EFFECTS OF ALTERNATIVE GRASS SPECIES ON GRAZING PREFERENCE OF SHEEP FOR WHITE CLOVER

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ABSTRACT

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Despite the importance of a high white clover (*Trifolium repens*) content in temperate pastoral systems in terms of livestock performance and nitrogen fixation, the proportion of white clover in grass-clover pastures is often low (<20%). This thesis examined in two experiments whether the white clover content of pastures could be improved by sowing white clover with alternative grass species to diploid perennial ryegrass (*Lolium perenne* L.).

In a pasture experiment, DM production, pasture composition and morphology of grass-clover mixtures was measured over the establishment year (January 2007 to January 2008) where white clover was sown in fine mixtures with diploid perennial ryegrass, tetraploid perennial ryegrass, timothy (*Phleum pratense* L.) and cocksfoot (*Dactylis glomerata* L.). Pastures were irrigated and rotationally grazed with on-off grazing with Coopworth ewe hoggets. Total annual DM production of pasture was more than 20% higher in tetraploid (12521 kg DM ha^{-1}) and diploid (11733 kg DM ha^{-1}) perennial ryegrass than timothy (9751 kg DM ha^{-1}) and cocksfoot (9654 kg DM ha^{-1}). However, timothy (5936 kg DM ha^{-1}) and cocksfoot (5311 kg DM ha^{-1}) had more than four times higher white clover annual DM production than tetraploid (1310 kg DM ha^{-1}) and diploid (818 kg DM ha^{-1}) ryegrass. Pasture growth rate at the first three harvests in autumn was significantly greater in tetraploid and diploid ryegrass than timothy and cocksfoot. Timothy and cocksfoot had a higher proportion of white clover than tetraploid and diploid perennial ryegrass throughout the entire year. This was due to more and larger white clover plants in timothy and cocksfoot plots.

In a grazing preference experiment, the partial preference of sheep for white clover offered in combination with the same grass species as in the pasture experiment was measured in five grazing tests in May, September, October, November and December 2007. Pastures were sown in January 2007. Paired plots (grass and clover both 4.2 m x 10 m) were grazed by three Coopworth ewe hoggets between 9am and 5pm, and preference was recorded by decline in pasture mass and visual scan sampling for grazing time. Grazing preference for clover was generally low throughout these tests (e.g. average apparent DM intake from clover = 47%; average grazing time from clover = 44%). Several explanations are proposed for this low preference including a high N content and intake rate of the grass relative to the clover. No significant differences were found among the grass treatments in total grass grazing time, total clover grazing time, ruminating time, the proportion of grazing time on clover, selective coefficient for clover and DM intake percentage from clover at any date. There was no significant change in overall sward surface height (SSH) decline among grass treatments throughout all the tests except December 2007 when the overall SSH decline for cocksfoot was significantly lower than the other species.

The study indicated that the rapid growth rate of perennial ryegrass in the early phase of pasture establishment, rather than differences in partial preference, was the key factor limiting white clover content in the mixed swards relative to cocksfoot and timothy pastures. It is concluded that high clover-containing pastures capable of delivering high per head performance can be established through the use of slow establishing pasture species such as timothy and cocksfoot.

KEYWORDS: tetraploid perennial ryegrass, diploid perennial ryegrass, timothy, cocksfoot, white clover, *Lolium perenne*, *Phleum pratense*, *Dactylis glomerata*, *Trifolium repens*, grazing preference, mixed swards, monocultures, growth rate.

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1 CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background

Pastures containing a mixture of perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens)* form the basis of low-cost animal production systems in temperate regions of the world (Caradus *et al.*, 1996). White clover provides nitrogen (N) to the pasture via nitrogen fixation, and is also a forage of high feeding value relative to grass. Numerous studies show that as the proportion of white clover in the pasture increases there is improved performance of both sheep, beef and dairy cows (Caradus *et al.*, 1996; Parsons *et al.*, 2006), with performance on pure white clover swards generally exceeding performance on mixed grass-clover pastures (Cosgrove *et al.*, 2003). Thus, the ability to sustain a high proportion of clover in the pasture is important for N input into pastures and high animal performance.

Ideally at least 25-45% of the total herbage grown dry matter (DM) in grass-white clover pastures should be clover to achieve adequate N inputs and high animal performance (Thomas, 1992; Kemp *et al.*, 1999). However, in most temperate pastures the average white clover content over the year is less than 20% (Ettema and Ledgard, 1992). Thus, white clover contents are usually too low to support the full annual DM production potential of ryegrass-white clover pastures. This leads to greater reliance on nitrogenous fertilisers, which in turn may reduce legume content further particularly if stocking rate is not increased to harvest the extra feed resulting from N fertilizer (Clark and Harris, 1996). With increases in the price of N fertilizer and concerns over the impacts of excessive N fertiliser usage causing increased N losses via leaching and to atmosphere, there is clearly a need to develop methods to improve the proportion of clover in pastures.

One strategy to improve the legume content of pastures has been to develop via plant breeding improved white clover cultivars. However, although new cultivars have performed well in small plot trials, their effect on clover content and animal performance when evaluated at the farm scale has been relatively small (Crush *et al.*, 2006). Parsons *et al*. (2006) reviewed a range of other strategies that may be used to increase the white clover content of pastures. These included the use of pure white clover and grass swards as spatially separated monocultures, the manipulation of N fixation and N uptake relationships between grasses and clovers, and the alteration of competition and diet selection through the use of alternative grass species to perennial ryegrass. Parsons *et al*. (2006) noted that to develop practical strategies to increase the clover content of the pasture and diet requires an understanding of animal behaviour, including grazing preference and diet selection. This is because one of the key factors affecting grass-legume interactions is diet selection and the extent to which clover and grass are grazed within a pasture. Previous studies show that livestock prefer a diet of around 60-80% white clover when white clover is offered in combination with perennial ryegrass (Newman *et al.*, 1994b; Penning *et al.*, 1995b; Cosgrove *et al.*, 1996; Torres-Rodriguez *et al.*, 1997; Rutter *et al.*, 2005b). As mixed pastures rarely contain this amount of white clover, livestock often select clover out of the pasture (Cosgrove and Edwards, 2007). In turn, this places clover at a disadvantage in terms of plant to plant competition and contributes to low clover content in the sward.

1.2 Objectives

This thesis focuses on the use of alternative grass species to diploid perennial ryegrasses as a means to improve white clover content. The compatibility of several kinds of grass species, — diploid and tetraploid perennial ryegrass, timothy (*Phleum pratense*) and cocksfoot (*Dactylis glomerata*) — with white clover are explored. It is proposed that the white clover content may be higher with alternative grass species as they are less competitive with white clover and because they have grazing preference closer to that of white clover (Edwards *et al.*, 2008).

The objectives of this work were:

1. To determine the effect of grass species on pasture production, composition and morphology of mixed grass-white clover pastures over the establishment year, and
2. To determine the effect of grass species on partial preference of sheep for white clover.

2 CHAPTER TWO

LITERATURE REVIEW

2.1 Scope of literature review

This literature review concentrates on grass-clover pastures for either irrigated or summer moist environments. Brock (2006) indicated that the amount of rainfall in summer that was needed for white clover survival was 40 mm/month and 60 mm/month for production. The significance of white clover in New Zealand pastures, the background of low clover content and how diet selection affects clover content is reviewed. Methods to improve the white clover content are then discussed. Finally, aims and specific objectives for this study are given.

2.2 Significance of white clover

2.2.1 Nitrogen fixation

Nitrogen (N) fixation is a remarkable characteristic which legumes possess, and its process is carried out by rhizobia, the generic name of *Azorhizobium*, *Bradyrhizobium*, *Photorhizobium*, *Rhizobium* and *Sinorhizobium* bacteria (McKenzie *et al.*, 1999; Taiz and Zeiger, 2002). These nitrogen-fixing bacteria convert atmospheric N, di-nitrogen gas (N_2), into ammonium ($NH4^+$), which is easily available for plants, with the nitrogenase enzymes (Taiz and Zeiger, 2002). Apart from other kind of free-living microorganisms in soils, rhizobia have a symbiotic relationship with legume species, such as white clover. In return for providing nitrogen, these bacteria obtain carbohydrates as an essential nutrient and anaerobic environment within the root tissues of the host legume, particularly in nodules (Langer, 1990; McKenzie *et al.*, 1999; Taiz and Zeiger, 2002).

The contribution of N to pastures via N fixation is one of the primary grounds that legumes are chosen as a pasture species. Nitrogen fixed by legume is passed to grasses when clover dies or via dung and urine. Potential N-fixation rates from white clover range 600-700 kg N ha^{-1} $year^{-1}$ (Crush 1987). However, the presence of mineral N (such as from N fertilizer) and factors which reduce white clover growth and abundance (e.g. grass competition, diet selection) result in much lower N fixation rates. Thus, reported N fixation rates range from 17 kg N ha^{-1} $year^{-1}$ in infertile hill pastures to 380 kg N ha^{-1} $year^{-1}$ in intensively managed pastures (Crush, 1987). In the absence of mineral N, there is a direct positive relationship between N fixation and white clover growth (Hoglund and Brock, 1987). Therefore, from the point of view of improving N inputs into pastures, it is important to increase the white clover content of the pasture. Thomas (1992) estimated that legume contents of 20-45% could provide the N requirements of a sustainable productive pasture. However, the legume content of most pastures is less than 20%, and thus N supply is too low to support the full productive potential of ryegrass based pastures (Parsons *et al.*, 2006).

2.2.2 Nutritive and feeding value

White clover is regarded as a high quality forage for livestock in grazed temperate pastures. High quality results from a greater nutritive and feeding value for white clover compared with other pasture species such as perennial ryegrass (*Lolium perenne* L.). Nutritive value refers to the animal response per unit of feed intake and reflects available nutrients which are required by animals, including crude protein, lipids, fat-soluble vitamins, macro-elements (sodium, calcium, potassium, phosphorus, sulphur, magnesium, chlorine), micro-elements (cooper, cobalt, selenium, iodine, iron, zinc, manganese) and energy (metabolisable or digestible energy) (Ulyatt, 1981; Waghorn and Clark, 2004). Feeding value refers to animal production response (e.g. g $head^{-1}$ day^{-1}) and therefore is a function of both intake and nutritive value (Ulyatt, 1981). Compared to grass species, including perennial ryegrass, white clover contains higher crude protein, readily fermentable carbohydrate (e.g. water-soluble sugars and pectin), and metabolisable energy (ME) but lower structural carbohydrate (e.g. cellulose), lignin and fibre (Ulyatt *et al.*, 1977; Waghorn and Clark, 2004).

Relative feeding values for sheep and cattle are consistently higher in white clover than grasses (Tables 2.1 and 2.2). The dietary advantages of white clover over grass species may be attributed to a higher proportion of non-structural carbohydrates and lower content of structural carbohydrates (Ulyatt *et al.*, 1977). Compared with structural carbohydrates such as hemicellulose and cellulose, non-structural carbohydrates, including water-soluble sugars and pectin, are more fermentable, and more easily digested in the rumen (Ulyatt *et al.*, 1977). Hence, a higher ratio of non-structural carbohydrates to structural carbohydrate is nutritionally favourable (Ulyatt *et al.*, 1977). The proportions of readily fermentable carbohydrate and structural carbohydrate, and ratios of these carbohydrates in ryegrass and white clover are seen in Table 2.3. The considerably higher value of the ratio for white clover (1.17) than that for ryegrass (0.42) indicates that ryegrass is more slowly digested in the rumen, and in turn the nutritive content of clover is more likely to be utilised for animal production.

In addition, feeding values of grass species can vary with the presence and degree of endophyte infection. For instance, Edwards *et al*. (1993) demonstrated that the intake of endophyte-infected (wild type) perennial ryegrass by sheep was lower than that of endophyte-free grass within the same species, and suggested a subsequent reduction of animal performance. Therefore, when endophyte-infected, the grass species may show lower animal performance even if the feeding value (e.g. ME) of the grass was high.

Furthermore, the nutritive value of white clover declines less than that of grass species with the onset of reproductive development, increasing temperatures and with long regrowth intervals than perennial ryegrass does (Waghorn and Clark, 2004). Thus, legume dominated pasture may be easier to manage for high nutritive value, than a grass dominated pasture.

Table 2.1 The feeding values of several pasture species in terms of sheep live weight (adopted from Ulyatt 1981).

Species	Relative feeding value
Perennial ryegrass `Grasslands Ruanui' (diploid)	100
Perennial ryegrass `Grasslands Ariki' (tetraploid)	111
Perennial ryegrass `Grasslands Manawa' (diploid)	148
Timothy, Common cultivar	129
White clover `Grasslands Huia'	192

Table 2.2 The comparative feeding values of pastures in dry matter intake (DMI) and milksolids (MS) production of cows during a mid-late-lactation period (adopted from Johnson and Thomson 1996).

	Total nitrogen content (%)	Relative feeding value in DMI	Relative feeding value in MS
Perennial ryegrass `Yatsyn-1' (diploid)	4.02	100	100
Timothy `Grasslands Kahn'	4.24	104	109
Cocksfoot `Grasslands Kara'	4.03	117	109
White clover `Grasslands Kopu'	4.26	96	168

Table 2.3 Chemical composition (%DM) of perennial ryegrass and white clover in New Zealand (Ulyatt *et al.*, 1977).

	Cutting height (cm)	Readily fermentable carbohydrate (a)	Structural carbohydrate (b)	a / b
Ryegrass (`Ruanui')	15	12.3	29.5	0.42
White clover (`Huia')	10	20.3	17.3	1.17

The intake rate of sheep and cattle (g DM min^{-1}) increases as the proportion of white clover in the pasture increases, with consistently greater intake rates in pure white clover than ryegrass swards (Penning *et al.*, 1991; Edwards *et al.*, 1995; Penning *et al.*, 1995b). This is partly due to larger bite masses from white clover than ryegrass, although the difference in intake rate may be smaller than expected due to an associated decline in prehension rate as bite mass increases. The larger bite masses are in turn due to larger bite areas, with there being little difference in bite depth between ryegrass and white clover (Edwards *et al.*, 1995). However, the factor contributing most to the higher intake rates of white clover than ryegrass is the lower mastication cost for clover than for grass (Newman *et al.*, 1992; Parsons *et al.*, 1994b; Penning *et al.*, 1995b). In general, higher intake rates lead to greater daily intakes in white clover than perennial ryegrass (Penning *et al.*, 1995b). However, in some cases, animals reduce grazing time, and increases in daily intake do not arise (Penning *et al.*, 1995b).

The greater nutritive value and higher intake rate combine to give improved feeding value and livestock performance as the proportion of white clover in the pasture increases. For example, in a dairy study, milk production per cow increased from 0.80 kg milk solids (MS) cow^{-1} day^{-1} at 20% clover content to 0.93 kg MS cow^{-1} day^{-1} at 50% clover content in the diet (Harris *et al.*, 1997). In lamb growth studies, Gibb and Treacher (1984) found a high correlation (R = 0.78) of empty-live-weight gain per head with the proportion of clover as organic matter in a diet. In addition, growth of lambs is consistently higher on pure clover pastures than grass-clover mixtures. For instance, average daily gain of weaned lambs was much higher in clover monoculture swards (345 g $head^{-1}$ day^{-1}) than in the mixtures of grass and clover (205 g $head^{-1}$ day^{-1}) (Cosgrove *et al.*, 2003).

2.2.3 Seasonal growth pattern

A further useful feature of perennial ryegrass and white clover mixtures reflects their complementary growth patterns. Ryegrass and clover have complementary patterns of seasonal growth with grasses being more productive during autumn, winter and spring, and clover potentially (when given adequate water) more productive during summer (Brock, 2006; Parsons *et al.*, 2006).

2.2.4 Background of low clover content

Perennial ryegrass-white clover pastures in New Zealand frequently contain less white clover than necessary to meet the requirement for high animal production (Chapter 1). With regard to the causes of low clover content in a mixed pasture of New Zealand pastoral farming, Brock (2006) mentioned three factors. First, seedling establishment methods that enhance grass establishment, rather than clover establishment, such as high sowing rates of grass, direct drilling at high speed, sowing clover too deep and sowing clover too late in autumn. Second, management to maximise grass mass, such as increased N fertiliser use, infrequent and lenient grazing and selection of more productive grasses. Third, selective grazing for clover over grasses.

2.3 Effects of diet selection

Diet selection is where the diet harvested differs from the diet on offer in the sward and reflects some sward components but not others being harvested. For example, more clover is generally selected than that which is on offer (Newman *et al.*, 1992; Parsons *et al.*, 1994a; Penning *et al.*, 1995a; Cosgrove *et al.*, 1996). This places clover at a disadvantage in terms of plant to plant competition with ryegrass (reviewed in Cosgrove and Edwards 2007), particularly when ryegrass is dense and tall. Although selecting clover may increase the proportion of clover in diet initially, it may limit clover growth and make clover less competitive with grass, and finally may reduce the amount available in a mixed pasture.

2.3.1 Diet selection

Diet selection is a function of grazing preference modified by environmental constraints. Thus, as a first step in determining the impact of grazing livestock on pasture composition it is important to have knowledge of the grazing preference of livestock.

2.3.2 Partial preference

Considerable research now shows that sheep, cattle and goats all exhibit a partial preference for white clover over perennial ryegrass. When offered freely voluntary choices between pure swards of white clover and perennial ryegrass, they select 60-80% white clover as a diet, but always continue to eat perennial ryegrass to some extent (Newman *et al.*, 1994a; Parsons *et al.*, 1994a; Penning *et al.*, 1995a; Cosgrove *et al.*, 1996). This takes place despite the situation where these animals are able to acquire a diet of pure clover at no extra foraging cost. There is also a diurnal pattern of preference, with sheep and cattle preferring clover in the morning, but eating more ryegrass as the day passes (Parsons *et al.*, 1994a; Penning *et al.*, 1995a).

It has not been clearly deciphered yet why partial grazing preference would take place (Rutter, 2006). Soder *et al.* (2007) reviewed the basis of this partial preference, listing a range of hypothesis. These include maintenance of rumen function (Rutter *et al.*, 2000), maintenance of appropriate C:N ratio in rumen (Dewhurst *et al.*, 2000; Merry *et al.*, 2002; Rutter, 2006), predation hazard and the perceived risk of predators (Newman *et al.*, 1995) and avoidance of toxins (Kyriazakis and Oldham, 1993). Rutter (2006) concluded that ruminant animals possibly select a diet to acquire a balance between dual goals, which might compete between them, and it is not necessarily that partial preference occurred due to a single common basis supporting these goals. In this context, it is important to note that the grazing preference results mentioned above are based on white clover in comparison to diploid perennial ryegrass cultivars. It is not known whether the partial preference of 60-80% would be different for other grass species if tetraploid versus diploid perennial ryegrasses were used.

2.3.3 Other potential elements regulating grazing preference

Numerous nutritive and mineral constituents of a pastoral diet have been implicated in grazing preference. The digestibility and ME of a pasture species may be one of the factors for grazing preference since the diet selectively grazed generally contain higher digestibility and ME than those of the average pastures in the same paddock (Jamieson and Hodgson, 1979). This can be happened under lax grazing to a larger extent, and is less likely to be exhibited in intensive grazing systems as the opportunities for selecting a specific diet are greater in the former case and limited in the latter one (Cosgrove and

Edwards, 2007). Mineral contents (e.g. calcium and potassium content and/or various mineral ratios, etc) of a pasture plant show both positive and negative correlation with palatability amongst several cultivars of cocksfoot offered to heifers (Mizuno *et al.*, 1998). Edwards *et al*. (1993) suggested that the negative grazing preference of sheep for cocksfoot might have occurred due to the low N content of cocksfoot herbage. The relatively higher degree of grazing preference of sheep has also been seen among several weeds with relatively high mineral content in a tussock grasslands (Hughes, 1975). Hence, measurement of these chemical constituents is necessary in this study.

Besides nutritive aspects, morphological features of a pasture species have been thought as one of the possible factors which affect animal intake behaviour. Orr *et al*. (2004) suggested that ingestive characteristics of heifers might be influenced by sheath tube and leaf length when grass was grazed and by herbage mass as white clover was ingested. The texture of a plant is possibly a limiting factor for grazing preference in a certain situation, especially, where animals can select the favourable diet from the abundant pastures with a variety of species and / or cultivars. Flexibility of leaf and stem of cocksfoot (*Dactylis glomerata* L.), for example, is positively correlated with palatability amongst cultivars in autumn (Mizuno, 1999). Taking account of those, morphological measurement is also needed in this investigation.

2.4 Increasing clover content of temperate pastures

2.4.1 Clover breeding and sowing

The importance of a higher clover content means that methods are sought to improve the clover content of pastures. Plant breeders have suggested that new cultivars may increase the clover content of pastures (Woodfield *et al.*, 2001). However, recent studies of new versus old cultivars have shown little impact on clover content on dairy production when compared at the farm scale (Crush *et al.*, 2006). A further approach is to use reduced sowing rates of competing grasses or using less competitive grasses such as timothy (*Phleum pratense*), with the aim to have less competition with the slow establishing white clover (Cullen, 1958; Hurst *et al.*, 2000). Cullen (1958) demonstrated deleterious effects of even moderate (10 kg ha^{-1}) sowing rates of ryegrass on the establishment of slow establishing species such as white clover. Furthermore, sowing method also has a scope for being reconsidered to promote 'clover-friendly' seed beds. Shallow sowing depth (5 mm) and firm seed beds are recommended for achieving successful emergence of clover (Brock, 2006)

2.4.2 Spatial separation of monocultures

Edwards *et al*. (2008) and Parsons *et al*. (2006) summarised a further strategy to increase clover content, that being the use of spatially separated monocultures of grass and clover in the same field. The approach is to present plant species in an area ratio that more closely matches the animal's perspective of what constitutes an optimal diet. Animal preferences then ensure that neither species should be grazed to extinction, and that the direct effects of selective grazing are minimized. Moreover, the selection and sampling costs associated with grazing a conventionally finely inter-mixed species sward may be minimised

(Champion *et al.*, 2004).

Establishing and growing grass and clover separately may also have some advantages in the ease of fertilising management and weed control, and the improvement of performance which each individual species owns (Parsons *et al.*, 2006). In a review Edwards *et al.* (2008) showed the per-animal performance from spatially separated monocultures of ryegrass and white clover is generally higher than that from conventional mixtures (*c.* + 10% in milk; + 25% in live weight gain, Table 2.1), and similar to that in pure white clover monocultures.

Apart from its great potential, there are some concern to be considered for spatial separation of pasture species. White clover monocultures produce 25% less in annual herbage production than a fully fertilised perennial ryegrass monoculture (Harris and Hoglund, 1977). A simple simulation model for New Zealand dairy farming by Cosgrove (2005), however, shows milk solids per hectare should improve up to a point where 60% of pasture allowance was white clover. Thus, the demerit of monoculture use in total annual DM yield is possibly compensated by improvement of animal production. Relatively even seasonal distribution of forage can also contribute to compensate the disadvantage of lower DM production at peak in spring in grass monocultures. According to Chapman and Kenny (2005), the higher DM production of white clover in summer, when adequate soil moisture is available, is more profitable than that of growing the same amount of feed in spring in pasture-based dairy farm systems in southern Australia.

Nitrogen transfer losses from white clover to grass are also concerned both aboveground (as urine and dung distribution should follow partial preference patterns) and underground (as clover litter is less likely to be provided to the companion grass species) (Edwards *et al.*, 2008), and it may increase the possibility of N deficiency in grass in spatially separated monocultures in comparison to finely mixed pastures (Sharp, 2007). Further, potential N losses from clover monocultures may be greater than ryegrass-white clover mixed swards (Sharp, 2007), especially in cool seasons (MacDuff *et al.*, 1990). Still, the efficient utilisation of white clover monocultures has a potential for mitigating the total amount of N fertiliser use for pastoral farming. Pest attack by nematodes and clover root weevil is a be concerned (Parsons *et al.*, 2006).

2.4.3 N fixation and uptake

In addition to spatial separation of monocultures, Parsons *et al.* (2006) suggested other methods, including altering the trade-off between N fixation and uptake of clover. The rationale is a notion that soil mineral N derived from the legume increases grass proportion and inevitably decreases clover proportion in mixed swards. To make clover more competitive against accompanying grass for acquiring soil mineral N, more aggressive root systems of clover are required (Parsons *et al.*, 2006).

2.4.4 Alternative grass species

A further possibility is to reduce the preference for the legume species relative to the grass species (Cosgrove and Edwards, 2007). Altering preference for plant species can have complex outcomes, especially when the animals revisit the same area and the rate of replacement of the food resources has been altered, dynamically, by the choices the animals originally made. Initially showing a strong preference for one species may increase the proportion of that species in the diet. However, the consumption of that species may reduce the presence and/or growth rate of it meaning that on subsequent visits there may be less of the preferred item, and more of the less preferred item, available (Parsons *et al.*, 1991). Thus, it would be necessary to reduce the relative preference for a preferred item (e.g. legume) to have any consequence of increased nutritive value (e.g. more legume) in the pasture and diet. Preference tests for grasses and legumes, with legumes other than white clover, exhibited similar partial preferences to those found with white clover: 75% (Cosgrove *et al.*, 1997) and 73% (Torres-Rodriguez *et al.*, 1997) for heifers with *Lotus corniculatus*; and 73% for sheep with sulla (*Hedysarum coronarium* L.) (Rutter *et al.*, 2005b). Thus, there appears to be limited scope for altering preference, and consequently sward composition, simply by moving to an alternative legume species. The alternative approach is to use variation in preference of animals for grass species. For example, the use alternative grass species to perennial ryegrass that have a higher preference relative to white clover. Thus in mixed pastures, there might be less impact on white clover through selective grazing. An alternative way of expressing this is that plant species with a lower preference differential are sought and that partial preference closer to 50:50 (clover:grass) than the 70:30 would be advantageous.

There are some reports that certain grass species are more preferred than the others. For example, Phillips and Yousseff (2003) showed that timothy and perennial ryegrass (cultivar or ploidy was not mentioned) were more preferred than cocksfoot and red fescue (*Festuca rubra*). However, partial preference for white clover was not recorded in this study. Anecdotal reports also suggest that tetraploid perennial ryegrass is more preferred than diploid. But, again, no direct tests relative to white clover of whether partial preference altered have been reported. Meanwhile, other grass species may have a negative effect on white clover as they are of low preference. Previous work suggests cocksfoot has low grazing preference (Edwards *et al.*, 1993), although this may be due to the low N content of cocksfoot herbage.

2.5 Compatibility of grass pasture species with white clover in mixtures

It is important to know the compatibility between a grass species and white clover when a binary mixture of pastures is introduced onto a pastoral farm. Perennial ryegrass generally has a notorious reputation as a companion species with the clover in terms of low clover content (Chapter 1). Fothergil and Davies (1993) demonstrated considerably higher white clover content in tetraploid than diploid perennial ryegrass/white clover mixtures (13.7% vs 8.3% for tetraploids and diploids, respectively) under set－stocked condition, and Davies (1988) reported higher level of compatibility of tetraploids with white clover than diploids.

Unlike these ryegrass species, timothy is regarded as a slow establishing species (230 ℃d for 50% field emergence, (Moot *et al.*, 2000)) and a comparable plant to white clover (150 ℃d for 50% field emergence, (Moot *et al.*, 2000)) within a mixed sward. The clover composition in timothy-white clover mixtures usually exceeds 20%, and is often double of that found in ryegrass-based mixtures (Watkin, 1975; Stevens *et al.*, 1993; Charlton and Stewart, 2000). Moreover, Skuodiene and Repsiene (2005) achieved over 30% clover content in timothy-white clover swards, with the white clover composition reaching 38.5% within the same type of swards in the cutting and rotational grazing system.

Cocksfoot is also known as a slow establishing (Moot *et al.*, 2000) and as an aggressive species in dryland pasture (Moloney, 1993). This implies that cocksfoot may be compatible with white clover during the establishment phase in mixed pastures but incompatible after establishment. Black and Lucas (2000) reported that white clover proportion in cocksfoot-white clover pastures declined from 24% at 15 months after sowing to 1% at 3 years, and the compatibility of cocksfoot with white clover was higher during the establishment phase than diploid perennial ryegrass but lower after the pasture developed.

In all these studies, however, it is not clear whether differences in composition are due to these species having a high grazing preference or poor competitive ability during establishment or as adult plant relative to white clover.

2.6 Aim

The aim of this thesis is to consider the potential role of using alternative grass species to alter partial preference with the goal of increasing clover content of pastures. Two studies were conducted. The first compared growth, composition and morphology of pastures made up of white clover growing with either diploid perennial ryegrass, tetraploid perennial ryegrass, timothy or cocksfoot. The second examined sheep partial preference for white clover compared to same four grass species.

2.7 Specific objectives of this study were:

1. To determine the effect of grass species on pasture production, composition and morphology of mixed grass-white clover pastures over the establishment year; and
2. To determine the effect of grass species on partial preference of sheep for white clover.

3 CHAPTER THREE

THE EFFECT OF GRASS SPECIES ON PASTURE PRODUCTION, COMPOSITION, SEEDLING ESTABLISHMENT AND MORPHOLOGICAL PROPERTY OF MIXED GRASS-CLOVER PASTURES

3.1 Materials and methods

3.1.1 Experimental site and design

The study was carried out in plots established in Iversen field I1, Field Services Centre (43 º 38 ’S, 172 º 28 ’E, 11 m a.m.s.l), Lincoln University in January 2007. The soil type is a Wakanui silt loam (Udic Ustocherept, USDA Soil Taxonomy). The experimental design was four replicates of grass-clover mixtures with four treatments of grass species: (i) tetraploid perennial ryegrass, (ii) diploid perennial ryegrass (*Lolium perenne* L.) (both ryegrass cultivars contained AR1 endophyte), (iii) timothy (*Phleum pratense* L.) and (iv) cocksfoot (*Dactylis glomerata* L.), sown with white clover (*Trifolium repens* L.) and laid out in a randomised block design giving 16 plots (Figure 3.1). The dimension of each experimental plot was 4.2 m x 5 m. Results of soil tests taken across the experiment on 20 January 2007 are shown in Table 3.1 (MAF Quick Test). Based on these results, superphosphate was applied to all plots on 20 March 2007 at 300 kg superphosphate ha^{-1}.

Table 3.1 Soil pH, Olsen P and calcium, magnesium, sodium and sulphur (all MAF quick the units) for experimental site on 20 January 2007.

pH	Olsen-soluble P ($\mu g\ ml^{-1}$)	Ca	Mg	K	Na	Sulphate-S
6.4	10	13	32	10	14	5

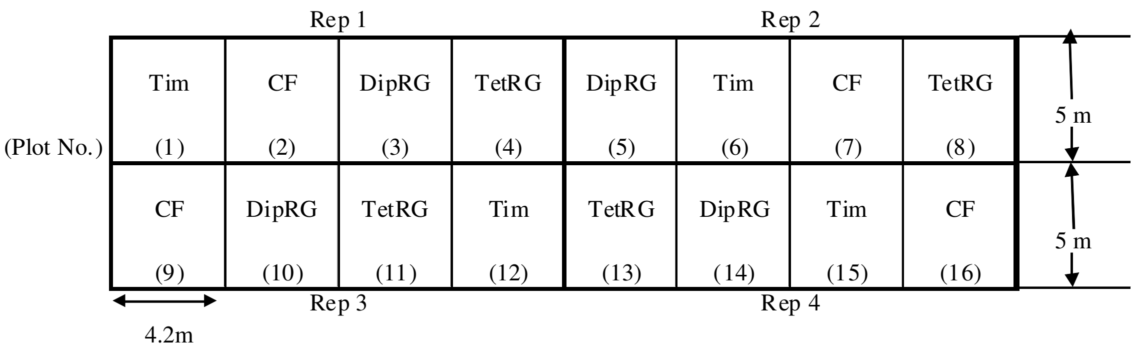

Figure 3.1 Plot design for the pasture production, composition, seedling establishment and morphological study. Codes used: Tim: timothy; DipRG: diploid perennial ryegrass; TetRG: tetraploid ryegrass; CF: cocksfoot. All plots were sown with white clover.

3.1.2 Pasture establishment

The site was ploughed and rolled, and 2 L ha^{-1} of glyphosate was applied to remove weeds on 1 November 2006, and left fallow until January 2007. On 4 January 2007, the site was again sprayed with 3 L ha^{-1} of glyphosate, and rolled with a 12 t roller to create a firm seed bed in preparation for sowing. Seeds were drilled with a 15 cm spacing using a double disc type drillseeder between each row on 8 January 2007. The species, cultivars and sowing rates used in the trial are shown in Table 3.2.

Table 3.2 Pasture species, cultivars and sowing rates used in the DM production, composition and morphology trial.

Pasture species	Cultivar	Ploidy	Sowing rate (kg ha^{-1})	Seed No. (seeds m^{-2})	Thousand seed weight (g)
Perennial ryegrass*	Quartet	Tetraploid	15	460	3.264
Perennial ryegrass*	Bronsyn	Diploid	12	543	2.208
Timothy	Viking	Diploid	3	813	0.369
Cocksfoot	Vision	Diploid	3	500	0.600
White clover	Demand	Diploid	3	446	0.673

*Ryegrass cultivars contained ARI endophyte.

3.1.2.1 Irrigation

The plots were irrigated on 3 occasions during the experiment on 27 February, 29 March and 26-27 November in 2007. Approximately 28 mm was applied each time.

3.1.2.2 Grazing

Pastures were topped with a mower to approximately 4 cm height on 16 March 2007. Thereafter, pastures were grazed in common at approximately 1-2 month intervals under mob-grazing conditions with around 100 ewe hoggets for all four replicates (336 m^2) or 50 to 70 head for two replicates (168 m^2). Grazing commenced once pasture mass had reached around 2500 kg DM ha^{-1} on the plots with the highest DM (Plate 3.1), and grazing ceased when pasture mass reached on the lowest plots with around 1000 kg DM ha^{-1} (Plate 3.3). Grazing typically took 1 to 2 days depending on pasture mass (Plate 3.2). There was some uneven grazing, reflecting differences in grazing preference. To minimise these impacts and even up pasture height, pastures were trimmed with a mower to 4 cm high within 1 to 2 days post grazing.

Plate 3.1 Photo showing experimental plots in August 2007.

Plate 3.2 Photo showing experimental plots during grazing in August 2007.

Plate 3.3 Photo showing a diploid perennial ryegrass plot after grazing in August 2007.

3.1.3 Measurements

3.1.3.1 DM production and composition

Pasture mass and composition were measured in two 0.2 m^2 quadrats cut to ground level before and after each grazing which occurred on 15 March, 28 March, 25 May, 24 August, 28 September, 7 November and 6 December in 2007. From the quadrat cut before grazing, a sub-sample was sorted into live grass, white clover, weeds and dead material. The sorted samples were oven-dried at 65˚C for at least 24 hours, weighed and the percentage contribution of the different components determined. From post-grazing quadrats, only pasture mass was measured. Accumulated DM between successive harvests was used to calculate total DM production and pasture growth rates.

3.1.3.2 Grass and white clover populations

The number of grass and white clover plants within a unit length of 40 cm was counted at four points in each plot positioned along a drill row on 2 March 2007 and 9 January 2008. To allow comparison with an area with no grass competition, the number of white clover plants was counted in four 0.4 m drill rows in 3 replicates of the preference trial plots on the same date (For details of the these plots, see clover plots for preference trial; Figure 4.1 and Section 4.1.1).

3.1.3.3 Grass and clover plant morphology

Morphological measurements of grass and white clover plants were taken on 12 March 2007 (i.e. approximately 2 months after sowing and 4 days before the first harvest) and 9 January 2008 (i.e. approximately 1 year after sowing and 1 month after the final grazing occasion). At each sampling date, a total of 10 white clover and 5 grass plants were collected from each plot. Root material was collected with each sample by digging plants to a depth of approximately 20 to 25 cm. Soil was then washed from each plant. For each clover plant, the number of stolons and fully expanded leaves were counted, and the height of the tallest petiole was measured. A stolon was defined as, and counted, when it had an expanded leaf on a piece of visible stolon. An expanded leaf was recognised as a pair of those in a condition that these leaves on a single petiole had more than two leaflets expanded with a 150 degrees or more angle. For each grass plant, the height of the longest extended tiller was measured, and the number of tillers was counted. Plants were then separated into root and shoot material, and the bulked samples from each plot oven-dried at 65 ºC for 24 hours before weighing. The mean root and shoot weight per plant was then calculated. Of these morphological measurements, tallest shoot length, root mass and number of opened leaves of clover were measured to see the influence of companion grass species on the growth of clover among treatments at the early and late phase of the first year of establishment.

3.1.3.4 Pasture nutritive value

Pasture snip samples designed to be representative of the material eaten by sheep (top third of canopy) were collected from each plot prior to grazing in November 2007 (7 hours after sunrise, one day before the test on each occasion) and then pooled across four replicates. Samples were freeze-dried and ground, before analysis for the concentration of metabolisable energy (ME) by near infra-red spectrometry (NIRS).

3.1.4 Calculations

3.1.4.1 Total DM yield of pasture, grass, clover, weeds and dead material from sowing to the end of grazing trials

Total DM yield was computed to be the sum of the differences in herbage mass between post grazing mass and the pre grazing mass at the following grazing, and the herbage mass before topping on 16 March 2007.

3.1.4.2 Daily growth rates of pasture, grass, clover and weeds at each grazing time

Daily growth rate of pasture, grass, clover and weeds were calculated respectively using the differences of herbage DM mass of these components between each pre grazing at a trial and the post-grazing at the very previous grazing divided by the number of days between each trial.

3.1.4.3 Botanical composition

The proportion of grass, clover, weeds and dead material were determined by calculating the % on a dry matter mass basis of these herbage components in the sub-sample from the quadrat sample collected before each grazing trial.

3.1.5 Weather data

Monthly rainfall and air temperature were collected from the Broadfields weather station, located approximately 2 km from the experimental site.

3.1.6 Statistical analysis

Data were analysed by analyses of variance (ANOVA) of a randomized block design using the statistical package GenStat (2007, GenStat 10th Edition, Lawes Agricultural Trust, Rothamsted experimental Station). Means were separated by LSD test following a significant ANOVA. For total DM yield, daily growth rates and botanical composition data, all analyses were carried out on the average of the two samples for each plot before these statistical tests.

3.2 Results

3.2.1 Climate

Monthly rainfall and average monthly air temperature at Lincoln University during the field experiment and in the past 20 years are shown Tables 3.3 and 3.4. Monthly rainfall was less than average from January to May 2007 except March (magnitude of difference of rainfall is 16.8 mm). After May, monthly rainfall was higher than average until the end of 2007, and the average of monthly rain fall over that period was more than 20 mm higher than that in the past. Total precipitation during this research (661.9 mm) was slightly higher than the average of last 20 years (620.6 mm) (Table 3.3). Air temperature was warmer than average in May 2007 and cooler than average in December 2007.

Table 3.3 Monthly rainfall at Lincoln University from January 2007 to January 2008. The 20 year average between 1986 and 2006 is shown for comparison.

	Monthly rainfall (mm)	Long-term average monthly rainfall (mm)
2007		
Jan	16.4	41.3
Feb	15.4	36.3
Mar	49.6	44.2
Apr	36.3	49.4
May	21.2	51.8
Jun	61.6	58.1
Jul	62.4	52.0
Aug	100.0	60.2
Sep	3.0	39.7
Oct	97.6	48.9
Nov	68.6	48.8
Dec	110.6	48.7
2008		
Jan	19.2	41.3
Total	661.9	620.6
Average	50.9	47.7

Table 3.4 Average monthly air temperature at Lincoln University from January 2007 to January 2008. The 20 year average 1986 and 2006 is shown for comparison.

	Average monthly air temperature (℃)	Long term average monthly air temperature (℃)
2007		
Jan	15.0	16.4
Feb	15.7	16.3
Mar	15.6	14.5
Apr	11.4	11.7
May	11.8	9.5
Jun	5.7	6.7
Jul	6.4	6.0
Aug	7.3	7.3
Sep	10.9	9.4
Oct	11.3	11.5
Nov	12.7	12.8
Dec	12.6	15.1
2008		
Jan	17.1	16.4
Average	11.8	11.8

3.2.2 Total DM yield

Total DM yield of pasture, grass, clover, weeds and dead material from January 2007 to December 2007 is shown in Table 3.5. Tetraploid and diploid ryegrass plots had higher total DM than timothy and cocksfoot (Table 3.5). Total DM yield of grasses ranged from 2182 DM ha^{-1} for timothy to 9562 DM ha^{-1} produced for tetraploid ryegrass. Total grass DM production of tetraploid- and diploid ryegrass was approximately three times that of timothy and cocksfoot. Total white clover DM production was greater by 4 times in timothy, followed by cocksfoot, compared with tetraploid ryegrass and diploid ryegrass, with significant differences between each species ($P < 0.001$). Total weed DM production was 3-4 times greater in timothy and cocksfoot than diploid and tetraploid ryegrass (P <

0.001). In contrast, total dead DM production in timothy and cocksfoot was only 40% of that in diploid or tetraploid ryegrass ($P < 0.001$).

Table 3.5 Total dry matter production of pasture, grass, clover, weed and dead material components (kg DM ha^{-1}) from 8 January to 6 December 2007. P-values are from ANOVA. Means were separated using a least significant difference (LSD) following a significant ANOVA. Values followed by different letters within a column are significantly different.

	Total	Grass	Clover	Weeds	Dead material
Tet RG	12521_a	9562_a	1310_c	201_b	1448_a
Dip RG	11733_a	9158_a	818_d	93_b	1663_a
Timothy	9751_b	2182_b	5936_a	771_a	863_b
Cocksfoot	9654_b	2679_b	5311_b	741_a	923_b
P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
LSD	999	576	430	213	101

3.2.3 Pasture growth rates

Pasture growth rates of the mixed grass-clover pastures from 8 January 2007 to 6 December 2007 are shown in Figure 3.2. Pasture growth rate ranged from 6 kg DM ha^{-1} d^{-1} in diploid ryegrass in winter to 91 kg DM ha^{-1} d^{-1} in tetraploid ryegrass in the summer (December) 2007. Pasture growth rate at the first three harvests was greater in tetraploid and diploid ryegrass than timothy and cocksfoot. Pasture growth rate declined in all pastures during winter, and did not differ significantly among grasses in September. Between September and October, timothy and cocksfoot pastures grew faster ($P<0.05$) than tetraploid and diploid ryegrass pastures. Between October and November, diploid ryegrass had slower growth (nearly 14 kg DM ha^{-1} d^{-1}) than the other pastures ($P<0.001$).

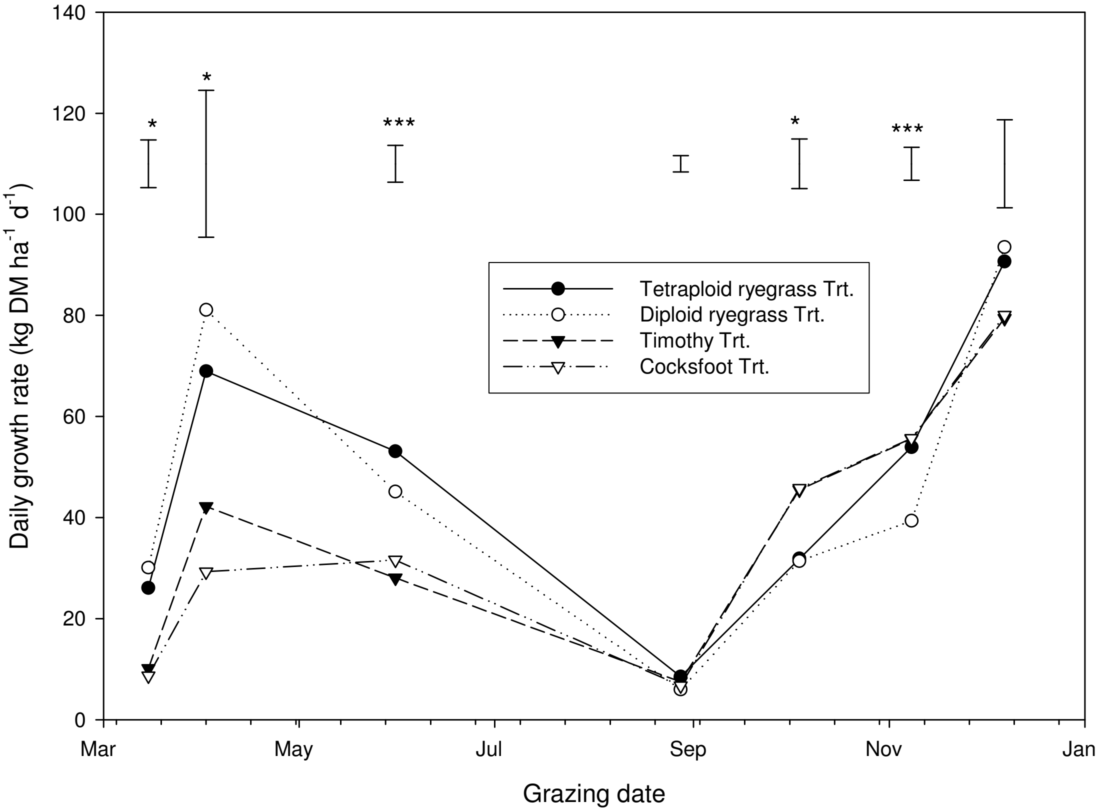

Figure 3.2 Pasture growth rates of grass-white clover pastures from 8 January 2007 to 6 December 2007. The vertical bars represent the LSD for comparing the differences among grass treatments at each date. Asterisks indicate significance of treatments effects at each date, * $P < 0.05$, *** $P < 0.001$(***).

3.2.4 Botanical composition

Tetraploid and diploid ryegrass pastures had around four times higher ($P<0.001$) grass percentage almost throughout the trial than timothy and cocksfoot (Figure 3.3a). There was no significant difference between diploid and tetraploid ryegrass in grass percentage, except in November, when diploid ryegrass had a higher grass percentage. There was no significant difference between timothy and cocksfoot in grass percentage throughout the year. The percentage of clover showed the reverse pattern being greater ($P<0.001$) in timothy and cocksfoot than tetraploid and diploid ryegrass throughout the year (Figure 3.3b). No significant differences in clover percentage were found between tetraploid and diploid ryegrass or between timothy and cocksfoot at any date. The dicot weed content of the pastures (mainly *Capsella bursa-pastoris*, *Poa* spp. and *Rumex* spp.) fluctuated, ranging from nearly 0% in June to 30% in September (Figure 3.3c). Weed percentage was not significantly different among the four pastures, except in May where there was a significantly ($P<0.05$) higher percentage (7.8%) of weeds in timothy than tetraploid and diploid ryegrass and cocksfoot. The percentage of dead material ranged from 0 to 15.5% (Figure 3.3d). In March and April, dead material percentage was higher ($P<0.001$) in tetraploid and diploid ryegrass than timothy or cocksfoot pastures.

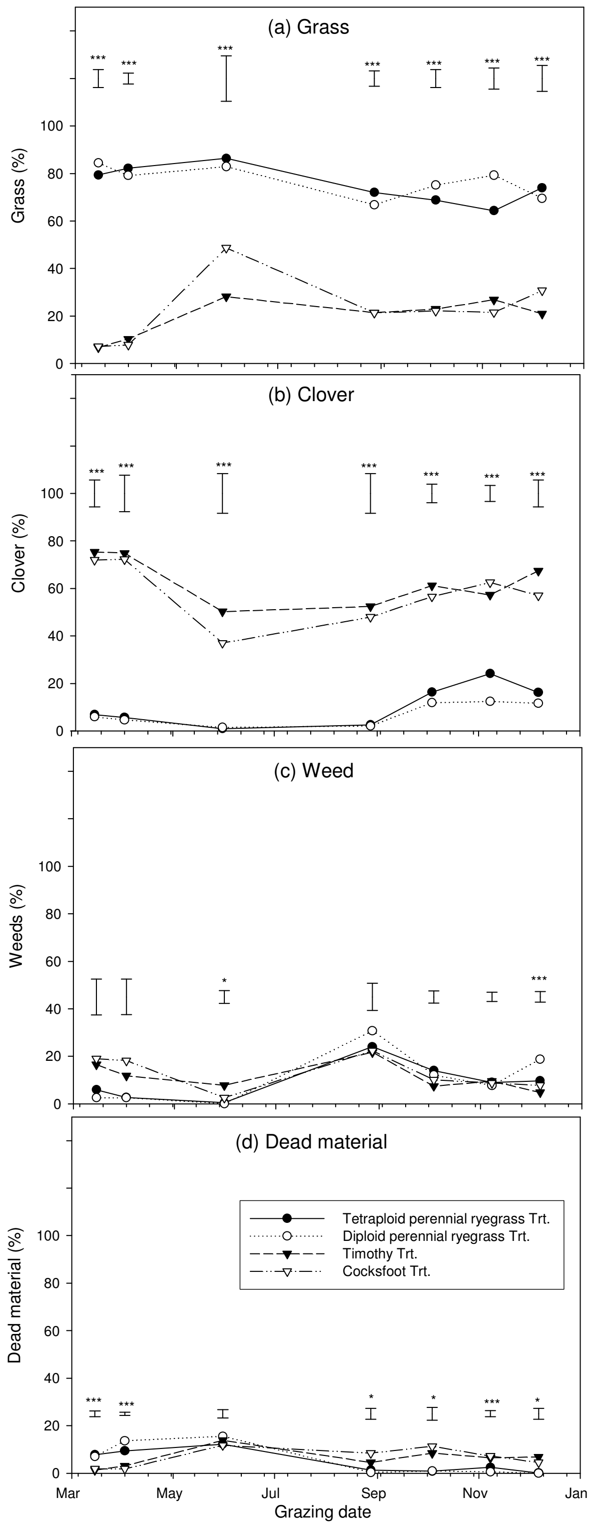

Figure 3.3 The botanical composition (% by DM in pre-grazing mass) of (a) grass, (b) white clover, (c) weeds (dicot and grass) and (d) dead material in the four grass-white clover mixtures from March to December 2007. The vertical bars represent the LSD for comparing the differences among swards types at a given grazing occasion. Asterisks indicate significance of treatments effects at each date, * $P < 0.05$, *** $P < 0.001$(***).

3.2.5 Plant density

Table 3.6 shows the number of grass and clover plants per m^2 in March 2007 and January 2008 in each pasture, and the number of clover plants in pure swards of white clover (see preference experiment, Chapter 4, Section 4.1.1 and 4.1.2). On average, the combined total number of grass and clover plants per m^2 declined during the experiment from an average of 158 to 118. Total plant number did not differ among treatments in the early phase of pasture development (March 2007) but was greater (P<0.05) in tetraploid and diploid ryegrass than timothy and cocksfoot in January 2008. In March 2007 and January 2008 there were more grass plants in diploid and tetraploid ryegrass than timothy and cocksfoot. The decline in plant number from March 2007 to January 2008 of grasses ranged from 25% (for both ryegrasses) to 35% for timothy. In March 2007, the number of clover plants was highest in cocksfoot, followed by timothy, with the fewest clover plants in tetraploid and diploid ryegrass pastures. In January 2008, the number of clover plants was highest (P<0.05) in timothy, followed by cocksfoot, tetraploid ryegrass with diploid ryegrass the lowest (Table 3.6). The number of clover plants declined the least in tetraploid ryegrass (58 versus 55 plants m^{-2}) and the most in cocksfoot (96 versus 63 plants m^{-2}). Grass-white clover plots had 42 to 70% of the number of clover plants in pure swards in January 2008.

Table 3.6 Number of plants per m^2 in mixed swards and pure monoculture swards in autumn (March) 2007 and in summer (January) 2008. P values are from one way ANOVA; ns = no significant difference. Means followed by the same letters are not significantly different according to LSD tests (α=0.05) following a significant ANOVA.

March2007				
	Total plants	Grass	Clover	Clover in monoculture
Tet RG	154.7	95.9_a	58.8_c	126.5
Dip RG	160.9	107.2_a	53.6_c	
Timothy	155.7	74.2_b	81.5_b	
Cocksfoot	151.6	54.7_b	96.9_a	
P-value	ns	< 0.05	< 0.001	
LSD	25.4	25.4	14.88	

January 2008				
	Total plants	Grass	Clover	Clover in monoculture
Tet RG	127.9_a	72.2_a	55.7_{bc}	100.4
Dip RG	122.7_a	80.4_a	42.3_c	
Timothy	119.6_b	48.5_b	71.2_a	
Cocksfoot	101.1_b	37.1_b	63.9_{ab}	
P-value	< 0.05	< 0.001	< 0.05	
LSD	14.4	12.9	13.8	

3.2.6 Clover and grass morphology

Diploid and tetraploid ryegrass plants had more tillers per plant, longer shoots, and greater root and shoot mass than timothy and cocksfoot plants in March 2007 (P < 0.05, Table 3.7). In January 2008, tiller numbers were similar in tetraploid, diploid ryegrass and cocksfoot. Tetraploid and diploid ryegrass had greater tiller numbers than timothy. Grass shoot mass in January 2008 was greater in tetraploid and diploid ryegrass and cocksfoot than timothy.

Table 3.7 The number of tillers per plant, tallest shoot length, and root and shoot mass of individual grass species in March 2007 and in January 2008. P values are from one way ANOVA; ns = no significant difference. Means followed by the same letters are not significantly different according to LSD tests (α=0.05) following a significant ANOVA.

March 2007					
	No. of tillers	Tallest shoot length (mm)	Root mass (g)	Shoot mass (g)	Root mass /shoot mass
Tet RG	10.2_a	263_a	0.428_a	1.12_a	0.38
Dip RG	15.9_a	321_a	0.411_a	1.40_a	0.29
Timothy	4.02_b	103_b	0.047_b	0.15_b	0.31
Cocksfoot	3.65_b	92_b	0.045_b	0.11_b	0.41
P-value	< 0.05	< 0.05	< 0.05	< 0.05	
LSD	5.29	153	0.291	0.78	

January 2008					
	No. of tillers	Tallest shoot length (mm)	Root mass (g)	Shoot mass (g)	Root mass /shoot mass
Tet RG	56.9_a	220_b	3.78	18.5_a	0.20
Dip RG	67.6_a	239_b	2.43	15.9_a	0.15
Timothy	26.1_b	243_b	0.46	6.6_b	0.07
Cocksfoot	46.5_{ab}	366_a	1.28	16.0_a	0.08
P-value	< 0.05	< 0.001	ns	< 0.05	
LSD	26.3	44.0	2.73	8.2	

In March 2007, the number of stolons per white clover plant and fully opened leaves per white clover plant were greater in timothy and cocksfoot than tetraploid and diploid ryegrass pastures. Root mass followed a similar pattern, although cocksfoot and diploid ryegrass did not differ significantly. In January 2008, stolon and leaf number did not differ among treatments. Root and shoot mass of clover were lower in tetraploid and diploid ryegrass pastures than timothy and cocksfoot pastures (Table 3.8).

Table 3.8 The number of stolons, fully opened leaves, length of longest above-ground part, and root and shoot weight per plant of white clover plants in March 2007 and January 2008. P values are from one way ANOVA; ns = no significant difference. Means followed by the same letters are not significantly different according to LSD tests (α=0.05) following a significant ANOVA.

March 2007						
	No. of stolons	No. of opened leaves	Tallest shoot length (mm)	Root mass (g DM)	Shoot mass (g DM)	Root mass /shoot mass
Tet RG	2.55_b	9.62_b	128	0.0362_c	0.219	0.17
Dip RG	2.80_b	10.52_b	140	0.0446_{bc}	0.282	0.16
Timothy	5.37_a	16.77_a	77	0.0751_a	0.391	0.19
Cocksfoot	4.85_a	14.27_{ab}	61	0.0675_{ab}	0.269	0.25
P-value	< 0.05	< 0.05	ns	< 0.05	ns	
LSD	1.48	4.71	80	0.0253	0.178	

January 2008						
	No. of stolons	No. of opened leaves	Tallest shoot length (mm)	Root mass (g)	Shoot mass (g)	Root mass /shoot mass
Tet RG	29.9	28.4	105.3_b	0.194_b	1.47_b	0.13
Dip RG	21.6	24.1	117.4_b	0.173_b	1.20_b	0.14
Timothy	33.3	27.5	158.1_a	0.415_a	2.70_a	0.15
Cocksfoot	34.6	26.0	131.3_{ab}	0.392_a	2.23_{ab}	0.18
P-value	ns	ns	< 0.05	< 0.05	< 0.05	
LSD	9.8	10.4	35.6	0.125	0.96	

3.2.7 Pasture nutritive value

Metabolisable energy (ME) of grass and white clover in mixed swards did not differ among the treatments in November 2007 but values were considerably high (Table 3.9)

Table 3.9 Concentrations of metabolisable energy (MJ ME kg^{-1} DM) of grass and white clover in the binary mixtures on 7 November 2007.

	Grass	Clover
Tet RG	12.8	13.0
Dip RG	12.3	13.0
Timothy	12.6	13.1
Cocksfoot	12.5	13.1

3.3 Discussion

The total pasture yields and composition data measured over the first year (Table 3.5) indicate that highly productive pastures of high nutritive value were established in all four grass treatments. However, the yield and botanical composition were all influenced by the grass species planted.

3.3.1 White clover yield: timothy and cocksfoot versus ryegrass species

The white clover content was higher in timothy and cocksfoot pastures than tetraploid and diploid perennial ryegrass swards throughout the trial period. Over the entire growth period of 11 months 5-6t DM ha^{-1} of white clover was grown in timothy and cocksfoot swards but only 0.8-1.3t DM ha^{-1} in ryegrass swards. The greater white clover content in timothy than diploid ryegrass pastures is consistent with previous research. Watkin (1975) showed white clover content of timothy-white clover mixtures was about one and a half times that of diploid ryegrass-white clover pastures.

The higher white clover content of cocksfoot than ryegrass pastures is in contrast to several other studies noting less clover when white clover is grown with cocksfoot (Moloney, 1993; Black and Lucas, 2000; Hurst *et al.*, 2000), particularly in dryland, sites subject to summer moisture stress. The difference may reflect that this trial was irrigated and of short duration. For example, Black and Lucas (2000) in an unirrigated trial on the same soil type in a neighbouring paddock to this experiment noted similar white clover content in ryegrass and cocksfoot pastures in the first year, but more white clover in ryegrass than cocksfoot (albeit low in both) two years later.

The combination of species-specific thermal times (Tt) for seedling emergence and seedling growth may provide an explanation for the higher clover content in timothy and cocksfoot than ryegrass pastures, particularly at the initial harvests. For example, white clover (150 ℃d) and perennial ryegrass (160 ℃d) have similar thermal time requirements for field emergence (Moot *et al.*, 2000) and would therefore have emerged at similar time. Thermal time requirements of timothy (230 ℃d) and cocksfoot (250 ℃d) are higher than that of white clover (150 ℃d) (Moot *et al.*, 2000), meaning white clover would have emerged earlier. This is reflected in fewer seedlings of timothy and cocksfoot at the first measurement period. Differences in the numbers of seeds sown per m^{-2} were unlikely to have played a significant role in the number of seedlings of cocksfoot and timothy; the number of seeds sown was higher in timothy than other species (Table 3.2), while similar numbers of cocksfoot and ryegrass seeds were sown (Table 3.2).

A further explanation for the higher clover content in timothy and cocksfoot pastures may be the higher grazing preference for these legume dominated grazing plots leading to lower grazing residuals. Grazing residuals were lower in timothy and cocksfoot (276 and 197 kg DM ha^{-1}, respectively) than both ryegrasses (531 and 843 kg DM ha^{-1}, respectively for tetraploids and diploids) (Table 3.10). This may have suppressed timothy and cocksfoot, or alternatively, provided more space for stolon expansion in timothy and cocksfoot pasture leading to greater clover content.

Table 3.10 Total dry matter of overall pasture after each grazing occasion (kg DM ha^{-1}) from 8 January to 6 December 2007.

	APR	MAY	SEP	OCT	NOV	DEC	mean
Tet RG	634	1001	410	318	497	327	531
Dip RG	1065	1262	658	674	761	639	843
Timothy	150	318	152	278	176	110	197
Cocksfoot	134	419	264	410	234	195	276

Despite similar thermal time requirements for emergence of white clover (150 ℃d) and perennial ryegrass (160 ℃d) (Moot *et al.*, 2000), diploid and tetraploid ryegrass were dominant in clover-mixtures throughout the year (Table 3.5). One of the reasons for this is that white clover is sensitive to the presence or density of its neighbouring species such as perennial ryegrass (Haggar *et al.*, 1985). This may be more significant in the early phase of establishment, rather than the late phase. Some morphological data are consistent with this possibility in this experiment. For instance, number of stolons and open leaves, and root mass of white clover were higher in timothy and cocksfoot treatments than diploid and tetraploid perennial ryegrass treatments at the early stage of establishment (Table 3.8) whereas tiller number and root mass of grass were higher in both types of perennial ryegrass-based mixtures than in timothy- and cocksfoot-based mixtures at the same time

(Table3.7). Moreover, timing of axillary shoot development is also regarded as a major determinant of successful ryegrass establishment in clover-mixed swards (Black *et al.*, 2002). For example, the thermal time requirements for the appearance of the first tiller of perennial ryegrass is 373 ℃d. This indicates the initiation of secondary leaf development is considerably earlier than the first white clover stolon (532 ℃d). As a consequence, ryegrass can expand tillers much earlier than the clover extends their stolons (Black *et al.*, 2006), meaning that the perennial ryegrass is very competitive for light with white clover. This was reflected in lower white clover plant weights at the final harvest in both ryegrasses compared with cocksfoot and timothy, despite there being no differences at the first harvest (Table 3.8).

3.3.2 White clover content of diploid versus tetraploid perennial ryegrass

There were few differences in clover content between diploid and tetraploid ryegrass (Figure 3.3b). This contrasts with several previous studies noting higher clover content in tetraploid than diploid ryegrasses. For example, Fothergill and Davies (1993) demonstrated higher annual clover content in tetraploids (13.7%) than diploids (8.3%) throughout a 5-year measurement under set-stocked grazing. Swift *et al.* (1992) also showed high clover contribution to tetraploid ryegrass mixtures, ranging from 13% to 26% during 3 consecutive years of measurement in a continuous grazing system although diploid mixed swards were not examined simultaneously. The lack of difference may reflect two main factors: (i) the short-term nature of mixed swards and (ii) rotational grazing management. Most of these previous studies were longer than the 12 months of this study, and the difference in clover composition between grass treatments emerged over time, which perhaps depends on the difference of tiller numbers and competitive ability between these grasses (Frame and Boyd, 1986; Fothergil and Davies, 1993; Swift *et al.*, 1993). Grazing management is also likely to alter intake behaviour of ruminants such as selective grazing (Cosgrove and Edwards, 2007) and consequently affect botanical composition in mixed swards. The result that mixtures with tetraploid ryegrass were grazed more compared to the mixtures with diploid ryegrass (post-grazing mass : diploids = 843 kg DM ha^{-1}, tetraploids = 531 kg DM ha^{-1}, Section 3.3.1) may be a possible explanation to support the idea, leading to the expectation (Chapter 4) of lower partial preference for clover in the tetraploid, and less selective pressure. However, in this study, hard rotational grazing may have minimised the animals' opportunities for selective grazing and encouraged clover in both tetraploids and diploids. Greater difference might be expected under a set-stocking system where the effect of grazing preference and diet selection can be exerted more strongly.

3.3.3 Total Pasture Production

The greater total production in the ryegrass pastures than cocksfoot and timothy pastures (2425 kg DM ha^{-1}) over the establishment year was due to the rapid ryegrass establishment and subsequent growth over the first 3 months. Of particular note, was the greater growth of the ryegrass pastures than timothy and cocksfoot over the first autumn period. However, spring growth rates were similar (or occasions higher in cocksfoot) across grass treatments, indicating limited long term effect.


(a)


(b)

Plate 3.4 Seedlings in a tetraploid perennial ryegrass / white clover sward 45 days after sowing (a and b). (22 February 2007, 10 days before 1st plant number measurement).


(a)


(b)

Plate 3.5 Seedlings in a diploid perennial ryegrass / white clover sward 45 days after sowing (a and b). (22 February 2007, 10 days before 1st plant number measurement). Diploid ryegrasses grew relatively faster to small extent at this stage in comparison to tetraploid ones. Clover grew vertically according to the height of neighbouring grass plants.


(a)


(b)

Plate 3.6 Seedlings in a timothy / white clover sward 45 days after sowing (a and b). (22 February 2007, 10 days before 1st plant number measurement). A higher predominance of clover over timothy. Clover plant height is quite low and has much lesser competition with timothy.


(a)


(b)

Plate 3.7 Seedlings in a cocksfoot / white clover sward 45 days after sowing (a and b) (22 February 2007, 10 days before 1st plant number measurement). An extremely low number of cocksfoot plants.


(a)


(b)

Plate 3.8 Tetraploid ryegrass / white clover mixture (above, a) and timothy / white clover mixture (below, b) on 20 Jun 2007, six months after sowing.

4 CHAPTER FOUR

THE EFFECT OF GRASS SPECIES ON GRAZING PREFERENCE OF SHEEP FOR WHITE CLOVER AND GRASS

4.1 Materials and methods

4.1.1 Experimental site and design

The grazing study was carried in plots established in field I1, Field Services Centre, (43 º 38 'S, 172 º 28 'E, 11 m a.m.s.l), Lincoln University in January 2007. The soil type is a Wakanui silt loam (Udic Ustocherept, USDA Soil Taxonomy). The experimental design was three replicates of four grass species laid out in a randomised block design. The experimental plots were 4.2 m x 10 m swards of pure grass sown beside 4.2 m x 10 m swards of pure white clover (Figure 4.1). Soil samples were collected on 20 January 2007 and analysed with a MAF Quick Test (see Table 3.1). Based on these results, superphosphate (0-9-0-12) was applied to the plots on 20 March 2007 at 300 kg ha^{-1}.The grass monocultures excluding cocksfoot and clover plots were fertilized with 50 kg N ha^{-1} as urea on 20 March 2007.All plots were fertilised with 40 kg N ha^{-1} as urea on 6 August 2007. White clover plots were fertilized as well as pasture growth at this time was slow due to cool temperatures. On 27 September and 26 October, 20 kg N ha^{-1} as urea was applied only onto the grass monocultures. The aim of fertilizing the grass monocultures throughout with N fertiliser was to establish an N concentration in the herbage that would approximate that of green, leafy grass growing within a grass-clover mixture.

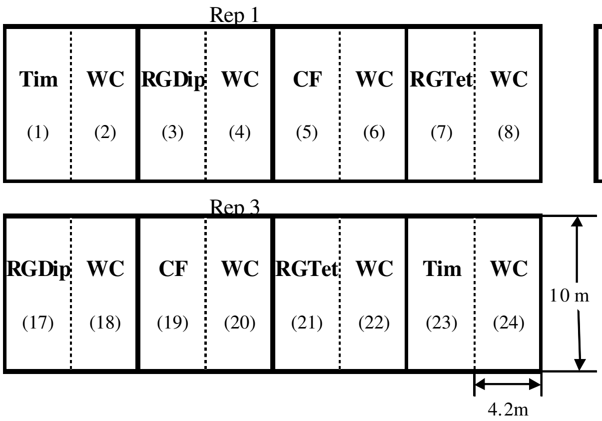

Figure 4.1 Plot design for grazing preference trial. Tim: timothy; DipRG: diploid perennial ryegrass; TetRG: tetraploid ryegrass; CF: cocksfoot; WC: white clover.

4.1.2 Pasture management

4.1.2.1 Cultivars and sowing rates

The site was ploughed and rolled, and 2 L ha^{-1} of glyphosate was applied to remove weeds on 1 November 2006, and left fallow until January 2007. On 4 January 2007, the site was again sprayed with 3 L ha^{-1} of glyphosate, and rolled with a 12 t roller to create a firm seed bed in preparation for sowing. Seeds were drilled with a 15 cm spacing using a double disc type drillseeder between each row on 8 January 2007. The species, cultivars and sowing rates used are shown in Table 4.1. To establish sufficiently dense monocultures for the preference tests, higher sowing rates were set up for monoculture plots compared to mixture plots. All plots excluding cocksfoot monocultures were topped to even pasture height on 16 March 2007. Cocksfoot establishment was poor at that time, and then plots were re-sown with 3 kg cocksfoot ha^{-1} on 23 March 2007.

Table 4.1 Pasture species, cultivars and sowing rates used in the grazing preference trial.

Pasture species	Cultivar	Ploidy	Sowing rate ($kg\ ha^{-1}$)	Seed No. ($seeds\ m^{-2}$)	Thousand seed weight (g)
Perennial ryegrass*	Quartet	Tetraploid	20	613	3.264
Perennial ryegrass*	Bronsyn	Diploid	15	679	2.208
Timothy	Viking	Diploid	6	1626	0.369
Cocksfoot	Vision	Diploid	3	500	0.600
White clover	Demand	Diploid	4	594	0.673

*Ryegrass cultivars contained ARI endophyte.

4.1.2.2 Irrigation

The plots were irrigated on 3 occasions during the experiment on 27 February, 29 March and 26-27 November in 2007. Approximately 28 mm was applied each time.

4.1.3 Preference tests

Preference tests for the four grass-white clover combinations were carried out on 5 occasions in 2007: 22-24 May, 11-13 September, 15-18 October, 8-12 November and 11-14 December. The rationale of using a range of dates was to cover variation in grass and clover quality and morphology throughout the year, including those key changes that occur during the grass reproductive phase.

For preference tests, each plot containing a sward of grass beside a sward of white clover was stocked with three Coopworth ewe hoggets (mean liveweight : 42.8kg) (i.e. 3 sheep x 4 plots = 12 sheep per block) for 8 hours (from 9 am to 5 pm) only on a test day (Plate 4.1). The preference test was carried out on one block of four plots per day, thus taking 3 days to complete all three blocks. A different set of 12 sheep (36 in total) was used for each block. When not in use, the sheep were grazed in a permanent pasture paddock which is mainly grass-dominant, located on the next paddock prior to the tests from one day before the first test day to the end of the third test day. Three sheep was considered the minimum number of sheep to be used in a preference test so that sheep exhibit ordinary grazing behaviour (Penning *et al.*, 1993). After each preference test, plots were grazed with a large mob of sheep to ensure a low pasture residual across the pastures of approximately 1000 kg DM ha^{-1} and were trimmed with a mower to approximately 4 cm high within 1 or 2 days post grazing to even up pasture height. Plots were then allowed to regrow without grazing until the next preference test took place.

Plate 4.1 View of a preference test site from the observation tower (September 2007).

4.1.4 Measurements

4.1.4.1 Animal behaviour measurements

Foraging behaviour was scored by visual scan sampling of each sheep at 5 minute intervals throughout the day 9 am to 5 pm (Orr *et al.*, 2005). Sheep were scored in the following categories: grazing white clover, grazing grass, ruminating and idling (Plates 4.2 and 4.3). Idling was defined as when a sheep had no specific jaw movements and was often associated with the sheep sitting down (Orr *et al.*, 2005) (Plate 4.3). Grazing time on grass and clover, and ruminating and idling time were converted from the observation scores multiplied by 5, assuming the same behaviour over the previous 5 minutes. The percentage of grazing time on clover was calculated as a measure of grazing preference. A selection coefficient for white clover (θ) was adapted from the method of Ridout and Robson (1991) and calculated as: θ = (Proportion clover in total dry matter intake / proportion grass in total dry matter intake) / (Proportion clover in pre-grazing mass / proportion grass in pre-grazing mass). For this coefficient, a value of 1 for θ implies that no differential selection is taking place, while a value of 2 indicates that a unit of clover is twice as likely to be grazed as a unit of grass. Values of below 1 represent that a unit of grass is more likely to be preferred than a unit of clover. The average of the three sheep was used as the unit of replication as their behaviour could not be considered independent of each other (Penning *et al.*, 1993). The percentage of dry matter intake (DMI) for clover was calculated as: DMI% for clover = (difference between pre-grazing and post-grazing mass in clover) / [(difference between pre-grazing and post-grazing mass in clover) + (difference between pre-grazing and post-grazing mass in grass)].

Plate 4.2 View of a preference test site from the observation tower (September 2007). Two sheep grazing on clover and a sheep ingesting grass.

Plate 4.3 A sheep in idle state. This sheep would be scored as “idling” due to no jaw movement. It will be counted as “ruminating” in the case where jaw movement (chewing or ruminating) is observed.

4.1.4.2 Pasture measurements

Sward surface height (SSH)

Sward surface height was measured in each grass and white clover plot using a sward stick before and after the preference test and every 2 hours during the grazing preference test, with 25 contacts per plot. Visual scan sampling ceased while SSH measurements were being made but sheep remained in the plot. The decline in height and clover during the preference test was used as a further measure of grazing preference.

Pasture mass and plant morphology

Pasture measurements were made in two 0.2 m^2 quadrats cut to ground level in each grass and white clover plot of each replicate prior to and after each preference test. For grasses, a subsample (around one quarter of sample) was taken and measurements made of: number of tillers, extended tiller length and sheath tube length of each tiller. The sub-sample was then sorted into live lamina, dead material, sheath material and reproductive parts, For white clover, weeds were separated from pure clover and a subsample (around one quarter of sample) was taken, and then dried after the number of grazed and ungrazed (lamina intact) petioles were counted. The dry weight (oven-drying at 65°C for 24 hours) of the components and the number of tillers was calculated from the contribution of their weight to total weight of the respective samples and the total sample weight. The proportion of grazed petioles was used as an additional measure of grazing preference.

Pasture nutritive value

Pasture snip samples designed to be representative of the material eaten by sheep (top third of canopy) were collected from each plot prior to grazing (7 hours after sunrise, one day before the test on each occasion). Samples were freeze-dried and ground, before analyses for the concentration of metabolisable energy (ME), the percentage of N, water soluble carbohydrate (WSC), digestibility, and neutral detergent fibre (NDF) by near infra-red spectrometry (NIRS). Snip samples from the May, October and December tests were analysed for macronutrients (calcium (Ca), potassium (K), magnesium (Mg), nitrogen (N), sodium (Na), phosphorus (P) and sulphur (S)) by the methods of Dumas combustion for N and nitric acid / hydrogen peroxide digestion followed by ICP-OES for other elements at R J Hill Laboratories Limited (Hamilton, New Zealand). Macronutrient samples were pooled across the three replicates.

4.2 RESULTS

4.2.1 May preference test

4.2.1.1 Pasture characteristics

Grass pasture mass ranged from 1245 to 2637 kg DM ha^{-1} and was significantly greater in timothy and cocksfoot than both ryegrasses (Table 4.2). Both ryegrasses had a lower proportion of grass and higher proportion of dead matter than timothy and cocksfoot (Table 4.2). Cocksfoot plots contained the lowest number of tillers per m^2 and had the longest leaf and sheath tube. (Table 4.2). The proportion of lamina was higher in timothy and cocksfoot than both ryegrasses (Table 4.2). Clover had lower pasture mass than all grass plots, and only contained a small percentage of weed. Cocksfoot was considerably taller than the other grass species at the start of grazing since only cocksfoot plots were not topped on 16 March 2007 (see Section 4.1.2.1).

Table 4.2 Pasture mass, composition and morphology of grass and clover plots in each grass treatment combination prior to the May preference test. P values are from one way ANOVA. Means with same subscript within a row are not significantly different according to LSD test following a significant ANOVA.

	TetRG	DipRG	Tim	CF	P - value	LSD
Grass plots						
Total pasture DM yield (kg ha^{-1})	1338_b	1245_b	2637_a	2396_a	< 0.05	947.1
Grass (%)	61.2_b	57.4_b	78.7_a	82.8_a	< 0.001	7.44
Weed (%)	0	3.6	1.0	2.3	ns	3.37
Dead (%)	38.8_a	42.2_a	21.2_b	14.9_b	< 0.001	7.69
No. of tillers per m^2	2728_a	3191_a	3403_a	1904_b	< 0.01	715.1
No. of greenleaves per tiller	2.0_b	1.8_b	3.4_a	3.3_a	< 0.001	0.33
Leaf length (mm)	129.4_b	123.8_b	130.4_b	234.3_a	< 0.001	22.13
Sheath tube length (mm)	33.2_b	36.1_b	38.5_b	80.2_a	< 0.001	6.15
Lamina (%)	38.7_b	34.8_b	53.3_a	54.6_a	< 0.001	6.39
Psuedostems (%)	22.5_b	22.8_b	25.5_b	30.1_a	< 0.05	4.46
Dead matter (%)	38.8_a	42.4_a	21.2_b	15.3_b	< 0.001	7.48
Reproductive parts (%)	0	0	0	0		
Sward surface height (cm)	15.5	16.7	18.1	28.6	< 0.01	4.36
Clover plots						
Total pasture DM yield (kg ha^{-1})	1252	1111	1244	1287	ns	203.2
Clover (%)	96.0	91.7	92.6	87.7	ns	13.20
Weed (%)	4.0	8.3	7.4	12.3	ns	13.2
Sward surface height (cm)	9.8	9.1	9.1	9.1	ns	0.74

ME (range 12.6 to 13.5 MJ ME kg^{-1} DM) and N% (range 4.8 to 5.3%) were high in all forages (Table 4.3). Cocksfoot was considerably lower in WSC content than other species (Table 4.3). Clover contained markedly lower NDF than grasses (Table 4.3).

Table 4.3 Nutritive value of grass and clover determined by NIRS prior to the May preference test. P values are from one way ANOVA. Means with same subscript within a row are not significantly different according to LSD test following a significant ANOVA.

	TetRG	DipRG	Tim	CF	Clover	P - value	LSD
ME (MJ ME kg^{-1} DM)	13.4_b	13.0_c	13.5_a	12.7_d	12.6_d	< 0.001	11.27
N (%DM)	4.8_c	4.8_c	5.1_{ab}	5.3_a	4.9_b	< 0.05	0.27
Water soluble carbohydrate (%DM)	17.3_{ab}	16.1_{bc}	17.7_a	11.0_d	15.3_c	< 0.001	1.16
Digestibility (%DM)	87.2_a	85.0_b	87.7_a	82.7_d	83.4_c	< 0.001	0.81
Neutral detergent fibre (%DM)	29.6_{bc}	30.7_b	28.6_c	34.8_a	18.5_d	< 0.001	1.90

Both ryegrasses had a higher S concentration than cocksfoot and timothy (Table 4.4). Timothy contained the highest concentration of P, and the lowest concentration of K, Ca and Na (Table 4.4). Of note is the very low Na concentration in timothy. Clover was higher in Ca and lower in K and S than grasses (Table 4.4). It also had lower Na content compared to all grasses except timothy.

Table 4.4 The concentration of minerals (%DM) contained in laminae of grass and clover prior to the May grazing trial.

	Tet RG	Dip RG	Tim	CF	WC
P%	0.35	0.35	0.46	0.32	0.41
K%	4.1	3.9	3.7	4.0	3.4
S%	0.54	0.50	0.34	0.40	0.29
Ca%	0.45	0.48	0.32	0.32	0.99
Mg%	0.20	0.21	0.17	0.17	0.18
Na%	0.37	0.35	0.02	0.11	0.11

4.2.1.2 Grazing behaviour and pasture changes

Total grazing time was longer in diploid perennial ryegrass than other treatments (Table 4.5). Other grazing behaviour and preference measures did not differ among grass species. Sheep spent 43% to 50% of grazing time on clover. Selection coefficient was higher in timothy than others but did not significantly differ across the treatments. There were no significant effects of grass species on decline in the percentage of grazed petioles or the decline in pasture height or mass (Figure 4.2a and b; Table 4.5). On average grass height declined 8.2 cm, and clover height declined 3.1 cm.

Table 4.5 Grazing behaviour and changes in pasture for the May preference test. P values are from one way ANOVA. Means with same subscript within a row are not significantly different according to LSD test following a significant ANOVA. DMI = dry matter intake. SSH = sward surface height.

	TetRG	DipRG	Tim	CF	P - value	LSD
Grazing behaviour						
Total grazing (min)	227_{ab}	243_{a}	198_{b}	198_{b}	< 0.05	32.5
Grazing grass (min)	131	131	103	100	ns	58.2
Grazing clover (min)	97	112	94	98	ns	46.0
Ruminating (min)	76	56	69	84	ns	52.3
Idling (min)	130	134	167	151	ns	66.6
Grazing time on clover (%)	43.0	46.5	48.2	50.2	ns	23.68
Selection coefficient for clover	0.59	0.50	1.42	0.90	ns	1.352
DMI for clover in diet (%)	63.2	44.3	68.1	48.0	ns	82.5
Pasture changes						
Decline of clover SSH (cm, overall)	2.8	3.6	2.6	3.5	ns	0.83
Decline of grass SSH (cm, overall)	7.9	8.7	7.6	8.5	ns	4.24
Decline of clover SSH (cm, 1st 2hrs)	1.2	0.9	0.8	1.0	ns	1.42
Decline of grass SSH (cm, 1st 2hrs)	1.9	2.2	1.7	2.9	ns	1.75
Grazed petioles (%)	55.1	49.4	49.8	61.4	ns	23.58
Decline of clover mass (%)	45.3	29.8	38.9	42.0	ns	46.42

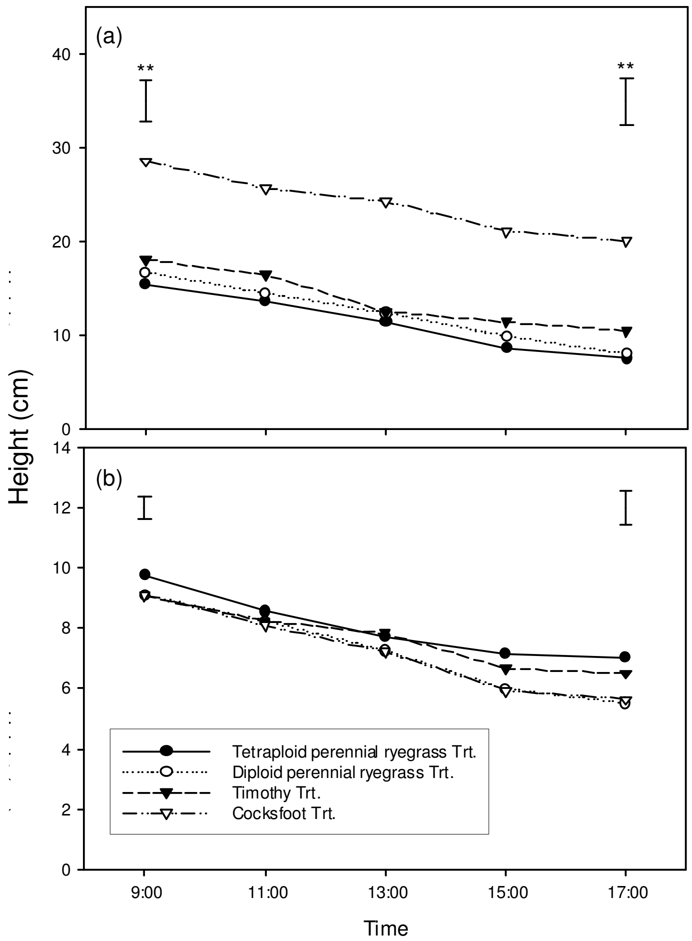

Figure 4.2 Sward surface height (SSH) (cm) of (a) grass and (b) clover plots in paired comparisons during the May trial. The vertical bars represent the LSD for comparing the differences among grass treatments at the start and end of grazing occasion.

4.2.2 September preference test

4.2.2.1 Pasture characteristics

Grass pasture mass ranged from 1708 to 2033 kg DM ha^{-1} but did not differ among treatments (Table 4.6). Grass, weed and dead percentage did not differ among grass species (Table). Both ryegrasses had more tillers per m^2 than timothy and cocksfoot (Table 4.6), but fewer green leaves per tiller (Table 4.6). Clover had a lower pasture mass than all grass plots, and only contained a small percentage of weeds.

Table 4.6 Pasture mass and pasture composition of grass and clover plots in each grass treatment combination prior to the September grazing. P values are from one way ANOVA. Means with same subscript within a row are not significantly different according to LSD test following a significant ANOVA.

	TetRG	DipRG	Tim	CF	P - value	LSD
Grass plots						
Total pasture DM yield (kg ha^{-1})	1708	1714	2033	1592	ns	727.9
Grass (%)	89.8	88.1	92.0	87.1	ns	9.15
Weed (%)	0.6	1.4	0.8	6.7	ns	7.32
Dead (%)	9.6	10.6	7.2	6.2	ns	6.6
No. of tillers per m^2	5003a	4789a	2998b	2623b	< 0.05	1624
No. of greenleaves per tiller	2.6c	2.6c	3.6a	3.0b	< 0.001	0.17
Leaf length (mm)	114.9	110.7	126.7	126.3	ns	28.34
Sheath tube length (mm)	15.4b	21.8a	14.1b	21.4a	< 0.05	4.57
Lamina (%)	64.7	58.0	66.9	63.3	ns	10.83
Psuedostems (%)	25.7	31.3	25.9	30.0	ns	5.64
Dead matter (%)	9.7	10.7	7.2	6.7	ns	6.62
Reproductive parts (%)	0	0	0	0		
Sward surface height (cm)	13.3	13.1	10.9	12.1	ns	3.29
Clover plots						
Total pasture DM yield (kg ha^{-1})	1172	1148	1145	1272	ns	149.5
Clover (%)	95.0	93.8	94.5	94.2	ns	9.08
Weed (%)	5.0	6.2	5.5	5.8	ns	9.08
Sward surface height (cm)	8.3	7.7	7.5	7.5	ns	1.60

ME (range 12.8 to 13.5 MJ ME kg^{-1} DM) was high in all forages with timothy having the lowest value (Table 4.7). N% was the lowest in both ryegrasses, although both values remained relatively high (>3.5%). Clover plots had lower WSC and NDF contents than grass plots (Table 4.7).

Table 4.7 Nutritive value of grass and clover determined by NIRS prior to the September preference test. P values are from one way ANOVA. Means with same subscript within a row are not significantly different according to LSD test following a significant ANOVA.

	TetRG	DipRG	Tim	CF	Clover	P - value	LSD
ME (MJ ME kg^{-1} DM)	13.5_a	13.2_{bc}	12.8_d	13.3_b	13.2_c	< 0.001	0.10
N (%DM)	3.6_d	3.9_c	4.8_b	4.5_c	5.0_a	< 0.001	0.13
Water soluble carbohydrate (%DM)	35.6_a	31.7_b	20.8_d	27.6_c	17.0_e	< 0.001	1.05
Digestibility (%DM)	89.8_a	88.0_b	84.2_d	87.4_b	85.5_c	< 0.001	0.65
Neutral detergent fibre (%DM)	23.6_c	25.9_b	28.3_a	22.0_d	17.3_e	< 0.001	0.90

4.2.2.2 Grazing behaviour and pasture changes

There were no significant differences in grazing behaviour among grass species (Table 4.8). Sheep spent around 33 to 49 % of grazing time on clover. Selection coefficients were all below 1 but did not differ with grass treatments. The proportion of DMI for clover was slightly higher (<12%) in cocksfoot than in the other treatments. There were no significant effects of grass species on decline in height except timothy declined the quickest in the first two hours (Figure 4.3a). On average grass height declined 7.6 cm, and clover height declined 4.1 cm. The percentage of grazed petioles and decline in pasture mass did not differ among species. (Figure 4.3b, Table 4.8).

Table 4.8 Grazing behaviour and changes in pasture for the September preference test. Means with same subscript within a row are not significantly different according to LSD test following a significant ANOVA. DMI = dry matter intake. SSH = sward surface height.

	TetRG	DipRG	Tim	CF	P - value	LSD
Grazing behaviour						
Total grazing (min)	264	290	259	269	ns	46.5
Grazing grass (min)	175	191	135	159	ns	53.1
Grazing clover (min)	89	103	124	109	ns	38.0
Ruminating (min)	48	49	24	32	ns	20.9
Idling (min)	127	97	156	139	ns	47.8
Grazing time on clover (%)	33.5	35.5	48.2	40.5	ns	14.45
Selection coefficient for clover	0.62	0.59	0.67	0.58	ns	0.33
DMI for clover in diet (%)	42.9	39.4	42.1	50.9	ns	36.8
Pasture changes						
Decline of clover SSH (cm, overall)	5.2	4.1	3.9	4.0	ns	1.37
Decline of grass SSH (cm, overall)	8.3	8.4	6.2	7.5	ns	2.76
Decline of clover SSH (cm, 1st 2hrs)	2.1	1.9	1.8	1.4	ns	0.75
Decline of grass SSH (cm, 1st 2hrs)	6.1_a	5.4_a	2.0_b	4.8_a	< 0.05	2.67
Grazed petioles (%)	56.0	62.0	62.4	66.2	ns	23.59
Decline of clover mass (%)	52.1	50.9	51.0	55.7	ns	20.31

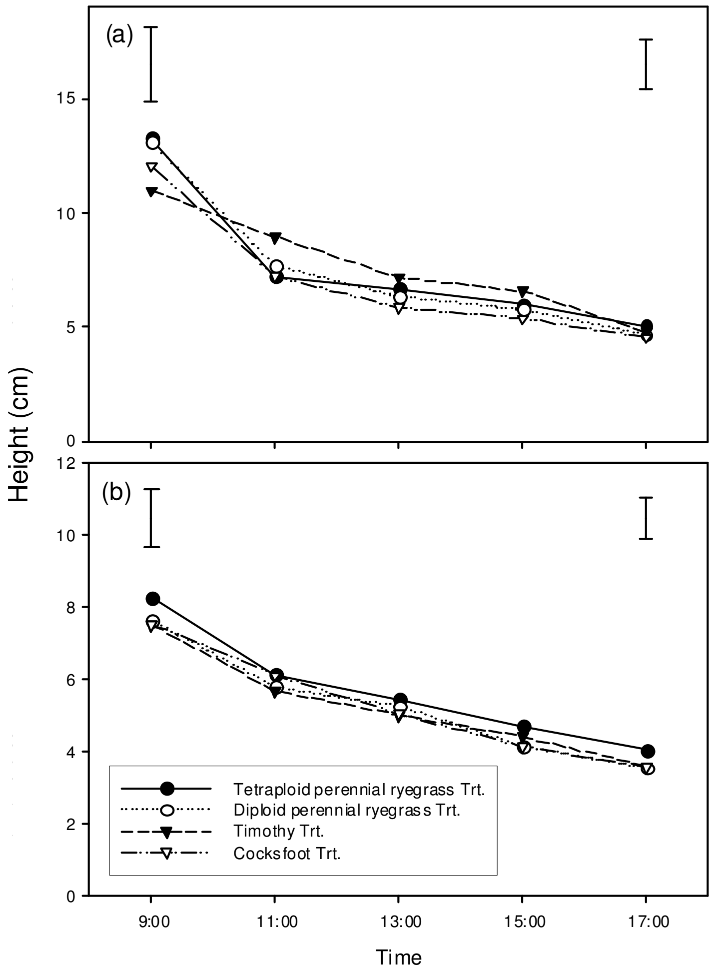

Figure 4.3 Sward surface height (cm) of (a) grass and (b) clover plots in paired comparisons during the September trial. The vertical bars represent the LSD for comparing the differences among grass treatments at the start and end of grazing occasion.

4.2.3 October preference test

4.2.3.1 Pasture characteristics

Grass pasture mass ranged from 2473 to 2869 kg DM ha^{-1} but did not differ among treatments (Table 4.9). Cocksfoot plots contained higher proportion of weeds (Table 4.9). Both ryegrasses had more tillers per m^2 than timothy and cocksfoot (Table 4.9), but fewer green leaves per tiller (Table 4.9). The proportion of lamina was the greatest in tetraploid ryegrass followed by timothy, cocksfoot and diploid ryegrass. The proportion of psuedostems followed the reverse pattern (Table 4.9). Clover had a lower pasture mass than all the grass plots, and contained a small percentage of weeds (<15%), mainly *Poa annua*.

Table 4.9 Pasture mass and pasture composition of grass and clover plots in each grass treatment combination prior to the October grazing. P values are from one way ANOVA. Means with same subscript within a row are not significantly different according to LSD test following a significant ANOVA.

	TetRG	DipRG	Tim	CF	P - value	LSD
Grass plots						
Total pasture DM yield (kg ha^{-1})	2473	2542	2869	2674	ns	1249.4
Grass (%)	88.2	85.9	85.3	82.0	ns	8.44
Weed (%)	3.1_b	5.0_b	1.6_b	12.1_a	< 0.05	5.64
Dead (%)	8.8	9.2	13.1	5.9	ns	5.11
No. of tillers per m^2	5980_a	4571_a	3219_b	2693_b	< 0.05	2024
No. of greenleaves per tiller	2.2_c	2.2_c	3.1_a	2.8_b	< 0.001	0.26
Leaf length (mm)	155.1	141.2	165.6	172.6	ns	58.3
Sheath tube length (mm)	28.9	59.2	48.6	53.6	ns	28.82
Lamina (%)	62.7_a	39.0_d	52.9_b	49.6_c	< 0.01	7.68
Psuedostems (%)	28.2_d	51.4_a	33.8_c	43.7_b	< 0.001	4.32
Dead matter (%)	9.1	9.7	13.3	6.7	ns	5.34
Reproductive parts (%)	0	0	0	0		
Sward surface height (cm)	16.6	20.6	17.9	18.9	ns	4.35
Clover plots						
Total pasture DM yield (kg ha^{-1})	2070	2118	1992	1928	ns	547
Clover (%)	85.7	86.2	90	92.2	ns	14.94
Weed (%)	14.3	13.8	10.0	7.8	ns	0.15
Sward surface height (cm)	10.7	11.6	11.6	11.8	ns	2.18

ME (range 12.6 to 13.1 MJ ME kg^{-1} DM) was high in all forages with cocksfoot having the lowest value (Table 4.10). N% was lowest in both ryegrasses, although both values remained relatively high (>4.0%). Clover plots had lower WSC and NDF contents than grass plots. WSC concentration was the greatest in tetraploid ryegrass, followed by diploid ryegrass, timothy and cocksfoot (Table 4.10).

Table 4.10 Nutritive value of grass and clover by NIRS prior to the October preference test. P values are from one way ANOVA. Means with same subscript within a row are not significantly different according to LSD test following a significant ANOVA.

	TetRG	DipRG	Tim	CF	Clover	P - value	LSD
ME (MJ ME kg^{-1} DM)	13.1_a	12.7_c	13.0_{ab}	12.6_d	12.8_{bc}	< 0.01	0.20
N (%DM)	4.2_c	4.0_c	4.7_b	4.6_b	5.2_a	< 0.001	0.41
Water soluble carbohydrate (%DM)	24.7_a	23.5_b	22.1_c	17.4_d	14.7_e	< 0.001	1.14
Digestibility (%DM)	87.2_a	84.5_{bc}	85.4_{ab}	83.1_c	84.1_{bc}	< 0.01	1.46
Neutral detergent fibre (%DM)	28.3_b	31.0_a	25.8_c	30.8_a	17.3_d	< 0.001	1.68

Timothy had the highest proportion of N and P among grasses, and the lowest in Ca and Na (Table 4.11). Clover was higher in N, P and Ca and total macronutrient proportion, and lower in S than grasses (Table 4.11). Both ryegrasses had a higher S concentration than cocksfoot and timothy (Table 4.11). Timothy contained the highest concentration of P, and the lowest concentration of Ca and Na (Table 4.11). Of note is the very low Na concentration in timothy.

Table 4.11 The percentage of macronutrients (%DM) contained in laminae of grass and clover prior to the October grazing.

	Tet RG	Dip RG	Tim	CF	WC
P%	0.32	0.32	0.40	0.33	0.42
K%	3.0	2.6	2.9	2.6	2.9
S%	0.44	0.41	0.35	0.37	0.33
Ca%	0.36	0.39	0.31	0.34	1.06
Mg%	0.16	0.15	0.15	0.14	0.19
Na%	0.32	0.32	< 0.01	0.22	0.16

4.2.3.2 Grazing behaviour and pasture changes

Total grazing time was the greatest in the two ryegrasses, intermediate in cocksfoot and lowest in timothy (Table 4.12). Grazing time on grass, clover and ruminating time did not differ with grass species. Idling time was longer in timothy than other grass species. The percentage of time spent grazing clover ranged from 23% to 36%, but was not affected by species (Table 4.12). Selection coefficients were all below 1 but did not differ with grass treatments (Table 4.12). DMI% was lower in timothy than the other treatments, its percentage was more than 50% lower than tetraploid perennial ryegrass. There were no significant effects of grass species on decline in height or clover mass. On average grass height declined 9.9 cm, and clover height declined 4.6 cm. The percentage of grazed petioles was the highest in tetraploid and diploid perennial ryegrass, intermediate in cocksfoot, and the lowest in timothy (Table 4.12).

Table 4.12 Grazing behaviour and changes in pasture for the October preference test. Means with same subscript within a row are not significantly different according to LSD test following a significant ANOVA. DMI = dry matter intake. SSH = sward surface height.

	TetRG	DipRG	Tim	CF	P - value	LSD
Grazing behaviour						
Total grazing (min)	228_{ab}	236_{a}	198_{c}	217_{b}	< 0.01	13.7
Grazing grass (min)	143	181	144	156	ns	40.9
Grazing clover (min)	84	56	54	62	ns	47.4
Ruminating (min)	112	84	56	91	ns	39.9
Idling (min)	95_{b}	115_{b}	181_{a}	127_{b}	< 0.01	39.7
Grazing time on clover (%)	36.4	23.0	27.9	28.0	ns	19.02
Selection coefficient for clover	0.50	0.40	0.25	0.40	ns	0.49
DMI for clover in diet (%)	42.8	33.6	18.4	31.1	ns	37.3
Pasture changes						
Decline of clover SSH (cm, overall)	4.38	4.01	4.87	5.12	ns	1.976
Decline of grass SSH (cm, overall)	8.31	10.22	9.74	11.13	ns	1.886
Decline of clover SSH (cm, 1st 2hrs)	2.1	2.3	3.5	1.9	ns	2.65
Decline of grass SSH (cm, 1st 2hrs)	3.7	6.0	6.5	6.4	ns	4.37
Grazed petioles (%)	53.3_{a}	47.1_{ab}	17.9_{c}	30.6_{bc}	< 0.01	17.42
Decline of clover mass (%)	36.6	26.4	12.8	30.8	ns	35.86

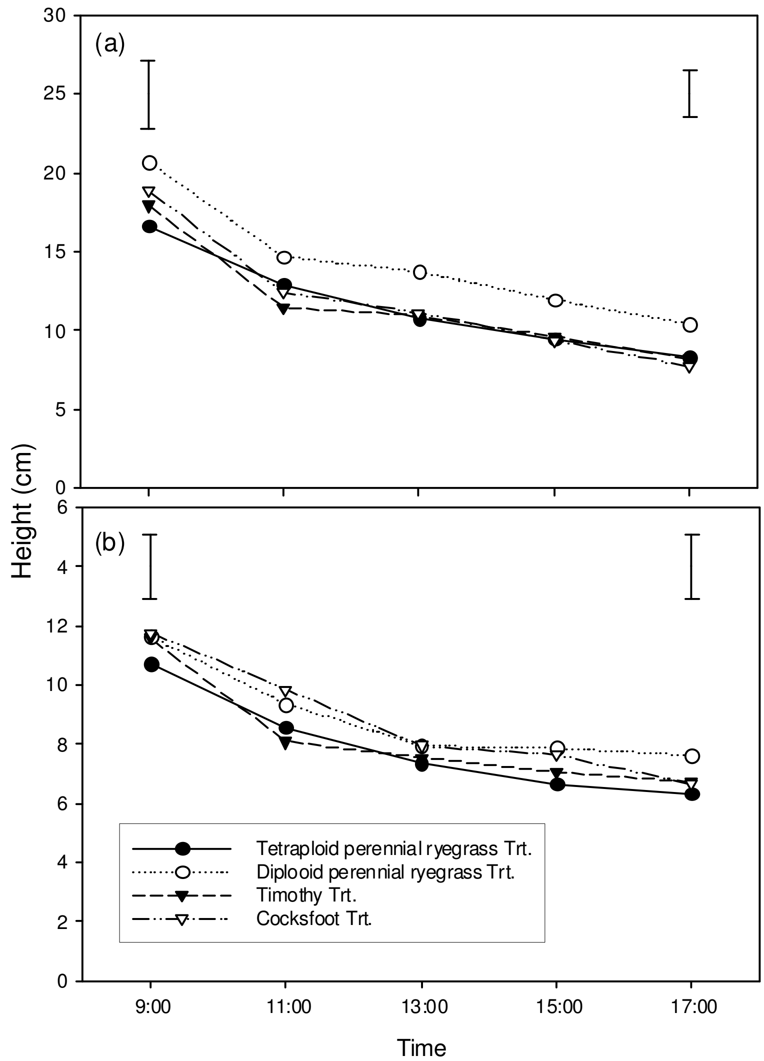

Figure 4.4 Sward surface height (cm) of (a) grass and (b) clover plots in paired comparisons during the October trial. The vertical bars represent the LSD for comparing the differences among grass treatments at the start and end of grazing occasion.

4.2.4 November preference test

4.2.4.1 Pasture characteristics

Grass pasture mass ranged from 1694 to 2203 kg DM ha^{-1} but did not differ among treatments (Table 4.13). There was a higher proportion of weeds in timothy and cocksfoot than tetraploid and diploid ryegrass (Table 4.13). Both ryegrasses had more tillers per m^2 than timothy and cocksfoot (Table 4.13), but fewer green leaves per tiller (Table 4.13). The proportion of lamina was the greatest in tetraploid ryegrass followed by timothy, cocksfoot and diploid ryegrass. The proportion of psuedostems followed the reverse pattern (Table 4.13). Clover had a lower pasture mass than all the grass plots, and contained a small percentage of weed (<10%), mainly *Poa annua*.

Table 4.13 Pasture mass and pasture composition of grass and clover plots in each grass treatment combination prior to the November grazing. P values are from one way ANOVA. Means with same subscript within a row are not significantly different according to LSD test following a significant ANOVA.

	TetRG	DipRG	Tim	CF	P - value	LSD
Grass plots						
Total pasture DM yield (kg ha^{-1})	2203	1784	1722	1694	ns	831.4
Grass (%)	93.1	94.2	92.2	92.3	ns	3.17
Weed (%)	1.1_c	2.0_b	4.2_{ab}	5.7_a	< 0.05	3.00
Dead (%)	5.8	3.8	3.7	2.0	ns	3.70
No. of tillers per m^2	5044_a	4017_{ab}	2627_{bc}	1781_c	< 0.05	1591.3
No. of greenleaves per tiller	2.6_c	2.5_c	3.3_a	2.9_b	< 0.001	0.27
Leaf length (mm)	148.3	134.8	131.5	142.2	ns	31.26
Sheath tube length (mm)	25.1	40.9	25.5	37.1	ns	16.60
Lamina (%)	63.5_a	43.9_b	59.7_a	45.9_b	< 0.05	11.53
Psuedostems (%)	30.6_b	52.3_a	36.4_b	49.5_a	< 0.01	11.12
Dead matter (%)	5.8	3.7	3.8	2.1	ns	3.80
Reproductive parts (%)	0	0	0	2.5	ns	2.18
Sward surface height (cm)	16.0	17.1	13.7	14.9	ns	3.81
Clover plots						
Total pasture DM yield (kg ha^{-1})	1820	1687	1644	1769	ns	296.0
Clover (%)	94.0	91.0	90.2	92.9	ns	8.72
Weed (%)	6.0	9.0	9.8	7.1	ns	8.72
Sward surface height (cm)	10.1	9.6	9.8	10.1	ns	1.39

ME (range 12.3 to 13.0 MJ ME kg^{-1} DM) was high in all forages with timothy and diploid ryegrass having the lowest value (Table 4.14). N% was lowest in diploid ryegrass, with other grasses having similar N%. Clover plots had lower WSC and NDF contents than grass plots (Table 4.14).

Table 4.14 Nutritive value of grass and clover determined by NIRS prior to the November preference test. P values are from one way ANOVA. Means with same subscript within a row are not significantly different according to LSD test following a significant ANOVA.

	TetRG	DipRG	Tim	CF	Clover	P - value	LSD
ME (MJ ME kg^{-1} DM)	12.8_{ab}	12.4_{cd}	12.6_{bc}	12.3_{d}	13.0_{a}	< 0.001	0.22
N (%DM)	4.2_{b}	3.9_{c}	4.6_{b}	4.4_{b}	5.2_{a}	< 0.01	0.55
Water soluble carbohydrate (%DM)	21.0_{a}	20.5_{a}	19.7_{a}	16.3_{b}	13.8_{c}	< 0.001	1.47
Digestibility (%DM)	84.6_{a}	81.9_{bc}	82.9_{b}	81.0_{c}	85.1_{a}	< 0.01	1.72
Neutral detergent fibre (%DM)	28.7_{a}	31.1_{a}	25.3_{b}	31.1_{a}	15.5_{c}	< 0.001	2.46

4.2.4.2 Grazing behaviour and pasture changes

There were no significant differences in grazing behaviour among grass species (Table 4.15) for any variable measured. On average grass height declined 9.4 cm, and clover height declined 5.5 cm. The selection coefficient was higher in tetraploid ryegrass than the other treatments although did not differ significantly among treatments and all values were below 1.0 (Table 4.15). DMI% for clover was slightly lower in diploid perennial ryegrass than in the other treatments.

Table 4.15 Grazing behaviour and changes in pasture for the November preference test. Means with same subscript within a row are not significantly different according to LSD test following a significant ANOVA. DMI = dry matter intake. SSH = sward surface height.

	TetRG	DipRG	Tim	CF	P - value	LSD
Grazing behaviour						
Total grazing (min)	202	231	223	232	ns	39.9
Grazing grass (min)	106	127	124	114	ns	41.4
Grazing clover (min)	96	104	99	118	ns	52.4
Ruminating (min)	62	76	48	58	ns	22.0
Idling (min)	149	107	142	123	ns	50.4
Grazing time on clover (%)	48.1	44.9	45.0	52.8	ns	21.08
Selection coefficient for clover	0.71	0.53	0.63	0.54	ns	0.19
DMI for clover in diet (%)	58.9	50.7	61.4	60.6	ns	31.8
Pasture changes						
Decline of clover SSH (cm, overall)	5.5	5.1	5.6	5.7	ns	1.20
Decline of grass SSH (cm, overall)	10.1	10.0	8.4	8.9	ns	3.06
Decline of clover SSH (cm, 1st 2hrs)	3.5	2.2	3.2	2.8	ns	1.36
Decline of grass SSH (cm, 1st 2hrs)	6.3	4.2	3.8	5.3	ns	5.41
Grazed petioles (%)	62.1	63.1	61.2	57.2	ns	25.12
Decline of clover mass (%)	69.4	57.5	61.7	60.8	ns	26.72

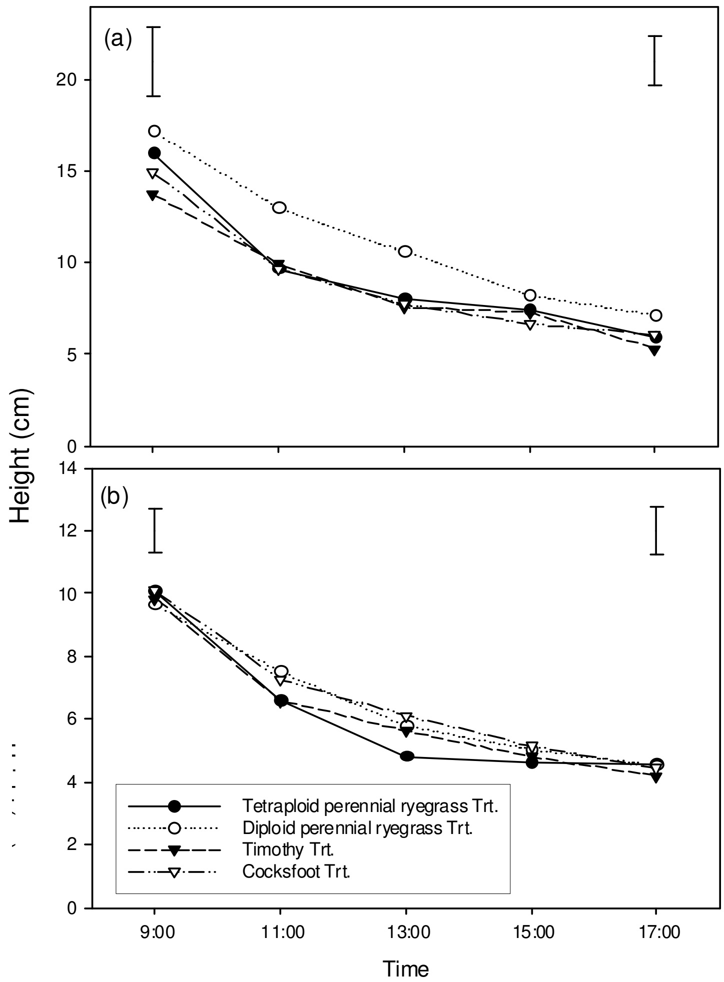

Figure 4.5 Sward surface height (cm) of (a) grass and (b) clover plots in paired comparisons during the November trial. The vertical bars represent the LSD for comparing the differences among grass treatments at the start and end of grazing occasion.

4.2.5 December preference test

4.2.5.1 Pasture characteristics

Grass pasture mass ranged from 2692 to 3397 kg DM ha^{-1} but did not differ among treatments (Table 4.16). There was a higher proportion of weeds in cocksfoot than the other species (Table 4.16). Both ryegrasses had fewer green leaves per tiller than the other grasses (Table 4.16). Clover had a lower pasture mass than all the grass plots, and contained a small percentage of weed (<10%), mainly *Poa annua*. All the grass species except timothy had reproductive parts in this month but overall a low percentage of tillers remained reproductive (<15%) (Table 4.16).

Table 4.16 Pasture mass and pasture composition of grass and clover plots in each grass treatment combination prior to the December grazing. P values are from one way ANOVA. Means with same subscript within a row are not significantly different according to LSD test following a significant ANOVA.

	TetRG	DipRG	Tim	CF	P - value	LSD
Grass plots						
Total pasture DM yield (kg ha^{-1})	3397	3124	2889	2692	ns	821.3
Grass (%)	95.9	94.2	92.7	89.6	ns	6.0
Weed (%)	1.6_b	1.7_b	3.1_{ab}	7.1_a	< 0.05	4.44
Dead (%)	2.5	4.1	4.2	3.3	ns	3.99
No. of tillers per m^2	4711	5116	3499	2807	ns	2431.0
No. of greenleaves per tiller	2.7_b	2.4_c	3.6_a	2.8_b	< 0.001	0.31
Leaf length (mm)	193	164.5	184.2	189.9	ns	39.88
Sheath tube length (mm)	31.2	46.6	35.9	37.0	ns	13.11
Lamina (%)	44.3	32.5	50.3	46.9	ns	12.26
Psuedostems (%)	47.8	48.3	45.4	42.4	ns	5.91
Dead matter (%)	2.5	4.2	4.3	3.5	ns	4.13
Reproductive parts (%)	5.4	15.0	0	7.2	ns	10.59
Sward surface height (cm)	24.5	25.2	22.5	24.1	ns	3.06
Clover plots						
Total pasture DM yield (kg ha^{-1})	3065	2888	2968	2939	ns	288.4
Clover (%)	96.8	93.7	96.5	96.1	ns	7.13
Weed (%)	3.2	6.3	3.5	3.9	ns	7.13
Sward surface height (cm)	16.8	16.4	16.5	18.0	ns	1.96

Metabolisable energy concentration was moderate in diploid ryegrass, timothy and cocksfoot, and high in tetraploid ryegrass and clover (Table 4.17). The percentage of N was high in clover. Water soluble carbohydrate was higher for tetraploid and diploid ryegrass and the lowest for clover. Neutral detergent fibre was significantly high in diploid ryegrass and low in clover (Table 4.17).

Table 4.17 Nutritive value of grass and clover determined by NIRS prior to the December preference test. P values are from one way ANOVA. Means with same subscript within a row are not significantly different according to LSD test following a significant ANOVA.

	TetRG	DipRG	Tim	CF	Clover	P - value	LSD
ME (MJ ME kg^{-1} DM)	12.2_b	11.4_d	11.8_c	11.8_c	12.6_a	< 0.001	0.21
N (%DM)	3.1_{bc}	2.6_c	3.3_b	3.6_b	4.9_a	< 0.001	0.61
Water soluble carbohydrate (%DM)	23.0_a	21.3_a	18.1_b	13.0_c	14.6_c	< 0.001	2.03
Digestibility (%DM)	79.6_b	73.5_d	75.8_c	76.4_c	81.6_a	< 0.001	1.55
Neutral detergent fibre (%DM)	35.8_b	43.3_a	32.5_c	38.1_b	18.1_d	< 0.001	3.04

Diploid ryegrass had the lowest percentage of N and K (Table 4.18). Cocksfoot contained the highest N, P, K, S and Ca in the grasses. Of note is the very low Na concentration in timothy. White clover was had a high concentration of N, P, K, Mg, and Ca, and a low concentration of Na relative to the grasses (Table 4.18).

Table 4.18 The percentage of macronutrients (%DM) contained in laminae of grass and clover prior to the December grazing.

	Tet RG	Dip RG	Tim	CF	WC
P%	0.28	0.27	0.32	0.32	0.36
K%	2.5	2.0	2.5	2.6	2.6
S%	0.34	0.30	0.27	0.35	0.28
Ca%	0.34	0.34	0.41	0.41	1.07
Mg%	0.17	0.16	0.18	0.17	0.24
Na%	0.38	0.26	<0.01	0.34	0.22

4.2.5.2 Grazing behaviour and pasture changes

Total grazing time was greater in tetraploid and diploid ryegrasses than cocksfoot and timothy. Selection coefficient was the lowest in timothy but all values were below 1.0 and did not significantly differ across the treatments. DMI% was around 1.3 to 1.5 times higher in cocksfoot than in the other treatments. Decline in grass height was lower in cocksfoot than other three grass species (Table 4.19).

Table 4.19 Grazing behaviour and changes in pasture for the December preference test. Means with same subscript within a row are not significantly different according to LSD test following a significant ANOVA. DMI = dry matter intake. SSH = sward surface height.

	TetRG	DipRG	Tim	CF	P - value	LSD
Grazing behaviour						
Total grazing (min)	245_b	281_a	216_b	225_b	$P < 0.05$	39.7
Grazing grass (min)	132	113	99	72	ns	71.0
Grazing clover (min)	113	167	117	153	ns	74.6
Ruminating (min)	81	69	79	63	ns	24.5
Idling (min)	116_{bc}	92_c	146_{ab}	153_a	$P < 0.05$	35.1
Grazing time on clover (%)	45.9	59.2	53.8	68.9	ns	25.55
Selection coefficient for clover	0.42	0.43	0.36	0.51	ns	0.16
DMI for clover in diet (%)	38.1	43.2	37.9	56.1	ns	25.8
Pasture changes						
Decline of clover SSH (cm, overall)	7.1	8.3	6.3	8.9	ns	2.94
Decline of grass SSH (cm, overall)	14.2_a	15.2_a	13.2_a	11.6_b	$P < 0.05$	2.25
Decline of clover SSH (cm, 1st 2hrs)	3.0	3.6	3.2	5.0	ns	2.70
Decline of grass SSH (cm, 1st 2hrs)	10.1	6.3	7.4	5.1	ns	4.00
Grazed petioles (%)	47.8	49.3	43.1	43.3	ns	25.75
Decline of clover mass (%)	42.4	43.3	37.6	44.8	ns	26.87

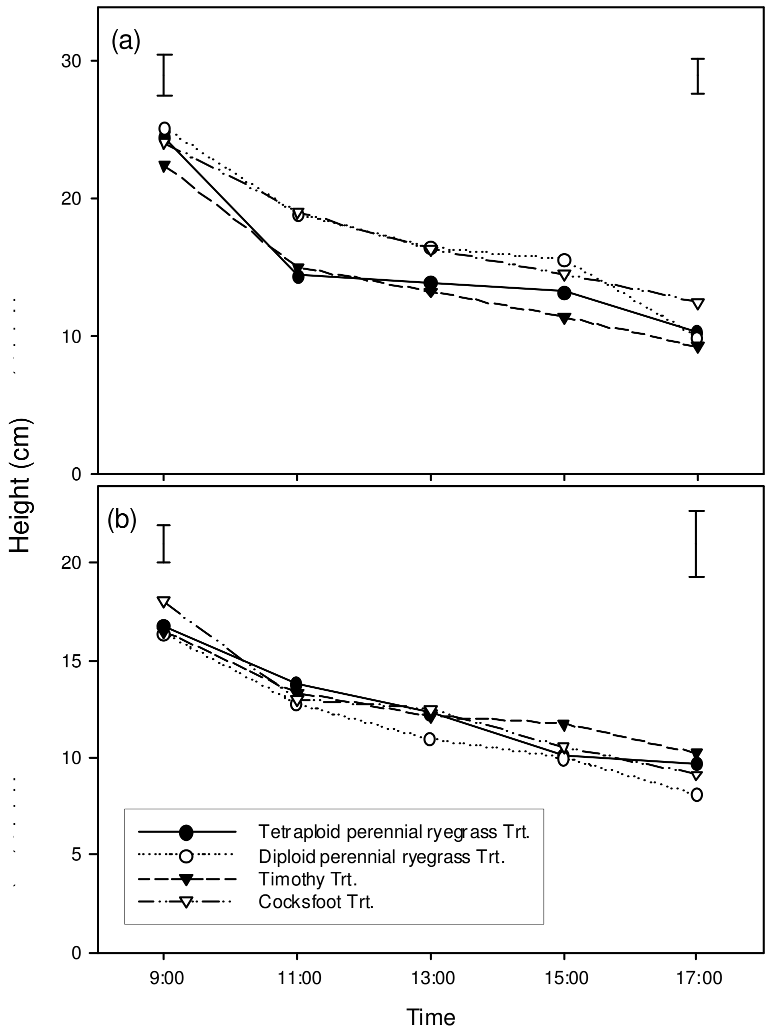

Figure 4.6 Sward surface height (cm) of (a) grass and (b) clover plots in paired comparisons during the December trial. The vertical bars represent the LSD for comparing the differences among grass treatments at the start and end of grazing occasion.

4.2.6 Summary of percentage of grazing time on white clover

The average percentage of grazing time on clover ranged from 23% to 68.9% and did not differ significantly among treatments during the period (Figure 4.7). After reaching the lowest preference in October, the mean value of each grazing treatment increased until December (Figure 4.7). The mean value of the percentage of grazing time on clover averaged over the treatments was significantly higher in December and lower in October (P

< 0.001). The mean percentage of grazing time on clover during the overall period did not differ significantly among treatments

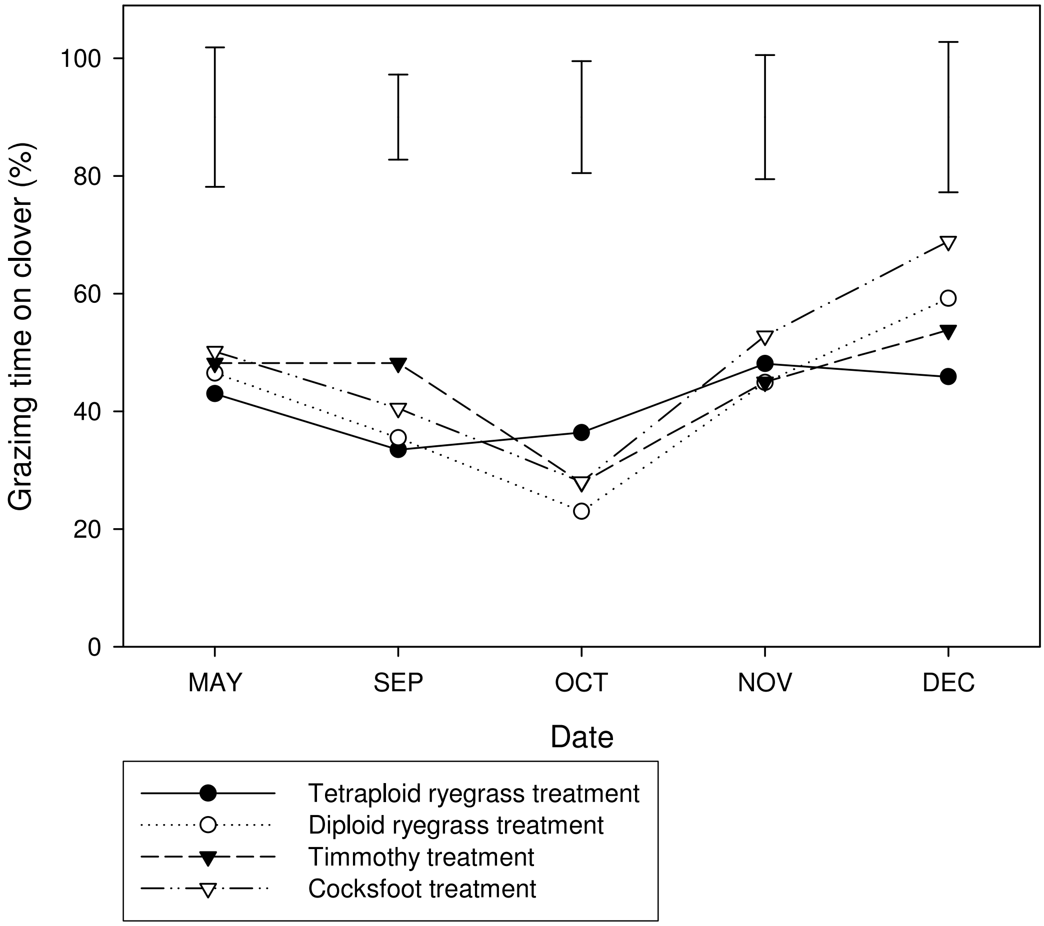

Figure 4.7 Proportion of grazing time on clover plots at each test from May to December 2007. The vertical bars represent the LSD for comparing the differences among grass treatments at a given grazing occasion.

A strong positive correlation coefficient was obtained between the percentage of clover grazing time and NDF% in grass and the (r = 0.70), and between the percentage of clover grazing time and the ratio of NDF% to N% of grass (r = 0.68). The correlation between the percentage of clover grazing time and the N% of grass was negative and less strong (Table 4.20).

Table 4.20 Correlation between average percentage of grazing time on clover plots and NDF% in grass species, between clover grazing time% and N% in grass, between the mean proportion of grazing time on clover and a ratio of NDF to N at each test from May to December 2007.

	MAY	SEP	OCT	NOV	DEC
Mean grazing time on clover (%)	47.0	39.4	28.8	47.7	57.0
Mean grass NDF (%DM)	30.9	25.0	29.0	29.1	37.4
Mean grass N (%DM)	5.0	4.2	4.4	4.3	3.2
NDF / N	5.7	5.5	6.0	6.1	10.5
Correlation coefficient					
NDF x grazing time on clover			0.70		
N x grazing time on clover			-0.49		
NDF / N x grazing time on clover			0.68		

4.3 DISCUSSION

4.3.1 Low partial preference

Across the grazing studies there was little evidence of a high partial preference for white clover. The preference for white clover based on the percentage of grazing time ranged from 23% to 68.9%. Only on one occasion (December 2007) did the partial preference approach 70%. This result contrasts with numerous other studies that have noted that the partial preference for white clover when offered with ryegrass in unlimited foraging conditions is around 70%. For example, in the review of Rutter (2006), most values of partial preference were in the range 60-80%, with this result occurring for sheep, cattle and goats. However, occasionally values of lower partial preference have been recorded.

Cosgrove *et al*. (1996) found that cattle spent 47% of grazing time on white clover in the early summer and autumn preference tests (December and May). However, in preference tests conducted at another time of the year (February, summer), cattle spend 60-70% of grazing time on white clover. In addition, the proportion of DMI for white clover was also low (average 45%, range 18-60%). This denotes that sheep grazed more grass than white clover in most treatments and at most grazing occasions, and exhibited little partial preference for white clover throughout the five preference tests.

4.3.1.1 Preference for grasses

A number of possible explanations for the low partial preference exist. The first possible explanation is that the low partial preference for clover may be high potential intake rate of grass relative to clover, based upon stronger preference for grass species in this study than white clover, excluding during the December test. Sheep have been shown on occasions to prefer pastures that have the highest intake rate (Illius *et al.*, 1992). For example, Illius *et al*. (1992) showed sheep preferred mixed grass-clover turves which had the highest intake rate. It is likely that the grass pastures had a high potential intake rate compared to the clover pastures in this study. The young pastures (< 1 year old) were grazed to a low pasture mass after each preference test so that the resulting grass pastures at the next preference test were always green and leafy. High grass intake rate may have depressed any partial preference result. In support of this general concept, a re-analysis of data in Williams (2006) showed that the partial preference for clover increased as the ratio of intake rate of clover to grass increased (A.M. Nicol, 2008, pers. comm.). This stresses the need in future studies to consider how preference may alter as the intake rate potential of the grass changes relative to the clover (e.g. as might be achieved through changes in tiller density, height reductions, age of pastures and reproductive stage). High intake rates of grasses can also be presumed through the green leafy nature of the pastures and the high ME content (Plates 4.4 and 4.5; Tables 4.3, 4.7, 4.10, 4.14 and 4.17).

Plate 4.4 Fully grazed cocksfoot (October 2007).

Plate 4.5 Fully grazed tetraploid perennial ryegrass (September 2007).

4.3.1.2 N content

The second possible explanation for the low partial preference may be the high N content of the grass herbage. Throughout the study the N % of the grass ranged from 2.6% N to 5.3% N, and was often similar to the clover which ranged from 4.9% N to 5.2% N. Several studies using confined feeding treatments have observed that animals alter diet selection to balance their protein intake (e.g. Kyriazakis and Oldham, 1993; Villalba and Provenza, 1997) and studies with sheep indicate that they do prefer grasses of high N content. For example, Edwards *et al*. (1993) showed preference for N fertilized grass (4.8% N) over unfertilized (3.4% N) grass, but did not measure effects on partial preference for clover. In a further study, Cosgrove *et al*. (2002) showed that sheep showed a 70:30 partial preference for perennial ryegrass with concentrations of 45 and 32 g N kg^{-1} DM (4.5% and 3.2% N, respectively). But, in a study where N fertilizer was applied to ryegrass plots in grass-clover preference tests, there was no difference in partial preference for clover between N fertilized grass (4.5% N) and unfertilized grass (3.2% N) (Cosgrove *et al.*, 2002). Cosgrove *et al*. (2002) concluded that N is not the reason why animals prefer white clover, and that manipulating the N concentration in grass will not cause the switch in preference required for animals to easily satisfy their preference from typical mixed species pastures that are grass dominant and have a low proportion of clover.

4.3.1.3 Not getting complete preference test

The third possible explanation for low partial preference for clover may be the fact that preference tests were not conducted over the entire day. Sheep show a diurnal pattern of preference, preferring clover in the morning and grass in the afternoon (Parsons *et al.*, 1994a; Penning *et al.*, 1995b). In this study, preference tests ran from 9 am to 5 pm. Thus, it is possible that the first grazing bout of clover was missed. For example, doing some simple calculations for November 2007 where the first part of the day (from sunrise to 9 am), assuming that animals grazed clover for the duration from sunrise to 9 am, is added into actually measured minutes for grazing clover shows that the percentage of clover in the diet improves in each species (tetraploid perennial ryegrass: 48% (actual) vs 72% (simulated); diploid perennial ryegrass: 45% vs 69%; timothy: 45% vs 70%; cocksfoot: 53% vs 72%).

This indicates that missing clover bout may have reduced partial preference although this takes no account of grass grazing bouts which are typically observed late in the day (Parsons *et al.*, 1994a; Penning *et al.*, 1995b). Inclusion of these would move partial preference back closer to 50%. Furthermore, in short term preference tests with turves (Newman *et al.*, 1994b), more than 90% preference for clover has been observed.

4.3.1.4 Novelty

The fourth possible explanation for low partial preference for clover may be the effect of the background the sheep were grazing on prior to preference tests. Sheep have been observed to show preference for novelty, preferring items that they had not grazed previously. For example, Parsons *et al.* (1994a) showed sheep from a grass background initially showed a strong preference for clover (90%) while those from a clover background showed a strong preference for grass (70%). These effects lasted less than 1 day. However, in the current study sheep grazed on a predominantly grass background of low clover content prior to the preference tests. Thus, if anything they should have shown a stronger, not weaker, preference for clover.

4.3.1.5 Fibre and N concentration

The fifth possible explanation for low partial preference for clover may be the effect of fibre in "grass", or the balance between N and fibre concentration in "pastures". The highest mean value of grazing time percentage on clover plots was found in all the treatments in December, when grass had the lowest N% and the highest NDF% on over the whole experimental period (Sections 4.2.1, 4.2.2, 4.2.3, 4.2.4 and 4.2.5). A strong correlation coefficient was obtained between NDF% in grass and the percentage of clover grazing time (r = 0.70), and the ratio of NDF% to N% of grass also relatively strongly correlated with the proportion of grazing time on clover (r = 0.68). These imply the possible involvement of dietary fibre of grass herbage in grazing on white clover. In general, dietary fibre is known as an important factor for stability of ruminal function in terms of effective functioning of the microflora (Forbes, 2007). Perhaps, dietary fibre concentration may be, not a single determinant, one of the complex factors for N ingestion by ruminants when diet with high N% was offered. For example, there is a notion that diet with high N% can be consumed by ruminants if sufficient fibre was offered, namely, that white clover with high-N% can be fully grazed if grass contained enough fibre. Although Cosgrove *et al*. (2002) concluded that N concentration in grass is not an independent factor to alter grazing preference, the results from their tests still afford scope for considering the possibility of N as an important element to affect grazing preference and the significance of balance between N and fibre concentration in pastures. Cosgrove *et al*. (2002) showed that sheep preferred high N-fertilised ryegrass to low N ryegrass when these grasses were offered as alternatives, and sheep also exhibited a strong preference for white clover (high-N) over ryegrass of two treatments with different levels of N fertiliser rates (high- and low-N). Unfortunately, NDF% was not reported in that experiment, but the degree of NDF concentration within a same grass species can be conjectured as generally N%

increases and NDF% decreases according to N fertiliser rates increase (Moller *et al.*, 1996; McKenzie *et al.*, 2003). Hence, the ratio of NDF% to N% was assumedly lower in the high-N fertilised ryegrass and higher in the nil-N fertilised ryegrass. Therefore, if these ryegrasses had enough concentration of fibre, the results from Cosgrove *et al*. (2002) may support the concept of N-fibre balance, and N concentration remains as a strong factor to positively affect grazing preference. Alternatively, the positive correlation between fibre concentration in grass and grazing time percentage on clover might be because of sheep simply rejected grazing grass with higher fibre content and then selected clover with less fibre content. This idea can be applied to the December test when a certain level of flowering (<15% DM) in grass species was found.

4.3.2 No grass species effect on preference

A feature of the results was that grass species and ploidy did not significantly affect partial preference for white clover. On no occasion in the 5 preference tests conducted was there any evidence of a treatment effect of grass species. This is perhaps surprising given previous evidence of difference in preference between grass species (e.g. Edwards *et al.*, 1993).

4.3.2.1 Timothy

The failure of timothy to have different preference ranking may reflect the low Na content of the herbage. Throughout the three occasions of analyses, Na concentration in timothy was 0.02% or less, and this follows the report by Sherrell (1978). Previous studies indicate that sheep show preference for herbage containing high Na content. Sheep require 0.07% Na in the herbage for maintenance (Towers and Smith, 1983). Gillespie *et al*. (2006)

showed sheep were strongly attracted to hill pastures of low Na content (< 0.03% Na) when coarse agricultural salt (NaCl) was applied. Furthermore, Chiy *et al*. (1998) showed sheep exhibited a preference for Na fertilized ryegrass even when the unfertilized ryegrass had relatively high Na%. Apart from Na%, NDF% in timothy (ave. 28.1%) was also lower than other grasses (ave. 31.0%) in the current research. If dietary fibre was positively involved in grazing preference in this study, this might be another part of the grounds of low preference for timothy.

4.3.2.2 Cocksfoot

Previous studies have shown that sheep show a low preference for clover (Edwards *et al.*, 1993), but low preference for cocksfoot compared to white clover was not observed in this study. This may reflect the high N content of the cocksfoot herbage compared to previous dryland studies where cocksfoot is of much lower N content. However, as the study of Cosgrove *et al*. (2002) which showed partial preference was not altered by N fertilizing the grass, N is not a single rationale for sheep to graze pastures

4.3.2.3 Effect of pasture mass and height

Grazing animals have previously been shown to make foraging decisions on the basis of pasture mass or pasture height. These factors influence the ease of access and prehension of pastures and may affect animals' diet selection and grazing time on the plot (Pulido and Leaver, 2001; Phillips, 2002). In this study, variation existed in pasture mass and height among grass species prior to grazing, particularly in the May preference test. However, this did not appear to affect preference, either the percentage of grazing time on clover or clover intake, as neither of these was affected by grass species at any time. Correlation coefficient between the percentage of grazing time on clover and the pre-grazing SSH of white clover was 0.44, and the coefficient between the proportion of grazing time on clover plots and the pre-grazing SSH of grass species was 0.36. Sward surface height might affect grazing time or herbage intake to some extent as it did in the previous studies (e.g. Pulido and Leaver, 2001) since clover SSH relative to grass SSH was constantly lower. If SSH was the primary factor to limit grazing time on clover plots in this study, animals would have grazed tall clover more than short ones. Grazing behaviour was, in fact, often observed in the area of white clover with lower sward height through this research, rather than in the area of clover with higher sward height (Plate 4.6, 4.7, 4.8 and 4.9). This may be because taller white clover patches were more likely to contain higher N derived from dung or urine in the previous grazing occasion than shorter ones, and sheep might avoid ingesting swards with excessive N. Furthermore, the selection coefficient, which contains a factor of pre-grazing pasture mass as a variable, did not differ significantly among treatments at any dates (Table 4.5, 4.8, 4.12, 4.15 and 4.19). These results indicate that at no time did grass or clover height or mass appear limiting of intake in this study (Penning *et al.*, 1991), and affect grazing preference to large extent. In other studies over long time periods (Rook *et al.*, 2002), lower preferences for clover have been observed but only when both clover and grass have become very short and restrictive of intake. Thus animals switch to alterative species to maintain intake.

Plate 4.6 Laxly grazed clover patch after the preference test (October 2007). Bare patch is a point where a pre-grazing herbage sample was collected.

Plate 4.7 Fully grazed clover with low sward height (October 2007).

Plate 4.8 Ungrazed tall clover in the same paddock as Plate 4.7 (October 2007).

Plate 4.9 Contrast between fully grazed and ungrazed clover after preference test (December 2007). Few flowers of white clover were left in the fully grazed area near the electric fence. Lower sward height of clover in the area can be recognised from the smaller size of their leaves compared to the size in the central area in this paddock.

4.3.2.4 Effect of WSC on grazing preference

Grazing animals have previously been shown to make foraging decisions on the basis of the water soluble carbohydrate concentration of the forage. For example, sheep showed animals prefer forage of higher water-soluble carbohydrate concentration (Ciavarella *et al.*, 2000). In this study WSC concentration was high in all grass species, often higher in tetraploid and diploid perennial ryegrass than timothy and cocksfoot (Table 4.3, 4.7, 4.10, 4.14 and 4.17). But, this had no effect on partial preference. Thus, there is little evidence that increasing WSC of grass would be a method to reduce the partial preference shown for clover, so alleviating grazing pressure on the clover.

4.3.3 Possible nutritive value concept

Possible nutritive value (pNV) is a function of grazing time or DMI and herbage nutritive value, and a concept to simulate the diet actually ingested by animals during the preference test day, although the true value ought to be considered with the presence of weeds and the extent of grazed psuedostems, which would affect nutritive properties of grass species (i.e. nutritive values differ between in laminae and in psudostems). For example, when mean ME % of herbage samples of timothy and white clover was 14.0 and 12.0 MJ ME kg^{-1} DM, respectively, and grazing time on grass and clover were 50% and 50%, respectively, the pNV in ME of the timothy treatment will be 13.0 MJ ME kg^{-1} DM (i.e. timothy: (14.0 x 0.50 = 7.0) + clover (12.0 x 0.50 = 6.0)). The grazing time percentage can also be replaced into DMI%. The simple calculation indicated that the magnitude of the difference between maximum and minimum of pNV in every simulated nutritional property via both grazing time proportion and DMI% for clover was smaller than that of the four grass species prior to the tests even when variables (i.e. grazing time% on clover or DMI% for clover) widely ranged. For instance, DMI% for clover ranged between 18% and 43% in the October test but the differences of pNV were smaller than those of nutritive values among grass species (ME: 0.5 (grass) vs 0.3 (pNV); N: 0.7 vs 0.4; WSC: 7.3 vs 4.2; NDF: 5.2 vs 3.0). This infers the possibility that the animals might have aimed at acquiring and balancing nutritive properties by adjusting grass-clover intake. This notion is partly supported by a hypothesis by Rutter *et al.* (2000) that a partial preference results from the ruminants' balancing N and carbon components in the diet. Scott and Provenza (2000) demonstrated that lambs had a strong preference for the nutrients lacking in the basal diet. Hence, it may be plausible that grazing preference was largely influenced by nutritional factors in the current study.

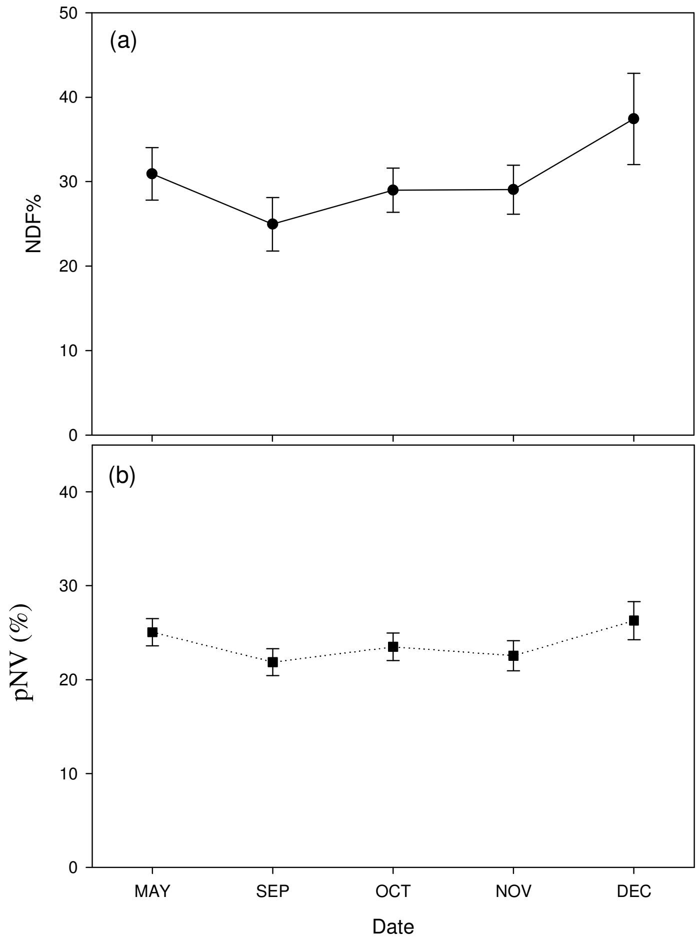

Figure 4.8 Comparison of neutral detergent fibre concentration of dry matter between (a) snipped grasses (tetraploid and diploid perennial ryegrass, timothy and cocksfoot) prior to grazing, and (b) possible nutritive values (pNVs) (%) calculated from the percentage of grazing time on grass and clover by treatments at each date. The vertical bars indicate the difference between the maximum and minimum of (a) mean nutritive values among the grass species or (b) of mean pNVs among the treatments of the date.

5 CHAPTER FIVE

GENERAL DISCUSSION

There was little evidence of partial preference for clover approaching 60-70% in this study as has generally been reported. Some of the reasons for this have been suggested, including a high %N of grass relative to other studies, the study not including the immediate post grazing period before sunset, which is often dominated by a preference for white clover, and the high intake rate of grass species relative to white clover. No definitive explanation to the low partial preference emerges. However, the proposed high intake rate of the new grass pastures may be a plausible explanation that needs further examination.

A clear feature to emerge from this study was the lack of any significant effect of grass species on the partial preference shown for white clover. Thus, there was no evidence from this study, at least, to support the hypothesis that altering grass species could be used as a method to reduce the grazing preference shown for clover, which might paradoxically result in a higher proportion of clover in the sward and the diet (Parsons *et al.*, 1991; Edwards *et al.*, 2008). However, some significant differences among grass species in the grazing preference tests may change the partial preference shown for white clover according to the type of alternative grass species when N content of pastures decreased. For example, tiller number and green leaf number per tiller significantly differed between two ryegrass species, tetraploid and diploid perennial ryegrass, and other grass species, timothy and cocksfoot, in most seasons (Table 4.2, 4.6, 4.9, 4.13 and 4.16), and timothy and cocksfoot contained higher percentage of N compounds in their laminae constantly during this research (Table 4.3, 4.7, 4.10, 4.14 and 4.17). When N content of pastures is low, the difference of N content among pasture species necessarily would become crucial, and the ease of biting green pastures (i.e. greater tiller number or more green leaves per tiller) can be one of the positive factors to acquire higher N intake from pastures, and consequently ruminants may exhibit partial preference for clover and preference for grass may vary among offered grass species. It would be important to confirm the generality of the result of this study using grass species with a lower N content and lower intake rate potential than those currently used.

An alternative (animal rather than plant based) approach to manipulating pasture and diet composition may be to use variation in partial preference within animals. Nicol *et al.* (2008) (see also Edwards *et al.*(2008)) discussed this concept with the idea of breeding of more and less selective lines of stock. Nicol *et al.* (2008) showed variation among animals within a flock in diet selection and that siblings and mothers exhibited similar behaviour. This indicates the possibility of including diet selection into breeding programmes and developing lines of selective and non selective sheep which could be used in manipulate diet and pasture (Winder *et al.*, 1995).

The mixed species pasture study indicated that pastures of high quality were created in all treatments. For example, metabolisable energy content ranged 12.3 to 13.1 MJ ME kg^{-1} DM in November 2007 and clover content occasionally exceeded 85%. Of note is the very high white clover content of the timothy and cocksfoot pastures. Due to the lack of any effect of grass species on grazing preference, it appears the high clover content in timothy and cocksfoot mixtures reflects in part the slow establishment of these grasses, which allowed more and larger clover plants to establish.

One concern often expressed over high white clover content in pastures is the low DM production of white clover; white clover monocultures only produce around 75% the DM of a fully fertilised grass sward (Harris and Hoglund, 1977). However, the lost DM production in this study was relatively small in mixtures over the first year (approximately 17-23% of total DM reduction compared to diploid and tetraploid ryegrass, Table 3.5) due to high clover production in timothy- and cocksfoot-white clover plots, and growth of timothy pastures was sometimes higher than ryegrass pastures in the first spring.

A positive side of the high clover content in timothy and cocksfoot pastures is the markedly improved livestock production that is often exhibited with high clover content. For example, daily growth rates of lamb on white clover (321 g day^{-1}) were markedly higher that other species (average 244 g day^{-1}) (Brown, 1990). Timothy monocultures also show high performance in dairy production (Johnson and Thomson, 1996). Timothy-white clover mixtures also resulted in greater live weight gain in goats than do the combinations of white clover with the other grass species including perennial ryegrass and cocksfoot (Stevens *et al.*, 1992). Thus, a key point for farming systems with slow establishing grass species, is the high clover content that occurs in the first year, which enables very high livestock growth rates, with animals to be finished quicker with lower maintenance costs. This would give timothy based pastures and advantage over ryegrass based pastures at least in the first year. If desired, timothy pastures could be drilled with ryegrass pastures at a later date to improve the DM production of the pastures.

It is quite difficult to compare pasture productivity of the same grass species between pasture production tests and grazing preference tests throughout this experiment with accuracy as some factors were different between these two tests. For instance, grazing frequency is different between these two experiments. Six grazing tests were carried out in the pasture experiment whereas five occasions in the preference test. Grass plots in the preference test received urea of 130 kg N ha^{-1} and accompanied clover plots did 40 kg N ha^{-1} while mixed swards in the pasture test did no urea. However, the values of pre-grazing pasture mass can be used to contrast pasture productivity between these two kinds of swards to some extent since all plots were sown on the same day and trimmed with a mower to approximately same height after every grazing test in both types of experiments. Total dry matter yield of grass and clover, and the sum of the yield of both species in monocultures and mixed pastures are shown in Table 5.1. Clover monocultures produced more clover mass than mixtures with grass species during the experimental period (Table 5.1). Comparing tetraploid and diploid perennial ryegrass, timothy and cocksfoot grew more in pure swards than in mixed swards with white clover (Table 5.1). Total yield was higher in pure sward plots than mixed pastures in all of the treatments. In terms of total annual herbage production and clover yield, monoculture plots demonstrated the superiority over mixed swards (Table 5.1). Despite the lower sowing rates for mixture plots relative to monoculture plots, the fact that mixture plots received no urea and relatively great impact through more frequent grazing opportunities, both types of ryegrass plots in mixtures yielded close or more grass than did monocultures (Table 5.1). This may emphasise the importance of white clover as companion pasture species in a mixed sward in terms of growth of perennial ryegrass.

Table 5.1 Annual dry matter production of grass, clover and the sum of grass and clover in pure swards from 8 January to 6 December 2007 and mixed swards from 8 January to 14 December 2007 (kg DM ha^{-1}). The number excluded the dry matter values of weeds and dead material.

	Monocultures			Mixtures		
	Grass yield	Clover yield	Grass and clover yield	Grass yield	Clover yield	Grass and clover yield
TetRG	9836	8736	18572	9562	1310	10872
DipRG	9029	8169	17198	9258	818	10076
Tim	10637	8373	19010	2182	5936	8118
CF	9509	8601	18110	2679	5311	7990

Monocultures of white clover had higher plant density than did grass-clover mixed swards in this study (Table 3.7) although this may be in part due to higher sowing rates for monocultures relative to mixtures (Table 3.2 and 4.1). Higher density of white clover can be thought as a primary factor to increase clover DM production during the first year of pasture establishment through comparison of clover production between in monocultures and in mixtures with grass species. Spatially separated monocultures of clover and grass in the current study indicated the advantages in total DM production and clover content, which are more likely to give higher performance on animal production, on condition that sowing rates, grazing frequency and fertiliser application were unequal between the pasture production test and the grazing preference test.

This study focussed on grazing preference and alternative species as methods to increase the clover content of pastures. These are a limited set of methods and other pasture based methods may be suitable to enhance clover content in the first few years after pasture establishment at least. For example, perennial ryegrass may be drilled into clover monocultures or binary mixtures of white clover and slow-establishing grass such as timothy and cocksfoot after clover is fully established (Hurst *et al.*, 2000; Peter, 2004). Once fully established, clover may be sufficiently competitive with perennial ryegrass. Indeed the ryegrass may benefit from the high N environment created by the high clover pastures. Alternatively, lower seeding rates of ryegrass may be used. Peter (2004) stated that suppression of slow-establishing pasture species such as white clover and timothy by perennial ryegrass may occur even at sowing rate of 5 kg ha^{-1} for perennial ryegrass. Hurst *et al*. (2000) demonstrated that perennial ryegrass seeding rate of 3.5 kg ha^{-1} was sufficient to cause the poor sociability of ryegrass with white clover. Spring sowing of slow-establishing grass species such as timothy and cocksfoot with white clover may also minimise the disadvantage of these grasses in total DM yields as the growth rate of these slow-establishing grasses is greater than that of both types of perennial ryegrass (Section 3.2.3). Finally, clover and ryegrass may be drilled in alternative mono-cultural rows. This may be large strips (e.g. paddock half grass and half clover) or smaller strips of alternating 15 to 45 cm rows. Large monocultures create difficulty in management but do allow differential application of N fertilizer to the grass. Narrow strips maintain the advantages of clover monocultures and mixed pastures within a same paddock (as the clover invades into the grass). Stock are still able to select the pastures of desired content, and N transfer is still likely to be effective from the clover to the grass (Rutter *et al.*, 2005a; Ibboston, 2006; Edwards *et al.*, 2008).

Future research

This study shows that new pastures of high clover content can be established with a range of grass species. The study raises specific issues about the role of grazing preference that need further work.

1. Establish the relationship between intake rate of grass (and clover) and grazing preference for clover. This could be achieved by drilling grass pastures of the same cultivar at different seeding rate (density) and spacing, and comparing in preference tests with clover. Alternatively, pastures of different age could be used as an additional method to create variation in intake rate.

2. Determine the effect of grass N% relative to clover N% on grazing preference for clover, including the involvement of other nutritive values such as fibre concentration. This could be achieved by offering N fertilized grass species in combination with clover species.

3. Determine the role of herbage Na content in partial preference for clover. It is hypothesised that increasing the Na content of timothy by salt (NaCl) application may increase the preference shown for the grass to levels higher than other grass species.

6 CHAPTER SIX

CONCLUSIONS

Tetraploid and diploid perennial ryegrass-white clover pastures out-yielded timothy- and cocksfoot -white clover mixtures in total DM production (by approximately 2000-2600 kg DM ha^{-1} more pasture) during the first 12 months after sowing. The advantage in DM yield of pastures in both types of ryegrass mixtures depends greatly upon their higher growth rates in the early establishing phase of swards, compared with timothy- and cocksfoot-mixtures. While tetraploid and diploid ryegrass plots had high grass growth rates, clover growth was suppressed markedly compared to timothy and cocksfoot in the early phase of pasture establishment. This leads to white clover growth exceeding timothy and cocksfoot growth in the first year. Pastures of such high white clover content are highly likely to deliver very high levels of stock performance per head.

It is concluded that the rapid growth rate of a pasture species in the early phase of pasture establishment was a key factor for limiting clover content in a mixed sward in the first year, and partial preference for white clover might be of less importance in determining pasture composition.

Across the grazing preference studies, there was little evidence of partial preference for white clover. Several possible explanations for the low partial preference exist including (1) the high N content of the grass herbage, (2) incomplete days in preference test, (3) novelty, (4) the effect of fibre in grass forage, or the balance between N and fibre concentration in pastures and (5) high intake rate of grass relative to white clover. However, no clear explanation emerged.

Grass species and ploidy did not affect partial preference for white clover. The low preference for timothy may be due to low Na and low fibre concentrations in the timothy herbage. Grass or clover height or mass did not limit intake largely in this study and water soluble carbohydrate had not observed effect on partial preference. A simple calculation of nutritive values of the possibly ingested pastures showed the possibility that the animals might have aimed at acquiring and balancing nutritive properties by adjusting grass-clover intake, but this needs more precise measurement of intake rate to make definitive conclusions.

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