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Effect of herb-clover mixes on weaned lamb growth

A thesis presented in partial fulfilment of the requirements for the degree

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Dedicated to my ever loving parents

Amma and Thaththa

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Abstract

The quality and production of ryegrass (*Lolium perenne* L.) /white clover (*Trifolium repens*) pastures are seasonal in New Zealand. Earlier research showed that a sward mix of plantain (*Plantago lanceolata*), chicory (*Cichorium intybus* L.), white- and red-clover (*Trifolium pratense*) resulted in greater lamb live weight gains in the late summer early autumn period. However, this has not been tested across all the seasons in New Zealand.

Therefore, research was undertaken for two consecutive years (2011/2012 and 2012/2013) on three sward mixes; Pasture mix, Plantain mix and Chicory mix in early spring, late spring and early summer (late spring), summer and autumn. The Pasture mix consisted of perennial ryegrass and white clover. The Plantain mix consisted of plantain, white- and red-clover. The Chicory mix consisted of plantain, chicory, white- and red-clover. It was hypothesised that lamb performance (live weight, live weight gain (LWG) and carcass weight) and apparent carcass weight production per ha would be greatest in the Plantain and Chicory mixes in all four periods. Secondly it was hypothesised that Plantain and Chicory mixes would have lower feed conversion ratios (FCR) with higher herbage utilization efficiencies (EHU%) than the Pasture mix.

In each period weaned lambs were reared in the three herbage treatments for a maximum of two months. Lambs were weighed fortnightly and they were

slaughtered within 12 hours of being off the pasture at the end of the experiment. Carcass weights were obtained from the abattoir.

The Plantain and Chicory mixes had a higher feeding value than the Pasture mix during early spring to autumn. Both Plantain and Chicory mixes produced heavier ($P<0.05$) lambs, higher ($P<0.05$) live weight gains (LWG) and carcass weights compared to the Pasture mix in all periods. Total apparent carcass weight production per ha were 407, 748 and 709 kg/ha in year one and 474, 607 and 642 kg/ha in year two in the Pasture mix, Plantain mix and Chicory mix, respectively. Both Plantain and Chicory mixes had lower ($P<0.05$) feed conversion ratios (FCR) and higher ($P<0.05$) herbage utilization efficiencies (EHU%) compared to the Pasture mix.

This research has shown that sheep farmers in New Zealand can finish lambs at a faster rate for heavier carcasses using herb-clover mixes from spring to autumn than on ryegrass/white clover pastures.

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Chapter 1 : General Introduction

Pre-amble

The New Zealand sheep industry is currently more focused on sheep meat production than wool (SONZAF 2010). Sheep production in New Zealand is managed to ensure lambing coincides with the spring pasture flush (Morris *et al.*, 1993a). This approach results in lamb production being seasonal with more lambs slaughtered in summer and autumn than in other periods of the year (Anonymous 2014). Therefore, the supply of lamb meat to both the domestic and export markets is not consistent throughout the year. This has affected lamb price stability.

Ryegrass (*Lolium perenne* L.)/white clover (*Trifolium repens*) is the major pasture used in New Zealand (Hodgson *et al.*, 2005). However, under dry weather conditions herbage productivity (Kemp *et al.*, 1999; Valentine and Matthew 1999) and quality can be poor (Barry *et al.*, 1998; Powell *et al.*, 2007) reducing stocking rates (Webby and Bywater 2007) and animal performance. Therefore, it is necessary to consider alternative forages that have a higher nutritive value and production in summer and autumn, while still achieving good annual production. Alternative herbage such as plantain (*Plantago lanceolata*), chicory (*Cichorium intybus* L.), white- and red-clover (*Trifolium pratense*) have a higher nutritive and feeding value than the ryegrass (Barry 1998; Hodgson and Brookes 1999; Waghorn *et al.*, 2007; Hayes *et al.*, 2010). In addition, pure swards of plantain (Moorhead *et al.*, 2002), chicory (Cruickshank 1986; Scales *et al.*, 1995; Barry 1998; Holst *et al.*, 1998), white clover (Cruickshank 1986; Marley *et al.*, 2005) and red clover (Moorby *et al.*, 2004; Marley *et al.*, 2005) result in greater lamb live weight gains than achieved by ryegrass/white clover pasture. Therefore, it can be hypothesised that a herb-clover mix will result in greater lamb performance than a ryegrass/white clover sward. In support of this it

has been shown that in autumn a herb-clover mix of plantain, chicory, white- and red-clover did result in greater lamb growth rates than a ryegrass/white clover sward in New Zealand (Golding *et al.*, 2011). However, it is unknown whether this would occur during other periods of the year.

This thesis is based around the examination of the performance of lambs on three herbage treatments (Pasture mix vs Plantain mix vs Chicory mix) over two consecutive years. The Pasture mix consisted of perennial ryegrass (*Lolium perenne* L. cultivar One50) and white clover (*Trifolium repens* cultivar Bounty). The Plantain mix consisted of plantain (*Plantago lanceolata* cultivar Ceres Tonic), white- and red-clover (*Trifolium pratense* cultivar Sensation). The Chicory mix consisted of plantain, chicory (*Cichorium intybus* L. cultivar Puna II), white clover and red clover. The following questions were addressed in this thesis:

- i. Would the Plantain and Chicory mixes produce greater lamb live weight and carcass weights on a per animal basis compared to the Pasture mix?
- ii. Is it possible to develop calibration equations for both Plantain and Chicory mixes to estimate herbage dry matter mass using both the plate meter and the sward stick?
- iii. Does the sward composition (botanical composition) of the Plantain and Chicory mixes change throughout the year?
- iv. Do the lambs select different herbage species during different periods of the year?
- v. What are the financial and physical performances of the three herbage treatments (Pasture mix, Plantain mix and Chicory mix) over the two years?

Chapter 2 : Literature Review

2.1 Introduction

The sheep meat and wool industries are one of New Zealand's major agricultural industries, contributing significantly to New Zealand's economy (Taylor *et al.*, 1985). These industries generate New Zealand \$ 7.5 billion export earnings annually by exporting 92% of sheep meat and 90% of wool (Morris 2013). When considering the global scenario, New Zealand contributed 6% of global lamb production and 14% of global wool production in the year 2007 (Meat & Wool New Zealand 2009) .

New Zealand's major lamb meat export markets are the European Union, North Asia, North America, Middle East and Pacific countries (Beef+Lamb New Zealand 2011). Future lamb meat export markets are likely to be more Asian focused due to their fast economic growth (Beef+Lamb New Zealand 2013). New Zealand produces 60 % of the world's lamb meat exports (Beef+Lamb New Zealand 2013). Historically, New Zealand mainly exported frozen carcasses, however this has changed to value added chilled lamb cuts (Hodgson *et al.*, 2005) of bone-in or boneless cut form (Anonymous 2014).

The main feed source for sheep on cultivatable land is the conventional pasture mix, perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens*) pasture (Hodgson *et al.*, 2005). However, the quality and quantity of this pasture is seasonal with a peak in quality and production in the spring and early summer period (Hodgson and Brookes 1999; Mathews *et al.*, 1999). Therefore, alternative pasture and herb species either as a mix or as a sole herbage are being investigated to find a reliable alternative for ryegrass and white clover pasture for a more prolonged period of the year. Finding alternative pastures or herb species that are of high quality, and

produce significant quantity from early spring to late autumn, would be of benefit to the New Zealand lamb meat production system.

The objectives of this literature review are to review the sheep industry in New Zealand with emphasis on lamb meat production in different seasons. The review covers in detail, literature related to perennial ryegrass, white clover, red clover (*Trifolium pratense*), plantain (*Plantago lanceolata*) and chicory (*Cichorium intybus*) all of which, could be used for lamb meat production.

2.2 Seasonality of lamb meat production

New Zealand lamb exports and slaughter are greater during summer and autumn compared to the spring and winter months (Figures 2-1 and 2-2). Lamb slaughter in New Zealand is at a minimum during late autumn to late spring as during this period ewes are pregnant or lactating with the next crop of lambs (Morris *et al.*, 1993b).

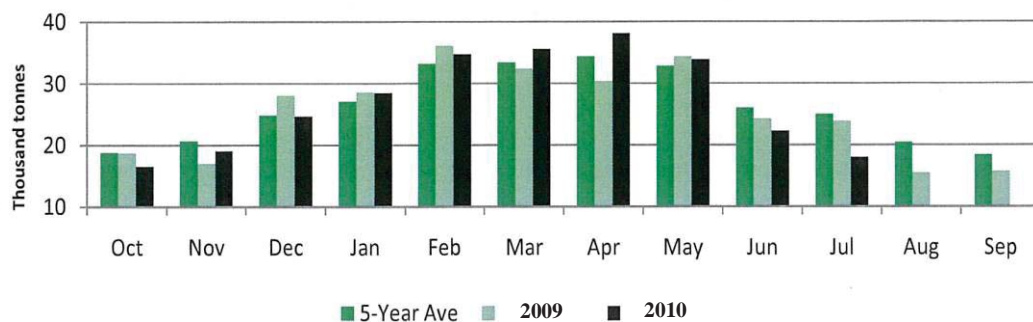


Figure 2-1: New Zealand lamb exports (thousand tonnes) by months (October to September year) for 2009, 2010 and the five year average as a comparison.

Source (Agrifax 2010)

The monthly price paid to farmers is generally inverse to slaughter number in each month. As an example prices are low when the export tonnage is high (February to

May) and conversely, as product supply decreases (July to November) prices increase (Figure 2-3). Farmers who can produce lambs during the winter/spring months often receive a premium.

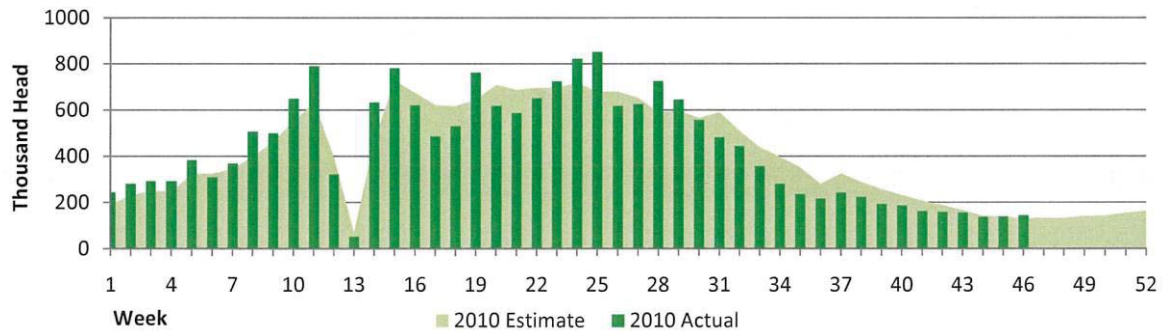


Figure 2-2: Estimated and actual New Zealand lamb slaughter (thousand head) (week 1 = beginning of October 2009 and 30th September 2010).

Source (Agrifax 2010).

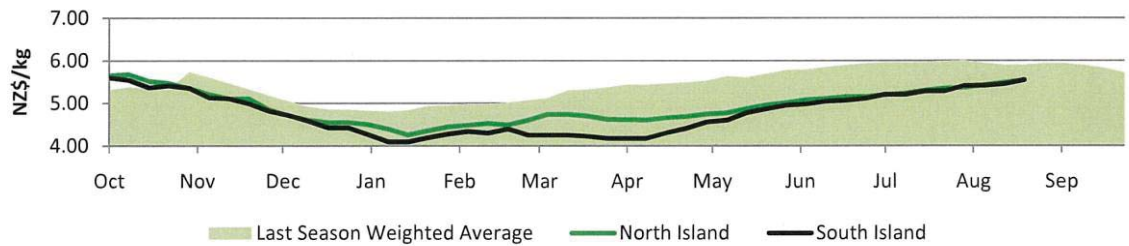


Figure 2-3: Lamb schedule price (NZ\$/kg) for October 2009 to September 2010 year for North Island (—) and South Island (—) together with 2008/2009 season as a comparison.

Source (Agrifax 2010)

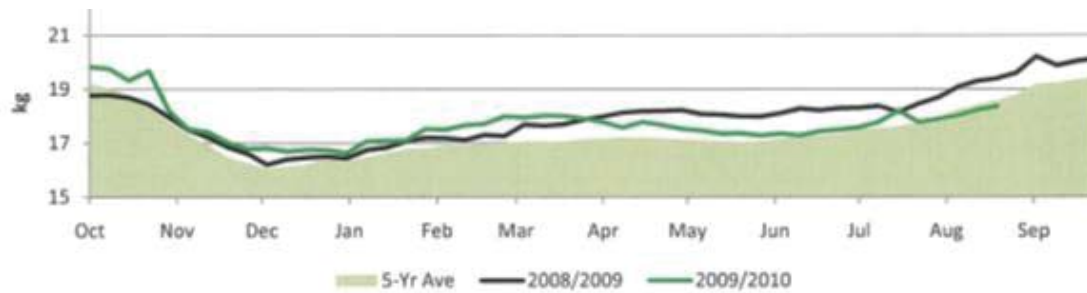


Figure 2-4: Monthly lamb average carcass weight (kg) at slaughter for 2008/2009 (—), 2009/2010 (—) and the five year average as a comparison.

Source (Agrifax 2010)

2.3 Seasonal effect on lamb carcass weights

Carcass weights also tend to follow the seasonal price pattern peaking during the winter and early spring months (Figure 2-4) when lambs are approximately one year old (Taylor and Andrewes 1987). Conversely, carcass weights during summer are generally lower as lambs are often slaughtered soon after weaning and at a younger age (Figure 2-4). During summer pasture quality can be poor (Figure 2-5) and pasture growth starts to decline depending on the location of the farm in New Zealand (Figures 2-6).

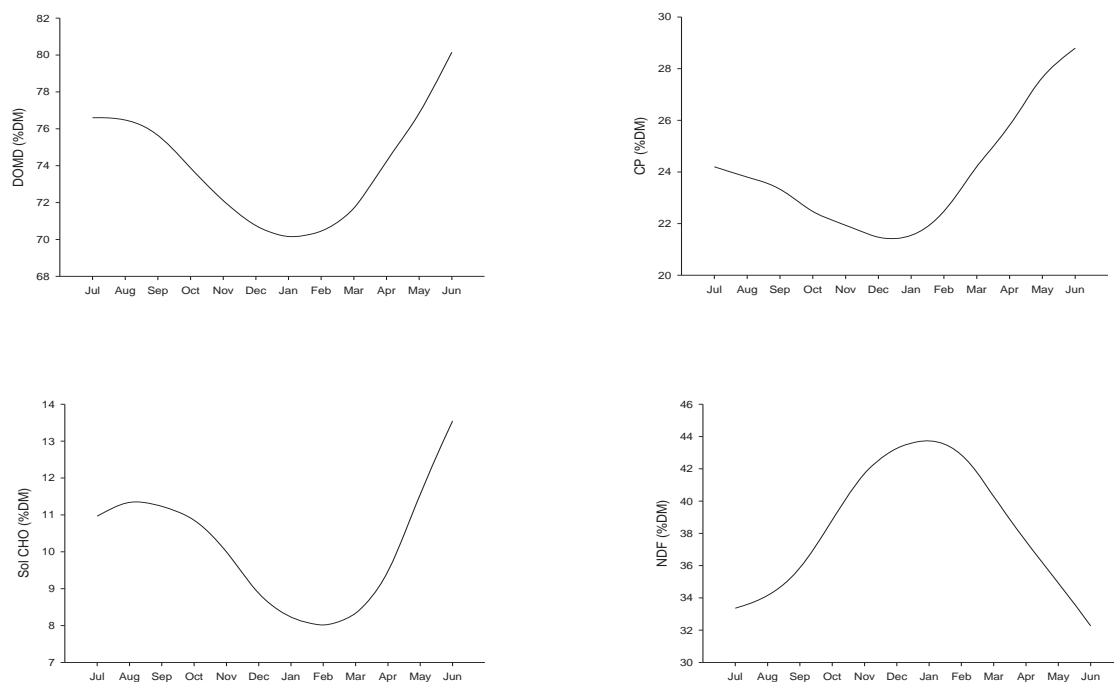


Figure 2-5: Monthly digestible organic matter digestibility (DOMD), crude protein (CP), soluble carbohydrates (Sol CHO) and neutral detergent fibre (NDF) percentages (% DM) of ryegrass/white clover pasture.

Source: (Hodgson and Brookes 1999)

During summer and autumn, digestible organic matter digestibility (DOMD), crude protein (CP) and soluble carbohydrates are very low but the neutral detergent fibre (NDF) is at its maximum (Figures 2-5) in ryegrass/white clover pastures (Hodgson and Brookes 1999). This high NDF is due to the increase in cell wall content with the maturity of the ryegrass/white clover pastures following the emergence of reproductive parts of the plant (Hodgson and Brookes 1999). These factors contribute to low lamb growth rates and hence, low carcass weights during summer and autumn (Fraser *et al.*, 1999; Powell *et al.*, 2007).

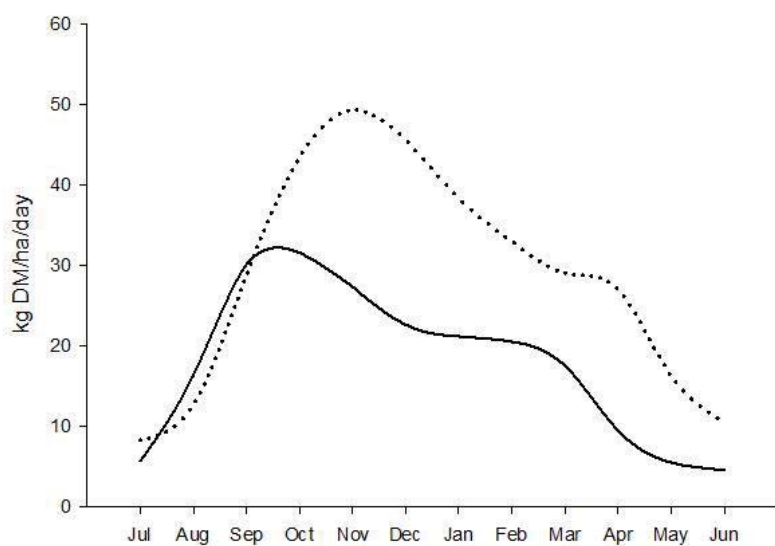


Figure 2-6: Monthly pattern of pasture growth (DM kg/ha/day) for a North Island Hill country sheep and beef farm (—) and a South Island sheep farm (.....), New Zealand.

Source: (Mathews *et al.*, 1999)

2.4 Ryegrass/white clover pasture in managed New Zealand grasslands

The managed grasslands of New Zealand have a range of forage species comprising grasses and legumes that can be grown and utilised in a wide range of conditions (Saggar *et al.*, 2007). Perennial ryegrass and white clover are the dominant grass and legume species found in these grasslands (Waghorn and Clark 2004; Hodgson *et al.*, 2005). Perennial ryegrass is the lowest cost forage in New Zealand and is well adapted to the local climatic conditions (Burke *et al.*, 2002). White clover has been identified as the ‘keystone to the development of New Zealand pastures’ (Hodgson *et al.*, 2005). The bacterium *Rhizobium trifolii* that lives in white clover root nodules fixes atmospheric nitrogen and enhances the soil nitrogen (N) fertility levels. New Zealand North Island hill pastures typically contain 5% of white clover (Nicholas *et*

al., 2004) whereas in older lowland pastures it can be 10% (Brock and Hay 2001; Hoskin and Gee 2004).

2.5 Lamb production on herbages

Lambs with higher post-weaning daily live weight gains are more efficient as they achieve marketable target live weights sooner (Kemp *et al.*, 2010). However, research indicates that lambs on either ryegrass or ryegrass/white clover pasture do not consistently achieve growth rates above 200 g per day (Cruickshank 1986; Deaker *et al.*, 1994; Young *et al.*, 1994; Scales *et al.*, 1995; Fraser and Rowarth 1996; Bluett *et al.*, 1999; Fraser *et al.*, 1999; Moorhead *et al.*, 2002; Fraser *et al.*, 2004; Moorby *et al.*, 2004; Speijers *et al.*, 2004; Marley *et al.*, 2005; Golding *et al.*, 2011). Therefore, there is scope to have alternative herbages to ryegrass/white clover pastures that enhance post-weaning lamb performance. Herbs such as plantain (Moorhead *et al.*, 2002) and chicory (Scales *et al.*, 1995) and the legumes white clover (Cruickshank 1986) and red clover (Fraser *et al.*, 2004) as pure swards are known to improve lamb performance. However, one significant limitation in the use of these herbages, is the seasonality of their production. White clover may not survive after a summer drought and its re-growth depends on the buried seed content in the soil (Hodgson *et al.*, 2005). Deep rooted perennial herbs like chicory and red clover are summer active (Langer 1967; Brown *et al.*, 2005). However, their persistence and growth are poor in winter (Hay and Ryan 1989; Purves and Wynn-Williams 1989; Moloney and Milne 1993) while, plantain is more active in spring than in summer (Kemp *et al.*, 2010). Another drawback of these species is the survival and long term productivity (Hodgson *et al.*, 2005). Thus, one potential way to overcome these limitations is to use them as a herb-clover mix.

A mix of herbs provides 'bio security' from outbreaks such as pests and diseases (Cocks 2001), as well as producing higher quality feed in summer (Kemp *et al.*, 2010). A herb-clover mix can potentially be more stable during drought conditions, can reduce the growth of weeds compared to a single sward (Sanderson *et al.*, 2004) and can improve productivity (Tracy and Sanderson 2004). Kemp *et al.* (2010) suggested that farmers could achieve 'marketable target weight' lambs sooner by feeding a herb and legume mix compared to a ryegrass/white clover pasture. Supporting this statement, Golding *et al.* (2011) reported that a herb-clover mix of plantain, chicory, white- and red-clover in late summer early autumn period produced higher lamb daily live weight gains and greater carcass weights compared to perennial ryegrass/white clover pasture, a plantain/pasture sward (plantain, perennial ryegrass and white clover) and an older pasture (perennial ryegrass and other grasses). Herb mixes have also been shown to improve multiple bearing ewe performance in spring (Hutton *et al.*, 2010; Kenyon *et al.*, 2010). It has been suggested that to improve the performance of high producing animals, herb mixes are a better option than ryegrass pastures only (Hughes *et al.*, 1980; Waghorn and Clark 2004). Combined results suggest a sustainable herb legume mix that is productive in many seasons should allow for improved livestock production systems in New Zealand.

What is not known is whether the performance of weaned lambs on a herb-clover mix would be greater in the period from early spring to autumn as these herbage cannot be grazed in winter (Hume *et al.*, 1995; Clapham *et al.*, 2001; Li and Kemp 2005). The lamb performance on a per ha per year basis, needs to be greater than the ryegrass/white clover pasture if the herb-clover mixes to be accepted by farmers. The

agronomic properties and the lamb performance on the individual species within a potential herb-clover mix need to be understood and will be reviewed in the following sections starting with the perennial ryegrass followed by white clover, red clover, plantain and chicory. The focus of the following sections will be on their potential use as a feed for finishing weaned lambs for slaughter.

2.6 Herbage species that could be used in sward mixes

2.6.1 Perennial ryegrass (*Lolium perenne*)

2.6.1.1 Morphology and cultivars



Ryegrass (Figure 2-7) is a green perennial which has leaves 3-20 cm long (Lambrechtsen 1972) and a shallow root system (Hoglund and White 1985). In New Zealand there are many New Zealand and overseas ryegrass cultivars available (Lancashire *et al.*, 1978; Stewart 2006).

Figure 2-7: Description of the plant (Perennial ryegrass).

An ecotype found on T.R. Ellett's Farm, Mangere, Auckland, New Zealand resulted in 'Grassland Nui' and 'Ellett' perennial ryegrass. This exceptional ecotype became the basis of many North Island, New Zealand ryegrass cultivars (Stewart 2006). Recently released ryegrass cultivars include 'Matrix', 'Ceres Cannon', 'Grassland Supreme', 'Extreme', 'Arrow', 'Hillary', 'Revolution', 'Commando', 'Aberdart', 'Tolosa', 'Bealey', 'Banquet', 'Ultra', 'Alto', 'Halo', 'Expo', 'Samson' and 'Grasslands Sterling' (Stewart 2006 and www.dairynz.co.nz). The annual production of perennial ryegrass in New Zealand is 10-25 tonnes DM per ha (Kemp *et al.*, 1999).

2.6.1.2 Nutrient Composition

The nutrient content of ryegrass varies depending on the season, stage of maturity and management practises (Burke *et al.*, 2002). Digestible organic matter digestibility (DOMD), crude protein (CP) and soluble carbohydrate (Sol CHO) of ryegrass are at their lowest and neutral detergent fibre (NDF) at its maximum level during summer (Hodgson and Brookes 1999). Crude protein percentage range between 15 and 26%, NDF percentage ranges between 35 and 55%, ADF percentage range between 20 and 31% and ME ranges between 9.0 and 11.4 MJ per kg DM (Table 2-1). Grace (1983) stated that the mineral content in ryegrass is sufficient to meet the requirement of animals when fed *ad-lib*, however Mg and Na are at marginal concentrations for livestock in ryegrass.

2.6.1.3 Anti-nutrients present in ryegrass

Saprophytic fungi present in ryegrass produce mycotoxins (Lambert *et al.*, 2004) which cause facial eczema (Langer 1994; Waghorn and Clark 2004) in sheep, cattle, horses and deer (Malcolm *et al.*, 1985). Neurotoxins (lolitrems) produced by a lolium endophyte fungi (*Neotyphodium lolii*) is known to cause ryegrass staggers (Langer 1994) and symptoms appear when the animals are disturbed. They run 'with a stiff gait', stagger, fall and show severe muscular spasms (Malcolm *et al.*, 1985). Fletcher (1986) showed that the chemical peramine produced by endophyte present in ryegrass helps the grass to survive Argentine stem weevil attack. He further noted that the level of endophyte varies depending on the stress level of the plants. The endophyte produces chemicals lolitrem B and ergovaline, that can have a negative impact on lamb growth and performance. Fletcher (1986) noted that endophyte

present in ryegrass caused subclinical effects and depressed the live weight gain of sheep in spring and reduced serum prolactin levels.

Table 2-1: Nutrient content of perennial ryegrass (DM basis).

Author	Herbage quality (% DM)			
	CP ¹	NDF ²	ADF ³	ME ⁴ (MJ/kg DM)
<i>New Zealand</i>				
Burke <i>et al.</i> (2000)	16	48	-	-
Burke <i>et al.</i> (2002)	19	-	-	-
Fraser and Rowarth (1996)	20	-	-	-
Golding <i>et al.</i> (2011)	20	48		9.0
Hutton <i>et al.</i> (2010)	15	35	20	10.8
Restrepo and Barry (2005)	19	44	-	-
<i>Other Countries</i>				
Andersson and Lindberg (1997)	15	-	-	-
Carlson <i>et al.</i> (1998)	20	-	-	-
Edwards (2003)	15	-	-	-
Fulkerson <i>et al.</i> (2007)				
Summer	22	52	31	9.9
Autumn	24	50	27	10.0
Winter	24	49	23	11.4
Spring	26	55	26	11.1
Moorby <i>et al.</i> (2004)	19	51	30	-

¹crude protein (CP); ²neutral detergent fibre (NDF); ³acid detergent fibre (ADF), ⁴metabolisable energy (ME).

2.6.1.4 Seasonal Growth

Re-growth of ryegrass tillers is often high in winter and spring and can be promoted by grazing management including increased frequency and intensity of spring grazing (McKenzie *et al.*, 2006). Ryegrass is in the vegetative growth phase between

winter and spring (Fulkerson *et al.*, 1998) while, it reaches its highest maturity and seed setting during summer (Fulkerson *et al.*, 1998; Mathews *et al.*, 1999).

2.6.1.5 Animal Performance

The lamb live weight gains on ryegrass range between 98 and 231 g per day and carcass weights range between 14.9 and 20.0 kg (Table 2-2). It has been suggested that potential growth of animals may not be obtained by grazing sole diets of perennial ryegrass (Barry 1981; Fraser and Rowarth 1996). Higher live weight gains are obtained from lambs during spring (Cruickshank 1986).

The purpose of the herbage species tables (2-2, 2-4, 2-5, 2-7, 2-10, 2-12) is to give an indication of the range of live weights and carcass weights observed in studies. Across studies, there is however, significant variation due to season, age of lambs, feed availability, breed and sex of lambs. These limitations are acknowledged.

Table 2-2: Live weight gain and carcass weight of lambs grazing perennial ryegrass.

Author	Live weight gain (g/head/day)	Carcass weight (kg)
Bluett <i>et al.</i> (1999)		-
<i>Cultivar – Aries HD</i>	110	
<i>Yatsyn 1</i>	98	
Cruickshank (1986)	227	-
Deaker <i>et al.</i> (1994)	135	15.6
Fraser and Rowarth (1996)	121	16.2
Fraser <i>et al.</i> (1999)		
<i>Year one</i>	150	15.0
<i>Year two</i>	133	14.9
Fraser <i>et al.</i> (2004)	184	18.8
Marley <i>et al.</i> (2005)	201	-
Moorby <i>et al.</i> (2004)	219	17.8
Moorhead <i>et al.</i> (2002)	135	-
Scales (1993)	160	20.0
Scales <i>et al.</i> (1995)	182	-
Speijers <i>et al.</i> (2004)	182	17.7
Young <i>et al.</i> (1994)	104	-

2.6.2 White Clover (*Trifolium repens*)

2.6.2.1 Morphology and cultivars



White clover (Figure 2-8) is a stoloniferous plant having prostrate stolons/shoots and growth points. These normally escape being grazed if rooted (Korte *et al.*, 1987). Each shoot consists of internodes and nodes with leaf, bud and roots. At the stage of flowering a stalk and flower head appears from a bud instead of a stolon (Korte *et al.*, 1987). White clover stolons have a shallow root system (Hoglund and White 1985).

Figure 2-8: Description of the Plant (White clover).

The tap root of white clover dies after one to two years and thereafter the survival of the plant mainly depends on the roots produced by nodes (Kilpatrick and Dunn 1961).

New Zealand has been a world leader in breeding white clover since the release of ‘Grassland Huia’ cultivar in 1964. Presently there are cultivars for a range of conditions such as cultivars suitable for winter growth, cultivars that withstand wet weather, drought or rotational grazing, cultivars with *Sclerotinia* resistance and cultivars having greater cool season vigour (Barclay 1969; Williams 1983; Macfarlane and Sheath 1984; Bosch *et al.*, 1986; Widdup *et al.*, 1989; Cooper and

Chapman 1993; Caradus *et al.*, 1996a; Mather *et al.*, 1996). The annual production of white clover is in the range of 7-10 tonnes DM per ha (Hyslop 1999).

2.6.2.2 Nutrient Composition

Caradus *et al.* (1996b) observed that white clover is rich in readily fermentable carbohydrates and minerals such as calcium, phosphorus, magnesium, copper, zinc and cobalt; but low in lipids, sugars, lignin, cellulose and minerals like sodium and selenium. It has relatively lower levels of structural carbohydrates and higher levels of digestible proteins compared to ryegrass (Ulyatt 1981). Crude protein percentage range between 24 and 30%, NDF percentage range between 26 and 34%, ADF percentage range between 19 and 23% and ME range between 9.3 and 11.7 MJ per kg DM (Table 2-3).

Table 2-3: Nutrient content of white clover (DM basis).

Author	Herbage quality (% DM)			
	CP ¹	NDF ²	ADF ³	ME ⁴ (MJ/kg DM)
Andersson and Lindberg (1997)	24	-	-	-
Burke <i>et al.</i> , (2000)	27	26	-	-
Edwards (2003)	24	-	-	-
Fulkerson <i>et al.</i> (2007)				
<i>Summer</i>	24	28	21	10.0
<i>Winter</i>	30	29	19	10.5
<i>Spring</i>	28	34	23	9.3
Li and Kemp (2005)	28	-	-	-
Lindsay <i>et al.</i> (2007)	28	26	-	11.7

¹crude protein (CP); ²neutral detergent fibre (NDF); ³acid detergent fibre (ADF), ⁴metabolisable energy (ME).

2.6.2.3 Seasonal Growth

A favourable temperature for the growth of white clover is in the range of 18-30⁰C (Mitchell 1956) and hence in New Zealand its maximum production occurs in summer (Valentine and Kemp 2007). White clover stolons can be buried due to treading and earthworm activity (Lane *et al.*, 2000) during winter. These stolons start to grow in spring and continue growing into summer and autumn (Harris 1987; Caradus *et al.*, 1996b). Although frequent grazing during spring is favourable to white clover growth (Brougham 1960; Bryant 1991), overgrazing is detrimental in summer (Caradus *et al.*, 1996b). Low rainfall levels in summer also affect the growth of white clover (McKenzie *et al.*, 2006).

2.6.2.4 Animal Performance

Higher live weight gains are observed in animals fed with white clover compared to ryegrass (Ulyatt 1981), hybrid ryegrass (Ulyatt 1970), lotus (Ulyatt *et al.*, 1977) and phalaris (Soeparno and Davies 1987). The lamb live weight gains on white clover range between 201 and 320 g per day and carcass weights range between 20.1 and 22.9 kg which are generally greater than the values observed in a ryegrass/white clover pasture mix (Table 2-4). The higher level of white clover in a ryegrass/white clover diet enhances the digestibility and intake of protein and energy (Harris *et al.*, 1997). Higher lamb live weight gains were observed in lambs when fed ryegrass with white clover (Soetrisno *et al.*, 1994) as white clover has a higher feeding value than ryegrass (Ulyatt 1981) (Table 2-5).

Table 2-4: Live weight gain and carcass weight of lambs grazing white clover.

Author	Live weight gain (g/head/day)	Carcass weight (kg)
Cruickshank (1986)	320	-
Deaker <i>et al.</i> (1994)	222	20.1
Fraser and Rowarth (1996)	226	22.9
Marley <i>et al.</i> (2005)	282	-
Lindsay <i>et al.</i> (2007)	311	-
Scales (1993)	201	20.2

Table 2-5: Live weight gain and carcass weight of lambs grazing ryegrass/white clover pastures.

Author	Live weight gain (g/head/day)	Carcass weight (kg)
Appleton (2011)	231	17.0
Golding <i>et al.</i> (2011)	119	14.6
Lindsay <i>et al.</i> (2007)	160	-
Restrepo <i>et al.</i> (2002)	189	-

2.6.3 Red Clover (*Trifolium pratense*)

2.6.3.1 Morphology and cultivars



Red clover (Figure 2-9) is a short lived perennial (Frame *et al.*, 1998) having hairs on the underside of the leaves and pink or dull red flowers (Langer 1994). Initially, when the seed is germinating it develops a radicle, which in time develops into a taproot. Then two cotyledons and a single unifoliate leaf will appear after 5-20 days of germination above the soil surface (Frame *et al.*, 1998).

Figure 2-9: Description of the Plant (Red Clover).

The tap root of red clover develops branches at regular intervals during the seedling stage and it grows into deeper soil layers, while the main axis above ground develops branches and true leaves (Frame *et al.*, 1998).

Current red clover cultivars in New Zealand include ‘Dorset Marl’, ‘Deben’, ‘Red Head’, ‘Grasslands Pawera’ (late flowering cultivar), ‘Grasslands Hamua’ (Langer 1994), ‘Grasslands Colenso’ (early flowering cultivars) and ‘Grasslands G27’ (Rumball *et al.*, 1997). Red clover cultivars in New Zealand vary in the concentration of phyto-oestrogens and formononetin levels and productive traits (Charlton and Stewart 1999). While these chemicals influence reproductive performance in sheep they do not affect lamb growth. Cultivar ‘Grasslands Sensation’

is a high yielding cultivar in spring and summer (Claydon *et al.*, 2003). Among the other cultivars ‘Crossway’, ‘Broadway’ and ‘Tuscan’ are high in yield and persistence. The newly released variety ‘Grasslands Relish’ was selected for greater persistence (Ford and Barrett 2011). The annual herbage production of red clover is in the range of 11-15 tonnes DM per ha (Hyslop 1999).

2.6.3.2 Nutrient Composition

Red clover is relatively high in Metabolisable energy, crude protein and lower in fibre compared to grass based pastures (Valentine and Kemp 2007). Crude protein percentage ranges between 22 and 30%, NDF percentage ranges between 34 and 41%, ADF percentage ranges between 25 and 38% and ME ranges between 9.2 and 13.4 MJ per kg DM (Table 2-6). Steinshamn (2010) observed that red clover had higher levels of apparent dry matter digestibility, organic matter, NDF and hemicelluloses contents than lucerne. The nutrient content of red clover varies with season.

2.6.3.3 Seasonal growth

Red clover becomes dormant in winter and highly productive in summer (Valentine and Kemp 2007). It can tolerate the lower moisture conditions in summer due to its deep tap root and other roots (Kemp *et al.*, 1999).

Table 2-6: Nutrient content of red clover (DM basis).

Author	Herbage quality (% DM)			
	CP ¹	NDF ²	ADF ³	ME ⁴ (MJ/kg DM)
Andersson and Lindberg (1997)	22	-	-	-
Barry (1998)		-	-	13.4
Brown <i>et al.</i> (2005)	25	-	-	10.9
Edwards (2003)	22	-	-	
Fulkerson <i>et al.</i> (2007)				
<i>Summer</i>	24	40	26	9.2
<i>Winter</i>	30	35	25	10.0
<i>Spring</i>	30	41	38	9.5
Restrepo and Barry (2005)	24	34	-	-

¹crude protein (CP); ²neutral detergent fibre (NDF); ³acid detergent fibre (ADF), ⁴metabolisable energy (ME).

2.6.3.4 Animal Performance

The live weight gains on red clover range between 150 and 305 g per day and carcass weights range between 16.8 and 18.8 kg (Table 2-7). Lambs grazing on red clover had higher live weight gain and reached slaughter weight earlier compared to lambs on perennial ryegrass (Fraser *et al.*, 2004; Moorby *et al.*, 2004). Frame *et al.* (1998) stated that the intake of lambs was greater on red clover compared to ryegrass. Lambs on red clover had significantly higher carcass weights than the lambs grazed on perennial ryegrass (Speijers *et al.*, 2004).

Table 2-7: Live weight gain and carcass weight of lambs grazing red clover.

Author	Live weight gain of lambs (g/head/day)	Carcass weight (kg)
Fraser <i>et al.</i> (2004)	305	18.4
Moorby <i>et al.</i> (2004)	263 ¹	18.0
	215 ²	18.6
Marley <i>et al.</i> (2005)	292	-
Speijers <i>et al.</i> (2004)	228	18.8
Campbell <i>et al.</i> (2011)	150	16.8

¹Red clover with high formononetin concentration

²Red clover with low formononetin concentration

2.6.4 Plantain (*Plantago lanceolata*)

2.6.4.1 Morphology and cultivars



Plantain (Figure 2-10) or narrow leaf plantain or ribgrass (Fraser and Rowarth 1996; Stewart 1996) is a perennial having a rosette growth form with a deep tap root (Rumball *et al.*, 1997; Kemp *et al.*, 1999). It has an erect posture with many vegetative shoots. The leaves are lanceolate to ovate lanceolate (long and wider in the middle with a tapering to a point at each end) (Rumball *et al.*, 1997).

Figure 2-10: Description of the Plant (Plantain).

The pseudo petiole is half the length of the lamina. The flowers have a scape or a long internode at the basal part emerging from the crown (Rumball *et al.*, 1997).

Research in plantain began in 1987 in New Zealand (Rumball *et al.*, 1997). After breeding, selecting and progeny testing plantain (*Plantago lanceolata* L.) was identified as a potential herb for ruminants and released as a pasture species in New Zealand in 1993 (Rumball *et al.*, 1997).

Initially there were two cultivars developed from the *Plantago lanceolata* namely, 'Grasslands Lancelot' and 'Ceres Tonic' (Stewart 1996; Rumball *et al.*, 1997) (Table 2-8). However, 'Grasslands Lancelot' was withdrawn from the market due to

the superiority of ‘Ceres Tonic’(Anonymous 2011). The annual production of plantain is around 17 tonnes DM per ha (Powell *et al.*, 2007).

Table 2-8: Morphological differences in *Plantago lanceolata* cultivars Grassland Lancelot, Ceres Tonic and Common Flat weed type.

Character	Grassland Lancelot	Ceres Tonic	Common Flat weed type
Growth habit	Semi erect	Very erect	Prostrate
Leaf size	Medium large	Very large	Small medium
Tiller number	High	Medium	Medium high
Winter growth	Low	High	Very low
Summer growth	High	High	Low

Source: (Stewart 1996)

2.6.4.2 Nutrient Composition

The crude protein percentage of plantain varies depending on the season, having a higher crude protein percentage in warmer conditions and a lower percentage in colder conditions (Sanderson *et al.*, 2003). Crude protein percentage ranges between 13 and 25%, NDF percentage ranges between 28 and 37%, ADF percentage 24% and ME ranges between 10.7 and 12.8 MJ per kg DM (Table 2-9). Fraser and Rowarth (1996) found that the crude protein contents of ‘Grasslands Lancelot’ leaves and stems were 20% and 14% (DM basis), respectively.

Table 2-9: Nutrient content of plantain (DM basis).

Author	Herbage quality (% DM)			
	CP ¹	NDF ²	ADF ³	ME ⁴ (MJ/kg DM)
Best (2011)	24	23	-	11.8
Burke <i>et al.</i> (2000)	25	28	-	-
Corkran (2009)				
<i>March</i>	13	21	-	12.5
<i>May</i>	18	14	-	12.8
Hayes <i>et al.</i> (2010)	17	37	24	10.7
Sano <i>et al.</i> (2003)	14	32	24	-

¹crude protein (CP); ²neutral detergent fibre (NDF); ³acid detergent fibre (ADF); ⁴metabolisable energy (ME).

Cell wall nutrients such as cellulose, hemi cellulose and lignin content are lower in plantain compared to ryegrass (Wilman and Riley 1993; Stewart 1996). Minerals such as calcium, magnesium, sodium, phosphorous, zinc, copper and cobalt content in plantain are comparatively higher than that of perennial ryegrass/white clover based pastures (Stewart 1996).

2.6.4.3 Seasonal growth

Plantain tolerates drought (Malden 1924; Ivins 1952; Mook *et al.*, 1989) and summer heat (Stewart 1996). ‘Grassland Lancelot’ cultivar is dormant in winter while ‘Ceres Tonic’ cultivar is active in winter (Stewart 1996). A plantain plant can be comprised predominantly of stems towards late summer and autumn (Fraser and Rowarth 1996).

2.6.4.4 Animal Performance

The live weight gains on plantain range between 90 and 222 g per day and carcass weights range between 15.1 and 17.9 kg (Table 2-10). Fraser and Rowarth (1996) found that lambs fed with ‘Grasslands Lancelot’ had slower growth compared to the lambs fed with white clover and chicory . In contrast, Moorhead *et al.* (2002) found that lambs grazing on pure ‘Ceres Tonic’ plantain swards obtained a higher live weight gain (64% higher) compared to lambs grazing on pure ryegrass swards.

Wilson (2009) reported that the lambs on plantain/pasture mix (plantain, ryegrass and white clover) had lower live weight gains than the lambs on pasture mix (ryegrass/white clover) but the carcass weights did not differ. In an Australian study, plantain and white clover mix swards produced higher live weight gains in lambs compared to ryegrass/white clover swards (Chin 1996). Similarly, superior live weight gains were observed in lambs fed with a sward mix of plantain, red clover and white clover compared to ryegrass/white clover, tall fescue-clover and cocksfoot-clover swards (Stewart 1996).

According to Stewart (1996), plantain is palatable if it is grazed before flowering when the stems are still soft. With age, reproductive stems and mature leaves become less palatable to animals. Supporting the above statement, Corkran (2009) observed that lambs tend to eat only the tips of the mature plantain leaves. Moorhead *et al.* (2002) found that lambs willingly grazed the immature seed heads of plantains but kept away from the ryegrass seed heads. Stewart (1996) also stated that immature reproductive stems of plantain before flowering are highly palatable to stock.

Table 2-10: Live weight gain of lambs and carcass weight of lambs grazing plantain.

Author	Live weight gain of lambs (g/head/day)	Carcass weight (kg)
Appleton (2011)	205	16.8
Best (2011)	188	17.0
Campbell <i>et al.</i> (2011)	90	15.1
Deaker <i>et al.</i> (1994)	143	16.8
Fraser and Rowarth (1996)	109	16.0
Johnston (2010)		
<i>Year one</i>	219	17.9
<i>Year two</i>	109	15.9
Moorhead <i>et al.</i> (2002)	222	-

2.6.5 Chicory (*Cichorium intybus*)

2.6.5.1 Morphology and cultivars



Chicory (Figure 2-11) is a native forage in Europe, many parts of Asia, Africa, and America (Li and Kemp 2005). Chicory belongs to the family Asteraceae. It was first recorded in New Zealand in 1867 (Hooker 1867).

Figure 2-11: Description of the Plant (Chicory).

Substantial chicory breeding activity has been carried out in New Zealand to improve the forage quality of chicory (Hume *et al.*, 1995) and as a result chicory cultivar ‘Grasslands Puna’ was developed and released in New Zealand in 1985 and it was the first forage chicory cultivar in the world (Rumball 1986).

Description of the plant

Grasslands Puna produces leafy stems with inflorescences during late spring and these can grow up to more than 2 m in height if un-grazed (Rumball 1986; Hare *et al.*, 1987; Barry 1998). Flowers occur normally in summer (Rumball 1986). Puna chicory has a ‘long thick tap root’ and new shoots will appear from the crown and these shoots will produce their own adventitious roots (Rumball 1986). Currently there are a number of chicory cultivars worldwide (Wang and Cui 2011) including ‘Grasslands Puna’, ‘Puna II’, ‘Choice’, ‘Grouse’ and ‘Chico’ which are used in New Zealand (Li and Kemp 2005).

Management of chicory and other uses

Chicory can be grown in different soil types including acidic soils (King *et al.*, 2010). Mechanical cutting and rotational grazing are best to maintain the size of chicory plants and avoid seed setting (Holst *et al.*, 1998; Alemseged 2000; Alemseged *et al.*, 2003). Replanting may be needed after three years as the productive lifespan of chicory plants tends to diminish thereafter (Alemseged *et al.*, 2003). Annual production of chicory is 9-14 tonnes DM per ha (Li and Kemp 2005; Powell *et al.*, 2007).

2.6.5.2 Nutrient Composition

The crude protein percentage of chicory is comparatively lower than legumes (Li and Kemp 2005). Crude protein percentage ranges between 11 and 24%, NDF percentage ranges between 13 and 38%, ADF percentage 22% and ME ranges between 7.0 and 13.7 MJ per kg DM (Table 2-11). Chicory has a higher mineral content, especially copper and zinc, compared to ryegrass and red clover but the total nitrogen content is lower (Rumball 1986; Li *et al.*, 2006). Further, depending on the soil type, potassium concentration can be high (Barry 1998). The concentration of soluble sugars and pectin in chicory is similar to that of red clover whereas the concentration of structural carbohydrates (hemi cellulose and cellulose) is lower than that of perennial ryegrass (Barry 1998). Turner *et al.* (1999) stated that NDF and ADF content in chicory are lower than lucerne.

Table 2-11: Nutrient content of chicory (DM basis).

Author				
	CP ¹	NDF ²	ADF ³	ME ⁴ (MJ/kg DM)
Barry (1998)	-	-	-	13.7
Brown <i>et al.</i> (2005)	18			11.3
Burke <i>et al.</i> (2000)	19	23	-	-
Crush and Evans (1990)	19	-	-	-
Hayes <i>et al.</i> (2010)	20	35	22	10.8
King <i>et al.</i> (2010) ⁵	11	-	-	7.0
Li and Kemp (2005)	24	-	-	-
Restrepo and Barry (2005)	12	13	-	-
Sulas (2004)	18	38	-	-
Yang (2008)	20	-	-	-

¹crude protein (CP); ²neutral detergent fibre (NDF); ³acid detergent fibre (ADF), ⁴metabolisable energy (ME).

⁵post grazing pasture.

2.6.5.3 Seasonal growth

Chicory is generally dormant in winter (Hoskin *et al.*, 1999a; Li and Kemp 2005) although, this can vary between cultivars (Kunelius and McRae 1999; Rumball *et al.*, 2003 a; Rumball *et al.*, 2003 b). The growth rate of chicory is higher in late spring and early summer (Li and Kemp 2005). It begins to flower in late spring and summer with peak flowering occurring in December in New Zealand (Hare *et al.*, 1987). Li *et al.* (1997) noted that chicory populations tend to decrease during grazing in late autumn.

2.6.5.4 Animal Performance

The live weight gains on chicory range between 146 and 311 g per day and carcass weights range between 18.3 and 22.0 kg (Table 2-12). Barry (1998) noted that young

lambs fed chicory had higher growth rates in late summer and autumn compared to feeding perennial ryegrass. The live weight gain of lambs grazed on chicory is similar to the live weight gain of lambs grazed on legumes such as lucerne and white clover (Holst *et al.*, 1998; Li and Kemp 2005). Tannins and sesquiterpene lactones present in chicory have the ability to reduce nematode and helminth parasites infection in animals (Scales *et al.*, 1995; Marley *et al.*, 2003; Athanasiadou *et al.*, 2007), which could have advantages for lamb growth.

Table 2-12: Live weight gain and carcass weight of lambs (g/head/day) grazing chicory.

Author	Live weight gain of lambs (g/head/day)	Carcass weight (kg)
Barry (1998)	273	
Cruickshank (1986)	290	
Deaker <i>et al.</i> (1994)	180	18.3
Fraser and Rowarth (1996)	192	21.7
Holst <i>et al.</i> (1998)		
<i>Group 4</i> ¹	304	18.5
<i>Group 5</i> ²	262	22.0
Hopkins <i>et al.</i> (1995)	243	22.0
Komolong (1994)	273	-
Scales <i>et al.</i> (1995)	311	-
Young <i>et al.</i> (1994)	146	-

¹cryptorchid weaned lambs (64 lambs per group)

²cryptorchid weaned lambs (32 lambs per group).

2.7 Techniques and measurements

The herbage and lamb measurement techniques and protocols used in this thesis are briefly explained in this section. However, it is not meant to be a detailed review of each technique or protocol.

2.7.1 Herbage measurements

2.7.1.1 Preference and/or selection of herbage by lambs

Preference of a herbage for an animal is classified as what it ‘wants to eat’ if the herbage is available without restrictions while, selection is the choice when the herbage is in a mixed diet (Hodgson and Brookes 1999; Rutter 2006). Preference depends on the senses including sight, touch, taste and smell and also chemical and physical properties of the herbage (Hodgson and Brookes 1999). Selection depends on the palatability, nutrient content and the availability of the herbage (Waghorn *et al.*, 2007). Selection can be measured in the field using a mixed diet by observing an animal’s choice for selecting one herbage over the other (Rutter 2006). Preference and selection for herbages will also vary depending on the age, species and stocking rate of the animals (Hodgson *et al.*, 1994). Any herbage that has higher preference and/or selection will be grazed more than the other plant species. It is therefore possible that the preferred or selected herbage will become less available with time (Crawley 1983).

Corkran (2009) observed that in a diet selection experiment with mixed swards of plantain, chicory and red clover and in a preference experiment with monocultures of plantain, chicory and red clover that the lambs had lower preference for plantain compared to the other species on some occasions. Pain *et al.* (2010) in a stall fed

experiment with monocultures of chicory, lucerne, red clover and ryegrass, also observed that lambs had lower preference for plantain over the other species. However, in general there is little information available on lamb preference and/or selection when offered a mixed sward of plantain, chicory, white- and red-clover under grazing conditions. An experiment related to diet preference and/or selection might help explain the high lamb growth performances achieved in herb-clover mixes and to see whether preference and/or selection might differ between seasons. Similarly, this might also provide direction on whether this preference and/or selection is likely to affect herbage composition over time.

2.7.1.2 Herbage DM mass measurement

Herbage mass measurements are important to determine the amount of herbage available and that harvested by animals (Hodgson *et al.*, 1999). Tools such as the rising plate meter, electronic capacitance meter or a simple pasture ruler can be used to calculate ryegrass/white clover DM mass after appropriate calibration (Michell and Large 1983; Sanderson *et al.*, 2001).

Rising plate meter method

Herbage mass can be calculated using an equation (varies with the manufacturer) such as given below.

Herbage mass (kg DM/ha) = $(a \times \text{rising plate meter reading}) + b$ (Hodgson *et al.*, 1999)

Note: a and b are constants

The regression equations and R^2 values of earlier studies used to predict DM mass in ryegrass based pastures using the rising plate meter are presented in Table 2-13. These studies indicate that, a wide range of equations and R^2 values have been found.

Quadrat cut method

A direct method to measure herbage mass is the quadrat cut method. Herbage within a quadrat is cut to ground level using a hand shear (electric sheep shearing hand piece powered by battery) (Mannetje 1978; Frame 1981). Depending on the area under grazing, the number of quadrat cuts will vary. In order to avoid contamination of soil a 'sled' could be attached underneath the hand piece (Michell and Large 1983). The samples should be washed, oven dried (70-80⁰C) and weighed to determine the herbage DM mass (Earle and McGowan 1979).

2.7.1.3 Sward surface height measurements using sward stick and/or pasture ruler

The sward stick and/or pasture ruler are used to measure the height of the herbage. Sward height measurements are used to make management decisions related to length of the grazing period and DM intake (Morris *et al.*, 1993b). Herbage height measurements obtained using the pasture ruler can then be converted to give an estimated herbage yield in kg DM per ha based on previous calibrations (Gerrish and Roberts 1999). Using the sward stick, individual sward height readings can be recorded. Then DM mass is calculated using an equation specific to the individual sward stick. The regression equations and R^2 values of earlier studies used to predict sward DM mass using sward heights of ryegrass based pastures are presented in

Table 2-14. As with the plate meter a range of equations and R² values have been found.

The reasons for higher error rates

The higher error rates in predicted herbage DM mass by both plate meter and sward height measurements can be due to short stubble height, the presence of seed heads, stem materials, variable herbage species, dead matter, uneven ground, seasonal variation, treading damage and human error (Webby and Pengelly 1986; Murphy *et al.*, 1995; Hodgson *et al.*, 1999; Sanderson *et al.*, 2001).

Table 2-13: R² values of prediction equations used to measure herbage DM mass on ryegrass based pastures using the rising plate meter.

Reference	Regression equation	No. of observations	R ²	Error % or cv
Michell and Large (1983)				
<i>March – June</i>	$y^2=1011+271x^3$	71	0.92	
<i>June - September</i>	$y^2=925+385x^3$	47	0.88	
Piggot (1986)	-	45	0.74	19
Webby and Pengelly (1986)				
<i>Autumn</i>	-	677	0.73	
<i>Winter</i>	-	954	0.70	
<i>Spring</i>	-	688	0.87	
Fulkerson and Slack (1993) [*]	-	1242	0.80	61
Gabriels and Berg (1993)				
<i>Plastic rising plate meter^a</i>	$y^2=1.03+\log(\text{plastic})+\log(\text{CMR})+\text{days}+\text{dry/wet}$	335	0.86	28
<i>Metal rising plate meter^a</i>	$y^2=1.42+\log(\text{metal})+\log(\text{CMR})+\text{days}+\text{dry/wet}$	227	0.89	27
Murphy <i>et al.</i> (1995)				
<i>Pre-grazing</i>	$y^2=392.9+317.8x^3$	120	0.52	29
<i>Post-grazing</i>	$y^2=1237.6+53.4x^3$	120	0.003	18
Sanderson <i>et al.</i> (2001)	$y^2=1084+0.56x^3$	123	0.31	26
Litherland <i>et al.</i> (2008)	$y^2=1034+151x^3$	2279	0.52	-

¹ cv coefficient of variation

² y=herbage DM mass (kg/ha)

³ x=rising plate meter reading

^aCMR (corrected capacitance meter reading), log (plastic) and log (metal) are the respective rising plate meter readings, dry=0 and wet=1(quantitative factors)

Table 2-14: R² values of prediction equations used to measure the sward height on ryegrass based pasture using sward stick.

Reference	Regression equation	No. of observations	R ²	Error % or cv ¹
<i>Sward stick</i>				
Piggot (1986)		45	0.77	18
<i>Pre-grazing</i>	$y^2=1200+160x^3$			
<i>Post-grazing</i>	$y^2=800+160x^3$			
Webby and Pengelly (1986)	$y^2=1000+125 x^3$			-
<i>Summer</i>		549	0.67	
<i>Autumn</i>		677	0.69	
<i>Winter</i>		954	0.76	
<i>Spring</i>		688	0.56	
<i>Late spring</i>		484	0.67	
Murphy <i>et al.</i> (1995)				
<i>Pre-grazing</i>	$y^2=398.1+71.6x^3$	120	0.49	27
<i>Post-grazing</i>	$y^2=931.8+79.9x^3$	120	0.10	21
Litherland <i>et al.</i> (2008)	$y^2=756+186x^3$	2528	0.44	-
<i>Pasture ruler</i>				
Sanderson <i>et al.</i> (2001)	$y^2=1434+0.41 x^4$	89	0.16	-

¹ cv=coefficient of variation.

²y= herbage DM mass (kg/ha).

³x=sward stick reading (cm).

⁴x=Pasture ruler reading (cm).

2.7.1.4 The use of plate meter and sward stick in herb-clover mixes of plantain and chicory

The plate meter and sward stick are designed for the measurement of DM mass and sward height of ryegrass/white clover based pastures. Therefore, all calibration equations have been calculated from ryegrass/white clover based pastures. Presently there is an increased use of herb-clover mixes of plantain and chicory based pastures (Kemp *et al.*, 2010). However, there are no calibration equations available to estimate DM mass from either the sward stick or plate meter in these herb-clover

mixes. The only method is quadrat cuts. This method is time consuming and laborious. Hence, if such calibration equations can be developed for the plate meter and sward stick to measure the DM mass of herb-clover mixes it will be highly effective for making day to day farm management decisions.

2.7.1.5 In-vitro digestibility and metabolisable energy (ME) content

The nutrient composition of herbage can be determined by analysing either fresh or frozen herbage samples in a laboratory (Jones 1981) using *in-vitro* digestibility procedures (Tilley and Terry 1963). The samples can be analysed for in-vitro organic matter digestibility (OMD), dry matter digestibility (DMD) and digestible organic matter digestibility (DOMD) according to Roughan and Holland (1977) and Total nitrogen by “Dumas” procedure (AOAC method 968.06) and neutral detergent fibre (NDF) and acid detergent fibre (ADF) by a Tecator Fibretec System (Robertson and Van Soest 1981). These analyses will provide the nutrient content of the herbages available for livestock (Waghorn *et al.*, 2007) enabling determination of the feeding value of herbage (Ulyatt 1981; Coleman and Henry 2002). Metabolisable energy (ME) of the herbage can be calculated by multiplying digestible organic matter digestibility (DOMD%) by a factor of 0.163 (Geenty and Rattray 1987).

The nutrient composition of the herb-clover mix of plantain, chicory, white- and red-clover has been analysed using the above methods by Hutton *et al.* (2010) and Kenyon *et al.* (2010) from spring to early summer, and Golding *et al.* (2011) from late summer early autumn. In general it has been found that herb-clover mixes have relatively higher in ME, organic matter digestibility (OMD) and lower fibre content (NDF and ADF) than ryegrass/white clover pastures. However, the nutrient

composition of this herb-clover mix has not been analysed in other seasons. It would be of benefit to know the nutrient composition of this herb-clover mix in all seasons.

2.7.1.6 Botanical composition

Knowledge of the botanical and morphological composition (proportion of grasses, legumes or herbs, weeds, dead matter, stem materials, leaf materials) of the herbage inform the nutrient status of the herbage (Hodgson and Brookes 1999) and likely animal production (Lambert and Litherland 2000). Botanical and morphological composition varies depending on the grazing management system (Leaver 1987) and time (Matthews *et al.*, 1999). Botanical composition is determined by separating the herbage sample into different species/components and drying in a draught oven for at least 24 hours at 70⁰ C to determine the relative composition on dry matter basis (Arnold 1987).

The botanical composition of the herb-clover mix of plantain, chicory, white- and red-clover has been carried out by Hutton *et al.* (2010) and Kenyon *et al.* (2010) from spring to early summer, and Golding *et al.* (2011) from late summer early autumn. However, it has not been tested over all seasons. Hence, it will be useful to know the botanical composition of the herb-clover mix in different seasons to understand the availability of each species in all seasons as it will likely affect the nutrient composition and lamb performance. Further due to animal preference it might change over time.

2.7.2 Animal measurements

2.7.2.1 Live weight gain

Live weight gain is the increase in the live weight as a result of the increase in muscle weight, fat deposits or excess fluids like water, organs and tissues (Carles 1983). It can be calculated by using the weekly, fortnightly or monthly live weights and is generally expressed as 'g per head per day' (Hyslop *et al.*, 2000).

2.7.2.2 Carcass weight

Carcass weight is the weight of the skinned, tailless, eviscerated, headless and footless body of an animal excluding kidneys and kidney fat (Kirton 1989). It is important to determine the sale price at slaughter.

2.7.2.3 Dressing out percentage (DO%)

Dressing out percentage is the yield of carcass weight as a percentage of either the full or fasted live weight (Kirton and Morris 1989; Purchas *et al.*, 1989). It is calculated by the following equation;

$DO\% = \text{hot or cold carcass weight} / \text{live weight off pasture} \times 100$ (Kirton *et al.*, 1984).

$\text{Cold carcass weight} = \text{hot carcass weight} - (\text{hot carcass weight} \times 4.5/100)$ (Kirton *et al.*, 1984).

Factors such as live weight, sex, breed, fat content (Kirton and Morris 1989), herbage quality, allowance and species, time of slaughter and time of weighing off pasture, can all affect the DO% (Litherland *et al.*, 2010).

A DO% of 42% has been obtained by Golding *et al.* (2011) in lambs on the herb-clover mix in the late summer early autumn period. However, no data for DO% was found in the literature in other seasons using herb-clover mix.

2.7.2.4 GR measurement

Lamb carcasses are classified into different fat classes according to the GR tissue depth measurement (Figure 2-12) by the New Zealand lamb export system (Kirton 1989). The name GR was used in the honour of Mr E. Greville, the Chief Supervising Grader, New Zealand Meat Producers Board.

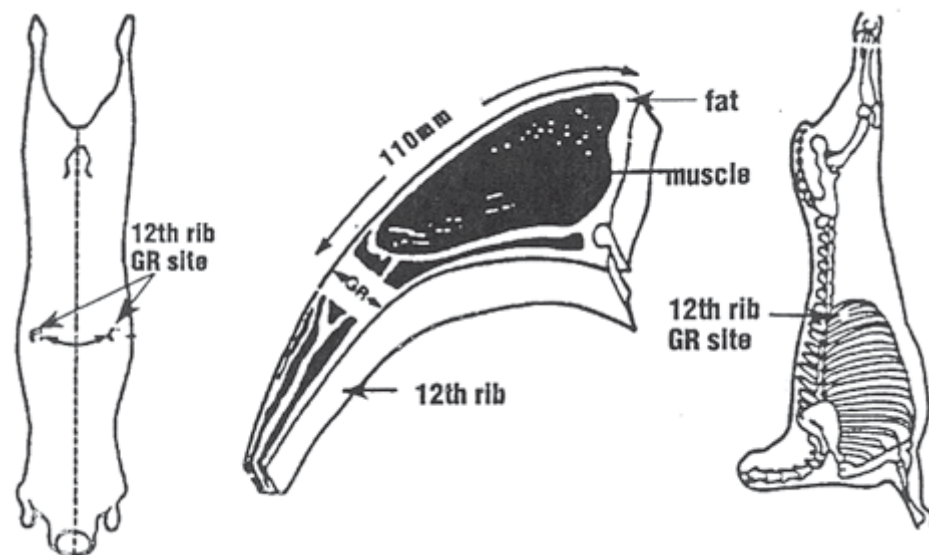


Figure 2-12: Soft tissue depth measurement (GR tissue depth measurement).

GR is the total tissue thickness between the surface of a lamb carcass and the rib at a point 11 cm from the midline in the region of the 12th rib (Kirton 1989). GR tissue depth measurement explains 50-75% of the variation in carcass fatness (Kirton *et al.*, 1985). Sheep farmers in New Zealand are paid based on both GR measurement and carcass weight (Kirton *et al.*, 1984; Litherland *et al.*, 2010). Therefore, higher

carcass weights and GR tissue depths generally result in higher prices, but this will not always be true as there will be a penalty for excessively fat carcasses (Kirton and Johnson 1979; Anonymous 2004).

2.8 Summary

This literature review has indicated that ryegrass/white clover pasture is commonly the main diet of lambs in New Zealand. However, depending on the season, ryegrass/white clover pasture growth patterns, production and quality can vary. Studies have indicated herbage quality and lamb performance can be higher on pure forage herbs (plantain and chicory) and clover (white clover and red clover) swards. However, use of these for finishing lambs for many months of the year in a mixed sward have not been evaluated to date. Therefore, the following experiments were undertaken to evaluate the performances of these herb and clover mixed swards on a multi-year basis.

2.9 A brief overview of the experimental chapters

Chapter 3: This chapter gives a description of the farmlets and how the farmlet experiments were undertaken. The farmlets were Pasture mix (i), Plantain mix (ii) and Chicory mix (iii). This chapter also gives detailed descriptions of the procedures used to collect samples for botanical composition, pre- and post-grazing herbage DM mass, herbage quality analysis and soil nutrient analysis.

Chapter 4: On each farmlet, lambs were finished in all three treatments in early spring (i), late spring and early summer (late spring) (ii), summer (iii) and autumn (iv). In winter lambs were finished only in the Pasture mix. The hypothesis of this

chapter was that the Plantain mix and Chicory mix farmlets would display greater lamb performance than the Pasture mix.

Chapter 5: The calibration equations for both the plate meter and sward stick are developed for ryegrass/white clover pasture. These have not been developed for herb-clover mixes. The development of methods to measure herbage DM mass in both Plantain and Chicory mixes were undertaken in this chapter. This chapter developed equations to calculate the herbage DM in both Plantain and Chicory mixes using either plate meter readings or sward height measurements.

Chapter 6: This chapter has two sections.

Section A explains the botanical composition of the three herbage mixes of two years. There were two aims. The first aim was to determine if the management practices used in this thesis resulted changes in the composition in all herbage treatments. The second aim was to determine if the percentage of weeds increased over time.

Section B describes the selection of different plant species by lambs across the periods early spring, late spring, summer and autumn. There were two hypotheses for this section. The first hypothesis was that the most selected species in the herbage treatments would be white- and red-clover and that this selection would be maintained across the different periods. The second hypothesis was that plantain in the Plantain mix and Chicory mix would be selected at a lower proportion than the other species and that this low selection would be consistent in all four periods.

Chapter 7: This chapter discusses the seasonal influence of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on production aspects of lambs; final live weight, live weight gain, carcass weight, apparent carcass weight production per ha, feed conversion ratio (FCR) and efficiency of herbage utilization (EHU).

Chapter 8: The final chapter summarizes the findings of this research, outlines potential limitations of the research and indicates recommendations for future research in this field.

Chapter 3 : Materials and methods of the experimental chapters
four to seven

3.1 Summary of Farmlet, Design, Management and Data collection

Experiments were undertaken in two consecutive years (2011/2012 and 2012/2013) with each year divided into five periods namely; winter, early spring, late spring and early summer, summer and autumn. The experiments for each period during the first year and second year were called “*Experiment one (2011/2012)*” and “*Experiment two (2012/2013)*” respectively. The experimental period for each year are presented in Figure 3-1. The experimental site was situated between 40⁰21’ S and 175⁰37’ E on the Moginie Pasture and Crop Research Unit, Massey University 4 km south of Palmerston North, New Zealand with an altitude of 30 m. The soil type was Tokomaru Silt Loam which is imperfectly to very poorly drained due to a fragipan (Cowie and Rijkse 1977).

Monthly soil temperature and rainfall during the experimental periods is shown in Figures 3-2. These experiments were conducted with the approval of the Massey University Animal Ethics Committee (MUAEC 10119).

The experiments consisted of three herbage treatments; a ‘Pasture mix’ perennial ryegrass (*Lolium perenne* L.) cultivar One50 and white clover (*Trifolium repens*) cultivar Bounty; ‘Plantain mix’ plantain (*Plantago lanceolata*) cultivar Ceres Tonic, white- and red-clover (*Trifolium pratense*) cultivar Sensation; ‘Chicory mix’ plantain, chicory (*Cichorium intybus* L.) cultivar Puna II, white- and red-clover in each experiment. Cryptorchids and/or castrated crossbred male lambs were stratified by live weight and allocated to one of the three treatments to ensure that there was no difference in live weights at the start of each experiment. Each treatment included

three mobs of lambs serving as replicates. Each mob was rotationally grazed within the same three paddocks for each treatment replicate.

The Pasture mix was used in all of the five periods but the Plantain and Chicory mixes were only used during early spring, late spring and early summer, summer and autumn. The two herbage treatments were not grazed in winter because of their partial dormancy and slow herbage growth rate (Kemp *et al.*, 2010).

Also, the poorly drained soil condition of the Tokomaru silt loam during the winter rain (Cowie and Rijkse 1977) would have resulted in treading damage to the crown of plantain and chicory (Li and Kemp 2005; Kemp *et al.*, 2010) affecting the persistence of these species throughout the year. If required the Pasture mix was grazed hard using ewes whenever necessary to maintain the pasture quality.

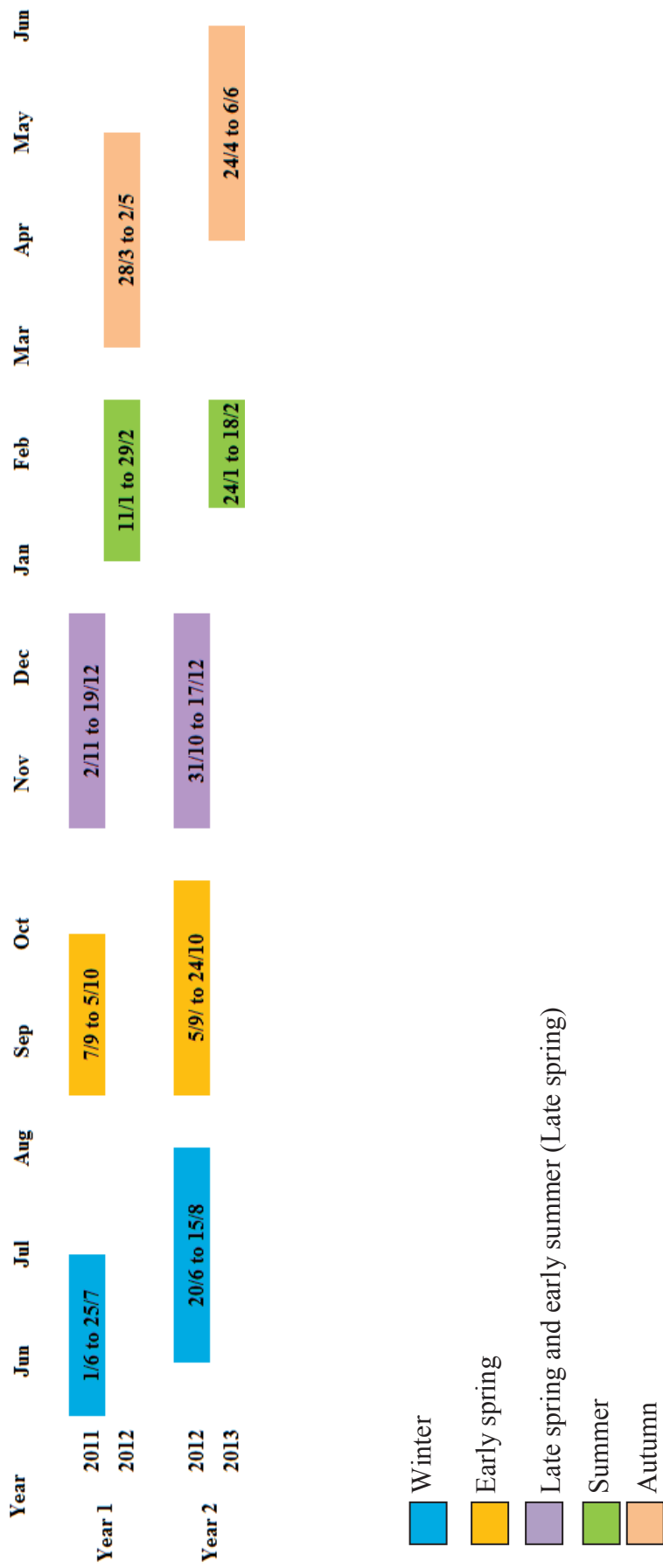


Figure 3-1: Experimental periods for year one (2011/2012) and year two (2012/2013).

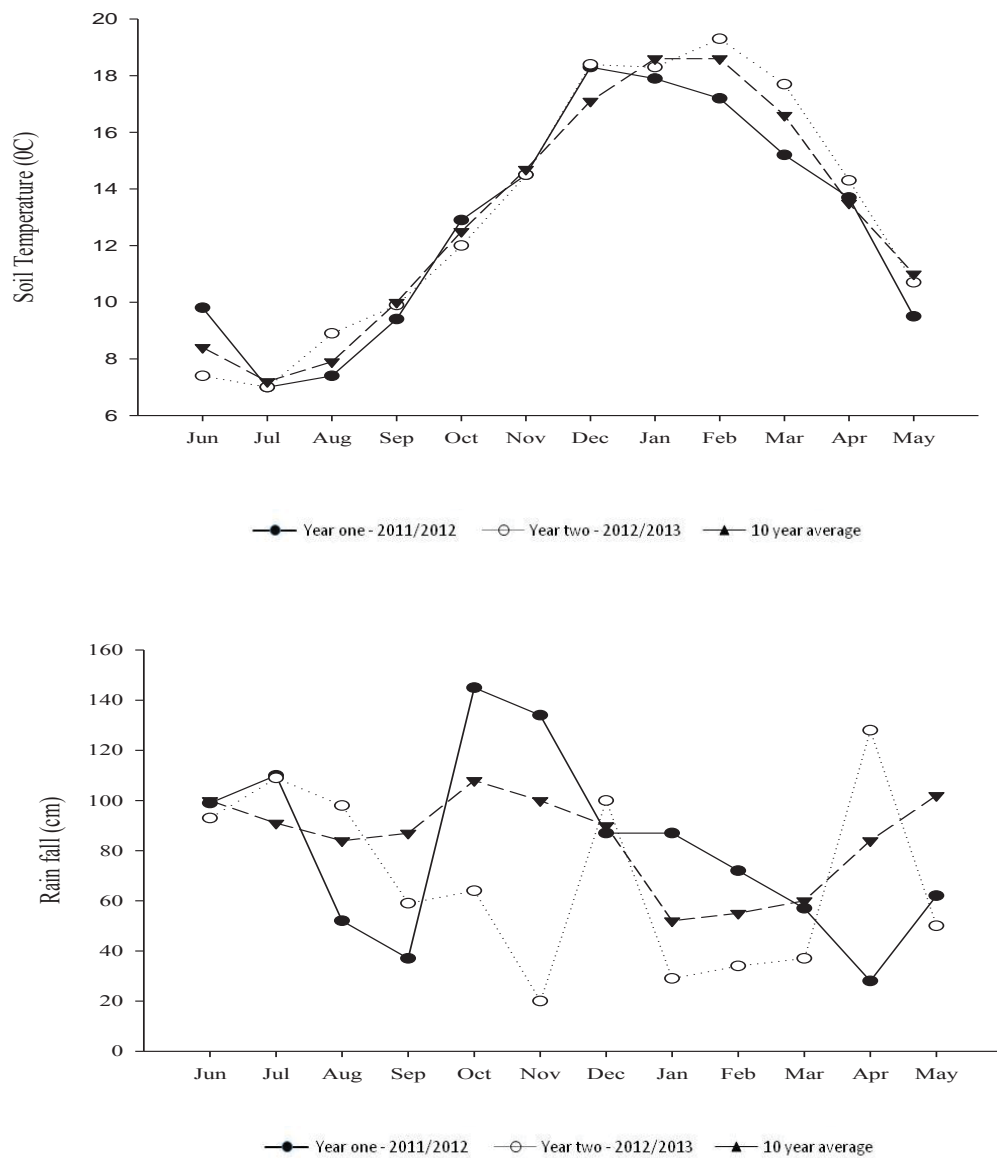


Figure 3-2: Monthly and 10 year average of soil temperature (°C) and the rainfall (mm) at the experimental site.

Source: National Institute of Water and Atmospheric Research (NIWA), AgResearch, Palmerston North, New Zealand. Weather station site was situated between $-40^{\circ}38'$ S and $175^{\circ}61'$ E and Network Number is E0536D

The farmlets used for the three herbage treatments consisted of 28 paddocks with two half paddocks (see Appendix Figure 10.1). Therefore, each herbage treatment had nine paddocks. The size of each paddock was 0.25 ha. Therefore, the total

grazing area per herbage treatment was 2.25 ha (0.25 ha x 3 mobs x 3 paddocks). Each paddock was divided in half using a temporary electric fence to ensure herbage control during the experiments.

3.2 Field preparation

The farmlets were established with the respective treatments using the following sowing rates (kg/ha);

Pasture mix; ryegrass 20 kg and white clover 4 kg

Plantain mix; plantain 6 kg, white clover 4 kg and red clover 6 kg

Chicory mix; chicory 6 kg, plantain 6 kg, white clover 4 kg and red clover 6 kg.

Pasture mix

The perennial ryegrass cultivar One50 and white clover cultivar Bounty paddocks were sown in 2009.

Plantain mix

Plantain paddocks were power harrowed to remove approximately $\frac{1}{3}$ of the existing two year old plantain cultivar Ceres Tonic. Then plantain cultivar Ceres Tonic, white clover cultivar Bounty and red clover cultivar Sensation seeds were sown in autumn 2011.

Chicory mix

Chicory paddocks were power harrowed to remove approximately $\frac{1}{3}$ of the existing two year old plantain cultivar Ceres Tonic. After that plantain cultivar Ceres Tonic, chicory cultivar Puna II, white clover cultivar Bounty and red clover cultivar Sensation seeds were sown in autumn 2011.

All Plantain mix and Chicory mix paddocks were mowed to a height of 10-12 cm in May 2011 and in June 2011 to help control weeds and to reduce competition from the already established plantain on the establishing herb and clover seedlings.

3.3 Fertilizer application

A 30% Potash Super (phosphorous 6.3%, potassium 15%, sulphur 7.7% and calcium 14%) basal fertilizer mixture (Ravensdown, New Zealand) was added at a rate of 400 kg per ha to all the paddocks in autumn 2011 and in autumn 2013.

Urea (Ravensdown, New Zealand) was added to all the paddocks at a rate of 67 kg per ha (30 kg N/ha) in August and December 2011, October 2012 and March 2013.

Cropmaster 13 (Ravensdown, New Zealand) was applied in June 2011 at a rate of 200 kg per ha as a source of nitrogen (12.6%), phosphorous (14%) and potassium (15%) to all the treatments. Cropmaster 15 was applied in May 2012 at a rate of 200 kg per ha as a source of nitrogen (15.1%), phosphorous (10%), potassium (10%) and sulphate (7.7%) to all the treatments.

3.4 Herbicide application

Weeds such as *Urtica urens* (stinging nettle), *Chenopodium album* (fathen), *Hypochaeris radicata* (catsear), *Ranunculus acris* (giant buttercup), *Ranunculus sardous* (hairy buttercup), *Rumex obtusifolius* (broad-leaved docks), *Juncus communis* (rushes), *Poa annua* (annual bluegrass) and *Cirsium vulgare* (scotch thistle) were present in all the pasture and herb-clover mix paddocks.

Gallant Ultra herbicide (active ingredient haloxyfop, Dow AgroSciences, New Zealand) was applied in late August 2011 and April 2013 at a rate of 0.5 litre per ha with 1 litre per ha Uptake (active ingredient 582 g/l paraffinic oil and 240 g/l alkoxyated alcohol non-ionic surfactants) to control the spread of grass weeds mainly other ryegrass and *Poa annua* in the paddocks of the Plantain and Chicory mixes. Roundup (active ingredient glyphosate (Nufarm Limited, New Zealand) diluted at 20:1 was applied via a rotating carpet roller weed wiper to control rushes in May 2012.

Mowing using the tractor and mower at a height of 10-12 cm during summer (late January and mid-February) each year also helped to control the spread of docks and rushes in the Plantain mix and Chicory mix paddocks.

3.5 Pesticide application

Slug Out Slug baits (active ingredient Metaldehyde 10 g/l, Nufarm Limited, New Zealand) were applied at a rate of 15 kg per ha to control slugs in the Plantain mix in March and August 2012.

3.6 Experimental methods used in each season

Each period the lambs were purchased on a Friday from the Livestock Saleyards, Feilding, New Zealand. Exception was the late spring/early summer lambs which were purchased from Landcorp Farming Limited, Manawatu. On arrival at the experimental site they were drenched with Zolvix (Active ingredient: 25 mg/ml Monepantel (Novartis Animal Health, New Zealand) at a rate of 1 ml per 10 kg body weight and left in a holding paddock near the experimental paddocks until the starting date of each experiment which was the following Wednesday. During the

experimental period lambs were drenched every four weeks with Ancare 'Matrix' triple combination drench (active ingredients 1 g/l Abamectin; 40 g/l Levamisole HCL; 22.7 g/l Oxfendazole) at a rate of 1 ml per 5 kg body weight (Merial Ancare, Manukau City, New Zealand).

Prior to each experiment the lambs were tagged with electronic ear tags, weighed (un-fasted) and grouped into each treatment. Then according to the treatment each lamb was tagged with a colour tag (Pasture mix - green; Plantain mix - blue; Chicory mix - pink) and sprayed a coloured mark to differentiate mobs/replicates (heads, shoulders and tails) in each treatment (Table 3-1). The lambs were then, moved to their respective paddocks and rotated according to the herb/pasture growth in each period (see Appendix Figure 10.3). Each mob was rotated among the same three paddocks during the experiment. Lambs were offered *ad-lib* intake with a herbage allowance of three times their predicted intake of 1.5 kg DM per head per day (Kenyon and Webby 2007; Kerr 2010) in all experiments. To ensure *ad-lib* conditions lambs were shifted into a new paddock when the post-grazing sward surface height reached 5 cm in the Pasture mix and 7 cm in the Plantain and Chicory mixes.

Lambs were weighed (un-fasted) every fortnight and their live weights were recorded separately for each treatment mob in each period. Each experiment was conducted until either the lambs gained body weight of D_1+10 kg (maximum 56 days) or the herb/pasture growth was not sufficient to meet lamb *ad-lib* feeding requirements. Lambs were weighed and dagged on their final day and electronic ear tags were removed before being trucked to Alliance Meat Works (Dannevirke, New

Zealand). They were trucked in the late afternoon and slaughtered, in the early morning of the following day.

Table 3-1: Description of each mob/replicate of each treatment.

Treatment	Mob	Paddock
Pasture mix	Head	1, 6, 8
	Shoulder	2, 4, 7
	Tail	3, 5, 9
Plantain mix	Head	22, 23, 26
	Shoulder	20, 24, 28
	Tail	21, 25, 27
Chicory mix	Head	10, 15, 17
	Shoulder	13, 14, 19
	Tail	11, 12, 16/18,



Measurements taken after slaughter included carcass weight and video image analysis (VIA) scan measurements including GR tissue depth measurement (thickness of tissue over 12th rib 110 mm from the midline of the carcass), leg, loin and shoulder yields (Kirton and Johnson 1979; Rius-Vilarrasa *et al.*, 2009). In addition to the above, each carcass was valued according to the carcass weight and individual wool content by the processing company (Alliance Meat Works, Dannevirke, New Zealand).

Prior to the commencement of the next season's experiment a two to three weeks period free of stock was maintained to allow the pasture and herbage to re-grow to the prescribed pre-grazing heights.

3.7 Refugia population of unselected gastrointestinal nematodes in the soils of the farmlets using a population of adult ewes

A small population of adult ewes (two ewes per mob per treatment) was introduced to the experiments from the summer 2012 to autumn 2013. The objective of this practice was to maintain a proportion of nematode eggs that had not been exposed to anthelmintics and which were intended to act as a refugia population of unselected gastrointestinal nematodes in the soils of the farmlets. This practice was to help avoid the existing nematodes becoming resistant to the anthelmintic drenches routinely used (Waller 1999) during the experiments. There were six adult ewes per herbage treatment. Altogether, there were 18 adult ewes per experiment (6 per herbage treatment x 3 herbage treatments) in each season. For each experiment, different ewes were introduced.

3.8 Herbage measurements in each experiment in each season

3.8.1 Botanical composition

Prior to and after each experimental period herbage samples were collected from all paddocks to determine the botanical composition. Twelve herbage samples from each of the nine paddocks within each treatment were cut at the ground level the width of an electric shearing hand piece and approximately 20 cm long. The twelve samples were then thoroughly mixed and a 30 g sub-sample was taken to determine the proportion of ryegrass, white clover, red clover, plantain, chicory, weeds (non-

sown species) and dead matter. After separation, each portion was dried in a draught oven for at least 24 hours at 70⁰ C to determine the relative composition (% dry matter basis). Botanical composition was determined for each paddock separately. Average composition of the nine paddocks per treatment was used as the botanical composition of each treatment.

3.8.2 Pre- and post-grazing mass

Four pre-grazing herbage quadrat cuts (0.1 m²) at ground level were taken in each paddock to determine the pre-grazing herbage dry matter (DM) mass each time the lambs were moved to a new paddock. Four post-grazing herbage quadrat cuts (0.1 m²) were taken within 24 hours of the removal of lambs from each paddock to determine post-grazing herbage dry matter (DM) mass (Brown *et al.*, 2005). The samples were washed and oven dried in a draught oven at 70⁰ C for a minimum of 24 hours. These dry weights were used to calculate the herbage mass on a DM basis.

3.8.3 Sward surface heights

Fifty sward surface height measurements per paddock were recorded using an Automated Sward Stick (JENQUIP, Fielding, New Zealand) to determine the height of the next grazing paddock (pre-grazing paddock). As the paddocks were divided into two halves, 25 sward surface height measurements per half a paddock were recorded from the most recent post-grazing paddock to determine the post-grazing height. Prior to the first measurement, the initial sward stick meter reading was noted down. Then at the end of the 50 (pre-grazing) or 25 (post-grazing) sward height measurements the final meter reading was recorded. Then using these two measurements the height of the sward surface was determined according to an

equation developed for the above sward stick. Sward height was measured to the free standing leaf height excluding stems and seed heads (Webby and Pengelly 1986).

3.8.4 Herbage quality

Two enclosed cages were placed in each paddock during the grazing period. The herbage inside these cages was not disturbed during the grazing period. Two grab herbage samples were collected from each post-grazing paddock and frozen at -20°C during the experimental periods. Two samples were randomly selected out of six samples per herbage treatment (two samples per paddock x 3 paddocks or replicates) at each post-grazing. Samples were freeze dried, ground to pass a 1 mm screen and analysed for in-vitro organic matter digestibility (OMD), dry matter digestibility (DMD) and digestible organic matter digestibility (DOMD) (Roughan and Holland 1977). The OMD, DMD and DOMD results were expressed on a DM basis. Total nitrogen for CP analysis was determined by “Dumas” procedure (AOAC method 968.06) using a Leco total combustion method (LECO Corporation, St. Joseph, MI, USA) and corrected for DM basis. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were analysed by a Tecator Fibretec System (Robertson and Van Soest 1981). Alpha amylase was added during the extraction to remove the starch completely (AOAC method 2002.04) and the results were corrected for DM basis.

3.8.5 Net herbage accumulation rate (NHAR)

Net herbage accumulation rate (NHAR) was calculated using the most recent pre-grazing and immediate previous post-grazing herbage DM masses and the interval days between the sample cuts within a paddock (Frame 1981; Matthews *et al.*, 1999).

3.9 Soil nutrient analysis

Soil samples were collected to a depth of 7.5 cm from all the paddocks using a soil auger in April 2011 and May 2012 to determine the nutrient status of the soil. The samples were air-dried, ground and used in the analysis. pH, Olsen P, available sulphate (SO₄) and sodium (Na) were determined using the method given by Blakemore *et al.* (1987). Potassium (K), calcium (Ca) and magnesium (Mg) were determined by atomic emission (K) and absorption (Ca and Mg) spectroscopy following digestion in nitric acid. Cation Exchange Capacity (CEC) was determined using the method given by Hesse (1971). Soil volume was the measure of the weight of air-dried soil (g) per volume (ml) and used to convert results to a volume basis.

These soil samples were analysed at the Fertilizer and Lime Research Centre, Institute of Agriculture and Environment, Massey University (Tables 3-2, 3-3 and 3-4). These data were used to decide the annual basal fertilizer rates in the present research.

Table 3-2: Soil nutrient status for the Pasture mix in 2011 and 2012.

Sample	Year 1			Year 2		
	1	2	3	1	2	3
pH*	5.5	5.4	5.4	5.4	5.5	5.4
Olsen P ($\mu\text{gP/g}$)	25.1	24.2	28.4	27.6	27.6	32.8
SO ₄ ($\mu\text{gS/g}$)	9.8	22.3	23.5	10.3	12.1	11.7
K (me/100g)	0.2	0.18	0.21	0.36	0.28	0.33
Ca (me/100g)	5.4	5.9	5.1	5.4	5.3	5.1
Mg (me/100g)	0.71	0.7	0.71	0.75	0.74	0.69
Na (me/100g)	0.07	0.06	0.06	0.44	0.22	0.22
CEC (me/100g)	13	14	12	13	13	13
Soil volume (g/ml)	0.95	0.99	0.98	0.96	0.90	0.90

pH* in water basis.

Table 3-3: Soil nutrient status for the Plantain mix in 2011 and 2012.

Sample	Year 1			Year 2		
	1	2	3	1	2	3
pH	5.6	5.7	5.6	5.4	5.4	5.4
Olsen P ($\mu\text{gP/g}$)	32.2	26.5	31.3	30.0	24.8	30.9
SO ₄ ($\mu\text{gS/g}$)	7.5	7.0	7.5	7.5	6.1	10.3
K (me/100g)	0.50	0.61	0.50	0.58	0.44	0.69
Ca (me/100g)	5.7	5.8	5.5	5.4	5.1	6.1
Mg (me/100g)	0.98	1.02	0.96	0.96	0.92	1.07
Na (me/100g)	0.08	0.11	0.10	0.24	0.21	0.34
CEC (me/100g)	15	15	13	13	14	14
Soil volume (g/ml)	0.95	0.99	0.93	0.95	0.92	0.92

pH* in water basis.

Table 3-4: Soil nutrient status for the Chicory mix in 2011 and 2012.

Sample	Year 1			Year 2		
	1	2	3	1	2	3
pH	5.6	5.6	5.6	5.5	5.5	5.5
Olsen P ($\mu\text{gP/g}$)	32.7	32.7	29.4	29.5	34.7	31.4
SO ₄ ($\mu\text{gS/g}$)	10.3	8.5	7.3	8.6	9.3	11.4
K (me/100g)	0.42	0.46	0.43	0.45	0.51	0.52
Ca (me/100g)	5.7	5.6	5.6	5.5	5.7	6.0
Mg (me/100g)	1.00	1.02	1.04	0.98	0.92	1.07
Na (me/100g)	0.11	0.12	0.10	0.28	0.29	0.33
CEC (me/100g)	13	13	13	13	14	14
Soil volume (g/ml)	1.00	0.94	1.01	0.90	0.93	0.93

pH* in water basis.

**Chapter 4 : Effect of Plantain mix and Chicory mix on the live
weight gain (LWG) and carcass weight of lambs compared to
Pasture mix**

**A part of Section A was published in the Proceedings of the New Zealand
Grassland Association;**

SINHADIPATHIGE S. C. S., KENYON P. R., KEMP P. D., MORRIS S. T. and MOREL P. C.

H. (2012) Can herb-clover mixes increase lamb liveweight gains in spring?

Proceedings of the New Zealand Grassland Association, **74**, 137-142.

4.1 Abstract

Lamb performance was evaluated in three herbage treatments (Pasture mix, Plantain mix and Chicory mix) in two consecutive years including different periods namely early spring, late spring and early summer (late spring), summer and autumn. The hypothesis of this chapter was that Plantain and Chicory mixes would produce greater lamb performance compared to Pasture mix during each period. In the early spring period, Chicory mix performed better than the Pasture mix during both experiments and Plantain mix produced higher lamb performance during Experiment two compared to the Pasture mix. In the late spring to summer period both herb-clover mixes produced higher lamb performance compared to the Pasture mix during both experiments. In autumn LWG and carcass weights were higher in both herb-clover mixes during both experiments but dressing out percentage (DO%) was higher only during the Experiment one in herb-clover mixes compared to the Pasture mix. The Plantain and Chicory mixes produced heavier lambs at slaughter with greater carcass weights and dressing out percentages and per ha carcass weight production compared to the Pasture mix. The Chicory mix performed better than the Plantain mix when compared across both years.

Keywords: Pasture mix, Plantain mix, Chicory mix, Live weight gain, Carcass weight

4.2 Introduction

The New Zealand lamb export industry is based on exporting chilled meat cuts rather than whole carcasses (Chrystall *et al.*, 1989; Matthews *et al.*, 2007). However, this requires a steady supply of freshly killed lamb which can be difficult due to the majority of lambs being born in spring matching New Zealand's seasonal pasture growth pattern (Morris *et al.*, 1993a; Burke *et al.*, 2002; Fisher 2004) and hence, slaughtered in the late summer and autumn seasons. Therefore, systems which allow for finishing lambs in most, if not all seasons would help facilitate a continuous supply of lambs.

Perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.) pasture is the main forage available in managed grasslands in New Zealand (Lancashire *et al.*, 1978; Powell *et al.*, 2007). It is the least cost forage and is well adapted to New Zealand's climatic conditions. It also can withstand grazing pressure in various environments (Burke *et al.*, 2002). However, this herbage mix has a seasonal pattern of production influencing animal performance (Jacobs *et al.*, 1999; Morris *et al.*, 2004; McKenzie *et al.*, 2006) and can limit post weaning lamb growth (Hughes *et al.*, 1980; Fraser and Rowarth 1996). Therefore, alternative herbage systems are required to allow weaned lambs to achieve their growth potential (Waghorn and Clark 2004). The herbages, plantain (*Plantago lanceolata* L.), chicory (*Cichorium intybus*), white- and red-clover (*Trifolium pratense* L.) are generally associated with higher metabolisable energy (ME) and feeding value characteristics (Barry 1998; Li and Kemp 2005; Fulkerson *et al.*, 2007; Waghorn *et al.*, 2007; Hayes *et al.*, 2010) compared to ryegrass/white clover pastures. Studies have indicated pure swards of plantain (Moorhead *et al.*, 2002), chicory (Cruickshank

1986; Scales *et al.*, 1995; Barry 1998; Holst *et al.*, 1998), red clover (Moorby *et al.*, 2004; Marley *et al.*, 2005) and white clover (Cruickshank 1986; Marley *et al.*, 2005) all result in greater lamb live weight gains (LWG) than a ryegrass/white clover pasture.

Recently, research has shown that a herb-clover mix containing plantain, chicory, white- and red-clover resulted in improved performance of ewes and lambs in lactation (Hutton *et al.*, 2010; Kenyon *et al.*, 2010) and weaned lamb LWG in autumn (Golding *et al.*, 2011). Kemp *et al.* (2010) suggested that a combination of both ryegrass/white clover pasture and herb-clover mix could be used for finishing lambs all year round using the herb-clover mix from spring to autumn period and perennial ryegrass/white clover pasture during winter. If this is to be the case, lamb growth rates on the herb-clover mixes need to be equal to or greater than those on ryegrass/white clover pasture in the seasons spring to autumn given that the herb-clover mixes cannot be utilised in winter (Hume *et al.*, 1995; Kemp *et al.*, 1999; Kemp *et al.*, 2010).

Therefore, a research programme was undertaken over five different periods of the year, over all four seasons for two consecutive years (Figure 3-1). Herbage and lamb performance were compared using two herb-clover mixes namely *Plantain mix*; plantain, white- and red-clover and *Chicory mix*; plantain, chicory, white clover and red clover. The hypothesis was that Plantain and Chicory mixes would produce greater lamb performance (i.e. live weights, live weight gains and heavier carcass weights) compared to the Pasture mix (ryegrass and white clover). The five different

periods were; early spring (Section A), late spring and early summer (Section B), summer (Section C), autumn (Section D) and winter (Section E).

The overall methodology and data collection protocol related to each section are explained in detail in Chapter 3. Only the minor amendments related to the specific methodology and data collection within each period are discussed in each of the following sections. At the end of each section the results are summarised and brief reference is made to previous literature. At the end of the chapter a full discussion is undertaken of the results across the five periods.

4.3 Section A

Effect of Plantain mix and Chicory mix on the live weight gain (LWG) and carcass weight of lambs compared to Pasture mix in the early spring period over two consecutive years

4.3.1 Overview

To date the growth of weaned lambs on herb-clover mixes compared to ryegrass/white clover sward in spring has not been examined. Spring in New Zealand is associated with high ryegrass/white clover pasture growth rates and adequate pasture quality characteristics (Valentine and Kemp 2007). Therefore, it might be expected that there would be little advantage from the herb-clover mixes for lamb growth and carcass composition above those observed on ryegrass/white clover. Hence, an experiment was conducted in the early spring for two consecutive years to test this.

4.3.2 Materials and methods

The two experiments were undertaken from 7th September to 5th October 2011 (*Experiment one*) and 5th September to 24th October 2012 (*Experiment two*).

4.3.2.1 Animal management

Experiment one (2011)

One hundred and ninety five cryptorchid Romney cross male lambs aged approximately 11 months (41.3 ± 0.16 kg) were selected on 7th September 2011 (D₁). The lambs were assigned to one of three herbage treatment groups 'Pasture mix'

n=69; 'Plantain mix' n=69; 'Chicory mix' n=57. Lambs were stratified by live weight and allocated to the treatments to ensure that there was no difference in live weights at the start of the experiment. Each treatment included three mobs of lambs serving as replicates (i.e. n=23, n=23 and n=19 for Pasture mix, Plantain mix and Chicory mix per mob, respectively).

The nine groups of lambs (three treatments by three mobs/replicates) rotationally grazed their assigned treatment plots twice during the experimental period. The stocking rates (lambs/ha) were 30 lambs per ha in the Pasture and Plantain mixes and 25 lambs per ha in the Chicory mix. Different stocking rates were used in order to maintain predicted herbage masses in all three treatments (i.e. final average herbage mass to be similar to start average herbage mass) and also assuming *ad-lib* requirements were equal to herbage growth. The studies of Matthews *et al.* (1999), Li and Kemp (2005), Powell *et al.* (2007) and Kemp *et al.* (2010) were used to predict herbage growth during both experimental periods.

Lambs were orally drenched on D₁ for internal parasite control (see Chapter 3 page 56 for details). They were weighed within an hour of removal from the herbage on D₁, D₁₄, D₂₁ and D₂₈. On D₂₈ all lambs were slaughtered.

Experiment two (2012)

The same experimental design was repeated in 2012 using 198 cryptorchid Romney cross male lambs aged approximately 10 months (34.8±0.40 kg) beginning on 5th September (D₁). The stocking rate for this experiment was 32 lambs per ha in all treatments. This included adult ewes (six ewes per treatment) introduced to provide

contamination with nematode eggs (details are given in Chapter 3). Therefore, each of the treatment had a total of 66 lambs split into three mobs (i.e. n=22 per mob) and six ewes (two ewes per mob). The nine groups of lambs (three treatments by three mobs) rotationally grazed their assigned treatment plots three times during the experiment.

Lambs were weighed on D₁, D₁₄, D₂₁, D₃₅ and D₄₉. One third of the lambs (the 10 heaviest lambs in each mob) were slaughtered on D₂₂. This was required due to the low growth of herbage and to ensure *ad-lib* feeding conditions were maintained. All the remaining lambs were drenched again on D₂₁ and vaccinated against “clostridial myocarditis” as one lamb in Pasture mix died of the disease. The remaining lambs were slaughtered on D₅₀.

4.3.2.2 Herbage quality

Grab herbage samples collected on D₇ in 2011, D₇ and D₃₇ in 2012 and were analysed to estimate the nutritive value of the herbage consumed by lambs.

4.3.2.3 Statistical analysis - Experiment one and Experiment two

All the data were tested for normality and outliers using Minitab 16 statistical software before the analysis in SAS version 9.2 (SAS 2008).

Individual lamb data (apparent intake per lamb per day, live weight, carcass weight, leg, loin, shoulder (% yield of carcass) and GR tissue depth measurement) and herbage data (pre- and post-grazing dry matter production, sward heights) were analysed using a nested linear model with herbage treatment as a fixed effect and

replicate (*mob* for lamb data or *paddock* for herbage data) nested within herbage treatment as a random effect using proc GLM in SAS version 9.2 (SAS 2008) for each experiment separately. The means were separated using LSD procedure in proc GLM.

Pre- and post-grazing herbage mass data for each rotation were used in the analysis of herbage DM mass. Apparent intake per lamb per day was calculated according to Matthews *et al.* (1999) by taking the difference between pre-grazing DM mass and post-grazing DM mass divided by grazing intensity (lambs/ha/day). Pre- and post-grazing sward surface height data for each rotation were used in the analysis of pre- and post-grazing sward surface heights.

In experiment two, lamb live weight gains were calculated considering the two different days to slaughter (D_1 to D_{21} days and D_1 to D_{49} days). However, carcass measurements of both slaughter dates were analysed together irrespective of the two separate slaughter dates.

The herbage quality data were analysed using randomised block design model using proc GLM. Crude protein, NDF and ADF values were corrected for DM basis before analysing. Metabolisable energy (ME) was calculated by multiplying digestible organic matter digestibility (DOMD%) by 0.163 (Geenty and Rattray 1987). The means were separated using LSD procedure in proc GLM.

Apparent live weight production per ha for each treatment was calculated by taking the difference between D_1 total live weight per ha per treatment and final live weight

per ha per treatment. Apparent carcass weight production per ha for each treatment was calculated by taking the difference between total carcass weight production per ha per treatment at slaughter and estimated carcass weight production at D₁ per ha per treatment. Estimated carcass weight production at D₁ was assumed to be 40% of D₁ live weight (Kirton *et al.*, 1984) for all lambs.

4.3.3 Results

4.3.3.1 Herbage mass

Experiment one (2011)

Pre- and post-grazing herbage masses and apparent DM intake did not differ ($P>0.05$) between treatments (Table 4-1).

Experiment two (2012)

Pre- and post-grazing herbage masses and apparent DM intake did not differ ($P>0.05$) between treatments (Table 4-1).

Table 4-1: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on the pre- and post-grazing herbage dry matter (DM) mass and apparent DM intake in early spring (mean \pm s.e.).

Treatment	Pre-grazing (kg/ha)	Post-grazing (kg/ha)	Apparent DM intake (kg/head/day)
<i>Experiment one (2011)</i>			
Pasture mix	2438 \pm 176.5	1544 \pm 108.3	3.8 \pm 0.71
Plantain mix	2901 \pm 157.8	1344 \pm 96.9	3.5 \pm 0.63
Chicory mix	2954 \pm 157.8	1457 \pm 96.9	3.8 \pm 0.64
<i>Experiment two (2012)</i>			
Pasture mix	4155 \pm 202.1	2905 \pm 137.4	1.6 \pm 0.19
Plantain mix	4102 \pm 202.1	2617 \pm 137.4	1.9 \pm 0.19
Chicory mix	3949 \pm 202.1	2540 \pm 137.4	1.7 \pm 0.19

Differing superscripts within columns and experiments indicate means that were significantly different ($P < 0.05$).

4.3.3.2 Sward height

Experiment one (2011)

Pre-grazing sward heights did not differ ($P > 0.05$) between herbage treatments (Table 4-2). However, the Plantain mix had a lower ($P < 0.05$) post-grazing sward height compared to the Pasture mix.

Experiment two (2012)

Plantain and Chicory mixes had higher ($P < 0.05$) pre-grazing sward heights than the Pasture mix (Table 4-2). Post-grazing sward height was lower ($P < 0.05$) in the Pasture mix than the Chicory mix.

Table 4-2: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on pre- and post-grazing sward height measurements in early spring (mean \pm s.e.).

Treatment	Pre-grazing (cm)	Post-grazing (cm)
<i>Experiment one (2011)</i>		
Pasture mix	14.0 \pm 0.60	7.6 ^b \pm 0.53
Plantain mix	14.1 \pm 0.54	6.1 ^a \pm 0.47
Chicory mix	14.3 \pm 0.54	7.1 ^{ab} \pm 0.47
<i>Experiment two (2012)</i>		
Pasture mix	13.1 ^a \pm 0.73	7.9 ^a \pm 0.57
Plantain mix	21.2 ^b \pm 0.73	9.1 ^{ab} \pm 0.57
Chicory mix	21.6 ^b \pm 0.73	9.7 ^b \pm 0.57

Differing superscripts within columns and experiments indicate means that were significantly different ($P < 0.05$).

4.3.3.3 Herbage composition

Experiment one (2011) and Experiment two (2012)

In both experiments, ryegrass was the dominant species before and after completion of the experiment in the Pasture mix (Table 4-3). Plantain was the dominant species in both the Plantain and the Chicory mixes before and after the completion of the experiments. Total clover (white clover and red clover) percentages were 7-20% and 8-24% in Experiment one in the Plantain mix and Chicory mix respectively. In Experiment two total clover percentages were 19-30% and 20-22% in the Plantain mix and Chicory mix respectively.

4.3.3.4 Herbage quality

Experiment one (2011)

In-vitro Organic matter digestibility (OMD) percentage and Metabolisable energy (ME) values were higher ($P<0.05$) in the Chicory mix than the Plantain mix which in turn were higher ($P<0.05$) than the Pasture mix (Table 4-4). Crude protein percentage did not differ ($P>0.05$) between treatments. The Plantain and Chicory mixes had a lower ($P<0.05$) NDF percentage than the Pasture mix. The Pasture mix had a higher ($P<0.05$) ADF percentage compared to the Plantain mix. Plantain mix had a higher ($P<0.05$) ash percentage compared to the Pasture mix.

Experiment two (2012)

Organic matter digestibility percentage was higher ($P<0.05$) in the Chicory mix than the Plantain mix which in turn was higher ($P<0.05$) than the Pasture mix (Table 4-4). Crude protein percentage in the Pasture mix was higher ($P<0.05$) compared to the Chicory mix. Nutrient detergent fibre percentage was higher ($P<0.05$) in the Pasture mix than the Plantain mix which in turn was higher ($P<0.05$) than the Chicory mix. Ash percentage was higher ($P<0.05$) in the Chicory mix compared to the Pasture mix. Metabolisable energy value was highest ($P<0.05$) in the Plantain and Chicory mixes than the Pasture mix.

Table 4-3: The percentage (%) of various herbage species within each herbage treatment prior to and after Experiment one and Experiment two in early spring.

Herbage species	Pasture mix		Plantain mix		Chicory mix	
	Prior to (23/8/2011)	After (27/10/2011)	Prior to (23/8/2011)	After (27/10/2011)	Prior to (23/8/2011)	After (27/10/2011)
<i>Experiment one (2011)</i>						
Ryegrass	73	74	—	—	—	—
Plantain	—	—	42	56	38	38
Chicory	—	—	—	—	9	15
White clover	6	4	4	13	4	15
Red clover	—	—	3	7	4	9
Weeds [#]	12	16	51	22	45	21
Dead matter	9	6	0	2	0	2
<i>Experiment two (2012)</i>						
	Before (24/8/2012)	After (30/10/2012)	Before (24/8/2012)	After (30/10/2012)	Before (24/8/2012)	After (30/10/2012)
Ryegrass	60	53	—	—	—	—
Plantain	—	—	63	42	46	34
Chicory	—	—	—	—	24	26
White clover	3	6	14	19	13	13
Red clover	—	—	5	11	7	9
Weeds [#]	27	33	11	17	5	8
Dead matter	11	8	7	11	5	10

Weeds[#] - all the other non-sown species (including other grasses and weeds) except the main pasture and herb species in the treatments.

Table 4-4: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on various herbage quality parameters in early spring (mean \pm s.e.).

Treatment	Herbage quality (% DM)					ME ⁵ (MJ/kg DM)
	OMD ¹	CP ²	NDF ³	ADF ⁴	Ash	
<i>Experiment one (2011)</i>						
Pasture mix	71.1 ^a \pm 0.29	24.7 \pm 1.73	43.0 ^b \pm 0.58	21.9 ^b \pm 1.08	11.5 ^a \pm 0.33	10.4 ^a \pm 0.05
Plantain mix	76.8 ^b \pm 0.29	20.9 \pm 1.73	28.7 ^a \pm 0.58	16.4 ^a \pm 1.08	13.1 ^b \pm 0.33	11.1 ^b \pm 0.05
Chicory mix	78.4 ^c \pm 0.29	17.9 \pm 1.73	26.9 ^a \pm 0.58	17.9 ^{ab} \pm 1.08	12.2 ^{ab} \pm 0.33	11.4 ^c \pm 0.05
<i>Experiment two (2012)</i>						
Pasture mix	71.3 ^a \pm 0.53	26.3 ^b \pm 1.31	41.8 ^c \pm 1.15	21.5 \pm 0.69	10.5 ^a \pm 0.47	10.4 ^a \pm 0.07
Plantain mix	76.4 ^b \pm 0.53	23.5 ^{ab} \pm 1.31	31.6 ^b \pm 1.15	22.7 \pm 0.69	11.4 ^{ab} \pm 0.47	11.1 ^b \pm 0.07
Chicory mix	78.3 ^c \pm 0.53	21.7 ^a \pm 1.31	27.9 ^a \pm 1.15	21.0 \pm 0.69	12.9 ^b \pm 0.47	11.3 ^b \pm 0.07

Differing superscripts within columns and experiments indicate means that were significantly different (P<0.05).

¹Organic matter digestibility (OMD); ²crude protein (CP); ³neutral detergent fibre (NDF); ⁴acid detergent fibre (ADF), ⁵metabolisable energy (ME).

4.3.3.5 Animal live weight

Experiment one (2011)

There was no difference (P>0.05) in live weight at D₁, D₁₄ or D₂₈ among treatments while at D₂₁ Pasture mix and the Chicory mix lambs were heavier (P<0.05) than Plantain mix lambs (Table 4-5). Chicory mix lambs had greater (P<0.05) LWG between D₁ and D₂₈ than the Pasture mix lambs.

Experiment two (2012)

There was no difference (P>0.05) in live weight at D₁ or D₁₄ among treatments (Table 4-5). However, Plantain mix and Chicory mix lambs were heavier (P<0.05) at D₂₁ and D₄₉ compared to Pasture mix lambs. Similarly, Plantain mix and Chicory mix lambs had greater (P<0.05) LWG between both slaughter dates (D₁ and D₂₁ and D₁ and D₄₉) compared to the Pasture mix lambs.

Table 4-5: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on lamb live weight and daily live weight gain (LWG) in early spring (mean \pm s.e.).

Treatment	n ¹	Live weight (kg)				n ¹	LWG (D ₁ -D ₂₈) (g/day)
		D ₁	D ₁₄	D ₂₁	D ₂₈		
<i>Experiment one (2011)</i>							
Pasture mix	69	41.4 \pm 0.07	48.0 \pm 0.22	49.9 ^b \pm 0.21	50.4 \pm 0.35	69	321.8 ^a \pm 10.0
Plantain mix	69	41.2 \pm 0.07	48.6 \pm 0.22	48.3 ^a \pm 0.21	50.6 \pm 0.35	69	336.0 ^{ab} \pm 10.0
Chicory mix	57	41.3 \pm 0.08	47.8 \pm 0.25	49.5 ^b \pm 0.24	51.4 \pm 0.38	57	360.0 ^b \pm 20.0
<i>Experiment two (2012)</i>							
	n ¹	D ₁	D ₁₄	D ₂₁	D ₂₈	n ¹	LWG (D ₁ -to slaughter) (g/day)
Pasture mix	66	34.6 \pm 0.16	39.2 \pm 0.29	41.6 ^a \pm 0.28	45.7 ^a \pm 0.30	66	320.7 ^a \pm 10.77
Plantain mix	66	34.8 \pm 0.16	40.0 \pm 0.29	43.2 ^b \pm 0.28	48.7 ^b \pm 0.30	66	397.3 ^b \pm 10.77
Chicory mix	66	34.9 \pm 0.16	40.1 \pm 0.29	42.9 ^b \pm 0.28	47.7 ^b \pm 0.31	66	366.5 ^b \pm 10.77

Differing superscripts within columns and experiments indicate means that were significantly different (P<0.05).
¹ number of lambs per treatment.

4.3.3.6 Carcass weight

Experiment one (2011)

The heaviest ($P < 0.05$) carcass weights were observed in the Chicory mix lambs followed by the Plantain mix lambs which in turn were heavier ($P < 0.05$) than the Pasture mix lambs (Table 4-6). Dressing out percentage (DO%) was greater ($P < 0.05$) in the Chicory mix lambs than the Pasture mix lambs. Leg and loin yield percentages did not differ ($P > 0.05$) between treatments (Table 4-7). However, shoulder yield percentage and GR tissue depths were greater ($P < 0.05$) in Plantain and Chicory mix lambs compared to Pasture mix lambs.

Experiment two (2012)

Plantain mix lambs had greater ($P < 0.05$) carcass weights than Chicory mix lambs which in turn had greater ($P < 0.05$) carcass weights than the Pasture mix lambs (Table 4-6). The DO% was greater ($P < 0.05$) in Plantain mix and Chicory mix lambs than Pasture mix lambs. GR tissue depths were greater ($P < 0.05$) in the Plantain mix and Chicory mix lambs than Pasture mix lambs (Table 4-7).

Table 4-6: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on carcass weight and dressing-out percentage (DO%) of lambs in early spring (means \pm s.e.).

Treatment	n ¹	Carcass weight (kg)	DO% ³
<i>Experiment one (2011)</i>			
Pasture mix	69	21.1 ^a \pm 0.11	42.0 ^a \pm 0.36
Plantain mix	69	21.8 ^b \pm 0.11	43.0 ^{ab} \pm 0.36
Chicory mix	57	22.3 ^c \pm 0.12	43.3 ^b \pm 0.40
<i>Experiment two (2012)</i>		Carcass weight (kg) ²	
Pasture mix	66	18.1 ^a \pm 0.17	39.5 ^a \pm 0.29
Plantain mix	66	20.3 ^c \pm 0.17	41.4 ^b \pm 0.29
Chicory mix	66	19.7 ^b \pm 0.17	41.3 ^b \pm 0.29

Differing superscripts within columns and experiments indicate means that were significantly different (P<0.05).

¹ number of lambs per treatment.

² this included lambs slaughtered at both days D₂₂ and D₅₀.

³ DO% =(carcass weight/final live weight) \times 100. Final live weight was taken on farm approximately 12 hours before slaughter.

Table 4-7: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on lamb leg, loin, shoulder yields (% of total carcass) and GR tissue depth measurement in early spring (means \pm s.e.).

Treatment	n ¹	Leg yield %	Loin yield %	Shoulder yield %	GR (mm)
<i>Experiment one (2011)</i>					
Pasture mix	69	22.3 \pm 0.13	15.2 \pm 0.05	16.7 ^a \pm 0.06	8.5 ^a \pm 0.27
Plantain mix	69	22.2 \pm 0.13	15.0 \pm 0.05	17.1 ^b \pm 0.06	9.4 ^b \pm 0.27
Chicory mix	57	22.3 \pm 0.15	15.1 \pm 0.06	17.1 ^b \pm 0.06	9.6 ^b \pm 0.31
<i>Experiment two (2012)²</i>					
Pasture mix	66	22.9 \pm 0.20	15.3 \pm 0.07	16.9 \pm 0.12	7.0 ^a \pm 0.21
Plantain mix	66	22.4 \pm 0.21	15.2 \pm 0.08	16.9 \pm 0.13	9.5 ^b \pm 0.21
Chicory mix	66	22.4 \pm 0.22	15.2 \pm 0.08	17.1 \pm 0.13	9.3 ^b \pm 0.22

Differing superscripts within columns and experiments indicate means that were significantly different ($P < 0.05$).

¹number of lambs per treatment.

²this included lambs slaughtered at both days D₂₂ and D₅₀.

4.3.3.7 Apparent live weight and carcass weight production per ha - Experiment one (2011) and Experiment two (2012)

The Plantain mix apparent live weight and carcass weight production per ha were greater than the Pasture mix and Chicory mix in 2011 but with very little difference in apparent live weight production per ha (range 255-288 kg/ha) and carcass weight production per ha (range 140-163 kg/ha) between treatments (Table 4-8). While in 2012, both Plantain mix and Chicory mix apparent live weight and carcass weight production per ha were greater than the Pasture mix.

Table 4-8: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on apparent live weight and carcass weight production per ha (kg/ha) in early spring.

	Pasture mix	Plantain mix	Chicory mix
<i>Experiment one (2011)</i>			
Area per treatment (ha)	2.25	2.25	2.25
No. of lambs per treatment (no.)	69	69	57
Stocking rate (no. of lambs per ha)	30	30	25
D ₁ Live weight (kg/ha)	1269	1263	1047
Live weight at D ₂₈ (kg/ha)	1545	1551	1302
Apparent live weight production per ha (kg/ha)	276	288	255
Estimated carcass weight* at D ₁ (kg/ha)	508	505	419
Total carcass weight (kg/ha)	648	668	564
Apparent carcass weight production per ha (kg/ha)	140	163	145
<i>Experiment two (2012)</i>			
Area per treatment (ha)	2.25	2.25	2.25
No. of lambs per treatment (no.)	66	66	66
Stocking rate ¹ (no. of lambs per ha)	32	32	32
D ₁ Live weight (kg/ha)	1002	1008	1007
Live weight at D ₂₈ (kg/ha)	1323	1414	1378
Apparent live weight production per ha (kg/ha)	321	406	371
Estimated carcass weight* at D ₁ (kg/ha)	401	403	403
Total carcass weight (kg/ha)	523	585	568
Apparent carcass weight production per ha (kg/ha)	122	182	165

* based on a 40% of D₁ live weight (Kirton *et al.*, 1984).

¹ includes the population of farmlets ewes (two ewes/mob/treatment).

4.3.4 Discussion of the early spring period

The aim of this section was to examine weaned lamb performance on herb-clover mixes compared to the Pasture mix in early spring period. The herbage dry matter masses and sward height measurements in all three herbage treatments indicated herbage intake should not have been limiting (Webby and Pengelly 1986; Kenyon and Webby 2007). This allowed for comparison of lamb performance on these herbages under unrestricted grazing conditions.

The Chicory mix lambs had greater LWG but not final live weights compared to the Pasture mix lambs in Experiment one. While both Plantain mix and Chicory mix lambs had both greater LWG and final live weights in Experiment two compared to the Pasture mix lambs. Higher lamb performance achieved in this experiment is similar to the lamb performance obtained by Golding *et al.* (2011) using a plantain, chicory, white- and red-clover mix (herb-clover mix) during the late summer autumn period.

The overall improved lamb performance in this section might be explained by the quality of the herbage consumed by the lambs in the two herb-clover mixes compared to the Pasture mix lambs. The OMD % and ME were greatest in the herb-clover mixes compared to ryegrass/white clover in both experiments. In addition, Plantain and Chicory mixes had lower NDF % than the Pasture mix in both experiments. The higher fibre concentrations in the Pasture mix may have limited lamb feed intake (Burke *et al.*, 2002). Similarly, Golding *et al.* (2011) obtained higher OMD % and ME for the herb-clover mix and higher NDF % for the ryegrass/white clover pasture. Higher nutrient composition in plantain, chicory and

clovers increases the feeding value of herb-clover mixes compared to ryegrass (Waghorn *et al.*, 2007). As a result of the higher feeding value, these herb-clover mixes may have enhanced lamb voluntary intake and nutrient digestibility (Hodgson and Brookes 1999). Hence, the higher lamb performance in the herb-clover mixes is not unexpected given the herbage quality parameters discussed.

The Plantain mix and Chicory mix lambs had heavier carcass weights than the Pasture mix lambs. The heavier carcass weights resulted greater DO % in the Plantain mix lambs (in the Experiment two) and Chicory mix lambs (in both experiments) compared to the Pasture mix lambs. Similar carcass weights and DO % were obtained by Golding *et al.* (2011) in the late summer autumn period using a herb-clover mix. There was no difference in the leg and loin yield percentages between treatments, however, shoulder yield percentages were greater in the Plantain mix and Chicory mix lambs in Experiment one but not in Experiment two. GR tissue depths were greater in the Plantain mix and Chicory mix lambs than Pasture mix lambs in both experiments. Golding *et al.* (2011) also obtained higher GR tissue depths in lambs in the herb-clover mix compared to ryegrass/white clover lambs during their experiment.

The overall effect of individual lamb live weights and carcass weights resulted in higher apparent live weight and carcass weight per ha in both Plantain and Chicory mixes than the Pasture mix. The combined results indicate that these herb-clover mixes can be used effectively for lamb finishing systems in the early spring period.

4.4 Section B

Effect of Plantain mix and Chicory mix on the live weight gain (LWG) and carcass weight of lambs compared to Pasture mix in the late spring and early summer period (late spring) over two consecutive years

4.4.1 Overview

The herb-clover mixes produced greater lamb performance in early spring period (Section A). However, as yet the effect of the herb-clover mixes on lamb performance in the late spring and early summer period has not been investigated. Therefore, two experiments were carried out during late spring and early summer period in 2011 and 2012 to examine lamb performance on herb-clover mixes compared to ryegrass/white clover.

4.4.2 Materials and methods

The two experiments were carried from 2nd November to 19th December in 2011 (*Experiment one*) and 31st October to 17th December 2012 (*Experiment two*).

4.4.2.1 Animal management

Experiment one (2011)

Two hundred and seventy cryptorchid Romney cross male lambs aged four months (32.5 ± 0.20 kg) were selected on 2nd November 2011 (D₁). The lambs were assigned to one of three herbage treatment groups. 'Pasture mix' n=90; 'Plantain mix' n=90; 'Chicory mix' n=90. Lambs were stratified by live weight and allocated to one of the

three treatments to ensure that there was no difference in live weights at the start of the experiment. Each treatment included three mobs of lambs serving as replicates (i.e. n=30 per mob).

The nine groups of lambs (three treatments by three mobs) rotationally grazed their assigned treatment plots three times during the experimental period. The stocking rate (lambs/ha) was 40 lambs per ha in all three treatments. The same stocking rate was used as it was assumed *ad-lib* feed requirements would be equal to predicted herbage growth (i.e. final average herbage mass to be similar to start average herbage mass) at this time of the year (Matthews *et al.*, 1999; Li and Kemp 2005; Powell *et al.*, 2007; Kemp *et al.*, 2010).

Lambs were orally drenched on D₁ for internal parasites control. They were weighed within an hour of removal from the herbage on D₁, D₁₅, D₂₆, and D₄₇. One third of the lambs (10 heaviest lambs in each mob) were slaughtered on D₂₇. This was required due to the low herbage growth and to ensure *ad-lib* grazing conditions were maintained. All remaining lambs were drenched again on D₂₆ for internal parasites and slaughtered on D₄₈.

Experiment two (2012)

The same experimental design was repeated in 2012 using 270 cryptorchid Romney cross male lambs aged four months (32.6±0.19 kg) beginning on 31st October 2012 (D₁). The stocking rate for this experiment was also 40 lambs per ha per treatment excluding the six adult ewes per treatment introduced to provide contamination with nematode eggs (details are given in Chapter 3). Therefore, each treatment had a total

of 90 lambs split into three mobs (i.e. n=30 per mob). All lambs were drenched on D₁ for internal parasites.

Lambs were weighed on D₁, D₁₅, D₂₈, D₃₅, and D₄₇. As practised in Experiment one, a third of the lambs (n=10) were slaughtered on D₃₆ while all the remaining lambs were slaughtered on D₄₈.

4.4.2.2 Herbage quality

Herbage samples collected on D₈ and D₄₇ in 2011, D₁₂ and D₄₇ in 2012 and were analysed to estimate the nutritional value of the herbage consumed by lambs.

4.4.2.3 Statistical analysis - Experiment one and Experiment two

All the data were tested for normality and outliers using Minitab 16 statistical software before the analysis in SAS version 9.2 (SAS 2008).

Individual lamb data (apparent intake per lamb per day, live weight, carcass weight, leg, loin, shoulder (% yield of carcass) and GR tissue depth measurement) and herbage data (pre- and post-grazing dry matter production, sward heights) were analysed using a nested linear model with herbage treatment as a fixed effect and replicate (*mob* for lamb data or *paddock* for herbage data) nested within herbage treatment as a random effect using proc GLM in SAS version 9.2 (SAS 2008) for each experiment separately. The means were separated using LSD procedure in proc GLM.

Pre- and post-grazing herbage mass data for each rotation were used in the analysis of herbage DM mass. Apparent intake per lamb per day was calculated according to Matthews *et al.* (1999) by taking the difference between pre-grazing DM mass and post-grazing DM mass divided by grazing intensity (lambs/ha/day) for each season. Pre- and post-grazing sward surface height data for each rotation were used in the analysis of pre- and post-grazing sward surface heights.

In both experiments, lamb live weight gains were calculated considering the two different days to slaughter (D_1 to D_{26} days and D_1 to D_{47} days in Experiment one, D_1 to D_{35} days and D_1 to D_{47} days in Experiment two) due to the two slaughter dates. However, carcass measurements of both slaughter dates were analysed together irrespective of separate slaughter date.

The herbage quality data were analysed using randomised block design model using proc GLM. Crude protein, NDF and ADF values were corrected for DM basis before analysing. Metabolisable energy (ME) was calculated by multiplying digestible organic matter digestibility (DOMD%) by 0.163 (Geenty and Rattray 1987). The means were separated using LSD procedure in proc GLM.

Apparent live weight production per ha for each treatment was calculated by taking the difference between D_1 total live weight per ha per treatment and final live weight per ha per treatment. Apparent carcass weight production per ha for each treatment, was calculated by taking the difference between total carcass weight production per ha per treatment at slaughter and estimated carcass weight production at D_1 per ha

per treatment. Estimated carcass weight production at D₁ was assumed to be 40% of D₁ live weight (Kirton *et al.*, 1984) for all lambs.

4.4.3 Results

4.4.3.1 Herbage mass

Experiment one (2011)

The Pasture mix had higher ($P < 0.05$) pre- and post-grazing herbage masses than both the Plantain and Chicory mixes (Table 4-9). Apparent DM intake did not differ ($P > 0.05$) between treatments.

Experiment two (2012)

Pre- and post- grazing herbage masses were significantly higher ($P < 0.05$) in Pasture mix compared to both the Plantain and Chicory mixes (Table 4-9). Apparent DM intake was not different ($P > 0.05$) between treatments.

Table 4-9: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on the pre- and post-grazing herbage dry matter (DM) mass and apparent DM intake in late spring (mean \pm s.e.).

Treatment	Pre-grazing (kg/ha)	Post-grazing (kg/ha)	Apparent DM intake (kg/head/day)
<i>Experiment one (2011)</i>			
Pasture mix	4150 ^b \pm 208.3	3065 ^b \pm 214.7	1.1 \pm 0.07
Plantain mix	2963 ^a \pm 170.1	1890 ^a \pm 175.3	1.3 \pm 0.06
Chicory mix	2643 ^a \pm 165.3	1866 ^a \pm 167.8	1.1 \pm 0.06
<i>Experiment two (2012)</i>			
Pasture mix	5277 ^b \pm 263.1	3870 ^b \pm 161.8	1.9 \pm 0.31
Plantain mix	3770 ^a \pm 263.1	2331 ^a \pm 161.8	2.0 \pm 0.31
Chicory mix	3719 ^a \pm 263.1	2355 ^a \pm 161.8	1.9 \pm 0.31

Differing superscripts within columns and experiments indicate means that were significantly different ($P < 0.05$).

4.4.3.2 Sward height

Experiment one (2011)

Pre- and post-grazing sward heights did not differ ($P > 0.05$) between treatments (Table 4-10).

Experiment two (2012)

The Chicory mix had a higher ($P < 0.05$) pre-grazing sward height compared to the Pasture mix (Table 4-10). Post-grazing sward height was higher ($P < 0.05$) in the Pasture mix compared to both the Plantain and Chicory mixes.

Table 4-10: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on pre- and post-grazing sward height measurements in late spring (mean \pm s.e.)

Treatment	Pre-grazing (cm)	Post-grazing (cm)
<i>Experiment one (2011)</i>		
Pasture mix	16.0 \pm 0.67	8.6 \pm 0.83
Plantain mix	17.0 \pm 0.55	6.5 \pm 0.68
Chicory mix	16.7 \pm 0.50	7.4 \pm 0.62
<i>Experiment two (2012)</i>		
Pasture mix	14.6 ^a \pm 0.75	9.8 ^b \pm 0.51
Plantain mix	15.3 ^{ab} \pm 0.75	6.9 ^a \pm 0.51
Chicory mix	17.1 ^b \pm 0.78	7.4 ^a \pm 0.53

Differing superscripts within columns and experiments indicate means that were significantly different ($P < 0.05$).

4.4.3.3 Herbage composition

Experiment one (2011) and Experiment two (2012)

In both experiments, ryegrass was the dominant species in the Pasture mix and plantain was the dominant species in both Plantain mix and Chicory mix before and after each experiment (Table 4-11). Total clover (white clover and red clover) percentages were 20-38% and 24-26% in Experiment one in the Plantain mix and Chicory mix respectively. In Experiment two total clover percentages were 30-46% and 20-22% in the Plantain mix and Chicory mix respectively.

Table 4-11: The percentage (%) of various herbage species within each herbage treatment prior to and after Experiment one and Experiment two in late spring.

Herbage species	Pasture mix		Plantain mix		Chicory mix	
	Prior to (27/10/2011)	After (6/1/2012)	Prior to (27/10/2011)	After (6/1/2012)	Prior to (27/10/2011)	After (6/1/2012)
<i>Experiment one (2011)</i>						
Ryegrass	74	55	–	–	–	–
Plantain	–	–	56	41	38	28
Chicory	–	–	–	–	15	23
White clover	4	10	13	18	15	16
Red clover	–	–	7	20	9	10
Weeds [#]	16	18	22	5	21	7
Dead matter	6	17	2	16	2	16
<i>Experiment two (2012)</i>						
	Prior to (30/10/2012)	After (7/1/2013)	Prior to (30/10/2012)	After (7/1/2013)	Prior to (30/10/2012)	After (7/1/2013)
Ryegrass	53	41	–	–	–	–
Plantain	–	–	42	24	34	21
Chicory	–	–	–	–	26	33
White clover	6	6	19	9	13	5
Red clover	–	–	11	37	9	15
Weeds [#]	33	37	17	15	8	13
Dead matter	8	16	11	16	10	13

Weeds[#] - all the other non-sown species (including other grasses and weeds) except the main pasture and herb species in the treatments.

4.4.3.4 Herbage quality

Experiment one (2011)

Organic matter digestibility percentage was higher ($P<0.05$) in the Chicory mix compared to the Plantain mix which in turn was higher ($P<0.05$) than the Pasture mix (Table 4-12). The Pasture mix had higher ($P<0.05$) NDF and ADF percentage compared to both the Plantain and Chicory mixes. The Plantain mix had a higher ($P<0.05$) NDF percentage compared to the Chicory mix. The ash percentage was higher ($P<0.05$) in the Chicory mix compared to both the other two treatments. Both the Plantain and chicory mixes had higher ($P<0.05$) ME values than the Pasture mix.

Experiment two (2012)

Organic matter digestibility and CP percentages were higher ($P<0.05$) in the Chicory mix compared to the Pasture mix (Table 4-12). Neutral detergent fibre percentage was higher ($P<0.05$) in the Pasture mix than the Chicory mix.

Table 4-12: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on various herbage quality parameters in late spring (mean \pm s.e.).

Treatment	Herbage quality (% DM)					ME ⁵ (MJ/kg DM)
	OMD ¹	CP ²	NDF ³	ADF ⁴	Ash	
<i>Experiment one (2011)</i>						
Pasture mix	68.3 ^a ±0.95	15.5±1.07	48.2 ^c ±1.36	26.2 ^b ±1.21	9.3 ^a ±0.78	10.1 ^a ±0.13
Plantain mix	75.0 ^b ±0.95	18.6±1.07	32.9 ^b ±1.36	20.8 ^a ±1.21	11.1 ^a ±0.78	10.9 ^b ±0.13
Chicory mix	78.7 ^c ±0.95	18.5±1.07	26.7 ^a ±1.36	18.0 ^a ±1.21	14.5 ^b ±0.78	11.3 ^b ±0.13
<i>Experiment two (2012)</i>						
Pasture mix	70.1 ^a ±1.85	16.7 ^a ±2.84	47.2 ^b ±3.65	23.6±2.37	9.0±1.64	10.3±0.28
Plantain mix	74.5 ^{ab} ±1.85	25.2 ^{ab} ±2.84	37.6 ^{ab} ±3.65	24.7±2.37	13.7±1.64	10.7±0.28
Chicory mix	77.2 ^b ±1.85	25.6 ^b ±2.84	28.9 ^a ±3.65	18.6±2.37	13.1±1.64	11.1±0.28

Differing superscripts within columns and experiments indicate means that were significantly different (P<0.05).

¹Organic matter digestibility (OMD); ²crude protein (CP); ³neutral detergent fibre (NDF); ⁴acid detergent fibre (ADF); ⁵metabolisable energy (ME).

4.4.3.5 Animal live weight

Experiment one (2011)

At D₁₅ the Plantain mix lambs were heavier (P<0.05) than the Chicory mix lambs (Table 4-13). Plantain mix lambs were also the heaviest (P<0.05) at D₂₆. At D₄₇ Plantain and Chicory mix lambs were heavier (P<0.05) than the Pasture mix lambs. The highest (P<0.05) LWG between both slaughter dates (D₁ and D₂₆ and D₁ and D₄₇) was observed in the Plantain mix lambs followed by the Chicory mix lambs which in turn had a greater (P<0.05) LWG than the Pasture mix lambs.

Experiment two (2012)

Chicory mix lambs were heavier (P<0.05) at D₃₅ than the Pasture mix lambs (Table 4-13). Both Plantain mix and Chicory mix lambs had greater (P<0.05) live weights at

D₄₇ than Pasture mix lambs. The LWG between both slaughter dates (D₁ and D₃₅ and D₁ and D₄₇) was greatest (P<0.05) in Plantain mix and Chicory mix lambs than the Pasture mix lambs.

4.4.3.6 Carcass weight

Experiment one (2011)

Both Plantain mix and Chicory mix lambs had heavier (P<0.05) carcass weights and greater DO% than the Pasture mix lambs (Table 4-14). Similarly, shoulder and loin yield percentages and GR tissue depths were greater (P<0.05) in Plantain mix and Chicory mix lambs than the Pasture mix lambs, while leg yield percentage was greater (P<0.05) in Pasture mix lambs than those in the other two treatments (Table 4-15).

Experiment two (2012)

Carcass weights and DO% were greater (P<0.05) in Plantain mix and Chicory mix lambs than the Pasture mix lambs (Table 4-14). Leg yield was lower (P<0.05) in the Chicory mix lambs than the Pasture mix lambs (Table 4-15). In contrast, loin yield was higher (P<0.05) in the Chicory mix lambs than the Pasture mix lambs. GR tissue depths were greater (P<0.05) in the Plantain and Chicory mix lambs compared to Pasture mix lambs.

Table 4-13: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on lamb live weight and daily live weight gain (LWG) in late spring (mean \pm s.e.).

Treatment	n ¹	Live weight (kg)			n ¹	LWG (D ₁ -to slaughter) (g/day)	
		D ₁	D ₁₅	D ₂₆			D ₄₇
<i>Experiment one (2011)</i>							
Pasture mix	90	32.4 \pm 0.86	36.5 ^{ab} \pm 0.21	37.4 ^a \pm 0.29	60	39.7 ^a \pm 0.36	190.3 ^a \pm 9.63
Plantain mix	90	32.5 \pm 0.86	36.9 ^b \pm 0.21	40.2 ^b \pm 0.29	60	44.4 ^b \pm 0.36	304.5 ^c \pm 9.63
Chicory mix	90	32.5 \pm 0.86	36.1 ^a \pm 0.21	38.2 ^a \pm 0.29	60	43.0 ^b \pm 0.36	262.2 ^b \pm 9.63
<i>Experiment two (2012)</i>							
	n ¹	D ₁	D ₁₄	D ₃₅	D ₄₇	n ¹	LWG (D ₁ -to slaughter) (g/day)
Pasture mix	90	32.6 \pm 0.06	37.5 \pm 0.33	42.2 ^a \pm 0.30	42.7 ^a \pm 0.38	90	243.9 ^a \pm 8.17
Plantain mix	90	32.5 \pm 0.06	37.2 \pm 0.33	43.0 ^{ab} \pm 0.30	46.2 ^b \pm 0.38	90	315.9 ^b \pm 8.17
Chicory mix	90	32.6 \pm 0.06	37.7 \pm 0.33	43.0 ^b \pm 0.30	46.7 ^b \pm 0.38	90	329.2 ^b \pm 8.22

Differing superscripts within columns and experiments indicate means that were significantly different ($P < 0.05$).
¹ number of lambs per treatment.

Table 4-14: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on carcass weight and dressing-out percentage (DO%) of lambs in late spring (means \pm s.e.).

Treatment	n ¹	Carcass weight ² (kg/lamb)	DO% ³
<i>Experiment one (2011)</i>			
Pasture mix	90	15.7 ^a \pm 0.20	39.4 ^a \pm 0.32
Plantain mix	90	18.3 ^b \pm 0.20	41.4 ^b \pm 0.32
Chicory mix	90	17.8 ^b \pm 0.20	41.4 ^b \pm 0.32
<i>Experiment two (2012)</i>			
Pasture mix	90	17.1 ^a \pm 0.22	40.1 ^a \pm 0.28
Plantain mix	90	19.3 ^b \pm 0.22	41.8 ^b \pm 0.28
Chicory mix	90	19.6 ^b \pm 0.22	42.0 ^b \pm 0.29

Differing superscripts within columns and experiments indicate means that were significantly different ($P < 0.05$).

¹number of lambs per treatment.

²this included lambs slaughtered at both days D₂₇ and D₄₈ in year one and D₃₆ and D₄₈ in year two.

³DO% = (carcass weight/final live weight) \times 100. Final live weight was taken on farm approximately 12 hours before slaughter.

Table 4-15: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on lamb leg, loin, shoulder yields (% of total carcass) and GR tissue depth measurement in late spring (means \pm s.e.).

Treatment	n ¹	Leg yield %	Loin yield %	Shoulder yield %	GR (mm)
<i>Experiment one</i>					
<i>(2011)</i>					
Pasture mix	90	23.9 ^b \pm 0.12	14.9 ^a \pm 0.04	17.2 ^a \pm 0.07	3.4 ^a \pm 0.44
Plantain mix	90	23.0 ^a \pm 0.12	15.1 ^b \pm 0.05	17.5 ^b \pm 0.07	7.9 ^b \pm 0.44
Chicory mix	90	23.3 ^a \pm 0.12	15.1 ^b \pm 0.05	17.6 ^b \pm 0.07	7.0 ^b \pm 0.44
<i>Experiment two</i>					
<i>(2012)</i>					
Pasture mix	90	22.9 ^b \pm 0.12	15.0 ^a \pm 0.06	17.2 \pm 0.13	5.6 ^a \pm 0.38
Plantain mix	90	22.5 ^{ab} \pm 0.13	15.1 ^{ab} \pm 0.06	17.5 \pm 0.13	7.7 ^b \pm 0.39
Chicory mix	90	22.4 ^a \pm 0.13	15.2 ^b \pm 0.06	17.5 \pm 0.13	8.3 ^b \pm 0.40

Differing superscripts within columns and experiments indicate means that were significantly different ($P < 0.05$).

¹number of lambs per treatment.

4.4.3.7 Apparent live weight and carcass weight production per ha - Experiment one (2011) and Experiment two (2012)

The Plantain mix produced greater apparent live weight and carcass weight per ha than both the Pasture and Chicory mixes in Experiment one (Table 4-16). In contrast, in Experiment two the Chicory mix produced greater apparent live weight and carcass weight per ha compared to the Plantain and the Pasture mixes.

Table 4-16: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on apparent live weight and carcass weight production per ha (kg/ha) in late spring.

	Pasture mix	Plantain mix	Chicory mix
Experiment one (2011)			
Area per treatment (ha)	2.25	2.25	2.25
No. of lambs per treatment (no.)	90	90	90
Stocking rate ¹ (no. of lambs per ha)	40	40	40
D ₁ Live weight (kg/ha)	1296	1300	1302
Live weight at D ₂₈ (kg/ha)	1587	1778	1719
Apparent live weight production per ha (kg/ha)	291	478	417
Estimated carcass weight* at D ₁ (kg/ha)	518	520	521
Total carcass weight (kg/ha)	626	735	711
Apparent carcass weight production per ha (kg/ha)	108	215	190
Experiment two (2012)			
Area per treatment (ha)	2.25	2.25	2.25
No. of lambs per treatment (no.)	90	90	90
Stocking rate ¹ (no. of lambs per ha)	40	40	40
D ₁ Live weight (kg/ha)	1302	1302	1288
Live weight at D ₂₈ (kg/ha)	1709	1846	1846
Apparent live weight production per ha (kg/ha)	407	544	558
Estimated carcass weight* at D ₁ (kg/ha)	521	521	515
Total carcass weight (kg/ha)	684	772	776
Apparent carcass weight production per ha (kg/ha)	163	251	261

* based on a 40% D₁ live weight (Kirton *et al.*, 1984).

¹ excluding the population of farmlets ewes (two ewes/mob/treatment).

4.4.4 Discussion of the late spring period

The aim of this section was to compare the lamb performance on herb-clover mixes with the Pasture mix in the late spring and early summer period. Herbage dry matter masses and sward height measurements suggested that the herbage allowance was not limiting in both experiments (Webby and Pengelly 1986; Kenyon and Webby 2007). This allowed for the testing of lamb performance on all mixes under conditions where lamb intake was not limiting.

Both the Plantain mix and Chicory mix lambs had higher final live weights and greater LWG compared to the Pasture mix lambs in both experiments. These results and those of Golding *et al.* (2011) support the results obtained in Section A. The higher lamb performance in Section A in both herb-clover mixes were attributed to the higher quality of both herb-clover mixes. Similarly, in this section there were greater ME in both herb-clover mixes in Experiment one, OMD % in both herb-clover mixes in Experiment one and Chicory mix in Experiment two and CP % in the Chicory mix in Experiment two than in ryegrass/white clover sward.

Carcass weights and DO% were greater in both herb-clover mix lambs compared to Pasture mix lambs in both experiments. This supports the findings of Section A and also by Golding *et al.* (2011). Lambs in both herb-clover mixes had greater loin yield percentage (both herb-clover mixes in Experiment one and Chicory mix in Experiment two), shoulder yield percentage (both herb-clover mixes in Experiment one) and GR tissue depths (both herb-clover mixes in both experiments) compared to Pasture mix lambs. The greater GR tissue depths in this section matches the results of Section A and by Golding *et al.* (2011). The herb-clover mix lambs had lower leg

yield percentage compared to the Pasture mix lambs (in both herb-clover mixes in Experiment one and Chicory mix lambs in Experiment two).

Both herb-clover mixes produced higher apparent live weights and carcass weights per ha than the ryegrass/white clover sward in both experiments. These results indicate that during late spring and early summer period of the year the herb-clover mixes are a more suitable option for finishing lambs than a ryegrass/white clover sward.

4.5 Section C

Effect of Plantain mix and Chicory mix on the live weight gain and carcass weight of lambs compared to Pasture mix in the summer period over two consecutive years

4.5.1 Overview

Dry weather conditions prevail in summer creating variation in the pasture production (Kemp *et al.*, 1999; McKenzie *et al.*, 1999; Valentine and Matthew 1999; Valentine and Kemp 2007) and quality (Barry *et al.*, 1998; Powell *et al.*, 2007). Often farmers need to adjust their stocking rates and production system accordingly to cater for any feed shortage during this period. In addition, seed head formation of herbage (Leaver 1987; McKenzie *et al.*, 1999) can reduce sward quality. In contrast, herbs such as plantain, chicory and red clover can be productive and produce a quality sward in this period (Hume *et al.*, 1995; Stewart 1996; Holst *et al.*, 1998; Kemp *et al.*, 1999) than a perennial ryegrass/white clover pasture. Therefore, inclusion of such summer active species can potentially enhance per ha herbage output (Goold 1985; Hume *et al.*, 1995). Further a herb mix of multiple species could be a more stable sward during stress conditions like drought and may also reduce weed growth compared to a single sward (Sanderson *et al.*, 2004). To date pure swards of plantain, chicory, white- and red-clover have been reported to enhance the lamb growth rates during the summer and autumn periods compared to perennial ryegrass (Fraser and Rowarth 1996; Moorhead *et al.*, 2002; Fraser *et al.*, 2004; Moorby *et al.*, 2004; Li and Kemp 2005; Marley *et al.*, 2005). Golding *et al.*

observed that a herb-clover mix of plantain, chicory, white- and red-clover increase lamb LWG in late summer early autumn period (2011).

Section A (early spring) and Section B (late spring and early summer) provide support to the fact that the herb-clover mixes are an effective herbage option for finishing lambs during the ‘early spring’ and ‘late spring and early summer’ periods. Therefore, this experiment was carried out during two consecutive summer periods to determine if the same herb-clover mixes could produce greater lamb performance compared to a Pasture mix in the summer period.

4.5.2 Materials and methods

The experiments were carried out from 11th January to 29th February 2012 (*Experiment one*) and 24th January to 18th February 2013 (*Experiment two*).

4.5.2.1 Animal management

Experiment one (2012)

Two hundred and sixteen cryptorchid Romney cross male lambs aged approximately three and a half months (32.8 ± 0.23 kg) were selected for the present study on 11th January 2012 (D₁). Lambs were stratified by live weight and allocated to one of the three treatments to ensure that there was no difference in live weights at the start of the experiment ‘Pasture mix’ n=48; ‘Plantain mix’ n=84; ‘Chicory mix’ n=84. Each treatment included three mobs of lambs serving as replicates (i.e. n=16, n=28 and n=28 for Pasture mix, Plantain mix and Chicory mix per mob respectively).

The nine groups of lambs (three treatments by three mobs) rotationally grazed their assigned treatment plots twice during the experimental period. The stocking rates were 24 lambs per ha in the Pasture mix and 40 lambs per ha in the Plantain and Chicory mixes including the adult ewes (six ewes per treatment) introduced to provide contamination with nematode eggs (details are given in Chapter 3). Different stocking rates were used in order to maintain predicted herbage masses in all three treatments (i.e. final average mass to be similar to start average mass) and also assuming *ad-lib* herbage intake was equal to herbage growth. The studies of Matthews *et al.* (1999), Li and Kemp (2005), Powell *et al.* (2007), and Kemp *et al.* (2010) were used to predict herbage growth during both experimental periods.

Lambs were orally drenched on D₁ for internal parasite control and subsequently re-drenched on D₂₈. Lambs were weighed within an hour of removal from the herbage on D₁, D₁₄, D₂₈, D₄₂, and D₄₉. As 38% of the Pasture mix lambs, 31% of the Plantain mix lambs and 32% of the Chicory mix lambs were infected with scabby mouth disease (Gardiner *et al.*, 1967) during the first week of the experiment, the whole flock of lambs were injected with Bivato^(R) 200 antibiotic (active ingredient Oxytetracycline 200mg/ml; Boehringer-Ingelheim, USA) at a rate of 4 ml/lamb on D₈ as a preventative measure. Severely infected lambs (five lambs) were treated again with Betamox Long Action antibiotic (active ingredient Amoxicillin 150mg/ml; Norbrook Laboratories, UK) at a rate of 4 ml/lamb on D₁₄ and D₁₉ and were also sprayed with 4% Iodine solution around the nasal area on D₈ and D₁₂. One lamb in the Chicory mix died. After the first rotation, Plantain mix and the Chicory mix paddocks were mowed to a height of 10-12 cm to control weeds and remove the seed heads and other reproductive structures (Labreveux *et al.*, 2006). This practise

promoted the vegetative growth of the herb-clover mixes. All the lambs were slaughtered on D₅₀.

Experiment two (2013)

The same experimental design was repeated in 2013 using 162 cryptorchid Romney cross male lambs aged four months (35.8 ± 0.16 kg) beginning on 24th January (D₁). The stocking rates were 24 lambs per ha in Pasture mix (n=48) and the Plantain mix (n=48). It was 32 lambs per ha in the Chicory mix (n=66). Each treatment included three mobs of lambs serving as replicates (i.e. n=16, n=16 and n=22 for Pasture mix, Plantain mix and Chicory mix per mob respectively). Stocking rates included the adult ewes (six ewes per treatment) introduced to provide contamination with nematode eggs (details are given in Chapter 3). Lower stocking rate was used in the Pasture and Plantain mixes due to the lower herbage growth rates since the last experiment in the late spring and early summer of 2012 (Section B). Lambs were weighed on D₁, D₁₄ and D₂₅. Lambs were drenched on D₁ for internal parasite control. All the lambs were slaughtered on D₂₆ due to dry weather conditions (weather data are presented in Chapter 3) affecting herbage growth. After the first rotation, the Plantain mix and the Chicory mix paddocks were mowed as in Experiment one.

4.5.2.2 Herbage quality

Grab herbage samples were collected on D₇, D₂₇ and D₄₉ in 2012, D₇ and D₂₅ in 2013. These were analysed to estimate the nutritional value of the herbage consumed by lambs.

4.5.2.3 Statistical analysis - Experiment one and Experiment two

All the data were tested for normality and outliers using Minitab 16 statistical software before the analysis in SAS version 9.2 (SAS 2008).

Individual lamb data (apparent intake per lamb per day, live weight, carcass weight, leg, loin, shoulder (% yield of carcass) and GR tissue depth measurement) and herbage data (pre- and post-grazing dry matter production, sward heights) were analysed using a nested linear model with herbage treatment as a fixed effect and replicate (*mob* for lamb data or *paddock* for herbage data) nested within herbage treatment as a random effect using proc GLM for each experiment separately. The means were separated using LSD procedure in proc GLM.

Pre- and post-grazing herbage mass data for each rotation were used in the analysis of herbage DM mass. Apparent intake per lamb per day was calculated according to Matthews *et al.* (1999) by taking the difference between pre-grazing DM mass and post-grazing DM mass divided by grazing intensity (lambs/ha/day) for each season. Pre- and post-grazing sward surface height data for each rotation were used in the analysis of pre- and post-grazing sward surface heights.

The herbage quality data were analysed using randomised block design model using proc GLM. Crude protein, NDF and ADF values were corrected for DM basis before analysing. Metabolisable energy (ME) was calculated by multiplying digestible organic matter digestibility (DOMD%) by 0.163 (Geenty and Rattray 1987). The means were separated using LSD procedure in proc GLM.

Apparent live weight production per ha for each treatment was calculated by taking the difference between D₁ total live weight per ha per treatment and final live weight per ha per treatment. Apparent carcass weight production per ha for each treatment, was calculated by taking the difference between total apparent carcass weight production per ha per treatment at slaughter and estimated carcass weight production at D₁ per ha per treatment. Estimated carcass weight production at D₁ was assumed to be 40% of D₁ live weight (Kirton *et al.*, 1984) for all lambs.

4.5.3 Results

4.5.3.1 Herbage mass

Experiment one (2012)

The Pasture mix had higher ($P < 0.05$) pre-grazing herbage mass compared to the Plantain mix (Table 4-17) which in turn had higher ($P < 0.05$) pre-grazing herbage masses compared to the Chicory mix. Post-grazing herbage masses were lower ($P < 0.05$) in the Plantain and Chicory mixes compared to the Pasture mix. Apparent DM intake was not different ($P > 0.05$) between treatments.

Experiment two (2013)

The Pasture mix had higher ($P < 0.05$) pre- and post-grazing herbage mass compared to both Plantain and Chicory mixes (Table 4-17). Apparent DM intake was higher ($P < 0.05$) in the Plantain mix lambs compared to the Pasture mix and Chicory mix lambs.

Table 4-17: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on the pre- and post-grazing herbage dry matter (DM) mass and apparent DM intake in summer (mean \pm s.e.).

Treatment	Pre-grazing (kg/ha)	Post-grazing (kg/ha)	Apparent DM intake (kg/head/day)
<i>Experiment one (2012)</i>			
Pasture mix	4749 ^c \pm 266.9	3543 ^b \pm 224.8	1.8 \pm 0.15
Plantain mix	4243 ^b \pm 203.9	2768 ^a \pm 171.7	1.9 \pm 0.12
Chicory mix	3649 ^a \pm 203.9	2419 ^a \pm 171.7	1.6 \pm 0.12
<i>Experiment two (2013)</i>			
Pasture mix	5314 ^b \pm 223.3	4085 ^b \pm 236.5	1.9 ^a \pm 0.23
Plantain mix	4223 ^a \pm 223.3	2104 ^a \pm 236.5	3.2 ^b \pm 0.23
Chicory mix	4279 ^a \pm 223.3	2498 ^a \pm 236.5	1.9 ^a \pm 0.23

Differing superscripts within columns and experiments indicate means that were significantly different ($P < 0.05$).

4.5.3.2 Sward height

Experiment one (2012)

Pre-grazing sward height was higher ($P < 0.05$) in both Plantain and Chicory mixes compared to the Pasture mix (Table 4-18). Post-grazing sward height was higher ($P < 0.05$) in the Pasture mix compared to Plantain mix.

Experiment two (2013)

The Chicory mix had higher ($P < 0.05$) pre-grazing sward heights than the Plantain mix which in turn had higher pre-grazing sward heights ($P < 0.05$) than the Pasture mix (Table 4-18).

Table 4-18: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on pre- and post-grazing sward height measurements in summer (mean \pm s.e.).

Treatment	Pre-grazing (cm)	Post-grazing (cm)
<i>Experiment one (2012)</i>		
Pasture mix	15.2 ^a \pm 1.74	9.5 ^b \pm 0.69
Plantain mix	22.0 ^b \pm 1.33	7.2 ^a \pm 0.52
Chicory mix	21.2 ^b \pm 1.33	8.0 ^{ab} \pm 0.52
<i>Experiment two (2013)</i>		
Pasture mix	14.6 ^a \pm 0.78	10.1 \pm 1.09
Plantain mix	18.2 ^b \pm 0.78	10.9 \pm 1.09
Chicory mix	27.5 ^c \pm 0.78	11.9 \pm 1.09

Differing superscripts within columns and experiments indicate means that were significantly different ($P < 0.05$).

4.5.3.3 Herbage composition

Experiment one (2012) and Experiment two (2013)

In both experiments, ryegrass was the dominant species before and after the experiment in the Pasture mix (Table 4-19). Plantain was the dominant species in both, Plantain and the Chicory mixes before and after the experiment. Total clover (white clover and red clover) percentage was 38% and 25-26% in Experiment one in the Plantain mix and Chicory mix respectively. In Experiment two total clover percentage was 34-46% and 18-20% in the Plantain mix and Chicory mix respectively.

Table 4-19: The percentage (%) of various herbage species within each herbage treatment prior to and after the *Experiment one* and *Experiment two* in summer.

Herbage species	Pasture mix		Plantain mix		Chicory mix	
	Prior to (6/1/2012)	After (14/3/2012)	Prior to (6/1/2012)	After (14/3/2012)	Prior to (6/1/2012)	After (14/3/2012)
<i>Experiment one (2012)</i>						
Ryegrass	55	57	–	–	–	–
Plantain	–	–	41	42	28	34
Chicory	–	–	–	–	23	26
White clover	10	13	18	18	16	13
Red clover	–	–	20	20	10	12
Weeds [#]	18	15	5	7	7	3
Dead matter	17	15	16	13	16	12
<i>Experiment two (2013)</i>						
	Prior to (7/1/2013)	After* (8/4/2013)	Prior to (7/1/2013)	After* (8/4/2013)	Prior to (7/1/2013)	After* (8/4/2013)
Ryegrass	41	66	–	–	–	–
Plantain	–	–	24	40	21	21
Chicory	–	–	–	–	33	47
White clover	6	2	9	1	5	1
Red clover	–	–	37	33	15	17
Weeds [#]	37	19	15	9	13	3
Dead matter	16	13	16	17	13	11

* as there was a dry weather condition throughout the *Experiment two*, sample collection for post botanical composition had to be postponed until the pasture and herbage had sufficiently re-grown in all the paddocks. Weeds[#] - all the other non-sown species (including other grasses and weeds) except the main pasture and herb species in the treatments.

4.5.3.4 Herbage quality

Experiment one (2012)

Organic matter digestibility and ash percentages and ME value were lower ($P<0.05$) in the Pasture mix compared to both the Plantain and Chicory mixes (Table 4-20). Crude protein percentage was higher ($P<0.05$) in the Plantain mix compared to both the Pasture and Chicory mixes. Neutral detergent fibre percentage was higher ($P<0.05$) in the Pasture mix compared to both the Plantain and Chicory mixes.

Experiment two (2013)

Organic matter digestibility and CP percentages and ME value were higher ($P<0.05$) in the Plantain and Chicory mixes than the Pasture mix (Table 4-20). Pasture mix had the highest ($P<0.05$) NDF and ADF percentages than the Plantain mix which in turn were higher ($P<0.05$) than the Chicory mix. In contrast, the Chicory mix had higher ($P<0.05$) ash percentage than both Pasture and Plantain mixes.

Table 4-20: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on various herbage quality parameters in summer (mean \pm s.e.).

Treatment	Herbage quality (% DM)					ME ⁵ (MJ/kg DM)
	OMD ¹	CP ²	NDF ³	ADF ⁴	Ash	
<i>Experiment one (2012)</i>						
Pasture mix	69.4 ^a \pm 1.00	18.7 ^a \pm 1.10	46.3 ^b \pm 1.25	23.6 \pm 0.80	10.1 ^a \pm 0.50	10.1 ^a \pm 0.12
Plantain mix	74.4 ^b \pm 1.00	24.2 ^b \pm 1.10	34.6 ^a \pm 1.25	24.0 \pm 0.80	11.9 ^b \pm 0.50	10.8 ^b \pm 0.12
Chicory mix	74.8 ^b \pm 1.00	20.1 ^a \pm 1.10	32.3 ^a \pm 1.25	23.1 \pm 0.80	13.1 ^b \pm 0.50	10.8 ^b \pm 0.12
<i>Experiment two (2013)</i>						
Pasture mix	64.5 ^a \pm 1.30	11.5 ^a \pm 0.82	53.7 ^c \pm 1.59	28.3 ^c \pm 0.96	8.7 ^a \pm 0.67	9.5 ^a \pm 0.16
Plantain mix	73.8 ^b \pm 1.30	18.8 ^b \pm 0.82	39.1 ^b \pm 1.59	26.2 ^b \pm 0.96	9.1 ^a \pm 0.67	10.8 ^b \pm 0.16
Chicory mix	77.1 ^b \pm 1.30	17.2 ^b \pm 0.82	29.2 ^a \pm 1.59	20.6 ^a \pm 0.96	12.8 ^b \pm 0.67	11.1 ^b \pm 0.16

Differing superscripts within columns and experiments indicate means that were significantly different ($P < 0.05$).

¹Organic matter digestibility (OMD); ²crude protein (CP); ³neutral detergent fibre (NDF); ⁴acid detergent fibre (ADF); ⁵metabolisable energy (ME).

4.5.3.5 Animal live weight

Experiment one (2012)

The Plantain mix and Chicory mix lambs were heavier ($P < 0.05$) on D₂₈, D₄₂ and D₄₉ than the Pasture mix lambs (Table 4-21). Live weight gain between D₁ and D₄₉ was greater ($P < 0.05$) in the Plantain mix and Chicory mix lambs than the Pasture mix lambs.

Experiment two (2013)

The Plantain mix and the Chicory mix lambs were heavier ($P < 0.05$) on D₂₅ than the Pasture mix lambs (Table 4-21). Similarly, the Plantain mix and Chicory mix lambs had greater ($P < 0.05$) LWG between D₁ and D₂₅ compared to the Pasture mix lambs.

4.5.3.6 Carcass weight

Experiment one (2012)

Plantain mix and Chicory mix lambs had greater ($P<0.05$) carcass weights and DO% than the Pasture mix lambs (Table 4-22). Similarly, GR tissue depths were greater ($P<0.05$) in the Plantain mix and the Chicory mix lambs compared to the Pasture mix lambs although, leg yield was greater ($P<0.05$) in Pasture mix lambs compared to the lambs in the other two treatments (Table 4-23). Loin yield was greater ($P<0.05$) in the Plantain mix lambs compared to Pasture mix lambs.

Experiment two (2013)

Carcass weight and DO% were greater ($P<0.05$) in the Plantain mix and Chicory mix lambs compared to the Pasture mix lambs (Table 4-22). Leg yield also was greater ($P<0.05$) in the Pasture mix but GR tissue depths were greater ($P<0.05$) in Plantain mix and Chicory mix lambs (Table 4-23). Shoulder yield was greater ($P<0.05$) in the Plantain mix lambs compared to the Chicory mix lambs.

Table 4-21: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on lamb live weight and daily live weight gain (LWG) in summer (mean \pm s.e.).

Treatment	n ¹	Live weight (kg)					n ¹	LWG (D ₁ -D ₄₉) (g/day)
		D ₁	D ₁₄	D ₂₈	D ₄₂	D ₄₉		
<i>Experiment one (2012)</i>								
Pasture mix	48	32.8 \pm 0.03	35.3 ^a \pm 0.60	38.3 ^a \pm 0.59	40.1 ^a \pm 0.61	41.1 ^a \pm 0.40	48	169.0 ^a \pm 8.67
Plantain mix	84	32.8 \pm 0.02	36.9 ^{ab} \pm 0.45	40.7 ^b \pm 0.45	43.2 ^b \pm 0.46	43.9 ^b \pm 0.30	84	226.0 ^b \pm 6.53
Chicory mix	84	32.9 \pm 0.02	37.3 ^b \pm 0.46	40.9 ^b \pm 0.45	44.4 ^b \pm 0.47	43.3 ^b \pm 0.30	84	213.5 ^b \pm 6.57
<i>Experiment two (2013)</i>								
	n ¹	D ₁	D ₁₄	D ₂₅		n ¹	LWG (D ₁ -D ₂₅) (g/day)	
Pasture mix	48	35.9 \pm 0.08	37.0 \pm 0.22	38.8 ^a \pm 0.34		48	120.4 ^a \pm 12.54	
Plantain mix	48	35.8 \pm 0.08	37.4 \pm 0.22	41.6 ^b \pm 0.33		48	231.1 ^b \pm 12.38	
Chicory mix	66	35.9 \pm 0.07	37.7 \pm 0.19	41.4 ^b \pm 0.29		66	221.1 ^b \pm 10.78	

Differing superscripts within columns and experiments indicate means that were significantly different (P<0.05).
¹ number of lambs per treatment.

Table 4-22: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on carcass weight and dressing-out percentage (DO%) of lambs in summer (means \pm s.e.).

Treatment	n ¹	Carcass weight (kg/lamb)	DO% ²
<i>Experiment one (2012)</i>			
Pasture mix	48	15.7 ^a \pm 0.26	38.0 ^a \pm 0.42
Plantain mix	84	18.7 ^b \pm 0.20	42.5 ^b \pm 0.32
Chicory mix	84	18.4 ^b \pm 0.20	42.4 ^b \pm 0.32
<i>Experiment two (2013)</i>			
Pasture mix	48	14.5 ^a \pm 0.14	37.5 ^a \pm 0.22
Plantain mix	48	16.8 ^b \pm 0.13	40.3 ^b \pm 0.22
Chicory mix	66	16.5 ^b \pm 0.12	39.9 ^b \pm 0.19

Differing superscripts within columns and experiments indicate means that were significantly different ($P < 0.05$).

¹ number of lambs per treatment.

² DO% = (carcass weight/final live weight) \times 100. Final live weight was taken on farm approximately 12 hours before slaughter.

Table 4-23: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on lamb leg, loin, shoulder yields (% of total carcass) and GR tissue depth measurement in summer (means \pm s.e.).

Treatment	n ¹	Leg yield %	Loin yield %	Shoulder yield %	GR (mm)
<i>Experiment one (2012)</i>					
Pasture mix	48	23.3 ^b \pm 0.16	14.5 ^a \pm 0.10	16.6 \pm 0.11	4.9 ^a \pm 0.17
Plantain mix	84	22.3 ^a \pm 0.12	14.8 ^b \pm 0.08	16.9 \pm 0.09	8.0 ^b \pm 0.13
Chicory mix	84	22.3 ^a \pm 0.12	14.7 ^{ab} \pm 0.08	16.8 \pm 0.09	8.2 ^b \pm 0.13
<i>Experiment two (2013)</i>					
Pasture mix	48	24.1 ^b \pm 0.29	14.7 \pm 0.01	17.5 ^{ab} \pm 0.12	3.5 ^a \pm 0.57
Plantain mix	48	22.9 ^a \pm 0.30	15.0 \pm 0.10	17.7 ^b \pm 0.12	6.1 ^b \pm 0.57
Chicory mix	66	22.9 ^a \pm 0.26	14.7 \pm 0.09	17.2 ^a \pm 0.11	5.8 ^b \pm 0.50

Differing superscripts within columns and experiments indicate means that were significantly different ($P < 0.05$).

¹number of lambs per treatment.

4.5.3.7 Apparent live weight and carcass weight production per ha - Experiment one (2012) and Experiment two (2013)

The Plantain mix apparent live weight and carcass weight production per ha were greater than both the Pasture mix and Chicory mix in Experiment one (Table 4-24).

In Experiment two, the Chicory mix apparent live weight and carcass weight production per ha were greater than both the Pasture mix and Plantain mix.

Table 4-24: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on apparent live weight and carcass weight production per ha (kg/ha) in summer.

	Pasture mix	Plantain mix	Chicory mix
<i>Experiment one (2012)</i>			
Area per treatment (ha)	2.25	2.25	2.25
No. of lambs per treatment (no.)	48	84	84
Stocking rate ¹ (no. of lambs per ha)	24	40	40
D ₁ Live weight (kg/ha)	699	1224	1226
Live weight at D ₂₈ (kg/ha)	872	1632	1593
Apparent live weight production per ha (kg/ha)	173	408	367
Estimated carcass weight* at D ₁ (kg/ha)	280	490	490
Total carcass weight (kg/ha)	332	694	676
Apparent carcass weight production per ha (kg/ha)	52	204	186
<i>Experiment two (2013)</i>			
Area per treatment (ha)	2.25	2.25	2.25
No. of lambs per treatment (no.)	48	48	66
Stocking rate ¹ (no. of lambs per ha)	24	24	32
D ₁ Live weight (kg/ha)	765	764	1051
Live weight at D ₂₈ (kg/ha)	824	882	1199
Apparent live weight production per ha (kg/ha)	59	118	148
Estimated carcass weight* at D ₁ (kg/ha)	306	306	420
Total carcass weight (kg/ha)	310	351	474
Apparent carcass weight production per ha (kg/ha)	4	45	54

* based on a 40% D₁ live weight (Kirton *et al.*, 1984).

¹ includes the population of farmlets ewes (two ewes/mob/treatment).

4.5.4 Discussion of the summer period

The aim of this section was to determine whether herb-clover mixes would produce greater lamb performance compared to a Pasture mix during the summer period. Experiment two was restricted to 25 days as the predicted herbage growth was not sufficient to meet *ad-lib* feeding requirements set at the start of experiment (Matthews *et al.*, 1999). However, overall herbage dry matter masses and sward height measurements during each experiment indicated that the herbage allowance was not limiting (Webby and Pengelly 1986; Kenyon and Webby 2007). This allowed for the testing of lamb performance on all mixes under conditions where lamb intake was not limiting.

Lamb final live weights and LWG were greater in both herb-clover mixes than the Pasture mix lambs in each experiment. These results support those obtained from herb-clover mixes in sections A and B and those of Golding *et al.* (2011). As reported in sections A and B herbage quality of both herb-clover mixes was greater than that of ryegrass/white clover sward. Specifically OMD % and ME were higher and NDF % was lower in the herb-clover mixes than ryegrass/white clover sward in both experiments. Therefore, the superior lamb performance in both herb-clover mixes is likely due to the higher nutritional quality of the herb-clover mixes and the inferior lamb performance in the Pasture mix is likely due to the poor nutritional quality of the Pasture mix during the summer period (Hodgson and Brookes 1999).

Carcass weights and DO% were greater in the herb-clover mixes compared to the Pasture mix in both experiments. Similarly, greater lamb carcass weights and DO% were obtained from both herb-clover mixes in sections A and B and also by Golding

et al. (2011). The GR tissue depths were greater in lambs in both herb-clover mixes compared to the Pasture mix lambs also supporting the results in sections A and B. Lambs in both herb-clover mixes had lower leg yield percentages in both experiments compared to the Pasture mix lambs as observed in Section B.

The apparent live weight and carcass weight production per ha was again higher in the herb-clover mixes than the Pasture mix in both experiments reinforcing the results obtained in sections A and B. The higher per ha production in the herb-clover mixes in Experiment one and in the Chicory mix in Experiment two, is a combination of both more lambs per ha and higher individual lamb performance due to the higher stocking rates. In contrast, the higher per ha production in the Plantain mix over Pasture mix in Experiment two is solely due to improved individual lamb performance as the stocking rates did not differ in both Plantain and Pasture mixes. These results emphasize that both herb-clover mixes have the potential to improve lamb performance significantly on a per ha basis, during the summer period compared to the Pasture mix and match the results from previous sections.

4.6 Section D

Effect of Plantain mix and Chicory mix on the live weight gain (LWG) and carcass weight of lambs compared to Pasture mix in the autumn period over two consecutive years

4.6.1 Overview

In autumn, pasture production starts to decline (Valentine and Kemp 2007). One of the drawbacks of perennial ryegrass/white clover pasture is the low persistence during the dry periods of summer and autumn due to their shallow root systems (Brown *et al.*, 2005). Pasture quality starts to decline in late spring with advancing maturity and is lowest during the early autumn when high levels of dead matter are present (Fraser *et al.*, 1999; Litherland and Lambert 2007). However, with the autumn rains, new growth starts along with the decomposition of dead matter, thereby increasing pasture quality (Kemp *et al.*, 1999; Litherland and Lambert 2007). Herbage such as plantain, chicory, white- and red-clover are effective in this period as they display higher herbage quality compared to ryegrass (Fraser and Rowarth 1996; Moorby *et al.*, 2004; Speijers *et al.*, 2004; Marley *et al.*, 2005).

The results in Section C indicated that a herb-clover mix can be effective for lamb finishing during summer when the production and quality of the ryegrass/white clover sward can be inferior (Golding *et al.*, 2011). In addition, greater lamb performance was observed in early spring (Section A) and in late spring and early summer (Section B) on the herb-clover mixes. Therefore, this experiment examined

whether Plantain and Chicory mixes would improve lamb production in the autumn period compared to the Pasture mix.

4.6.2 Materials and methods

The two experiments were from 28th March to 2nd May 2012 (*Experiment one*) and from 24th April to 6th June 2013 (*Experiment two*).

4.6.2.1 Animal management

Experiment one (2012)

One hundred and eighty nine cryptorchid Romney cross male lambs approximately aged six months (34.2 ± 0.22 kg) were selected for the present study on 28th March 2012 (D₁). Lambs were stratified by live weight and allocated to one of the three treatments to ensure that there was no difference in live weights at the start of the experiment, ‘Pasture mix’ n=57; ‘Plantain mix’ n=66; ‘Chicory mix’ n=66. Each treatment included three mobs of lambs serving as replicates (i.e. n=19, n=22 and n=22 for Pasture mix, Plantain mix and Chicory mix per mob respectively).

The nine groups of lambs (three treatments by three mobs) rotationally grazed their assigned treatment plots twice during the experimental period. The stocking rate (lambs/ha) was 28 lambs per ha in the Pasture mix. Both the Plantain and Chicory mixes had a stocking rate of 32 lambs per ha. The stocking rates including the adult ewes (six ewes per treatment) introduced to provide contamination with nematode eggs (details are given in Chapter 3). Different stocking rates were used in order to maintain predicted herbage masses in all three treatments (i.e. final average mass to be similar to start average mass) and also allowing for *ad-lib* feeding condition. The

studies of Matthews *et al.* (1999), Li and Kemp (2005), Powell *et al.* (2007) and Kemp *et al.* (2010) were used to predict herbage growth during both experimental periods.

Lambs were orally drenched for internal parasite control and treated with Zn capsules on D₁. Zn capsules were given as a preventative measure against facial eczema disease (Munday *et al.*, 1997). The scabby mouth vaccine (Nottingham 2013) was given by scratching the under arm skin (extra dermally) on D₂ to all the lambs. Lambs were weighed within an hour of removal from the herbage on D₁, D₁₄, D₂₇ and D₃₅. On D₃₆ the lambs were slaughtered.

Experiment two (2013)

The same experimental design was repeated in 2013 using 150 cryptorchid Romney cross male lambs aged seven months (34.1 ± 0.19 kg) beginning on 24th April 2013 (D₁). The Pasture mix (n=57) and Chicory mix (n=57) had a stocking rate of 28 lambs per ha in each and the Plantain mix (n=36) had a stocking rate of 19 lambs per ha. Each treatment included three mobs of lambs serving as replicates (i.e. n=19, n=12 and n=19 for Pasture mix, Plantain mix and Chicory mix per mob respectively). The stocking rates including the adult ewes (six ewes per treatment) introduced to provide contamination with nematode eggs (details are given in Chapter 3). A lower stocking rate was used for the Plantain mix as the herbage growth was not sufficient to meet the predicted *ad-lib* feeding requirements (Matthews *et al.*, 1999; Li and Kemp 2005; Powell *et al.*, 2007; Kemp *et al.*, 2010).

Lambs were weighed on D₁, D₁₄, D₂₈, and D₄₃. All lambs were drenched on D₁ and D₁₄ for internal parasite control. Lambs were re-drenched after 14 days of the experiment instead of 21 days to allow for earlier selling of the lambs if the herbage growth was slow. They were also treated with Zn capsules on D₅ as practised in Experiment one. All the lambs were slaughtered on D₄₄ at the Alliance Meat Works (Levin, New Zealand).

4.6.2.2 Herbage quality

Grab herbage samples were collected on D₉ and D₃₅ in 2012, D₈, D₂₂ and D₄₃ in 2013. They were analysed to estimate the nutritional value of the herbage consumed by lambs.

4.6.2.3 Statistical analysis - Experiment one and Experiment two

All the data were tested for normality and outliers using Minitab 16 statistical software before the analysis in SAS version 9.2 (SAS 2008).

Individual lamb data (apparent intake per lamb per day, live weight, carcass weight, leg, loin, shoulder (% yield of carcass) and GR tissue depth measurement) and herbage data (pre- and post-grazing dry matter production, sward heights) were analysed using a nested linear model with herbage treatment as a fixed effect and replicate (*mob* for lamb data or *paddock* for herbage data) nested within herbage treatment as a random effect using proc GLM in SAS version 9.2 (SAS 2008) for each experiment separately. The means were separated using LSD procedure in proc GLM.

Pre- and post-grazing herbage mass data for each rotation were used in the analysis of herbage DM mass. Apparent intake per lamb per day was calculated according to Matthews *et al.* (1999) by taking the difference between pre-grazing DM mass and post-grazing DM mass divided by grazing intensity (lambs/ha/day) for each season. Pre- and post-grazing sward surface height data for each rotation were used in the analysis of pre- and post-grazing sward surface heights.

The herbage quality data were analysed using randomised block design model using proc GLM. Crude protein, NDF and ADF values were corrected for DM basis before analysing. Metabolisable energy (ME) was calculated by multiplying digestible organic matter digestibility (DOMD%) by 0.163 (Geenty and Rattray 1987). The means were separated using LSD procedure in proc GLM.

Apparent live weight production per ha for each treatment was calculated by taking the difference between D₁ total live weight per ha per treatment and final live weight per ha per treatment. Apparent carcass weight production per ha for each treatment, was calculated by taking the difference between total Apparent carcass weight production per ha per treatment at slaughter and estimated carcass weight production at D₁ per ha per treatment. Estimated carcass weight production at D₁ was assumed to be 40% of D₁ live weight (Kirton *et al.*, 1984) for all lambs.

4.6.3 Results

4.6.3.1 Herbage mass

Experiment one (2012)

The pre-grazing and post-grazing herbage masses were highest ($P<0.05$) in the Pasture mix compared to the other two treatments (Table 4-25). The Plantain mix had higher ($P<0.05$) post-grazing herbage masses compared to the Chicory mix. Apparent DM intake was higher ($P<0.05$) in the Pasture mix lambs compared to Plantain mix lambs.

Experiment two (2013)

Pasture mix had higher ($P<0.05$) pre- and post-grazing herbage masses compared to the Plantain and Chicory mixes (Table 4-25). Apparent DM intake was higher ($P<0.05$) in the Plantain mix and Chicory mix lambs compared to the Pasture mix lambs.

Table 4-25: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on the pre- and post-grazing herbage dry matter (DM) mass and apparent DM intake in autumn (mean \pm s.e.).

Treatment	Pre-grazing (kg/ha)	Post-grazing (kg/ha)	Apparent DM intake (kg/head/day)
<i>Experiment one (2012)</i>			
Pasture mix	6131 ^b \pm 179.1	4209 ^c \pm 190.4	2.9 ^b \pm 0.30
Plantain mix	4138 ^a \pm 138.8	2789 ^b \pm 147.5	1.9 ^a \pm 0.23
Chicory mix	3964 ^a \pm 160.2	2294 ^a \pm 170.3	2.3 ^{ab} \pm 0.27
<i>Experiment two (2013)</i>			
Pasture mix	3426 ^b \pm 120.8	2536 ^b \pm 136.1	1.2 ^a \pm 0.20
Plantain mix	2571 ^a \pm 120.8	1650 ^a \pm 136.1	2.1 ^b \pm 0.20
Chicory mix	2856 ^a \pm 120.8	1744 ^a \pm 136.1	1.9 ^b \pm 0.20

Differing superscripts within columns and experiments indicate means that were significantly different ($P < 0.05$).

4.6.3.2 Sward height

Experiment one (2012)

Pre- and post- grazing sward heights were not different ($P > 0.05$) among the treatments (Table 4-26).

Experiment two (2013)

Pre-grazing sward heights were higher ($P < 0.05$) in the Chicory mix compared to the Pasture and Plantain mixes (Table 4-26). Post-grazing sward heights were not different ($P > 0.05$) among the treatments.

Table 4-26: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on pre- and post-grazing sward height measurements in autumn (mean \pm s.e.).

Treatment	Pre-grazing (cm)	Post-grazing (cm)
<i>Experiment one (2012)</i>		
Pasture mix	14.7 \pm 1.74	9.4 \pm 0.67
Plantain mix	17.2 \pm 1.40	8.2 \pm 0.54
Chicory mix	18.8 \pm 1.47	7.6 \pm 0.57
<i>Experiment two (2013)</i>		
Pasture mix	17.3 ^a \pm 0.94	8.7 \pm 0.47
Plantain mix	18.1 ^a \pm 0.94	9.4 \pm 0.47
Chicory mix	24.0 ^b \pm 0.94	9.6 \pm 0.47

Differing superscripts within columns and experiments indicate means that were significantly different ($P < 0.05$).

4.6.3.3 Herbage composition

Experiment one (2012) and Experiment two (2013)

In both experiments, ryegrass was the dominant species in the Pasture mix and plantain was the dominant species in both Plantain mix and Chicory mix before and after each experiment (Table 4-27). Total clover (white clover and red clover) percentages were 22-38% and 13-25% in Experiment one in the Plantain mix and Chicory mix respectively. In Experiment two total clover percentages were 26-34% and 12-18% in the Plantain mix and Chicory mix respectively.

Table 4-27: The percentage (%) of various herbage species within each herbage treatment prior to and after the *Experiment one* and *Experiment two* in autumn.

Herbage species	Pasture mix		Plantain mix		Chicory mix	
	Prior to	After	Prior to	After	Prior to	After
	(14/3/2012)	(2/7/2012)	(14/3/2012)	(2/7/2012)	(14/3/2012)	(2/7/2012)
<i>Experiment one (2012)</i>						
Ryegrass	57	68	–	–	–	–
Plantain	–	–	42	60	34	55
Chicory	–	–	–	–	26	22
white clover	13	2	18	11	13	6
Red clover	–	–	20	11	12	7
Weeds [#]	15	20	7	8	3	3
Dead matter	15	10	13	10	12	7
<i>Experiment two (2013)</i>						
	Prior to	After	Prior to	After	Prior to	After
	(8/4/2013)	(2/7/2013)	(8/4/2013)	(2/7/2013)	(8/4/2013)	(2/7/2013)
Ryegrass	66	81	–	–	–	–
Plantain	–	–	40	60	21	45
Chicory	–	–	–	–	47	36
white clover	2	0	1	5	1	4
Red clover	–	–	33	21	17	8
Weeds [#]	19	15	9	12	3	4
Dead matter	13	4	17	2	11	3

Weeds[#] - all the other non-sown species (including other grasses and weeds) except the main pasture and herb species in the treatments.

4.6.3.4 Herbage quality

Experiment one (2012)

Chicory mix had higher ($P < 0.05$) OMD percentage and ME value than the Plantain mix which in turn were higher than the Pasture mix (Table 4-28). Plantain mix had a higher ($P < 0.05$) CP percentage than the Pasture mix. Pasture mix had a higher

($P < 0.05$) NDF percentage than the Plantain mix which in turn was higher ($P < 0.05$) than the Chicory mix. Ash percentage was higher ($P < 0.05$) in the Plantain and Chicory mixes compared to the Pasture mix.

Experiment two (2013)

Plantain and Chicory mixes had higher ($P < 0.05$) OMD percentage and ME value than the Pasture mix (Table 4-28). Crude protein percentage was higher ($P < 0.05$) in the Plantain mix compared to the Pasture mix which in turn was higher ($P < 0.05$) than the Chicory mix. Pasture mix had a higher ($P < 0.05$) NDF percentage than the Plantain and Chicory mixes. Chicory mix had a higher ($P < 0.05$) ash percentage than the Pasture and Plantain mixes.

Table 4-28: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on various herbage quality parameters in autumn (mean \pm s.e.).

Treatment	Herbage quality (% DM)					ME ⁵ (MJ/kg DM)
	OMD ¹	CP ²	NDF ³	ADF ⁴	Ash	
<i>Experiment one (2012)</i>						
Pasture mix	67.7 ^a \pm 0.44	19.8 ^a \pm 0.98	48.5 ^c \pm 1.08	23.9 \pm 0.93	9.7 ^a \pm 0.29	9.9 ^a \pm 0.07
Plantain mix	74.8 ^b \pm 0.44	24.2 ^b \pm 0.98	34.7 ^b \pm 1.08	23.2 \pm 0.93	12.3 ^b \pm 0.29	10.8 ^b \pm 0.07
Chicory mix	77.6 ^c \pm 0.44	23.0 ^{ab} \pm 0.98	29.3 ^a \pm 1.08	20.7 \pm 0.93	13.0 ^b \pm 0.29	11.1 ^c \pm 0.07
<i>Experiment two (2013)</i>						
Pasture mix	74.9 ^a \pm 0.39	29.3 ^b \pm 1.06	39.5 ^b \pm 0.88	19.3 \pm 1.70	12.7 ^a \pm 0.32	10.8 ^a \pm 0.05
Plantain mix	81.3 ^b \pm 0.39	33.3 ^c \pm 1.06	22.1 ^a \pm 0.88	15.7 \pm 1.70	13.6 ^a \pm 0.32	11.6 ^b \pm 0.05
Chicory mix	82.0 ^b \pm 0.39	23.7 ^a \pm 1.06	19.5 ^a \pm 0.88	17.1 \pm 1.70	16.1 ^b \pm 0.32	11.6 ^b \pm 0.05

Differing superscripts within columns and experiments indicate means that were significantly different ($P < 0.05$).

¹Organic matter digestibility (OMD); ²crude protein (CP); ³neutral detergent fibre (NDF); ⁴acid detergent fibre (ADF), ⁵metabolisable energy (ME).

4.6.3.5 Animal live weight

Experiment one (2012)

The Chicory mix lambs were heavier ($P<0.05$) than the Pasture mix lambs at D_{14} (Table 4-29). Both Plantain mix and the Chicory mix lambs were heavier ($P<0.05$) at D_{27} and D_{35} compared to the Pasture mix lambs. Live weight gain between D_1 and D_{35} was greater ($P<0.05$) in Plantain mix and the Chicory mix lambs compared to the Pasture mix lambs.

Experiment two (2013)

Plantain mix lambs were heavier ($P<0.05$) than the Chicory mix lambs which in turn were heavier ($P<0.05$) than the Pasture mix lambs at D_{43} (Table 4-29). The Plantain mix lambs had greater ($P<0.05$) LWG between D_1 and D_{43} than the Chicory mix lambs which in turn had greater ($P<0.05$) LWG than the Pasture mix lambs.

Table 4-29: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on lamb live weight and daily live weight gain (LWG) in autumn (mean ± s.e.).

Treatment	n ¹	Live weight (kg)				n ¹	LWG (D ₁ -D ₃₅) (g/day)
		D ₁	D ₁₄	D ₂₇	D ₃₅		
<i>Experiment one (2012)</i>							
Pasture mix	57	34.3 ± 0.04	39.0 ^a ± 0.22	40.1 ^a ± 0.34	39.9 ^a ± 0.54	57	159.7 ^a ± 13.18
Plantain mix	66	34.2 ± 0.04	39.4 ^{ab} ± 0.20	42.3 ^b ± 0.31	44.5 ^b ± 0.50	66	294.9 ^b ± 12.24
Chicory mix	66	34.3 ± 0.04	39.9 ^b ± 0.20	42.4 ^b ± 0.31	43.1 ^b ± 0.50	66	254.8 ^b ± 12.24
<i>Experiment two (2013)</i>							
	n ¹	D ₁	D ₁₄	D ₂₈	D ₄₃	n ¹	LWG (D ₁ -D ₄₃) (g/day)
Pasture mix	57	34.1 ± 0.02	37.6 ± 0.48	39.5 ± 0.28	41.4 ^a ± 0.21	57	169.7 ^a ± 5.05
Plantain mix	36	34.2 ± 0.03	36.0 ± 0.61	39.8 ± 0.35	45.0 ^c ± 0.26	36	252.3 ^c ± 6.35
Chicory mix	57	34.1 ± 0.02	37.0 ± 0.48	40.2 ± 0.28	43.1 ^b ± 0.21	57	207.7 ^b ± 5.05

Differing superscripts within columns and experiments indicate means that were significantly different (P<0.05).
¹ number of lambs per treatment.

4.6.3.6 Carcass weight

Experiment one (2012)

Plantain mix and Chicory mix lambs produced heavier ($P<0.05$) carcass weights than the Pasture mix lambs (Table 4-30). Chicory mix lambs had greater ($P<0.05$) DO% than the Plantain mix lambs which in turn had greater ($P<0.05$) DO% than the Pasture mix lambs.

Leg yield percentage was greater ($P<0.05$) in the Pasture mix lambs compared to Plantain mix and Chicory mix lambs (Table 4-31). Shoulder yield percentage was greater ($P<0.05$) in the Chicory mix lambs compared to Pasture mix lambs. GR tissue depths were higher ($P<0.05$) in Plantain mix and Chicory mix lambs compared to Pasture mix lambs.

Table 4-30: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on carcass weight and dressing-out percentage (DO%) of lambs in autumn (means \pm s.e.).

Treatment	n ¹	Carcass weight (kg/lamb)	DO% ²
<i>Experiment one (2012)</i>			
Pasture mix	57	15.2 ^a \pm 0.15	38.0 ^a \pm 0.36
Plantain mix	66	18.6 ^b \pm 0.14	41.8 ^b \pm 0.34
Chicory mix	66	18.7 ^b \pm 0.14	43.0 ^c \pm 0.33
<i>Experiment two (2013)</i>			
Pasture mix	57	16.7 ^a \pm 0.27	40.4 ^a \pm 0.58
Plantain mix	36	18.6 ^b \pm 0.34	41.4 ^{ab} \pm 0.73
Chicory mix	57	18.2 ^b \pm 0.27	42.3 ^b \pm 0.58

Differing superscripts within columns and experiments indicate means that were significantly different ($P < 0.05$).

¹number of lambs per treatment.

²DO% = (carcass weight/final live weight) \times 100. Final live weight was taken on farm approximately 12 hours before slaughter.

Experiment two (2013)

Both Plantain and Chicory mixes produced heavier ($P < 0.05$) lamb carcass weights than the Pasture mix lambs (Table 4-30). Dressing out percentage was greater in the Chicory mix lambs than the Pasture mix lambs. The percentage of leg, loin and shoulder yields were not different ($P > 0.05$) among the treatments. However, GR tissue depths were higher ($P < 0.05$) in Plantain mix and Chicory mix lambs compared to Pasture mix lambs (Table 4-31).

Table 4-31: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on lamb leg, loin, shoulder yields (% of total carcass) and GR tissue depth measurement in autumn (means \pm s.e.).

Treatment	n ¹	Leg yield %	Loin Yield %	Shoulder yield %	GR (mm)
<i>Experiment one (2012)</i>					
Pasture mix	57	24.1 ^b \pm 0.22	15.0 \pm 0.12	16.6 ^a \pm 0.13	3.8 ^a \pm 0.13
Plantain mix	66	22.6 ^a \pm 0.21	15.1 \pm 0.11	16.9 ^{ab} \pm 0.12	8.4 ^b \pm 0.12
Chicory mix	66	22.8 ^a \pm 0.20	15.2 \pm 0.11	17.2 ^b \pm 0.11	8.3 ^b \pm 0.11
<i>Experiment two (2013)</i>					
Pasture mix	57	21.8 \pm 0.12	14.1 \pm 0.11	16.5 \pm 0.08	7.3 ^a \pm 0.39
Plantain mix	36	21.3 \pm 0.15	14.2 \pm 0.14	16.6 \pm 0.10	10.2 ^b \pm 0.50
Chicory mix	57	21.6 \pm 0.12	14.2 \pm 0.11	16.7 \pm 0.08	9.2 ^b \pm 0.39

Differing superscripts within columns and experiments indicate means that were significantly different ($P < 0.05$).

¹number of lambs per Treatment.

4.6.3.7 Apparent live weight and carcass weight production per ha - Experiment one (2012) and Experiment two (2013)

Table 4-32 indicates that on a per ha basis, Plantain and the Chicory mixes produced more apparent live weights and carcass weights of lambs than the Pasture mix in both experiments. In 2013, the Chicory mix apparent live weight and carcass weight production were greater than Pasture mix and Plantain mix. Although, the Pasture mix had a higher apparent live weight production per ha than the Plantain mix, apparent carcass weight production per ha was higher in the Plantain mix during the Experiment two.

Table 4-32: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on apparent live weight and carcass production per ha (kg/ha) in autumn.

	Pasture mix	Plantain mix	Chicory mix
<i>Experiment one (2012)</i>			
Area per treatment (ha)	2.25	2.25	2.25
No. of lambs per treatment (no.)	57	66	66
Stocking rate ¹ (no. of lambs per ha)	28	32	32
D ₁ Live weight (kg/ha)	868	1004	1005
Live weight at D ₂₈ (kg/ha)	1007	1286	1263
Apparent live weight production (kg/ha)	139	282	258
Estimated carcass weight* at D ₁ (kg/ha)	347	402	402
Total carcass weight (kg/ha)	378	538	544
Apparent carcass weight production (kg/ha)	31	136	142
<i>Experiment two (2013)</i>			
Area per treatment (ha)	2.25	2.25	2.25
No. of lambs per treatment (no.)	57	36	57
Stocking rate ¹ (no. of lambs per ha)	28	19	28
D ₁ Live weight (kg/ha)	864	547	865
Live weight at D ₂₈ (kg/ha)	1049	721	1091
Apparent live weight production (kg/ha)	185	174	226
Estimated carcass weight* at D ₁ (kg/ha)	346	219	346
Total carcass weight (kg/ha)	423	298	462
Apparent carcass weight production (kg/ha)	77	79	116

* based on a 40% D₁ live weight (Kirton *et al.*, 1984).

¹ includes the population of farmlets ewes (two ewes/mob/treatment).

4.6.4 Discussion of the autumn period

The aim of this section was to determine whether the Plantain and Chicory mixes would produce greater lamb performance as found in sections A, B and C compared to the Pasture mix in the autumn period. The drought conditions that prevailed during the late summer 2013 (see climate data in Chapter 3) resulted in a delay to the start of Experiment two until late April. However, the herbage dry matter masses and sward height measurements in all three herbage treatments in both experiments indicated that herbage intake was not limiting (Webby and Pengelly 1986; Kenyon and Webby 2007). This allowed for the testing of lamb performance on all mixes under conditions where lamb intake was not limiting.

The live weight gain (LWG) and final lamb live weights were greater in both of the herb-clover mixes in both experiments compared to the Pasture mix as observed in sections A, B and C. Again this is likely due to the higher quality of the herb-clover mixes compared to the Pasture mix. The Plantain and Chicory mixes had higher OMD % and ME in both experiments than the Pasture mix as found in sections A, B and C and by Golding *et al.* (2011).

Lamb carcass weights were also greater in both herb-clover mixes compared to the Pasture mix as observed in sections A, B and C. Dressing out percentage was greater in the herb-clover mixes in Experiment one like in sections A, B and C but not in Experiment two compared to the Pasture mix. The leg yield percentages were lower in both herb-clover mixes compared to the Pasture mix in Experiment one as observed in sections B and C. The shoulder yield percentage was greater only in the Chicory mix compared to the Pasture mix in Experiment one but there

was no difference in Experiment two. Herb-clover mixes had higher shoulder yield percentages in Experiment one in sections A and B. GR tissue depths were higher in both herb-clover mixes compared to the Pasture mix in both experiments. Similarly, in the sections A, B and C greater GR tissue depths were observed in the herb-clover mix lambs compared to the Pasture mix lambs.

Both the Plantain and Chicory mixes produced higher apparent live weight and carcass weight per ha in both years as found in sections A, B and C. During Experiment one, both Plantain mix and Chicory mix had a higher stocking rates than the Pasture mix. Thus, the extra performance on a per ha basis is due to the combination of more lambs and higher individual lamb performance. While, in Experiment two Plantain mix had a lower stocking rate due to the lower herbage growth. Nevertheless, Plantain mix produced more apparent live weight and carcass weight per ha compared to the Pasture mix indicating that the higher individual lamb live weight and carcass weights resulted in the higher per ha lamb production in the Plantain mix.

4.7 Section E

Effect of Pasture mix on the growth rate and carcass weight of lambs in the winter period over two consecutive years

4.7.1 Overview

Perennial ryegrass (*Lolium perenne*) may vary in production and quality in different seasons but is effective during the winter period when other forages are dormant (Litherland and Lambert 2007; Kemp *et al.*, 2010). Plantain and Chicory mixes cannot be grazed in winter due to their partial dormancy and susceptibility to damage on heavy wet soils (Hume *et al.*, 1995; Hoskin *et al.*, 1999b; Li and Kemp 2005; Kemp *et al.*, 2010). However, to allow for a true production evaluation on a per ha per year basis, it is important to determine the amount of lamb that can be finished on the Pasture mix treatment in the winter period. Thus, for this section lambs were only managed on ryegrass/white clover pasture in the winter over two consecutive winter periods (2011 and 2012).

4.7.2 Materials and methods

The two experiments were carried out from 1st June to 27th July 2011 (*Experiment one*) and 20th June to 15th August 2012 (*Experiment two*).

4.7.2.1 Animal management

Experiment one (2011)

Forty five cryptorchid Romney cross male lambs aged nine months (35.96 ± 0.48 kg) were selected for the present experiment on 1st June 2011 (D₁). Lambs were stratified by live weight and allocated to one of the three mobs/replicates to ensure there was no difference in live weights at the start of the experiment (i.e. n=15 per mob). The three mobs of lambs rotationally grazed their assigned paddocks three times during the experimental period. The stocking rate was 20 lambs per ha.

Lambs were orally drenched on D₁ and D₂₈ for internal parasite control. They were treated for lice using *Wipe Out* (at a rate of 2 ml/10 kg live weight; Active ingredient Deltamethrin 10 g/l, Schering-Plough Animal Health Limited, New Zealand) on D₂₈. Lambs were weighed within an hour of removal from the herbage on D₁, D₁₄, D₂₈, D₄₂ and D₅₆. They were slaughtered on D₅₇.

Experiment two (2012)

The same experimental design was repeated in 2012 using 36 cryptorchid Romney cross male lambs aged four months (35.8 ± 0.16 kg) beginning on 20th June (D₁). The stocking rate was 18 lambs per ha. This included the adult ewes (two ewes per mob) introduced to provide contamination with nematode eggs. Therefore, each mob had 12 lambs and two ewes. The three mobs of lambs rotationally grazed their assigned paddocks three times during the experimental period.

Lambs were orally drenched on D₁ and D₂₈ for internal parasite control. They were treated for lice on D₂₈. Lambs were weighed within an hour of removal from the herbage on D₁, D₁₄, D₂₈, D₄₃ and D₅₆. They were slaughtered on D₅₇.

4.7.2.2 Herbage quality

Grab herbage samples were collected on D₁₀ and D₅₄ in 2011, D₁₂ and D₅₆ in 2012. They were analysed to estimate the nutritional value of the herbage consumed by lambs.

4.7.2.3 Statistical analysis – Experiment one and Experiment two

All the data were tested for normality using Minitab 16 statistical software before the analysis in SAS version 9.2 (SAS 2008).

Individual lamb data (apparent intake per lamb per day, live weight, carcass weight, leg, loin, shoulder (% yield of carcass) and GR tissue depth measurement) and herbage data (pre- and post-grazing dry matter production, sward heights) were analysed using a simple ANOVA with herbage replicate or mob as a fixed effect using proc GLM for each experiment separately. The means were separated using LSD procedure in proc GLM.

Pre- and post-grazing herbage mass data for each rotation were used in the analysis of herbage DM mass. Apparent intake per lamb per day was calculated according to Matthews *et al.* (1999) by taking the difference between pre-grazing DM mass and post-grazing DM mass divided by grazing intensity (lambs/ha/day)

for each season. Pre- and post-grazing sward surface height data for each rotation were used in the analysis of pre- and post-grazing sward surface heights.

The herbage quality data were analysed using a simple ANOVA using proc GLM across years (Experiment one - 2011 and Experiment two - 2012). Crude protein, NDF and ADF values were corrected for DM basis before analysing. Metabolisable energy (ME) was calculated by multiplying digestible organic matter digestibility (DOMD%) by 0.163 (Geenty and Rattray 1987). The means were separated using LSD procedure in proc GLM.

Apparent live weight production per ha was calculated by taking the difference between D₁ total live weight per ha and final live weight per ha across all the three mobs. Apparent carcass weight production per ha was calculated by taking the difference between total Apparent carcass weight production per ha at slaughter and estimated carcass weight production at D₁ per ha across all the three mobs. Estimated carcass weight production at D₁ was assumed to be 40% of D₁ live weight (Kirton *et al.*, 1984) for all lambs.

4.7.3 Results

4.7.3.1 Herbage mass

Experiment one (2011)

The pre-grazing herbage masses were highest ($P < 0.05$) in replicate one and two compared to replicate three (Table 4-33). Post-grazing herbage mass was higher

($P < 0.05$) in replicate one compared to replicate three. However, apparent DM intake was not different ($P > 0.05$) among the replicates.

Experiment two (2012)

The pre-grazing herbage mass was higher ($P < 0.05$) in replicate one compared to replicate three (Table 4-33). Post-grazing herbage mass and apparent DM intake were not different ($P > 0.05$) among the replicates.

Table 4-33: Effect of Pasture mix on the pre- and post-grazing herbage dry matter (DM) mass and apparent DM intake in winter (mean \pm s.e.).

Replicate	Pre-grazing (kg/ha)	Post-grazing (kg/ha)	Apparent DM intake (kg/head/day)
<i>Experiment one (2011)</i>			
Replicate 1	2033 ^b \pm 101.1	1566 ^b \pm 82.4	1.2 \pm 0.30
Replicate 2	1851 ^b \pm 101.1	1527 ^{ab} \pm 82.4	1.1 \pm 0.30
Replicate 3	1517 ^a \pm 101.1	1304 ^a \pm 82.4	0.7 \pm 0.30
Average	1800 \pm 58.7	1466 \pm 47.8	1.0 \pm 0.17
<i>Experiment two (2012)</i>			
Replicate 1	3446 ^b \pm 127.8	2555 \pm 111.7	2.1 \pm 0.36
Replicate 2	3281 ^{ab} \pm 180.8	2456 \pm 157.9	2.7 \pm 0.51
Replicate 3	2947 ^a \pm 180.8	2229 \pm 157.9	2.8 \pm 0.51
Average	3280 \pm 90.9	2449 \pm 79.4	2.4 \pm 0.26

Differing superscripts within columns and experiments indicate means that were significantly different ($P < 0.05$).

4.7.3.2 Sward height

Experiment one (2011) and Experiment two (2012)

Pre- and post-grazing sward heights were not different ($P>0.05$) between replicates in Experiment one and in Experiment two (Table 4-34).

4.7.3.3 Herbage composition

Experiment one (2011) and Experiment two (2012)

The ryegrass was the dominant species in both experiments (Table 4-35).

Table 4-34: Effect of Pasture mix on pre- and post-grazing sward height measurements in winter (mean \pm s.e.).

Replicate	Pre-grazing (cm)	Post-grazing (cm)
<i>Experiment one (2011)</i>		
Replicate 1	12.5 \pm 0.91	8.2 \pm 0.72
Replicate 2	12.2 \pm 0.91	7.7 \pm 0.72
Replicate 3	11.4 \pm 0.91	6.8 \pm 0.72
Average	12.0 \pm 0.54	7.6 \pm 0.42
<i>Experiment two (2012)</i>		
Replicate 1	12.5 \pm 0.56	6.7 \pm 0.42
Replicate 2	12.2 \pm 0.56	6.7 \pm 0.42
Replicate 3	11.4 \pm 0.56	6.0 \pm 0.42
Average	12.0 \pm 0.33	6.5 \pm 0.25

Table 4-35: The percentage (%) of various herbage species within the Pasture mix prior to and after the *Experiment one* and *Experiment two* in winter.

Herbage species	Prior to 25/04/2011	After 23/08/2011
<i>Experiment one (2011)</i>		
Ryegrass	75	73
white clover	3	6
Weeds [#]	15	12
Dead matter	8	9
<i>Experiment two (2012)</i>		
	Prior to 19/06/2012	After 27/8/2011
Ryegrass	68	60
white clover	2	3
Weeds [#]	20	27
Dead matter	10	10

Weeds[#] - all the other non-sown species (including other grasses and weeds) except the main pasture and herb species in the treatments.

4.7.3.4 Herbage quality

There was no difference ($P > 0.05$) in the herbage quality measurements within and between experiments (Table 4-36).

Table 4-36: Effect of Pasture mix on various herbage quality parameters in winter (mean \pm s.e.).

Experiment	Herbage quality (%DM)					ME ⁵ (MJ/kg DM)
	OMD ¹	CP ²	NDF ³	ADF ⁴	Ash	
One (2011)	70.4 \pm 0.68	26.3 \pm 0.84	43.2 \pm 1.16	23.3 \pm 0.97	12.8 \pm 1.65	10.2 \pm 0.15
Two (2012)	72.6 \pm 0.68	32.0 \pm 0.84	39.4 \pm 1.16	21.2 \pm 0.97	14.6 \pm 1.65	10.4 \pm 0.15

¹Organic matter digestibility (OMD); ²crude protein (CP); ³neutral detergent fibre (NDF); ⁴acid detergent fibre (ADF); ⁵metabolisable energy (ME).

4.7.3.5 Animal live weight

There was no difference ($P>0.05$) in live weight on all weighing occasions between D_1 to D_{56} among the mobs in both experiments (Table 4-37). The LWG between D_1 and D_{56} was greater ($P<0.05$) in mob two compared to mob three in Experiment one. Mob one and two had greater ($P<0.05$) LWG between D_1 and D_{56} compared to mob three in Experiment two.

4.7.3.6 Carcass weight

Experiment one (2011)

There was no difference ($P>0.05$) in either individual lamb carcass weight or DO% between the mobs (Table 3-38). Similarly, leg, loin and shoulder yields were not different ($P>0.05$) between the mobs (Table 3-39).

Experiment two (2012)

There was no difference ($P>0.05$) in either individual lamb carcass weight or DO% between the mobs (Table 3-38). Similarly, leg, loin and shoulder yields were not different ($P>0.05$) between the mobs. Mob two lambs had higher GR tissue depths than mob three lambs (Table 3-39).

Table 4-37: Effect of Pasture mix on lamb live weight and live weight gain (LWG) in winter (mean \pm s.e.).

Replicate	n ¹	Live weight (kg)						n ¹	LWG (D ₁ -D ₅₆) (g/day)
		D ₁	D ₁₄	D ₂₈	D ₄₂	D ₅₆			
<i>Experiment one (2011)</i>									
Mob 1	15	36.0 \pm 0.82	38.8 \pm 0.84	39.8 \pm 0.86	42.2 \pm 0.89	44.9 \pm 0.92	15	158.1 ^{ab} \pm 9.39	
Mob 2	15	35.8 \pm 0.82	39.2 \pm 0.84	40.6 \pm 0.86	43.6 \pm 0.89	45.1 \pm 0.92	15	165.5 ^b \pm 9.39	
Mob 3	15	36.1 \pm 0.82	39.1 \pm 0.84	40.0 \pm 0.86	42.1 \pm 0.89	43.4 \pm 0.92	15	131.2 ^a \pm 9.39	
Average		36.0 \pm 0.48	39.0 \pm 0.49	40.1 \pm 0.50	42.7 \pm 0.52	44.5 \pm 0.54		151.6 \pm 5.48	
<i>Experiment two (2012)</i>									
	n ¹	D ₁	D ₁₄	D ₂₈	D ₄₃	D ₅₆	n ¹	LWG (D ₁ -D ₅₆) (g/day)	
Mob 1	12	36.8 \pm 1.06	42.9 \pm 1.30	44.1 \pm 1.33	47.8 \pm 1.40	49.9 \pm 1.33	12	233.6 ^b \pm 9.30	
Mob 2	12	36.3 \pm 1.06	41.5 \pm 1.30	43.5 \pm 1.33	47.5 \pm 1.40	49.8 \pm 1.33	12	241.8 ^b \pm 9.30	
Mob 3	12	36.9 \pm 1.06	41.5 \pm 1.30	43.9 \pm 1.33	46.2 \pm 1.40	47.5 \pm 1.33	12	190.5 ^a \pm 9.30	
Average		36.6 \pm 0.62	42.0 \pm 0.76	43.8 \pm 0.78	47.2 \pm 0.82	49.1 \pm 0.78		222.0 \pm 5.44	

Differing superscripts within columns and experiments indicate means that were significantly different (P<0.05).
¹ number of lambs per mob.

Table 4-38: Effect of Pasture mix on carcass weight and dressing-out percentage (DO%) of lambs in winter (means \pm s.e.).

Replicate	n ¹	Carcass weight (kg/lamb)	DO% ²
<i>Experiment one (2011)</i>			
Mob 1	15	18.4 \pm 0.89	42.3 \pm 0.69
Mob 2	15	17.2 \pm 0.89	41.4 \pm 0.72
Mob 3	15	17.9 \pm 0.89	42.2 \pm 0.69
Average		17.8 \pm 0.52	42.0 \pm 0.41
<i>Experiment two (2012)</i>			
Mob 1	12	20.0 \pm 0.59	40.1 \pm 0.72
Mob 2	12	20.5 \pm 0.59	41.1 \pm 0.72
Mob 3	12	19.3 \pm 0.59	40.7 \pm 0.72
Average		19.9 \pm 0.34	40.6 \pm 0.42

¹number of lambs per mob.

²DO% =(carcass weight/final live weight) \times 100. Final live weight was taken on farm approximately 12 hours before slaughter.

Table 4-39: Effect of Pasture mix on lamb leg, loin, shoulder yields (% of total carcass) and GR tissue depth measurement in winter (means \pm s.e.).

Replicate	n ¹	Leg yield %	Loin Yield %	Shoulder yield %	GR (mm)
<i>Experiment one (2011)</i>					
Mob 1	15	22.3 \pm 0.28	14.4 \pm 0.20	16.7 \pm 0.28	7.1 \pm 0.56
Mob 2	15	21.8 \pm 0.28	14.4 \pm 0.20	16.2 \pm 0.28	7.3 \pm 0.56
Mob 3	15	22.0 \pm 0.26	14.0 \pm 0.19	16.6 \pm 0.27	6.7 \pm 0.52
Average		22.1 \pm 0.16	14.3 \pm 0.12	16.5 \pm 0.16	7.0 \pm 0.32
<i>Experiment two (2012)</i>					
Mob 1	12	22.6 \pm 0.36	14.8 \pm 0.22	16.1 \pm 0.29	8.1 ^{ab} \pm 0.66
Mob 2	12	21.9 \pm 0.34	15.0 \pm 0.21	16.8 \pm 0.28	9.1 ^b \pm 0.63
Mob 3	12	22.6 \pm 0.33	14.9 \pm 0.20	16.8 \pm 0.27	7.1 ^a \pm 0.60
Average		22.4 \pm 0.20	14.9 \pm 0.13	16.6 \pm 0.16	8.1 \pm 0.37

Differing superscripts within columns indicate means that are significantly differ ($p < 0.05$).
¹number of lambs per mob.

4.7.3.7 Apparent live weight and carcass weight production per ha -

Experiment one (2011) and Experiment two (2012) in winter

Apparent live weight and carcass weight production were higher in Experiment two compared Experiment one (Table 4-40).

Table 4-40: Apparent live weight and carcass production per ha (kg/ha) during the winter period in the Pasture mix.

<i>Experiment one (2011)</i>	
Area per treatment (ha)	0.25
No. of lambs per treatment (no.)	15
Stocking rate (no. of lambs per ha)	20
D ₁ Live weight (kg/ha)	719
Live weight at D ₂₈ (kg/ha)	889
Apparent live weight production (kg/ha)	170
Estimated carcass weight* at D ₁ (kg/ha)	288
Total carcass weight (kg/ha)	357
Apparent carcass weight production (kg/ha)	69
<i>Experiment two (2012)</i>	
Area per treatment (ha)	0.25
No. of lambs per treatment (no.)	12
Stocking rate ¹ (no. of lambs per ha)	19
D ₁ Live weight (kg/ha)	586
Live weight at D ₂₈ (kg/ha)	785
Apparent live weight production (kg/ha)	199
Estimated carcass weight* at D ₁ (kg/ha)	234
Total carcass weight (kg/ha)	319
Apparent carcass weight production (kg/ha)	85

* based on a 40% D₁ live weight.

¹ includes the population of farmlets ewes (two ewes/mob/treatment).

4.7.4 Discussion of the winter period

This experiment was carried out to determine the lamb carcass production during two consecutive winter periods. Pre- and post-grazing sward DM masses and the height measurements showed that the herbage allowance during both experiments was not limiting (Orr *et al.*, 1990; Kenyon and Webby 2007). The nutrient composition of the ryegrass/white clover was similar to the results obtained by

Litherland *et al.* (2002). The LWG in both experiments are similar to the LWG obtained by Nicol *et al.* (2010) during the winter season. Carcass weight and DO% data was also similar to the values obtained by Nicol *et al.* (2010).

4.8 Overall discussion

The hypothesis of this chapter was that the Plantain and Chicory mixes would produce greater lamb live weights and heavier carcasses compared to a Pasture mix. Herbage DM masses of all three herbage treatments in all the sections (A to E) indicated that feed intake should not have been limited (Webby and Pengelly 1986; Hodgson and Brookes 1999; Kenyon and Webby 2007).

In most periods (Experiment two in the Section A and in all groups in sections B, C and D) lambs in the herb-clover mix had greater LWG and final live weights than the Pasture mix lambs. Golding *et al.* (2011) reported an LWG of 246 to 247 g/day using a herb-clover mix similar to the Chicory mix during the late summer early autumn period. In the present experiment in sections A to D the LWG were 223 to 392 g/day in the Plantain mix, 208 to 367 g/day in the Chicory mix and 120 to 322 g/day in the Pasture mix. Combined data indicates that the herb-clover mixes can be used by farmers to increase lamb growth rates over the spring to autumn seasons.

The higher nutrient composition in plantain, chicory and clovers (Fulkerson *et al.*, 2007; Waghorn *et al.*, 2007) compared to the ryegrass/white clover sward would likely have resulted in higher feeding values. Hayes *et al.* (2010) observed that both plantain and chicory had superior nutritional composition than lucerne (*Medicago sativa* L) and many grass species. Findings of Cave *et al.* (2014) and Pain *et al.*

(2014) also indicate that the herb-clover mix had a higher nutritive value. In sections A to D, the herb-clover mixes had greater OMD % and ME compared to the Pasture mix. This difference was also reported by Golding *et al.* (2011) in late summer early autumn period. The higher nutrient digestibility and energy content of the herb-clover mixes combined with its higher rate of feed passage and digestibility (Hodgson and Brookes 1999; Litherland *et al.*, 2010) resulted in faster growth rates in lambs in herb-clover mixes compared to the Pasture mix lambs. Further supporting this notion of faster rate of feed passage or digestibility in each period (Sections A-D), the fibre content of the Pasture mix was higher than in both herb-clover mixes, which can limit feed intake and negatively affect lamb growth (Burke *et al.*, 2002; Waghorn *et al.*, 2007).

The DO% was 1-3% higher on most occasions in both herb-clover mixes except for Experiment two in Section D. Similarly, DO% was also greater in the study of Golding *et al.* (2011) during the late summer early autumn period. Dressing out percentage has been reported to be higher with higher pre slaughter fasting live weights and with highly digestible forages like plantain, chicory and white clover both of which likely explain the differences observed and also with higher GR tissue depths (Kirton *et al.*, 1984; Deaker *et al.*, 1994; Litherland *et al.*, 2010). Litherland *et al.* (2010), reported that lambs grazing chicory and white clover had higher DO% (54 % and 52% respectively) than both plantain and ryegrass (45% each) while, Deaker *et al.*(1994) observed higher DO% for plantain, chicory and white clover (48% each) compared to ryegrass (45%). Kirton *et al.* (1968) and Litherland *et al.* (2010) reported that DO% may vary from season to season as forage quality changes with different seasons which might help explain the variations observed between

sections. Further, the time period between the final weighing and killing can also influence DO% (Litherland *et al.*, 2010).

In New Zealand lamb prices are determined using both GR tissue depths and carcass weights (Kirton *et al.*, 1984; Litherland *et al.*, 2010). Lambs in the Plantain and Chicory mixes had greater GR tissue depths (6.1 to 10.2 mm and 5.8 to 9.6 mm, respectively) than the lambs in the Pasture mix (3.4 to 8.5 mm) in sections A to D. Similarly Golding *et al.* (2011) also obtained a higher GR tissue depth (4.2 mm) for the herb-clover mix compared to the ryegrass/white clover pasture (3.4 mm). Litherland *et al.* (2010) obtained greater GR tissue depths with pure swards of plantain, chicory and white clover compared to ryegrass. However, Fraser *et al.* (2004) and Speijers *et al.* (2004) observed that there was no difference in the depth of LD (latissimus dorsi) or subcutaneous fat at finish when lambs fed with pure swards of red clover, lucerne, lotus or perennial ryegrass. GR tissue depth is positively related with the carcass weight (Kirton and Johnson 1979) which helps explain at least part of the greater GR tissue depths observed in the herb-clover mixes. None of the carcasses in any treatment fell into the 'T' or 'F' grades of high or excessive fat classes during the experimental period. Hence, none of the carcasses fell into GR depths that receive a penalty in price.

The greater carcass weights (17 to 22 kg in sections A to D) obtained in both herb-clover mixes compared to the Pasture mix (15 to 21 kg in sections A to D) in the present experiment were due to a combination of greater final live weights and higher DO%. Similarly, Golding *et al.* (2011) also obtained a higher carcass weight (16 kg) in the herb-clover mix lambs. Fraser and Rowarth (1996) obtained greater

carcass weights by feeding pure swards of plantain, chicory and white clover and Speijers *et al.* (2004) by feeding red clover. Therefore, the results in this experiment and that of Golding *et al.* (2011) indicate that farmers can utilize herb-clover mixes to increase carcass weights and thereby the value of each lamb compared to a ryegrass/white clover sward. Farmers are currently not paid on individual carcass yield traits (leg, loin and shoulder yields). However, if such a payment system was to come into effect the value of herb-clover mix carcass might be even higher than the ryegrass/white clover carcass as these cuts are of higher value.

The higher lamb live weights, carcass weights and on occasion stocking rates resulted in greater apparent live weight and carcass weight production per ha in early spring (Section A), late spring and early summer (Section B), summer (Section C) and autumn (Sections D Experiment one) in the Plantain and Chicory mixes compared to the Pasture mix. Thus, by utilizing a herb-clover mix farmers can produce more product per ha as well as on a per animal basis compared to the Pasture mix.

While the results in this chapter clearly indicate greater performance of herb-clover mixes over ryegrass/white clover sward these experiments also allowed for comparison between the herb-clover mixes. Chicory mix lambs had greater carcass weights during early spring in Experiment one. Plantain mix lambs had greater LWG during late spring and early summer in Experiment one and greater carcass weights during early spring in Experiment two and final live weights and LWG in autumn in Experiment two compared to the Chicory mix lambs. However, in all the other sections and experiments both the Plantain mix and Chicory mix lambs had similar

final live weights, LWG and carcass weights. In all periods excluding early spring, both the Plantain and Chicory mixes had similar stocking rates in Experiment one. However, during the summer and autumn periods in Experiment two, the Chicory mix had higher stocking rates compared to the Plantain mix. As a result, the Chicory mix had more lambs during year two than the Plantain mix. Thus, the Chicory mix appeared to be more productive in the dry periods of the year while Plantain mix tended to be more productive during the other periods. Therefore, the productivity of either Plantain mix or Chicory mix may depend on the environmental conditions. It is suggested that, in drier parts of New Zealand it is likely that the Chicory mix might be more suitable than the Plantain mix.

4.9 Conclusions

Both Plantain and Chicory mixes produced heavier lambs at slaughter and displayed greater carcass weights and a higher DO% compared to the Pasture mix. Therefore, these results indicate that farmers could utilize herb-clover mixes comprising of plantain and/or chicory, white- and red-clover to improve lamb performance in comparison to the ryegrass/white clover pasture over the period from spring to autumn. The Chicory mix appeared to be more suitable during the dry periods of the year compared to the Plantain mix suggesting the use of the two herb-clover mixes is dependent on the farm environmental conditions.

**Chapter 5 : Alternative method to measure herbage dry matter
(DM) mass in Plantain and Chicory mixed swards grazed by lambs**

A part of this chapter was published in the Proceedings of the New Zealand Society of Animal Production;

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chicory mixed swards grazed by lambs. *Proceedings of the New Zealand Society of
Animal Production*, **74**, 5-10.

5.1 Abstract

Calibration equations are available to determine the dry matter (DM) mass of pasture using either sward height or plate meter readings. Currently there are no methods available for determining DM in a herb-clover mix other than using quadrat cuts. The aim of this chapter was to determine the relationships between herbage DM mass as measured by quadrat cuts vs both sward height and plate meter readings for herb-clover mixes during four periods from early spring to autumn. Pre- and post-grazing herbage DM masses (kg DM/ha) in the Plantain mix (plantain (*Plantago lanceolata*), white clover (*Trifolium repens*) and red clover (*T. pratense*)) and in the Chicory mix (plantain, chicory (*Cichorium intybus*), white clover and red clover) were estimated by collecting quadrat cuts. For each quadrat cut a plate meter reading and five sward height measurements were also recorded. Separate regression equations were then developed for quadrat herbage DM mass vs sward height and plate meter readings and also between sward height vs plate meter readings. In addition data from the Plantain and Chicory mixes were pooled to obtain a data set for a combined herb-clover mix. The individual R^2 values were significant for all three relationships and ranged from 0.49 to 0.86. The concordance correlation coefficient (CCC) for all three relationships fell between 0.56 and 0.94 in the present study. The relative prediction error (RPE) for all three relationships varied between 18 and 29%. The regression equations developed in the present chapter by these non-destructive methods would enable farmers to obtain a reliable estimate of the herbage DM mass with a level of precision sufficient for making day-to-day grazing management decisions on farm. The data do suggest different regression equations need to be utilised for different periods of the year.

Keywords: Regression equations, Quadrat cuts and sward heights, Quadrat cuts and plate meter, Herb-clover mixes

5.2 Introduction

The increased use of pastures based on plantain and chicory has created a demand for a simple and objective method to estimate the herbage dry matter (DM) mass of these pastures. Subjective visual estimations of herbage DM mass or sward height are less precise than objective measures (Frame 1981) and can lead to either an over or under estimation of the true value (Hodgson *et al.*, 1999). The standard objective method used to determine DM mass is quadrat cuts (Hodgson *et al.*, 1999; Sanderson *et al.*, 2001). The method involves cutting pasture, washing, oven drying and weighing of the samples. This method is destructive, time consuming and expensive from a farmer perspective and thus not used on farm (Webby and Pengelly 1986). Therefore, there are clear benefits from alternative non-destructive, objective measures of pasture. Alternative methods for determining herbage DM mass or sward height of ryegrass/white clover swards include the sward stick or the rising plate meter (JENQUIP, Fielding, New Zealand) (Hodgson *et al.*, 1999). The rising plate meter provides an estimate (kg DM/ha) based on the pasture height, density and the species present in the sward (Fulkerson and Slack 1993; Hodgson *et al.*, 1999). The automated sward stick measures the height (cm) of the sward (Frame 1981; Stewart *et al.*, 2001). The calibration equations for both the plate meter and sward stick in ryegrass/white clover pastures are well established (Hodgson *et al.*, 1999). Herb-clover mixes are becoming more common in New Zealand pastures (Kemp *et al.*, 2010). The standard method for measuring herbage DM mass on herb-clover mixes is via the quadrat cuts with no calibration equations existing for either using plate meter or sward stick for herb-clover mixes. Therefore, this chapter has three objectives in respect to the herb-clover mixes;

- i. Determine the relationship between herbage DM mass measured by the quadrat cut method and sward surface height measurements using the sward stick.
- ii. Determine the relationship between herbage DM mass measured by quadrat cut method and plate meter readings.
- iii. Determine if the above relationships are consistent across four periods (early spring, late spring and early summer (late spring), summer and autumn).

5.3 Materials and methods

This study was carried out in the Plantain and the Chicory mixes from September 2012 to June 2013 over the periods of early spring, late spring, summer and autumn. This study was undertaken in the same paddocks used in Chapter 4.

Within each herbage type (Plantain mix and Chicory mix) three paddocks served as replicates. Pre- and post-grazing herbage DM masses in the herb-clover mixes were taken using a direct measurement by collecting four quadrat cuts (0.1 m²) per paddock in each grazing rotation (Brown *et al.*, 2005). The samples were then washed and oven dried in a draught oven at 70⁰ C for a minimum of 24 hours. The dry weights were then used to calculate the herbage mass on a DM basis (details are given in Chapter 3).

Before each quadrat was cut, five sward height readings were recorded using the sward stick (JENQUIP, Fielding, New Zealand). Prior to start, the initial sward stick meter reading was noted and at the end of the five sward height measurements the final meter reading was recorded. Then using these two values the average sward

height of each quadrat was determined. In addition, a single plate meter reading (JENQUIP, Fielding, New Zealand) was recorded for each quadrat cut (Hodgson *et al.*, 1999). Therefore, for each pre- and post-grazing quadrat cut, there was a plate meter reading and a sward height measurement. Hence, at each pre- or post-grazing measurement, 12 plate meter readings (1 plate meter reading x 4 quadrat cuts x 3 paddocks) and 12 sward height measurements (1 sward height measurement x 4 quadrat cuts x 3 paddocks) were obtained for each treatment at each grazing rotation. The total number of plate meter readings and sward height measurements obtained per treatment per grazing period varied by period (early spring, late spring, summer or autumn) depending on the length of the grazing period. The total measurements recorded were 168, 192, 72 and 144 for early spring, late spring, summer and autumn grazing periods, respectively.

5.4 Statistical analysis

The relationships between quadrat herbage DM mass and sward height, quadrat herbage DM mass and plate meter readings as well as between sward height and plate meter readings were analysed within periods and across periods for each herbage mix individually and when both herbage mixes combined, via proc GLM in SAS 9.2 (SAS 2008). Individual prediction equations were developed for the different periods (early spring, late spring, summer and autumn) assuming that the periodical effect was greater than the treatment effect. To determine if one ‘combined herb’ equation was suitable for both, the plate meter and sward height vs herbage DM mass, sward height and plate meter measurements for both the Plantain and Chicory mixes were ‘pooled’.

Concordance correlation coefficient (CCC), relative prediction error (RPE) and CV were used to evaluate the level of prediction of herbage DM mass for a given sward height or plate meter reading. Concordance correlation coefficient (CCC) and RPE were calculated as follows.

$$\text{RPE} = (\text{MPE}/\bar{A}) \times 100$$

$$\text{CCC} = 2S_{AP}/(S^2_A + S^2_P + (\bar{A} - \bar{P})^2)$$

where,

$$\text{MPE (mean prediction error)} = \sqrt{\frac{1}{n} \sum_{i=1}^n (A_i - P_i)^2}$$

A_i is the i^{th} observed quadrat cut herbage DM mass value and P_i is the i^{th} predicted herbage DM mass value predicted by using either sward heights or plate meter readings. Means are the \bar{A} and \bar{P} . S^2_A and S^2_P are the variances and S_{AP} is the covariance of A_i and P_i .

If CCC is equal to '1' that means the prediction is a perfect positive agreement. Any CCC value above 0.60 has been considered as a substantial prediction (Fuentes-Pila *et al.*, 1996; Visser *et al.*, 2012). The relative prediction error (RPE) is the variation in the observed and predicted values as a percentage of the herbage DM mass. Any RPE value above 20% has been considered as a poor prediction (Fuentes-Pila *et al.*, 1996).

5.5 Results

5.5.1 Relationship between quadrat cuts and sward height and plate meter

5.5.1.1 Plantain sward mix

All models tested for herbage DM mass vs sward height across all periods were significant ($P < 0.05$) with R^2 values ranging from 0.49 to 0.74 (Table 5-1). All models tested for herbage DM mass vs the plate meter readings across all periods were significant ($P < 0.05$) with R^2 values ranging from 0.54 to 0.68. Similarly, all models tested for the relationship between sward height vs the plate meter readings across all periods were significant ($P < 0.05$) with R^2 values ranging from 0.51 to 0.86.

The regression equations for herbage DM mass vs sward height were different ($P < 0.05$) among all periods except early spring and late spring. The regression equations for herbage DM mass vs the plate meter readings for early spring and late spring were different ($P < 0.05$) from summer and autumn.

Concordance correlation coefficients (CCC) and relative prediction error (RPE) for herbage DM mass vs sward height across all periods ranged from 0.66 to 0.84 and 20 to 26% respectively. Concordance correlation coefficients (CCC) and RPE for herbage DM mass vs the plate meter readings across all periods ranged from 0.70 to 0.81 and 18 to 27% respectively. Concordance correlation coefficients (CCC) and RPE for the relationship between sward height vs the plate meter readings across all periods ranged from 0.84 to 0.94 and 19 to 27% respectively.

5.5.1.2 Chicory sward mix

All models tested for herbage DM mass vs sward height across all periods were significant ($P < 0.05$) with R^2 values ranging from 0.54 to 0.62 (Table 5-2). All models tested for herbage DM mass vs the plate meter readings across all periods were significant ($P < 0.05$) with R^2 values ranging from 0.52 to 0.66. Similarly, all models tested for the relationship between sward height vs the plate meter readings across all periods were significant ($P < 0.05$) with R^2 values ranging from 0.57 to 0.81.

The regression equations during early spring, late spring and summer for herbage DM mass vs sward height and also for herbage DM mass vs the plate meter readings were different ($P < 0.05$) with the autumn values. The regression equations for the relationship between sward height vs the plate meter readings during early spring, late spring and autumn were different ($P < 0.05$) from summer values.

Concordance correlation coefficients (CCC) and relative prediction error (RPE) for herbage DM mass vs sward height across all periods ranged from 0.56 to 0.76 and 25 to 27% respectively. Concordance correlation coefficients (CCC) and RPE for herbage DM mass vs the plate meter readings across all periods ranged from 0.67 to 0.79 and 21 to 26% respectively. Concordance correlation coefficients (CCC) and RPE for the relationship between sward height vs the plate meter readings across all periods ranged from 0.73 to 0.89 and 24 to 27% respectively.

5.5.1.3 Combined plantain and chicory mix (pooled) relationship

All models tested for herbage DM mass vs sward height across all periods were significant ($P < 0.05$) with R^2 values ranging from 0.51 to 0.64 (Table 5-3). All models tested for herbage DM mass vs the plate meter readings across all periods were significant ($P < 0.05$) with R^2 values ranging from 0.52 to 0.63. Similarly, all models tested for the relationship between sward height vs the plate meter readings across all periods were significant ($P < 0.05$) with R^2 values ranging from 0.55 to 0.83.

The regression equations during early spring, late spring and summer for herbage DM mass vs sward height and also for herbage DM mass vs the plate meter readings were different ($P < 0.05$) from the autumn values. The regression equations for the relationship between sward height vs the plate meter readings during early spring and late spring were different ($P < 0.05$) from summer and late spring was different ($P < 0.05$) from autumn.

Concordance correlation coefficients (CCC) and relative prediction error (RPE) for herbage DM mass vs sward height across all periods ranged from 0.67 to 0.79 and 24 to 27% respectively. Concordance correlation coefficients (CCC) and RPE for herbage DM mass vs the plate meter readings across all periods ranged from 0.69 to 0.77 and 24 to 29% respectively. Concordance correlation coefficients (CCC) and RPE for the relationship between sward height vs the plate meter readings across all periods ranged from 0.71 to 0.91 and 23 to 25% respectively.

5.5.2 Scatter plots

The plots suggest that the relationship between the quadrat cut DM mass and sward height was positive, up to approximately 20 cm and 25 cm for the Plantain and Chicory mixes, respectively (Figure 5-1 and 5-2). The plots suggest that the relationship between the herbage DM mass and the plate meter readings was positive up to approximately 20 units and 25 units for the Plantain and Chicory mixes respectively. Sward height vs the plate meter readings relationship appeared positive until 20 units and 30 units in the Plantain and the Chicory mixes respectively.

The plots suggest that the pooled relationship between herbage DM mass and sward height was positive up to approximately 25 cm (Figure 5-3). The pooled relationship between herbage DM mass and the plate meter readings was positive up to approximately 30 units. Further the pooled relationship between sward heights vs the plate meter readings was positive up to approximately 40 units.

Table 5-1: The relationships between quadrat cut herbage DM mass and sward height and plate meter measurements for the Plantain sward mix during four periods (early spring, late spring, summer and autumn) of the year.

	Early spring	Late spring	Summer	Autumn	Mean
Number of samples (n)	n=168	n=192	n=72	n=144	n=576
Sward height					
¹ Regression (kg DM/ha)	1647.8+124.4x ^c	1609.5+152.6x ^c	1188.1+161.1x ^b	834.3+109.9x ^a	1418.5+129.4x
R ²	0.66	0.49	0.74	0.59	0.50
² SE of slope (kg DM/ha)	6.93	11.26	11.54	7.75	5.44
³ CCC	0.80	0.66	0.84	0.74	0.66
⁴ RPE (%)	21	26	23	20	29
Mean (kg DM/ha)	3296.0±54.28	3016.6±57.45	3163.6±86.65	2110.2±36.04	2889.9±35.11
Plate meter					
⁵ Regression (kg DM/ha)	1884.7+86.3x ^b	1753.6+107.4x ^b	1204.4+129.9x ^a	843.0+100.3x ^a	1511.1+100.4x
R ²	0.63	0.54	0.61	0.68	0.54
² SE of slope (kg DM/ha)	5.09	7.12	12.34	5.78	3.86
³ CCC	0.78	0.71	0.74	0.81	0.70
⁴ RPE (%)	22	25	27	18	28
Mean (kg DM/ha)	3296.0±56.06	3016.6±54.36	3163.6±105.13	2110.2±31.71	2889.9±33.51
Sward height vs Plate meter					
⁶ Regression (cm)	2.5+0.66x	2.4+0.58x	2.7+0.63x	2.2+0.74x	2.5+0.65x
R ²	0.86	0.76	0.51	0.77	0.76
² SE of slope (cm)	0.02	0.02	0.07	0.03	0.02
³ CCC	0.87	0.86	0.84	0.94	0.87
⁴ RPE (%)	22	27	27	19	28
Mean (cm)	13.2±0.23	9.2±0.18	12.3±0.63	11.6±0.19	11.4±0.13

¹ kg DM/ha = dry matter + slope X average sward height (x).

⁶ sward height = sward height + slope X average plate meter reading (x).

² SE of slope, standard error of slope.

Differring superscripts (a, b) within rows indicate means that were significantly different (P<0.05).

³ CCC = Concordance Correlation Coefficient.

⁴ RPE = relative prediction error = Mean Prediction Error/Mean of the observed values X 100 .

⁵ kg DM/ha = dry matter + slope X average plate meter reading (x).

Table 5-2: The relationships between quadrat cut herbage DM mass and sward height and plate meter measurements for the Chicory sward mix during four periods (early spring, late spring, summer and autumn) of the year.

	Early spring	Late spring	Summer	Autumn	Mean
Number of samples (n)	n=168	n=192	n=72	n=144	n=576
<u>Sward height</u>					
¹ Regression (kg DM/ha)	1553.3+118.5x ^b	1465.8+142.6x ^b	1534.8+119.1x ^b	814.2+104.6x ^a	1453.8+112.5x
R ²	0.54	0.54	0.56	0.62	0.46
² SE of slope (kg DM/ha)	8.53	9.48	12.50	6.89	5.05
³ CCC	0.70	0.56	0.72	0.76	0.63
⁴ RPE (%)	25	25	26	27	30
Mean (kg DM/ha)	3198.9±63.10	2993.5±54.77	3388.7±103.90	2299.8±51.99	2929.4±36.81
<u>Plate meter</u>					
⁵ Regression (kg DM/ha)	1677.6+84.2x ^b	1660.2+91.3x ^b	1768.6+72.9x ^b	869.4+76.3x ^a	1561.3+77.7x
R ²	0.52	0.55	0.57	0.66	0.48
² SE of slope (kg DM/ha)	6.28	6.04	7.50	4.61	3.36
³ CCC	0.67	0.71	0.73	0.79	0.65
⁴ RPE (%)	21	25	25	26	30
Mean (kg DM/ha)	3198.9±64.32	2993.5±54.65	3388.7±102.68	2299.8±49.16	2929.4±36.16
<u>Sward height vs Plate meter</u>					
⁶ Regression (cm)	2.3+0.64x ^a	2.3+0.57x ^a	5.4+0.46x ^b	2.8+0.61x ^a	2.8+0.58x
R ²	0.79	0.81	0.57	0.75	0.75
² SE of slope (cm)	0.03	0.02	0.05	0.03	0.01
³ CCC	0.88	0.89	0.73	0.85	0.85
⁴ RPE (%)	24	24	25	27	28
Mean (cm)	13.9±0.26	10.7±0.18	15.6±0.65	14.2±0.32	13.1±0.15

¹kg DM/ha = dry matter + slope X average sward height (x). ⁶ sward height = sward height + slope X average plate meter reading (x).

²SE of slope, standard error of slope.

³CCC = Concordance Correlation Coefficient.

⁴RPE = relative prediction error = Mean Prediction Error/Mean of the observed values X 100 .

⁵kg DM/ha = dry matter + slope X average plate meter reading (x).

Differing superscripts (a, b) within rows indicate means that were significantly different (P<0.05).

Table 5-3: The common relationships between quadrat cut herbage DM mass and sward height and plate meter measurements for herb-clover mix during four periods (early spring, late spring, summer and autumn) of the year.

	Early spring	Late spring	Summer	Autumn	Mean
Number of samples (n)	n=336	n=384	n=144	n=288	n=1152
<u>Sward height</u>					
¹ Regression (kg DM/ha)	1603.9+121.1x ^b	1569.8+144.0x ^b	1396.7+135.1x ^b	854.0+104.7x ^a	1460.1+118.4x
R ²	0.59	0.51	0.64	0.61	0.47
² SE of slope (kg DM/ha)	5.48	7.29	8.56	4.94	3.69
³ CCC	0.75	0.67	0.79	0.76	0.64
⁴ RPE (%)	27	26	25	24	30
Mean (kg DM/ha)	3247.5±41.79	3005.1±40.08	3276.1±69.23	2205.0±31.63	2909.6±25.59
<u>Plate meter</u>					
⁵ Regression (kg DM/ha)	1794.6+84.4x ^b	1752.4+95.0x ^b	1716.1+83.7x ^b	1019.8+75.50x ^a	1596.7+83.8x
R ²	0.57	0.52	0.53	0.63	0.49
² SE of slope (kg DM/ha)	4.03	4.63	6.59	3.41	2.53
³ CCC	0.72	0.69	0.69	0.77	0.66
⁴ RPE (%)	24	26	29	24	27
Mean (kg DM/ha)	3247.5±43.13	3005.1±39.33	3276.1±78.63	2205.0±30.77	2909.6±25.20
<u>Sward height vs Plate meter</u>					
⁶ Regression (cm)	2.4+0.65x ^{ab}	2.4+0.58x ^a	4.5+0.50x ^c	3.3+0.61x ^{bc}	2.8+0.60x
R ²	0.83	0.79	0.55	0.75	0.75
² SE of slope (cm)	0.02	0.02	0.04	0.02	0.01
³ CCC	0.91	0.88	0.71	0.86	0.86
⁴ RPE (%)	23	25	25	25	25
Mean (cm)	13.6±0.17	10.0±0.13	13.9±0.45	12.9±0.19	12.2±0.10

¹ kg DM/ha = dry matter + slope X average sward height (x). ⁶ sward height = sward height + slope X average plate meter reading (x).

²SE of slope, standard error of slope.

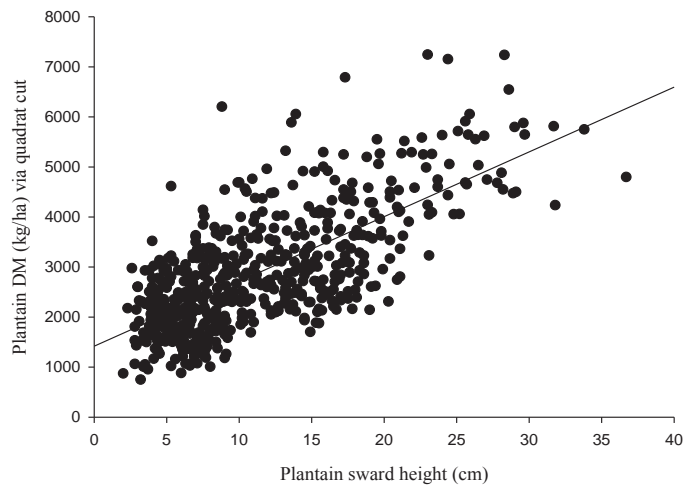
³CCC = Concordance Correlation Coefficient.

⁴RPE = relative prediction error = Mean Prediction Error/Mean of the observed values X 100 .

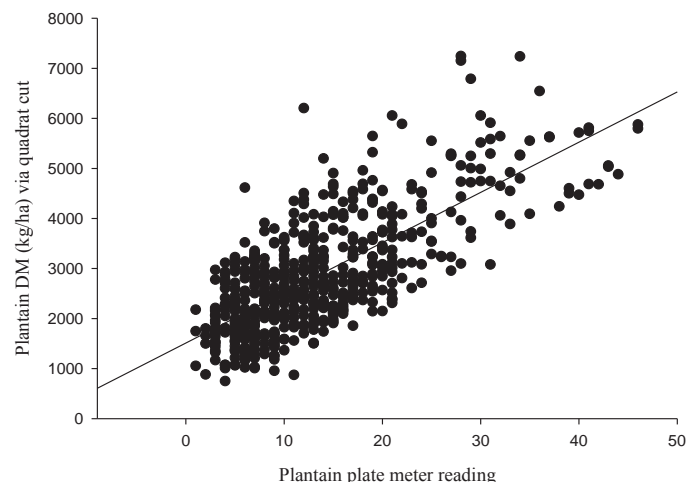
⁵ kg DM/ha = dry matter + slope X average plate meter reading (x).

Differing superscripts (a, b) within rows indicate means that were significantly different (P<0.05).

a)



b)



c)

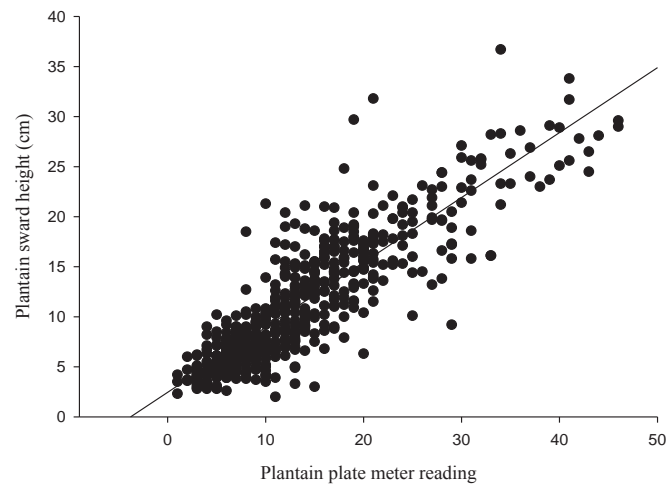
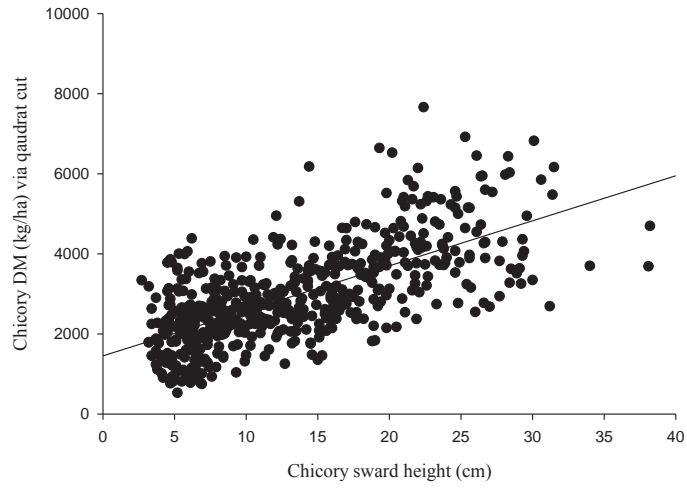
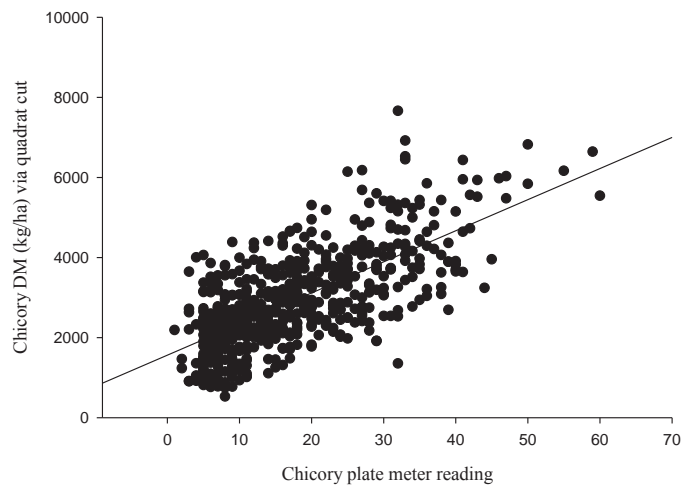


Figure 5-1: Scatter plots of the relationships between quadrat cut herbage DM mass vs sward height (a) and plate meter measurements (b) and sward height vs plate meter measurements (c) for the Plantain mix.

a)



b)



c)

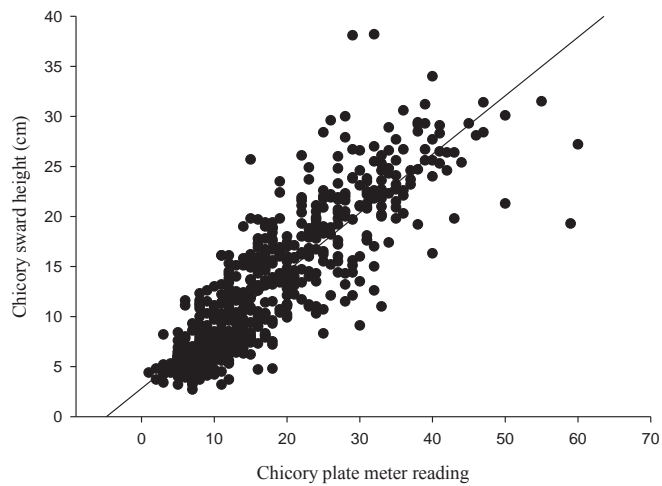


Figure 5-2: Scatter plots of the relationships between quadrat cut herbage DM mass vs sward height (a) and plate meter measurements (b) and sward height vs plate meter measurements (c) for the Chicory mix.

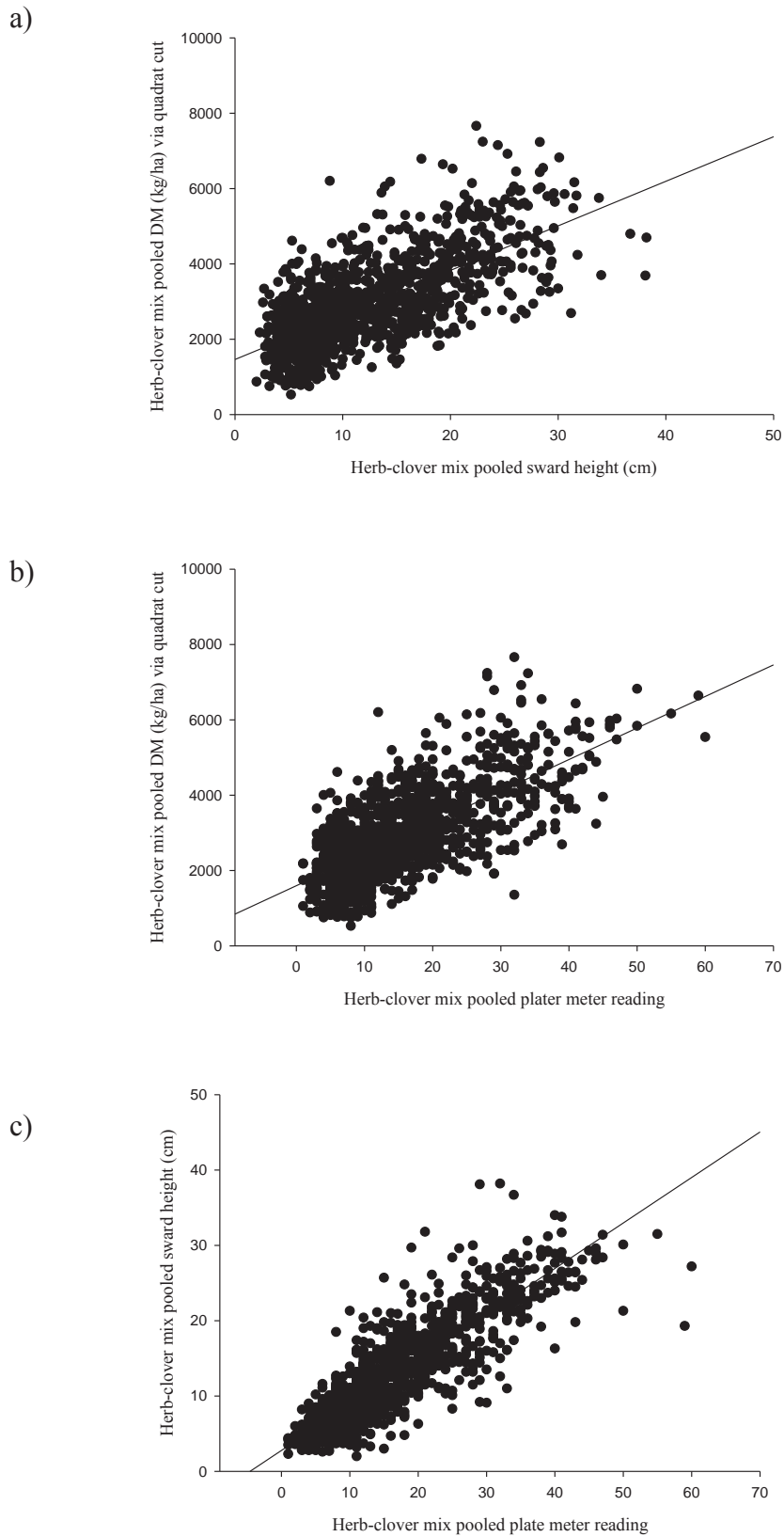


Figure 5-3: Scatter plots of the relationships between quadrat cut herbage DM mass vs sward height (a) and plate meter measurements (b) and sward height vs plate meter measurements (c) for herb-clover mix pooled (combined) sample.

5.6 Discussion

The aims of this chapter were to determine the regression relationships between quadrat cut herbage DM mass vs sward height and plate meter readings for the Plantain mix and Chicory mix and for the combined herb-clover mix and to determine whether the relationships were consistent across periods.

Across the individual Plantain and Chicory mixes and when both were combined the R^2 for all three relationships; herbage DM mass vs sward height and plate meter readings and the relationship between sward height and plate meter readings were positive and significant for all four periods, ranging from 0.49 to 0.86. Webby and Pengelly (1986) using ryegrass/white clover based pastures obtained R^2 values of 0.23, 0.61 and 0.76 for pre-grazed, post-grazed and pooled data for the relationship between sward height and herbage DM mass and R^2 values ranging from 0.56-0.76 from winter to autumn. Sanderson *et al.* (2001) observed an R^2 of 0.31 for herbage DM mass vs plate meter for grass/legume pastures. Piggot (1986) obtained R^2 values of 0.82-0.88 for the relationship between either total or grazable DM mass vs both sward height and plate meter for ryegrass/white clover pastures. Litherland *et al.* (2008) with ryegrass-based pastures obtained an R^2 of 0.44 for an annual linear regression equation between herbage DM mass vs sward heights and an R^2 of 0.43 for December-January period, 0.41 for March-May period, 0.55 for June-August period and 0.42 for September-November period. Litherland *et al.* (2008) also obtained an R^2 of 0.52 for an annual linear regression equation between herbage DM mass vs rising plate meter and R^2 values of 0.56, 0.61, and 0.50 for summer, spring and winter respectively for ryegrass-based pastures. The R^2 for all three relationships in the present study were higher than the values obtained by Litherland *et al.* (2008) but like Litherland *et al.* (2008), the values were different for

different periods. For sward heights higher R^2 values were observed during the summer and for plate meter readings higher R^2 values were observed during the autumn for all three sward types. The intercept of all regression equations were above 1000 kg DM/ha. The relationships developed by Webby and Pengelly (1986) for the ryegrass/white clover based pastures also started with an intercept of approximately 1000 kg DM/ha. Thus, it is evident that an intercept of zero is impractical due to the errors during measurements and the variations in the field conditions (Sanderson *et al.*, 2001). The presence of multiple species and dead matter in the Plantain and Chicory mixes may have caused a variation in the DM mass and sward height measurements and hence contribute to the variation in the linear regression intercepts and R^2 values across periods. The percentage of dead matter in the Plantain and Chicory mixes varied from 6-16% from spring to autumn with higher proportions in the summer in the present study. The data related to different herbage species and dead matter for each period in the Plantain and Chicory mixes were explained in detail in Chapter 4 and Chapter 6 Section A.

The concordance correlation coefficient (CCC) (Lin 1989) for all three relationships fell between 0.56 and 0.94 in the present study. If CCC is equal to '1' that means the prediction is a perfect positive agreement. Any CCC value above 0.60 has been considered as a substantial prediction (Fuentes-Pila *et al.*, 1996; Visser *et al.*, 2012). The relative prediction error (RPE) is the variation in the observed and predicted values as a percentage of the herbage DM mass. The coefficient of variation (CV) is a measure of the variation in the error rates as a percentage of mean herbage DM mass. Both RPE and CV ranged from 18% and 29%. Any RPE value above 20% has been considered as a poor prediction (Fuentes-Pila *et al.*, 1996). A generally acceptable CV range for pastures is 15-20% (Fulkerson and Slack 1993; Hodgson *et al.*, 1999; Sanderson *et al.*, 2001). The

relatively high error rates in the present study (Gabriels and Berg 1993) indicate variability in the data set used. Piggot (1986) obtained CVs in the range of 15-19% for total or grazable DM mass vs sward height and plate meter for ryegrass/white clover pastures. Murphy *et al.* (1995) obtained CV of 27% and 28% for the relationship between bluegrass (*Poa pratensis* L.)/white clover pastures pre-grazing herbage DM mass vs both sward height and plate meter respectively. Sanderson *et al.* (2001) observed 26% RPE and CV for grass/legume pasture herbage DM mass vs plate meter equations. The plate meter was designed for ryegrass/white clover pastures (Sanderson *et al.*, 2001) which might explain the higher CV in the herb-clover DM mass estimations as the actual weight of the plate meter may not be appropriate (Murphy *et al.*, 1995). The relatively high RPE and CV in the regression equations for sward heights could be due to the presence of seed head, stem materials and the variable heights of the multiple species within each sward type in this study (Webby and Pengelly 1986). The presence of dead matter, uneven ground, seasonal variation, treading damage and human error are known to contribute to the variation in equations such as these (Murphy *et al.*, 1995; Hodgson *et al.*, 1999; Sanderson *et al.*, 2001). The overall strength of regression equations are also dependant on the number of readings recorded with increased measurements increasing precision (Fulkerson and Slack 1993). The data set used in the present study consisted of both pre- and post-grazing measurements with 288 pre- and 288 post-grazing measurements for each sward type. Therefore, the present herbage DM mass predictions using either sward heights or plate meter readings can be used with a reasonable level of precision adequate to make satisfactory day-to-day grazing management decisions related to herb-clover mixes on farm. If this data set is combined with that of future studies further precision in the regression equations should occur.

The regression equations developed for herbage DM mass vs sward heights in the Plantain mix were similar between early spring and late spring but different from both summer and autumn which also differed. While, the regression equations for herbage DM mass vs plate meter in the Plantain mix were similar during early spring and late spring, and also during summer and autumn. However, the regression equations for early spring and late spring were different from the regression equations for summer and autumn. In contrast, in both the Chicory and the combined herb-clover mixes, the regression equations for the above relationships during early spring and late spring and summer did not differ but all were different from the autumn period. This variation indicates that farmers should consider utilising different equations for different periods of the year for accurate estimates of herbage DM mass in herb-clover mixes with the proviso that they can readily judge the appropriate time to change equations.

5.7 Conclusion

The results of this study indicate that herbage DM mass of Plantain and Chicory mixes and the combined herb-clover mix can be estimated using either the sward heights or plate meter readings. The regression equations developed in the present study by these non-destructive methods would enable farmers to obtain a reliable estimate of the herbage DM mass with a level of precision sufficient for making daily decisions related to grazing management on farms. The data suggest different regression equations need to be utilised for different periods of the year. Hence, farmers need to be able to judge the appropriate time to change equations.

**Chapter 6 : Herbage composition and selection of different herbage
species by the lambs**

Chapter 6 Section A

Effect of grazing on herbage botanical composition over two years in the Pasture mix, Plantain mix and Chicory mix

6.1 Section A: Abstract

A sward's botanical composition can influence lamb production. The botanical compositions of each treatment, Pasture mix, Plantain mix and Chicory mix were determined across five different periods (winter, early spring, late spring and early summer (late spring), summer and autumn) for two consecutive years. The aim was to determine if the management practice used in this thesis resulted in changes in the composition of the herbage treatments. White clover percentage decreased ($P < 0.05$) in the summer and autumn in the second year in all three treatments. The proportion of plantain declined in late spring and summer in both the Plantain and Chicory mixes in both years. The proportion of red clover in both herb-clover mixes and the proportion of chicory in the Chicory mix increased during the late spring to summer period in both years. Weed percentage in the Pasture mix increased ($P < 0.05$) towards the end of the second year but, decreased ($P < 0.05$) in the herb-clover mixes across both years. In conclusion, this study provides evidence to indicate that herb-clover mixes can persist as a multi-species mix over at least a two-year period.

Keywords: Botanical composition, Pasture mix, Plantain mix, Chicory mix

6.2 Introduction

Lamb meat production in New Zealand is mainly based on low cost but intensively managed high quality ryegrass/white clover pastures throughout the year (Valentine and Kemp 2007). However, pasture growth varies over different seasons within a year depending on temperature, rainfall and soil fertility (Valentine and Kemp 2007). Sward mixes that are productive across a range of conditions should be effective in providing feed requirements for finishing lambs (Kemp *et al.*, 2010) in comparison to mono species. This could help facilitate more consistent lamb production in New Zealand throughout the year.

Factors such as a sward's botanical and morphological composition including the percentage of grasses and legume, leaf and stem materials, dead matter and weeds and its growth and nutritive value in different seasons all influence lamb production (Lambert and Litherland 2000). The botanical composition of a sward can be altered depending on the grazing management system (Leaver 1987). For example herbs such as plantain and chicory are susceptible to both winter grazing and treading damage (Hume *et al.*, 1995; Stewart 1996; Clapham *et al.*, 2001; Li and Kemp 2005), which are likely to negatively affect their proportion within a mixed sward. However, in this thesis these herb-clover mixes were not grazed in winter. It is also known that the grazing behaviour of animals can change sward composition (Parsons *et al.*, 1994). Therefore, there is the potential for changes in the botanical composition of the sward mixes (Pasture mix, Plantain mix and Chicory mix) used in this thesis over the two year period. The present study examined the sward composition over two years. The aim was to determine if the management practice used in this thesis resulted changes in the composition in all herbage treatments.

6.3 Materials and methods

This research was conducted at the Moginie Pasture and Crop Research Unit, Massey University from June 2011 to June 2013. There were three treatments; Pasture mix (ryegrass and white clover), Plantain mix (plantain, white clover and red clover) and Chicory mix (plantain, chicory, white clover and red clover). Details related to the treatments, sowing rates, farmlets and weather conditions during the experiment are given in Chapter 3.

There were five different grazing periods for the Pasture mix (winter, early spring, late spring and early summer (late spring), summer and autumn) in two consecutive years. The Plantain and Chicory mixes had only four grazing periods (early spring, late spring and early summer (late spring), summer and autumn excluding winter) in two consecutive years. After each grazing period there was a rest period (see Chapter 7 Table 7-2) to allow herbage to re-grow before the commencement of the next grazing cycle. During the late spring to autumn period the Pasture mix paddocks were grazed with ewes from outside the experiment for five consecutive days, to clean-up the residual pasture and maintain the pasture quality. Table 6-1 indicates the total rainfall for each season.

6.3.1 Sample collection for botanical composition

For each grazing period, botanical composition was determined at the start and end of the experiment. Within each grazing period (winter, early spring, late spring, summer and autumn) herbage samples were collected from all the paddocks (replicates) to determine botanical composition. Even though the Plantain and Chicory mixes were not grazed during the winter, herbage samples were collected to determine botanical composition in this period.

As previously outlined in Chapter 3, twelve herbage samples each of 20 cm width using an electric hand shear, were cut at the ground level from each paddock (replicate). The twelve samples were mixed thoroughly and a 30 g sub-sample (per each paddock) was hand separated into individual species to determine the following proportions in each treatment. Pasture mix; ryegrass, white clover, weeds and dead matter (Figure 6-1). Plantain mix; plantain, white clover, red clover, weeds and dead matter; Chicory mix; plantain, chicory, white clover, red clover, weeds and dead matter (Figure 6-2). Further details regarding botanical composition of each period are given in Chapter 4 sections A to E.

All non-sown species within each treatment were classified as weeds but were not sorted into different weed or grass species. After separation, each portion was dried in a draught oven for at least 24 hours at 70⁰ C to determine the relative composition on a percentage dry matter basis. Botanical composition was determined for each paddock separately. Average composition of the nine paddocks per treatment was used as the botanical composition of each treatment for a given time point, either at start or end of the experiment.

Table 6-1: Ten year average and yearly total rainfall (mm) for each period.

Season	10 year average	Year one (2011/2012)	Year two (2012/2013)
Winter	275	261	300
Spring	295	316	143
Summer	197	259	163
Autumn	246	147	215

Source: National Institute of Water and Atmospheric Research (NIWA), AgResearch, Palmerston North, New Zealand. Weather station site was situated between $-40^{\circ} 38'$ S and $175^{\circ} 61'$ E and Network Number is E0536D approximately one km from the experimental site.

6.4 Statistical analysis

Each herbage treatment was analysed separately using proc GLM in SAS version 9.2 (SAS 2008). Botanical composition across years was analysed using a linear model with year, period, botanical composition at start and at end and the interaction between year and period as fixed effects. The means were separated using LSD procedure in proc GLM.

Correlation analysis was carried out using proc CORR to determine the correlation between variables; herbage DM mass, weed percentage and year for each treatment separately.



Figure 6-1: Different species in the Pasture mix.

(Note: grasses other than the ryegrass are considered as weeds).



Figure 6-2: Different species in the herbage treatments (Plantain or Chicory mixes).

(Note: all the other non-sown species including other grasses are considered as weeds).

6.5 Results

The results show the average botanical composition for each herbage treatment for each period.

6.5.1 Pasture mix

Year one

Higher ($P < 0.05$) percentages of ryegrass were observed in winter (74%) and early spring (73.2%) compared to late spring (64.2%), summer (56.8) and autumn (62.5%) (Figure 6-3). The white clover percentage was highest ($P < 0.05$) in summer (13%) compared to late spring (7.1%) and autumn (7.5%) which in turn were higher ($P < 0.05$) than in winter (4.4%). The weed percentage did not differ ($P > 0.05$) between periods. The dead matter percentages were higher ($P < 0.05$) in summer (15%) and autumn (12.6%) compared to early spring (7.3%) and winter (8.5%).

Year two

The ryegrass percentage was higher ($P < 0.05$) in autumn (73.3%) compared to winter (64.2%) which in turn was higher ($P < 0.05$) than in early spring (56.6%) (Figure 6-3). The lowest ($P < 0.05$) percentages of ryegrass were in late spring (47.1%) and summer (53.6%). A higher ($P < 0.05$) white clover percentage was observed in late spring (5.7%) compared to winter (2.4%) and summer (3.9%) with the lowest ($P < 0.05$) percentage in autumn (1.1%). The weed percentage was higher ($P < 0.05$) in late spring (35.5%) compared to early spring (30.1%) and winter (23.2%) which in turn had higher ($P < 0.05$) percentages than autumn (17%). The dead matter percentage in summer (14.3%) was higher ($P < 0.05$) than in autumn (8.7%).

Across years

The percentage of ryegrass in winter, early spring and in late spring during year two was lower ($P < 0.05$) compared to year one (Figure 6-3). The percentage of ryegrass was higher ($P < 0.05$) in autumn during year two compared to year one. The percentage of white clover in summer and autumn during year two were lower ($P < 0.05$) than in year one. In contrast, the weed percentage in winter, early spring, late spring and in summer of year two were higher ($P < 0.05$) than in year one. Dead matter composition did not change ($P > 0.05$) between the years.

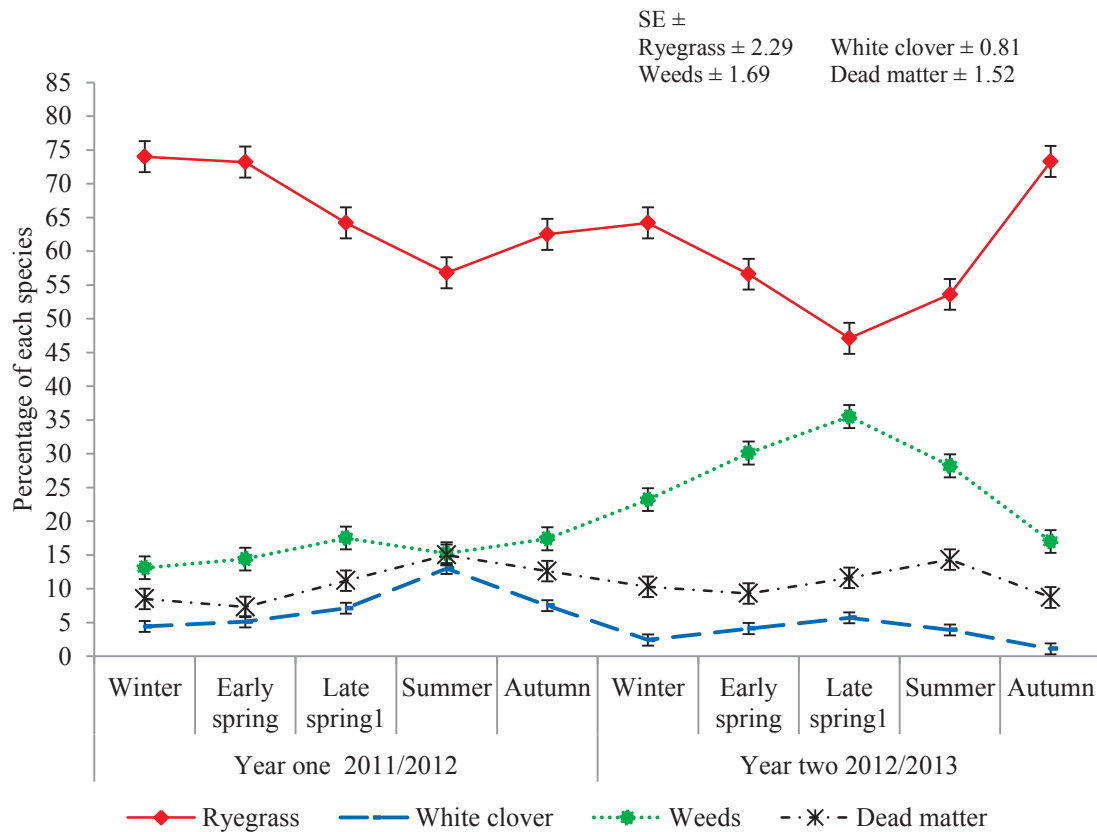


Figure 6-3: Botanical composition (%) within each year and across the two years in the Pasture mix.

¹Late spring and early summer.

6.5.2 Plantain mix

Year one

Higher ($P < 0.05$) percentages of plantain were observed in winter (57.6%) and early spring (52%) compared to summer (41.1%) (Figure 6-4). The plantain percentages in late spring (48.6%) and autumn (50.9%) did not differ ($P > 0.05$) to the other periods. The white clover percentage was higher ($P < 0.05$) in summer (19%) than autumn (14.6%) which in turn were higher ($P < 0.05$) than in winter (4.4%) and early spring (8.2%). The white clover percentage in late spring (16.2%) was higher ($P < 0.05$) than in winter and early spring. The red clover percentages were higher ($P < 0.05$) in late spring (13.3%), summer (19.5%) and in autumn (15.7%) than in winter (3.8%) and early spring (5.8%). The highest ($P < 0.05$) percentages of weed were observed in winter (33.7%) and early spring (33%) than in late spring (13.3%). The weed percentages in summer (6.4%) and autumn (7.5%) were lower ($P < 0.05$) than in winter and early spring. The dead matter percentages were higher ($P < 0.05$) in summer (14%) and autumn (11.3%) than in winter (0.6%) and early spring (0.9%).

Year two

The plantain percentage was higher ($P < 0.05$) in winter (61.6%) than in autumn (50%) which in turn were higher ($P < 0.05$) than in late spring (33.5%) and summer (32.4%) (Figure 6-4). The plantain percentage in early spring (52.9%) were higher ($P < 0.05$) than in late spring and summer. The white clover percentages were higher ($P < 0.05$) in winter (12.3%), early spring (16.3%) and in late spring (13.9%) than in summer (4.8%) and autumn (3.3%). The highest ($P < 0.05$) percentage of red clover was observed in summer (34.4%) compared to late spring (23.1%) which in turn were higher ($P < 0.05$) than in

winter (8.2%) and early spring (8%). The red clover percentage in autumn (27.2%) was higher ($P<0.05$) than in winter and early spring. The weed percentage did not differ ($P>0.05$) among the treatments. The dead matter percentage was highest ($P<0.05$) in summer (16%) than in late spring (13%) which in turn were higher than in winter (8.6%) and early spring (8.9%). The dead matter percentage in autumn (9.2%) was lower ($P<0.05$) than in summer.

Across years

The plantain percentage in late spring in year two was lower ($P<0.05$) than in late spring year one (Figure 6-4). The white clover percentages were higher ($P<0.05$) in winter and early spring in year two than in year one. The white clover percentages were lower ($P<0.05$) in summer and autumn in year two than in year one. The red clover percentages were higher ($P<0.05$) in early spring, late spring, summer and autumn in year two compared to year one. The highest ($P<0.05$) red clover percentage was observed in year two in summer. The highest ($P<0.05$) weed percentage was observed in year one in winter. The weed percentages were lower ($P<0.05$) in winter and early spring in year two than in year one. The dead matter percentages were higher ($P<0.05$) in winter, early spring and late spring in year two compared to year one.

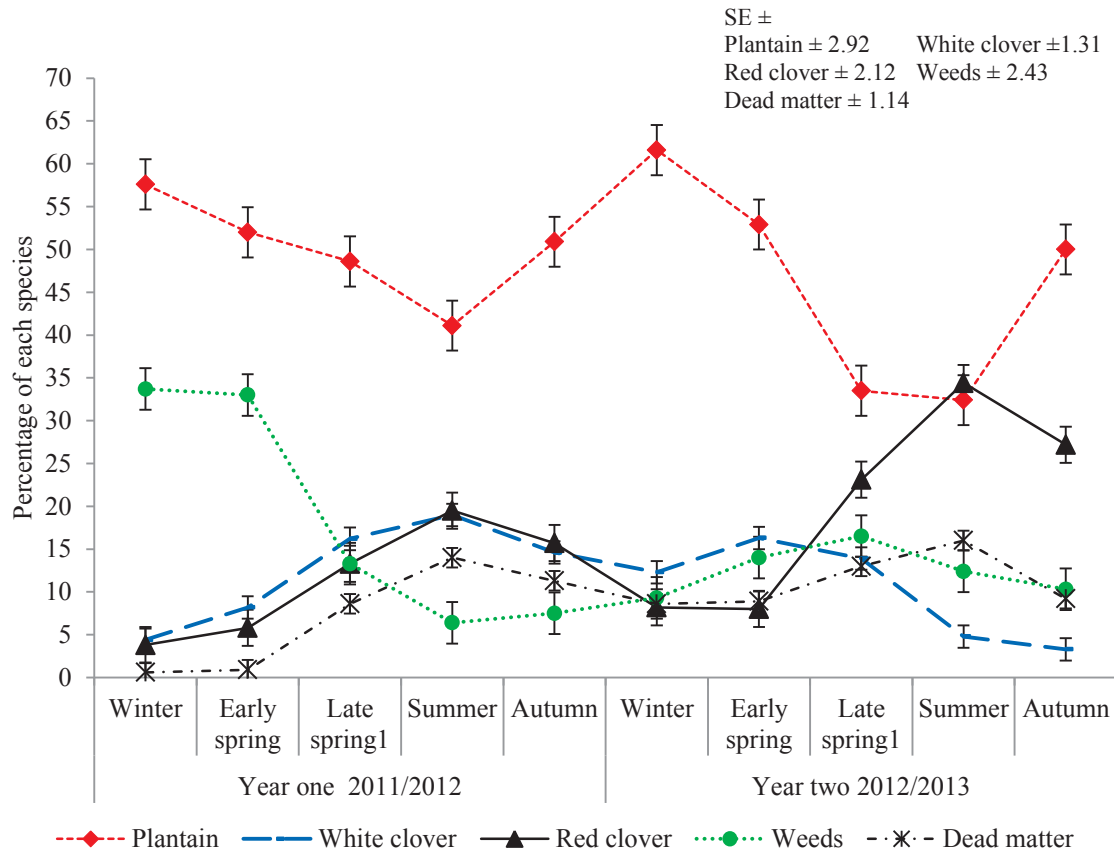


Figure 6-4: Botanical composition (%) within each year and across the two years in the Plantain mix.

¹Late spring and early summer.

6.5.3 Chicory mix

Year one

The chicory percentages were higher ($P < 0.05$) in summer (24.4%) and autumn (24%) than in winter (13.8%) and early spring (12.3%) (Figure 6-5). The chicory percentage in late spring (19.2%) did not differ ($P > 0.05$) between other periods. The highest ($P < 0.05$) plantain percentages were observed in winter (46.1%) and autumn (44.6%) than in late spring (33.2%) and summer (31.2%). The plantain percentage in early spring (38.2%) did

not differ ($P>0.05$) from other periods. The white clover percentages were higher ($P<0.05$) in late spring (15.5%) and summer (14.5%) than in early spring (9.4%) and autumn (9.3%) which in turn was higher ($P<0.05$) than in winter (4.2%). The red clover percentages were higher ($P<0.05$) in summer (11.2%) than in winter (3.3%) and early spring (6.5%). The red clover percentages in late spring (9.7%) and autumn (9.6%) were higher ($P<0.05$) than in winter. The weed percentages were higher ($P<0.05$) in winter (32.5%) and early spring (32.5%) than in late spring (13.5%) which in turn were higher ($P<0.05$) than in summer (4.8%) and autumn (2.8%). The highest ($P<0.05$) dead matter percentage was observed in summer (13.9%) than in late spring (8.9%) and autumn (9.7%) which in turn were higher ($P<0.05$) than in winter (0.1%) and early spring (1.1%).

Year two

Higher ($P<0.05$) chicory percentages were recorded in summer (41%) and autumn (42.1%) than in winter (23.1%), early spring (25.6%) and in later spring (30.6%) (Figure 6-5). The highest ($P<0.05$) plantain percentage was observed in winter (50.7%) compared to early spring (39.9%) which in turn was higher ($P<0.05$) than in late spring (26%) and summer (19.9%). The plantain content in autumn (33.2%) was higher ($P<0.05$) than in summer but lower ($P<0.05$) than in winter. The white clover percentage was higher ($P<0.05$) in early spring (12.6%) than in late spring (8.6%) which in turn was higher ($P<0.05$) than in summer (2.7%) and autumn (2.1%). The white clover percentage in winter (9.3%) was also higher ($P<0.05$) than in summer and autumn but did not differ ($P>0.05$) from early spring and late spring. The red clover percentages were higher ($P<0.05$) in summer (15.4%) and autumn (12.1%) than in winter (6.6%) and early spring (7.4%). The red clover percentage in late spring (11.3%) was higher ($P<0.05$) than in winter but not differ ($P>0.05$) from other periods. The weed percentage was higher

($P < 0.05$) in late spring (11.5%) than in winter (3.9%) and autumn (3.5%). The weed percentage in early spring (7.1%) and summer (8.5%) did not differ ($P > 0.05$) from other periods. The highest ($P < 0.05$) dead matter percentage was observed in late spring (11.9%) and summer (12.6%) compared to winter (6.3%), early spring (7.5%) and autumn (7%).

Across years

The chicory percentages in early spring, late spring, summer and autumn in year two were higher ($p < 0.05$) compared to year one (Figure 6-5). The plantain percentages in summer and autumn in year two were lower ($p < 0.05$) compared to year one. The white clover percentage in winter in year two was higher ($p < 0.05$) than in winter in year one. The white clover percentages in late spring, summer and autumn in year two were lower ($p < 0.05$) than in year one. The red clover percentage in summer in year two was higher ($p < 0.05$) than in year one. The weed percentages in winter and early spring in year two were lower ($p < 0.05$) than in year one. The highest ($P < 0.05$) weed content was observed in year one in winter and early spring. The dead matter percentages in winter, early spring and late spring in year two were higher ($p < 0.05$) than in year one. The dead matter percentage was lower ($P < 0.05$) in autumn in year two than in year one.

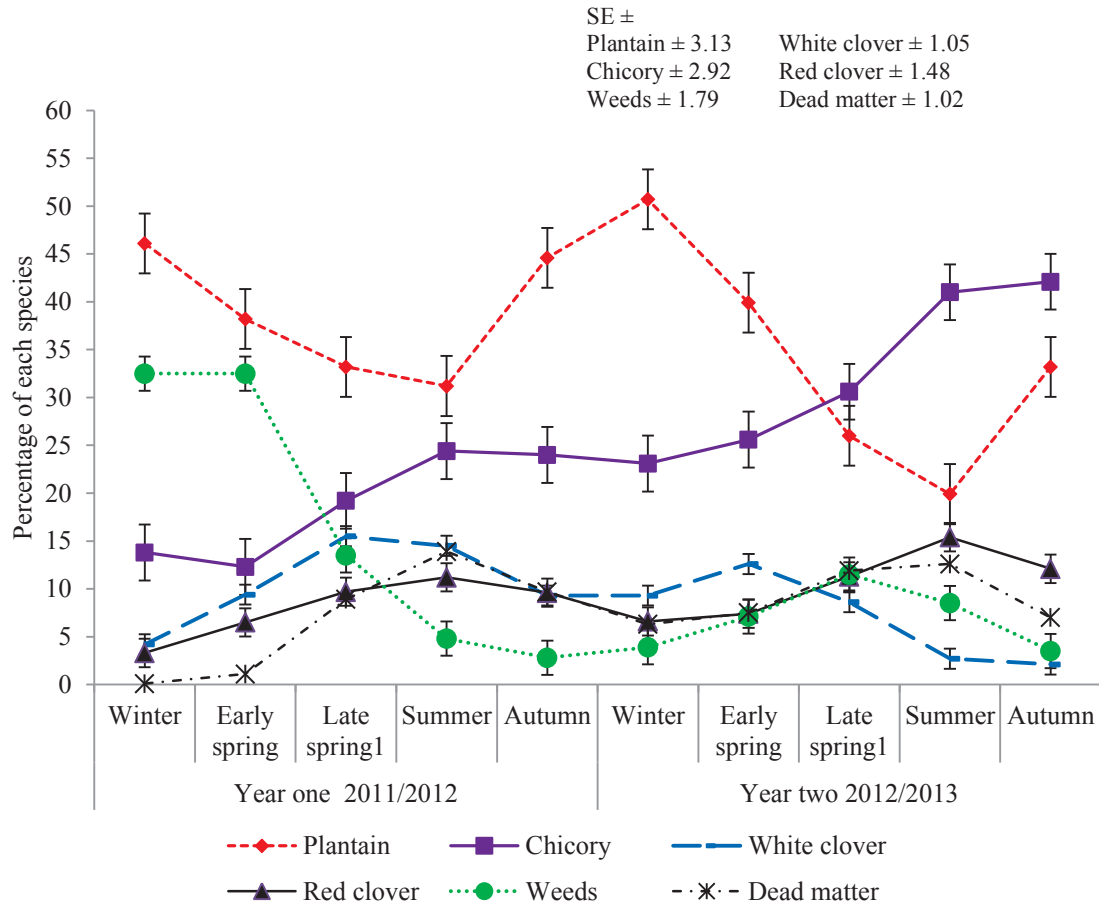


Figure 6-5: Botanical composition (%) within each year and across the two years in the Chicory mix.

¹Late spring and early summer.

6.5.4 Correlation between herbage DM mass (kg/ha) vs the weed percentage vs year

There was a positive correlation ($P < 0.05$) between herbage DM mass and weed percentage (Pearson correlation coefficient 0.24432 $p = 0.0009$) in the Pasture mix. In contrast, there was no correlation between the herbage DM mass and weed percentage in both the Plantain and Chicory mixes.

6.6 Discussion

The aim of this section was to determine if the management practice used in this thesis resulted changes in the composition in all herbage treatments.

Pasture mix

The proportion of ryegrass was higher during the spring period compared to the summer in both years. Hard grazing practised during the late spring and summer maintained a balanced composition between ryegrass and white clover as reported by Matthews *et al.* (1999). The proportion of the white clover content declined substantially over the summer and autumn in the second year. There was a drought in the North Island during summer of the second year (Anonymous 2014). McKenzie *et al.* (2006) observed that low rainfall levels in summer affected the growth of white clover. While, Kemp *et al.* (1999) stated that white clover has poor persistence when the annual rainfall is below 600 mm. Therefore, the low rainfall conditions may have been responsible for the poorer white clover persistence in the Pasture mix.

Plantain mix

It was observed, that the proportion of the plantain in the Plantain mix during late spring and summer in both years decreased but increased during winter, spring and autumn. This pattern suggests that plantain may prefer cooler temperatures and moist conditions as suggested by Stewart (1996) in comparison to drier conditions. In contrast, red clover being summer active (Kemp *et al.*, 1999) was higher in proportion during late spring to autumn but declined during winter and early spring. The white clover content was highest

during late spring and autumn in the first year and greatly declined after late spring in the second year and remained low. The main growth period of white clover is generally during spring and summer (Kemp *et al.*, 1999). As stated previously, the low rainfall conditions in the second year may have affected the persistence of white clover.

Chicory mix

In the Chicory mix, plantain was the major species in year one but in year two chicory dominated. As in the Plantain mix, the plantain content in the Chicory mix declined in proportion during summer in both years. In contrast, chicory and red clover were dominant in the Chicory mix in late spring and summer. Hume *et al.* (1995) and Kemp *et al.* (2010) stated that chicory and red clover are more productive in summer. The deep tap root allows chicory to be active in dry weather conditions (Li and Kemp 2005). This suggests that the Chicory mix was more productive during the summer than the Plantain mix (see Chapter 7 section 7.5.6 for verification of this). The white clover percentage declined in year two as indicated earlier most likely due to the low rainfall conditions.

Proportion of weeds in the three herbage treatments

The weed content increased until the late spring in the second year in the Pasture mix as the proportion of ryegrass reduced. There was a significant positive correlation between herbage DM mass and weed content in the Pasture mix in the present experiment. In contrast, there was no correlation between herbage DM mass and weed content in the Plantain and Chicory mixes. The density of plantain, chicory and the clovers may have reduced the invasion of weeds in the herb-clover mixes. However, plant density was not

measured in this thesis to verify this. Further, grazing pressure due to the rotational grazing management used may have controlled and manipulated the herbage and weed species in the Plantain and Chicory mixes (Matthews *et al.*, 1999). Although if this was the case a similar reduction in weed species might have been expected in the ryegrass/white clover mix.

Proportion of dead matter in the three herbage treatments

Dead matter percentage was highest in summer and autumn compared to winter and late spring in all three herbage treatments. Lambs may have been selectively grazing the green leaf material in the sward mixes leaving a greater portion of mature parts behind in the drier periods (Hodgson and Brookes 1999). Such selective grazing may have also created a ground cover of unpalatable materials towards the latter part of the grazing experiment. The poor herbage quality in the Pasture mix led to reduce stocking rates during summer and autumn (Fraser *et al.*, 1999; Matthews *et al.*, 1999). As a result, there was a greater opportunity for selective grazing to leave patches of un-grazed pasture in the Pasture mix. To ensure this issue was not made worse, during late spring, summer and autumn either after the first grazing rotation or at the end of each experimental period, the Pasture mix paddocks were grazed hard using mature ewes, to clean up the remaining poor quality herbage to maintain the pasture quality. It is known that grazing management whether hard grazing or lax, can impact on the accumulation of mature stems and leaf materials, weeds and dead matter (Buttler *et al.*, 1987). Plantain mix and Chicory mix paddocks were mowed in summer to remove tall weed species and unpalatable seed head stems during both years. This management practice may have also contributed to the increased dead matter percentage in summer in both mixes.

The Plantain and Chicory mixes persisted as multi species mixes during spring to autumn in both years under the grazing management system used. The proportion of the weed content in both the Plantain and Chicory mixes declined over time suggesting that the mixes became dense leaving less space for the invasion of other non-sown species as suggested by Sanderson *et al.* (2004) although, as indicated earlier this was not measured. It has been suggested that a critical factor for the persistence of the multi species herb mix is a two to three weeks rest period (Sulas 2004) between grazing before the commencement of the next experiment, allowing for these mixes to re-grow. The avoidance of the hard grazing of the herb-clover mixes by maintaining a post-grazing sward height of 7 cm and maintenance of a steady herbage cover in the herb-clover mixes by either selling lambs earlier or reducing the stocking rates where necessary, also likely ensured over grazing did not occur. In addition, these mixes were not grazed during winter, which is the dormant period of chicory and poor survival in winter can occur through grazing (Hume *et al.*, 1995; Clapham *et al.*, 2001; Li and Kemp 2005) especially in the loamy soil type being used. Li and Kemp (2005) stated that if the winter is wet and the soil is water logged herbs should not be grazed, thus enabling the crown to be protected from treading damage. Combined these factors may have assisted the persistence of these herb-clover mixes throughout the year and reduced the space for weed invasion. Having a mix of herbage that can tolerate a varying degree of climatic conditions enables the losses sustained by one species to be balanced by another over time (Cocks 2001; Sanderson *et al.*, 2004; Tracy and Sanderson 2004). Hence, in this experiment chicory and red clover survived and were productive in the drier period, which maintained a consistent herbage cover ensuring there was no space for the invasion of weeds. Future studies might wish to follow these herb-clover mixes for a longer time to determine if they remain multi species.

6.7 Conclusion

The proportion of plantain and/or chicory, white- and red-clover in the Plantain mix and the Chicory mix differed across time and enabled the Plantain and Chicory mixes to be productive during the early spring to autumn period across both years. However, the proportion of plantain declined in late spring and summer in both the Plantain and Chicory mixes in both years. This suggests that plantain prefers summer moist weather conditions rather than very dry weather conditions. The proportion of red clover in both herb-clover mixes and the proportion of chicory in the Chicory mix increased during the late spring to summer period in both years. This supports the earlier findings that both red clover and chicory survive and are productive in dry conditions. The white clover percentage decreased towards the summer and autumn in the second year in all three treatments most likely due to the very dry conditions that prevailed during the summer of the second year. The weed percentage in both herb-clover mixes decreased towards the end of the second year possibly due to the multi species mixes leaving less space for invasion of weeds. In conclusion, this study provides evidence that herb-clover mixes can persist as multi species mix over a two year period at least.

In the next section (Section B) of this chapter, the selection of different species by the lambs in the three herbage treatments in different periods in year one is discussed. It is possible that at least some of the changes observed in this section could be explained by animal selection.

Chapter 6 Section B

Do lambs proportionally select different plant species between different periods of the year?

6.8 Section B: Abstract

An experiment was carried out across four different periods of the year (early spring, late spring and early summer (late spring), summer and autumn) with lambs in the three herbage treatments (Pasture mix, Plantain mix and Chicory mix) to examine two hypotheses. The first hypothesis was that the most selected species in the herbage treatments would be white- and red-clover and that this selection would be maintained across the different periods. The second hypothesis was that the plantain in the Plantain mix and Chicory mix would be selected at a lower proportion than the other species and that this selection would be consistent in all four periods. Lambs selectively grazed a higher ($P < 0.05$) proportion of ryegrass than white clover plants in early spring however, there was no difference ($P > 0.05$) in the proportional selection in other periods in the Pasture mix. In the Plantain mix lambs grazed a higher ($P < 0.05$) proportion of red clover during late spring and summer and a higher ($P < 0.05$) proportion of plantain in summer than white clover. In the Chicory mix a higher ($P < 0.05$) proportion of red clover was grazed during late spring to autumn. A higher ($P < 0.05$) proportion of plantain and chicory were grazed than white clover in summer. During both early spring and summer, a higher ($P < 0.05$) proportion of white clover was grazed by both Plantain mix and Chicory mix lambs compared to the Pasture mix lambs. Red clover was the most selected species in the present experiment. In contrast to what was hypothesised, plantain was selected by the Plantain mix and Chicory mix lambs at varying proportions in different periods.

Keywords: Transects, Plantain, Chicory, White Clover, Red Clover, Selection

6.9 Introduction

There are two terms commonly used in grazing behaviour studies. These are ‘selection’ and ‘preference’. Selection is defined as ‘what an animal actually eats’ from a mixed sward depending on its availability, accessibility and palatability. Preference is ‘what an animal wants to eat’ when there is minimum physical constraints (Hodgson 1979; Parsons *et al.*, 1994; Rutter 2006). In a mixed sward parameters such as botanical composition, nutritive value, sward height, plant morphology, stage of growth and palatability of herbage and previous experience (Milne 1991; Newman *et al.*, 1992; Parsons *et al.*, 1994; Rutter 2006) all affect an animal’s choice to select a given herbage. Further, the choice of species selected on the first day can alter the species composition in a mixed sward and therefore the choices available in subsequent days (Parsons *et al.*, 1994). Thus, over time grazing choice (i.e. selection) can change.

There is considerable literature on diet selection and preference with ryegrass/white clover swards (Clark *et al.*, 1982; Milne 1991; Newman *et al.*, 1992; Parsons *et al.*, 1994; Rutter 2006). If given a choice sheep proportionally eat more white clover than ryegrass (Cosgrove and Edwards 2007). In contrast, there is a lack of information on preference, either between pure swards of forage herbs or in herb-clover mixes. In a preference study with monocultures of plantain, chicory and red clover under field conditions, Corkran (2009) observed that lambs grazed more red clover than chicory followed by plantain. Further, preference for plantain was greater in late autumn than in early autumn. Similar results have been observed in a diet selection study undertaken using a mixed sward of plantain, chicory and red clover. In that study, lambs also selected red clover over chicory followed by plantain (Corkran 2009). Pain *et al.* (2010) in an indoor study, where lambs were offered pure swards of plantain, chicory, red clover and ryegrass found that the

preference for both plantain and ryegrass were lower than the preference for red clover and chicory. Recently, Cave *et al.* (2014) examined diet selection within a herb-clover mix of plantain, chicory, white- and red-clover in four different seasons. They observed that lambs preferentially selected red clover from late spring to autumn. They also observed that selection differed between seasons and within species.

Previous studies have shown that the feeding value of white clover is superior to chicory which in turn is superior to red clover while ryegrass has a lower feeding value (Waghorn *et al.*, 2007). The feeding value of plantain has not been examined, but plantain can have high fibre content (Stewart 1996), which might suggest a lower feeding value. In addition the ME content in the white- and red-clover are generally higher than plantain (Lindsay *et al.*, 2007; Hayes *et al.*, 2010). Hence, the lower selection levels observed by Corkran (2009) and Pain *et al.* (2010) for plantain may not be surprising.

In this context, the following experiment was undertaken across four different periods of the year (early spring, late spring and early summer (late spring), summer and autumn) assuming lambs were unlikely to have experience with the herb-clover mixes and likely little experience with red clover. Three herbage treatments (Pasture mix, Plantain mix and Chicory mix) were examined with two hypotheses. The first hypothesis was that the most selected species in the herbage treatments would be white- and red-clover and that this selection would be maintained across the different periods. The second hypothesis was that plantain in the Plantain mix and Chicory mix would be selected at a lower proportion than the other species and that this low selection would be consistent in all four periods.

6.10 Materials and methods

6.10.1 Background

This experiment was undertaken in the three herbage treatments in the year June 2011 to June 2012 (Year one). The herbage treatments were Pasture mix (ryegrass/white clover), Plantain mix (plantain, white clover and red clover) and the Chicory mix (plantain, chicory, white clover and red clover). Details regarding these treatments and the lamb grazing experiments were given in Chapters 3 and 4. It was assumed lambs were unlikely to have any experience with the herb-clover mixes but they had grazed ryegrass and white clover and possibly traces of red clover before being introduced to the experiment. The experiment was undertaken in four different grazing periods of the year (early spring, late spring and early summer (late spring), summer and autumn).

6.10.2 Preparation of transects

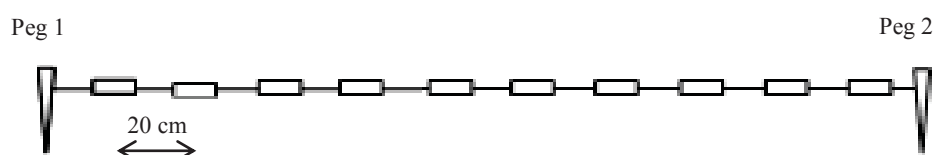


Figure 6-6: Design of a Transect.

Transects as illustrated in Figure 6-6 were used to randomly tag plants. The procedure was as follows. Two wooden pegs were placed randomly in the paddock at a distance of two meters. Then a metal rod, which had been marked with ten tapes each at 20 cm distance apart, was placed in between the two wooden pegs. Each tape was given a letter from A to J. The plant that was nearest to each tape was tagged at the base using a

coloured wire so that the plant was clearly visible (Figure 6-7). There were ten tagged plants per transect. Twenty transects were prepared within each randomly selected paddock in each period per herbage treatment. There was only one paddock used for each herbage treatment within each grazing period. Therefore, each herbage treatment had 20 transects with a total of 200 tagged plants.

Only the sown species within each herbage treatment were tagged. As an example weeds were not tagged. Hence, the Pasture mix had only two tagged species; ryegrass and white clover. The Plantain mix had three tagged species; plantain, white- and red-clover while, the Chicory mix had four tagged species; plantain, chicory, white clover and red clover.



Figure 6-7: Individually tagged plants.

6.10.3 Animal management

The stocking rates used for each period are given in Table 6-3. In each period, paddocks containing the transects were grazed at both the beginning of the grazing experiment and at the start of the second rotation, when lambs returned to the same paddock again. Thus, there were two transect readings per treatment in each period. At the first grazing the

herbs (plantain and chicory) would have been novel. At the second grazing within the same period (on average 22 to 29 days after the first grazing), lambs would have had experience with the herb species.

Each recording period was for three consecutive days. Each tagged plant was checked at 24 hour intervals to determine whether it had been eaten or not. If a leaf and/or leaves and/or reproductive material (flowers/panicles) or stem/s of the tagged plant were grazed partially or fully it was considered as eaten or grazed on the first day this was observed (Figures 6-8 and 10.4). When an individual plant was recorded as eaten it was not checked again. The outcome variable in this analysis was binary (0 or 1). If the tagged plant had been eaten or grazed it was given a notation of '1' and if the plant had not been eaten or grazed it was given a notation of '0'. Day one data were used to interpret the proportional selection of different species on the first day of each period when the lambs were introduced to the respective treatment for the first time. Day three data were used to determine whether the lambs had eaten more of a given species over the three day period. Day two data was not utilised. The aim was to determine within each herbage mix the proportion of the total available plants within a given species selected i.e. within the ryegrass/white clover, what proportion of the total clover tagged was consumed.

Thus, from this experiment the proportion of available ryegrass and white clover in the Pasture mix, available plantain, white- and red-clover in the Plantain mix and available plantain, chicory, white- and red-clover in the Chicory mix eaten by the lambs in each period could be ascertained.

Table 6-2. Stocking rate (no. of lambs/ha) used in different periods.

Treatment	Early spring	Late spring ¹	Summer ²	Autumn ²
Pasture mix	30	40	24	28
Plantain mix	30	40	40	32
Chicory mix	25	40	40	32

¹Late spring and early summer (2nd November to 19th December in 2011)

² including the population of farmlets ewes (two ewes/mob/treatment).

During each period different flocks of lambs were introduced.



Figure 6-8. Grazed individual plant.

6.11 Statistical analysis

All the data were analysed using Proc. GENMOD in SAS version 9.2 (SAS 2008). Each herbage treatment was analysed separately. Within each herbage treatment, the proportional selection of tagged species between different periods were analysed using period, and species and the interaction between period and species as fixed effects. The same model was used for day 1 and day 3.

A further model tested the proportional selection of tagged white clover across different periods using period, herbage treatment and the interaction between period and herbage treatment as fixed effects. This model was used for day 1 and day 3.

6.12 Results

The number of tagged plants per treatment was a representative sample of the botanical composition of that treatment during the respective period (see Chapter 6 Section A *Year one* and Tables 6-4 to 6-6).

Table 6-3: Total number and the percentages of different tagged plant species in the Pasture mix at the start of each grazing.

Period	Species		Total ⁴	Percentage values (%)	
	Rye ²	WC ³		Rye ²	WC ³
Early spring	173	27	200	86.5	13.5
Late spring ¹	176	24	200	88.0	12.0
Summer	147	53	200	73.5	26.5
Autumn	182	18	200	91.0	9.0

¹ Late spring and early summer (2nd November to 19th December in 2011).

² Number of tagged perennial ryegrass plants.

³ Number of tagged white clover plants.

⁴ Total number of tagged plants.

Table 6-4: Total number and the percentages of different tagged plant species in the Plantain mix at the start of each grazing.

Period	Species			Total ⁴	Percentage values (%)		
	Plantain	WC ³	RC ⁵		Plantain	WC ³	RC ⁵
Early spring	110	35	55	200	55.0	17.5	27.5
Late spring ¹	138	41	21	200	69.0	20.5	10.5
Summer	120	40	40	200	60.0	20.0	20.0
Autumn	152	17	31	200	76.0	8.5	15.5

¹ Late spring and early summer (2nd November to 19th December in 2011).

³ Number of tagged white clover plants.

⁴ Total number of tagged plants.

⁵ Number of tagged red clover plants.

Table 6-5: Total number and the percentages of different tagged plant species in the Chicory mix at the start of each grazing.

Period	Species				Total ⁴	Percentage values (%)			
	Plantain	chicory	WC ³	RC ⁵		Plantain	chicory	WC ³	RC ⁵
Early spring	117	55	14	14	200	58.5	27.5	7.0	7.0
Late spring ¹	102	48	22	28	200	51.0	24.0	11.0	14.0
Summer	79	66	24	31	200	39.5	33.0	12.0	15.5
Autumn	85	56	16	43	200	42.5	28.0	8.0	21.5

¹ Late spring and early summer (2nd November to 19th December in 2011).

³ Number of tagged white clover plants.

⁴ Total number of tagged plants.

⁵ Number of tagged red clover plants.

6.12.1 Proportional selection of tagged ryegrass and tagged white clover in different periods by the Pasture mix lambs

6.12.1.1 Proportional selection on day one across periods

Diet selection

The proportional selection was calculated for each species separately within each treatment and each period for day one and day three. The results are presented in the following section.

Between species

During early spring on day one, lambs proportionally grazed 43% of the available ryegrass and 22% of the available white clover (Figure 6-9 and Table 6-7). This shows that lambs selectively grazed a higher ($P < 0.05$) proportion of ryegrass than white clover plants in early spring. During late spring, summer and autumn there was no difference ($P > 0.05$) in the proportional selection of either ryegrass or white clover.

Within species

Lambs selectively grazed a higher ($P < 0.05$) proportion of ryegrass during early spring and autumn compared to late spring which in turn was higher ($P < 0.05$) than summer. A higher ($P < 0.05$) proportion of white clover were selectively grazed during early spring, late spring and autumn than summer.

6.12.1.2 Proportional selection on day three across periods

Between species

By the end of day three during the early spring, lambs proportionally grazed 89% of the available ryegrass and 76% of the available white clover (Figure 6-9 and Table 6-7). This shows that the lambs grazed a higher ($P < 0.05$) proportion of ryegrass than white clover. There was no difference ($P > 0.05$) in the proportional selection of these species during other periods.

Within species

A higher ($P < 0.05$) proportion of ryegrass was grazed during early spring than late spring which in turn was higher ($P < 0.05$) than autumn. Lambs grazed a higher ($P < 0.05$) proportion of white clover during early spring, late spring and autumn compared to summer.

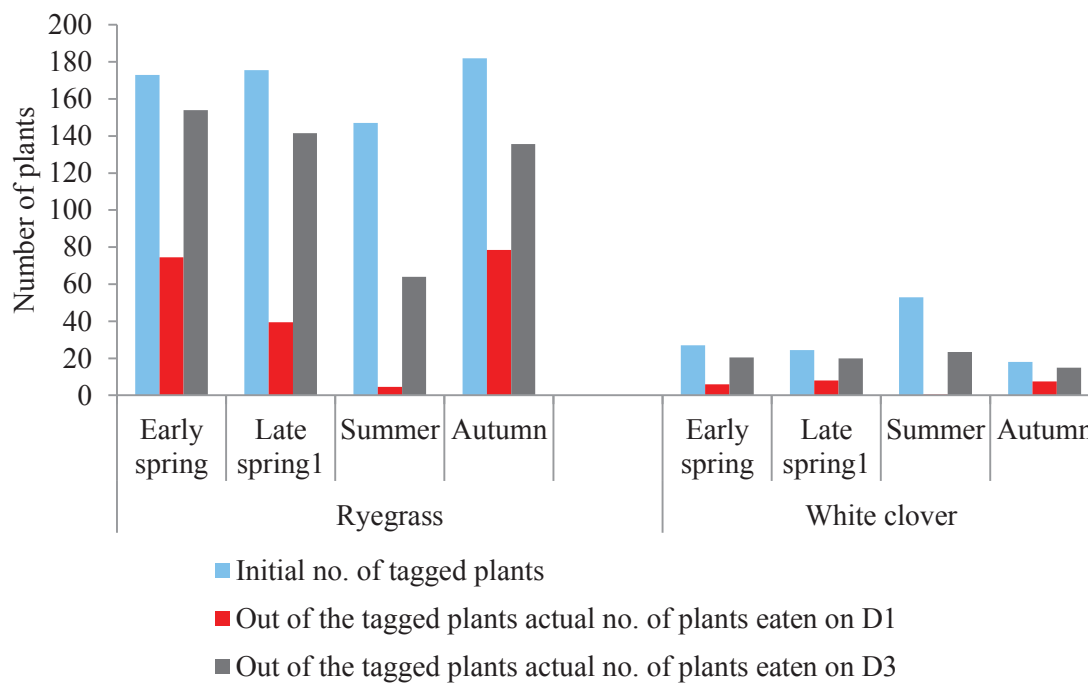


Figure 6-9: Number of tagged ryegrass and tagged white clover plants eaten by lambs on day one and day three during different periods in the Pasture mix.

¹Late spring and early summer (2nd November to 19th December in 2011).

Table 6-6: Proportional selection of tagged ryegrass and tagged white clover on day one and three during different periods by the Pasture mix lambs (logit lsmeans \pm se, back transformed percentages (%)) are given in brackets).

Day	Period	Species		Level of significance		
		Ryegrass	White clover	Species	Season	Species x season
One	Early spring	-0.28 ^{bz} \pm 0.11 (43%)	-1.25 ^{ay} \pm 0.33 (22%)	0.0002	<0.0001	0.0112
	Late spring ^l	-1.24 ^y \pm 0.13 (23%)	-0.72 ^y \pm 0.30 (33%)			
	Summer	-3.46 ^x \pm 0.34 (3%)	-4.65 ^x \pm 1.00 (1%)			
	Autumn	-0.28 ^z \pm 0.11 (43%)	-0.34 ^y \pm 0.34 (42%)			
Three	Early spring	2.09 ^{bz} \pm 0.17 (89%)	1.15 ^{ay} \pm 0.32 (76%)	0.0071	<0.0001	0.0559
	Late spring ^l	1.23 ^y \pm 0.14 (81%)	1.49 ^y \pm 0.37 (82%)			
	Summer	-0.26 ^w \pm 0.12 (44%)	-0.23 ^x \pm 0.20 (44%)			
	Autumn	1.07 ^x \pm 0.12 (74%)	1.61 ^y \pm 0.45 (83%)			

Within the period interaction given by differing superscripts (a,b) within rows indicates significant difference (P<0.05).

Between period interaction given by differing superscripts (w,x,y,z) within columns indicates significant difference (P<0.05).

^lLate spring and early summer (2nd November to 19th December in 2011).

6.12.2 Proportional selection of tagged plantain, white clover and tagged red clover by lambs in different periods in the Plantain mix

6.12.2.1 Proportional selection on day one across periods

Between species

During early spring on day one, lambs proportionally grazed 55% of the available plantain, 49% of the available white clover and 51% of the available red clover (Figure 6-10 and Table 6-8). However, this selective grazing was not different ($P>0.05$). During late spring lambs grazed a higher ($P<0.05$) proportion of available red clover than plantain and white clover. During summer lambs grazed a higher ($P<0.05$) proportion of available plantain and red clover compared to white clover. There was no difference ($P>0.05$) in the proportional selection of species during autumn.

Within species

A higher ($P<0.05$) proportion of available plantain was grazed during summer compared to early spring which in turn was higher ($P<0.05$) than late spring. Proportional selection of plantain was lowest ($P<0.05$) during autumn compared to other periods. There was no difference ($P>0.05$) in proportional selection of available white clover across all the periods. A higher ($P<0.05$) proportion of available red clover were grazed during late spring and summer compared to early spring and autumn.

6.12.2.2 Proportional selection on day three across periods

Between species

By the end of day three during early spring, lambs proportionally grazed 93% of the available plantain, 81% of the available white clover and 87% of the available red clover

(Table 6-8). Hence, during early spring lambs grazed a higher ($P < 0.05$) proportion of plantain than white clover (Figure 6-10 and Table 6-8). There was no difference ($P > 0.05$) in the proportional selection of available red clover in early spring. During summer, lambs grazed a higher ($P < 0.05$) proportion of available plantain and red clover than white clover. A higher ($P < 0.05$) proportion of available red clover was grazed than plantain and white clover during autumn.

Within species

Lambs grazed a higher ($P < 0.05$) proportion of available plantain during summer compared to early spring and late spring which in turn were higher ($P < 0.05$) than autumn. A higher ($P < 0.05$) proportion of available white clover was grazed during late spring compared to early spring and autumn. A higher ($P < 0.05$) proportion of available red clover was grazed during summer compared to early spring and autumn.

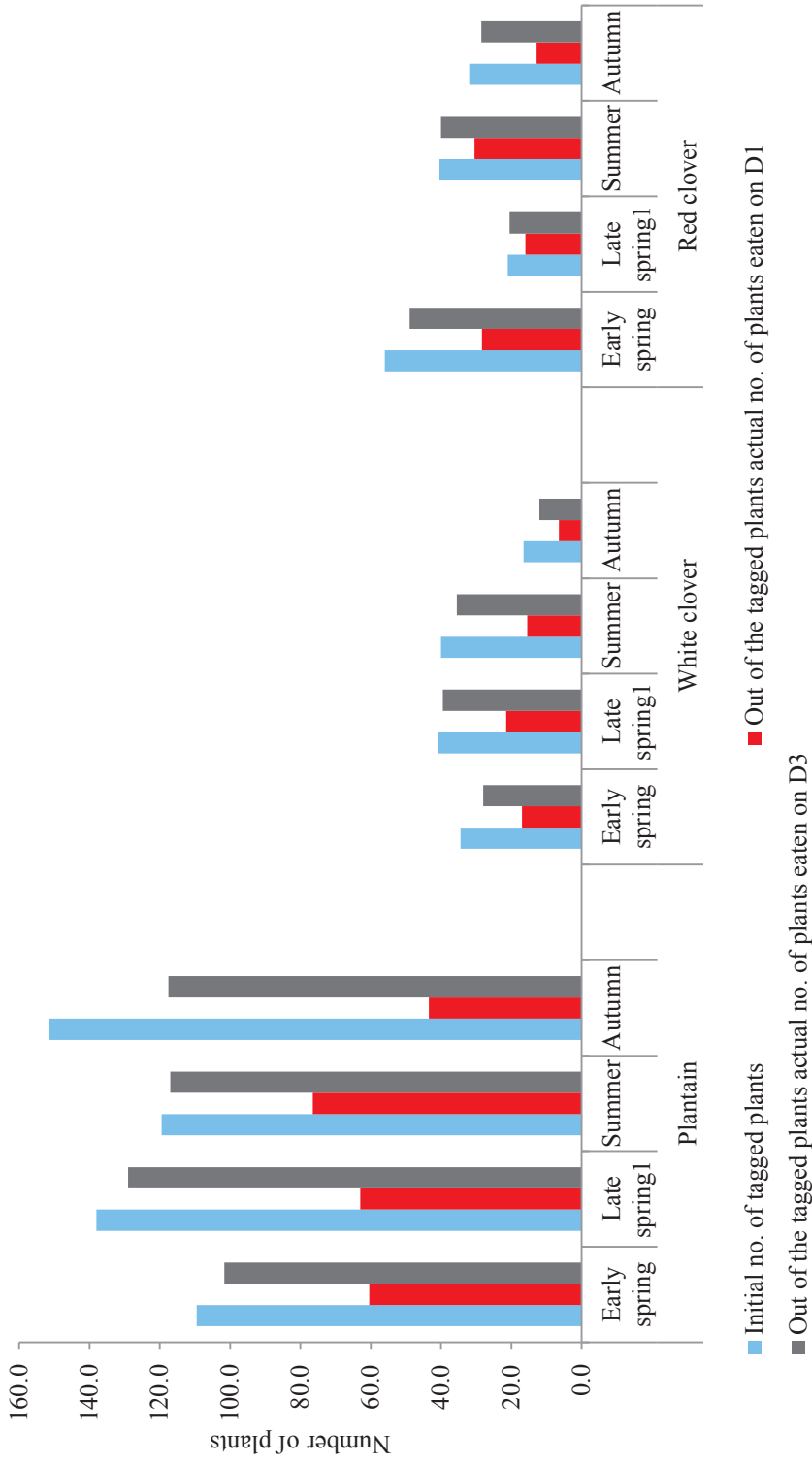


Figure 6-10: Number of tagged plantain, white- and red-clover plants eaten by lambs on day one and day three during different periods in the Plantain mix.

¹Late spring and early summer (2nd November to 19th December in 2011).

Table 6-7: Proportional selection of a species, tagged plantain, white clover and tagged red clover on day one and three during different periods by the Plantain mix lambs (logit lsmeans \pm se, back transformed percentages (%)) are given in brackets).

Day	Period	Species			Level of significance		
		Plantain	White clover	Red Clover	Species	Season	Species x season
One	Early spring	0.21 ^y \pm 0.13 (55%)	-0.03 \pm 0.24 (49%)	0.03 ^x \pm 0.23 (51%)	0.0020	<0.0001	<0.0001
	Late spring ¹	-0.17 ^{a x} \pm 0.12 (46%)	0.10 ^a \pm 0.22 (52%)	1.16 ^{b y} \pm 0.36 (76%)			
	Summer	0.58 ^{b z} \pm 0.13 (64%)	-0.46 ^a \pm 0.23 (39%)	1.12 ^{b y} \pm 0.26 (75%)			
	Autumn	-0.91 ^w \pm 0.13 (29%)	-0.43 \pm 0.36 (39%)	-0.58 ^x \pm 0.26 (36%)			
Three	Early spring	2.56 ^{b y} \pm 0.24 (93%)	1.46 ^{a x} \pm 0.31 (81%)	1.93 ^{ab x} \pm 0.34 (87%)	0.0856	<0.0001	0.0078
	Late spring ¹	2.66 ^y \pm 0.24 (93%)	0.96 ^y \pm 0.59 (96%)	3.71 ^{xy} \pm 1.01 (98%)			
	Summer	3.85 ^{b z} \pm 0.45 (98)	2.07 ^{a xy} \pm 0.35 (89%)	4.38 ^{b y} \pm 1.01 (99%)			
	Autumn	1.24 ^{a x} \pm 0.14 (78%)	0.98 ^{a x} \pm 0.39 (73%)	2.10 ^{b x} \pm 0.40 (89)			

Within the period interaction given by differing superscripts (a,b) within rows indicates significant difference (P<0.05).

Between period interaction given by differing superscripts (w,x,y,z) within columns indicates significant difference (P<0.05).

¹Late spring and early summer (2nd November to 19th December in 2011).

6.12.3 Proportional selection of tagged plantain, chicory, white clover and tagged red clover in different periods by the Chicory mix lambs

6.12.3.1 Proportional selection on day one across periods

Between species

During early spring on day one, lambs proportionally grazed 57% of the available plantain, 60% of the available chicory, 69% of the available white clover and 68% of the available red clover (Figure 6-11 and Table 6-9). This selection was not different ($P > 0.05$). During late spring lambs grazed a higher ($P < 0.05$) proportion of available red clover than plantain, chicory and white clover. During summer, a higher ($P < 0.05$) proportion of available red clover was grazed than plantain and chicory which in turn were proportionally grazed more ($P < 0.05$) than white clover. During autumn lambs grazed a higher ($P < 0.05$) proportion of available red clover than plantain and chicory. A higher ($P < 0.05$) proportion of available white clover was grazed than chicory in autumn.

Within species

Lambs grazed a higher ($P < 0.05$) proportion of available plantain during early spring, late spring and summer than autumn. A higher ($P < 0.05$) proportion of available chicory was grazed during early spring, late spring and summer than autumn and also, a higher ($P < 0.05$) proportion of chicory was grazed during summer than late spring. A higher ($P < 0.05$) proportion of available white clover were grazed during early spring, late spring and autumn than summer. Lambs grazed a higher ($P < 0.05$) proportion of available red clover during late spring and summer compared to autumn.

6.12.3.2 Proportional selection on day three across periods

Between species

By the end of day three during early spring, lambs proportionally grazed 96% of the available plantain, 97% of the available chicory, 93% of the available white clover and red clover, respectively (Figure 6-11 and Table 6-9). This selection was not different ($P < 0.05$). A higher ($P < 0.05$) proportion of available plantain and white clover were grazed than chicory during late spring. A higher ($P < 0.05$) proportion of available red clover was grazed than plantain and chicory which in turn were proportionally grazed more ($P < 0.05$) than white clover during summer. During autumn, a higher ($P < 0.05$) proportion of available plantain and red clover were grazed than chicory.

Within species

A higher ($P < 0.05$) proportion of available plantain was grazed during late spring than autumn. A higher ($P < 0.05$) proportion of available chicory was grazed during summer than late spring and in turn was proportionally grazed more ($P < 0.05$) than in autumn. A higher ($P < 0.05$) proportion of chicory was grazed during early spring than autumn. There was no difference ($P > 0.05$) in the proportional selection of available white clover in different periods. A higher ($P < 0.05$) proportion of available red clover was grazed during summer than early spring, late spring and autumn.

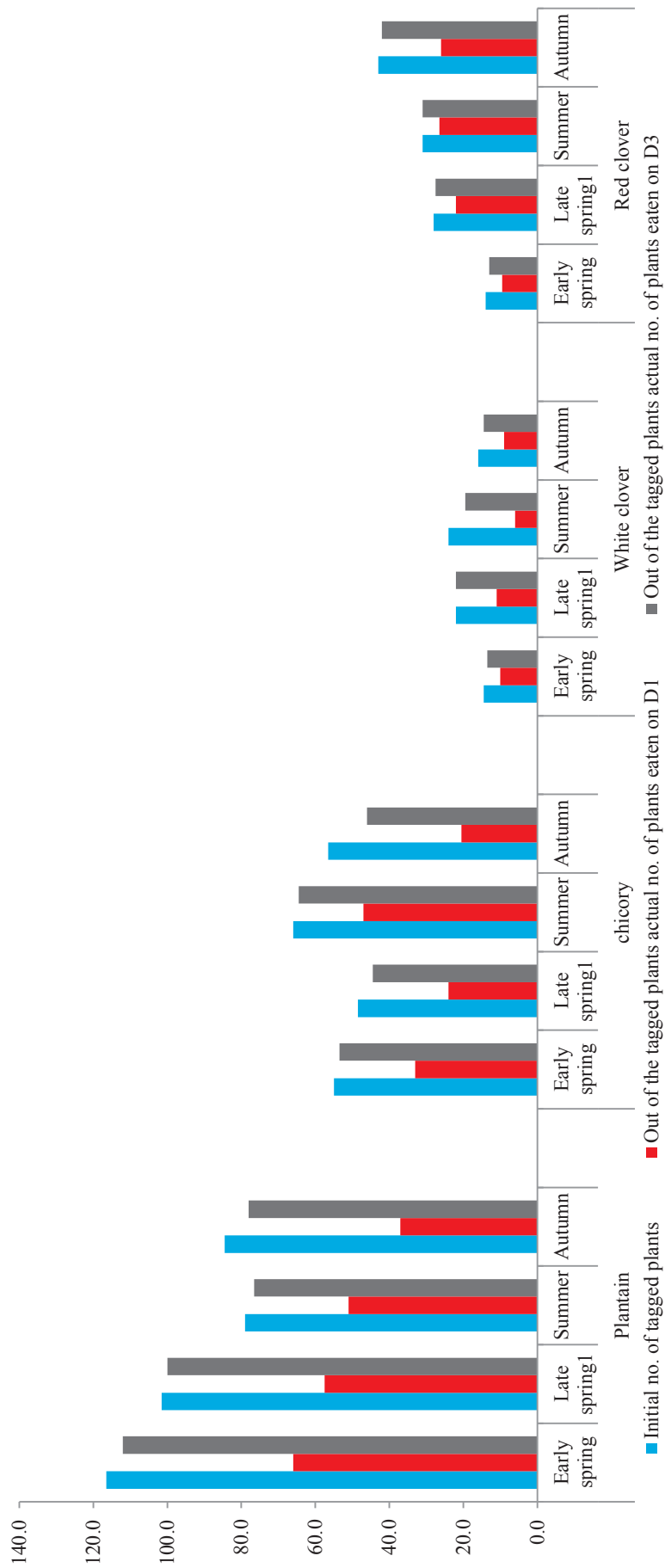


Figure 6-11: Number of tagged plantain, chicory, white- and red-clover plants eaten by lambs on day one and day three during different periods in the Chicory mix.

[†]Late spring and early summer (2nd November to 19th December in 2011).

Table 6-8: Proportional selection of a species, tagged plantain, chicory, white clover and tagged red clover on day one and three during different periods by the Chicory mix lambs (logit lsmeans \pm se, back transformed percentages (%)) are given in brackets).

Day	Period	Species				Level of significance		
		Plantain	Chicory	White clover	Red Clover	Species	Season	Species x season
One	Early spring	0.27 ^y \pm 0.13 (57%)	0.41 ^{yz} \pm 0.19 (60%)	0.80 ^y \pm 0.40 (69%)	0.75 ^{xy} \pm 0.40 (68%)	<0.0001	<0.0001	<0.0001
	Late spring ¹	0.27 ^{a,y} \pm 0.14 (57%)	-0.02 ^{a,y} \pm 0.20 (49%)	-0.00 ^{a,y} \pm 0.30 (50%)	1.30 ^{b,y} \pm 0.33 (79%)			
	Summer	0.60 ^{b,y} \pm 0.17 (65%)	0.91 ^{b,z} \pm 0.19 (71%)	-1.10 ^{a,x} \pm 0.33 (25%)	1.77 ^{c,y} \pm 0.36 (85%)			
	Autumn	-0.25 ^{ab,x} \pm 0.16 (44%)	-0.56 ^{a,x} \pm 0.20 (36%)	0.25 ^{bc,y} \pm 0.36 (56%)	0.42 ^{c,x} \pm 0.22 (60%)			
Three	Early spring	3.21 ^{xy} \pm 0.34 (96%)	3.57 ^{yz} \pm 0.59 (97%)	2.60 \pm 0.73 (93%)	2.56 ^x \pm 0.73 (93%)	0.0006	<0.0001	0.0003
	Late spring ¹	4.20 ^{b,y} \pm 0.58 (99%)	2.41 ^{a,y} \pm 0.37 (92%)	26.37 ^b \pm 0.93 (100%)	4.01 ^{ab,x} \pm 1.01 (98%)			
	Summer	3.42 ^{b,xy} \pm 0.45 (97%)	3.76 ^{b,z} \pm 0.58 (98%)	1.47 ^a \pm 0.37 (81%)	26.37 ^{c,y} \pm 1.01 (100%)			
	Autumn	2.48 ^{b,x} \pm 0.29 (92%)	1.48 ^{a,x} \pm 0.24 (81%)	2.27 ^{ab} \pm 0.61 (91%)	3.74 ^{b,x} \pm 0.72 (98%)			

Within the period interaction given by differing superscripts (a,b) within rows indicates significant difference (P<0.05).

Between period interaction given by differing superscripts (w,x,y,z) within columns indicates significant difference (P<0.05).

¹Late spring and early summer (2nd November to 19th December in 2011).

Table 6-9: Proportional selection of tagged white clover across all the periods between treatments (Pasture mix vs Plantain mix vs Chicory mix) (logit lsmeans \pm se, back transformed percentages (%)) are given in bracket).

Day	Period	Treatment			Level of significance		
		Pasture mix	Plantain mix	Chicory mix	Season	Treatment	Season x treatment
One	Early spring	-1.25 ^{a,y} \pm 0.33 (22%)	-0.03 ^b \pm 0.24 (49%)	0.80 ^{b,y} \pm 0.40 (69%)	<0.0001	<0.0001	<0.0001
	Late spring ^l	-0.72 ^{a,y} \pm 0.30 (33%)	0.10 ^b \pm 0.22 (52%)	0.00 ^{ab,y} \pm 0.30 (50%)			
	Summer	-4.65 ^{a,x} \pm 1.00 (1%)	-0.46 ^b \pm 0.23 (39%)	-1.10 ^{b,x} \pm 0.33 (25%)			
	Autumn	-0.34 ^y \pm 0.34 (42%)	-0.43 \pm 0.36 (39%)	0.25 ^y \pm 0.36 (56%)			
Three	Early spring	1.15 ^y \pm 0.32 (76)	1.45 ^x \pm 0.31 (81)	2.60 ^x \pm 0.73 (93)	<0.0001	<0.0001	0.0002
	Late spring ^l	1.49 ^{a,y} \pm 0.37 (82)	3.27 ^{b,y} \pm 0.59 (96)	25.37 ^{b,y} \pm 0.93 (100)			
	Summer	-0.23 ^{a,x} \pm 0.20 (44)	2.07 ^{b,xy} \pm 0.35 (89)	1.47 ^{b,x} \pm 0.37 (81)			
	Autumn	1.61 ^y \pm 0.45 (83)	0.98 ^x \pm 0.39 (73)	2.27 ^x \pm 0.61 (91)			

Within the period interaction given by differing superscripts (a,b) within rows indicates significant difference (P<0.05).
 Between period interaction given by differing superscripts (x,y) within columns indicates significant difference (P<0.05).
^lLate spring and early summer (2nd November to 19th December in 2011).

6.12.4 Proportional selection of tagged white clover plants across all the periods between treatments

6.12.4.1 Proportional selection on day one across periods

Between treatments

During early spring on day one, Pasture mix, Plantain mix and Chicory mix lambs proportionally grazed 22, 49 and 69% of the available white clover respectively (Table 6-10). During both early spring and summer a higher ($P<0.05$) proportion of available white clover was grazed by both Plantain mix and Chicory mix lambs compared to the Pasture mix lambs. The Plantain mix lambs grazed a higher ($P<0.05$) proportion of available white clover during late spring compared to the Pasture mix lambs.

Within treatments

The Pasture mix and Chicory mix lambs proportionally grazed more ($P<0.05$) available white clover during early spring, late spring and autumn compared to summer within each treatment. There was no difference ($P>0.05$) in the proportional grazing of available white clover within the Plantain mix lambs when compared across all periods.

6.12.4.2 Proportional selection on day three across periods

Between treatments

During early spring on day three, Pasture mix, Plantain mix and Chicory mix lambs proportionally grazed 76, 81 and 93% of the available white clover (Table 6-10).

During late spring and summer both Plantain mix and Chicory mix lambs grazed a higher ($P<0.05$) proportion of available white clover than Pasture mix lambs.

Within treatments

The Pasture mix lambs proportionately grazed more ($P<0.05$) available white clover during early spring, late spring and autumn compared to summer. The Plantain mix lambs proportionately grazed more ($P<0.05$) available white clover during late spring than early spring and autumn. Chicory mix lambs proportionally grazed more ($P<0.05$) available white clover during late spring than early spring, summer and autumn.

6.13 Discussion

This experiment had two hypotheses. The first hypothesis was that the most selected species in the herbage treatments would be white- and red-clover and that this selection would be maintained across the different periods. The second hypothesis was that the plantain in the Plantain mix and Chicory mix would be selected at a lower proportion than the other species and that this low selection would be consistent in all four periods. The day one results help explain which species lambs select proportionally when they have a free choice while day three results help give an insight as to how long the lambs should be left in a paddock before they begin to re-graze herbage and hence, may need to be shifted.

Pasture mix

The diet consisted of more ryegrass than white clover in all four periods. During early spring, lambs proportionally selected more ryegrass than white clover. Ryegrass quality is known to be higher in spring than summer (Hodgson *et al.*, 1999; Hyslop *et al.*, 2000). Selection is influenced by availability, accessibility and palatability (Hodgson 1979; Parsons *et al.*, 1994; Rutter 2006). This may suggest that the lambs proportionally grazed more ryegrass than white clover on the first day of early spring because it was abundantly available and of good quality. However, this selection of ryegrass over white clover on day one was not observed in the other three periods (late spring, summer and autumn) although in all periods ryegrass was the dominant species. It is unknown why this difference occurred. The relatively low proportion of white clover in all periods may help explain why it was not selected at a higher rate than ryegrass as hypothesised.

Within both species (ryegrass and white clover), each species was proportionally selected less in summer compared to the other periods. Although individual herbage quality parameters were not measured, the digestible organic matter digestibility, crude protein and soluble carbohydrates are generally higher and the neutral detergent fibre content is lower in ryegrass during spring and autumn than in summer (Hodgson and Brookes 1999). Further ME in summer is generally lower in ryegrass (Fulkerson *et al.*, 2007). This might help explain the low selection rate of ryegrass in summer. In contrast, the nutritive value of white clover is consistent throughout the year (Waghorn and Clark 2004; Stewart *et al.*, 2014) and hence, low nutritive value is not a reason for the low selection of white clover in this period. During summer the stocking rates were reduced in coincide with lower herbage predicted growth rates (Table 6-3). As a result, it is likely lambs had more chance to select ryegrass and white clover plants outside the tagged plants transects, which might help explain the low selection rates.

Lambs selected ryegrass over white clover on day three only in the early spring. After grazing consecutively for three days, more than 70% of the available ryegrass and white clover plants were eaten in all periods except in summer. This suggests that within a short time period lambs, would start to re-graze the already eaten herbage. This might begin to affect lamb performance and hence, consideration to move them might be needed.

The data do not suggest one species might be selected out of Pasture mix over time. Previous research has shown that the continuous selection of ryegrass and white clover can affect the sward's species composition (Milne 1991; Parsons *et al.*, 1994).

However to test this hypothesis long term multi-year studies would be required. In Chapter 6 Section A it was observed that the percentage of ryegrass decreased towards late spring in year two but started to increase there afterwards. In contrast, white clover increased up to summer period in year one but then decreased. It was also noted that over time, that the weeds percentage increased (Chapter 6 Section A).

Plantain mix

This mix was dominated by plantain. On day one, plantain, white- and red-clover had similar proportional selection by lambs during the early spring and autumn periods. While, in late spring lambs proportionally selected more red clover. In summer, both plantain and red clover were selected over white clover. Overall results indicate that, red clover was the most selected species as observed previously by Corkran (2009), Pain *et al.* (2010) and Cave *et al.* (2014) with herb-clover mixes. During late spring there was more white clover than red clover tagged in the transects. Yet red clover was selected proportionally over white clover. Cave *et al.* (2014) also found a similar result from late spring to autumn. The reasons for this proportional selection is unknown, because both white- and red-clover are both of high feed quality (Barry 1998; Brown *et al.*, 2005). It might be due to the easier access to red clover plants due to their erect growth habit (Rumball *et al.*, 1997; Kemp *et al.*, 1999) compared to the prostrate growth habit of white clover (Korte *et al.*, 1987). During summer, both white- and red-clover plants were tagged in similar proportions but again red clover was the most selected species. This also supports the findings of the late spring period.

The selection for plantain over white clover in summer was not expected. It might be due to plantain being a novel species and more abundantly available than white clover. Previous research has indicated that lambs can prefer novel feeds that are not usually within their diet (Parsons *et al.*, 1994). However, if that was the reason, then the same results would expect in other periods. As individual quality parameters were not measured in the present experiment, it is difficult to determine whether these results were due to the differences in herbage quality.

After grazing consecutively for three days, more than 70% of the available plantain, and white clover and 80% of the available red clover plants were eaten in all periods. Again, this suggests that lambs would start re-grazing the already eaten herbage and the lambs would need to be moved. It was observed that the selection for red clover at day three was higher in summer and autumn than in early spring and late spring. Though red clover was the most selected species over time in this mix, in general the percentage of red clover was found to increase over time in the Plantain mix in Chapter 6 Section A. This indicates that the proportional selection of red clover over plantain and white clover did not affect the red clover composition in the Plantain mix in the short to medium term at least.

Chicory mix

As observed in the Plantain mix and by Corkran (2009), Pain *et al.* (2010) and Cave *et al.* (2014) previously, in general red clover was the most selected species in the Chicory mix. The higher selection observed for both plantain and chicory in summer over white clover in the present experiment was in contrast to what Cave *et al.*

(2014) observed during that same period. The availability of chicory and plantain and their erect nature might explain their selection over white clover in this period. Cave *et al.* (2014) suggested that the lower availability of white clover in the upper strata may have resulted a poor selection of white clover during early spring and late spring periods. The Chicory mix paddocks were mowed during summer (details are given in Chapter 3) to remove seed heads and maintain the vegetative growth (Li and Kemp 2005; Labreveux *et al.*, 2006), offering lambs good quality vegetative herbage of chicory and plantain. This might also explain the higher selection of chicory and plantain in summer over white clover.

After grazing consecutively for three days, on average more than 90% of the available plantain, chicory, white- and red-clover plants were eaten in all the periods. This might suggest similar proportional selection of the different herbage species might have a very small effect on herbage botanical composition over time. However, the results in Chapter 6 Section A indicate that both red clover and chicory percentages increased and plantain and white clover percentages decreased in the Chicory mix over time. The reason for this is unknown but, it might have been due to the deep rooted plants surviving better in the dry summer. A longer term study using this mix would enable to understand, whether this effect would be continued.

Selection for white clover

At the start, the Pasture mix consisted of 9 to 26%, Plantain mix 8 to 20% and Chicory mix 7 to 12% of white clover. Plantain mix and Chicory mix lambs proportionally grazed more white clover on day one compared to the Pasture mix

lambs in the early spring to summer period. This may be due to white clover being more abundant and available in these herb-clover mixes compared to the Pasture mix. Autumn was the period in which white clover selection did not differ between herbage treatments. This could be due to the fact that, the herbage quality might be lower in other species. Ryegrass and plantain quality can be relatively poor during summer and autumn, however the quality of chicory and red clover is known to be higher during this period (Fraser and Rowarth 1996; Hodgson and Brookes 1999). Therefore, lambs might have selected white clover in similar proportions, as its nutritional quality is relatively higher. However, as explained earlier, individual quality parameters were not measured in the present experiment.

By day three in late spring, summer and autumn between 73 to 100% of white clover in the Plantain and Chicory mixes were grazed. While in the Pasture mix, approximately 80% of the white clover was grazed in late spring and autumn. However, in summer only 44% was grazed. As explained earlier, the reasons for lower white clover selection during summer might be the relatively greater choice available outside the transects plants due to lower stocking rates in this period. Continuous lamb grazing is known to affect the persistence of white clover (Orr *et al.*, 1990) and it was observed that white clover became proportionally lower in all three herbage treatments (Chapter 6 Section A). Although this could also be due to the drier conditions prevailed in the North Island during summer of the second year (Anonymous 2014), affecting the growth of white clover as explained in Chapter 6 Section A.

In the present experiment, the proportional selection of an individual species within the herbage treatment was determined. However, the relative abundance of each tagged species compared to the total number of tagged plants from all the species in the treatment as discussed by Cave *et al.*(2014) was not considered in the present analysis. If that had have been calculated, the proportional selection of each species could have been determined based on the initial proportion of each species in the herbage treatment. This type of analysis helps to explain whether the proportional selection was due to the species being more abundantly available in the treatment or else due to the species being selected by the animal. Hence, in future would be of benefit to undertake such an analysis.

6.14 Conclusion

Red clover was the most selected species in the present experiment as hypothesised. However, white clover was not selected as hypothesised across the herbage treatments. The reason for this may be due to its lower availability than the ryegrass in the Pasture mix and the erect growth habit and abundant availability of plantain, chicory and red clover in the Plantain and Chicory mixes.

In contrast to what was hypothesised, plantain was selected at varying proportions compared to the other species in all periods. This might be explained by plantain being readily available in both herb-clover mixes and having an erect growth habit. Interestingly, selection has had only a minor effect, if any on the herbage botanical composition in the short to medium term as shown in Chapter 6 Section A. Longer term research is needed to determine whether the proportional selection of different species by lambs affects the botanical composition in these herbage treatments.

**Chapter 7 : Seasonal influence on production aspects of finishing
lambs on herb-clover mixes (Plantain mix and Chicory mix)
compared to a Pasture mix**

**A part of this chapter was published in Proceedings of the 22nd International
Grassland Congress;**

SOMASIRI S. C., KENYON P. R., KEMP P. D., MOREL P. C. and MORRIS S. T. (2013)
Herb and clover mixes increase average daily gain (ADG) of finishing lambs in
different seasons. *Proceedings of the 22nd International Grassland Congress*, 575-
576.

7.1 Abstract

The aim of this chapter was to determine the seasonal influence on lamb final live weight, live weight gain (LWG), carcass weight, apparent carcass weight production per ha, feed conversion ratio (FCR) and efficiency of herbage utilization (EHU) in lambs either grazing herb-clover mixes (Plantain mix: plantain (*Plantago lanceolata*), white clover (*Trifolium repens*) and red clover (*Trifolium pratense*) and Chicory mix: plantain, chicory (*Cichorium intybus*), white clover and red clover) or Pasture mix; ryegrass (*Lolium perenne*)/white clover sward during the early spring to autumn period. Therefore, research was carried out during five periods (winter, early spring, late spring and early summer (late spring), summer and autumn) for two consecutive years, 2011/2012 and 2012/2013. Herb-clover mixes were not grazed during the winter period. Pasture mix was grazed in all five periods. At the end of the each period lambs were slaughtered at a commercial abattoir and carcass weights were obtained. Plantain and Chicory mixes produced heavier lambs, higher lamb daily live weight gains, higher lamb carcass weights and apparent carcass weight production per ha compared to the Pasture mix during the early spring to autumn period. The herb-clover mixes had higher net herbage accumulation rate (NHAR), organic matter digestibility (OMD%), metabolisable energy (ME) and lower neutral detergent fibre (NDF%) in the summer and autumn periods compared to the Pasture mix. Herb-clover mixes had lower feed conversion ratios (FCR) and higher herbage utilization efficiencies (EHU%) compared to the Pasture mix. Combined results indicate that the herb-clover mixes can be more effective than the Pasture mix during the early spring (September to October), late spring (October to December), Summer (January to February) and autumn (March to May).

Keywords: herb-clover mixes, live weight gain, apparent carcass weight production per ha, feed conversion ratio, efficiency of herbage utilization

7.2 Introduction

Chapter four examined herbage and lamb production during early spring to winter periods of the year (early spring, late spring and early summer (late spring), summer, autumn and winter). In this chapter, the overall seasonal effects on herbage and lamb production were evaluated. It is important to compare the lamb performance in different periods to test whether the lamb performance would vary depending on the period. The data will also provide the opportunity to compare the differences in lamb performance in both herb-clover mixes; Plantain mix and Chicory mix. Feed conversion ratio (FCR) and efficiency of herbage utilization (EHU) are important parameters to test whether the herb-clover mixes are more efficient in converting herbage to meat than the Pasture mix. Therefore, the first hypothesis of this chapter was that herb-clover mixes (Plantain and Chicory mixes) would have greater lamb production (live weights, LWG, carcass weights, apparent carcass weight production per ha) during early spring, late spring and early summer (late spring), summer and autumn periods compared to ryegrass/white clover sward (Pasture mix). Secondly, herb-clover mixes would have lower FCR and higher EHU in the above periods compared to the Pasture mix.

7.3 Materials and methods

Herbage treatments and the experimental methodology are explained in detail in Chapter 3. Details regarding the experimental design in each of the study period are given in Chapter 4. The stocking rates in each period and total number of lambs reared in each herbage treatment are presented in Table 7-1 while the number of grazing days and interval days between each study period are shown in Table 7-2.

Table 7-1: The stocking rate (lambs/ha) and number of lambs reared each period and year on the herbage treatments (Pasture mix vs Plantain mix vs Chicory mix).

Period	Year one			Year two		
	Pasture mix	Plantain mix	Chicory mix	Pasture mix	Plantain mix	Chicory mix
Winter	20	-	-	16	-	-
Early spring	30	30	25	32	32	32
Late spring ¹	40	40	40	40	40	40
Summer	24	40	40	24	24	32
Autumn	28	32	32	28	19	28
Total no. of lambs reared in each treatment	309	309	297	297	240	279

Note: Stocking rates in summer and autumn in year one and all the five periods in year two include some adult ewes (6 ewes/treatment/season) present to ensure parasitic contamination of pasture treatments.

¹Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two) and stocking rates were excluding the adult ewes.

Table 7-2: Number of grazing days and the interval days between each grazing period when no lambs were present.

	Winter	Early spring	Late spring ¹	Summer	Autumn	Total days
Grazing period (days)						
Year one	56	28	47	49	35	215
Year two	56	49	47	25	43	220
Interval between grazing (days)						
Year one	-	44*	28	23	28	123
Year two	49	21*	7	38	65	180

* Number of days interval after the previous winter experiment.

¹Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two).

7.4 Statistical analysis

Herbage data (pre- and post-grazing herbage dry matter (DM) mass, *in-vitro* OMD, ME and NDF) and lamb data (apparent herbage DM intake, initial and final live weight, live weight gain (LWG), carcass weight and apparent carcass weight production per ha) from the periods of early spring, late spring and early summer, summer and autumn were analysed together excluding winter data. Within each year, both herbage and lamb data were analysed using a linear model with herbage treatment and period and their interaction as fixed effects and the paddock or mob of lambs (replicate) effect nested within the herbage treatment x period interaction using proc GLM in SAS version 9.2 (SAS 2008). The mean values determined in the lamb initial and final live weights were the mean for each period (early spring, late spring and early summer, summer and autumn). Winter data were analysed using a simple ANOVA with herbage replicate or mob as a fixed effect using proc GLM for each experiment separately. The means were separated using LSD procedure in proc GLM.

Net herbage accumulation rate (NHAR) was calculated using the most recent pre-grazing and immediate previous post-grazing herbage DM masses and the interval days between the sample cuts within a paddock (Frame 1981; Matthews *et al.*, 1999). Net herbage accumulation rate (Table 7-8) was analysed by a linear model taking year, period, herbage treatment and their interactions as fixed effects using proc GLM in SAS. Curves were developed using the “ksmooth” function for “Kernel Smoother” technique in “stats” package in R statistical software (R Core Team 2013). This method was used because of the scattered nature of individual

observations and as the parametric distribution of NHAR was unknown for these herb-clover mixes.

Metabolisable energy (ME) was calculated by;

$$\text{ME} = \text{DOMD}\% \times 0.163 \text{ (Geenty and Rattray 1987).}$$

Apparent DM intake per lamb per day (Table 7-9) was calculated using the equation of Matthews *et al.* (1999). Where,

$$\text{Apparent DM intake per lamb per day} = \frac{\text{pre-grazing DM mass} - \text{post-grazing DM mass}}{\text{grazing intensity}}$$

and,

$$\text{grazing intensity} = \frac{\text{number of animals} \times \text{number of days}}{\text{area grazed}}$$

Apparent carcass weight production per ha (Table 7-14) for each season was calculated using the following equations.

$$\text{Estimated buy-in carcass weight} = \text{initial live weight} \times 40\%$$

$$\text{Final carcass weight per ha (A)} = \text{final carcass weight} \times \text{stocking rate}$$

$$\text{Estimated Buy-in carcass weight per ha (B)}$$

$$= \text{estimated buy-in carcass weight} \times \text{stocking rate}$$

A 40% dressing-out percentage (Kirton *et al.*, 1984) and initial live weight were used to calculate estimated buy-in carcass weight.

Therefore, the apparent carcass weight production per ha = A-B

Feed Conversion Ratio (FCR) was calculated on dry matter (DM) basis using the following equations (Table 7-15).

$$\text{FCR} = \frac{\text{Total feed required for maintenance + growth (kg DM per ha) (C)}}{\text{Total live weight gain per ha (kg per ha)(D)}}$$

where, total feed requirement for lamb maintenance and growth (C) were calculated using the assumptions given below with reference to Nicol and Brookes (2007).

The metabolisable energy (ME) requirement for maintenance of lambs

eg. 40 kg lamb = 8.0 MJ ME/day and 50 kg lamb = 9.5 MJ ME/day

The ME requirement for growth (live weight gain of lambs)

eg. 35 kg lamb = 3.0 MJ ME/100 g LWG and 45 kg lamb = 3.5 MJ ME/100 g LWG

therefore, the total feed (kg DM/ha) requirement for maintenance + growth of lambs was (C);

$$= \frac{\text{ME requirement for maintenance/lamb} + \text{ME requirement for growth/lamb}}{\text{ME content of the herbage treatment}} \times \text{SR}$$

SR = stocking rate and,

Total live weight gain per ha kg/ha (D)

$$= [\text{end live weight (kg)} - \text{initial live weight (kg)}] \times \text{SR (lambs/ha)}$$

Efficiency of herbage utilization (EHU) was calculated using the following equations (Table 7-16).

$$\text{EHU} = \frac{\text{Total feed required for maintenance + growth (kg DM per ha) (E)}}{\text{Apparent herbage utilization (AHU) (kg DM per ha) (F)}} \times 100$$

where, ME requirement for *maintenance of lambs*;

$$= W^{0.75} \text{ (kg/lamb)} \times \text{SR (lambs/ha)} \times \text{no.of days reared (days)} \times 0.5 \text{ MJ ME/kg/day}$$

$W^{0.75}$ = metabolic live weight (kg)

it was assumed that 0.5 MJ ME/kg $W^{0.75}$ /day as the ME requirement for maintenance per lamb (Nicol and Brookes 2007).

where ME requirement for *growth of lambs*;

$$= \text{LWG (kg/lamb)} \times \text{ME required for growth/lamb (MJ ME/kg)} \times \text{SR (lambs/ha)}$$

it was assumed 35 kg lamb used = 3.0 MJ ME/100 g LWG and 45 kg lamb used = 3.5 MJ ME/100 g LWG (Nicol and Brookes 2007).

where, AHU (F) for lambs for each season or experimental period was calculated by using;

$$\text{AHU (F)} = \text{Apparent herbage intake (kg DM/ha)} \times \text{Total herbage growth (kg DM/ha)}$$

Where;

Apparent herbage intake (kg DM/ha)

$$= \text{pre-grazing herbage DM mass} - \text{post-grazing herbage DM mass}$$

and

$$\text{Total herbage growth} = \text{herbage growth per day} \times \text{duration of the grazing period}$$

7.5 Results

7.5.1 Pre-grazing herbage DM mass between periods

Across herbage treatments

There was no difference ($P>0.05$) in the pre-grazing herbage DM mass in the early spring period between the treatments during both years (Table 7-3). Pasture mix had greater ($P<0.05$) pre-grazing herbage DM mass compared to both Plantain and Chicory mixes in late spring and in autumn during year one. During year one in summer, Pasture had greater ($P<0.05$) pre-grazing herbage DM mass compared to Plantain mix which in turn had greater ($P<0.05$) pre-grazing herbage DM mass than the Chicory mix. During year two in late spring and in summer, Pasture mix had greater ($P<0.05$) pre-grazing herbage DM mass compared to both Plantain and Chicory mixes. During year two in autumn, Pasture mix had greater ($P<0.05$) pre-grazing herbage DM mass compared to Plantain mix.

Within herbage treatments

In the Pasture mix during year one in autumn, pre-grazing herbage DM mass was greater ($P<0.05$) than in summer which in turn was greater ($P<0.05$) than in late spring (Table 7-3). Lowest ($P<0.05$) pre-grazing herbage DM mass was observed in early spring in the Pasture mix. During year two, pre-grazing herbage DM mass was greater ($P<0.05$) in both late spring and summer than in early spring which in turn was greater ($P<0.05$) than in autumn.

In Plantain mix during year one in both summer and autumn, pre-grazing herbage DM mass was greater ($P < 0.05$) than in both early spring and late spring. Pre-grazing herbage DM mass during year two in early spring, late spring and in summer was greater ($P < 0.05$) than in autumn for Plantain mix.

In the Chicory mix during year one in both summer and autumn, pre-grazing herbage DM mass was greater ($P < 0.05$) than both early spring and late spring. Pre-grazing herbage DM mass during year two in early spring, late spring and in summer were greater ($P < 0.05$) than in autumn.

Table 7-3: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on pre-grazing herbage DM mass within each of the five study periods (winter, early spring, late spring and early summer, summer and autumn) (mean \pm s.e.).

Period	Pre- grazing herbage DM mass (kg/ha)		
	Pasture mix	Plantain mix	Chicory mix
<i>Year one 2011/2012</i>			
Winter	1800.0 \pm 59	*	*
Early spring	2438 ^w \pm 226	2901 ^x \pm 202	2954 ^x \pm 202
Late spring ¹	4150 ^{b x} \pm 202	2963 ^{a x} \pm 165	2643 ^{a x} \pm 158
Summer	4749 ^{c y} \pm 202	4243 ^{b y} \pm 155	3649 ^{a y} \pm 155
Autumn	6131 ^{b z} \pm 226	4138 ^{a y} \pm 175	3964 ^{a y} \pm 202
<i>Year two 2012/2013</i>			
Winter	3280 \pm 91	*	*
Early spring	4155 ^y \pm 201	4102 ^y \pm 201	3949 ^y \pm 201
Late spring ¹	5277 ^{b z} \pm 188	3770 ^{a y} \pm 188	3719 ^{a y} \pm 188
Summer	5314 ^{b z} \pm 301	4223 ^{a y} \pm 301	4279 ^{a y} \pm 301
Autumn	3426 ^{b x} \pm 213	2571 ^{a x} \pm 213	2856 ^{ab x} \pm 213

Differing superscripts (a,b,c) within rows and years indicate means that were significantly different (P<0.05).

Differing superscripts (w,x,y,z) within columns and years indicate means that were significantly different (P<0.05).

¹ Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two).

* No lambs present.

7.5.2 Post-grazing herbage DM mass between periods

Across herbage treatments

There was no difference (P>0.05) in the post-grazing herbage DM mass in early spring between herbage treatments during both years (Table 7-4). Pasture mix had greater (P<0.05) post-grazing herbage DM mass compared to both Plantain and Chicory mixes in late spring, and in summer during both years and in autumn during

year two. During year one in autumn, Pasture mix had greater ($P<0.05$) post-grazing herbage DM mass compared to the Plantain mix which in turn had greater ($P<0.05$) post-grazing herbage DM mass than the Chicory mix.

Table 7-4: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on post-grazing herbage DM mass within each of the five study periods (winter, early spring, late spring and early summer, summer and autumn) (mean \pm s.e.).

Period	Post-grazing herbage DM mass (kg/ha)		
	Pasture mix	Plantain mix	Chicory mix
<i>Year one 2011/2012</i>			
Winter	1466 \pm 48	*	*
Early spring	1544 ^x \pm 205	1344 ^x \pm 184	1457 ^x \pm 184
Late spring ¹	3065 ^b ^y \pm 184	1890 ^a ^y \pm 150	1866 ^a ^x \pm 144
Summer	3543 ^b ^y \pm 184	2768 ^a ^z \pm 140	2419 ^a ^z \pm 140
Autumn	4209 ^c ^z \pm 205	2789 ^a ^z \pm 159	2294 ^a ^y \pm 184
<i>Year two 2012/2013</i>			
Winter	2449 \pm 79	*	*
Early spring	2905 ^x \pm 150	2617 ^y \pm 150	2540 ^y \pm 150
Late spring ¹	3870 ^b ^y \pm 141	2331 ^a ^y \pm 141	2355 ^a ^y \pm 141
Summer	4085 ^b ^y \pm 226	2104 ^a ^y \pm 226	2498 ^a ^y \pm 226
Autumn	2536 ^b ^x \pm 159	1650 ^a ^x \pm 159	1744 ^a ^x \pm 159

Differing superscripts (a,b,c) within rows and years indicate means that were significantly different ($P<0.05$).

Differing superscripts (x,y,z) within columns and years indicate means that were significantly different ($P<0.05$).

¹Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two).

* No lambs present.

Within herbage treatments

In the Pasture mix during year one in autumn, post-grazing herbage DM mass was greater ($P<0.05$) than in both late spring and summer which in turn was greater ($P<0.05$) than in early spring (Table 7-4). During year two, in late spring and summer post-grazing herbage DM mass was greater ($P<0.05$) than in both early spring and autumn.

In the Plantain mix during year one in both summer and autumn, post-grazing herbage DM mass was greater ($P<0.05$) than in late spring, which in turn was greater ($P<0.05$) than in early spring. During year two in early spring, late spring and in summer all had greater ($P<0.05$) post-grazing herbage DM mass than in autumn.

In the Chicory mix during year one in summer, post-grazing herbage DM mass was greater ($P<0.05$) than autumn which in turn was greater ($P<0.05$) than in both early spring and late spring. During year two, in early spring, late spring and in summer all had greater ($P<0.05$) post-grazing herbage DM mass than in autumn.

7.5.3 *In-vitro* organic matter digestibility (OMD) between periods

Across herbage treatments

During year one in early spring and in summer, both Plantain and Chicory mixes had greater ($P<0.05$) OMD % than the Pasture mix (Table 7-5). During year one in both, late spring and autumn Chicory mix had greater ($P<0.05$) OMD % than the Plantain mix which in turn had greater OMD % than the Pasture mix. During year two, both Plantain and Chicory mixes had greater ($P<0.05$) OMD % than the Pasture mix in all the periods from spring to autumn.

Within herbage treatments

In the Pasture mix during year one, OMD % was greater ($P<0.05$) in early spring, late spring and in summer than in autumn (Table 7-5). In contrast, OMD % was greater ($P<0.05$) in autumn during year two than in late spring which in turn was greater ($P<0.05$) than in summer.

In the Plantain mix during year one, there was no difference ($P>0.05$) in the OMD % between periods. During year two OMD % was greater ($P<0.05$) in autumn than in early spring, late spring and in summer.

In the Chicory mix during year one, OMD % was lower ($P<0.05$) in summer compared to all the other periods. During year two OMD % was greater ($P<0.05$) in autumn than in both late spring and summer.

Table 7-5: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on *in-vitro* organic matter digestibility (OMD) within each of the five study periods (winter, early spring, late spring and early summer, summer and autumn) (mean \pm s.e.).

Period	Organic matter digestibility (OMD) % DM		
	Pasture mix	Plantain mix	Chicory mix
<i>Year one 2011/2012</i>			
Winter	70.4 \pm 0.68	*	*
Early spring	71.1 ^a _y \pm 1.24	76.8 ^b \pm 1.24	78.4 ^b _y \pm 1.24
Late spring ¹	68.3 ^a _y \pm 0.87	75.0 ^b \pm 0.87	78.7 ^c _y \pm 0.87
Summer	69.4 ^a _y \pm 0.71	74.4 ^b \pm 0.71	74.8 ^b _x \pm 0.71
Autumn	67.7 ^a _x \pm 0.87	74.8 ^b \pm 0.87	77.6 ^c _y \pm 0.87
<i>Year two 2012/2013</i>			
Winter	72.6 \pm 0.68	*	*
Early spring	71.3 ^a _{yz} \pm 1.35	76.4 ^b _x \pm 1.35	78.3 ^b _{xy} \pm 1.35
Late spring ¹	70.1 ^a _y \pm 1.35	74.5 ^b _x \pm 1.35	77.2 ^b _x \pm 1.35
Summer	64.5 ^a _x \pm 1.35	73.8 ^b _x \pm 1.35	77.1 ^b _x \pm 1.35
Autumn	74.9 ^a _z \pm 1.10	81.3 ^b _y \pm 1.10	82.0 ^b _y \pm 1.10

Differing superscripts (a,b) within rows and years indicate means that were significantly different (P<0.05).

Differing superscripts (x,y,z) within columns and years indicate means that were significantly different (P<0.05).

¹Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two).

* No lambs present.

7.5.4 Metabolisable energy (ME) between periods

Across herbage treatments

During year one, both Plantain and Chicory mixes had greater (P<0.05) ME value than the Pasture mix in all the periods from spring to autumn (Table 7-6). During year two, both Plantain and Chicory mixes had greater (P<0.05) ME value than the

Pasture mix in all periods from spring to autumn except in late spring where, Chicory mix had greater ($P<0.05$) ME value than the Pasture mix.

Within herbage treatments

In the Pasture mix during year one in early spring, late spring and summer, ME value was greater ($P<0.05$) than in autumn and during year two it was greater ($P<0.05$) in early spring, late spring and autumn than in summer (Table 7-6).

In the Plantain mix during year one, there was no difference ($P>0.05$) in ME value between periods. During year two, ME value were greater ($P<0.05$) in autumn than in early spring, late spring and in summer.

In the Chicory mix during year one, ME value was lower ($P<0.05$) in summer compared to all the other periods. During year two, there was no difference ($P>0.05$) in the ME value between different periods.

Table 7-6: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on metabolisable energy (ME) within each of the five study periods (winter, early spring, late spring and early summer, summer and autumn) (mean \pm s.e.).

Period	Metabolisable energy (ME) MJ/kg DM		
	Pasture mix	Plantain mix	Chicory mix
<i>Year one 2011/2012</i>			
Winter	10.2 \pm 0.15	*	*
Early spring	10.4 ^a _y \pm 0.17	11.1 ^b \pm 0.17	11.4 ^b _y \pm 0.17
Late spring ¹	10.1 ^a _y \pm 0.12	10.9 ^b \pm 0.12	11.3 ^b _y \pm 0.12
Summer	10.1 ^a _y \pm 0.10	10.8 ^b \pm 0.10	10.8 ^b _x \pm 0.10
Autumn	9.9 ^a _x \pm 0.12	10.8 ^b \pm 0.12	11.1 ^b _y \pm 0.12
<i>Year two 2012/2013</i>			
Winter	10.4 \pm 0.15	*	*
Early spring	10.4 ^a _y \pm 0.20	11.1 ^b _x \pm 0.20	11.3 ^b \pm 0.20
Late spring ¹	10.3 ^a _y \pm 0.20	10.7 ^{ab} _x \pm 0.20	11.1 ^b \pm 0.20
Summer	9.5 ^a _x \pm 0.20	10.8 ^b _x \pm 0.20	11.1 ^b \pm 0.20
Autumn	10.8 ^a _y \pm 0.16	11.6 ^b _y \pm 0.16	11.6 ^b \pm 0.16

Differing superscripts (a,b) within rows and years indicate means that were significantly different (P<0.05).

Differing superscripts (x,y,z) within columns and years indicate means that were significantly different (P<0.05).

¹Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two).

* No lambs present.

ME =DOMD% x 0.163 (Geenty and Rattray 1987).

7.5.5 Neutral detergent fibre (NDF) between periods

Across herbage treatments

During year one in early spring and in summer, Pasture mix had greater (P<0.05) NDF % than in both Plantain and Chicory mixes (Table 7-7). In both, late spring and autumn Pasture mix had greater (P<0.05) NDF % than the Plantain mix which in

turn had greater NDF % than the Chicory mix. During year two in early spring and in autumn, Pasture mix had greater ($P<0.05$) NDF% than both Plantain and Chicory mixes. In both, late spring and summer Pasture mix had greater ($P<0.05$) NDF % than the Plantain mix which in turn had greater NDF % than the Chicory mix.

Within herbage treatments

In the Pasture mix during year one in late spring and autumn, NDF % was greater ($P<0.05$) than in early spring and during year two it was greater ($P<0.05$) in summer than in early spring, late spring and in autumn (Table 7-7).

In the Plantain mix during year one, NDF % was greater ($P<0.05$) in both summer and autumn than in early spring. During year two in early spring, late spring and in summer, all had greater ($P<0.05$) NDF % than in autumn.

In the Chicory mix during year one, NDF % was greater ($P<0.05$) in summer compared to all the other periods. During year two, in early spring, late spring and in summer, all had greater ($P<0.05$) NDF % than in autumn.

Table 7-7: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on neutral detergent fibre (NDF) within each of the five study periods (winter, early spring, late spring and early summer, summer and autumn) (mean \pm s.e.).

Period	Neutral detergent fibre (NDF) % DM		
	Pasture mix	Plantain mix	Chicory mix
<i>Year one 2011/2012</i>			
Winter	43.2 \pm 1.16	*	*
Early spring	43.0 ^b ^x \pm 1.78	28.7 ^a ^x \pm 1.78	26.9 ^a ^x \pm 1.78
Late spring ¹	48.2 ^c ^y \pm 1.26	32.9 ^b ^{xy} \pm 1.26	26.7 ^a ^x \pm 1.26
Summer	46.3 ^b ^{xy} \pm 1.03	34.6 ^a ^y \pm 1.03	32.3 ^a ^y \pm 1.03
Autumn	48.5 ^c ^y \pm 1.26	34.7 ^b ^y \pm 1.26	29.3 ^a ^x \pm 1.26
<i>Year two 2012/2013</i>			
Winter	39.4 \pm 1.16	*	*
Early spring	41.8 ^b ^x \pm 2.45	31.6 ^a ^y \pm 2.45	27.9 ^a ^y \pm 2.45
Late spring ¹	47.2 ^c ^x \pm 2.45	37.6 ^b ^y \pm 2.45	28.9 ^a ^y \pm 2.45
Summer	53.7 ^c ^y \pm 2.45	39.1 ^b ^y \pm 2.45	29.2 ^a ^y \pm 2.45
Autumn	39.5 ^b ^x \pm 2.00	22.1 ^a ^x \pm 2.00	19.5 ^a ^x \pm 2.00

Differing superscripts (a,b) within rows and years indicate means that were significantly different (P<0.05).

Differing superscripts (x,y,z) within columns and years indicate means that were significantly different (P<0.05).

¹Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two).

* No lambs present.

7.5.6 Net herbage accumulation rates (NHAR) between different periods

Across herbage treatments

During year one in early spring and in summer and during year two in summer and in autumn there was no difference (P>0.05) in the NHAR between the treatments (Table 7-8). During year one in late spring, both Pasture and Plantain mixes had greater (P<0.05) NHAR compared to the Chicory mix. During year one in autumn,

both Plantain and Chicory mixes had greater ($P<0.05$) NHAR than the Pasture mix. During year two in early spring Pasture mix had greater ($P<0.05$) NHAR compared to both Plantain and Chicory mixes. During year two in late spring, the Pasture mix had greater ($P<0.05$) NHAR compared to both Plantain and Chicory mixes.

Within herbage treatments

In the Pasture mix during year one late spring, NHAR was greater ($P<0.05$) than in both early spring and autumn (Table 7-8). During year two in late spring, NHAR was greater ($P<0.05$) than in early spring which in turn was greater ($P<0.05$) than in both summer and autumn.

In the Plantain mix during year one in late spring, summer and in autumn all had greater ($P<0.05$) NHAR than in the early spring. During year two in late spring had greater ($P<0.05$) NHAR than in both early spring and summer which in turn had greater ($P<0.05$) NHAR than in autumn.

In the Chicory mix during year one, in both summer and autumn had greater ($P<0.05$) NHAR than both in early spring and late spring. During year two, in late spring had greater ($P<0.05$) NHAR than both in early spring and summer which in turn had greater ($P<0.05$) NHAR than in autumn.

Net herbage accumulation rate (NHAR) curves in the Pasture, Plantain and Chicory mixes (Figure 7-1) show that a greater herbage production occurs during the months of late spring and early summer period compared to the other periods. The herbage production is lowest during the winter months.

Table 7-8: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on net herbage accumulation rate (NHAR) within each of the five study periods (winter early spring, late spring and early summer, summer and autumn) (mean \pm s.e.).

Period	Net herbage accumulation rate (kg/ha/day)		
	Pasture mix	Plantain mix	Chicory mix
<i>Year one 2011/2012</i>			
Winter	27.8 \pm 6.56	*	*
Early spring	54.7 ^x \pm 9.78	46.7 ^x \pm 8.75	46.1 ^x \pm 8.75
Late spring ¹	95.6 ^b ^y \pm 11.29	73.7 ^b ^y \pm 8.75	47.6 ^a ^x \pm 7.99
Summer	72.1 ^{xy} \pm 9.78	85.7 ^y \pm 7.39	73.9 ^y \pm 7.58
Autumn	36.3 ^a ^x \pm 7.39	90.6 ^b ^y \pm 7.99	73.0 ^b ^y \pm 8.75
<i>Year two 2012/2013</i>			
Winter	66.4 \pm 7.27	*	*
Early spring	105.6 ^b ^y \pm 7.99	64.5 ^a ^y \pm 7.99	57.8 ^a ^y \pm 8.22
Late spring ¹	133.3 ^b ^z \pm 7.99	97.4 ^a ^z \pm 7.99	101.3 ^a ^z \pm 7.77
Summer	34.1 ^x \pm 11.29	52.7 ^y \pm 11.29	49.0 ^y \pm 11.29
Autumn	36.2 ^x \pm 7.99	32.1 ^x \pm 7.99	26.2 ^x \pm 7.99

¹Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two)

Differing superscripts (a,b) within rows and years indicate means that were significantly different (P<0.05).

Differing superscripts (x,y,z) within columns and years indicate means that were significantly different (P<0.05).

* No lambs present.

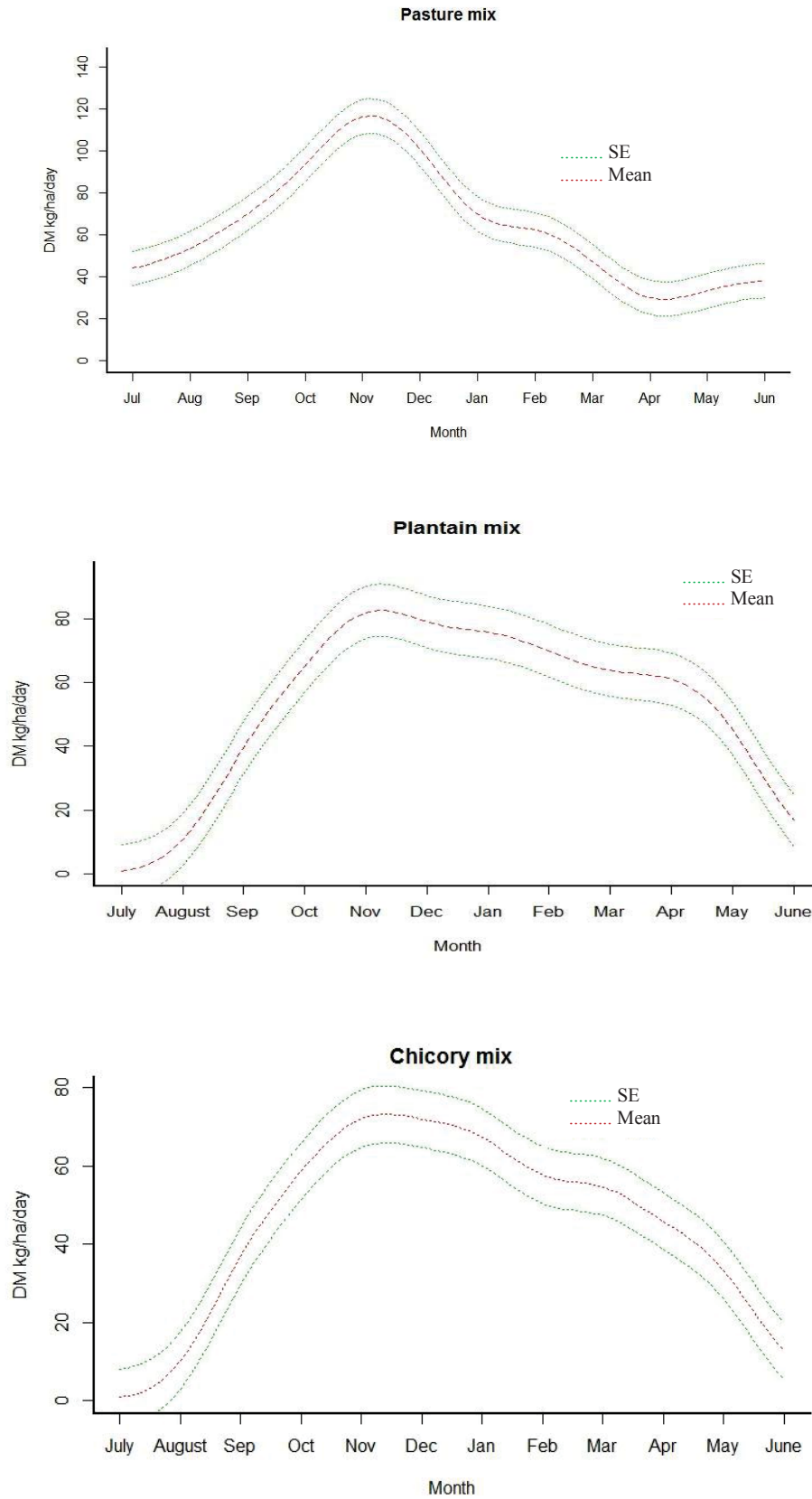


Figure 7-1: Monthly net herbage accumulation rate (NHAR) curves for the Pasture mix, Plantain mix and Chicory mix (..... SE and Mean).

7.5.7 Apparent herbage DM intake per lamb per day between periods

Across herbage treatments

During year one in autumn, Pasture mix lambs tended to have greater ($P<0.05$) apparent intakes compared to the Plantain mix lambs (Table 7-9). During year two in summer Plantain mix lambs had greater ($P<0.05$) apparent intakes compared to both Pasture mix and Chicory mix lambs. During year two in autumn, Plantain mix and Chicory mix lambs had greater ($P<0.05$) apparent intakes than Pasture mix lambs.

Within herbage treatments

Pasture mix lambs during year one had greater ($P<0.05$) apparent intakes in both early spring and autumn than in summer which in turn was greater ($P<0.05$) than in late spring (Table 7-9). There was no seasonal effect in the apparent intakes in year two.

Plantain mix lambs during year one had greater ($P<0.05$) apparent intakes in early spring than in both summer and autumn which in turn was greater ($P<0.05$) than in late spring. During year two, in summer apparent intakes were greater ($P<0.05$) than in early spring, late spring and in autumn.

Chicory mix lambs during year one had greater ($P<0.05$) apparent intakes in early spring than in autumn which in turn was greater ($P<0.05$) than in summer. There was no seasonal effect in the apparent intakes in year two.

Table 7-9: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on apparent herbage DM intake per lamb per day (kg DM /head/day) within each of the five study periods (winter, early spring, late spring and early summer, summer and autumn) (mean \pm s.e.).

Period	Apparent herbage DM intake per lamb per day (kg DM/head/day)		
	Pasture mix	Plantain mix	Chicory mix
<i>Year one 2011/2012</i>			
Winter	1.0 \pm 0.17	*	*
Early spring	3.8 ^z \pm 0.39	3.5 ^z \pm 0.35	3.8 ^z \pm 0.35
Late spring ¹	1.1 ^x \pm 0.35	1.3 ^x \pm 0.29	1.1 ^w \pm 0.28
Summer	1.8 ^y \pm 0.35	1.9 ^y \pm 0.28	1.6 ^x \pm 0.28
Autumn	2.9 ^b ^z \pm 0.39	1.9 ^a ^y \pm 0.32	2.3 ^{ab} ^y \pm 0.35
<i>Year two 2012/2013</i>			
Winter	2.4 \pm 0.26	*	*
Early spring	1.6 \pm 0.18	1.9 ^x \pm 0.18	1.7 \pm 0.18
Late spring ¹	1.9 \pm 0.17	2.0 ^x \pm 0.17	1.9 \pm 0.17
Summer	1.9 ^a \pm 0.27	3.2 ^b ^y \pm 0.27	1.9 ^a \pm 0.27
Autumn	1.2 ^a \pm 0.19	2.1 ^b ^x \pm 0.195	1.9 ^b \pm 0.19

Differing superscripts (a,b) within rows and years indicate means that were significantly different (P<0.05).

Differing superscripts (w,x,y,z) within columns and years indicate means that were significantly different (P<0.05).

¹Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two).

* No lambs present.

7.5.8 Initial live weights of lambs between periods

Across herbage treatments

There was no difference (P<0.05) in initial live weights between the treatments during both years (Table 7-10).

During year one in early spring, initial live weights were greater ($P<0.05$) than the initial live weights in all the other periods. During year two, initial live weights in summer were greater ($P<0.05$) than in early spring which in turn were greater ($P<0.05$) than in autumn. The lowest ($P<0.05$) initial live weights were observed in late spring lambs in all three treatments during year two.

Table 7-10: Initial live weight of lambs in the Pasture mix, Plantain mix and Chicory mix within each of the five study periods (winter, early spring, late spring and early summer, summer and autumn) (mean \pm s.e.).

Period	Initial live weight (kg)		
	Pasture mix	Plantain mix	Chicory mix
<i>Year one 2011/2012</i>			
Winter	36.0 \pm 0.48	*	*
Early spring	41.4 ^y \pm 0.07	41.2 ^y \pm 0.07	41.3 ^y \pm 0.08
Late spring ¹	32.4 ^x \pm 0.06	32.5 ^x \pm 0.06	32.5 ^x \pm 0.06
Summer	32.8 ^x \pm 0.08	32.8 ^x \pm 0.06	32.9 ^x \pm 0.06
Autumn	34.3 ^x \pm 0.08	34.2 ^x \pm 0.07	34.3 ^x \pm 0.07
<i>Year two 2012/2013</i>			
Winter	36.6 \pm 0.62	*	*
Early spring	34.6 ^y \pm 0.09	34.8 ^y \pm 0.09	34.9 ^y \pm 0.09
Late spring ¹	32.6 ^w \pm 0.08	32.5 ^w \pm 0.08	32.6 ^w \pm 0.08
Summer	35.9 ^z \pm 0.11	35.8 ^z \pm 0.11	35.9 ^z \pm 0.09
Autumn	34.1 ^x \pm 0.10	34.2 ^x \pm 0.12	34.1 ^x \pm 0.10

Differing superscripts (a,b,c) within rows and years indicate means that were significantly different ($P<0.05$).

Differing superscripts (w,x,y,z) within columns and years indicate means that were significantly different ($P<0.05$).

¹Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two).

* No lambs present.

7.5.9 Final live weights of lambs between periods

Across herbage treatments

During year one in both late spring and autumn, Plantain mix lambs were heavier ($P<0.05$) than Chicory mix lambs which in turn were heavier ($P<0.05$) than Pasture mix lambs at the end of the study (Table 7-11). During year one in summer, both Plantain mix and Chicory mix lambs were heavier ($P<0.05$) than the Pasture mix lambs at the end of the study.

During year two in both early spring and autumn Plantain mix lambs were heavier ($P<0.05$) than the Chicory mix lambs which in turn were heavier ($P<0.05$) than the Pasture mix lambs. In late spring and summer, both Plantain mix and Chicory mix lambs were heavier ($P<0.05$) than the Pasture mix lambs.

Within herbage treatments

In Pasture mix lambs during year one, early spring lambs were heavier ($P<0.05$) than the summer lambs which in turn were heavier ($P<0.05$) than both late spring and autumn lambs (Table 7-11). During year two, early spring lambs were heavier ($P<0.05$) than late spring lambs which in turn were heavier ($P<0.05$) than autumn lambs. The lowest ($P<0.05$) final live weights were observed in summer lambs during year two.

Table 7-11: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on final live weights of lambs within each of the five study periods (winter, early spring, late spring and early summer, summer and autumn) (mean ± s.e.).

Period	Final live weight (kg)		
	Pasture mix	Plantain mix	Chicory mix
<i>Year one 2011/2012</i>			
Winter	44.5±0.54	*	*
Early spring	50.4 ^z ±0.38	50.6 ^y ±0.38	51.4 ^y ±0.42
Late spring ¹	39.7 ^{a x} ±0.34	44.4 ^{c x} ±0.35	43.0 ^{b x} ±0.33
Summer	41.1 ^{a y} ±0.46	43.9 ^{b x} ±0.35	43.3 ^{b x} ±0.35
Autumn	39.9 ^{a x} ±0.42	44.5 ^{c x} ±0.39	43.1 ^{b x} ±0.39
<i>Year two 2012/2013</i>			
Winter	49.1±0.78	*	*
Early spring	45.7 ^{a z} ±0.33	48.7 ^{c z} ±0.33	47.7 ^{b z} ±0.33
Late spring ¹	42.7 ^{a y} ±0.28	46.2 ^{b y} ±0.28	46.7 ^{b y} ±0.28
Summer	38.8 ^{a w} ±0.40	41.6 ^{b w} ±0.39	41.4 ^{b w} ±0.34
Autumn	41.4 ^{a x} ±0.35	45.0 ^{c x} ±0.45	43.1 ^{b x} ±0.35

Differing superscripts (a,b,c) within rows and years indicate means that were significantly different (P<0.05).

Differing superscripts (w,x,y,z) within columns and years indicate means that were significantly different (P<0.05).

¹Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two).

* No lambs present.

In Plantain mix lambs during year one, early spring lambs were heavier (P<0.05) than late spring, summer and autumn lambs at the end of the study period. During year two, early spring lambs were heavier (P<0.05) than the late spring lambs which in turn were heavier (P<0.05) than the autumn lambs. The lowest (P<0.05) final live weights were observed in summer lambs.

In Chicory mix lambs during year one, early spring lambs were heavier ($P<0.05$) than late spring, summer and autumn lambs. During year two, early spring lambs were heavier ($P<0.05$) than the late spring lambs which in turn were heavier ($P<0.05$) than autumn lambs. The lowest ($P<0.05$) final live weights were observed in summer lambs.

7.5.10 Live weight gain (LWG) of lambs between different periods

Across herbage treatments

During year one in early spring, Chicory mix lambs had greater ($P<0.05$) LWG than the Pasture mix lambs (Table 7-12). During year one in both, late spring and autumn, Plantain mix lambs had greater ($P<0.05$) LWG than the Chicory mix lambs which in turn had greater ($P<0.05$) LWG than the Pasture mix lambs. During year one in summer, both Plantain mix and Chicory mix lambs had greater ($P<0.05$) LWG than the Pasture mix lambs. During year two in both early spring and autumn, Plantain mix lambs had greater ($P<0.05$) LWG than the Chicory mix lambs which in turn had greater ($P<0.05$) LWG than the Pasture mix lambs. During year two in late spring and in summer, both the Plantain mix and Chicory mix lambs had greater ($P<0.05$) LWG than the Pasture mix lambs.

Within herbage treatments

In Pasture mix lambs during year one, greater ($P<0.05$) LWG were observed in early spring than in late spring, summer and in autumn (Table 7-12). During year two, greater ($P<0.05$) LWG were observed in early spring than in late spring which in

turn were greater ($P < 0.05$) than in autumn. During year two, the lowest ($P < 0.05$) LWG were observed in summer.

In Plantain mix lambs during year one, greater ($P < 0.05$) LWG were observed in early spring than in both late spring and autumn which in turn were greater ($P < 0.05$) than in summer. During year two, greater ($P < 0.05$) LWG were observed in early spring than in late spring which in turn were greater ($P < 0.05$) than in autumn. During year two, the lowest ($P < 0.05$) LWG were observed in summer.

In Chicory mix lambs during year one, greater ($P < 0.05$) LWG were observed in early spring than in both late spring and autumn which in turn were greater ($P < 0.05$) than in summer. During year two, greater ($P < 0.05$) LWG were observed in early spring than in late spring which in turn were greater ($P < 0.05$) than in summer. During year two, the lowest ($P < 0.05$) LWG were observed in autumn.

Table 7-12: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on LWG of lambs within each of the five study periods (winter, early spring, late spring and early summer, summer and autumn) (mean \pm s.e.).

Period	LWG (g/day)		
	Pasture mix	Plantain mix	Chicory mix
<i>Year one 2011/2012</i>			
Winter	151.6 \pm 5.48		*
Early spring	321.8 ^a _y \pm 11.24	336.0 ^{ab} _z \pm 11.24	360.0 ^b _z \pm 12.37
Late spring ¹	190.3 ^a _x \pm 9.90	304.5 ^c _y \pm 9.84	262.2 ^b _y \pm 9.84
Summer	169.0 ^a _x \pm 13.62	226.0 ^b _x \pm 10.25	213.5 ^b _x \pm 10.32
Autumn	159.7 ^a _x \pm 12.48	294.9 ^c _y \pm 11.58	254.8 ^b _y \pm 11.58
<i>Year two 2012/2013</i>			
Winter	222.0 \pm 5.44		*
Early spring	320.7 ^a _z \pm 9.24	397.3 ^c _z \pm 9.24	366.5 ^b _z \pm 9.24
Late spring ¹	243.9 ^a _y \pm 7.85	315.9 ^b _y \pm 7.85	329.2 ^b _y \pm 7.90
Summer	120.4 ^a _w \pm 11.00	231.1 ^b _w \pm 10.87	221.1 ^b _x \pm 9.46
Autumn	169.7 ^a _x \pm 9.87	252.3 ^c _x \pm 12.42	207.7 ^b _w \pm 9.87

Note: the negative LWG values were excluded from analysis.

¹Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two).

Differing superscripts (a,b,c) within rows and years indicate means that were significantly different (P<0.05).

Differing superscripts (w,x,y,z) within columns and years indicate means that were significantly different (P<0.05).

* No lambs present.

7.5.11 Carcass weight of lambs between different periods

Across herbage treatments

During year one in early spring, Chicory mix lambs had heavier (P<0.05) carcass weights than the Plantain mix lambs which in turn had heavier (P<0.05) carcass weights than the Pasture mix lambs (Table 7-13). During year one in late spring,

Plantain mix lambs had heavier ($P<0.05$) carcass weights than the Chicory mix lambs which in turn had heavier ($P<0.05$) carcass weights than the Pasture mix lambs.

During year one in summer and in autumn, both Plantain mix and Chicory mix lambs had heavier ($P<0.05$) carcass weights than the Pasture mix lambs. During year two both Plantain mix and Chicory mix lambs had heavier ($P<0.05$) carcass weights than the Pasture mix lambs in all the periods.

Within herbage treatments

In Pasture mix lambs during year one, carcass weights were greater ($P<0.05$) in early spring than in both late spring and summer which in turn were greater ($P<0.05$) than in autumn (Table 7-13). During year two, carcass weights were greater ($P<0.05$) in early spring than in both late spring and autumn which in turn were greater ($P<0.05$) than in summer.

In Plantain mix lambs during year one, carcass weights were greater ($P<0.05$) in early spring than in all the other periods. During year two, carcass weights in early spring were greater ($P<0.05$) than in both late spring and autumn which in turn were greater ($P<0.05$) than in summer.

Table 7-13: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on carcass weight within each of the five study periods (early spring, late spring and early summer, summer and autumn) (mean ± s.e.).

Period	Carcass weight (kg)		
	Pasture mix	Plantain mix	Chicory mix
<i>Year one 2011/2012</i>			
Winter	17.8±0.52		*
Early spring	21.1 ^{a z} ±0.16	21.8 ^{b y} ±0.17	22.3 ^{c z} ±0.18
Late spring ¹	15.7 ^{a y} ±0.14	18.3 ^{c x} ±0.15	17.8 ^{b x} ±0.14
Summer	15.7 ^{a y} ±0.20	18.7 ^{b x} ±0.15	18.4 ^{b y} ±0.15
Autumn	15.2 ^{a x} ±0.18	18.6 ^{b x} ±0.17	18.7 ^{b y} ±0.17
<i>Year two 2012/2013</i>			
Winter	19.9±0.34		*
Early spring	18.1 ^{a z} ±0.21	20.3 ^{b z} ±0.21	19.7 ^{b z} ±0.21
Late spring ¹	17.1 ^{a y} ±0.18	19.3 ^{b y} ±0.18	19.6 ^{b z} ±0.18
Summer	14.5 ^{a x} ±0.25	16.8 ^{b x} ±0.25	16.5 ^{b x} ±0.21
Autumn	16.7 ^{a y} ±0.22	18.6 ^{b y} ±0.28	18.2 ^{b y} ±0.22

Differing superscripts (a,b,c) within rows and years indicate means that were significantly different (P<0.05).

Differing superscripts (w,x,y,z) within columns and years indicate means that were significantly different (P<0.05).

¹Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two).

* No lambs present.

In Chicory mix lambs during year one, carcass weights were greater (P<0.05) in early spring than in both summer and autumn which in turn were greater (P<0.05) than in late spring. During year two, carcass weights in both early spring and late spring were greater (P<0.05) than in autumn which in turn were greater (P<0.05) than in summer.

7.5.12 Apparent carcass weight production per ha between different periods

Across herbage treatments

During year one in early spring, apparent carcass weight production per ha was not different ($P>0.05$) among the treatments (Table 7-14). During year one in late spring Plantain mix had the greater ($P<0.05$) apparent carcass weight production per ha than the Chicory mix which in turn had greater ($P<0.05$) apparent carcass weight production per ha than the Pasture mix. During year one in summer and in autumn both Plantain and Chicory mixes had greater ($P<0.05$) apparent carcass weight production per ha than the Pasture mix. During year two, both Plantain and Chicory mixes had greater ($P<0.05$) apparent carcass weight production per ha than the Pasture mix in early spring, late spring and in summer. However, during year two in autumn Chicory mix had greater ($P<0.05$) apparent carcass weight production per ha than both Pasture and Plantain mixes.

Within herbage treatments

In the Pasture mix during year one in early spring, apparent carcass weight production per ha was greater ($P<0.05$) than in late spring which in turn was greater ($P<0.05$) than in summer (Table 7-14). The lowest ($P<0.05$) apparent carcass weight production per ha was observed in autumn during year one. In the Plantain mix during year one, apparent carcass weight production per ha was greater ($P<0.05$) in both late spring and summer than in both early spring and autumn. In the Chicory mix during year one in summer, apparent carcass weight production per ha was greater ($P<0.05$) than in late spring which in turn was greater ($P<0.05$) than in both early spring and autumn.

In year two, all three treatments had higher ($P<0.05$) apparent carcass weight production per ha in late spring than early spring which in turn had higher ($P<0.05$) apparent carcass weight production per ha than autumn. During year two, the lowest ($P<0.05$) apparent carcass weight production per ha was observed in summer in all three treatments.

Overall in year one, Plantain mix had the highest total apparent carcass weight production per ha than the Chicory mix. However, during year two the Chicory mix had the highest total carcass weight production per ha. During both years, Pasture mix had the lowest total carcass weight production per ha.

Table 7-14: Effect of herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) on apparent carcass weight production per ha within each of the five study periods (winter, early spring, late spring and early summer, summer and autumn) (mean \pm s.e.).

Period	Apparent carcass weight production per ha (kg/ha)		
	Pasture mix	Plantain mix	Chicory mix
<i>Year one 2011/2012</i>			
Winter	68.9 \pm 6.56		*
Early spring	138.0 ^z \pm 8.59	158.9 ^x \pm 8.59	143.7 ^x \pm 8.59
Late spring ¹	107.2 ^{a y} \pm 8.59	215.3 ^{c y} \pm 8.59	190.5 ^{b y} \pm 8.59
Summer	58.7 ^{a x} \pm 8.59	225.1 ^{b y} \pm 8.59	217.1 ^{b z} \pm 8.59
Autumn	34.3 ^{a w} \pm 8.59	148.5 ^{b x} \pm 8.59	157.7 ^{b x} \pm 8.59
Total ¹	407.1 ²	747.8	709.0
<i>Year one 2012/2013</i>			
Winter	84.3 \pm 6.56		*
Early spring	136.5 ^{a y} \pm 8.59	202.3 ^{b y} \pm 8.59	182.2 ^{b y} \pm 8.59
Late spring ¹	162.9 ^{a z} \pm 8.59	250.9 ^{b z} \pm 8.59	264.3 ^{b z} \pm 8.59
Summer	4.8 ^{a w} \pm 8.59	59.5 ^{b w} \pm 8.59	67.2 ^{b w} \pm 8.59
Autumn	85.3 ^{a x} \pm 8.59	94.1 ^{a x} \pm 8.59	128.2 ^{b x} \pm 8.59
Total ¹	473.8 ²	606.8	641.9

Differing superscripts (a,b,c) within rows and years indicate means that were significantly different (P<0.05).

Differing superscripts (w,x,y,z) within columns and years indicate means that were significantly different (P<0.05).

¹Statistically could not test.

²Included winter data.

¹Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two).

* No lambs present.

7.5.13 Feed Conversion Ratio (FCR) between different periods

Across herbage treatments

Both Plantain and Chicory mixes had lower ($P<0.05$) FCR than Pasture mix during both years (Table 7-15).

Table 7-15: Feed Conversion Ratio (FCR) for each herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) within each of the four study periods (early spring, late spring and early summer, summer and autumn) on DM basis (mean \pm s.e.).

Period	Feed Conversion Ratio (FCR)		
	Pasture mix	Plantain mix	Chicory mix
<i>Year one 2011/2012</i>			
Early spring	6.0 ^{b x} ± 0.17	5.4 ^{a x} ± 0.17	5.4 ^{a x} ± 0.17
Late spring ¹	8.2 ^{b y} ± 0.17	6.0 ^{a y} ± 0.17	6.1 ^{a y} ± 0.17
Summer	8.0 ^{b y} ± 0.17	6.5 ^{a y} ± 0.17	6.6 ^{a y} ± 0.17
Autumn	8.4 ^{b y} ± 0.17	5.9 ^{a y} ± 0.17	6.0 ^{a y} ± 0.17
Average ¹	7.6 ^b ± 0.08	5.9 ^a ± 0.08	6.0 ^a ± 0.08
<i>Year two 2012/2013</i>			
Early spring	6.7 ^{b x} ± 0.17	5.7 ^{a x} ± 0.17	5.9 ^{a x} ± 0.17
Late spring ¹	6.8 ^{b x} ± 0.17	5.8 ^{a x} ± 0.17	5.6 ^{a x} ± 0.17
Summer	10.7 ^{b z} ± 0.17	6.5 ^{a y} ± 0.17	6.6 ^{a y} ± 0.17
Autumn	8.1 ^{b y} ± 0.17	6.1 ^{a xy} ± 0.17	6.5 ^{a y} ± 0.17
Average ¹	8.1 ^b ± 0.08	6.1 ^a ± 0.08	6.2 ^a ± 0.08

¹ Excluding winter data.

¹ Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two).

Differing superscripts (a,b) within rows and years indicate means that were significantly different ($P<0.05$).

Differing superscripts (x,y,z) within columns and years indicate means that were significantly different ($P<0.05$).

Within herbage treatments

During year one the lowest ($P<0.05$) FCR was observed in early spring than in all the other periods in all three treatments (Table 7-15).

In the Pasture mix during year two in both early spring and late spring, FCR was lower ($P<0.05$) than in autumn which in turn was lower ($P<0.05$) than in summer. In the Plantain mix during year two in both early spring and late spring, FCR was lower ($P<0.05$) than in summer. In the Chicory mix during year two in both early spring and late spring, FCR was lower ($P<0.05$) than in both summer and autumn.

7.5.14 The efficiency of herbage utilization (EHU) by lambs between different periods

Across herbage treatments

During year one in early spring, the Pasture mix had greater ($P<0.05$) EHU than Plantain and Chicory mixes (Table 7-16). During year one in late spring and in autumn, the Plantain mix had greater ($P<0.05$) EHU than the Chicory mix which in turn had greater ($P<0.05$) EHU than the Pasture mix. During year one in summer, both Plantain and Chicory mixes had greater ($P<0.05$) EHU than the Pasture mix.

During year two in early spring, both Pasture and Plantain mixes had greater ($P<0.05$) EHU than the Chicory mix. During year two in late spring, Plantain mix had greater ($P<0.05$) EHU than the Pasture mix. During year two in summer, Chicory mix had greater ($P<0.05$) EHU than both Pasture and Plantain mixes.

During year two in autumn, both Pasture and Chicory mixes had greater ($P<0.05$) EHU than the Plantain mix.

Within herbage treatments

In the Pasture mix during year one, EHU was greater ($P<0.05$) in early spring than in late spring which in turn was greater ($P<0.05$) than in summer (Table 7-16). The lowest ($P<0.05$) EHU was observed in autumn. During year two, EHU was greater ($P<0.05$) in both early spring and late spring than in autumn which in turn was greater ($P<0.05$) than in summer.

In both Plantain and Chicory mixes during year one, EHU was greater ($P<0.05$) in late spring than in summer which in turn was greater ($P<0.05$) than in early spring. The lowest ($P<0.05$) EHU was observed in autumn. During year two, EHU was greater ($P<0.05$) in late spring than early spring which in turn was greater ($P<0.05$) than in autumn. The lowest ($P<0.05$) EHU was observed in summer in both Plantain and Chicory mixes.

Table 7-16: The efficiency of herbage utilization (EHU) (%) by lambs in each herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) within each of the four study periods (early spring, late spring and early summer, summer and autumn) (mean \pm s.e.).

Period	Efficiency of herbage utilization (%)		
	Pasture mix	Plantain mix	Chicory mix
<i>Year one 2011/2012</i>			
Early spring	87.6 ^{bz} \pm 1.73	59.5 ^{ax} \pm 1.73	56.5 ^{ax} \pm 1.73
Late spring ¹	77.0 ^{ay} \pm 1.73	89.4 ^{cz} \pm 1.73	83.3 ^{bz} \pm 1.73
Summer	41.7 ^{ax} \pm 1.73	66.6 ^{by} \pm 1.73	67.9 ^{by} \pm 1.73
Autumn	31.8 ^{aw} \pm 1.73	50.9 ^{cw} \pm 1.73	42.1 ^{bw} \pm 1.73
Average ¹	59.5 ^a \pm 0.86	66.6 ^c \pm 0.86	62.4 ^b \pm 0.86
<i>Year two 2012/2013</i>			
Early spring	53.9 ^{bz} \pm 0.93	53.1 ^{by} \pm 0.93	48.5 ^{ay} \pm 0.93
Late spring ¹	56.0 ^{az} \pm 0.93	61.9 ^{bz} \pm 0.93	59.3 ^{abz} \pm 0.93
Summer	21.8 ^{ax} \pm 0.93	19.9 ^{aw} \pm 0.93	26.8 ^{bw} \pm 0.93
Autumn	33.7 ^{by} \pm 0.93	25.0 ^{ax} \pm 0.93	30.3 ^{bx} \pm 0.93
Average ¹	41.3 \pm 0.47	40.0 \pm 0.47	41.2 \pm 0.47

Differing superscripts (a,b,c) within rows and years indicate means that were significantly different (P<0.05).

Differing superscripts (w,x,y,z) within columns and years indicate means that were significantly different (P<0.05).

¹ Excluding winter data.

¹ Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two).

7.6 Discussion

The first hypothesis of this chapter was that herb-clover mixes (Plantain and Chicory mixes) would have greater lamb production (live weights, LWG, carcass weights, apparent carcass weight production per ha) during early spring, late spring and early summer (late spring), summer and autumn periods compared to ryegrass/white clover sward (Pasture mix). Secondly, herb-clover mixes would have lower feed conversion ratio (FCR) and higher efficiency of herbage utilization (EHU) in the above periods compared to the Pasture mix.

The greater lamb performance obtained in herb-clover mixes in this chapter are similar to the results shown in Chapter 4. The reasons for these greater lamb performance are discussed in detail in Chapter 4 in sections A, B, C and D.

Net herbage accumulation rate (NHAR) curves highlight the seasonal availability of the herbage in different months of the year in all three treatments. All three NHAR curves peaked during the late spring period. The Pasture mix NHAR curve developed in the present experiment is a binominal pattern and is similar to the curves developed by Matthews *et al.* (1999) and McKenzie *et al.* (1999). The NHAR curves for both Plantain and Chicory mixes highlight that during the summer and autumn (months of January to May) periods these herb-clover mixes had a relatively higher NHAR than the Pasture mix. Similarly, both herb-clover mixes had greater nutritive value than the Pasture mix during these periods. Thus, the greater lamb performance during the summer and autumn periods in the Plantain and Chicory mixes were likely due to the availability of high quality herbage and efficient conversion of nutrients to meat. The NHAR curves developed for the

Plantain and Chicory mixes in the present experiment can be used as a planning aid for farmers. However, factors such as environmental and soil temperature, soil moisture and fertility level and the physiological state of the herbage can affect the daily herbage growth rates, thereby affecting the NHAR (McKenzie *et al.*, 1999). Interestingly, the NHAR for the herb-clover mixes in the present experiment are greater than the NHAR reported by Golding *et al.* (2011) during the late summer early autumn period on the same research station and soil type.

Feed conversion ratio (FCR) is used to identify animals that convert feed efficiently into live weight gain (Knott *et al.*, 2003). The most efficient system is one with a low FCR (Ahmad and Lloyd Davies 1986). In the present experiment, herb-clover mixes had lower FCR values compared to the Pasture mix. This shows that the lambs in the herb-clover mixes used less herbage to produce a kg live weight gain and converted herbage more efficiently to meat than the Pasture mix fed lambs. The Plantain and Chicory mixes had higher feeding value and energy levels than the Pasture mix during early spring to autumn. The higher ME content in the herb-clover mixes may have allowed for increased herbage intakes and the efficiency of feed conversion as suggested by Cosgrove and Edwards (2007). Ahmad and Lloyd Davies (1986) also obtained a low FCR for lambs fed with high energy diets while, Knott *et al.* (2003) observed that lambs with higher LWG had lower FCR compared to the lambs with lower LWG.

Efficiency of herbage utilization (EHU%) is the animal response (growth and maintenance) to feed intake (Meyer and Garrett 1967). The higher lamb performance during year one indicate that the lambs in the herb-clover mixes utilised herbage

more efficiently in the late spring to autumn period than the Pasture mix lambs. This is also supported by the lower FCR values in the herb-clover mixes. During year two in the summer and autumn periods, EHU% in the Chicory mix was greater than the Plantain mix. This indicates that the Chicory mix converted herbage more efficiently to meat than the Plantain mix. However, during these two periods the Chicory mix had higher stocking rates than the Plantain mix. Therefore, both the higher stocking rates and EHU% resulted in higher per ha meat production in the Chicory mix. The lambs in the Plantain mix had less competition due to the lower stocking rates compared to the lambs in the Chicory mix (Animut *et al.*, 2005). This may also explain the higher daily apparent intakes observed in the Plantain mix lambs than the Chicory mix lambs during the summer period in year two. However, the lower EHU% indicates that overall the Plantain mix was less efficient than the Chicory mix during this period.

7.7 Conclusion

As hypothesised, Plantain and Chicory mixes produced heavier lambs, higher lamb daily live weight gains, higher lamb carcass weights and greater apparent carcass weight production per ha compared to the Pasture mix during the early spring to autumn period. The higher NHAR in the summer and autumn periods in the herb-clover mixes increased the feeding value of the herb-clover mixes resulting in greater lamb performance during these periods. Herb-clover mixes had lower feed conversion ratios (FCR) and higher herbage utilization efficiencies (EHU%) compared to the Pasture mix. This indicates that the lambs in the herb-clover mixes used less herbage to produce a kg live weight gain and converted herbage more efficiently to meat than the Pasture mix fed lambs. Combined results indicate that the

herb-clover mixes can be more effective than the Pasture mix during early spring (September to October), late spring (October to December), Summer (January to February) and autumn (March to May). The greater EHU% in the Chicory mix during the year two summer and autumn periods indicates that the Chicory mix converted herbage more efficiently to meat than the Plantain mix.

Chapter 8 : General discussion

8.1 Introduction

Export revenue from lamb meat is a vital component in the New Zealand economy. Lamb meat production is seasonal in New Zealand depending on the ryegrass/white clover pasture production as lambs are reared solely on pasture. The quality of ryegrass/white clover pasture is higher in spring but lower during the summer/autumn period (Hodgson and Brookes 1999). Hence, farmers adjust the stocking rates to accommodate the poor quality and by slaughtering the lambs in summer and autumn more than in other periods of the year (Anonymous 2014). It would be advantageous to have other herbage that would be productive in summer and autumn. Pure swards of plantain, chicory, white- and red-clover have resulted in greater lamb live weight gains compared to ryegrass/white clover pasture. However, this has mostly been reported during the summer/autumn period (Cruickshank 1986; Hodgson and Brookes 1999; Moorhead *et al.*, 2002; Moorby *et al.*, 2004; Marley *et al.*, 2005). In addition there was only one study that investigated effects of a herb-clover mix on lamb growth (Golding *et al.*, 2011). Above study was also undertaken in late summer early autumn period.

Thus, the main focus of this PhD research was;

- i. To examine and compare whether the Plantain and Chicory mixes produce greater lamb live weight and carcass weights on a per animal basis compared to the Pasture mix.
- ii. Development of calibration equations for both Plantain and Chicory mixes to estimate herbage dry matter mass using either sward stick or a plate meter.
- iii. Examine whether the sward composition (botanical composition) of the Plantain and Chicory mixes change throughout the year.

- iv. Examine whether the lambs selected different herbage species during different periods of the year.
- v. Compare the financial and physical performances of the three herbage treatments (Pasture mix, Plantain mix and Chicory mix) over the two years.

8.2 Summary of the experimental chapters and conclusions drawn

8.2.1 Chapter 4: Effect of Plantain mix and Chicory mix on the live weight gain and carcass weight of lambs compared to Pasture mix

The hypothesis of this chapter was that Plantain and Chicory mixes would produce greater lamb performance (i.e. live weight, live weight gain and carcass weight) compared to the Pasture mix during each of the four periods investigated.

Lambs were introduced to the herbage treatments and reared for a maximum duration of two months. They were weighed fortnightly and slaughtered at the end of the study period. Overall this chapter showed that Plantain and Chicory mixes produced heavier lambs at slaughter with greater dressing out percentages, carcass weights and also per ha carcass weight production compared to the Pasture mix. In general, across the two years the Chicory mix performed better than the Plantain mix.

8.2.2 Chapter 5: Alternative method to measure herbage dry matter (DM) mass in Plantain mix and Chicory mix swards

It is essential to have a non-destructive method for farmers to use to estimate the herbage dry matter mass in the Plantain and Chicory mixes either using a sward stick or a plate meter. Therefore, the objective of this chapter was to develop prediction

regression equations to estimate herbage DM mass in the Plantain and Chicory mixes either by using a sward stick or a plate meter. Quadrat samples were taken to determine the herbage DM mass. Five sward stick measurements and a plate meter reading were taken before cutting the quadrat.

The individual R^2 values were significant ($P < 0.05$) for all relationships and ranged from 0.50 to 0.86. Mean coefficient of variations (CV) were significant ($P < 0.05$) for all relationships and varied between 18 and 30%. The regression equations developed in the present study by these non-destructive methods (either using sward stick or plate meter) would enable farmers to obtain reliable estimates of herbage DM mass with a level of precision to make day-to-day grazing management decisions on farms. The data does suggest different regression equations need to be utilised for the different periods of the year.

8.2.3 Chapter 6: Section A: Effect of grazing on herbage composition within and across different seasons over a two years in the Pasture mix, Plantain mix and Chicory mix

Factors such as a sward's botanical and morphological composition and the percentage of legumes or grasses, leaf or stem materials, dead matter or weeds in different seasons, all influence lamb production (Lambert and Litherland 2000).

There were two aims. The first aim was to determine if the management practises used in this thesis resulted changes in the composition in all herbage treatments. The second aim was to determine if the percentage of weeds increased over time.

Herbage samples were taken at the start and end of each experimental period, separated into different species and each species composition was determined on DM basis.

The proportion of plantain and red clover in the Plantain mix and plantain, red clover and chicory in the Chicory mix enabled Plantain and Chicory mixes to be productive during the early spring to autumn period. The weed percentage in the Pasture mix increased towards the end of the second year but it decreased in the herb-clover mixes across both years. Therefore, this experiment provides evidence that these herb-clover mixes will persist as multi species mixes over early spring to autumn period compared to the Pasture mix in the short to medium term at least.

8.2.4 Chapter 6: Section B: Do lambs select different plant species between different periods of the year?

Selection is defined as the animal's preference to eat a herbage species from a mixed sward depending on its availability, accessibility and palatability (i.e. 'what an animal actually eats') (Hodgson 1979; Parsons *et al.*, 1994; Rutter 2006). There were two hypotheses. The first hypothesis was that the most selected species in the herbage treatments would be white- and red-clover and that this selection would be maintained across the different periods. The second hypothesis was that plantain in the Plantain mix and Chicory mix would be selected at a lower proportion than the other species and that this low selection would be consistent in all four periods.

Red clover was the most selected species as hypothesised. However, white clover was not selected as hypothesised across the herbage treatments. In contrast to what

was hypothesised, plantain was selected by the Plantain mix and Chicory mix lambs at varying proportions in different periods and selection has had only a minor effect, if any on the herbage botanical composition.

8.2.5 Chapter 7: Seasonal influence on production aspects of finishing lambs on herb-clover mixes (Plantain mix and Chicory mix) compared to a Pasture mix

The first hypothesis of this chapter was that herb-clover mixes (Plantain and Chicory mixes) would have greater lamb production (live weights, LWG, carcass weights, apparent carcass weight production per ha) during early spring, late spring and early summer (late spring), summer and autumn periods compared to ryegrass/white clover sward (Pasture mix). Secondly, herb-clover mixes would have lower feed conversion ratio (FCR) and higher efficiency of herbage utilization (EHU) in the above periods compared to the Pasture mix.

As reported in the Chapter 4, the Plantain and Chicory mixes produced heavier lambs, higher lamb daily live weight gains, higher lamb carcass weights and carcass weight production per ha compared to the Pasture mix. This chapter also showed that these herb-clover mixes had lower FCR and higher EHU compared to the Pasture mix. This indicates that the herb-clover mixes are more efficient in lamb finishing than the Pasture mix during the period from early spring to autumn.

8.3 Practical implications of this thesis

8.3.1 Financial performances

The aim of this section was to compare the theoretical financial performances of the three treatments via preliminary examination of data from chapters 4 and 7 and Tables 8-1 and 8-2.

Across herbage treatments

During year one (2011/2012) early spring, Chicory mix lambs received higher ($P<0.05$) sale prices than the Pasture mix lambs (Table 8-1). During late spring Plantain mix lambs received higher ($P<0.05$) sale prices than the Chicory mix lambs which in turn received higher ($P<0.05$) sale prices than the Pasture mix lambs. During year one, both Plantain mix and the Chicory mix lambs received higher sale prices in summer and autumn than the Pasture mix lambs.

Within herbage treatments

Within all three herbage treatments during year one in early spring, sale prices were greater ($P<0.05$) than in late spring which in turn were greater ($P<0.05$) than in summer (Table 8-1). Lowest ($P<0.05$) sale prices were observed in autumn.

Across herbage treatments

During year two (2012/2013) early spring, Plantain mix lambs received higher ($P<0.05$) sale prices than the Chicory mix lambs which in turn received higher ($P<0.05$) sale prices than the Pasture mix lambs (Table 8-1). During year two late

spring, summer and autumn, both Plantain mix and Chicory mix lambs received higher sale prices than the Pasture mix lambs.

Within herbage treatments

Within the Pasture mix and Plantain mix during year two in early spring, sale prices were greater ($P < 0.05$) than in late spring and autumn which in turn were greater ($P < 0.05$) than in summer (Table 8-1). Sale prices during later spring and autumn were not different ($P > 0.05$).

Within the Chicory mix during year two in early spring, sale prices were greater ($P < 0.05$) than in late spring which in turn were greater ($P < 0.05$) than in autumn (Table 8-1). Lowest ($P < 0.05$) sale prices were observed in summer.

Table 8-1: Sale price per lamb in each herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) from winter to autumn (NZ\$/lamb) (mean ± s.e.).

Season	Pasture mix	Plantain mix	Chicory mix
<i>Year one 2011/2012</i>			
Winter	141.34±2.85	-	-
Early spring	166.15 ^{a z} ±1.45	170.36 ^{ab z} ±1.45	174.79 ^{b z} ±1.60
Late spring ¹	117.77 ^{a y} ±1.27	139.61 ^{c y} ±1.27	134.80 ^{b y} ±1.27
Summer	90.44 ^{a x} ±1.74	112.59 ^{b x} ±1.32	111.30 ^{b x} ±1.33
Autumn	79.58 ^{a w} ±1.60	101.67 ^{b w} ±1.51	101.45 ^{b w} ±1.49
Average ²	113.48 ^a ±0.76	131.06 ^b ±0.70	130.58 ^b ±0.71
<i>Year two 2012/2013</i>			
Winter	109.93±1.96	-	-
Early spring	102.21 ^{a z} ±1.58	115.18 ^{c z} ±1.58	109.24 ^{b z} ±1.58
Late spring ¹	80.41 ^{a y} ±1.35	91.22 ^{b y} ±1.34	92.73 ^{b y} ±1.35
Summer	57.44 ^{a x} ±1.84	71.45 ^{b x} ±1.84	68.90 ^{b w} ±1.59
Autumn	80.02 ^{a y} ±1.69	89.26 ^{b y} ±2.12	88.09 ^{b x} ±1.69
Average ²	80.02 ^a ±0.81	91.78 ^b ±0.87	89.74 ^b ±0.78

¹Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two).

²Excluding winter data.

Differing superscripts (a,b,c) within rows and years indicate means that were significantly different (P<0.05).

Differing superscripts (w,x,y,z) within columns and years indicate means that were significantly different (P<0.05).

During year one, the lowest cost of production (13,762 NZ\$/ha) was recorded in the Chicory mix (Table 8-2). While the cost of production of the Plantain mix (14,425 NZ\$/ha) was less than the Pasture mix (14,581 NZ\$/ha). The highest income was recorded from the Plantain mix (18,452 NZ\$/ha) followed by the Chicory mix (18,334 NZ\$/ha) and the lowest from the Pasture mix (16,921 NZ\$/ha). During year one all three treatments had produced a profit with the highest net return in the Chicory mix (4,572 NZ\$/ha) followed by Plantain mix (4,027 NZ\$/ha) and then the Pasture mix (2,340 NZ\$/ha).

During year two the lowest cost of production was recorded in the Plantain mix (11,352 NZ\$/ha) compared to the Chicory mix (12,575 NZ\$/ha) and Pasture mix (13,471 NZ\$/ha) (Table 8-2). The highest income was from the Chicory mix (11,876 NZ\$/ha) compared to the Pasture mix (11,865 NZ\$/ha) and Plantain mix (10,745 NZ\$/ha). A loss was recorded in the Pasture mix (-1,606 NZ\$/ha) while losses were also recorded in the Plantain mix (-607 NZ\$/ha) and Chicory mix (-699 NZ\$/ha). This was due to the lower lamb meat production per ha in all three treatments in year two due to the prevailing drought condition together with lower market prices of lambs (Anonymous 2014). The variation in the total costs between treatments was mainly due to the variation in the total number of lambs reared in each treatment.

The greater sale prices of lambs in the herb-clover mixes were predominantly due to the heavier carcass weights (Kirton *et al.*, 1984; Firth 2007; Litherland *et al.*, 2010) compared to the Pasture mix (see next section). None of the lambs fell into the ‘T’ or ‘F’ grades (excessive GR tissue depths), and hence excessive fat on the carcass (Kirton and Johnson 1979; Anonymous 2004), during the experimental period was not an issue.

Table 8-2: Cost of production and the income (NZ\$ per ha) from the intensive lamb finishing system of Plantain and Chicory mixes compared to a Pasture mix in year one and year two.

Description	Pasture mix ¹	Plantain mix	Chicory mix
<i>Cost</i>			
<i>Land preparation²</i>			
Year one 2011/2012	807	819	940
Year two 2012/2013	166	273	273
<i>Lambs³</i>			
Year one 2011/2012	12,870	12,702	11,927
Year two 2012/2013	12,480	10,302	11,492
<i>Animal health</i>			
Year one 2011/2012	245	245	243
Year two 2012/2013	212	205	210
<i>Ear Tags</i>			
Year one 2011/2012	397	397	397
Year two 2012/2013	355	355	355
<i>Transport cost</i>			
Year one 2011/2012	262	262	254
Year two 2012/2013	259	218	246
<i>Total cost</i>			
Year one 2011/2012	14,581	14,425	13,762
Year two 2012/2013	13,471	11,352	12,575
<i>Income</i>			
Lambs			
Year one 2011/2012	16,921	18,452	18,334
Year two 2012/2013	11,865	10,745	11,876
<i>Net returns</i>			
Year one 2011/2012	2,340	4,027	4,572
Year two 2012/2013	-1,606	-607	-699

¹Cost of production in the Pasture mix included the cost during the winter trial.

²This includes costs for seeds, fertilizer, agro-chemicals, labour cost for ploughing, harrowing, sowing and application of agro-chemicals and fertilizer

³Used the buy-in lamb price in each season to calculate the total cost of lambs.

8.3.2 Carcass weight, GR tissue depth measurement and sale price per lamb in each treatment

The Pasture mix and Plantain mix lambs had higher ($P < 0.05$) prices per kg carcass than the Chicory mix lambs in early spring, while the prices were not different between the herbage treatments in late spring (Table 8-3). Lambs in both herb-clover mixes had higher ($P < 0.05$) prices per kg carcass than the Pasture mix lambs in summer and autumn. The Plantain mix lambs had higher ($P < 0.05$) prices per kg carcass than the Chicory mix lambs in summer. However, both herb-clover mixes had greater ($P < 0.05$) carcass weights, GR tissue depths and lamb sale prices compared to the Pasture mix during all periods (early spring, late spring, summer and autumn). The Plantain mix had heavier ($P < 0.05$) carcass weights and lamb sale prices in summer than the Chicory mix. Both carcass weight and GR tissue depths are important parameters used to determine lamb sale prices in New Zealand (Kirton *et al.*, 1984; Litherland *et al.*, 2010). Further, this research indicated that the lamb sale prices are significantly correlated with both carcass weights and GR tissue depths and consequently carcass weights are also significantly correlated with the GR tissue depths. Therefore, greater carcass weights coupled with greater GR tissue depths (without being excessive) also led to higher sale prices.

Greater ($P < 0.05$) sale prices (per lamb and per kg carcass) were observed in early spring and late spring in all three treatments compared to summer and autumn. The greater per lamb sale prices are somewhat justified by the greater individual carcass weights obtained during this period compared to summer and autumn. In addition, in

this period there are fewer lambs available for slaughter compared to the late summer and autumn period which influence prices (Agrifax 2010).

Besides, during summer and autumn periods, herb-clover mixes were able to maintain their higher sale prices due to greater carcass weights and GR tissue depths compared to the Pasture mix (Table 8-3). This suggests that herb-clover mixes maintained a consistent supply of high quality product throughout early spring to autumn period that the market required, without the risk of falling into the excess fat classes.

Table 8-3: Carcass weight, GR tissue depth measurement and sale price per lamb in each treatment (Pasture mix vs Plantain mix vs Chicory mix) from early spring to autumn (NZ\$/lamb) (mean \pm s.e.).

Treatments	Period	Carcass weight (kg)	GR tissue depth (mm)	Sale price (NZ\$/lamb)	Price/kg carcass ³ (NZ\$/kg carcass)
Pasture mix ²	Early spring	19.7 ^{az} \pm 0.15	7.8 ^{az} \pm 0.21	135.1 ^{az} \pm 1.00	6.8 ^{bz} \pm 0.03
	Late spring ¹	16.4 ^{ay} \pm 0.13	4.7 ^{ax} \pm 0.20	99.2 ^{ay} \pm 0.85	6.1 ^y \pm 0.02
	Summer	15.0 ^{ax} \pm 0.17	4.1 ^{ax} \pm 0.25	73.9 ^{aw} \pm 1.16	4.8 ^{aw} \pm 0.03
	Autumn	16.0 ^{ay} \pm 0.16	5.7 ^{ay} \pm 0.23	79.8 ^{ax} \pm 1.06	5.0 ^{ax} \pm 0.03
Plantain mix	Early spring	21.0 ^{bz} \pm 0.15	9.4 ^{by} \pm 0.22	143.6 ^{bz} \pm 1.00	6.8 ^{bz} \pm 0.03
	Late spring ¹	18.9 ^{by} \pm 0.13	7.7 ^{bx} \pm 0.20	115.3 ^{by} \pm 0.85	6.2 ^y \pm 0.02
	Summer	18.0 ^{cx} \pm 0.15	7.4 ^{bx} \pm 0.21	97.6 ^{cx} \pm 0.99	5.4 ^{cx} \pm 0.03
	Autumn	18.6 ^{by} \pm 0.17	9.0 ^{by} \pm 0.25	97.2 ^{bx} \pm 1.13	5.2 ^{bw} \pm 0.03
Chicory mix	Early spring	20.9 ^{bz} \pm 0.15	9.5 ^{bz} \pm 0.23	141.0 ^{bz} \pm 1.03	6.7 ^{az} \pm 0.03
	Late spring ¹	18.7 ^{by} \pm 0.13	7.8 ^{bx} \pm 0.20	113.9 ^{by} \pm 0.85	6.2 ^y \pm 0.02
	Summer	17.5 ^{bx} \pm 0.14	7.1 ^{bw} \pm 0.20	92.9 ^{bx} \pm 0.94	5.2 ^{bx} \pm 0.03
	Autumn	18.4 ^{by} \pm 0.15	8.7 ^{by} \pm 0.22	95.3 ^{bx} \pm 1.02	5.2 ^{bx} \pm 0.03

Differing superscripts (a,b,c) between treatments indicate means that were significantly different ($P < 0.05$).

Differing superscripts (w,x,y,z) within treatment indicate means that were significantly different ($P < 0.05$).

¹Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two).

²Excluding winter data. ³Price per kg carcass = sale price/carcass weight

8.3.3 A feeding plan for a lower North Island lamb finishing farm with ryegrass/white clover swards and herb-clover mixes

Pasture growth rate in New Zealand varies within and between years depending on the changes in the temperature and rainfall pattern. The herbage growth rates of all three treatments were derived using weekly pre- and post-grazing herbage DM mass data collected for a two year period. The herbage growth curves developed for the Pasture mix show that during the winter period growth rate of the ryegrass/white clover sward was lower than the other periods of the year (Figure 8-1). Lamb prices are usually higher during this period (Table 8-1), however as there was low pasture growth rates, few lambs could be finished during the winter period. This is the period when no lambs were finished on the herb-clover mixes. Therefore, any advantage to ryegrass/white clover pasture in this period was small.

During the spring to autumn season the ME content in the herb-clover mixes were higher than the ME content of the Pasture mix (Figure 8-2). Therefore, the herb-clover mixes had an advantage in terms of quality of herbage supplied when the ryegrass/white clover pasture quality is at its lowest level. Furthermore, overall meat production per ha indicates that the lambs grazed on herb-clover mixes produced more meat per ha than the lambs on the Pasture mix in all the four periods from early spring to autumn (Appendix Table 10-1). Hence, if the farmers are prepared to invest in higher quality out of season herbages such as plantain, chicory, white- and red-clover in addition to the ryegrass/white clover swards then those farmers can use both these sward types more effectively as suggested by Kemp *et al.* (2010).

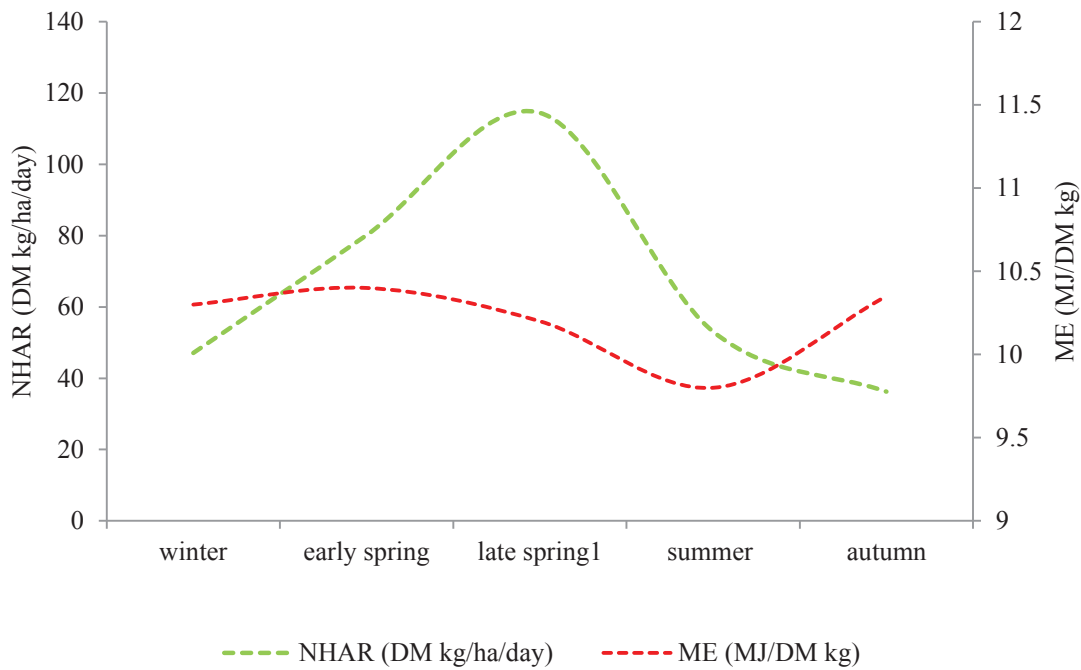


Figure 8-1: Pasture mix – net herbage accumulation rates (NHAR) and Metabolisable energy (ME) content.

¹Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two).

This thesis indicates that the Pasture mix could be used during winter and early spring without any substantial losses in production and profits and then from late spring to autumn farmers could use the herb-clover mixes for improved performance and profits.

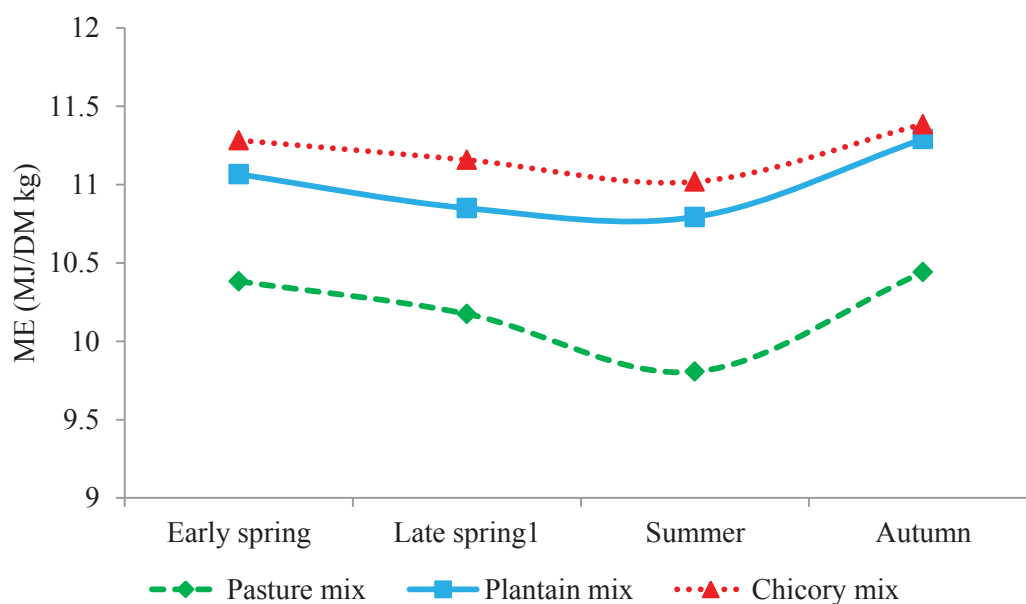


Figure 8-2: Metabolisable energy (ME) in the Pasture mix, Plantain mix and Chicory mix.

¹Late spring and early summer 2nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two).

8.3.4 Percentage of plantain and chicory in the herb-clover mixes across the two years

The plantain percentage during year two was significantly lower than in year one in both the Plantain and Chicory mixes (Figure 8-3). In contrast, chicory percentage increased towards the end of year two in the Chicory mix. The highest chicory percentage was observed in autumn during the second year. The rotational grazing and the mowing during summer may have had an impact on the chicory percentage. Barry (1998) and Alemseged *et al.* (2003) stated that the practice of rotational grazing maintains the number of shoots per plant in chicory. It was observed that during the winter and early spring period, the chicory percentage was relatively lower than in the late spring to autumn period. This observation supports earlier observations that chicory is dormant during colder weather conditions (Hume *et al.*,

1995; Clapham *et al.*, 2001; Li and Kemp 2005). In contrast, plantain percentage was relatively higher in the winter and early spring periods than in late spring and summer, supporting this finding, Stewart (1996) stated that plantain cultivar ‘Ceres Tonic’ is active in winter.

During year two, a drought prevailed across the whole North Island directly affecting farming practices (Anonymous 2014). Labreveux *et al.* (2004) and Moorhead and Piggot (2009) observed that plantain percentage decreased over the time in plantain based swards. Both Moorhead and Piggot (2009) and Stewart (1996) stated that plantain is suitable for summer and autumn warm weather conditions but they did not elaborate on the production aspects in very dry/drought conditions. Labreveux *et al.* (2004) found that the plant density of ‘Grassland Lancelot’ decreased towards the second year decreasing the yield. They reported that the yield of ‘Grassland Lancelot’ was three times lower during the second summer when the weather conditions were drier than the first summer. The present results suggest that the adverse weather conditions during the summer and autumn in the second year may have affected the production of the Plantain mix. However, chicory did better during the drought in year two. This suggests the Chicory mix might be a more stable option in areas that are prone to very dry conditions.

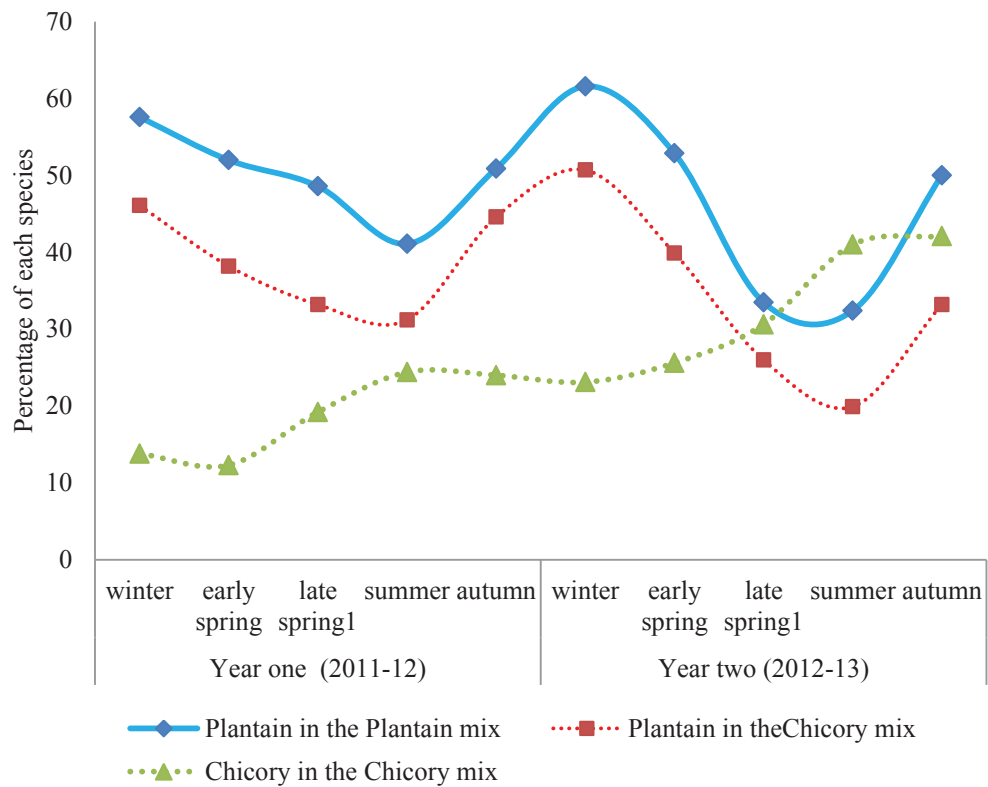


Figure 8-3: Percentage of plantain in the Plantain and Chicory mixes and chicory in the Chicory mix across different periods of the year.

¹Late spring and early summer ²nd November to 19th December in 2011 (Year one) and 31st October to 17th December 2012 (Year two).

8.4 Limitations and weaknesses of the study

The paddocks of the Plantain and Chicory mixes were mowed using a tractor during late spring and summer to remove the seed heads and maintain the vegetative growth. This practise damaged the plantain, white- and red-clover plants. The mowed stem materials left in the paddock created a difficult situation for grazing lambs in summer as these stem materials stuck to the wool and also covered the other herbage species in the paddock.

Broad leaved dock (*Rumex obtusifolius* L.) was the major weed found in the Plantain mix paddocks. It seemed to survive the chemical and mechanical control. The presence of this weed might have affected the plantain growth in the Plantain mix especially during the year two dry summer, reducing the percentage of plantain in the mix. Rushes (*Juncus acutus*) were found in both the Plantain mix and Chicory mix paddocks but were controlled by the chemical Roundup (active ingredient glyphosate) to some extent.

If the plate meter and sward height measurements were obtained in both years, it would have further increased the strength of the regression equations reducing the error rates and variability in the data set.

In the selection experiment (Chapter 6 Section B) the individual species quality parameters were not measured. If these parameters were known it might help in explaining the differences in selection.

The source of lambs was different during different periods. Therefore, the genotype of Romney crosses may have varied in the consecutive years for the same period. However, this situation was same for all three treatments within each period.

All lambs were sold at the end of each experimental period. This resulted in some lambs being underweight and hence, bearing a penalty from underweight lamb carcasses. This produced a negative income during some seasons especially in the Pasture mix. In an actual farmer situation, the underweight lambs might have been kept till they gained the required slaughter weight. But, as this was a PhD research programme, similar practices needed to be undertaken in all the treatments.

8.5 Recommendations for further research

This thesis does not cover the meat quality aspects. Researchers have found that the type of forage affects the meat flavour (Purchas *et al.*, 1986; Bailey *et al.*, 1988; Young *et al.*, 1994). It is important to test whether there is a difference in the meat quality between the three treatments. Therefore, a comprehensive laboratory analysis and tasting panel study could be undertaken.

A long term study using these herb-clover mixes would enable to understand, whether the effect of proportional selection found in the short to medium term would affect the herbage botanical composition over time. Furthermore, the change in weather conditions may also affect the herbage botanical composition during long dry summer periods. This suggests that lambs reared on herb-clover mixes during this period might have lower live weight gains.

Measurement of the plant density in the Plantain and Chicory mixes would have provided further evidence as to whether the rotational grazing management used and selective grazing by lambs and the environmental conditions experienced had any effect on the plant density in the swards. This data would provide additional information to that found in Chapter 6 Section A. However these studies need to be longer term i.e. at least five years.

The winter grazing of these herb-clover mixes was avoided as it was hypothesised that if grazed during winter, it would negatively affect the survival of these herb-clover mixes during the other seasons. Previous studies have shown that plantain, chicory and red clover are either dormant or semi dormant in winter (Hay and Ryan 1989; Purves and Wynn-Williams 1989; Moloney and Milne 1993; Kemp *et al.*, 2010). Further, grazing under water logging conditions can damage the growth points (Watkin and Clements 1978; Singleton *et al.*, 2000; Li and Kemp 2005) affecting their persistence in the long run. Therefore, a study could be carried out during the winter to understand the effect of winter grazing on the survival of these herb-clover mixes overtime. If no effect was found this could further strengthen the benefits found on a per ha per year basis for lamb production.

It may be of interest to study the effect of irrigation on the survival and production of these herb-clover mixes. It could be suggested that under irrigation the Plantain mix might be more productive. However, Hayes *et al.* (2010) indicated that even under irrigation, pure swards of plantain was less persistent compared to chicory in summer. In the present study there was a drought in the second year. As a result Plantain mix did not perform as expected. If productivity of herb-clover mixes was

found to be greater under irrigation, this would suggest that per lamb per ha productivity would be further enhanced compared to red clover.

A thorough impartial economic analysis considering all the costs and returns from the three treatments would be beneficial. In the present financial analysis, only the major costs (as shown in Table 8-2) and income from sale of lambs were considered. Modelling of the effects of different proportions of the herb-clover mixes and ryegrass/white clover pastures considering the other classes of farm livestock on a farm would also be of benefit. Combined this information would enable farmers to decide the proportion of the herb-clover mixes to be established on a farm.

8.6 Overall Conclusion

- i. This research indicates that by grazing herb-clover mixes it is possible to improve both lamb live weight gains and carcass weights from early spring to autumn relative to perennial ryegrass/white clover pastures.
- ii. It has been shown that calibration equations for Plantain and Chicory mix can be developed for measuring the herbage DM mass in different seasons using either the sward stick or plate meter.
- iii. Mixed swards of herbs and clovers were more productive than the ryegrass/white clover sward during late spring to autumn period with low weed percentage during both years.
- iv. When both herb-clover mixes were compared, the Chicory mix produced more consistent results compared to the Plantain mix over both years and that Chicory mix might be a more stable option in areas that are prone to very dry conditions. Both herb-clover mixes produced greater per ha carcass weight production (Plantain mix 1355 kg/ha and Chicory mix 1351 kg/ha respectively) compared to the Pasture mix (881 kg/ha) over both years.

Chapter 9 : References

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Appendix

Table 10-1: Live weight (LW) and carcass weight production per ha (kg/ha) for each herbage treatment (Pasture mix vs Plantain mix vs Chicory mix) in year one and year two.

Description	Year one			Year two		
	Pasture mix	Plantain mix	Chicory mix	Pasture mix	Plantain mix	Chicory mix
LW production per ha (kg/ha)						
- actual	*1049	1456	1297	*1171	1242	1303
- calculated	*1034	1524	1378	*1278	1337	1392
Carcass weight production per ha (kg/ha)						
- actual	*401	717	664	*451	557	596
- calculated	*414	642	580	*513	554	577

*Including winter data.

Actual LW production per ha (kg/ha) = \sum (total carcass weight/ha – buy-in carcass weight at D₁ for each experimental period: early spring, late spring, summer and autumn).

Calculated LW production per ha (kg/ha) = \sum (dressing out percentage DP% x total live weight gain per ha for each experimental period: early spring, late spring, summer and autumn).



Figure 10-1: Field map of the experimental site – Moginie Pasture and Crop Research Unit, Massey University



Plantain mix



Chicory mix



Pasture mix

Figure 10-2: The herbage Treatments



Figure 10-3: The overall research experimental design



Figure 10-4: Transect readings



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**STATEMENT OF CONTRIBUTION
TO DOCTORAL THESIS CONTAINING PUBLICATIONS**

(To appear at the end of each thesis chapter/section/appendix submitted as an article/paper or collected as an appendix at the end of the thesis)

We, the candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of Candidate: Sharini Carol Somasiri Sinhadipathige

Name/Title of Principal Supervisor: Professor Paul R. Kenyon


Name of Published Research Output and full reference:

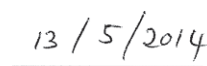
SOMASIRI S. C., KENYON P. R., MOREL P. C. H., KEMP P. D. and MORRIS S. T. (2014). Alternative method to measure herbage dry matter (DM) mass in Plantain and Chicory mixed swards grazed by lambs. Proceedings of the New Zealand Society of Animal Production (Accepted).

In which Chapter is the Published Work: Chapter 5

Please indicate either:

- The percentage of the Published Work that was contributed by the candidate: 80%
and / or
- Describe the contribution that the candidate has made to the Published Work:
Candidate has written and did the analysis for this publication work with the support from the co-authors.


Candidate's Signature


Date


Principal Supervisor's signature


Date