a$	228 $_b$
S.E.M.	0.15	
P-value	**<0.001**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

Two significant rainfall events of 13.4 mm on the 17th November, followed by a further 33.6 mm on the 11th December were sufficient for pasture growth (Figure 4.3). This enabled weaned lambs to graze the plots from 13th December 2016 to the 26th January. Water use averaged (P=0.727) 119 mm among all treatments during summer 2016/17.

A rainfall event of 8.4 mm occurred on the 7th March, followed by a further 53 mm across a four day period from the 11th-14th March 2017. This began to recharge the soil water profile and meant growth was initiated on the 13th March. Maintenance ewes were used for a 'clean-up' graze from the 19th April 2017 to the 2nd May 2017 (Appendices 2-5) to maintain the quality of the herbage and reduce competition for emerging sub clover seedlings.

The water use from summer and autumn was lower than the average water use during the two springs and is likely to mainly be soil evaporation. This is due to high potential soil water deficits in summer (Section 4.5), and minimal growth from the treatments during autumn as temperatures began to cool (Section 3.6.1.2).

Table 4.4: Water use (mm) from four dryland pastures during summer 2016/2017, and autumn 2017 at Ashley Dene, Canterbury.

Treatment	Summer	Autumn
CF/Sub	120	104
CF/S+B	119	102
PL/Sub	118	102
PL/S+B	117	106
Year mean	119	103
S.E.M.	1.9	4.5
P-value	0.727	0.919

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

4.4 Spring water use efficiency

The spring water use efficiency (WUE) was determined for each of the four pasture types by plotting the accumulated dry matter yield (kg/ha) against the accumulated water use (mm) from 2016-2018 (Figure 4.2). Accumulation began from the 1st July through to the 17th of October 2016, and 30th October 2017, when soil water was at the LL. The regression line was initially a poor fit because the initial growth was temperature limited. These data points reflected the cage cut results from dry matter Rotation 1 which related to the date range from 26th April 2016 to the 13th September 2016, which include the colder months. These were removed from the regression to determine spring water use when temperature was not confounding the results. WUE from PL pastures was ~23 kg DM/ha/mm, which 't'-test analysis found to be higher (P<0.001) than the WUE from CF pastures of ~19 kg DM/ha/mm. This was equivalent to 2.3 kg DM/t water and 1.9 kg DM/t water, respectively.

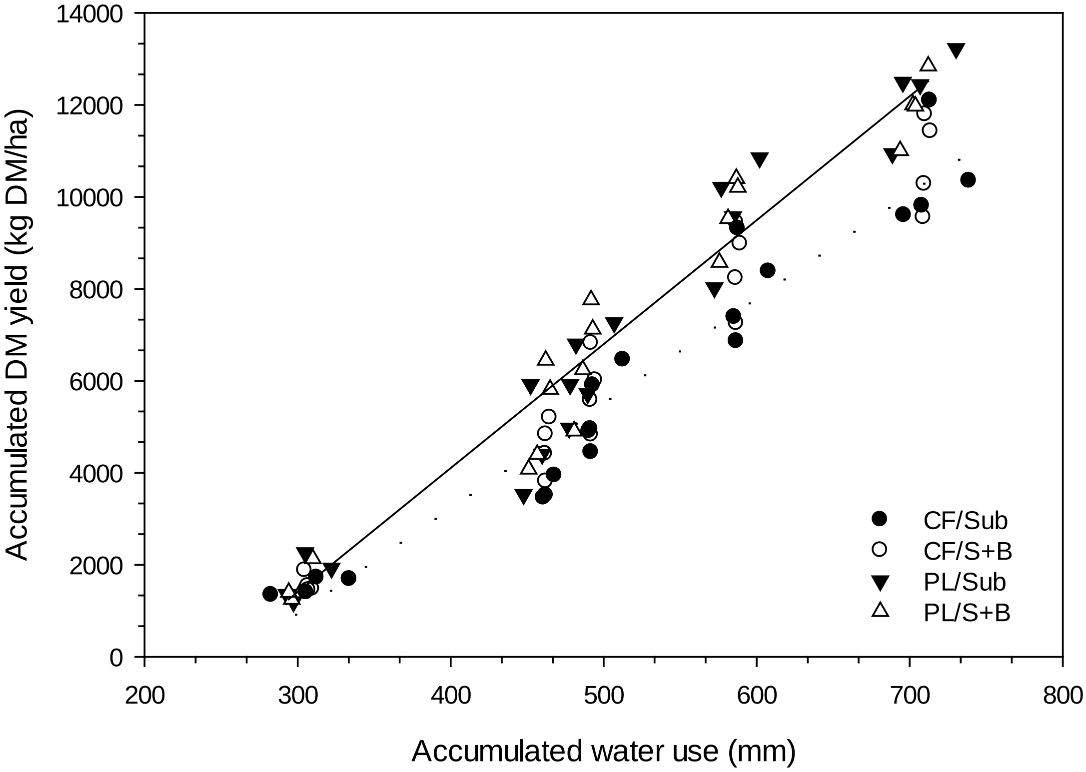


Figure 4.2: Water use efficiency (kg DM/ha/mm) from four dryland pastures from 2016-2018 at Ashley Dene, Canterbury. Treatment acronyms are listed in Table 3.3. Regression equations are listed in Table 4.5. The solid regression line relates to 'PL' pastures, while the dashed regression line related to 'CF' pastures.

Table 4.5: Regression equation and R^2 values for spring water use efficiency from CF and PL pastures from 2016-2018 at Ashley Dene, Canterbury.

Treatment	2016	
CF	= 19.2*x* - 3358	R^2=0.92
PL	= 23.1*x* - 4499	R^2=0.94

4.5 Soil moisture deficits

Soil water deficit results from Plot 3 are used as an example to represent the deficits that occurred across all pastures from 2016-2018 (Figure 4.3). The calculated plant available water capacity (PAWC) for Plot 3 was 125 mm extracted, but the maximum depth of soil extraction was 1.44 m (Table 4.1).

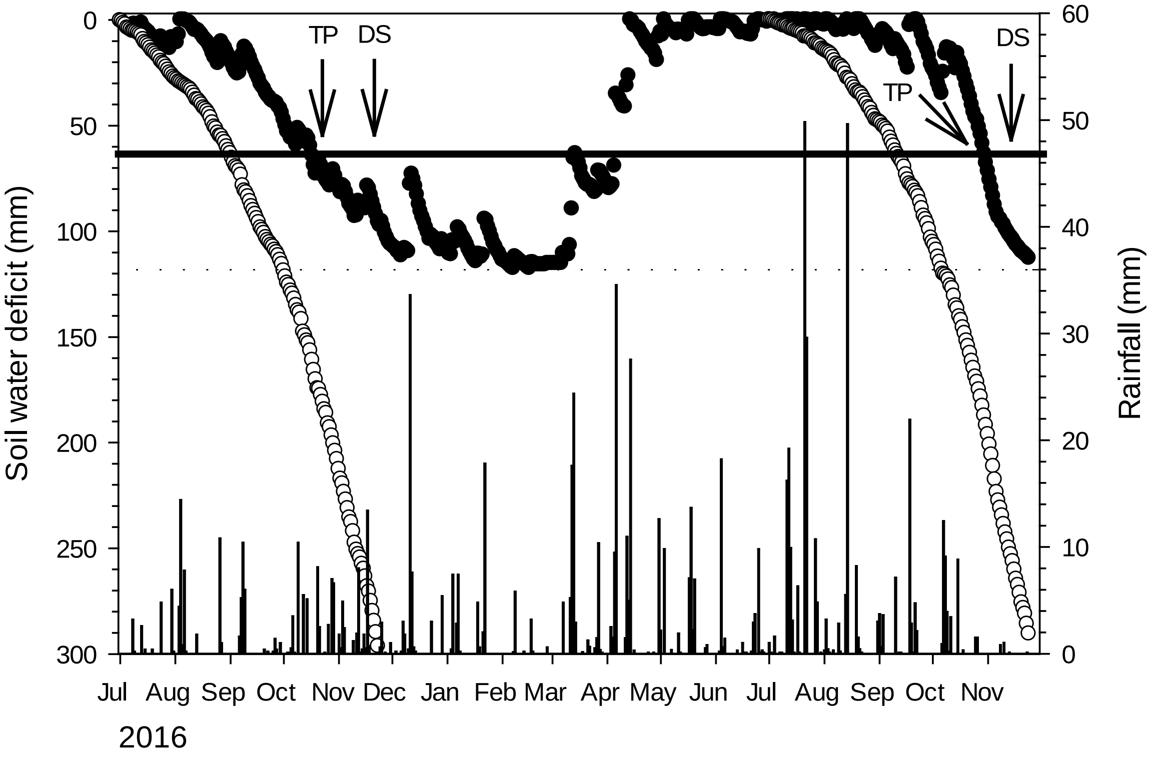


Figure 4.3: Actual soil water deficits (ASWD, mm; ●), potential soil moisture deficits (PSWD, mm; ○) and rainfall (vertical bars, mm) from 1st July 2016 to 15th November 2017 from Plot 3, at Ashley Dene, Canterbury. The PSWD starts re-accumulating from the 1st July of each year. The solid horizontal line represents the critical deficit of 62.5 mm. 'TP' relates to the trigger point at which ASWD >62.5 mm, and 'DS' related to the point at which plots were destocked, in spring of each year.

Specific to Plot 3, when the actual soil water deficit reaches >62.5 mm (half PAWC), water stress would first occur. This usually results in a loss of leaf area, then stomatal closure and wilting. In an irrigated situation, 0.5 x PAWC is used as a trigger point (TP) to start irrigation. So, for this dryland pasture study it is used as the point to assess when water stress could be expected to affect pasture growth. For Plot 3, this was reached on 17th October 2016, and due to insufficient rainfall, plots were destocked on the 18th November 2016. A significant (33.6 mm) rainfall event in December meant plots could be restocked for a period over summer from the 13th December to the 26th January. Recharge occurred through autumn, and field capacity was reached by mid-April. In spring 2017, the TP was reached on the 30th October, and following no rainfall, stock were removed from all plots on the 15th November. Due to the lack of November and December rainfall, plots were not stocked again over summer.

Figure 4.4 shows an example of the daily water use from Plot 3. Daily water use was calculated by subtracting the ASWD yesterday from the ASWD today, and adding this to today's rainfall minus drainage (if any). The daily water use curve reflects the potential soil moisture deficit curve in Figure 4.3, with periods of low water use relating to periods with high soil moisture deficits. All plots exhibited a similar pattern with the periods of highest water use being in spring when actual evapotranspiration was equal to potential evapotranspiration which indicates pastures were actively growing. Ewes and lambs were removed from all plots on the 18th November 2016 and 15 November 2017. These dates related to an ASWD of 79.8 mm and 103.9 mm, respectively. Water use ceased in late spring and summer as soil deficits increased and so pasture growth began to cease. Autumn rainfall alleviated potential soil water deficits on the 13th March 2017, and resulted in increased water use as pastures began to germinate and reestablish. However, growth slowed during winter with the cooler temperatures resulting in reduced water use.

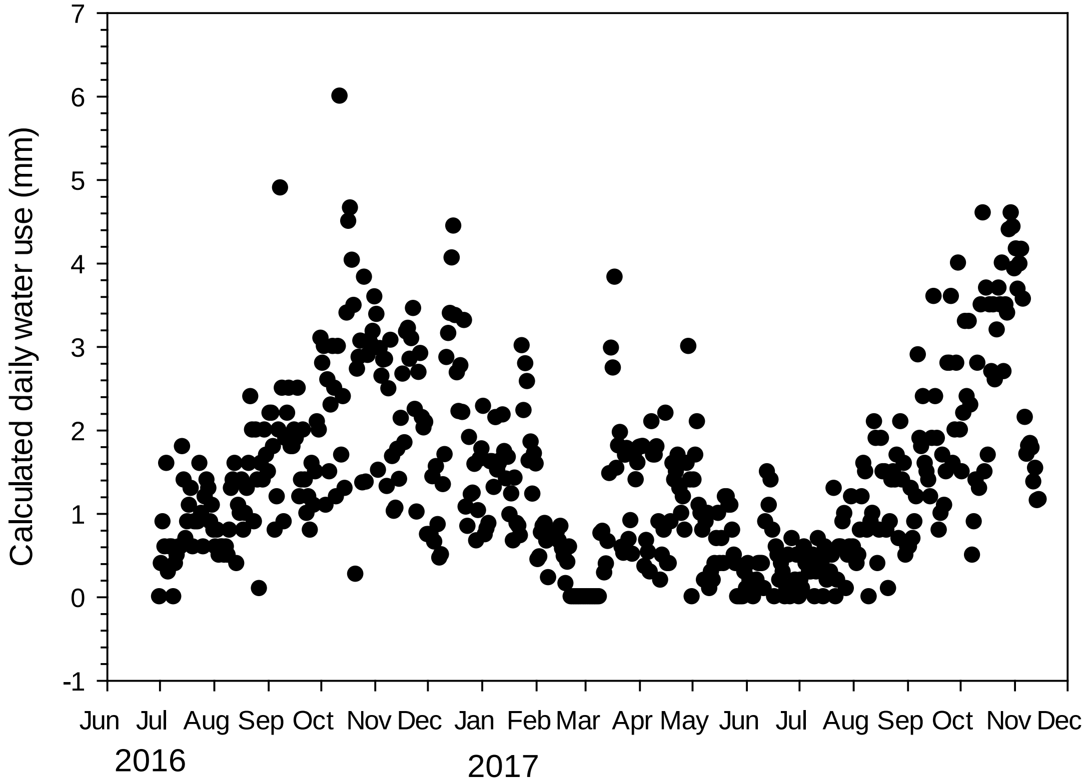


Figure 4.4: Daily water use from 1st July 2016 to 15th November 2017, from Plot 3 at Ashley Dene, Canterbury.

Calculated daily water use from Plot 3 was plotted against the daily PET to identify periods of potential water stress from 1st July 2016 to 15th November 2017 (Figure 4.5). Daily water use (as calculated earlier) was plotted against daily PET. The fixed 1:1 line represents when daily PET was equal to the actual daily water use. Any data points on this line are periods when no water stress has occurred. Points below the 1:1 line are times where actual evapotranspiration is reduced because greater than half the PAWC had been depleted. The figure shows ~100 data points below the 1:1 line with the bulk of these occurring in summer, and late spring of both years due to water becoming limiting on the 17th October 2016, and 30th October 2017.

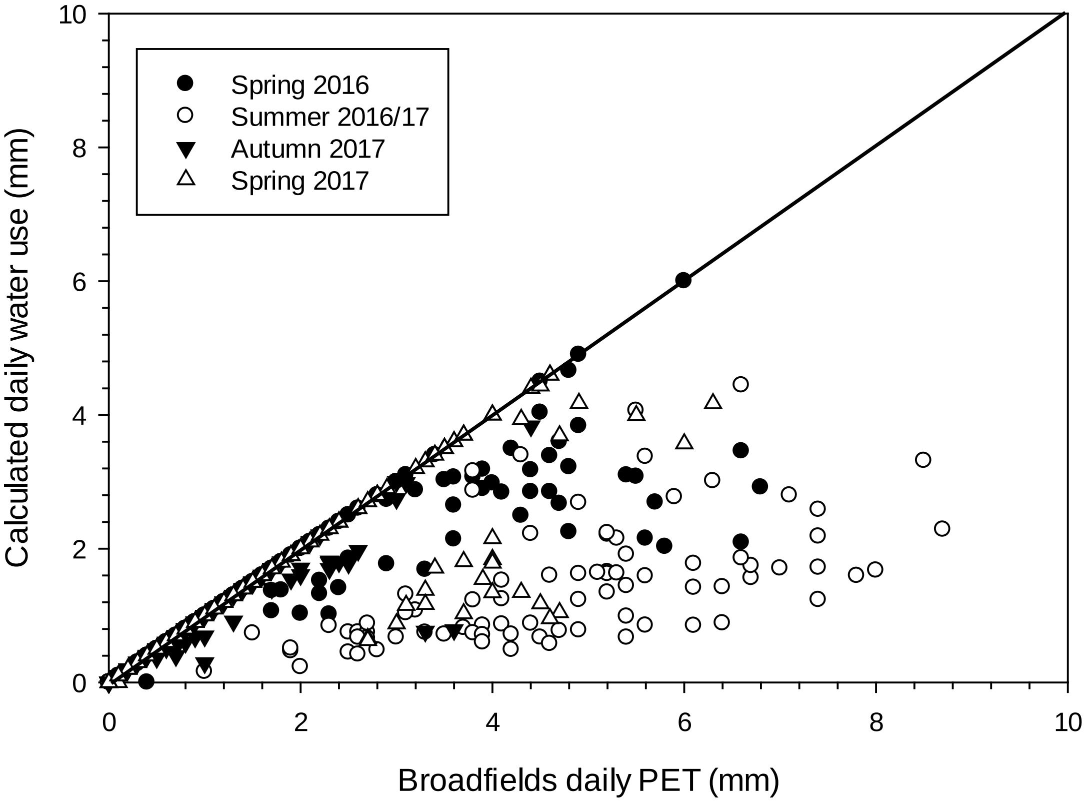


Figure 4.5: Calculated daily actual water use (mm) and daily PET (mm) calculated from Broadfields Meteorological Station, from 1st July 2016 to 15th November 2017, from Plot 3 at Ashley Dene, Canterbury.

5 ANIMAL LIVE WEIGHT AND PASTURE PRODUCTION

5.1 Introduction

The performance of an animal can be related to its diet. This in turn can be related back to pasture yield and quality, which influences carrying capacity, grazing days, and metabolisable energy and crude protein intake.

Chapter 5 quantifies the animal productivity from the four dryland pastures in Experiment 1 at Ashley Dene, Canterbury. Differences are explained in relation to pasture production, composition, and quality.

The objectives were to:-

- Quantify annual and seasonal live weight gain from the four dryland pasture treatments and relate any differences to daily live weight gain, or number of grazing days available.
- Quantify pasture growth in relation to dry matter yield and thermal time.
- Quantify seasonal and annual pasture yields based on cage cuts, and calculate pasture allocation per grazing day from these.
- Calculate the annual and seasonal metabolisable energy, crude protein, neutral detergent fibre, and acid detergent fibre yields of pastures measured by near infra-red spectrometry (NIR) analysis of pasture components and botanical composition.

5.2 Annual live weight gain (LWG)

The mean total LWG (kg/ha) was accumulated for each pasture within each of these two years of the 'MaxAnnuals' experiment (2016/17 and 2017/18). Annual live weight gain differed ($P<0.001$) between years, averaging 511 (±48.6) kg/ha in 2016/17, and 635 (±59.7) kg/ha in 2017/18 (Table 5.1). However, there was no difference in annual live weight gain among pastures in 2016/17 ($P=0.644$) or 2017/18 ($P=0.801$).

Orthogonal contrasts indicated there were also no differences in annual live weight gain between CF and PL ($P=0.634$), or Sub and S+B ($P=0.910$) pastures.

Table 5.1: Annual live weight gain (kg/ha) from sheep grazing one of four dryland plantain or cocksfoot based pastures at Ashley Dene, Canterbury.

Pasture	2016/17	2017/18
CF/Sub	492	614
CF/S+B	538	616
PL/Sub	528	665
PL/S+B	485	645
Mean	511 b	635 a
S.E.M.	16.3	
P-value	**<0.001**	

Note: Means followed by the same letter are not different at the α=0.05 level.

In 2016/17, the live weight production in spring and summer could be assessed. However, in 2017/18, data were only collected in the spring period so the between year comparison focusses on the pre-weaning live weight gain in spring. During spring of both years, all pastures were stocked with lactating ewes with twin lambs at foot (LAF) during spring. This LAF live weight gain accounted for 74-77% of total annual LWG in 2016/17, and 88-92% in 2017/18 (Figure 5.1). A loss in lactating ewe live weight was observed in plantain pastures in 2016/17. This loss is shown by the bars extending below the 0-point in Figure 5.1. Weaned lambs in summer accounted for 22-23% of total annual LWG in 2016/17. No weaned lamb data were able to be collected in summer 2017/18 because treatments were not stocked due to a lack of pasture growth (Section 4.5).

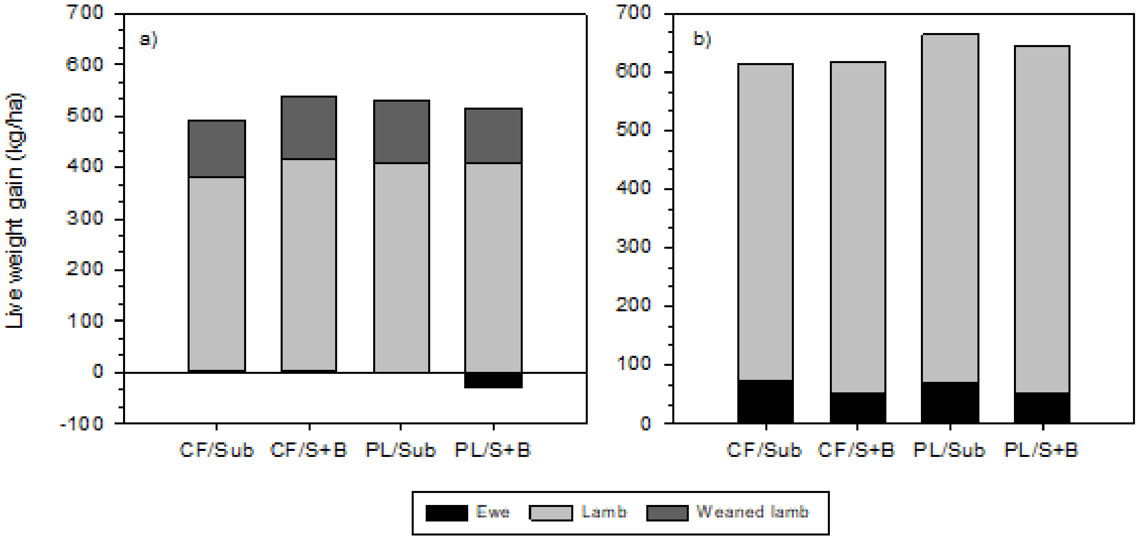


Figure 5.1: Total live weight gain (kg/ha) for lactating ewes, lambs at foot, and weaned lambs in (a) 2016/17 and (b) 2017/18 on four different pastures at Ashley Dene, Canterbury. Acronyms for pastures are given in Table 5.1.

5.3 Annual pasture yield

Mean total annual pasture yields did not differ (P=0.118) between years averaging 5684 (±254.3) kg DM/ha. Figure 5.2 shows the yield on offer for each treatment during each season across both years. In 2016, annual pasture yields include spring, summer, and autumn. However, in 2017, only spring yields were measured as this was the only season that grazing events took place in that year. Annual pasture yields among treatments did not differ (P=0.512) in 2016/17, but did differ among treatments (P=0.087) in 2017/18, with orthogonal contrasts indicating that PL pastures yielded 5768 kg DM/ha which was higher (P=0.029) than that from CF pastures of 4995 kg DM/ha.

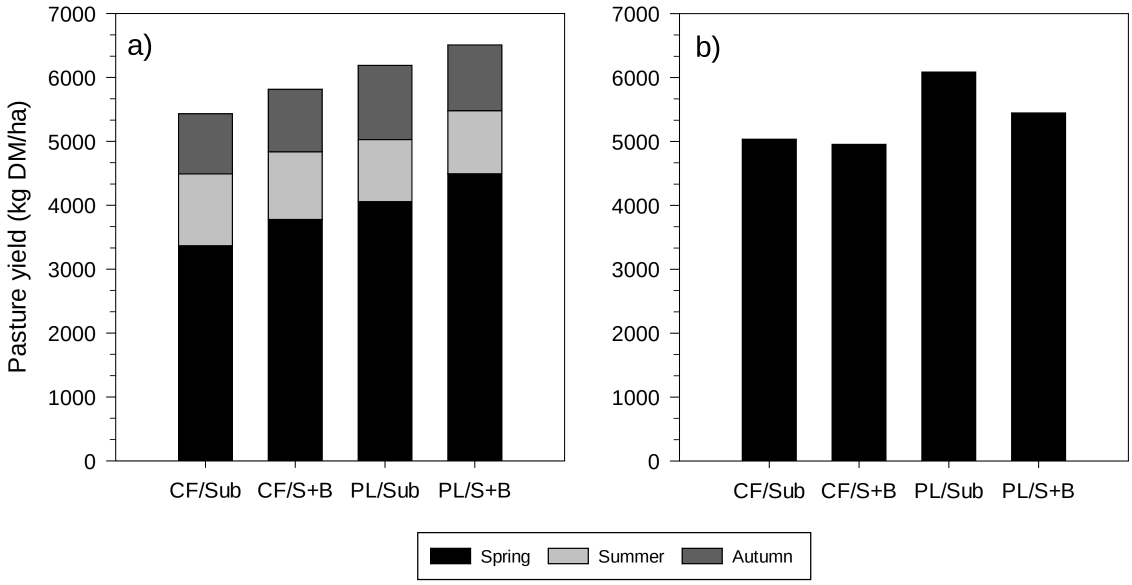


Figure 5.2: Total annual pasture yield (kg DM/ha) from four dryland pastures divided into seasonal grazing periods that match live weight gain measurements in (a) 2016/17 and (b) 2017/18 at Ashley Dene, Canterbury. Treatment acronyms are listed in Table 3.3.

5.4 Spring

5.4.1 Live weight gain

5.4.1.1 Lambs

Live weight gain from lambs at foot was lower (P<0.001) in spring 2016 at 402 (±26.9) kg LWG/ha compared with 574 kg/ha in the spring of 2017 (Table 5.2). Lambs at foot across all pasture types were not different in 2016 (P=0.624) or 2017 (P=0.726).

Orthogonal contrasts across years also indicated there were no differences in live weight gain from lambs at foot between CF and PL (P=0.324), or Sub and S+B pastures (P=0.643).

Table 5.2. Live weight gain (kg/ha) from lambs at foot on four dryland pastures during spring 2016 and spring 2017 at Ashley Dene, Canterbury.

Treatment	2016	2017
CF/Sub	380	542
CF/S+B	410	565
PL/Sub	410	595
PL/S+B	407	594
Mean	402 b	574 a
S.E.M.	12.3	
P-value	**<0.001**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

Individual lamb live weights were averaged for each treatment and linear regression lines fitted to estimate growth rates (Figure 5.3). There were only two points in 2016, so no coefficient of determination is presented. But it was assumed that in 2016, lamb growth would have followed the same linear growth trend as in 2017, so growth rates were predicted from the two points. The two years of lamb live weight data were used to analyse the change in live weight (finish weight – start weight) and this was run as 't'-tests to identify any differences in growth rates among the treatments during each spring. 't'-tests analysis did not identify any differences in lamb growth rates among treatments in either spring, but did identify a difference between CF and PL lambs across years. The results showed that PL lambs grew at 339 g/hd/d, which was faster (P=0.048) than CF lambs averaging 301 g/hd/d.

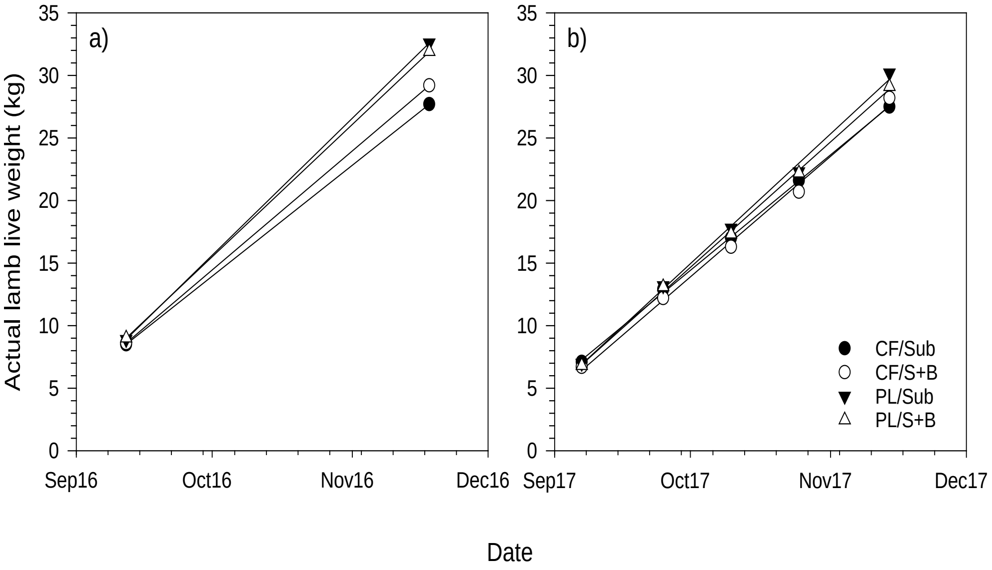


Figure 5.3: Lamb live weights during (a) spring 2016 and (b) spring 2017, from four dryland pastures at Ashley Dene, Canterbury. Treatment acronyms are listed in Table 3.3. Regression equations for 2016 and 2017 are listed in Table 5.3.

Table 5.3: Regression equations for lamb growth rates during spring 2016 and 2017, from four dryland pastures at Ashley Dene, Canterbury.

	2016	**2017**
CF/Sub	= 0.287x	= 0.298 x $R^2 = 0.99$
CF/S+B	= 0.308 x	= 0.311x $R^2 = 0.99$
PL/Sub	= 0.354x	= 0.335x $R^2 = 0.99$
PL/S+B	= 0.342x	= 0.324x $R^2 = 0.99$

Treatment acronyms are listed in Table 3.3.

5.4.1.2 Ewes

There were differences between years for spring LWG from ewes (Table 5.5). Lactating ewes in 2016 lost an average of 6 kg/ha ($P<0.001$), while ewes in 2017 gained an average of 61 kg/ha.

There were also live weight gain differences for ewes among treatments in both years (Table 5.5). The ewe weights at the beginning of the live weight period were variable (Table 5.4) due to the initial stocking process and this is likely to have caused differences in live weight among treatments. Ewes and lambs were placed in the trial plots as they became available from the main lambing flock. This meant it was not an option to wait until lambing had finished because pastures were growing rapidly so ewes were not sorted into similar weight groups before placing them on the plots. In 2016, CF pastures produced the highest live weight gain of 3.8 (±1.3) kg/ha), PL/Sub pastures lost 0.8 kg/ha. Ewes on PL/S+B pastures were the heaviest (Table 5.4) at the beginning of the spring live weight period. The most (P<0.001) weight (30.3 kg/ha) was lost from ewes on these pastures. In spring 2017, Sub pastures achieved the highest lactating ewe live weight gain of 70.8 (±5.4) kg/ha, while the additional balansa was not helpful with S+B pastures producing the lowest (P=0.002) gains of 50.7 (±5.4) kg/ha. Ewes on PL/S+B pastures were ~2 kg heavier than those on the remaining three pastures. This may have been a factor in the lower live weight gain from S+B pastures.

Table 5.4: Mean live weight (kg) of ewes (after lambing) at the time of introduction to the experimental area from four dryland pastures during spring 2016 and 2017 at Ashley Dene, Canterbury.

Treatment	**2016**	**2017**
CF/Sub	75.2 c	75.3 b
CF/S+B	80.9 a	75.8 b
PL/Sub	78.4 b	75.9 b
PL/S+B	81.1 a	77.9 a
S.E.M.	1.4	0.6
P-value	**0.004**	**<0.001**

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

Combining the two years, orthogonal contrasts showed that ewes gained 33 kg/ha from CF pastures which was higher (P<0.001) than the 22 kg/ha from PL pastures. Ewes grazing Sub pastures also gained 36 kg/ha which was more (P<0.001) than the 19 kg/ha gained from S+B pastures.

Table 5.5: Spring live weight gain (kg/ha) of lactating ewes on four dryland pastures during spring 2016 and spring 2017 at Ashley Dene, Canterbury.

Treatment	**2016**	**2017**
CF/Sub	3 a	72 a
CF/S+B	5 a	51 b
PL/Sub	-1 b	69 a
PL/S+B	-30 c	51 b
Mean	-6 b	61 a
S.E.M.	1.4	
P-value	**<0.001**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

Ewe live weights were recorded at the beginning and end of every live weight rotation. Actual ewe live weights were averaged for each treatment and were plotted with linear regression lines fitted and growth rates predicted (Figure 5.4). There were only two points in 2016, so no coefficient of determination is presented. Spring 2016 ewe growth rates averaged 9 g/hd/d and a loss of 43 g/hd/d on CF/Sub and CF/S+B pastures, respectively. Similarly, ewes on PL/Sub pastures lost 46 g/hd/d, and also lost 61 g/hd/d on PL/S+B pastures.

The actual ewe live weights were variable among treatments throughout the spring 2017 period, but a single linear regression was still fitted to get an average growth rate among the pastures. Spring 2017 ewe growth rates averaged 51 g/hd/d and 41 g/hd/d on CF/Sub and CF/S+B pastures, respectively. While ewes on PL/Sub pastures gained 9 g/hd/d, and 33 g/hd/d on PL/S+B pastures.

The live weight data were also used to analyse the overall change in live weight between the start and end of both spring periods by ‘t’-tests. These found no differences in ewe growth rates among pastures. This meant ewes in 2016 averaged a loss of 35 g/hd/d in 2016, and gained an average of 34 g/hd/d in 2017 among all pastures.

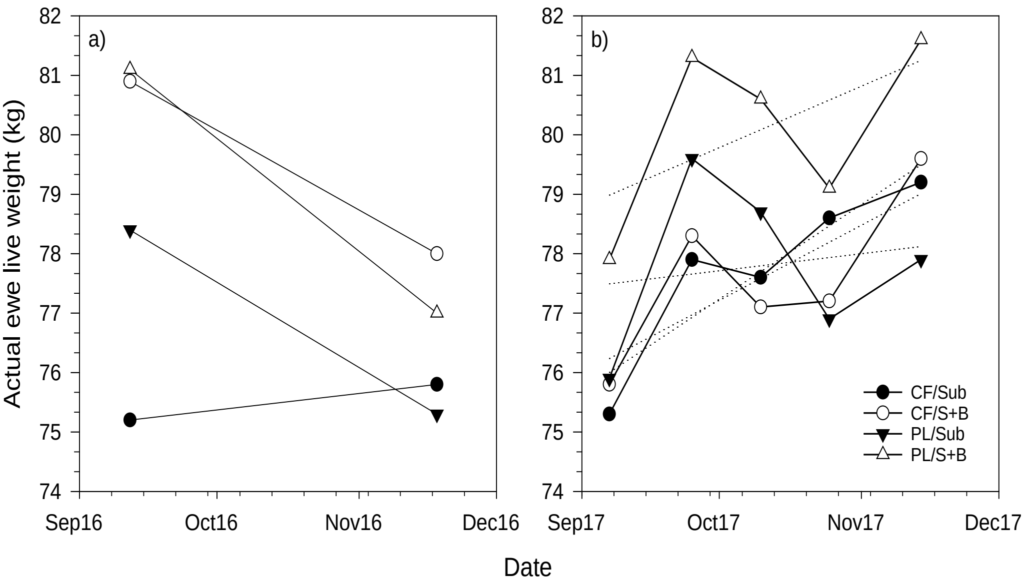


Figure 5.4: Ewe live weights during (a) spring 2016 and (b) spring 2017, from four dryland pastures at Ashley Dene, Canterbury. Treatment acronyms are listed in Table 3.3. Growth rates for 2016 and regression equation and R^2 values for 2017 are listed in Table 5.6. The dotted lines represent the regression lines fitted in 2017.

Table 5.6: Growth rates, and regression equations and R^2 values for ewe growth rates during spring 2016 and 2017, from four dryland pastures at Ashley Dene, Canterbury.

	2016	2017
CF/Sub	= 0.009*x*	0.051*x* R^2=0.82
CF/S+B	= -0.043*x*	0.041*x* R^2=0.57
PL/Sub	= -0.046*x*	0.009*x* R^2=0.02
PL/S+B	= -0.061*x*	0.033*x* R^2=0.31

Treatment acronyms are listed in Table 3.3.

5.4.1.3 *Ewe vs lamb growth rates*

Ewe growth rates were plotted against lamb growth rates (Figure 5.5). There was no relationship (R^2 = 0.009) between ewe and lamb growth rates in 2016 (Figure 5.5), with lamb growth rates ranging from 314 g/hd/d from ewes losing 200 g/hd/d, to 319 g/hd/d from ewes gaining 100 g/hd/d. During spring 2017, the relationship differed with ewes growing ≤100 g/hd/d supporting lambs with growth rates less than 318 g/hd/d, whereas the lambs of ewes growing greater than 200 g/hd/d were growing in excess of 342 g/hd/d.

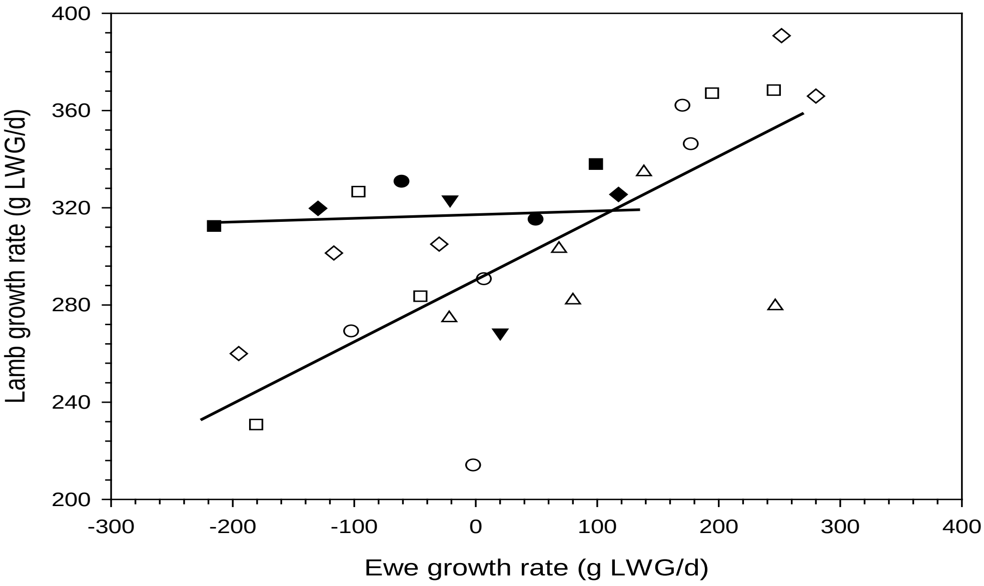


Figure 5.5: Ewe growth rates vs lamb growth rates (g/hd/d) during spring 2016 and spring 2017 at Ashley Dene, Canterbury. Regression equation and R^2 values are listed in Table 5.7. Treatment acronyms are listed in Table 3.3. Closed symbols relate to 2016, and open symbols are 2017. CF/Sub (▲,△), CF/S+B (●,○), PL/Sub (◆,◇), PL/S+B (■,□).

Table 5.7: Regression equations for ewe vs. lamb growth rates from four dryland pastures during spring 2016 and 2017 at Ashley Dene, Canterbury.

	2016	**2017**
Ewe vs lamb growth rate	= 0.018x + 317.1	= 0.231x + 295.5
	R^2 = 0.009	R^2 = 0.52

Treatment acronyms are listed in Table 3.3.

5.4.2 Grazing days

Spring 2016 resulted in an average GD/ha for lactating ewes plus lambs at foot across all four pastures of 649 GD/ha. Spring 2017 achieved 1229 GD/ha, which was 47% more (P<0.001) than in

2016 (Figure 5.6). Orthogonal contrasts across years indicated there were no differences in spring grazing days between CF and PL (P=0.677), or Sub vs S+B pastures (P=0.763).

Graze days per hectare (GD/ha) were comparable among pastures within both years and stock classes (Figure 5.6). In 2016, there was no GD/ha difference (P=0.522) among pastures for lactating ewes. Lactating ewes averaged 217 (±23.3) GD/ha. Grazing days also did not differ (P=0.474) among pastures for lambs at foot, which averaged 432 (±46.6) GD/ha in 2016.

In 2017, there was also no difference in GD/ha among pastures within stock classes. Lactating ewes (P=0.707) averaged 410 (±41.8) GD/ha, while lambs at foot (P=0.707) averaged 819 (±83.6) GD/ha.

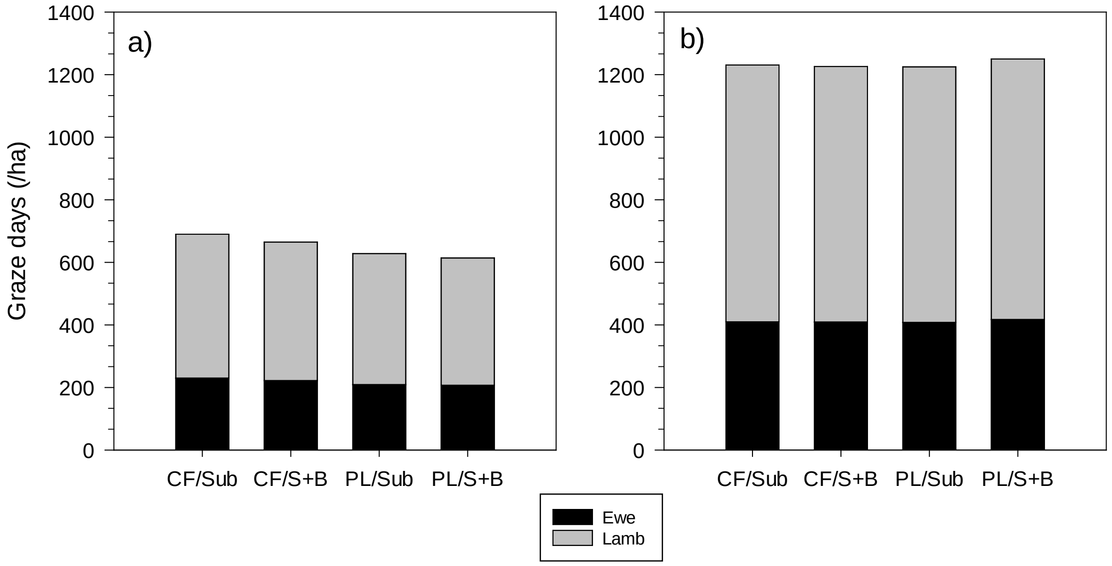


Figure 5.6: Grazing days (/ha) from lactating ewes and lambs at foot from four dryland pastures during (a) spring 2016 and (b) spring 2017 at Ashley Dene, Canterbury. Treatment acronyms are listed in Table 3.3.

5.4.3 Pasture growth

5.4.3.1 Pasture growth rates related to thermal time

Pasture growth per degree day averaged 6.4 kg DM/°C day in spring 2016, which was slower (P<0.001) than the 10.4 kg DM/°C day during spring 2017 (Table 5.8). There were no differences among treatments for spring pasture growth rates in 2016 (P=0.108) or 2017 (P=0.282). There were no differences in growth rates across years between CF and PL pastures (P=0.336), and Sub and S+B pastures (P=0.141).

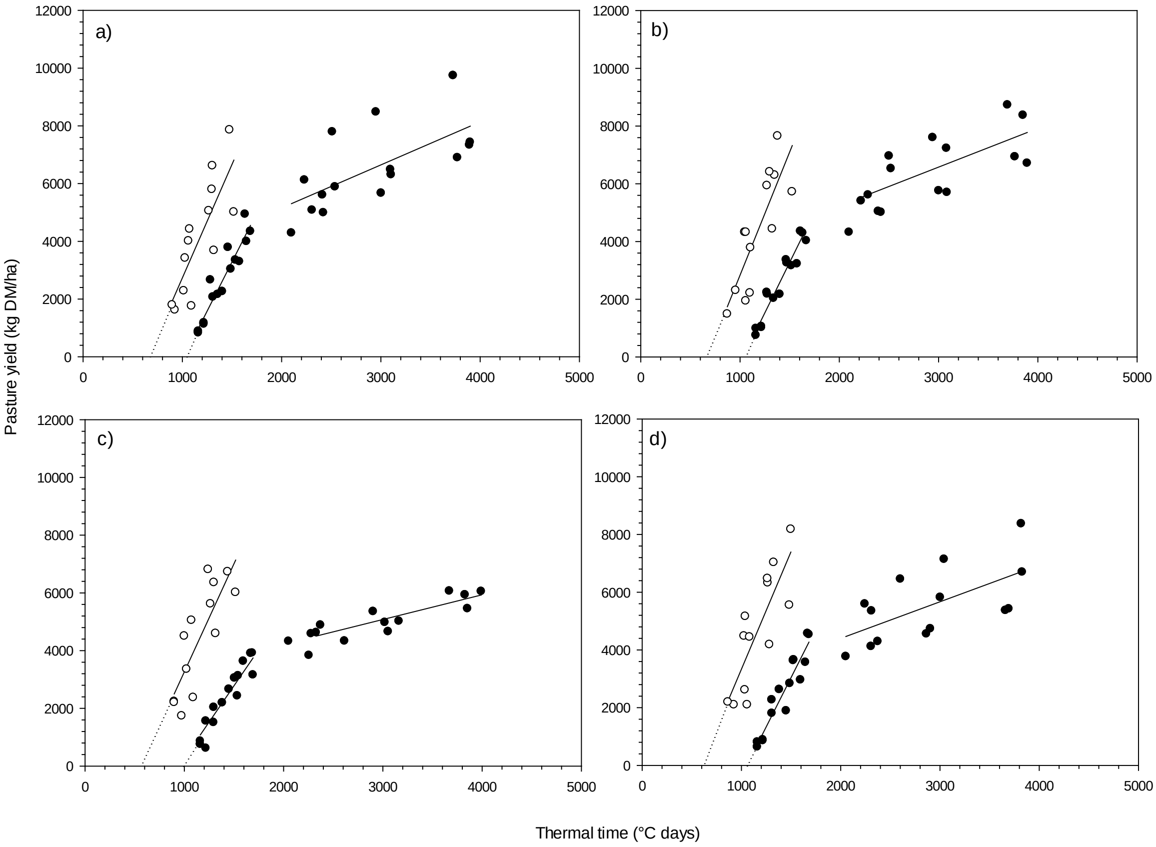


Figure 5.7: Plot specific examples of pasture yield (kg DM/ha) and related thermal time (°C days) from a) CF/Sub Plot 6, b) CF/S+B Plot 3, c) PL/Sub Plot 1, and d) PL/S+B Plot 2, during 2016 and 2017 at Ashley Dene, Canterbury. Regression lines are fitted to the spring 2016 and summer/autumn period in 2016/17, and the spring 2017 period. Growth rates for the spring periods are listed in **Table 5.8**.

Table 5.8: Pasture growth rates per degree day (kg DM/°C day) from four dryland pastures during spring 2016 and spring 2017 at Ashley Dene, Canterbury.

Treatment	**2016**	**2017**
CF/Sub	6.82	9.58
CF/S+B	6.76	11.4
PL/Sub	5.56	10.4
PL/S+B	6.56	10.3
Mean	6.42 b	10.43 a
S.E.M.	0.274	
P-value	**<0.001**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

5.4.3.2 Initiation of pasture growth

Thermal time was accumulated from the 1st April of each year. Pasture growth began at 1023 °Cd which related to 5th June in 2016, which was later (P<0.001) than in 2017 at 742 °Cd (18th May) (Table 5.9). There were no differences in pasture growth initiation among treatments in 2016 (P=0.163), but a trend was identified in 2017 that suggested CF pastures began growing later (P=0.051) at 770 °Cd (20th May), which was later than PL pastures at 715 °Cd (16th May).

Orthogonal contrasts across years found that initiation of CF growth was 896 °Cd (~28th May), which was later (P=0.026) than PL pastures at 869 °Cd (~26th May). A trend was also identified that suggested Sub pastures may have begun growing earlier (P=0.072) at 872 °Cd (~26th May), compared with 893 °Cd (~28th May) from S+B pastures.

Table 5.9: Initiation of pasture growth (°C days) accumulated from the 1st April of each year, from four dryland pastures during 2016 and 2017 at Ashley Dene, Canterbury.

Treatment	2016		2017
CF/Sub	1020		752
CF/S+B	1026		787
PL/Sub	998		718
PL/S+B	1048		711
Mean	1023 $_a$		742 $_b$
S.E.M.		14.9	
P-value		**<0.001**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

5.4.4 Pasture yields and allocation

5.4.4.1 Prior to set-stocking

There was no difference in the timing of the last grazing before set-stocking (Appendix 1-Appendix **4**) and there was no winter grazing in 2016 and 2017. Thus, each year had approximately four months of pasture growth before animals entered the experiment in spring. Pasture yields prior to set-stocking in spring differed between years (P<0.001). Yields in 2016 averaged 931 (±46.1) kg DM/ha which was less (P<0.001) than 50% of the 2065 (±46.1) kg DM/ha achieved in 2017. There were no differences among treatments in 2016 (P=0.542) or 2017 (P=0.405). There were no differences in pasture yields across years prior to set-stocking between CF and PL (P=0.518), or Sub and S+B pastures (P=0.949).

Table 5.10: Pasture yield (kg DM/ha) from cage cuts from four dryland pastures prior to set-stocking at the beginning of spring from 2016 and spring 2017 at Ashley Dene, Canterbury.

Treatment	2016-17		2017-18
CF/Sub	1011		1869
CF/S+B	958		1991
PL/Sub	953		2142
PL/S+B	801		2256
Mean	931 $_b$		2065 $_a$
S.E.M.		46.1	
P-value		**<0.001**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

5.4.4.2 Total spring yields and allocation

Total spring pasture yields differed (P=0.002) between years (Table 5.11). Yields in 2017 were 5.4 t DM/ha which was 38% more than the 3.9 t DM/ha achieved in 2016. This meant that on average, over the ~100-day spring period, pastures in 2016 grew at approximately 39 kg DM/ha/d, and 54 kg DM/ha/d in 2017, based on cage cut data. Spring pasture yields did not differ among treatments within years in 2016 (P=0.456), but orthogonal contrasts across years showed there was 5021 kg DM/ha from PL pastures, which was more (P=0.005) than the 4284 kg DM/ha from CF pastures. There was not difference between Sub and S+B pastures (P=0.875).

Table 5.11: Pasture yield (kg DM/ha) from cage cuts from four dryland pastures during spring 2016 and spring 2017 at Ashley Dene, Canterbury.

Treatment	2016		2017
CF/Sub	3367		5034
CF/S+B	3778		4955
PL/Sub	4057		6087
PL/S+B	4493		5448
Mean	3924 $_b$		5381 $_a$
S.E.M.		255.7	
P-value		**0.002**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

Mean pasture allocation for spring 2016 was 6.7 kg DM/ewe GD (4.9% of final ewe and lamb live weight), which was lower (P=0.003) than the 10.0 kg DM/ewe GD (7.2% of final ewe and lamb live weight) allocated in spring 2017 (Table 5.12). There was no difference among treatments in 2016 (P=0.993) or 2017 (P=0.218). There were no differences in pasture allocation across years between CF and PL (P=0.227), or Sub and S+B (P=0.437) pastures.

Table 5.12: Mean pasture allocation per ewe graze day (kg DM/ewe GD) from four dryland pastures during spring 2016 and spring 2016 at Ashley Dene, Canterbury.

Treatment	**2016**	**2017**
CF/Sub	6.6	9.4
CF/S+B	6.7	8.3
PL/Sub	6.7	9.2
PL/S+B	6.9	13.2
Year mean	6.7 $_b$	10.0 $_a$
S.E.M.	0.63	
P-value	**0.003**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

5.4.4.3 Monthly pasture yields and allocation during spring

Spring yield data were not collected during July and August in 2016, but were collected every month in 2017.

During the first month of the live weight period in September (Table 5.13), pasture yields differed between years (P<0.001). In 2016, yields were 1514 (±147.7) kg DM/ha which was only 51% of the 2970 (±170.3) kg DM/ha in 2017. There were no differences among treatments in September 2016 (P=0.582) or in 2017 (P=0.209). There were no differences in pasture yields across years during September between CF and PL (P=0.898), or Sub and S+B pastures (P=0.320).

Table 5.13: Pasture yield (kg DM/ha) from cage cuts from four dryland pastures during September during 2016/17 and 2017/18 at Ashley Dene, Canterbury.

Treatment	**2016-17**	**2017-18**
CF/Sub	1678	2648
CF/S+B	1538	3066
PL/Sub	1423	2913
PL/S+B	1418	3254
Year mean	1514 $_b$	2970 $_a$
S.E.M.	48.2	
P-value	**<0.001**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

Mean pasture allocation (kg DM/ewe GD) during September (Table 5.14) did not differ between years (P=0.209) averaging 10.0 (±0.72) kg DM/ewe GD across both years. There was also no difference in September pasture allocation among treatments in 2016 (P=0.710) or 2017 (P=0.414). Orthogonal contrasts across years indicated there were no differences in pasture allocation during September between CF and PL (P=0.526), or Sub and S+B pastures (P=0.955).

Table 5.14: Mean pasture allocation (kg DM/ewe GD) from four dryland pastures during September 2016 and September 2017 at Ashley Dene, Canterbury.

Treatment	2016		2017
CF/Sub	9.8		10.3
CF/S+B	9.9		8.2
PL/Sub	11.9		7.6
PL/S+B	10.9		11.0
Year mean	10.6		9.3
S.E.M.		0.72	
P-value		0.209	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

During October (Table 5.15), pasture yields differed between years (P<0.001). In 2016/17, yields were 1617 (±131.3) kg DM/ha which was less than the 2877 (±131.3) kg DM/ha achieved in 2017/18. There were no differences among treatments in October 2016/17 (P=0.331) or 2017/18 (P=0.311). There were no differences in pasture yields across years during October between CF and PL (P=0.854), or Sub vs S+B pastures (P=0.295).

Table 5.15: Pasture yield (kg DM/ha) from cage cuts from four dryland pastures during October 2016 and October 2017 at Ashley Dene, Canterbury.

Treatment	2016		2017
CF/Sub	1720		2648
CF/S+B	1739		2919
PL/Sub	1413		2976
PL/S+B	1595		2964
Year mean	1617 b		2877 a
S.E.M.		99.2	
P-value		**<0.001**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3

Mean pasture allocation during October was 6.1 (±0.93) kg DM/ewe GD in 2016, which was lower (P=0.033) than the 9.3 (±0.93) kg DM/ewe GD during 2017 (Table 5.16). A trend was identified (P=0.093) among treatments in 2016. This suggested that CF pastures had a mean pasture allocation of 6.5 kg DM/ewe GD, which was higher than the 5.7 kg DM/ewe GD allocated from PL pastures. There were no differences among treatments in 2017 (P=0.421). There were no differences across years in pasture allocation during October between CF and PL (P=0.151), or Sub vs S+B pastures (P=0.793).

Table 5.16: Mean pasture allocation (kg DM/ewe GD) from four dryland pastures during October 2016 and October 2017 at Ashley Dene, Canterbury.

Treatment	2016		2017
CF/Sub	6.6		7.7
CF/S+B	6.4		8.7
PL/Sub	5.2		7.3
PL/S+B	6.2		13.4
Mean	6.1 b		9.3 a
S.E.M.		0.93	
P-value		**0.033**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

During November (Table 5.17), pasture yields did not differ between years (P<0.069), but a trend was identified that suggested pastures yields of 1063 kg DM/ha were lower in 2016 than the 1267 kg DM/ha in 2017. Orthogonal contrasts also indicated there were no differences in pasture yields during November between CF and PL (P=0.662), or Sub and S+B pastures (P=0.778).

Table 5.17: Pasture yield (kg DM/ha) from cage cuts from four dryland pastures during November 2016 and November 2017 at Ashley Dene, Canterbury.

Treatment	2016		2017
CF/Sub	1034		1291
CF/S+B	989		1434
PL/Sub	1069		1212
PL/S+B	1161		1132
Year mean	1063		1267
S.E.M.		68.6	
P-value		**0.069**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

November pasture allocation was 7.7 kg DM/ewe GD in 2016, which was lower (P=0.010) than the 14.4 kg DM/ewe GD in 2017 of 11.1 kg DM/ewe GD (Table 5.18). There were no differences in mean November pasture allocation among treatments in 2016 (P=0.288) or 2017 (P=0.268). There were no differences in pasture allocation across years during November between CF and PL (P=0.151), or Sub vs S+B pastures (P=0.793).

Table 5.18: Mean pasture allocation (kg DM/ewe GD) from four dryland pastures during November 2016 at Ashley Dene, Canterbury.

Treatment	**2016**	**2017**
CF/Sub	8.3	12.9
CF/S+B	8.2	10.7
PL/Sub	7.0	16.8
PL/S+B	7.3	17.1
Mean	7.7 $_b$	14.4 $_a$
S.E.M.	1.4	
P-value	**0.010**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

5.4.5 Stocking rates per hectare

Stocking rates differed between years (P<0.001) averaging 9.1 ewes per hectare in spring 2016, and 12.7 ewes in spring 2017. This was expected given the differences in starting covers between years and demonstrates that the pastures were stocked based on herbage on offer. Stocking rates did not differ (P=0.149) among treatments in 2016, or within 2017 (P=0.976). There were no differences in stocking rates per hectare across years between CF and PL (P=0.283), or Sub vs S+B pastures (P=0.885).

Table 5.19: Mean stocking rate (/ha) of lactating ewes on four dryland pastures during spring 2016 and spring 2017 at Ashley Dene, Canterbury.

Treatment	**2016**	**2017**
CF/Sub	9.4	12.7
CF/S+B	9.2	12.8
PL/Sub	9.0	12.6
PL/S+B	8.8	12.9
Year mean	9.1 $_b$	12.7 $_a$
S.E.M.	0.24	
P-value	**<0.001**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

5.4.5.1 Monthly stocking rates per hectare

During September, mean stocking rate was 7.9 ewes/ha in 2016 which was lower (P<0.001) than the 14.1 ewes/ha in 2017 (Table 5.20). There were differences among treatments in 2016, with CF/S+B pastures having the highest (P=0.017) mean stocking rate of 9.4 ewes/ha, while PL/S+B had the lowest of 6.0 ewes/ha. There were no differences (P=0.930) among treatments during

September 2017. There were also no differences across years from CF and PL pastures (P=0.146) or Sub and S+B pastures (P=0.513).

Table 5.20: Mean stocking rate (/ha) of lactating ewes on four dryland pastures during September 2016 and September 2017 at Ashley Dene, Canterbury.

Treatment	2016	2017
CF/Sub	8.9 ab	13.7
CF/S+B	9.4 a	14.6
PL/Sub	7.2 bc	13.8
PL/S+B	6.0 c	14.3
Year mean	7.9 b	14.1 a
S.E.M.	0.56	
P-value	**<0.001**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

The mean stocking rate during October was 10.0 ewes/ha in 2016, which was lower (P<0.001) than the 14.0 ewes/ha in 2017 (Table 5.21).

Table 5.21: Mean stocking rate (/ha) of lactating ewes on four dryland pastures during October 2016 and October 2017 at Ashley Dene, Canterbury.

Treatment	2016	2017
CF/Sub	10.2	14.2
CF/S+B	9.8	14.1
PL/Sub	9.8	13.6
PL/S+B	10.0	14.0
Year mean	10.0 b	14.0 a
S.E.M.	0.08	
P-value	**<0.001**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

There was no difference (P=0.760) in November stocking rate between years averaging 9.3 ewes/ha. Differences were observed among treatments in 2017. CF/Sub pastures had the highest (P=0.007) mean stocking rate during November 2017 of 9.8 ewes/ha, while CF/S+B pastures had the lowest with 9.1 ewes/ha.

Table 5.22: Mean stocking rate (/ha) of lactating ewes on four dryland pastures during November 2016 and November 2017 at Ashley Dene, Canterbury.

Treatment	**2016**	**2017**
CF/Sub	8.6	9.8
CF/S+B	8.2	9.1
PL/Sub	9.8	9.5
PL/S+B	10.0	9.3
Year mean	9.1	9.4
S.E.M.	0.60	
P-value	0.760	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

5.4.5.2 Pasture cover vs stocking rates

An asymptotic curve was fitted to explain the relationship between pasture cover and stocking rate. Stocking rates increased with pasture cover up until a point of ~2000 kg DM/ha, where the curve starts to level off. (Figure 5.8). This meant that stocking rates only ranged from ~13-14 ewes/ha with pasture yields ranging from 2000 to 3000 kg DM/ha.

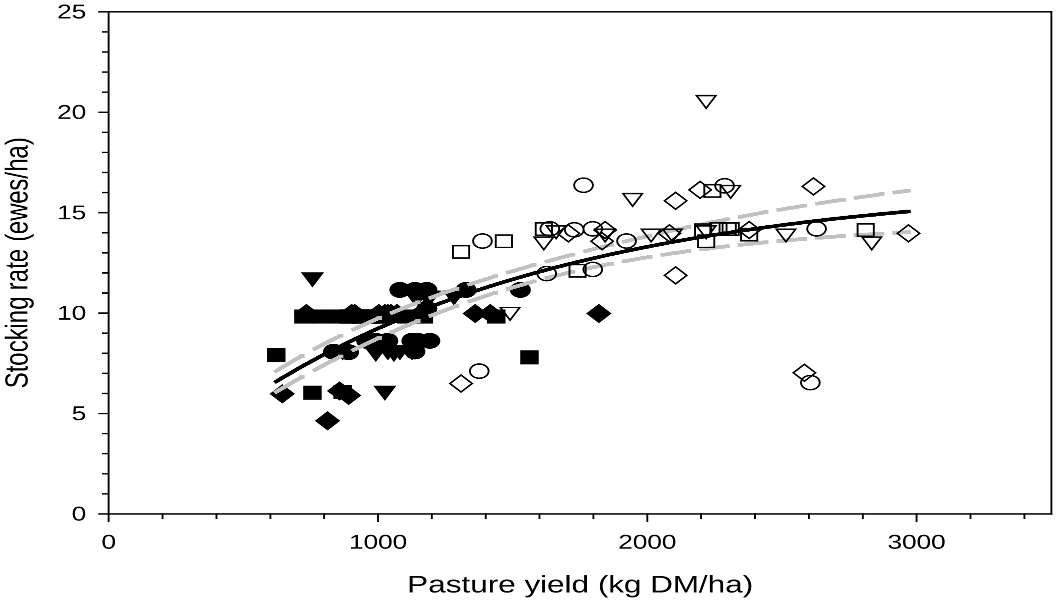


Figure 5.8: Pasture cover (kg DM/ha) vs stocking rate (ewes/ha) by pasture type and year from four dryland pastures during spring 2016 and spring 2017 at Ashley Dene, Canterbury. The dashed lines represent the 95% confidence interval. The regression equation is $y=16.5*(1-\exp(8.196^{-004})*x)$, $R^2=0.55$. Treatment acronyms are listed in Table 3.3.

5.4.6 Spring nutritive value

The metabolisable energy (ME), crude protein (CP), neutral detergent fibre (NDF), and acid detergent fibre (ADF) contents of the major pasture components during spring 2016 and spring 2017 are shown in Table 5.23.

Metabolisable energy averaged 10.6 (±0.08) MJ ME/kg DM during spring 2016 (Table 5.23), which was lower (P<0.001) than the 11.2 (±0.08) MJ ME/kg DM during spring 2017. There were differences among pasture components in both years. During spring 2016, the highest ME content was from the cocksfoot component at 10.8 MJ ME/kg DM, while the lowest (P=0.004) was from plantain with 10.3 MJ ME/kg DM. In spring 2017, ME was highest from ryegrass at 11.6 MJ ME/kg DM, and lowest (P<0.001) from the remaining three pasture components, averaging 11.0 (±0.10) MJ ME/kg DM.

Table 5.23: Mean metabolisable energy (ME; MJ ME/kg DM) and crude protein (CP; %) content of pre-grazing pasture components from four dryland pastures during spring 2016 and spring 2017 at Ashley Dene, Canterbury.

Component	**ME**		**CP**	
	2016	**2017**	**2016**	**2017**
Cocksfoot	10.8 a	10.9 b	13.4 b	16.2 b
Plantain	10.3 c	11.1 b	11.8 c	14.0 c
Ryegrass	10.5 bc	11.6 a	12.9 bc	13.9 c
Sub clover	10.7 ab	11.0 b	15.6 a	19.3 a
Mean	10.6 b	11.2 a	13.4 b	15.8 a
S.E.M.	0.08		0.48	
P-value	**<0.001**		**0.004**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

The CP content of pasture components during spring 2016 averaged 13.4 (±0.48)%, which was lower (P=0.004) than the 15.8 (±0.48)% during spring 2017 (Table 5.23). Crude protein content also differed among years. During 2016, sub clover (including runners) yielded the highest (P<0.001) average CP of 15.6%, while plantain had the lowest with 11.8%. In spring 2017, the highest CP content was also from the sub clover component with 19.3% and lowest from plantain and ryegrass at 14.0 (±0.36)%.

The differences in ME and CP content between years supports the differences in spring live weight gain of stock between years. In spring 2016, live weight gains were lower than spring 2017. Both ME and CP content were lower during spring 2016 also.

There was no difference (P=0.122) in mean NDF content between years averaging 42.0 (±1.42)%, but there were differences among components within years (Table 5.24). During spring 2016, cocksfoot had the highest NDF content at 53.7%, and lowest (P<0.001) from sub clover with 33.3%. During spring 2017, NDF content was also highest from the cocksfoot component with 54.5%, but lowest (P<0.001) from plantain and sub clover with 30.7 (±0.61)%.

Table 5.24: Mean neutral detergent fibre (NDF; %) and acid detergent fibre (ADF; %) content of pre-grazing pasture components from four dryland pastures during spring 2016 and spring 2017 at Ashley Dene, Canterbury.

Component	**NDF**		**ADF**	
	2016	**2017**	**2016**	**2017**
Cocksfoot	53.7 a	54.5 a	30.4 a	30.4 a
Plantain	44.7 b	31.0 c	28.9 a	23.3 d
Ryegrass	43.7 b	46.0 b	29.1 a	27.0 b
Sub clover	33.3 c	30.4 c	25.7 b	25.5 c
Mean	43.8	40.1	28.5 a	26.5 b
S.E.M.	1.42		0.46	
P-value	0.122		**0.011**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

The mean ADF content was 28.5% during spring 2016 (Table 5.24), which was higher (P=0.011) than the mean for spring 2017 at 26.5%. ADF differed among components within both years. During spring 2016, cocksfoot, plantain and ryegrass components averaged 29.5 (±0.71)%, while the ADF content from sub clover was lower (P<0.001) with 25.7%. In spring 2017, the cocksfoot component had the highest (P<0.001) ADF content at 30.4%, and plantain had the lowest with 23.3%.

The differences among ME, CP, NDF, and ADF content of the pre-grazing pasture components and differences in the proportions is likely to have influenced the accumulated ME, CP, NDF, and ADF yields.

5.4.7 Metabolisable energy and crude protein yields in spring

Total spring metabolisable energy and crude protein yields on offer were calculated by multiplying the measured total mean spring pasture yield by the measured mean ME and CP contents of each plot during spring. Spring 2016 yielded a total of 39.9 GJ ME/ha which was less (P<0.001) than the 59.8 GJ/ha in spring 2017 (Table 5.25). Across years, PL pastures had a mean ME yield of 52.9 GJ/ha, which was higher (P=0.017) than the 46.7 GJ/ha from CF pastures. There were no differences between Sub and S+B pastures (P=0.271).

Table 5.25: Total metabolisable energy (GJ/ha) and crude protein yields (kg/ha) of four dryland pastures during spring 2016 and spring 2017 at Ashley Dene, Canterbury.

Component	**ME**		**CP**	
	2016	**2017**	**2016**	**2017**
CF/Sub	35.4	56.0	451	906
CF/Sub	40.8	54.7	509	888
PL/Sub	35.3	67.6	444	1099
PL/S+B	47.8	60.8	618	908
Mean	39.9 $_{b}$	59.8 $_{a}$	506 $_{b}$	950 $_{a}$
S.E.M.	2.50		43.1	
P-value	**<0.001**		**<0.001**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

There was a difference (P<0.001) in total crude protein yields between years (Table 5.25). Spring 2016 had a CP yield of 506 kg/ha which was lower than the 950 kg/ha in spring 2017. Mean CP yields did not differ among treatments in spring 2016 (P=0.321) or spring 2017 (P=0.204). Across years, PL pastures yielded 767 kg/ha, which was higher (P=0.010) than the 689 from CF pastures. There was no difference between Sub and S+B pastures (P=0.825).

5.4.8 Neutral detergent fibre and acid detergent fibre yields in summer

Total NDF yields were not different (P=0.169) between years averaging 1759 (±135.8) kg/ha. (Table 5.26). There were also no differences in NDF yields among treatments in spring 2016 (P=0.866) or spring 2017 (P=0.856). Across years, there were no differences in NDF yields between CF and PL (P=0.908), or Sub and S+B pastures (P=0.402).

Table 5.26: Total neutral and acid detergent fibre yields (kg/ha) of four dryland pastures during spring 2016 and spring 2017 at Ashley Dene, Canterbury.

Component	**NDF**		**ADF**		
	2016	**2017**	**2016**	**2017**	
CF/Sub	1538	1928	989	1350	
CF/Sub	1765	1835	1082	1332	
PL/Sub	1360	1973	970	1548	
PL/S+B	1806	1864	1263	1391	
Mean	1617	1900	1076 $_{a}$	1405 $_{b}$	
S.E.M.	135.8		83.5		83.5
P-value	0.169		**0.018**		**0.018**

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

Total ADF yields averaged 1076 kg/ha during spring 2016, which was lower (P=0.018) than the 1405 kg/ha during spring 2017 (Table 5.26). There were no differences among treatments in spring 2016 (P=0.702) or spring 2017 (P=0.345). Across years, there were no differences between CF and PL pastures (P=0.168), or Sub and S+B pastures (P=0.469).

5.5 Summer

5.5.1 Live weight gain

Mean live weight gain from weaned lambs was 115 (±14.6) kg/ha in2016/17 (Table 5.27) and not different among treatments (P=0.866).

Table 5.27. Live weight gain (kg/ha) of weaned lambs and graze days (weaned lambs/ha) on four dryland pastures during summer from 2016-2017 at Ashley Dene, Canterbury.

Treatment	Live weight gain	Graze days
CF/Sub	109	206
CF/S+B	123	166
PL/Sub	119	169
PL/S+B	109	143
Year mean	115	171
S.E.M.	14.6	27.0
P-value	0.866	0.466

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

Individual weaned lamb live weights were averaged for each treatment (Figure 5.9). Throughout the duration of the summer live weight period, weaned lambs averaged 92 g/hd/d which was not different (P=0.424) among treatments despite a ~2 kg range in starting weights (Appendix 5).

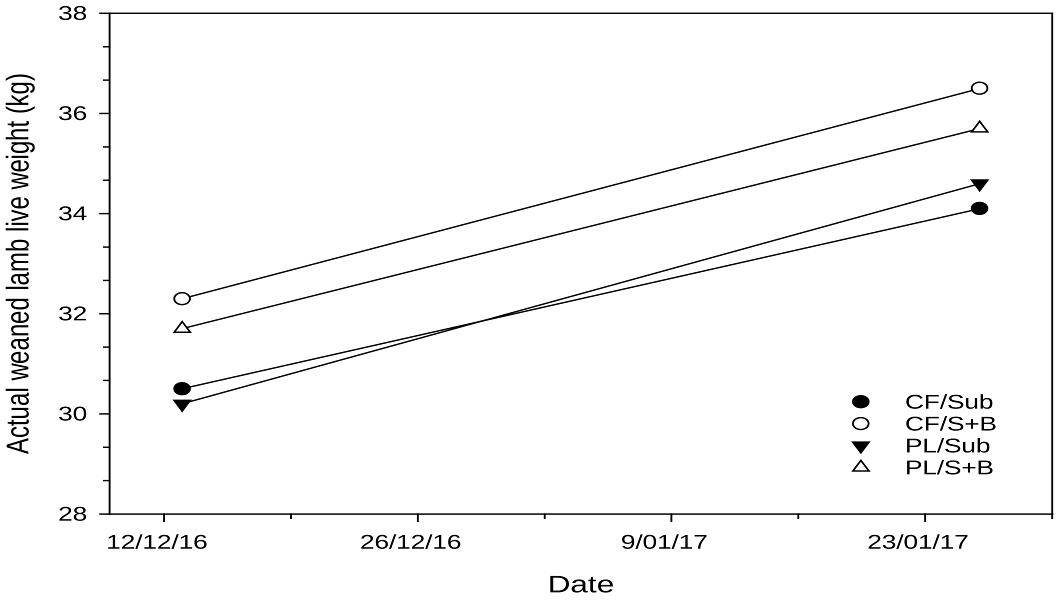


Figure 5.9: Weaned lamb growth rates during summer 2016/17, from four dryland pastures at Ashley Dene, Canterbury. Mean growth rate across all pastures was 92 g/hd/d/. Treatment acronyms are listed in Table 3.3.

5.5.2 Grazing days

The mean number of weaned lamb graze days (P=0.466) across all pastures was 171 (±27.0) GD/ha (Table 5.27).

5.5.3 Pasture yields and allocation

5.5.3.1 Total spring yields and allocation

Total pasture yield differed (P=0.483) among treatments in summer with CF pastures achieving 1091 kg DM/ha, which was higher (P<0.001) than the 588 kg DM/ha from PL pastures.

Table 5.28. Average pasture yield (kg DM/ha) from cage cuts from four dryland pastures during summer from 2016 – 2017 at Ashley Dene, Canterbury.

Treatment	**2016-17**
CF/Sub	1124 $_a$
CF/S+B	1058 $_a$
PL/Sub	533 $_b$
PL/S+B	643 $_b$
Year mean	840
S.E.M.	66.7
P-value	**<0.001**

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

5.5.3.2 Monthly pasture yields and allocation during summer

Monthly pasture yields during summer were only collected during 2016/17 when weaned lambs grazed the treatments. Pre-graze plate meter data were analysed. CF pastures yielded higher than PL pastures during all summer months. However, all four pastures followed the same declining yield trend from December through to February as water availability (Section 4.5) became a limiting factor to pasture growth (Section 4.5).

In December (Table 5.29), CF pastures averaged 1120 kg DM/ha (P=0.010) which was more (P=0.002) than the 743 kg DM/ha from PL pastures.

Table 5.29: Pasture yield (kg DM/ha) from cage cuts from four dryland pastures during December 2016, and January and February 2017 at Ashley Dene, Canterbury.

Treatment	December	January	February
CF/Sub	1085 $_a$	1111 $_a$	668 $_a$
CF/S+B	1155 $_a$	1042 $_a$	684 $_a$
PL/Sub	688 $_b$	452 $_b$	395 $_b$
PL/S+B	798 $_b$	614 $_{ab}$	509 $_b$
Year mean	931	805	564
S.E.M.	76.7	136.9	42.4
P-value	**0.010**	**0.048**	**0.003**

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

Pasture allocation during December 2016 (Table 5.30) did not differ among treatments (P=0.116), averaging 1.9 (±0.23) kg DM/weaned lamb GD, but CF pastures averaged 1.7 kg DM/weaned lamb GD, which was lower (P=0.036) than the 2.2 kg DM/weaned lamb GD from PL pastures.

Table 5.30: Mean pasture allocation (kg DM/weaned lamb GD) from four dryland pastures during December 2016 and January 2017 at Ashley Dene, Canterbury.

Treatment	December	January
CF/Sub	1.5	3.3
CF/S+B	1.8	3.8
PL/Sub	2.0	3.0
PL/S+B	2.4	3.3
Year mean	1.9	3.3
S.E.M.	0.23	0.35
P-value	0.116	0.520

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

In January, CF pastures yielded 1077 kg DM/ha from CF pastures which was more (P=0.048) than the 533 kg DM/ha from PL pastures (Table 5.29). Pasture allocation was not different among treatments (P=0.520) in January (Table 5.30), averaging 3.3 (±0.35) kg DM/weaned lamb GD.

In February (Table 5.29), there was 676 kg DM/ha from CF pastures which was more (P<0.001) than the 452 kg DM/ha from PL pastures. There were no allocation results for February as weaned lambs did not graze the plots due to insufficient feed.

5.5.4 Stocking rates per hectare

5.5.4.1 Monthly stocking rates per hectare

Weaned lamb stocking rates did not differ between December and January averaging 19.2 weaned lambs/ha on CF/Sub pastures, 17.9 weaned lambs/ha on CF/S+B pastures, 13.1 weaned lambs/ha on PL/Sub pastures, and 13.0 weaned lambs/ha on PL/S+B pastures. 't'-tests found CF pastures were stocked higher at 18.6 weaned lambs/ha (P<0.001) than PL pastures at 13.1 weaned lambs/ha.

Maintenance ewes were used for a 'clean-up' graze across the paddocks in February. February stocking rates were 93.7 ewes/ha on CF/Sub pastures, 100.5 weaned lambs/ha on CF/S+B pastures, 86.6 ewes/ha on PL/Sub pastures, and 92.3 ewes/ha on PL/S+B pastures. Maintenance ewe stocking rates averaged 97.1 ewes/ha on CF pastures which was higher (P=0.032) than the 89.5 ewes/ha on PL pastures. This shows that CF growth is vigorous during summer and is able to offer maintenance feed during the dry summer months.

5.5.5 Summer nutritive value

The mean ME, CP, NDF, ADF content from pre-graze pasture components during summer are shown in Table 5.31. There was no difference (P=0.173) in ME content, which averaged 10.0 (±0.18) MJ ME/kg DM. CP content was highest from sub clover with 13.0%, and lower from other components. The NDF content was greatest from cocksfoot and ryegrass at 52.2 (±2.38)%, and lowest (P=0.021) from plantain and sub clover with 44.6 (±2.38)%. ADF content was 31.4 (±0.87)% across all components during summer.

Table 5.31: Mean metabolisable energy (ME; MJ ME/kg DM), crude protein (CP; %), neutral detergent fibre (NDF; %) and acid detergent fibre (ADF; %) content of pre-grazing pasture components from four dryland pastures during summer 2016-2017 at Ashley Dene, Canterbury.

Component	ME	CP	NDF	ADF
Cocksfoot	10.3	9.8 b	52.0 a	31.6
Plantain	9.8	10.1 b	44.4 b	31.5
Ryegrass	9.8	10.9 b	52.3 a	32.1
Sub clover	10.0	13.0 a	44.8 b	30.9
Mean	10.0	11.4	47.7	31.4
S.E.M.	0.18	0.80	2.38	0.87
P-value	0.173	**0.007**	**0.021**	0.750

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

The differences in CP and NDF content were different among pasture components. Differences in the proportion of pasture components among treatments would have influenced the CP and NDF seasonal yields.

5.5.6 Metabolisable energy and crude protein yields in summer

Total summer metabolisable energy and crude protein yields on offer were calculated by multiplying the total mean measured summer pasture yield by the mean ME and CP content of each plot. Total ME yields did not differ (P=0.640) among treatments and averaged 11.0 (±1.01) GJ/ha during summer 2016/17 (Table 5.32). Total CP yields did not differ (P=0.904) among treatments averaging 111 (±15.1) kg/ha during summer 2016/17 (Table 5.32).

Table 5.32: Total metabolisable energy (GJ/ha) and crude protein (kg/ha) yields of four dryland pastures during summer 2016-2017 at Ashley Dene, Canterbury.

Treatment	ME	CP
CF/Sub	11.8	104
CF/S+B	11.1	115
PL/Sub	11.2	117
PL/S+B	9.9	106
Year mean	11.0	111
S.E.M.	1.01	15.1
P-value	0.640	0.904

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

5.5.7 Neutral detergent fibre and acid detergent fibre yields in summer

Total summer neutral detergent fibre and acid detergent fibre yields on offer were calculated by multiplying the measured total mean summer pasture yield by the mean measured NDF and ADF contents of each plot.

There were no differences in NDF and ADF yields among treatments during summer 2016/17, averaging 525 kg/ha, and 333 kg/ha, respectively (Table 5.33).

Table 5.33: Total neutral and acid detergent fibre yields (kg/ha) of four dryland pastures during summer 2016-2017 at Ashley Dene, Canterbury.

Treatment	**NDF**	**ADF**
CF/Sub	622	375
CF/S+B	469	305
PL/Sub	512	339
PL/S+B	498	312
Year mean	525	333
S.E.M.	42.9	27.8
P-value	0.151	0.345

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

5.6 Autumn

5.6.1 Live weight gain

There were no live weight production periods in autumn of both years.

5.6.2 Pasture yields

Insufficient data collected in autumn 2016 meant that pasture yields for this year could not be accurately analysed. Autumn 2017 showed no differences (P=0.253) among treatments at 1027 (±75.6) kg DM/ha.

Table 5.34. Pasture yield (kg DM/ha) from cage cuts from four dryland pastures during autumn (May and June) 2017 at Ashley Dene, Canterbury.

Treatment		2017	
CF/Sub		941	
CF/S+B		978	
PL/Sub		1161	
PL/S+B		1028	
Year mean		1027	
S.E.M.		75.6	
P-value		0.253	
Orthogonal contrasts	**Means**		**P value**
CF v PL	960	1095	0.108
S v S+B	1051	1003	0.542

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

5.6.2.1 *Monthly pasture yields during Autumn*

In May, there were no differences (P=0.614) among pastures which averaged 1068 (±120.9) kg DM/ha (Table 5.35). In June, there was 414 kg DM/ha from CF pastures which was less (P=0.039) than the 627 kg DM/ha from PL pastures. The difference between the mean pastures yields from May and June (Table 5.35) was due to the final grazing event ending on the 2nd May (Appendix 1Appendix **4**).

Table 5.35: Pasture yield (kg DM/ha) from four dryland pastures during May 2017 at Ashley Dene, Canterbury.

Treatment	May	June
CF/Sub	1140	400
CF/S+B	1162	427
PL/Sub	995	689
PL/S+B	977	565
Year mean	1068	520
S.E.M.	120.9	88.1
P-value	0.614	0.146

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

5.6.3 Autumn nutritive value

During autumn 2017 (Table 5.36), ME content was highest (P<0.001) from plantain at 11.3 MJ ME/kg DM, and lowest from cocksfoot and ryegrass at 10.7 (±0.06) MJ ME/kg DM. In contrast, CP and NDF content were highest from cocksfoot with 17.5% (P=0.037) and 55.1% (P<0.001), and lowest from ryegrass with 13.0%, and 49.3%, respectively. Acid detergent fibre was highest (P<0.001) from the cocksfoot and ryegrass components at 31.5 (±0.47)% and lowest from plantain with 23.4%. The nutritive value of sub clover was not measured as seedlings had just become established and there was insufficient herbage for NIRS analysis.

Table 5.36: Mean metabolisable energy (ME; MJ ME/kg DM), crude protein (CP; %), neutral detergent fibre (NDF; %), and acid detergent fibre (ADF; %) content of pre-grazing pasture components from four dryland pastures during autumn 2017 at Ashley Dene, Canterbury.

Component	ME	CP	NDF	ADF
Cocksfoot	10.7 $_{b}$	17.5 $_{a}$	55.1 $_{a}$	31.7 $_{a}$
Plantain	11.3 $_{a}$	14.8 $_{ab}$	32.4 $_{c}$	23.4 $_{b}$
Ryegrass	10.6 $_{b}$	13.0 $_{b}$	49.3 $_{b}$	31.2 $_{a}$
Sub clover	-	-	-	-
Mean	11.0	15.1	45.6	28.8
S.E.M.	0.06	1.03	1.30	0.47
P-value	**<0.001**	**0.037**	**<0.001**	**<0.001**

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

The differences in ME, CP, NDF, and ADF content among pasture components means that any differences in the proportion of these components in the pasture affected seasonal ME, CP, NDF, and ADF yields.

5.6.4 Metabolisable energy and crude protein yields in autumn

Total ME and CP yields did not differ among treatments averaging (P=0.167) 11.3 (±1.27) GJ/ha and 155 (±18.9) kg/ha (P=0.809), respectively (Table 5.37).

5.6.5 Neutral detergent fibre and acid detergent fibre yields in autumn

The total NDF and ADF yields during autumn 2017 averaged (P=0.252) 508 (±68.0) kg/ha, and 313 (±42.1) kg/ha, respectively (Table 5.37

Table 5.37: Total metabolisable energy (GJ/ha) and crude protein (kg/ha) yields of four dryland pastures during autumn 2017 at Ashley Dene, Canterbury.

Treatment	ME	CP	NDF	ADF
CF/Sub	9.7	166	551	314
CF/S+B	10.6	162	501	302
PL/Sub	14.3	146	597	374
PL/S+B	10.5	145	381	263
Year mean	11.3	155	508	313
S.E.M.	1.27	18.9	68.0	42.1
P-value	0.167	0.809	0.252	0.398

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

6 PASTURE INTAKE

6.1 Introduction

Feed intake is the primary driver of animal performance. Daily DM intake is the result of bite mass, bite frequency during grazing, and the time spent grazing over a day. The metabolisable energy and crude protein yields of a pasture can be related to pasture intake and used to calculate how much dry matter livestock must consume for maintenance and/or growth. In Chapter 5, the animal productivity was quantified from the four dryland pastures at Ashley Dene, Canterbury, and any differences were explained in relation to pasture production and quality.

The aim of Chapter 6 is to calculate the metabolisable energy and crude protein requirements needed to meet maintenance, and to determine growth of ewes and lambs based on the live weight values reported in Chapter 5. These requirements will then be related to pasture intake as measured by pre- and post-graze measurements of the four dryland pastures. Any differences will be explained in relation to pasture yield, composition, and quality.

The objectives are to:-

- Calculate the metabolisable energy and crude protein requirements to meet the maintenance and growth of ewes and lambs, measured in Chapter 5.
- Determine seasonal pasture intake in relation to pasture disappearance, and calculated energy requirement of animals, separately.
- Describe the botanical composition of pre- and post-grazing pasture mass, and relate this to pasture intake.

6.2 Spring

6.2.1 Seasonal calculated metabolisable energy requirement

The seasonal ME requirement for maintenance, live weight gain, and lactation were calculated using the values from (Nicol and Brookes, 2007b) for each year. Live weight gain and mean live weights during a rotation were necessary, as well as the week of lactation and number of lambs reared, to calculate the total energy requirement for lactation.

An example of calculating ME requirement during the lactation phase is given below. These values are an example only. Experimental values for each group of animals were used in the results.

Lactation ran for a period of 9 weeks. Over this time, energy requirement averaged 0.6 MJ ME/day for every 1 kg of lamb weaning weight, 5.5 MJ ME/100 g for LWG, and 3.0 MJ ME/100 g for weight loss.

Maintenance requirement for a 60 kg ewe is 9.0 MJ/ME/day (~0.15 MJ ME/kg live weight/day). Therefore, a 60 kg ewe with twin lambs weaned at 27 kg and gaining 9 g LWG/day during the ninth week of lactation had an energy requirement of 9.0 MJ ME/day for maintenance, 9 g/day * 5.5 MJ ME/100g LWG = 0.50 MJ ME/day for LWG, and (27 kg * 0.6 MJ ME/kg/day) * 2 lambs = 32.4 MJ ME/day for lactation. Therefore, the total energy requirement for the ewes plus lambs is 41.9 MJ ME/day (9.0 + 0.5 + 32.4). This was multiplied by the GD per hectare and converted from MJ to GJ to obtain the ME requirement for the duration of the spring period to meet animal performance.

Table 6.1 shows the seasonal calculated ME requirements to meet the maintenance, lactation, and growth demands from ewes and lambs across the four pastures for the total duration of the spring period. The values were different between years ($P<0.001$) averaging a total ME requirement for ewes and lambs of 10.3 GJ/ha in spring 2016, and 19.6 GJ/ha in spring 2017. The difference between the years reflects the stocking rate differences (Section 5.4.5) and the fact that ewes lost weight in 2016, but gained weight in 2017. This meant final ewe weights were lighter in spring 2016, than spring 2017. Thus, ewes in 2017 had higher ME requirements for maintenance and live weight gain. There were no significant differences among treatments in spring 2016 ($P=0.301$) or 2017 ($P=0.419$), but there was variation in the requirements due to the variation in ewe weights among treatments.

Across years, there was a trend ($P=0.055$) that suggested the mean calculated ME requirement differed among treatments with 15.7 GJ/ha for PL and 10% lower for CF based pastures.

Table 6.1: Seasonal calculated metabolisable energy (GJ/ha) and crude protein requirements (kg/ha) of ewes and lambs, based on Nicol and Brookes (2007), from four dryland pastures during spring 2016 and spring 2017 at Ashley Dene, Canterbury.

Treatment	**ME**		**CP**	
	2016	**2017**	**2016**	**2017**
CF/Sub	10.0	19.5	101.1	378 $_a$
CF/S+B	9.2	18.0	73.1	312 $_b$
PL/Sub	11.6	20.6	91.5	207 $_c$
PL/S+B	10.3	20.1	81.7	315 $_b$
Year mean	10.3$_b$	19.6$_a$	86.8$_b$	303$_a$
S.E.M.	0.50		6.72	
P-value	**<0.001**		**<0.001**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

The seasonal calculated ME requirement to meet animal performance was 22-28% of the total seasonal ME yield measured in Chapter 5 (Table 5.25) during spring 2016, and 30-34% during spring 2017 (Appendix 7).

6.2.2 Seasonal calculated crude protein requirement

The seasonal CP requirement for maintenance, live weight gain (and lactation where appropriate) were calculated in the same manner as for ME requirement ((Brookes and Nicol, 2007).

The calculated CP requirement to meet animal performance in spring 2016 was 87 kg/ha, which was lower (P<0.001) than the 303 kg/ha in spring 2017 (Table 6.1). These differences are again due to stocking rate differences between the years (Section 5.4.5). A trend was identified (P=0.060) during spring 2016 that suggested the CP requirement from Sub pastures was 96 kg/ha, which was higher than S+B pastures with a lower requirement of 77 kg/ha. This suggests that S+B pastures were stocked at lower rates. There were differences in CP requirement among treatments in 2017 (P = <0.001), with the highest requirement of 378 kg/ha from CF/Sub pastures, and the lowest from PL/Sub pastures of 207 kg/ha. Across years, CF pastures had a crude protein requirement of 216 kg/ha, which was higher (P=0.001) than the 174 kg/ha from PL pastures. There were no differences between Sub and S+B pastures (P=0.930).

The seasonal calculated CP requirement to meet animal performance was 16-20% of total measured CP yield during spring 2016, and 21-43% in spring 2017 (Appendix 8).

The CP to ME ratio of seasonal pasture yield (Table 5.25) during spring 2016 averaged 13 g CP/MJ ME among pastures, and spring 2017 averaged 15 g CP/MJ ME. Using the calculated requirements for ewes and lambs during spring (Table 6.1), the required ratio in pasture intake was 8 g CP/MJ ME during spring 2016, and 15 g CP/MJ ME during spring 2017 (Brookes and Nicol, 2007; Nicol and Brookes, 2007b). This suggests excess protein was available for consumption in 2016, but values met requirements in 2017. A high CP content in pastures can cause disruption in the rumen associated with increased ammonia levels, and thus increased metabolic costs to reduce the ammonia content.

6.2.3 Pasture intake

6.2.3.1 Calculated by energy requirement

Spring pasture intake was calculated by dividing the seasonal calculated metabolisable energy requirement (Section 6.2.1) by 11 MJ ME/kg DM – the mean measured ME content of spring pastures.

Table 6.2 shows calculated spring pasture intake was not different among treatments in either year (2016; P = 0.301, 2017; P = 0.419), but was different between years. In spring 2016, the mean intake calculated by energy requirement was 934 (±74.1) kg DM/ha, which was less (P<0.001) than the 1779 (±101) kg DM/ha in spring 2017. Across years, the calculated intake was 1423 kg DM/ha from PL pastures, which was greater (P=0.055) than the 1290 kg DM/ha from CF pastures. This suggests that ewes and lambs on plantain pastures were able to eat more, which supports the higher growth rates reported from lambs on PL pastures compared with those on CF (Figure 5.3).

Table 6.2: Pasture intake (kg DM/ha) of ewes and lambs calculated by energy requirement to meet maintenance and live weight change, and measured by pasture disappearance from four dryland pastures during spring 2016 and spring 2017 at Ashley Dene, Canterbury. Metabolisable energy content intake was measured at 11 MJ ME/kg DM.

Treatment	**Calculated**		**Measured**	
	2016	**2017**	**2016**	**2017**
CF/Sub	912	1774	997	1920
CF/S+B	837	1638	930	2282
PL/Sub	1050	1875	1083	2438
PL/S+B	937	1828	1084	2600
Year mean	934 $_b$	1779 $_a$	1024 $_b$	2310 $_a$
S.E.M.	45.7		54.0	
P-value	**<0.001**		**<0.001**	

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

Based on the calculated intake, pasture intake ranged from 4.0-4.5 kg DM/ewe GD in spring 2016, and 4.3-4.4 kg DM/ewe GD in spring 2017 (Appendix 9). Averaged across both springs, intake on CF pastures averaged 4.2 kg DM/ewe GD, which was lower than the 4.4 kg DM/ewe GD from PL pastures. The lower intake from CF pastures suggests these pastures had lower digestibility, which agrees with the measured NDF results during spring (Table 5.24).

Using these values, pasture utilisation was in a range of 21-27% of pasture yield in spring 2016, and 31-35% for spring 2017. Averaged across both springs, utilisation was 28-31% for all treatments. These utilisation values are consistent with the 28-32% measured ME yield relative to ME requirement in Section 6.2.1. The low utilisation rates suggest the pastures were of high quality, and only 28-32% of the pasture needed to be eaten to meet the calculated ME requirements for ewes and lambs.

6.2.3.2 Measured by pasture disappearance

Spring pasture intake was measured by pre- and post-graze pasture disappearance. Table 6.2 shows pasture intake was highest (P = <0.001) during spring 2017 at 2310 (±54.0) kg DM/ha compared with 1024 kg DM/ha in 2016. Based on these results, pasture utilisation ranged from 24-48% across treatments and years. The intake requirement calculated by ME (Section 6.2.3.1) ranged from 86-150% of the pasture intake measured by pasture disappearance. This suggests the intake measured by disappearance may have been overestimated due to lack of pasture uniformity and difficulty of calibrating the rising plate meter in the mixed pastures.

In 2016, intake measured by disappearance among pastures did not differ (P=0.206). In 2017, a trend suggested (P=0.098) more pasture was consumed from PL and S+B pastures, than CF and sub pastures.

Across years, measured intake was 1801 kg DM/ha on PL pastures was 269 kg DM/ha greater (P=0.033) than the intake from CF pastures. The greater intake from disappearance on PL pastures is consistent with the calculated pasture intake (Table 6.2), and also suggests that ewes and lambs on plantain pastures were able to eat more. This translates to the higher growth rates from lambs on PL treatments versus CF during spring (Figure 5.3).

Pasture intake/GD among treatments ranged from 4.4-5.5 (±0.46) kg DM/ewe GD in spring 2016, and 4.7-6.4 (±0.41) kg DM/ewe GD during spring 2017 (Appendix 10). The higher end of the range in 2017 exceeds the potential appetite of ewes (4% of ewe and lamb live weight) from all pastures except CF/Sub, which suggests that intake/GD measured by disappearance (Table 6.2) was slightly overestimated, but overall the results are consistent between methods.

Daily pasture intake (kg/DM) for ewes and lambs/GD was calculated (Table 6.3). The upper limit of the range used 4% of ewe and lamb live weight, which is the potential appetite described by (Court *et al*., 2010). The 4% of ewe and lamb live weight was calculated from the final weighing event during spring. The lower limit is the pasture intake required to supply ME for maintenance, LWG, and lactation of ewes and lambs. This was calculated by dividing the total ME required per day by the mean measured ME content of all pastures (11 MJ ME/kg DM) during spring. In Table 6.3, these ranges can be observed, as well as the pasture intake measured by pasture disappearance (in parenthesis) for each pasture of each spring.

Table 6.3: Calculated pasture intake (kg DM/GD) of ewes and lambs from four dryland pastures during spring 2016 and spring 2017 at Ashley Dene, Canterbury. The figure in the parenthesis is measured via pasture disappearance. The minimum figure on the range was calculated intake to meet energy requirement when measured ME content of spring pasture averaged 11 MJ ME/kg DM, and the maximum figure on the range is 4% of final spring ewe and lamb live weight.

Treatment	**2016-17**	**2017-18**
CF/Sub	(4.4) 4.0-5.2	(4.7) 4.4-5.6
CF/S+B	(4.9) 4.1-5.5	(6.0) 4.3-5.4 *
PL/Sub	(5.5) 4.5-5.6	(5.7) 4.3-5.6 *
PL/S+B	(5.2) 4.5-5.6	(6.4) 4.4-5.5 *

Note: Treatment acronyms are listed in Table 3.3. * denotes periods when the measured pasture disappearance lies outside the likely range.

For every treatment in spring 2016, pasture intake measured by pasture disappearance was within the predicted range. Thus, intake estimated by disappearance was likely to be relatively accurate for this season. During spring 2017, all measured pasture intakes were within or above the estimated range. The estimated pasture intake was equivalent to 4.1-4.7% of ewe and lamb live weight. This suggests calibration for these pastures was difficult and that pasture intake measured by disappearance may have been overestimated. Thus, actual intake of ewes and lambs was probably lower than that reported by disappearance. It remains to be tested whether potentially they were able to eat more than 4% of their live weight on high legume content pastures.

6.2.4 Pasture composition and preference

Pasture preference data were only collected during spring 2017 (Section 3.11.4). Figure 6.1 shows the mean pasture composition of spring pasture yield from the four treatments. The single 2016 bar shown on the graphs depicts the representative botanical composition for each of the pastures. The data were collected from the earliest destructive samples in spring 2016 – these were cage cuts made on the 27th October 2016. The 2017 preference data were measured from transects and pre- and post-graze quadrats used visual estimates of % cover. These began on the 7th September

2017, and were translated to botanical compositions to eliminate the bare ground component. The composition of pasture was divided into clover, sown grass, plantain, weed, and dead material. Subterranean, balansa and white clover were all combined into the 'clover' category for analysis. 'Weeds' were a combination of grasses and broadleaf weeds. The major weeds present were vulpia hair grass (*Vulpia bromoides* L.), annual mouse-eared chickweed (*Cerastium glomeratum* L.), and dock (*Rumex obtusifolius* L.).

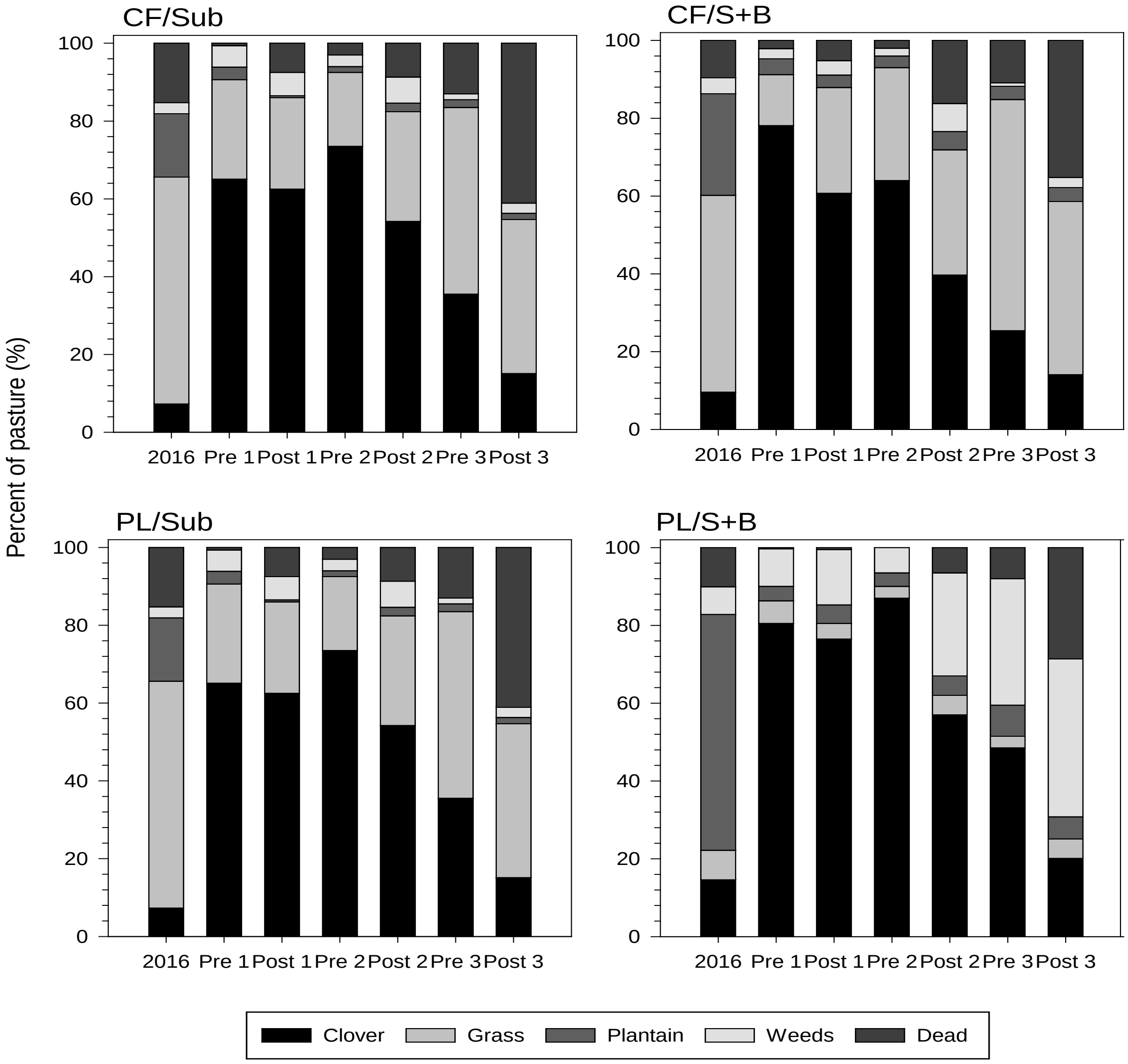


Figure 6.1: Pasture composition of cage cuts in spring 2016, and pre- and post-graze visual estimates for three rotations during spring 2017, from four dryland pastures at Ashley Dene, Canterbury. Cage cut samples were collected on the 27th October 2016. Treatment acronyms are listed in Table 3.3.

The low average clover content (~8%) across all pastures during spring 2016 led to the conclusion that the sub clover seed bank was empty. However, following an ideal autumn for sub clover germination and establishment in 2017, the spring 2017 clover content started with an average of ~75% which was a significant increase (P=0.002) from spring 2016 (Table 6.4). Across years, PL pastures yielded ~43% clover which was higher (P=0.047) than the ~40% clover from CF pastures. It was also identified that Sub pastures averaged ~37% clover, while S+B pastures averaged ~45% (P=0.002). This was an indication that balansa added to the total clover content.

Table 6.4: Percent (%) of total clover from cage cuts and quadrat cuts from four dryland pastures during 2016 and 2017 at Ashley Dene, Canterbury. Samples were collected on the 27th October 2016, and 9th September 2017.

Treatment	**2016**		**2017**
CF/Sub	6.2		64.6_{b}
CF/S+B	8.8		78.3_{a}
PL/Sub	3.8		74.9_{ab}
PL/S+B	12.8		80.9_{a}
Year mean	7.9_{b}		74.7_{a}
S.E.M.		2.48	
P-value		**0.002**	
Orthogonal contrasts	**Means**		**P value**
CF v PL	39.5	43.1	**0.047**
S v S+B	37.4	45.2	**0.002**

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

Due to the contribution of ryegrass to PL pastures being minimal, differences in the sown grass content of yields were observed between CF and PL pastures. CF pastures yielded an average of ~36% sown grass across years, compared with a lower (P<0.001) average of ~5% sown grass from PL pastures (Appendix 11).

The plantain component of the sward averaged 44% during spring 2016, which was higher (P<0.001) than the 3% from spring 2017 (Appendix 12). The lack of ryegrass in PL pastures was replaced by plantain. Over the two years, the mean percent of plantain in CF pastures was 12%, which was lower (P=0.005) than the 35% from PL pastures. There was no strong preference for plantain with it maintaining a small proportion (0.5 – 9%) of all pastures throughout the spring 2017 period.

The mean weed content from pastures in spring 2016 was 3% (P=0.293), while 2017 averaged 8% (Appendix 13). However, differences among treatments did arise during spring 2017 with PL/Sub pastures have the highest weed content of 16%, while the lowest (P=0.001) was from CF pastures with 4%. A trend was identified (P=0.058) across years that suggested that average weed content from CF pastures of 3% was lower than that from PL pastures of 8%.

There were no differences (P=0.101) in the content of dead material between the two springs averaging 6% across both years (Appendix 14). There were also no differences among the four pastures during 2016 (P=0.659) or 2017 (P =0.251). The preference for dead material was not strong. The proportion of dead material increased over time in all pastures.

6.3 Summer

6.3.1 Seasonal calculated metabolisable energy requirement

The seasonal ME requirement for maintenance and live weight gain of weaned lambs were calculated using the values from (Nicol and Brookes, 2007b) for summer 2016/17.

An example of calculating ME requirement for weaned lambs during summer:

The ME required for maintenance was 0.18 MJ ME/kg live weight/day, and 3.8 MJ ME/100 g for LWG. Thus, a 33 kg lamb growing at 191 g/day had a daily ME requirement of 33 * 0.18 MJ ME/kg/day = 5.9 MJ ME for maintenance, and 191 g * 3.8 MJ ME/100 g LWG = 7.3 MJ ME for LWG/day. Therefore, the combined ME requirement for maintenance and LWG of weaned lambs is 13.2 MJ ME/day (5.9 + 7.3). This was multiplied by the GD per hectare.

Table 6.5 shows the seasonal calculated ME requirements to meet the maintenance and growth demands measured from weaned lambs across the four pastures for the total duration of the summer period. There were no differences (P=0.658) in total calculated ME requirement of weaned lambs among treatments during summer.

Table 6.5: Seasonal calculated metabolisable energy (GJ/ha) and crude protein requirements (kg/ha) of weaned lambs, based on Nicol and Brookes (2007), from four dryland pastures during summer 2016-2017 at Ashley Dene, Canterbury.

Treatment	ME	CP
CF/Sub	1.92	19.2
CF/S+B	1.71	17.3
PL/Sub	2.29	23.8
PL/S+B	1.84	19.0
Year mean	1.94	19.8
S.E.M.	0.33	3.44
P-value	0.658	0.598

Note: Means followed by the same letter are not different at the α=0.05 level. Treatment acronyms are listed in Table 3.3.

The calculated ME requirement to meet maintenance and live weight change for weaned lambs came to 16-18% (Appendix 15) of total summer ME yield reported in Table 5.32. ME content of pasture intake is likely to be higher than the ME content in the overall pasture yields due to selective grazing targeting the high ME components. Thus, the %ME utilisation is likely to be lower than this range of values.

6.3.2 Seasonal calculated crude protein requirement

Calculated CP requirement was not different (P=0.598) among treatments during summer 2016/17 (Table 6.5), with weaned lambs requiring an average of 19.8 (±3.4) kg/ha from the four pastures.

The calculated CP requirement to meet maintenance and live weight change of weaned lambs came to 15-20% (Appendix 16) of the total seasonal CP yield reported in Table 5.32. This was in a similar range to the 16-18% calculated ME requirement of measured ME yield which suggests that CP intake may also have had an impact on animal performance during summer. The CP to ME ratio of seasonal pasture yield during summer (Table 5.32) was 9 g CP/MJ ME on CF/Sub pastures, 10 g CP/MJ ME on CF/S+B and PL/Sub pastures, and 11 g CP/MJ ME on PL/S+B pastures. Using the calculated requirements for weaned lambs (Table 6.5), the required ratio in pasture intake was 10 g CP/MJ ME (Brookes and Nicol, 2007; Nicol and Brookes, 2007b). This suggests that all pastures had sufficient protein available for consumption.

6.3.3 Pasture intake

6.3.3.1 Calculated by energy requirement

Summer pasture intake was calculated by dividing the summer calculated metabolisable energy requirement (Section 6.3.1) by 10 MJ ME/kg DM which was the mean measured ME content of summer pastures (Table 5.31).

Pasture intake calculated by energy requirement was not different (P=0.658) among treatments averaging 194 (±33.4) kg DM/ha (Table 6.6). These calculated values result in required pasture intakes in the range of 0.9-1.4 kg DM/GD (Appendix 17). Pasture utilisation was low, averaging 17% of summer pasture yield for CF/Sub, 16% for CF/S+B, and 24% and 19% for PL/Sub and PL/S+B pastures, respectively.

Table 6.6: Pasture intake (kg DM/ha) of weaned lambs calculated by energy requirement to meet maintenance and live weight change, and measured by pasture disappearance from four dryland pastures during summer 2016-2017 at Ashley Dene, Canterbury. Metabolisable energy content intake was estimated at 10 MJ ME/kg DM.

Treatment	Calculated	Measured
CF/Sub	192	572 a
CF/S+B	171	558 a
PL/Sub	229	275 b
PL/S+B	184	289 b
Year mean	194	424
S.E.M.	33.4	62.3
P-value	0.658	**0.010**

Note: Treatment acronyms are listed in Table 3.3. * denotes periods when the measured pasture disappearance lies outside the likely range.

6.3.3.2 Measured by pasture disappearance

Table 6.6 shows summer measured pasture intake from weaned lambs differed (P=0.010) among treatments in 2016/17. Intake was 565 kg DM/ha on CF pastures which was greater (P=0.001) than the 282 kg DM/ha from PL pastures. This does not relate well with the results from pasture intake calculated by ME requirement in Section 6.3.3.1. Measured pasture intake per weaned lamb graze day ranged from 2.0-3.6 kg DM (Appendix 18), which exceeds the potential appetite of 4% of live weight as described by (Court *et al.*, 2010) (Table 6.7). Creating calibrations on summer pastures is difficult and these results suggest the calculated values were more reliable.

Based on these measured values, pasture utilisation was 53% and 51% on CF/S+B and CF/Sub pastures, respectively. Whereas, utilisation from PL pastures was lower, with 28% from PL/Sub, and

29% from PL/S+B pastures. This suggests that weaned lambs were not eating the plantain component, which agrees with observations in the field (Smith, M. 9/1/17 Pers. comm).

Pasture intake/GD was calculated for weaned lambs during summer (Table 6.7). The 4% of weaned lamb live weight was calculated from the final weighing event during summer. The lower limit is the calculated pasture intake required to meet animal performance of weaned lambs. This was calculated by dividing the total ME required per day by the mean measured ME content of all pastures (10 MJ ME/kg DM) during summer. Pasture intake measured by disappearance was above the range for every treatment during summer 2016/17. Daily pasture intake to meet energy requirements for maintenance and live weight gain of weaned lambs was approximately double the potential appetite value for CF pastures, and was higher for PL pastures also. CF/Sub pastures were 9% of live weight, CF/S+B were 10%, while PL/Sub and PL/S+B were 6% and 7%, respectively. This is consistent with the difficulty in measuring summer pasture intake and suggests that actual intake was probably lower than measured.

Table 6.7: Calculated pasture intake (kg DM/GD) for weaned lambs from four dryland pastures during summer from 2016-2017 at Ashley Dene, Canterbury. The figure in the parenthesis is determined via pasture disappearance. The minimum figure on the range is calculated intake to meet energy requirement when ME content of pasture intake is 10 MJ ME/kg DM, and the maximum figure on the range is 4% of final weaned lamb live weight.

Treatment	2016-17
CF/Sub	(3.0) 0.9-1.4 *
CF/S+B	(3.6) 1.0-1.5 *
PL/Sub	(2.0) 1.4-1.4 *
PL/S+B	(2.5) 1.3-1.4 *

Note: Treatment acronyms are listed in Table 3.3. * denotes periods when the measured pasture disappearance lies outside the likely range.

Lambs are selective, and it is likely their ME intake was higher than the measured mean of 10 MJ ME/kg DM. However, changing this value would not have had an impact on the results. The minimum figure would have been lower as less intake is required to meet animal performance if the feed is of higher quality. Thus, the measured disappearance results would still have been outside the calculated intake range.

6.3.4 Pasture composition and preference

The botanical composition of summer pre-graze pasture yields are summarized in Figure 6.2. There were also no transects set up to record pasture preference during summer 2016/17.

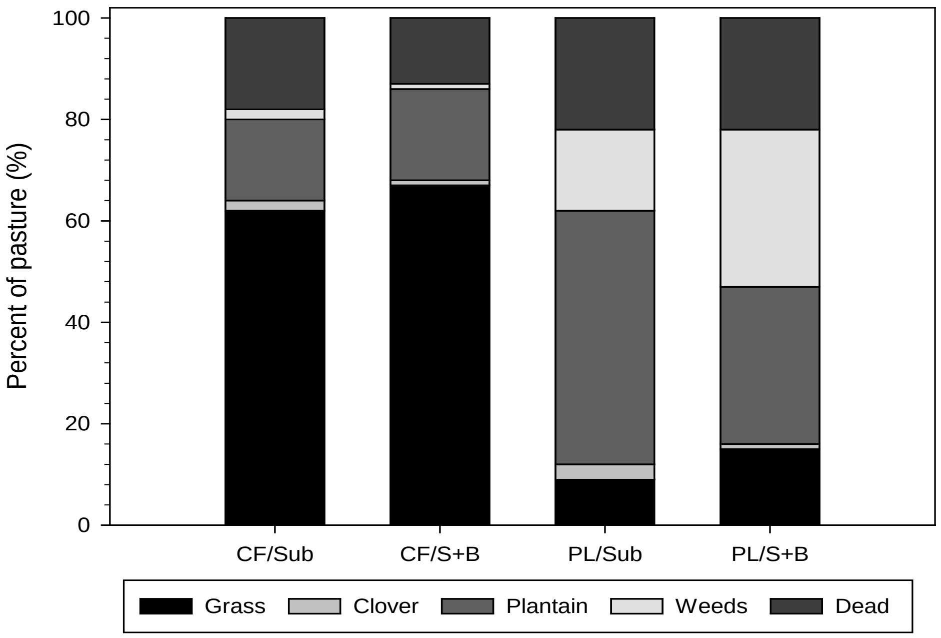


Figure 6.2: Pasture composition of earliest cage cut of summer pasture yield from four dryland pastures from 2016-2017 at Ashley Dene, Canterbury. Samples were collected on the 19th December 2016. Treatment acronyms are listed in Table 3.3.

During early summer, there were no differences in clover content among treatments, with all pastures averaging ~2 (±1)% (Appendix 19). The content of sown grass (Appendix 20) was ~65 (±5)% from CF pastures, which was higher ($P<0.001$) than the ~12 (±5)% of ryegrass present in PL pastures. Plantain was present in all treatments at the beginning of summer (Appendix 21). It averaged ~41 (±5)% from PL pastures, which was greater ($P=0.002$) than the ~17 (±5)% observed in CF pastures.

CF pastures had little weed (Appendix 22), averaging ~2 (±6)%, while PL pastures had a higher ($P=0.005$) weed content of ~24 (±6)%. The content of dead material (Appendix 23) averaged ~19 (±5)% across all pastures during summer 2016/17.

7 GENERAL DISCUSSION AND CONCLUSIONS

The aim of this research was to quantify live weight production of ewes and lambs off annual clover-based pastures from years 4 and 5 of the 'MaxAnnuals' grazing experiment based at Ashley Dene, Canterbury. In particular to determine whether the addition of balansa clover, plantain or ryegrass, contributed to higher live weight gains than the cocksfoot plus sub clover pasture.

This chapter discusses spring and summer live weight gains between the two years and among treatments. Differences are explained in relation to pasture quality and composition, pasture yields, allocation, intake, and available soil water.

7.1 Spring 2016 and 2017

7.1.1 Live weight gain

In spring 2016, lamb production of 402 kg/ha was lower than the 574 kg/ha achieved in 2017 (Table 5.2). Ewe live weight gain was also lower during spring 2016 with an average loss of 6 kg/ha, whereas ewes gained an average of 61 kg/ha in spring 2017.

In spring 2016, the trigger point at which half the PAWC had become depleted was 17th October. In spring 2017, this point was not reached until the 30th October. Lambing began around the 1st of September of each year which meant spring 2017 had an extra 13 days grazing. Lambs were growing at a rate of ~317 g/hd/d during spring 2017. This growth rate was multiplied by the extra 13 grazing days in 2017, and then multiplied again by the average spring 2017 stocking rate of 25.4 lambs/ha (Table 5.19). This resulted in a value of 105.7 kg/ha of lamb live weight gain that could be explained by the extra grazing days due to the soil water availability in spring 2017. However, the difference in lamb live weight gain between the years was 172 kg/ha. The difference between this value and the calculated value of 105.7 kg/ha, gives a result of 66.3 kg/ha. This means there was an extra 66.3 kg/ha of lamb live weight gain achieved in spring 2017 that could not be explained by soil water. The same was calculated for ewes in spring 2017, growing at an average rate of ~34 g/hd/d. Following the same method as above, this meant 5.6 kg/ha of ewe live weight gain in 2017 could be explained by soil water, leaving 49.4 kg/ha of ewe live weight gain in 2017 that also could not be explained by water. Thus, soil water was not the cause for the differences observed in live weight gain between the years.

The higher live weight gains from ewes and lambs during spring 2017 appears to be predominantly due to the pasture mass achieved in 2017 from similar environmental conditions. There was twice as much feed on offer when plots were stocked in 2017 predominantly due to faster growth rates of the pasture in spring (Figure 5.7). The higher pasture growth appears to have resulted from the higher winter annual clover content which averaged ~75% across all pastures in 2017, compared with only ~8% clover across all pastures in spring 2016. This supports earlier research from Ates *et al*. (2010), Hyslop *et al*. (2000) & Litherland and Lambert (2000) who found that legume content resulted in greater live weight gains.

There were no differences in lamb live weight gain among treatments in either year, but differences in lamb growth rates were identified. Across both years, lambs on PL pastures grew at 339 g/hd/d, which was faster (P=0.048) than lambs on CF pastures which averaged 301 g/hd/d. This difference was probably due to PL pastures yielding more clover than CF pastures across both years (Table 6.4). Compared with traditional ryegrass pastures, several studies have also found lambs grazing plantain have higher growth rates (Hutton *et al*., 2011; Judson, 2008; Kemp *et al*., 2010; Kemp *et al*., 2013; Moorhead *et al*., 2002) which may have also contributed to the PL lambs growing at a faster rate in 2016 when clover content was low in all pastures. The composition of the pastures during spring 2016 were less than 10% clover across all treatments. This meant that CF and PL pastures were greater than 50% cocksfoot and plantain, respectively. Mean NDF content from cocksfoot was 54%, while plantain was 45% (Table 5.24). Thus, lambs grazing PL pastures were offered feed of higher digestibility which resulted in higher pasture intake from PL than CF pastures (Table 6.2). This supports work by Burke *et al*. (2000) who found that lambs eating high protein and high digestible diets, had greater dry matter intakes as a consequence of a rapid fractional degradation rate. The higher digestibility from PL pastures in 2016, as well as the higher clover content across all pastures in 2017 resulted in higher lamb growth rates from lambs on PL pastures, and greater calculated intake from lambs (Appendix 9) in 2017. The difference in lamb growth rates did not result in differences in the overall live weight gain from lambs. This is due to there being no difference in stocking rates between the pastures (Table 5.19), even though PL pastures were higher yielding than CF pastures (Table 5.11).

There were differences in ewe live weight gain among pastures (Table 5.5), within both springs. There was no difference in composition of pastures in 2016, which suggests the differences in ewe live weight gain may have been due to the variability of actual ewe live weights at the beginning of the spring period. Ewes were not sorted into similar weight groups prior to the spring production period as the labour and time required was not available. It was also not an option to wait until lambing had finished because pastures were growing rapidly. Thus, a ewe and her set of lambs were placed into the trial plots as soon as they became available from the main flock. Thus, there was a wide range in ewe weights at the beginning of both spring periods. This meant that being a smaller ewe may have been an advantage as less feed would have been required to maintain and gain weight (Nicol and Brookes, 2007b). Figure 5.4 shows this for the CF/Sub ewes during spring 2016. These ewes began spring weighing the least of ~75 kg (~3.5 kg lighter than the next heaviest treatment). Because of the lower intake demands to meet maintenance and live weight gains from CF/Sub ewes, they managed to gain weight. CF/Sub ewes weighed ~0.5 kg heavier at the end of the spring 2016 period, whereas all other ewes that started heavier, had lost an average of ~3 kg live weight by the end of the spring 2016 period. Thus, although the stocking rate was consistent (Table 5.19) among treatments in terms of number of ewes, the absolute ewe live weight being carried differed among treatments.

There were also differences in the clover content (Table 6.4) among pastures in spring 2017. Clover content was greatest from S+B pastures averaging ~80% of the sward, which may have contributed to higher live weight gains. However, the opposite effect was actually observed, with Sub ewes achieving higher (Table 5.5) live weight gains than S+B ewes during spring 2017. Thus, the differences in ewe live weight gain among treatments in spring 2017 is likely to have been due to the variability in actual ewe live weights at the start of the spring period, rather than caused by differences in the pasture yields or composition.

As there were only two weighing events for ewes and lambs in spring 2016, the temporal pattern of growth of stock could not be accurately determined. However, in spring 2017, weighing took place every two weeks (Section 3.11) which enabled an accurate estimate of animal growth rates. The consistently linear increases in 2017 suggest the same linear pattern could be expected for 2016, so a single growth rate per day could be calculated. Ewe growth rates were similar across all treatments in both 2016 and the beginning of spring 2017. They started high when quality was high and demand from lambs was low. However, as the composition of PL pastures began to deteriorate and the demand from lambs became greater, the ewes on PL treatments began to lose weight or plateau, while ewe growth rates on CF only dropped slightly. Although, cocksfoot was not as digestible, the ME and CP were sufficient to meet animal performance (Table 5.23).

There was no relationship between ewe and lamb live weight gain ($R^2 = 0.01$) in spring 2016 (Figure 5.5). All lambs were growing at least 300 g/hd/d even when ewe growth rates ranged from losing 200 g/hd/d to gaining 100 g/hd/d. This suggests that in 2016, lamb growth rates were not influenced by ewe growth rates, and that ewes compensated by losing weight to maintain lamb growth rates (B+LNZ, 2010). During spring 2017, the relationship was positive between ewe and lamb growth rates ($R^2 = 0.52$). Ewes growing less than 100 g/hd/d supported lamb growth rates less than 300 g/hd/d. Whereas, ewes who had lambs growing 300 g/hd/d or more, were typically growing more than 100 g/hd/d themselves. The latter result is consistent with work from Croy (2017) where the higher legume content supported higher ewe and lamb live weight gain. The legume content also meant more feed was available in spring 2017. The greater quantity of high quality herbage in spring 2017, meant ewes had an allocation of 10 kg DM/GD compared with 6.7 kg DM/GD in 2016 (Table 5.12), and this enabled ewe and lamb live weight gain to be maximized.

7.1.2 Pasture composition

The importance of the legume component of pasture for live weight gain was highlighted by the differences in live weight gain seen between the two springs. Live weight gain was lower in spring 2016 when total clover content averaged only 8% across all pastures. Spring 2017 pastures averaged 75% clover meeting the ~70% preference for legume in the diet by sheep (Cosgrove and Edwards, 2007). This resulted in higher live weight gains and more grazing days, ultimately leading to greater animal production per hectare. This is supported by Hyslop *et al*. (2000) & Litherland and Lambert (2000) who both reported improved live weight gains when animals were offered pastures with higher clover content and high herbage mass.

It was expected that due to the loss of the ryegrass/fescue grass, there would be higher clover yields in PL pastures. However, this was not the case as there were no differences in clover content between CF and PL treatments across both years (Table 6.4). Clover content differed among Sub and S+B pastures, with overall clover content being ~8% higher in S+B pastures than Sub pastures. This suggests that the addition of balansa contributed to an increase in the clover component of the pastures, but this did not impact live weight gains. The management for balansa was difficult under grazing and was not given a chance to set seed after the first year. The combination of sub and balansa meant grazing management in mixes was difficult. This suggests it may be easier to use one species, or type of legume in a pasture mix and manage it correctly. Sub clover was able to set some seed each year, but few balansa clover plants were able to elongate and flower after Year 1.

The selective grazing of legumes by sheep means that over time, grass can become dominant in a legume/grass sward. This was mostly expected from the CF pastures due to the competitive nature of cocksfoot in dryland environments. However, it did not seem to impact the clover component of the CF swards until late spring when the preference and harder grazing of clover lead to an increase in the cocksfoot component (Section 6.2.4).

Across both years, the average grass component of the pastures was higher from CF pastures (~36%) than PL pastures (~5%) (Figure 6.1). This was expected due to the lack of persistence in PL pastures by the ryegrass/fescue hybrid grass. At the beginning of spring 2016, the plantain to ryegrass ratio from PL pastures was 13:1 due to the inability of the ryegrass/fescue hybrid to persist in the dry conditions. This is why the original 'RG' pastures were renamed to 'PL'. PL pastures had a high plantain content in 2016 averaging ~65%. However, this dropped to ~5% at the beginning of spring 2017 due to the increased annual clover content.

In the last year of the 'MaxAnnuals' experiment, the weed content of the PL pastures increased from ~4% to ~38% of the sward. There was no change in the weed component of CF pastures. This suggests that there was no grazing preference for weeds, and that CF pastures were persistent, but that PL pastures were beginning to diminish and be outcompeted by lower quality pasture components. This means plantain pastures may be an option for short-term (3-4 years) in dryland environments, but weed invasion is likely to compromise their production and persistence. CF pastures were successful at maintaining weed populations at less than 10% of the pasture after 5 years of growth. This is typical of cocksfoot pastures which retained a higher proportion of sown species in the original 'MaxClover' experiment (Mills *et al*., 2015b). In that case the CF/Sub pastures started Year 1 of the experiment with ~8 t DM/ha of cocksfoot, ~3 t DM/ha of sub clover. Eight years later, at the start of Year 9, the composition of the CF/Sub pastures were ~3 t DM/ha and ~1.5 t DM/ha of cocksfoot and sub clover, respectively. Between Years 1 and 9 of the 'MaxClover' experiment, the composition of weed in CF/Sub pastures was maintained to ~1% of the sward due to the "suppressive" growing habits of cocksfoot. Tozer *et al*. (2010) also found that annual grass weed establishment was lower in cocksfoot than perennial ryegrass pastures. The 'MaxAnnuals" result confirms that cocksfoot was a suitable companion species for sub clover as a long-term pasture option for dryland environments.

7.1.3 Pasture yields

Spring pasture yields offer the most reliable herbage mass under the dryland conditions experienced at Ashley Dene and the aim was for lactation to be aligned as closely as possible with this period.

Opening spring 2016 pasture covers averaged 931 kg/ha, which was lower than the 2065 kg/ha at the beginning of spring 2017 (Table 5.10). There was no winter grazing in either year. The difference in starting pasture covers between years resulted from differences in the timing of initiation of pasture growth and differences in pasture growth rates (Table 5.8 and Table 5.9) prior to the set-stocking period. Although the soil water status between years allowed an extra 13 days grazing in spring 2017, it was not a limiting factor during the growth period (Figure 4.3). The additional grazing days in 2017 accounted for an extra 105.7 kg/ha of live weight gain from lambs, and 5.6 kg/ha from ewes. However, this still left 66.3 kg/ha and 49.4 kg/ha of live weigh gain from lambs and ewes, respectively, that was not explained by soil water. Thus, the higher starting covers in spring 2017 were due to the higher percentage of annual clover. Sub clover is winter active, which means the higher clover content in 2017 caused growth to be initiated 281 degree days earlier (Table 5.9), with a greater proportion of the pastures actively growing during winter. Pasture growth rates were also higher in spring 2017 due to the higher clover content. In 2016, pasture growth calculated from cage cut data averaged 39 kg DM/ha/d, which was lower than the growth rate in 2017 of 54 kg DM/ha/d, or 6.42 kg DM/°Cd, and 10.4 kg DM/°Cd in 2016 and 2017, respectively (Table 5.8). This meant more dry matter was produced and resulted in higher opening pasture covers in spring 2017 when clover content was ~75%, compared with spring 2016 when clover content was ~8%. This result supports work by Ates *et al*. (2010) who measured cocksfoot and ryegrass pastures with sub clover and without sub clover over two years (2006-2008), also at Ashley Dene (Figure 2.3). They found that in spring 2007/08, yields produced from pastures including sub clover were 34-45% higher than those without, proving the ability of sub clover to provide additional dry matter, particularly in early spring. Together with the 'MaxClover' results of Mills *et al*. (2015b), current results confirm the benefits of sub clover in a dryland pasture.

Across years, PL pastures were higher yielding than CF pastures. This was probably due to the higher clover content in PL pastures, resulting in increased pasture growth rates. During the first month of the live weight period in September 2016 (Table 5.13), pasture yields averaged 1514 kg DM/ha which was only 51% of the 2970 kg DM/ha in 2017. Pasture yields remained high during the key sub clover growth period in October averaging 2877 kg DM/ha in 2017, which was again higher than yields in 2016 of 1617 kg DM/ha (Table 5.15). A trend was identified that suggested pasture yields during November were lower in 2016 of 1063 kg DM/ha, compared to 1267 kg DM/ha in 2017. Allocation was ~7 kg DM/ewe GD in November 2016, which was approximately half the allocation in November 2017. The higher pasture yields during every month of the spring 2017 live weight period was a factor contributing to the greater live weight gains in 2017, due to the higher clover content.

7.1.4 Pasture allocation

The main factors affecting ewe and lamb growth rates are daily pasture allocation and quality of the forage (Judson *et al*., 2009). Up until six weeks of age, milk intake has the most influence on lamb growth rates. However, from around two weeks of age (B+LNZ, 2010), lambs will begin to graze and their daily energy intake coming from forage will increase with time, especially for twins (Judson *et al*., 2009). The higher opening pasture covers in spring 2017 (Table 5.10) meant that the overall spring yields were 37% higher in 2017 than 2016 (Table 5.11). This led to ~90% more grazing days being achieved (Figure 5.6) and increased pasture allocations from 6.7 kg DM/ewe GD to 10 kg DM/ewe GD (Table 5.12).

Mean spring pasture allocation was 6.7 kg DM/ewe GD in 2016, compared to the allocated 10.0 kg DM/ewe GD during 2017 (Table 5.12). Penning (1986) reported that increased pasture allocation resulted in greater intake up until an asymptote. Rattray *et al*. (1982) determined sheep pasture allocation to be at least 8 kg DM/ewe GD before pasture intake no longer increased and the asymptote was reached. Thus, the pasture allocation of 6.7 kg DM/ewe GD in spring 2016 was insufficient to maximise pasture intake. However, the allocated 10 kg DM/ewe in spring 2017 exceeded the required pasture allocation. The nutritive value of the pasture allocated and the ease of availability and access to quality pasture components within the sward will have an effect on live weight gain (Cosgrove and Edwards, 2007). For example, pasture quality and allocation may be high, but if the covers are low, then intake will be reduced and live weight compromised. Thus, the higher pasture yields during every month of the spring 2017 live weight period, combined with the higher pasture allocations was due to the greater clover content in 2017, resulting in higher live weight gains.

7.1.5 Stocking rates

Grazing management throughout the experiment aimed to ensure that pasture allocation per GD was appropriate for the feed on offer, i.e. plots were not overstocked or understocked. This meant mean stocking rates were increased from 9.1 ewes/ha per treatment in spring 2016, to 12.7 ewes/ha in spring 2017 (Table 5.19).

Stocking rates throughout the spring live weight period were altered when necessary to match pasture yields using the ‘Put and Take’ method. The average stocking rates suggest that more animals could have been stocked initially in 2017, however it was fortunate that they were not stocked higher due to the lack of soil water availability later in the season.

7.1.6 Pasture quality

The energy remaining to an animal after pasture is eaten is known as the metabolisable energy (ME). Typical ME values of a pasture range from 8-12 MJ/kg DM (Lambert and Litherland, 2000).

The ME content in this experiment averaged 10.6 MJ ME/kg DM across the major pasture components during spring 2016, which was lower than the averaged 11.2 MJ ME/kg DM during spring 2017 (Table 5.23). Although the average ME from pasture components was lower in 2016, the quality of the pasture components was still high when compared with other studies (Brown *et al*., 2005; Waghorn and Barry, 1987). The ME content of a pasture is normally determined as the most limiting to animal performance.

The average crude protein content from New Zealand pastures ranges from 10-30% (Lambert and Litherland, 2000). The crude protein content followed a similar trend to metabolisable energy between the years. The CP content of the major pasture components averaged 13.4% in spring 2016, which was lower than the 15.8% in spring 2017 (Table 5.23). Compared to other studies (Brown *et al*., 2005; Frame *et al*., 1998; John and Lancashire, 1981), the CP content of the major pasture components in this study were low. This is likely due to samples collected for subsequent NIRs analysis including most portions of the plant. For example, the clover samples still had runners intact. Runners and stems are usually of lower CP than the leaves (Brown *et al*., 2005) which explains the overall low CP contents from both years. This also means the difference in CP between years is likely due to there being more leaf per runner in 2017.

For legume forages, NDF content below 40% is considered high quality (Van Saun, 2018). Higher NDF values are often associated with a decline in dry matter intake, but an increase in the chewing requirement due to decreased digestibility and thus, greater gut fill. There was no difference in the mean NDF content of pasture components between years averaging ~42.0%, but there were differences among components within years (Table 5.24). During spring 2016, cocksfoot had the highest NDF content at 53.7%, and lowest ($P<0.001$) was from sub clover at 33.3%. During spring 2017, NDF content was also highest from the cocksfoot component at 54.5%, but lowest ($P<0.001$) from plantain and sub clover at ~30.7%. This difference in spring NDF content between cocksfoot and plantain is also likely to be a factor in the observed differences between lamb growth rates on CF and PL (Figure 5.3).

Higher ADF values also suggest a lower quality pasture. Pastures with an ADF content less than 35% are considered high quality (Van Saun, 2018). The mean ADF content was 28.5% during spring 2016 (Table 5.24), which was higher than the mean for spring 2017 at 26.5%. ADF differed among components within both years. During spring 2016, ADF content from sub clover was the lowest with 25.7%, with the remaining pasture components averaging 29.5%. However, in spring 2017, plantain had the lowest ADF at 23.3%, followed closely by sub clover 25.5%. This meant that sub clover was of higher quality and the easiest to digest in spring 2016, but there was limited clover in the pastures meaning that stock were forced to graze the less digestible components. In 2017, the proportion of highly digestible plantain was low, but sub clover was high, allowing stock to graze high quality herbage for a longer period of time. The lower ADF content of plantain in 2017, could also be another factor contributing to the higher growth rates from PL lambs.

The difference in quality of pasture components may have influenced ewe and lamb growth rates due to the differences in botanical composition between and among years. Sheep grazing legumes and herbs generally have higher growth rates than those on grasses (Lambert and Litherland, 2000). For example, in this study, because the ME and CP content from clover was higher than most other pasture components across both years (Table 5.23), the higher proportion of clover in the sward in 2017 is likely to have impacted ewe and lamb growth rates. This is supported in work by Ulyatt (1981) who gave an extreme example of this by noting that sheep grazing pure white clover pastures, grew 90% faster than sheep on a pasture of only perennial ryegrass. This suggests the higher growth rates from ewes and lambs in 2017 are due to higher nutritional value and voluntary intake as a result of the higher clover content.

7.1.7 Pasture intake

The rate of intake is dependent upon bite rate and bite mass. There is a strong relationship between bite mass and pasture height. The greater the sward height, the greater the bite mass (Cosgrove and Edwards, 2007). Thus, it is assumed that the larger the pasture allocation, the easier it is for the animal to preferentially graze and increase its ME intake by selecting more palatable plant species and/or components (Nicol and Brookes, 2007b). This is consistent with results for spring 2017, due to the high percentage of clover in the sward. Thus, the higher allocation, combined with the high clover content in spring 2017 is likely to have been the major cause of higher spring 2017 live weight production.

As the mean measured ME content was l1 MJ ME/kg DM across both springs (Table 5.23), this is what was used for intake calculations. However, an average ME content of 12 has been used in some studies (Black and Ryan-Salter, 2016; Brown and Moot, 2004; Nicol and Brookes, 2007b). This is deemed to be the highest ME content possible from grazing the more palatable plant components (Nicol and Brookes, 2007b). Using a higher ME value than measured would have taken into account the likelihood of ewes and lambs actively selecting a diet of greater ME than the measured values for this experiment, and it would have meant that the calculated intake was the lowest amount required to meet animal performance.

The required CP:ME ratio of pasture intake to meet ewe and lamb performance during spring 2016, was 8 g CP/MJ ME (Table 5.25). However, the actual ratio on offer from pastures was 13 g CP/MJ ME. This suggests there was an excess of CP available for consumption in spring 2016 (Section 6.2.2). Ewes lost weight on PL pastures, while those on CF gained weight, but PL lambs grew faster than CF lambs. A diet comprised of high crude protein levels can cause disruption in the rumen of livestock. If the animal is consuming more protein than energy, microbial protein synthesis reduces, which can ultimately lead to high ammonia levels in the rumen (Chapman *et al*., 2007). This results in increased metabolic costs to eliminate the heightened ammonia content. It is possible that ewes may have lost weight dealing with the excess CP in the PL pastures, but that the ewe acted as an 'insulator' and so there was no effect on lamb growth rates. Further work would be required to isolate the impact of a high protein diet during lactation.

During spring 2016, intake per ewe GD measured by disappearance, was within the range specified from calculated intake (Table 6.3) for every pasture. This meant intake met the ME requirements for maintenance and live weight gain, but that ewes and lambs were not eating more than their potential appetite of 4% of their live weight (Court *et al*., 2010). However, in spring 2017, the intake measured by disappearance was higher than the calculated range and exceeded (Table 6.3) the potential appetite of the livestock for three out of the four pastures. This could be from overestimation due to the lack of pasture uniformity and difficulty of calibrating the rising plate meter in the mixed pastures due to "clumpiness" and differences in the proportion of leaf and stem in the sward (Haultain *et al*., 2014). It could also suggest that ewes and lambs were able to eat more than 4% of their body weight if consuming a highly digestible, high legume diet.

Pasture yields were sufficient to meet the intake calculated by energy requirement (Section 6.2.3.1) in both years. Calculated pasture intake in 2017 averaged 1779 kg DM/ha. This was almost double that in 2016 with 934 kg DM/ha (Table 6.3). Intake was higher in spring 2017 due to more feed available to be eaten by more animals. As indicated, this was a result of greater clover content leading to earlier growth and higher yields.

Using the calculated intake values (), pasture utilisation was in a range of 21-27% of pasture yield in spring 2016, and 31-35% for spring 2017. Both years produced low utilisation rates when compared with other legume-based pasture literature (Brown *et al*., 2005; Croy, 2017). This low utilisation is likely due to high allocation thus, potentially reducing the effect of utilisation.

7.1.8 Pasture preference

Pasture preference was only able to be analysed in spring 2017. This was done through a set of transect lines and pre- and post-graze visual %cover estimates converted to botanical composition. Ewes and lambs showed a strong preference for the clover component from all treatments (Figure 6.1). This is consistent with previous reports from Corkran (2009), Cosgrove and Edwards (2007) & Kemp *et al*. (2010) who found that sheep will preferentially graze legumes over grass.

Due to the high legume content across all pasture in 2017, grass and plantain components were consumed less than clover until the third grazing from CF and PL pastures (Figure 6.1). As the clover was preferentially grazed, its accessibility and availability in the sward decreased over time. This meant that by the third grazing, the grass and plantain components had become more easily accessible than the clover, which then supports their greater intake. The increase in grass percentage from CF pastures between post- and pre-graze events is probably due to the selectivity and harder grazing for clover over cocksfoot, allowing the cocksfoot component to increase its overall percentage in the sward.

There was no preference for weed, which meant its presence in the sward increased over time, especially in PL pastures where there was a lack of competition from other pasture components. However, the invasion of weeds in the PL pastures did not seem to affect lamb growth rates. Lambs appeared able to selectively graze more than ewes potentially due to their smaller mouthparts (Cosgrove and Edwards, 2007). This means that later in the season when the percentage of clover and quality of PL pastures had decreased, lambs may have been able to find what was remaining of clover in the PL pastures easier than ewes, thus maintaining a higher quality diet for longer. It is possible that the lamb’s ability to selectively graze, paired with lower daily intake requirements meant the growth rates from lambs on PL pastures could be maintained, while ewe growth rates were more affected by changes in composition. Another contributing factor could be the change in diet from lambs throughout spring. As lambs mature, the milk component of their diet will decrease, while the intake from pasture will increase (B+LNZ, 2010). Thus, if they were unable to meet their daily intake requirements from the pasture, they were still able to consume milk to maintain their growth rates.

The proportion of dead material increased over time in all pastures. This was expected due to low moisture, slower growth, and senescence coming into the late spring period, with animals actively selecting the other sward components.

7.1.9 Water

Summer dry farms are those that receive ≤800 mm of rainfall in a year (Brown and Green, 2003). These farms often experience soil water deficits with the onset of high summer temperatures and lack of rainfall. In this experiment, the random nature of the variability and randomization of treatments meant there was no differences in the PAWC and maximum depth of water extraction between plots (Table 4.1). This meant an average value for soil water use could be used across all plots. The potential and actual soil water deficits were accumulated from the 1st July of each year.

The point at which the ASWD was equal to 0.5 x PAWC (>62.5 mm), was labeled the 'trigger point' (TP) (Figure 4.3). This is assumed to be the point where water stress would first occur, and usually results in a loss of leaf area, then stomatal closure and wilting. The TP was first reached on the 17th October in 2016, and 30th October in 2017. This meant there was an extra 13 days grazing in spring 2017. The additional grazing days in 2017 accounted for an extra 105.7 kg/ha of live weight gain from lambs, and 5.6 kg/ha from ewes. However, this still left 66.3 kg/ha and 49.4 kg/ha of live weigh gain from lambs and ewes, respectively, that was not explained by soil water. Thus, the availability of water was not a factor causing the measured differences in live weight gain between the two springs.

Although statistically showing more water was used in 2016, in practice it only represented 12 mm which is three days growth at an actual evapotranspiration of 4 mm/day. So in practical terms, its unlikely to have made a difference (Table 4.4) and live weight gain was less in 2016 due to the lower clover content (Table 4.3). The water use efficiency across both years averaged ~23 kg DM/ha/mm from PL pastures, which was higher than the average of ~19 kg DM/ha/mm from CF pastures (Figure 4.2). The difference is likely due to the higher CP content in PL pastures (Moot *et al*., 2008).

These results support the importance of taking advantage of the spring period to maximize livestock production on dryland sheep farms. Prior to the spring period, the soils have usually been recharged over autumn/winter with adequate rainfall, but by summer, soils are usually lower yielding and unreliable, as soil water content can dry up rapidly, reducing nitrogen availability also. Thus, spring grazing management needs to focus on ensuring high water use efficiency and this is achieved by having a high annual legume content in pasture to maximise pre-weaning growth rates.

The lower clover content in spring 2016 is likely due to significant rainfall events in January and February 2016 which led to two false strikes events and resulted in death of sub clover seedlings (Smith, M. 9/1/17 Pers. Comm). The initiation of autumn rainfall in New Zealand is highly variable and can affect pasture production and consequently animal production, particularly in annual clover pastures (Dear and Loveland, 1984; Moot *et al*., 2003b). Sub clover is dependent on autumn rainfall for germination (Lucas *et al*., 2016), thus variation in this between years can result in subsequent differences in the germination success. The differences in sub clover establishment between a wet and a dry autumn are observed in this experiment. In 2016, when spring clover content was low, the autumn prior received 52 mm less rainfall than the long-term mean (LTM) of 223.7 mm (Section 3.6.1.1). March received below average rainfall with the first autumn rains not falling until 15th and 16th March 2016 (7.1 mm and 18.9 mm respectively). In 2017, the initiation of autumn rains were 8 days earlier than in spring 2016. The first autumn rainfall was 8.4 mm on the 7th of March. Four days later, another 53 mm fell over a four-day period from the 11th to 14th March. A very wet April followed, totaling 121.2 mm – more than double the LTM for April (Section 3.6.1.1). Although rainfall was below average in May and June, autumn 2017 was described as 'wet', totaling 265 mm of rainfall, which was 41.1 mm greater than the LTM for Autumn. This fully recharged the soil water profile (Figure 4.3) and prompted germination of sub clover seedlings. These differences in autumn rainfall are likely to be the cause for the differences in sub clover content between years.

Sub clover has hardseededness, which is a mechanism of seed dormancy that is used to control germination (Lucas *et al*., 2016). The hard seeds have an impermeable seed coat which means it is unable to germinate even when germination conditions are ideal. The hardseededness enables the sub clover to persist under a range of environmental conditions through the development of the soil banks (Taylor, 2005). Thus, because the sub clover was allowed to set seed in Year 1 of the 'MaxAnnuals' experiment, there was adequate seed in the seed bank to reestablish itself in 2017 with sufficient autumn rainfall, following false strikes and poor seed set in 2016.

7.2 Summer 2016/17

7.2.1 Live weight gain

Pasture yields allowed grazing of the treatments by weaned lambs to continue into summer 2016/17. However, out of the annual live weight gain achieved in 2016/17, weaned lambs (mixture of ram and ewe lambs) only accounted for 22-23% of this. Pasture utilisation and intake was low because the quantity and quality of pastures were poor. This means finishing pre-weaning in a dryland environment is key.

There were no differences in live weight gain of weaned lambs among treatments during summer (Table 5.27). There were also no differences in weaned lamb growth rates averaging 92 g/hd/d (Figure 5.9) among treatments despite a ~2 kg range in starting weights (Appendix 5). CF pastures were higher yielding than PL pastures during every month of summer (Table 5.29), but the nutritive value of the pastures did not differ, with the exception of plantain being the most digestible pasture component (Table 5.31). The higher digestibility of plantain meant weaned lamb growth rates were higher from PL pastures. But, the higher yields from CF pastures meant they could be grazed at higher stocking rates (Section 5.5.4) than PL pastures which resulted in no overall differences among pastures for weaned lamb live weight gain.

7.2.2 Pasture composition

During early summer, clover content averaged ~2% among all pastures (Appendix 19). The clover component was expected to be minimal during summer due to seed set and subsequent burr burial of sub clover before the onset of summer dry months.

Cocksfoot accounted for ~65% of CF pastures, and ryegrass ~12% of PL pastures (Appendix 20). Plantain was present in all treatments at the beginning of summer (Appendix 21), averaging ~41% in PL pastures, which was greater than the ~17% from CF pastures.

Weeds can become particularly invasive in dryland pastures during summer (Tozer *et al*., 2010). Weeds were still suppressed in CF pastures through summer averaging only ~2%, while the weed content in PL pastures was higher with ~24% (Appendix 22). This further illustrates the persistence from CF pastures and its ability to maintain low weed content within the sward (Mills *et al*., 2015b; Tozer *et al*., 2010). The major weeds present in this experiment were chickweed, vulpia hair grass, and dock. The weed content of a pasture should be maintained to a minimum. The competition between weeds and sown species can suppress pasture reduction, resulting in decreased livestock performance. Seeds of weed species can also contaminate carcasses or damage hides (Bourdot, 1996; Burton and Dowling, 2004).

The content of dead material did not differ among treatments (Appendix 23) averaging ~19% across all pastures during summer 2016/17.

This meant the major pasture components of CF pastures were cocksfoot, dead material, and plantain. PL pastures were mostly plantain, weeds, and dead material. This suggests that although there was ~12% ryegrass present in PL pastures, that it would not have been easily accessible and available within the sward.

7.2.3 Pasture yields

Pasture yields ranged from 0.9-1.1 t DM/ha (Table 5.28) and were not different among pastures. Plots were destocked in late November 2016 due to soil moisture deficits being exceeded (Figure 4.3). However, two significant rain events of 13.4 mm on the 17th November, followed by a further 33.6 mm on the 11th December, enabled growth to resume and plots to be restocked with weaned lambs from 13th December to 26th January. In a commercial farming situation, lambs would have had to been sold store at the end of the spring grazing period, or supplementary feed would have been required. This feed would probably have been grazed by ewes.

Pasture yields were higher from CF pastures during every month of the summer 2016/17 period (Table 5.29). This suggests that CF pastures thrived in the dry conditions experienced at Ashley Dene, and responded more quickly to in-season rainfall than PL-based pastures. This is due to the ability of cocksfoot to withstand a low moisture environment and still offer feed when sub clover has buried its burrs and does not offer any feed during summer. This is supported by various studies which have tested the performance of cocksfoot and its suitability to summer dry environments (Mills *et al*., 2015b; Rumball, 1982; Stevens *et al*., 1992). Recently, Sharifiamina (2018) found in an adjacent paddock, cocksfoot was the only grass that responded to that 33.6 mm rainfall event at Ashley Dene only in the presence of nitrogen. This implies that the nitrogen available from the sub clover was adequate to support the cocksfoot response in the current experiment. In her study, Sharifiamina (2018) found brome (*Bromus valdivianus*), tall fescue (*Festuca arundinacea*), and perennial ryegrass did not respond to this rainfall event when they had nitrogen. These results plus the previous ‘MaxClover’ experiment (Mills *et al*., 2015b) confirm the suitability of cocksfoot for dryland pastures.

7.2.4 Pasture allocation

There was no difference in the number of grazing days (Table 5.27) or yields (Table 5.28) among pastures during summer. This meant allocation averaged 1.9 kg DM/weaned lamb GD across all treatments (Table 5.30). This was lower than the determined allocation of 8 kg DM/ewe GD by Rattray *et al*. (1982) confirming that live weight gain was not maximised.

7.2.5 Stocking rates

Weaned lamb stocking rates did not differ between December and January, but CF pastures were stocked at 18.6 weaned lambs/ha which was higher than PL pastures with 13.1 weaned lambs/ha (Section 5.5.4.1). Although the digestibility of plantain was higher than cocksfoot (Table 5.31), higher yields from CF pastures meant they could be grazed at higher stocking rates than PL pastures which resulted in no overall differences among pastures for weaned lamb live weight gain.

7.2.6 Pasture quality

As expected, the quality of pastures declined in summer. The mean ME content of all pasture components dropped during summer to average 10 MJ ME/kg DM (Table 5.31), but this was still of reasonable quality when compared to the ME content during spring (Table 5.23). The decreased nutritive value exhibited in all pastures over summer resulted from the change from vegetative to reproductive development for some species, reduced growth from lack of soil moisture (Figure 4.3), and the loss of sub clover from the sward. Previous research has found plantain quality decreases during summer. For example, studies by Cave *et al*. (2015) & Fraser and Rowarth (1996) found the digestibility and protein content of plantain decreased in summer most probably due to entering the reproductive state. During this phase, plantain leaves age, and the seed head comprised 60% of the available dry matter, greatly reducing palatability and quality of the herb. The proportion of weed and dead material also greatly increased between spring and summer (Figure 6.2), especially in PL pastures. These unpalatable pasture components still contribute to dry matter yields, but negatively affected herbage quality.

Although the plantain component can decrease in quality during summer, it had a mean NDF content of 44%, which was still lower than the 52% from cocksfoot suggesting plantain was more easily digested. In plantain pastures, the three largest components were plantain (~40%), weeds (~24%), and dead (~22%). Cocksfoot accounted for ~65% yield with, ~17% plantain and ~16% dead material. The higher quantity of cocksfoot available to be eaten, meant CF pastures could be stocked higher (Section 5.5.4), compensating for its lower quality. This meant there were no differences in weaned lamb live weight gain among treatments.

7.2.7 Pasture intake

Yields were also consistent with the calculated intake requirements for summer 2016/17 (Table 6.2). Weaned lambs grew faster on PL pastures, but there were no differences in pasture intake calculated by energy requirement among the four pastures (Table 6.6). This supports the higher quality of PL pastures, due to the higher digestibility of plantain than cocksfoot (Table 5.36) during summer. Pasture intake measured by disappearance during summer (Table 6.6) exceeded the potential appetite (Table 6.7) of weaned lambs. This suggests that intake was overestimated, due to the difficulty of calibrating the rising plate meter in mixed pastures, as mentioned in Section 7.1.7.

Calculated by ME requirement, individual weaned lambs on PL pastures ate 1.1 kg DM/GD, which was more than the 0.8 kg DM/GD from lambs on CF pastures (Appendix 17). This is most likely due to the higher proportion of more easily digestible plantain in PL pastures. However, stocking rates were higher on CF pastures which led to no difference in the amount of pasture actually eaten (Table 6.6), and leading to no differences in live weight gain (Table 5.27).

Based on the calculated pasture intake results (Table 6.6), pasture utilisation was low in summer, averaging 17% of pasture yield for CF/Sub, 16% for CF/S+B, and 24% and 19% for PL/Sub and PL/S+B pastures, respectively. This reflects the poor state of all the pastures during summer, and is a factor resulting in the observed similar weaned lamb live weight gains among treatments. However, based on the measured pasture intake values (Table 6.6), pasture utilisation was 53% and 51% on CF/S+B and CF/Sub pastures, respectively. Whereas, utilisation from PL pastures was lower, with 28% from PL/Sub, and 29% from PL/S+B pastures. This is again likely to be from overestimation due to difficulty of calibrating the rising plate meter. Thus, the utilisation results based on the calculated values are more credible.

7.2.8 Pasture preference

Pasture preference was not recorded in summer 2016/17. But observations in the field suggested that plantain was not preferred by weaned lambs (Smith, M. 9/1/17 Pers. comm). Lambs were described as eating the more digestible top portion, or younger leaves of plantain only. This is consistent with previous research from Cave *et al*. (2015) who aimed to determine whether ewe lamb grazing behavior of plantain during late summer was affected by the time since it was last grazed. They found that the 3-week old plantain growth was grazed to a lower sward height than the height of the other ‘older’ plantain swards, suggesting that as plantain matures it becomes less palatable (Cave *et al*., 2015; Fraser and Rowarth, 1996) and is less preferred.

7.3 Implications

Provided it has set, or populations are already present, sub clover seed is present in the soil right from seed set at the end of spring/early summer. This means any major summer rainfall puts it at risk of false strikes. False strikes often occur when there is a substantial rainfall event during summer that is enough to encourage germination, followed by a prolonged dry period. This results in germination of sub clover with moisture, but these seedlings quickly die with no further rain and high temperatures. In a non-irrigated, dryland environment, there is nothing that can be done to prevent the risk of false strikes with sub clover, other than to expect that this may occur. However, ensuring that sufficient sub clover seed is returned to the seed bank every four to five years with flowering (Grigg *et al.*, 2008) is one way to ensure that there is plenty of seed in the seed bank incase false strikes do arise.

Subterranean clover seeds are adapted to germinate from burrs under the soil surface. Thus, the recommended method of sowing is by over drilling (Lucas *et al.*, 2016). It has long been proven that clovers can be successfully over-drilled into existing pastures provided the time of sowing is when grass growth is at its lowest, that a hard grazing has taken place prior to sowing, and that careful grazing management is carried out following establishment (Blackmore, 1962).

Subterranean clover requires careful management during its first spring following establishment. As carried out in Year 1 of this experiment, allowing sub clover to flower, set seed and bury its burrs is important to maintain sub clover in the seed bank and ensure successful establishment the following autumn. This was the focus of the first year of this experiment and this maintained sub clover to Year 5 without further emphasis on seed set. Heavy grazing during flowering can have detrimental effects on seedlings in the first spring. (Ates *et al.*, 2013) found that pastures that were grazed by sheep until early December had 50% fewer seedlings in the following autumn, compared with pastures that were taken out of grazing from mid-October before the onset of flowering. Ideally, stock should be removed from paddocks where sub clover is flowering. However, shutting up paddocks is not realistic in a real farming system, especially at that time of the year. An alternative to removing animals is to have lax grazing management (i.e. about 2000 kg DM/ha) using lower stocking rates than usual (Lucas *et al.*, 2017). This means flowers are likely to still be grazed, but less than would be eaten at higher stocking rates which means there will still be plants able to successfully flower and set their seed. Cattle can also be used to graze during flowering instead of sheep. The larger mouth parts of cattle mean they are not able to eat as far down into the pasture as sheep can with their small, narrow mouths. Thus, because sub clover is low-growing, it may be avoided if grazed by cattle or other animals with larger mouth parts. This practice has been used successfully in Marlborough on uncultivatable hill country (Grigg *et al*., 2008).

Using cocksfoot as a companion species in subterranean clover-based pastures is beneficial as it has high ME and CP, is well-suited to dryland conditions, and quickly fills any bare ground preventing the establishment of weeds. However, it was extensively used in pastures during the 1960-1970s (Moloney, 1993) where it gained a reputation for being “clumpy”. Good grazing management is required to ensure cocksfoot doesn’t get “clumpy”. As carried out in this experiment, this can be achieved through regular grazing, and hard ‘clean-up’ grazing events by ewes during summer and autumn to maintain the quality also.

7.4 Conclusions

- The live weight production achieved solely from ewes and lambs in the spring of 2017, was greater than the 2016 spring and summer periods combined.
- The greater proportion of sub clover in spring 2017 meant pasture growth was initiated earlier in autumn, resulting in higher opening spring pasture covers.
- Intake from ewes and lambs was 90% higher in spring 2017, due to a higher allocation of high yielding and quality herbage, comprised of ~75% clover.
- The addition of a secondary legume did not increase live weight gains, but did increase total clover content. To minimize management difficulties, it is recommended to concentrate on the most dominant legume only.
- Cocksfoot has exceptional persistence under dryland conditions and is a suitable companion grass for sub clover-based pastures in the long-term.
- Plantain pastures may be an option for short-term (3-4 years) in dryland environments, but weed invasion is likely to compromise their production and persistence.

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8 APPENDICES

Appendix 1: Summary of grazing periods for the CF/Sub treatment from spring 2016-2017. 'E&L' refers to ewes and lambs during lactation, 'WL' refers to weaned lambs, ewes refers to maintenance ewes. The phase was productive (Prod) when weight gain was measured, or maintenance (Maint) when stock were used to reduce grazing mass. SR refers to the equivalent stocking rate/ha for that treatment area.

Year	Rep	Phase	Stock	Date on	Date off	Ewe SR/ha	Lamb SR/ha	Other SR/ha
2016/17	3	Prod	E&L	6/09/2016	20/09/2016	8.0	12.4	
2016/17	4	Prod	E&L	6/09/2016	20/09/2016	8.2	16.3	
2016/17	1	Prod	E&L	13/09/2016	20/09/2016	10.1	20.2	
2016/17	2	Prod	E&L	13/09/2016	20/09/2016	8.1	16.1	
2016/17	1	Prod	E&L	20/09/2016	23/09/2016	8.6	17.2	
2016/17	1	Prod	E&L	23/09/2016	27/09/2016	11.1	22.3	
2016/17	2	Prod	E&L	27/09/2016	4/10/2016	11.1	22.3	
2016/17	3	Prod	E&L	4/10/2016	9/10/2016	11.1	22.3	
2016/17	4	Prod	E&L	9/10/2016	15/10/2016	11.1	22.3	
2016/17	1	Prod	E&L	15/10/2016	19/10/2016	11.1	22.3	
2016/17	2	Prod	E&L	19/10/2016	20/10/2016	11.1	22.3	
2016/17	2	Prod	E&L	20/10/2016	24/10/2016	8.6	17.2	
2016/17	3	Prod	E&L	24/10/2016	28/10/2016	8.6	17.2	
2016/17	4	Prod	E&L	28/10/2016	2/11/2016	8.6	17.2	
2016/17	1	Prod	E&L	2/11/2016	7/11/2016	8.6	17.2	
2016/17	2	Prod	E&L	7/11/2016	11/11/2016	8.6	17.2	
2016/17	3	Prod	E&L	11/11/2016	14/11/2016	8.6	17.2	
2016/17	4	Prod	E&L	14/11/2016	17/11/2016	8.6	17.2	
2016/17	1	Prod	WL	13/12/2016	22/12/2016		19.2	
2016/17	2	Prod	WL	22/12/2016	29/12/2016		19.2	
2016/17	3	Prod	WL	29/12/2016	5/01/2017		19.2	
2016/17	4	Prod	WL	5/01/2017	13/01/2017		19.2	
2016/17	1	Prod	WL	13/01/2017	16/01/2017		19.2	
2016/17	2	Prod	WL	16/01/2017	19/01/2017		19.2	
2016/17	3	Prod	WL	19/01/2017	21/01/2017		19.2	
2016/17	2	Prod	WL	21/01/2017	26/01/2017		19.2	
2016/17	1	Maint	Ewes	21/02/2017	22/02/2017			93.7
2016/17	2	Maint	Ewes	22/02/2017	24/02/2017			93.7
2016/17	3	Maint	Ewes	24/02/2017	25/02/2017			93.7
2016/17	4	Maint	Ewes	25/02/2017	27/02/2017			93.7
2017/18	4	Prod	E&L	4/09/2017	5/09/2017	10.0	20.2	
2017/18	3	Prod	E&L	5/09/2017	25/09/2017	12.3	24.5	
2017/18	4	Prod	E&L	5/09/2017	25/09/2017	12.2	24.2	
2017/18	2	Prod	E&L	8/09/2017	25/09/2017	16.2	32.7	
2017/18	1	Prod	E&L	12/09/2017	25/09/2017	16.2	32.3	
2017/18	1	Prod	E&L	25/09/2017	29/09/2017	14.2	28.3	
2017/18	2	Prod	E&L	29/09/2017	4/10/2017	14.2	28.3	
2017/18	3	Prod	E&L	4/10/2017	11/10/2017	14.2	28.3	
2017/18	4	Prod	E&L	11/10/2017	20/10/2017	14.2	28.3	
2017/18	1	Prod	E&L	20/10/2017	26/10/2017	14.2	28.3	
2017/18	2	Prod	E&L	26/10/2017	31/10/2017	14.2	28.3	
2017/18	3	Prod	E&L	31/10/2017	5/11/2017	14.2	28.3	
2017/18	4	Prod	E&L	5/11/2017	6/11/2017	14.2	28.3	
2017/18	4	Prod	E&L	6/11/2017	9/11/2017	7.1	14.2	
2017/18	1	Prod	E&L	9/11/2017	13/11/2017	7.1	14.2	
2017/18	2	Prod	E&L	13/11/2017	15/11/2017	7.1	14.2	

Appendix 2: Summary of grazing periods for the CF/S+B treatment from 2016-2017. Acronyms are listed in Appendix 1.

Year	Rep	Phase	Stock	Date on	Date off	Ewe SR/ha	Lamb SR/ha	Other SR/ha
2016/17	2	Prod	E&L	13/09/2016	20/09/2016	8.1	16.1	
2016/17	4	Prod	E&L	6/09/2016	20/09/2016	7.9	15.7	
2016/17	1	Prod	E&L	13/09/2016	20/09/2016	8.1	16.2	
2016/17	3	Prod	E&L	6/09/2016	20/09/2016	6.0	12.1	
2016/17	2	Prod	E&L	26/09/2016	1/10/2016	8.1	15.8	
2016/17	4	Prod	E&L	7/10/2016	14/10/2016	10.9	21.7	
2016/17	1	Prod	E&L	20/09/2016	23/09/2016	10.9	21.7	
2016/17	1	Prod	E&L	23/09/2016	26/09/2016	10.9	21.7	
2016/17	3	Prod	E&L	1/10/2016	7/10/2016	10.9	21.7	
2016/17	2	Prod	E&L	18/10/2016	19/10/2016	10.9	21.7	
2016/17	2	Prod	E&L	19/10/2016	24/10/2016	10.9	21.7	
2016/17	4	Prod	E&L	28/10/2016	2/11/2016	8.1	16.3	
2016/17	1	Prod	E&L	14/10/2016	18/10/2016	8.1	16.3	
2016/17	3	Prod	E&L	24/10/2016	28/10/2016	8.1	16.3	
2016/17	2	Prod	E&L	5/11/2016	10/11/2016	8.1	16.3	
2016/17	4	Prod	E&L	14/11/2016	17/11/2016	8.1	16.3	
2016/17	1	Prod	E&L	2/11/2016	5/11/2016	8.1	16.3	
2016/17	3	Prod	E&L	10/11/2016	14/11/2016	8.1	16.3	
2016/17	1	Prod	WL	13/12/2016	22/12/2016		17.9	
2016/17	2	Prod	WL	22/12/2016	29/12/2016		17.9	
2016/17	3	Prod	WL	29/12/2016	5/01/2017		17.9	
2016/17	4	Prod	WL	5/01/2017	13/01/2017		17.9	
2016/17	1	Prod	WL	13/01/2017	16/01/2017		17.9	
2016/17	2	Prod	WL	16/01/2017	19/01/2017		17.9	
2016/17	3	Prod	WL	19/01/2017	21/01/2017		17.9	
2016/17	2	Prod	WL	21/01/2017	26/01/2017		17.9	
2016/17	1	Maint	Ewes	21/02/2017	22/02/2017			100.5
2016/17	2	Maint	Ewes	22/02/2017	24/02/2017			100.5
2016/17	3	Maint	Ewes	24/02/2017	25/02/2017			100.5
2016/17	4	Maint	Ewes	25/02/2017	27/02/2017			100.5
2017/18	4	Prod	E&L	31/08/2017	4/09/2017	10.1	20.1	
2017/18	4	Prod	E&L	4/09/2017	25/09/2017	16.1	47.1	
2017/18	1	Prod	E&L	13/09/2017	25/09/2017	15.7	31.9	
2017/18	3	Prod	E&L	7/09/2017	25/09/2017	14.1	28.2	
2017/18	2	Prod	E&L	29/09/2017	4/10/2017	14.1	28.3	
2017/18	4	Prod	E&L	11/10/2017	20/10/2017	14.1	28.3	
2017/18	1	Prod	E&L	25/09/2017	29/09/2017	14.1	28.3	
2017/18	3	Prod	E&L	4/10/2017	11/10/2017	14.1	28.3	
2017/18	2	Prod	E&L	26/10/2017	31/10/2017	14.1	28.3	
2017/18	4	Prod	E&L	5/11/2017	6/11/2017	14.1	28.3	
2017/18	4	Prod	E&L	6/11/2017	9/11/2017	14.1	28.3	
2017/18	1	Prod	E&L	20/10/2017	26/10/2017	13.0	26.1	
2017/18	3	Prod	E&L	31/10/2017	2/11/2017	13.0	26.1	
2017/18	3	Prod	E&L	2/11/2017	5/11/2017	6.5	13.0	
2017/18	2	Prod	E&L	13/11/2017	15/11/2017	6.5	13.0	
2017/18	1	Prod	E&L	9/11/2017	13/11/2017	6.5	13.0	

Appendix 3: Summary of grazing periods for the PL/Sub treatment from 2016-2017. Acronyms are listed in Appendix 1.

Year	Rep	Phase	Stock	Date on	Date off	Ewe SR/ha	Lamb SR/ha	Other SR/ha
2016/17	4	Prod	E&L	6/09/2016	20/09/2016	5.8	11.7	
2016/17	3	Prod	E&L	6/09/2016	20/09/2016	5.9	11.9	
2016/17	1	Prod	E&L	13/09/2016	20/09/2016	8.0	16.1	
2016/17	2	Prod	E&L	13/09/2016	20/09/2016	8.2	16.2	
2016/17	1	Prod	E&L	20/09/2016	23/09/2016	6.1	12.2	
2016/17	1	Prod	E&L	23/09/2016	28/09/2016	9.8	19.7	
2016/17	2	Prod	E&L	28/09/2016	3/10/2016	9.8	19.7	
2016/17	3	Prod	E&L	3/10/2016	11/10/2016	9.8	19.7	
2016/17	4	Prod	E&L	11/10/2016	18/10/2016	9.8	19.7	
2016/17	1	Prod	E&L	18/10/2016	24/10/2016	9.8	19.7	
2016/17	2	Prod	E&L	24/10/2016	28/10/2016	9.8	19.7	
2016/17	3	Prod	E&L	28/10/2016	1/11/2016	9.8	19.7	
2016/17	4	Prod	E&L	1/11/2016	5/11/2016	9.8	19.7	
2016/17	1	Prod	E&L	5/11/2016	10/11/2016	9.8	19.7	
2016/17	2	Prod	E&L	10/11/2016	14/11/2016	9.8	19.7	
2016/17	3	Prod	E&L	14/11/2016	16/11/2016	9.8	19.7	
2016/17	4	Prod	E&L	16/11/2016	18/11/2016	9.8	19.7	
2016/17	1	Prod	WL	13/12/2016	22/12/2016		13.1	
2016/17	2	Prod	WL	22/12/2016	27/12/2016		13.1	
2016/17	3	Prod	WL	27/12/2016	31/12/2016		13.1	
2016/17	4	Prod	WL	31/12/2016	13/01/2017		13.1	
2016/17	1	Prod	WL	13/01/2017	19/01/2017		13.1	
2016/17	2	Prod	WL	19/01/2017	26/01/2017		13.1	
2016/17	1	Maint	Ewes	21/02/2017	22/02/2017			86.6
2016/17	2	Maint	Ewes	22/02/2017	24/02/2017			86.6
2016/17	3	Maint	Ewes	24/02/2017	25/02/2017			86.6
2016/17	4	Maint	Ewes	25/02/2017	27/02/2017			86.6
2017/18	4	Prod	E&L	4/09/2017	5/09/2017	9.3	23.4	
2017/18	4	Prod	E&L	5/09/2017	25/09/2017	16.1	31.6	
2017/18	3	Prod	E&L	5/09/2017	11/09/2017	16.1	32.3	
2017/18	2	Prod	E&L	8/09/2017	25/09/2017	12.1	24.1	
2017/18	3	Prod	E&L	11/09/2017	25/09/2017	14.1	21.6	
2017/18	1	Prod	E&L	13/09/2017	25/09/2017	18.2	36.7	
2017/18	1	Prod	E&L	25/09/2017	29/09/2017	13.6	27.1	
2017/18	2	Prod	E&L	29/09/2017	4/10/2017	13.6	27.1	
2017/18	3	Prod	E&L	4/10/2017	11/10/2017	13.6	27.1	
2017/18	4	Prod	E&L	11/10/2017	20/10/2017	13.6	27.1	
2017/18	1	Prod	E&L	20/10/2017	26/10/2017	13.6	27.1	
2017/18	2	Prod	E&L	26/10/2017	31/10/2017	13.6	27.1	
2017/18	3	Prod	E&L	31/10/2017	5/11/2017	13.6	27.1	
2017/18	4	Prod	E&L	5/11/2017	6/11/2017	13.6	27.1	
2017/18	4	Prod	E&L	6/11/2017	9/11/2017	7.0	14.0	
2017/18	1	Prod	E&L	9/11/2017	13/11/2017	7.0	14.0	
2017/18	2	Prod	E&L	13/11/2017	15/11/2017	7.0	14.0	

Appendix 4: Summary of grazing periods for the PL/S+B treatment from 2016-2017. Acronyms are listed in Appendix 1.

Year	Rep	Phase	Stock	Date on	Date off	Ewe SR/ha	Lamb SR/ha	Other SR/ha
2016/17	3	Prod	E&L	6/09/2016	20/09/2016	6.0	12.1	
2016/17	4	Prod	E&L	6/09/2016	20/09/2016	6.0	11.9	
2016/17	1	Prod	E&L	13/09/2016	20/09/2016	6.1	12.3	
2016/17	2	Prod	E&L	13/09/2016	20/09/2016	4.6	9.3	
2016/17	1	Prod	E&L	20/09/2016	23/09/2016	6.0	11.5	
2016/17	1	Prod	E&L	23/09/2016	29/09/2016	10.0	19.4	
2016/17	2	Prod	E&L	29/09/2016	5/10/2016	10.0	19.4	
2016/17	3	Prod	E&L	5/10/2016	11/10/2016	10.0	19.4	
2016/17	4	Prod	E&L	11/10/2016	19/10/2016	10.0	19.4	
2016/17	1	Prod	E&L	19/10/2016	24/10/2016	10.0	19.4	
2016/17	2	Prod	E&L	24/10/2016	28/10/2016	10.0	19.4	
2016/17	3	Prod	E&L	28/10/2016	1/11/2016	10.0	19.4	
2016/17	4	Prod	E&L	1/11/2016	5/11/2016	10.0	19.4	
2016/17	1	Prod	E&L	5/11/2016	10/11/2016	10.0	19.4	
2016/17	2	Prod	E&L	10/11/2016	14/11/2016	10.0	19.4	
2016/17	3	Prod	E&L	14/11/2016	16/11/2016	10.0	19.4	
2016/17	4	Prod	E&L	16/11/2016	18/11/2016	10.0	19.4	
2016/17	1	Prod	WL	13/12/2016	22/12/2016		13.0	
2016/17	2	Prod	WL	22/12/2016	27/12/2016		13.0	
2016/17	3	Prod	WL	27/12/2016	31/12/2016		13.0	
2016/17	4	Prod	WL	31/12/2016	13/01/2017		13.0	
2016/17	1	Prod	WL	13/01/2017	19/01/2017		13.0	
2016/17	2	Prod	WL	19/01/2017	26/01/2017		13.0	
2016/17	1	Maint	Ewes	21/02/2017	22/02/2017			92.3
2016/17	2	Maint	Ewes	22/02/2017	24/02/2017			92.3
2016/17	3	Maint	Ewes	24/02/2017	25/02/2017			92.3
2016/17	4	Maint	Ewes	25/02/2017	27/02/2017			92.3
2017/18	4	Prod	E&L	31/08/2017	4/09/2017	11.7	28.4	
2017/18	4	Prod	E&L	4/09/2017	25/09/2017	15.8	32.6	
2017/18	3	Prod	E&L	7/09/2017	15/09/2017	13.8	32.4	
2017/18	1	Prod	E&L	12/09/2017	25/09/2017	16.3	24.5	
2017/18	2	Prod	E&L	12/09/2017	20/09/2017	16.3	21.6	
2017/18	3	Prod	E&L	15/09/2017	25/09/2017	12.1	27.9	
2017/18	2	Prod	E&L	20/09/2017	25/09/2017	14.1	27.9	
2017/18	1	Prod	E&L	25/09/2017	29/09/2017	14.0	27.9	
2017/18	2	Prod	E&L	29/09/2017	4/10/2017	14.0	27.9	
2017/18	3	Prod	E&L	4/10/2017	11/10/2017	14.0	27.9	
2017/18	4	Prod	E&L	11/10/2017	20/10/2017	14.0	27.9	
2017/18	1	Prod	E&L	20/10/2017	26/10/2017	14.0	27.9	
2017/18	2	Prod	E&L	26/10/2017	31/10/2017	14.0	27.9	
2017/18	3	Prod	E&L	31/10/2017	5/11/2017	14.0	13.0	
2017/18	4	Prod	E&L	5/11/2017	6/11/2017	14.0	13.0	
2017/18	4	Prod	E&L	6/11/2017	9/11/2017	6.5	13.0	
2017/18	1	Prod	E&L	9/11/2017	13/11/2017	6.5		
2017/18	2	Prod	E&L	13/11/2017	15/11/2017	6.5		

Treatment acronyms are listed in Table 3.3.

Appendix 5: Mean live weight (kg) of weaned lambs at the time of introduction to the experimental area during summer 2016.

Treatment	2016/17
CF/Sub	30.5 $_b$
CF/S+B	32.3 $_a$
PL/Sub	30.2 $_b$
PL/S+B	31.7 $_a$
S.E.M.	0.5
P-value	**0.002**

Treatment acronyms are listed in Table 3.3.

Appendix 6: Dates of first introduction into paddocks by ewes and lambs during the set stocking period in 2016/17 and 2017/18 at Ashley Dene, Canterbury.

		Date introduced	
Plot	**Treatment**	**Spring 2016/17**	**Spring 2017/18**
16	**PL/S+B**	6/9/16	31/8/17
15	**CF/Sub**	6/9/16	4/9/17
14	**PL/Sub**	6/9/16	5/9/17
13	**CF/S+B**	6/9/16	7/9/17
12	**CF/Sub**	13/9/16	8/9/17
11	**PL/S+B**	13/9/16	12/9/17
10	**CF/Sub**	13/9/16	12/9/17
9	**CF/S+B**	13/9/16	13/9/17
8	**CF/S+B**	6/9/16	31/8/17
7	**PL/Sub**	6/9/16	4/9/17
6	**CF/Sub**	6/9/16	5/9/17
5	**PL/S+B**	6/9/16	7/9/17
4	**PL/Sub**	13/9/16	8/9/17
3	**CF/S+B**	13/9/16	12/9/17
2	**PL/S+B**	13/9/16	12/9/17
1	**PL/Sub**	13/9/16	13/9/17

Treatment acronyms are listed in Table 3.3.

Appendix 7: Metabolisable energy content (%) of spring pasture yield from four dryland pastures during 2016 and 2017 at Ashley Dene, Canterbury.

Treatment	2016		2017
CF/Sub	26.1		33.6
CF/S+B	21.5		32.2
PL/Sub	28.4		32.1
PL/S+B	27.1		30.2
Year mean	25.8		32.0
S.E.M.		1.89	
P-value		**0.040**	
Orthogonal contrasts	**Means**		**P value**
CF v PL	28.4	29.5	0.658
S v S+B	30.1	27.8	0.364

Treatment acronyms are listed in Table 3.3.

Appendix 8: Crude protein content (%) of spring pasture yield from four dryland pastures during 2016 and 2017 at Ashley Dene, Canterbury.

Treatment	**2016**		**2017**
CF/Sub	19.5		42.8 $_{a}$
CF/S+B	16.0		35.4 $_{a}$
PL/Sub	18.5		20.7 $_{b}$
PL/S+B	15.7		28.7 $_{ab}$
Year mean	17.4		31.9
S.E.M.		2.06	
P-value		**<0.001**	
Orthogonal contrasts	**Means**		**P value**
CF v PL	28.4	20.9	**0.006**
S v S+B	25.4	24.0	0.525

Treatment acronyms are listed in Table 3.3.

Appendix 9: Pasture intake by calculated energy requirement (kg DM/ewe GD) of spring pasture yield from four dryland pastures during 2016 and 2017 at Ashley Dene, Canterbury.

Treatment	**2016**		**2017**
CF/Sub	4.0 $_{b}$		4.4
CF/S+B	4.1 $_{b}$		4.3
PL/Sub	4.5 $_{a}$		4.3
PL/S+B	4.5 $_{a}$		4.4
Year mean	4.3		4.4
S.E.M.		0.04	
P-value		0.402	
Orthogonal contrasts	**Means**		**P value**
CF v PL	4.2	4.4	**0.007**
S v S+B	4.3	4.3	0.860

Treatment acronyms are listed in Table 3.3.

Appendix 10: Pasture intake by disappearance (kg DM/ewe GD) of spring pasture yield from four dryland pastures during 2016 and 2017 at Ashley Dene, Canterbury.

Treatment	**2016**		**2017**
CF/Sub	4.4		4.7
CF/S+B	4.9		6.0
PL/Sub	5.5		5.7
PL/S+B	5.2		6.4
Year mean	5.0 $_{b}$		5.7 $_{a}$
S.E.M.		0.20	
P-value		**0.030**	
Orthogonal contrasts	**Means**		**P value**
CF v PL	5.0	5.7	**0.060**
S v S+B	5.1	5.6	**0.039**

Treatment acronyms are listed in Table 3.3.

Appendix 11: Percent (%) of sown grass from cage cuts and quadrat cuts from four dryland pastures during 2016 and 2017 at Ashley Dene, Canterbury. Samples were collected on the 27th October 2016, and 9th September 2017.

Treatment	**2016**		**2017**
CF/Sub	57.0_{a}		25.3_{a}
CF/S+B	50.2_{a}		12.6_{b}
PL/Sub	4.0_{b}		4.4_{c}
PL/S+B	6.3_{b}		6.0_{c}
Year mean	29.4_{a}		12.1_{b}
S.E.M.	2.0		
P-value	**0.062**		
Orthogonal contrasts	**Means**		**P value**
CF v PL	36.3	5.2	**<0.001**
S v S+B	22.7	18.8	**0.006**

Treatment acronyms are listed in Table 3.3.

Appendix 12: Percent (%) of plantain from cage cuts and quadrat cuts from four dryland pastures during 2016 and 2017 at Ashley Dene, Canterbury. Samples were collected on the 27th October 2016, and 9th September 2017.

Treatment	**2016**		**2017**
CF/Sub	15.1_{b}		2.7_{b}
CF/S+B	25.6_{b}		4.2_{a}
PL/Sub	75.8_{a}		2.6_{b}
PL/S+B	57.9_{a}		4.2_{a}
Year mean	43.6_{a}		3.4_{b}
S.E.M.	2.4		
P-value	0.226		
Orthogonal contrasts	**Means**		**P value**
CF v PL	11.9	35.1	**0.005**
S v S+B	24.1	23.0	0.132

Treatment acronyms are listed in Table 3.3.

Appendix 13: Percent (%) of weeds from cage cuts and quadrat cuts from four dryland pastures during 2016 and 2017 at Ashley Dene, Canterbury. Samples were collected on the 27th October 2016, and 9th September 2017.

Treatment	**2016**		**2017**
CF/Sub	1.4		5.0_{b}
CF/S+B	3.5		2.5_{b}
PL/Sub	2.7		15.5_{a}
PL/S+B	5.6		10.2_{ab}
Year mean	3.3		8.3
S.E.M.		1.9	
P-value		0.293	
Orthogonal contrasts	**Means**		**P value**
CF v PL	3.1	8.5	**0.058**
S v S+B	6.2	5.5	0.876

Treatment acronyms are listed in Table 3.3.

Appendix 14: Percent (%) of dead material from cage cuts and quadrat cuts from four dryland pastures during 2016 and 2017 at Ashley Dene, Canterbury. Samples were collected on the 27th October 2016, and 9th September 2017.

Treatment	**2016**		**2017**
CF/Sub	14.1		0.2
CF/S+B	9.2		1.8
PL/Sub	10.2		2.8
PL/S+B	8.5		0.3
Year mean	10.5		1.3
S.E.M.		1.2	
P-value		0.101	
Orthogonal contrasts	**Means**		**P value**
CF v PL	6.3	5.5	0.915
S v S+B	6.8	5.0	0.707

Treatment acronyms are listed in Table 3.3.

Appendix 15: Metabolisable energy content (%) of summer pasture yield from four dryland pastures during 2016/2017 at Ashley Dene, Canterbury.

Treatment		**2016-17**	
CF/Sub		18.1	
CF/S+B		15.9	
PL/Sub		18.3	
PL/S+B		17.8	
Year mean		17.5	
S.E.M.		2.86	
P-value		0.929	
Orthogonal contrasts	**Means**		**P value**
CF v PL	17.0	18.1	0.722
S v S+B	18.2	16.9	0.659

Treatment acronyms are listed in Table 3.3.

Appendix 16: Crude protein content (%) of summer pasture yield from four dryland pastures during 2016/2017 at Ashley Dene, Canterbury.

Treatment		**2016-17**	
CF/Sub		20.1	
CF/S+B		15.2	
PL/Sub		18.6	
PL/S+B		18.3	
Year mean		18.1	
S.E.M.		3.22	
P-value		0.757	
Orthogonal contrasts	**Means**		**P value**
CF v PL	17.7	18.5	0.813
S v S+B	19.4	16.8	0.450

Treatment acronyms are listed in Table 3.3.

Appendix 17: Pasture intake by calculated energy requirement (kg DM/weaned lamb GD) of summer pasture yield from four dryland pastures from 2016-2017 at Ashley Dene, Canterbury.

Treatment		**2016-17**	
CF/Sub		0.9 d	
CF/S+B		1.0 c	
PL/Sub		1.4 a	
PL/S+B		1.3 b	
Year mean		1.2	
S.E.M.		0.02	
P-value		**<0.001**	
Orthogonal contrasts	**Means**		**P value**
CF v PL	0.8	1.1	**<0.001**
S v S+B	0.9	0.9	0.356

Treatment acronyms are listed in Table 3.3.

Appendix 18: Pasture intake by disappearance (kg DM/weaned lamb GD) of summer pasture yield from four dryland pastures from 2016-2017 at Ashley Dene, Canterbury.

Treatment		**2016-17**	
CF/Sub		3.0	
CF/S+B		3.6	
PL/Sub		2.0	
PL/S+B		2.5	
Year mean		2.8	
S.E.M.		0.44	
P-value		0.134	
Orthogonal contrasts	**Means**		**P value**
CF v PL	3.3	2.3	**0.041**
S v S+B	2.5	3.1	0.247

Treatment acronyms are listed in Table 3.3.

Appendix 19: Fraction of clover from cage cuts of summer pasture yield from four dryland pastures from 2016-2017 at Ashley Dene, Canterbury. Samples were collected on the 19th December 2016.

Treatment	**2016-17**
CF/Sub	0.02
CF/S+B	0.01
PL/Sub	0.02
PL/S+B	0.01
Year mean	0.02
S.E.M.	0.01
P-value	0.643

Orthogonal contrasts	**Means**		**P value**
CF v PL	0.02	0.02	0.722
S v S+B	0.02	0.01	0.241

Treatment acronyms are listed in Table 3.3.

Appendix 20: Fraction of sown grass from destructive pre-graze herbage samples of summer pasture yield from four dryland pastures from 2016-2017 at Ashley Dene, Canterbury. Samples were collected on the 19th December 2016.

Treatment	**2016-17**
CF/Sub	0.62 $_{a}$
CF/S+B	0.67 $_{a}$
PL/Sub	0.08 $_{b}$
PL/S+B	0.15 $_{b}$
Year mean	0.38
S.E.M.	0.05
P-value	**<0.001**

Orthogonal contrasts	**Means**		**P value**
CF v PL	0.65	0.12	**<0.001**
S v S+B	0.35	0.41	0.270

Treatment acronyms are listed in Table 3.3.

Appendix 21: Fraction of plantain from cage cuts of summer pasture yield from four dryland pastures from 2016-2017 at Ashley Dene, Canterbury. Samples were collected on the 19th December 2016.

Treatment	**2016-17**
CF/Sub	0.16 $_{b}$
CF/S+B	0.18 $_{b}$
PL/Sub	0.50 $_{a}$
PL/S+B	0.31 $_{a}$
Year mean	0.29
S.E.M.	0.05
P-value	**0.006**

Orthogonal contrasts	**Means**		**P value**
CF v PL	0.17	0.41	**0.002**
S v S+B	0.33	0.25	0.170

Treatment acronyms are listed in Table 3.3.

Appendix 22: Fraction of weeds from cage cuts of summer pasture yield from four dryland pastures from 2016-2017 at Ashley Dene, Canterbury. Samples were collected on the 19th December 2016.

Treatment	**2016-17**		
CF/Sub	0.02 b		
CF/S+B	0.01 b		
PL/Sub	0.16 ab		
PL/S+B	0.31 a		
Year mean	0.12		
S.E.M.	0.06		
P-value	**0.021**		
Orthogonal contrasts	**Means**		**P value**
CF v PL	0.02	0.24	**0.005**
S v S+B	0.09	0.16	0.321

Treatment acronyms are listed in Table 3.3.

Appendix 23: Fraction of dead material from cage cuts of summer pasture yield from four dryland pastures from 2016-2017 at Ashley Dene, Canterbury. Samples were collected on the 19th December 2016.

Treatment	**2016-17**		
CF/Sub	0.17		
CF/S+B	0.13		
PL/Sub	0.22		
PL/S+B	0.22		
Year mean	0.19		
S.E.M.	0.05		
P-value	0.476		
Orthogonal contrasts	**Means**		**P value**
CF v PL	0.15	0.22	0.167
S v S+B	0.20	0.18	0.658

Treatment acronyms are listed in Table 3.3.