THE EFFECT OF HERBAGE AVAILABILITY AND SPECIES CHOICE ON GRAZING PREFERENCE OF DAIRY CATTLE.

A Thesis Presented in Partial Fulfilment of the Requirements for the Degree of Masterate in Applied Science at Massey University.

ALBERTO TORRES-RODRÍGUEZ.

1997

Abstract.

Herbage intake is one of the factors determining animal performance. Intake and quality of the diet consumed by animals are both determined by selective grazing. The motivation to graze selectively is in part a function of dietary preferences. The study of diet selection requires knowledge of what animals prefer to eat when there are no or minimal constraints to them obtaining their diet. This experiment aimed to investigate the effect of relative availability of a preferred species on dairy cattle response at grazing, and to evaluate the feasibility of the use of monocultures of pasture species for studies of preferences of dairy cattle. Three species-contrasts each composed of two adjacent 1-ha monocultures of either White clover:Ryegrass (W_Rye), Lotus corniculatus:Ryegrass (L_Rye) or Lotus corniculatus:Red clover (L_Red) were used. White clover (W) and lotus (L) had been previously determined as preferred over ryegrass (Rye) and red clover (Red). Each species-contrast was subdivided into four plots and the height of the preferred species was set at 4, 6, 8 and 10 cm, whereas that of the less preferred species was set at 10 cm across plots. Groups of yearling Holstein heifers grazed the plots, and observations on grazing behaviour were made by recording grazing activity and species location at 10-minute intervals during daylight hours for three consecutive days, twice in summer and twice in autumn during 95/96 at the AgResearch Flock House Research Centre, near Bulls. During summer, a second week of grazing followed each period of observations for grazing activity, where attempts to estimate herbage dry matter intake and diet composition using the alkane technique were made. From the species-location information, total grazing time (GTt), expressed in hours, and distribution of GTt between preferred (GTp) and less preferred (GTl) species was obtained. The proportion of GTt allocated to grazing the preferred species was considered as a measure of preference. Statistical analysis was performed by GLM procedures of SAS. Regression analyses were carried out for grazing activity parameters on actual height of the preferred species.

Animals showed preference for a mixed diet with partial preference for the legume component (W, 67 %, and L, 70 %) over grass, whereas partial preference in the L_Red species-contrast was close to indifference (L, 55 %). However, this partial preference differed between seasons, being in general stronger in summer than in autumn. Partial preference decreased with decreases in height of the preferred species. However, herbage bulk density (BD) appeared to be important also in influencing preference since more marked responses to height were observed in autumn when sward had lower BD compared with summer. Botanical composition of the sward upper stratum was also considered to influence animal preferences.

Diet composition estimation from herbage and faecal alkanes suggested that animals consumed the preferred species at higher proportions than indicated by the proportion of GTt allocated to the preferred species. This was possibly due to differences in rate of intake between herbage species. However, more research is needed in this area in order to establish more accurately the relationship between these two techniques.

It is concluded that animals respond to changes in herbage availability of a preferred species and to species choice by adjusting grazing time between preferred and less preferred species. It would be appropriate to research the potential animal performance benefits of increasing the availability of a preferred species in proportion to that preferred by the animals.

This works confirms the use of monocultures of pasture species to be useful in the evaluation of preference of dairy cattle. Inclusion of a wider arrangement of species-contrasts is recommended.

This thesis is dedicated to my parents, Verardo Torres and Maria Rodríguez, and my sister, Nora.

Acknowledgements.

There are a large number of people whom I wish to thank for their assistance with this thesis.

First things first. Special thanks to M.Sc. Robert Fletcher at AgResearch Grasslands for statistical advice to analyse the data collected during the experiment.

Craig Anderson spent long hours of skilful technical assistance setting up experimental plots and dealing with animals whenever needed (except weekends and holidays!). Thanks for your friendship.

My thesis supervisors, Professor John Hodgson of Plant Science Department, and Dr. Gerald Cosgrove of AgResearch, for their patience in dealing with a 'non-native speaker' and their guidance throughout my entire program at Massey.

I am grateful to many people who participated in herbage sampling and data collection, particularly Nigel, Jennifer, and Cesar Poli. We all learnt something working together.

My sincere gratitude to the helpful Crown Research Library staff at AgResearch Grasslands, Steven Northover, Ann Ainscough and Sarah Nation, for their cooperation in finding and tracking down references, and for making the long visits to the library more bearable.

Thanks to Joanne Morris, Andrew Taylor and Helen Dick for their assistance in 'computer software troubleshooting'.

Thanks to the New Zealand Ministry of Foreign Affairs for the scholarship that allowed me to live this wonderful experience. Help from Ms. M. Smilie at the International Students' Office is also appreciated.

Many thanks to all those friendly people I met in this beautiful country, Jose Garcia and his family, Neville and Elizabeth Whitehead, Davidson's, Crouch's. All of them greatly enriched my stay in New Zealand.

I am indebted to Armando and Patricia Shimada, and their sons Toshio and Harumi for their generosity to a 'stranger'. People like them are making the world a better place to live in.

Thanks very much to my chief supervisor at the Animal Science Department, Professor Colin Holmes. Wise advice and friendship were always obtained from him.

I can only be deeply grateful to my unselfish wife Ixchel, for her support at 'almost' all times, and her tremendous patience to my long hours of absence over the period of study.

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1. Introduction.

The profitability of livestock production in forage based systems depends largely on the quantity and quality of the forage produced, the capacity of the animal to harvest and utilise that forage efficiently, as well as on the appropriate management of such resources (Forbes, 1988). Daily herbage intake is one of the factors determining animal performance (Allison, 1985). However, animal performance depends on the quality of the diet consumed, which is partly influenced by selective grazing as a function of dietary preferences Hodgson, 1979).

Grazing preference is defined as the discrimination exerted by the grazing animal between swards or sward components when there is no or minimal constraint imposed by the environment (Hodgson, 1979; Newman et al, 1995a), whereas partial preference refers to the proportional choice among two or more foods (Heady, 1964).

Selective grazing is defined as the removal of some sward components as plants or plant parts, rather than others, as a function of preference, modified by the opportunity for selection, which is in turn determined by the relative proportions of the preferred components in the sward, and their distribution within the canopy (Hodgson, 1979).

Grazing animals spend more time in activities regarding gathering and processing of food than animals in confinement (O'Connell et al, 1989) due to the slower intake rate and the greater diversity of food items to choose from. Confined animals essentially do not select their diet for they are provided with a total mixture of ingredients that keeps them from expressing preferences and consequently selection (Albright, 1993).

The importance of food preferences and selection by grazing animals is based on the impact these two aspects can have, firstly, on the energy and time spent in grazing activities, and secondly, on the quality of the diet consumed and on the amount of nutrients ingested (Heady, 1964) which eventually define the performance of the animal as bodyweight gain, milk production, etc. Thus, from the expression of food preferences and selection it is often observed that the diet selected by grazing animals differs in chemical composition from that of the herbage available. The diet is usually of higher nutritional quality than the herbage on offer (Van Dyne and Heady, 1965; Heinemann, 1970; Milne et al, 1982).

An animal shows its preference only when physical constraints on obtaining preferred food items are minimised (Parsons et al, 1994a). When studying dietary preferences, it is necessary to offer pairs of foods equally to allow grazing animals to express such preferences (Forbes and Kyriazakis, 1995). Further, it is important to consider which factors are likely to influence such preference and whether it is absolute or partial (Parsons et al, 1994a). Knowledge of grazing preference of cattle offers scope for designing grazing systems which will exploit the advantages of legumes or other alternative herbage species (Chapman et al, 1996; Cosgrove et al, 1996) selected by cattle.

1.1 Objectives.

This work was conducted to increase existing knowledge on grazing preferences of cattle, and to evaluate the usefulness of spatially separated monocultures grazing preferences studies.

The objectives sought in the present work were as follows:

- Use of paired monocultures to study partial preference using a range of species combinations.
- Investigate effect of relative availability (height) on partial preference.

2. Literature review.

This review focuses on the importance of grazing preferences and selection, as well as the factors that influence such preferences and selection by cattle. Factors which influence the rate of intake by and requirements of the grazing animals, with emphasis on the behavioural responses of the animal influenced by plant characteristics, are also included. The aim is to better understand such relationships which eventually form the basis for the management practices of animal production systems based on pasture. The use of new technology (e.g. alkanes of plant cuticular wax) for estimating dry matter intake and diet composition of grazing animals is also reviewed with particular emphasis for grazing behaviour studies, particularly diet preference and selection.

2.1 Factors influencing diet preference and selection.

Diet selection is a complex process that includes two major levels that must be clearly distinguished, spatial choice and species choice. When an animal has oriented itself in a habitat, it must decide when to lower the head and establish a feeding station, defined as the area available in a half-circle shape in front of and to each side of the grazing animal while its front feet are stationary. Within the feeding station, the animal must decide what individual plant species to consume from those among the range available, and beyond that, which plant parts will be eaten (Vallentine, 1990; Milne, 1991; Stuth, 1991; Stuth et al, 1993). Under uniform sward conditions, such as intensively managed temperate pastures, feeding station intervals are usually short, seldom more than a few seconds (Roguet and Prache, 1995). In contrast, when grazing sparse pastures or practising a high feeding selection on a large plant like a shrub, feeding stations are usually longer than when grazing uniform grass swards (Vallentine, 1990). Further, under uniform sward conditions with spatially separated herbage species, selection is made easier for the animal not having to spent more time searching for the preferred species (Parsons et a, 1994b).

Thus, the dietary preferences and consequently the diet selected by cattle are influenced by many factors, most of which fit within one of the following groups: environment, animal and plant factors. Dealing with all the aspects included in these groups is beyond the scope of this review, and only those directly relevant to this study will be included. The reader is referred to publications dealing with one or more of the mentioned groups for additional reading in the subject; for example animal factors (Illius and Gordon, 1987; Demment and Greenwood, 1988; Gordon and Illius, 1988; Birrel, 1989; Provenza, 1995), plant factors (Cowlishaw and Alder, 1960; Ungar and Noy-Meir, 1988; Birrel, 1989; Wilson and Kennedy, 1996), and environmental factors (Seath and Miller, 1946; Wardrop, 1953; Senft et al, 1985; Birrel, 1989), as well as to general readings on the subject (for example, Heady, 1964; Allison, 1985; Holmes, 1989; Vallentine, 1990).

2.1.1 Herbage factors influencing preference and diet selection.

Sward composition is one factor likely to influence the animals grazing activity (Poppi et al, 1987). For example, sward heterogeneity influences the intake per bite and bite rate through selective activity (Hodgson, 1990). This selectivity, when due to plant factors, implies different sward parameters that can be divided into aspects of quantity or availability and quality. Availability refers to the distribution (vertical and horizontal in the sward canopy) and quantity of the herbage in a certain area affecting herbage intake through the mechanics of gathering food. Quality refers to all physical and chemical features of the sward affecting herbage intake via selective grazing and in an indirect way through the rate at which ingested food is processed (Ungar and Noy-Meir, 1988).

Horizontal availability refers to the spatial arrangement of the plant species forming the pasture as the proportion (fractional cover) of ground area occupied by one species relative to another, whereas vertical availability refers to the vertical distribution of biomass of live and dead material within the sward as the bulk density (g DM/m^3) or height of one species relative to another at a given location (Gordon and Lascano, 1993). Total availability refers to total herbage mass per unit area.

Models for diet preference and selection of grazing herbivores have suggested that preference may be influenced by the relative vertical availability (e.g. height, bulk density) and the relative intake rate of the species in the sward (Newman et al, 1995a; Parsons et al, 1994b), through influencing the bite dimensions and bite mass of herbivores eating within a feeding station or patch (Edwards, 1994). Furthermore, selective grazing may be modified by the relative horizontal availability (e.g. area, distribution within the sward) of the pasture species in the sward (Parsons et al, 1994b), by influencing the rate of encounter with alternative foods in the environment (Edwards, 1994).

The nutritive value of the herbage, as measured by the concentration of nutrients in a feed, is dependent on the animal's capacity to absorb and utilise the digested nutrients (Ulyatt, 1981). It is one of the factors driving herbage intake (Hodgson, 1990). For example mineral content, especially when grazing in mineral-deficient areas (Waite, 1963), or forages with high levels of phosphate and potassium (Leigh, 1961), or sodium (Belovsky, 1981), has been related to selective grazing. On the other hand, both energy and protein concentration in foods have been found to be correlated with preference ranking by grazing cattle and sheep (Cowlishaw and Alder, 1960; Birrel, 1989). It is argued that animals have the ability to identify nutritious and potentially poisonous foods through post-ingestive consequences (Provenza, 1995) and/or physical attributes of foods through the senses (Bazely, 1990; Bazely and Ensor, 1989).

Most animals prefer green material rather than dead material, and leaf rather than stem material (Cowlishaw and Alder, 1960; Freer, 1981; Forbes and Hodgson, 1985; Poppi *et al*, 1987). These preferred materials are usually found in the uppermost sward stratum as young leaves, whereas the older leaves and dead material tend to be found at lower levels in the sward profile (Barthram and Grant, 1984). The selection for such material leads to a diet of higher quality than that of the sward profile (Van Dyne and Heady, 1965; Heinemann, 1969, 1970; Milne et al, 1982; Jung and Koon, 1985).

2.1.2 Animal factors influencing preference and diet selection.

The senses of sight, smell, taste and touch are implicated in selective grazing processes (Arnold, 1966a,b, 1970; Walton, 1983; Forbes and Kyriazakis, 1995) since the animals make use of the senses to identify and gather the leafy parts of the plant and immature seedheads (Arnold, 1970; Walton, 1983). In spite of the amount of work conducted in this area (see for example Arnold, 1966a,b; Krueger et al, 1974; Bazely and Ensor, 1989; Bazely, 1990), the extent to which each sense participates in diet selection processes is not fully understood. Nevertheless, it has been recently proved that the senses play an important role in the acquisition of food aversions and preferences through feedback consequences (Provenza, 1995).

Aversion is described as a decrease in preference for food just eaten as a result of sensory input (the taste, smell, texture, etc. of a food), and post-ingestive effects (effects of nutrients and or toxins on chemo-, osmo- and mechano-receptors) unique to each food, and that occur involuntarily in an animal (Provenza, 1996b). Thus, aversions in an animal occur to avoid toxic foods. However, since aversion does not necessarily have to be complete, the animal may eat some toxic material. Also, aversions occur when eating any food to satiety, or too frequently or in excess, thus regulating food intake and diet selection (Provenza, 1996b). In this regard, both prior experience and senses play an important role (Provenza, 1996a,b).

The degree to which ruminants will discriminate depends on the similarity among different plant species and parts, as determined by smell, taste and post-ingestive consequences, and on the specific sensory abilities of the animals related to olfaction, gustation and sight (Provenza and Balph, 1990). This is also in agreement with previous statements regarding the influence of previous experience on grazing preferences (Newman et al, 1992; Parsons et al, 1994a).

Familiarity and novelty have also been proposed as driving factors of diet preferences (Provenza, 1996a). Typically, animals prefer familiar foods to the novel ones which are regarded with caution. On the other hand, novel foods are eaten when familiar foods are eaten too frequently, or in excess, or when scarce.

Social facilitation also may influence grazing behaviour, since the animals tend to maintain a synchrony of activities by keeping within a group (Bailey et al, 1974; Alhassan and Kabuga, 1988; Rook and Huckle, 1995). Recently, Provenza and colleagues, from a series of reviews (Provenza and Balph, 1988, 1990), and experiments with lambs (Flores et al, 1989a,b) stated that early-age experiences are of great influence on adult preferences. Young animals accept a novel food more easily than adults, due in part to adults being less influenced in choice of diet by social models than young animals, specially because the latter are greatly influenced by their mothers. Provenza and Balph (1988, 1990) concluded that learning fine-tunes diet selection and harvesting ability of animals.

There are differences in degree of selection between individuals, since the diets selected by individuals within a herd vary considerably in both botanical and chemical composition. Van Dyne and Heady (1965) reported individual animal variations in dietary composition, especially in organic matter, crude protein and cellulose contents. Arnold (1964) cited by Arnold (1981) reported that the average content of grass in the diet of 20 sheep studied for a week ranged from 10 to 78 %.

The physiological status of the animal influences the total intake and rate of intake of herbage as well as the diet selected. High genetic merit cows for example, were reported to have higher intake rates than low genetic merit cows (Bao et al, 1992). In turn, thin animals have higher intake rates than fat animals (Hodgson, 1985).

It has also been documented for sheep (Demment and Greenwood, 1988; Moseley and Manendez, 1989; Penning et al, 1993) and to a lesser extent for cattle (Dumont et al, 1995a) that fasting influences meal length, and rate of intake, particularly when eating grass. Fasted animals graze at higher rates (Demment and Greenwood, 1988; Moseley and Manendez, 1989; Penning et al, 1993; Dumont et al, 1995a) and spend more time ruminating than unfasted animals (Demment and Greenwood, 1988).

It is thought that fatigue causes a decline in ingestion rate as grazing goes on or when the herbage is difficult to harvest (Holmes, 1989). It is also believed that the grazing animal uses its senses to assess the effort of harvesting, so that if the effort is too great compared with the benefit to obtain from a mouthful of herbage, the intake is limited below the demand for nutrients (Parsons et al, 1994b). Thus, animals may stop grazing when faced with very low forage availability (Vallentine, 1990).

Experience of the grazing animal influences feeding behaviour (Arnold, 1970; Matthews and Kilgour, 1980). Flores et al (1989a,b) reported that previous experience by lambs influenced bite rate and bite size when exposed to grasses and forbs differing in maturity and form. Thus, experience influences the efficiency with which lambs harvest forage shrubs by allowing higher bite rates in experienced than inexperienced animals (Flores et al, 1989a). Even though the latter may take larger bites this does not compensate for the lack of prehension skill reflected in lower feed intakes. Likewise, wethers that had been exposed to low-quality roughage early in life and then reared with good quality forage, were able to eat more low-quality roughage, and hence lessen the negative effects of undernutrition, than inexperienced animals (Distel et al, 1996). Previous experience has also been reported to influence food intake in weaning calves, with ease of prehension influencing the initial development of grazing ability of young calves (Forbes and Kyriazakis, 1995; Hodgson, 1971).

2.1.3 Rate of intake and its relation to preference.

The structure and composition of the sward have a major influence on the intake of the animal by influencing non-nutritional factors associated with the harvesting of herbage (Poppi *et al*, 1987). In fact, ease of prehension is one factor proposed to influence diet selection (Poppi *et al*, 1987) since it has been observed that animals prefer to eat from those foods with higher rate of intake (Kenney and Black, 1984a,b; Colebrook et al, 1987). Furthermore, food preference was found to be more strongly correlated with rate of intake than with *in vitro* digestibility of the organic matter of different hays offered to sheep (Kenney and Black, 1984a).

Phenology of forages is related to ease of prehension as the animals' harvesting efficiency is impaired when grazing mature compared with vegetative forages (Flores et al, 1989b; Dumont et al, 1995a). This impairment is observed as decreased bite size and rate of intake (Flores et al, 1989b; Dumont et al, 1995a).

Differences in canopy structure are common within the vertical structure of the sward profile and between pasture species, leading to differences in bulk density (BD) down the sward profile (Edwards, 1994; Edwards et al, 1995). Animals tend to graze a constant proportion of the sward height. This has been proved in situations where the sward is vertically homogeneous in bulk density and quality as in experiments with artificial turves (Laca et al, 1992; Mitchell et al, 1991), but also under relatively uniform conditions of sward experiments in the field (Barthram and Grant, 1984; Betteridge et al, 1994).

Sward surface height (SSH) and bulk density (BD) seem to be the sward parameters most important in defining bite size, although SSH is considered the best predictor for bite size and intake, at least for temperate pastures (Poppi *et al,* 1987). This is because it is the strongest factor of the sward positively correlated with bite depth and bite volume, and consequently bite size (Burlison *et al*, 1991; Ungar et al, 1991). Allden and Whittaker (1970) found rate of intake closely related to SSH, with an almost linear increase of bite size with sward height, until a certain point from which rate of biting decreased with further increases in height. They reported that beyond 7.7 cm height, the size of bite and the rate of biting by grazing sheep varied inversely to maintain a constant rate of intake. Dumont et al (1995a), reported that heifers grazed taller vegetative pastures in preference to short pastures working within a range of sward height from 7 to 18 cm.

Hodgson (1982a), Mitchell et al (1991), and Gong et al (1996), concluded that sward height exerts a greater influence on herbage intake than either the density of, or the proportion of green material in the surface horizon. Nonetheless, in the presence of a tall flower canopy, the rate of ingestion is more likely to be related to sward density or leaf:stem ratio especially for tropical pastures (Stobbs, 1973; Chacon and Stobbs, 1976). Thus, bite size increases with sward height, until the appearance of a flower horizon, whereupon bite size declines (Gong et al, 1996).

Bulk density, defined as the herbage mass per unit volume in the sward (Hodgson, 1982a; Ungar and Noy-Meir, 1988), was found to exert a negative effect on bite area, bite depth, bite volume and bite rate, but not in bite size. However, increasing BD values allowed higher intake rates in spite of the decrease in the former parameters (Mitchell et al, 1991).

The breaking strength of the plant material exerts an effect on intake through limiting the size of a bite when maximum force is required to prehend a bite of herbage. Plant maturity and previous grazing management cause the appearance of stems different in diameter and therefore, breaking strength can be limiting (Poppi *et al,* 1987).

Henry et al (1996) reported a decreased rate of intake in sheep as forage maturity increased, and assumed that intrinsic shear strength also increased with maturity. The proportion of leaf in the forages on offer accounted for 62 % of the variation in intake, masking the effect of other forage characteristics, including neutral detergent fibre (NDF), in vitro organic matter digestibility (IVOMD), nitrogen (N), and lignin content.

2.2 Partial preferences -mixed diets.

It is widely recognised that legumes have advantages over grasses in terms of nutritional and feeding value (Ulyatt, 1981; Ulyatt et al, 1988), and in allowing a higher rate of intake (Penning et al, 1991; 1995a), particularly for prostrate temperate legumes (Cosgrove and Mitchell, 1995).

Many studies on diet preferences and diet selection have been conducted with sheep and the information extrapolated to cattle. Earlier work (Clark and Harris, 1985; Curll et al, 1985; Heinemann, 1970; Milne et al, 1982) conducted with intermingled pastures reported that animals actively select for one of the components of the sward (e.g. the legume). However, due to the nature of the experiments (mixed pasture species within the sward canopy), it was not possible to determine whether this preference was total or partial, as demonstrated in more recent studies by Parsons and colleagues (Newman et al, 1994b; Parsons et al, 1994a; Penning et al, 1995c) and Cosgrove et al (1996), where the animals have been given the chance of choice between monocultures of ryegrass and white clover. In general, animals show partial preferences, even though they could meet intake requirements by grazing only one species (Newman et al, 1994b; Parsons et al, 1994a; Penning et al, 1995c; Cosgrove et al, 1996).

Partial preference can be influenced by factors such as previous diet (Newman et al, 1992; Parsons et al, 1994a), fasting (Dumont et al, 1995a; Newman et al, 1994b), herbage species abundance (Parsons et al, 1994a), and even ease of prehension of herbage reflected as differences in instantaneous intake rate (Poppi *et al*, 1987). This partial preference is usually for legume over grass, though this is not always the rule (Newman et al, 1992; Ogura and Sugawara, 1996), nor is it always true for combinations other than ryegrass and white clover.

It has been demonstrated in sheep that, when given the opportunity for choosing between monocultures of ryegrass and white clover, animals show an increased preference for the opposite species to the one grazed prior to the experiment (Newman et al, 1992; Parsons et al, 1994a). However, this preference is modified within the first 6 days of having free choice (Parsons et al, 1994a).

Newman et al (1994b) reported that 24 h-fasted sheep grazed less clover than did unfasted sheep. No clear evidence is reported in the literature for cattle, though Dumont et al (1995a) found no significant difference between fasted and unfasted heifers in preference for grazing cocksfoot pastures at different maturity states.

The physiological state (e.g. the animal's potential productiveness such as milk yield or stage of lactation, daily bodyweight gain, reproductive state, etc.) dictates the nutritional needs of the animal (NRC, 1996), and thus sensitivity to variations in sward parameters. Consequently, it is likely that physiological state may influence grazing preferences. Parsons et al (1994a), in an experiment on grazing preferences with dry and lactating ewes, observed that the latter tended to have a larger proportion of clover in their diets than that selected by dry ewes, although the difference was not statistically significant.

Thus, in studying the factors that affect diet selection of an animal, it is valuable to consider first what the animal would prefer to eat (Parsons et al, 1994a). Furthermore, understanding food partial preferences may help in controlling the vegetation in order to give the animals their preferred foods in adequate proportions (Heady, 1964), thus facilitating grazing management (Chapman et al, 1996). This emphasises the importance of the study of animals' grazing preferences.

Furthermore, the use of monocultures side by side allows control of the searching factor by enabling the animals to locate either of the pasture species on offer without search (Newman et al, 1995a). In this way, preferences measured as the time spent grazing each of the pasture species on offer, are more accurately assessed because animals can select their diet with minimum or nil influence on the grazing preference *per se* as occurs in the more complex intermingled swards (Newman et al, 1994b; Dumont et al, 1995a).

2.3 Herbage n-alkanes in diet selection and herbage intake studies.

Assessment of diet selection and estimation of herbage intake by grazing ruminants are a common interest for animal scientists, but the objective has been difficult to attain since accurate and convenient methods for estimating the botanical composition of the consumed diet are not available (Dove, 1993; 1996). A relatively new approach (Mayes et al, 1986) to the estimation of forage intake and botanical composition of the diet ingested is that based on the presence of saturated hydrocarbons, named alkanes, in the cuticle of plants (Dove and Mayes, 1991).

This approach is based on the fact that different odd-chain-length alkanes are naturally-occurring compounds in epidermal tissue of plants, and that these compounds vary in proportion between plant species (Dove et al, 1989a,b; 1990).

The analytical procedures for the determination of herbage and faecal n-alkanes involve chromatography of samples previously treated by saponification to convert esters to the corresponding alcohols and potassium salts of the acids, and a subsequent liquid-liquid extraction involving the addition of a n-hexane or n-heptane and water, followed by evaporation to remove excesses of water and alcohol, and finally by a solid-phase separation that allows other contaminants to be retained. This extraction process avoids possible interference in the chromatographic analysis of n-alkanes (Vulich et al, 1991; 1995).

Alkanes, particularly those of low chain length, are not completely recovered in faeces (Dove et al, 1989b). However, Vulich et al (1991) found no differences in faecal recovery rates of either dosed (C32 and C36) or the herbage odd-chained n-alkanes (C29, C31, C33 and C35), in a study estimating herbage intake. Thus by using long odd-chained alkanes and adjusting for faecal recovery, diet composition can be estimated by simultaneous equations or least squares procedures (Dove and Mayes, 1991;1996; Dove and Moore, 1995; Newman et al, 1995b), whereas by dosing adjacent even-chain length alkanes, due to the similar faecal recoveries, it allows errors from incomplete recovery to cancel out, and thus calculate diet herbage intake (Dove et al, 1989a,b; 1990) from the following equation:

$$Intake = \frac{Fi}{Fj} Dj \, / \, [Hi - \frac{Fi}{Fj} Hj]$$

where,

D*j* is the daily dose of synthetic (mg/day), even-chain alkanes;

H*i* and F*i* are the herbage and faecal concentrations of the natural alkane (mg/kg) respectively, and,

H*j* and F*j* are the herbage and faecal concentrations of the dosed alkane respectively.

On one hand, the longer-chain alkanes, that are more stable in terms of faecal recovery (Vulich et al, 1991), are not present in all plant material in concentrations high enough to be useful. However, the use of alkanes of shorter chain length is complicated by their very low recovery rates (Laredo et al, 1991). Furthermore, either low or similar levels of alkanes in the pasture species, makes the calculation of diet composition more variable particularly when using simultaneous equations (Dove, 1992; 1993). Thus, it has been suggested to include a spectrum of several n-alkanes in the analysis in order to use more differences among plant species and thus allow detection of small differences between plant species (Dove and Moore, 1995; Newman et al, 1995b).

2.3.1 Controlled-release devices.

Perhaps the major problem in applying the alkane technique has been the necessity for daily dosing of even-chained alkanes when measuring intake, which becomes a disturbing factor when conducting behavioural studies (Dove and Mayes, 1991). Engineering a device that allowed a continuous release of the product could enable behavioural studies to be conducted without having to disturb normal behaviour. Recently, alkanes have been dosed by means of a controlled release device (CRD) that allows continuous release of alkanes with the advantage of requiring handling of the animals only once, when the device is inserted into the rumen (Ralph, 1992; Taylor, 1994/95).

2.3.2 Diet composition through alkanes.

Prepared sets of two, three or four pasture species, including grasses and legumes, at different proportions have been analysed for n-alkanes in the pure species and in the mixtures to calculate species proportion within the mixture with a high level of accuracy (Dove, 1992; 1993). When mixtures of pasture species were fed to sheep the component proportions predicted through the alkanes technique reached an accuracy of 99% (Wen et al, 1995).

Even though there has not been enough research in the estimation of diet composition using the alkane technique, it has been proved that this technique can be more accurate than *in-vitro* based techniques for herbage intake estimations (Dove et al, 1990). This method has recently been evaluated under grazing conditions to prove its usefulness (Reeves et al, 1996). Thus, the application of the technique to diet selection studies is reliable since both intake and diet composition are based on the same principle. This principle is the presence of plant hydrocarbons of very low digestibility in the cuticle of plants. The different levels of plant hydrocarbons between plant species is what allows the estimation of diet composition (Mayes et al, 1995).

If on one hand, the literature shows that the alkane technique is not fully accurate in determining herbage intake of grazing animals, on the other hand, as pointed out by Piasentier et al (1995), it, along with the chromium technique are the only ones applicable for certain grazing conditions such as those with uniform swards. Furthermore, the n-alkane technique presents the advantages of involving less laboratory work than the chromium technique and considers individual animal differences in digestibility (Piasentier et al, 1995).

3. Materials and Methods.

3.1 Location.

This experiment was conducted at the AgResearch, Flock House Agricultural Centre, Bulls, located on the west coast of the North Island, New Zealand (latitude 40° 14' South, and longitude 175° 16' East). The soil type is described as Rangitikei fine sandy loam (Soil Bureau. 1965). The average rainfall is 875 mm with a dry period from January to March and strong westerly winds during October to November (Spring). The average monthly temperature ranges from 9°C (July) to 20°C (January).

3.2 Monocultures of pasture species.

Three two-ha paddocks were used, consisting of paired 1-ha monocultures of either

- -White clover (*Trifolium repens* cv. Kopu):Perennial Ryegrass (*Lolium perenne* cv. Yatsyn, high endophyte); or
- -*Lotus corniculatus* cv. Goldie: Ryegrass; or
- - *Lotus corniculatus*: Red clover (*Trifolium pratense*) cv. Colenso

These pastures had been sown in April 1994. A maintenance fertiliser dressing of 200 kg of di-ammonium phosphate was applied in each spring and the ryegrass monocultures received 250 kg N ha^{-1} applied as dressings of 125 kg ha^{-1} each over spring and summer to compensate for lack of N inputs from clover-N fixation.

These species-contrast plots were used in a previous grazing behaviour trial with cattle (Cosgrove et al, 1996, 1997) where white clover and lotus were shown to be preferred over ryegrass. In contrast, lotus was found to be only slightly preferred over red clover. Hereafter, white clover (W) and lotus (L) are referred to as preferred species whereas ryegrass and red clover are referred to as the less preferred species.

3.3 Treatments.

For the current trial, each species-contrast was subdivided into four plots of 25 X 200 m, giving a total of 12 plots, one half (25 X 100m) occupied by the preferred and the other half by the less preferred species (Figure 1).

Within species-contrasts the height of the preferred species was set at 4, 6, 8 or 10 cm, while the height of the less preferred species (Ryegrass, Rye; and Red clover, Red) was set at 10 cm across all plots. Each plot was grazed by 3 yearling Friesian heifers, and observations were made on grazing behaviour in two 3-day-periods (periods 1 and 2) in both summer and autumn. Animals were allocated to the experimental plots during the afternoon prior to commencing recording of grazing behaviour. The treatment height was allocated to plots at random within contrasts, prior to the commencement of the first Summer period. The same allocation of heights was used for period 2 in summer. For the Autumn periods, treatment height was allocated at random prior to commencement of each of the grazing periods. Periods 1 and 2 within the season were used as replicates in the statistical analysis.

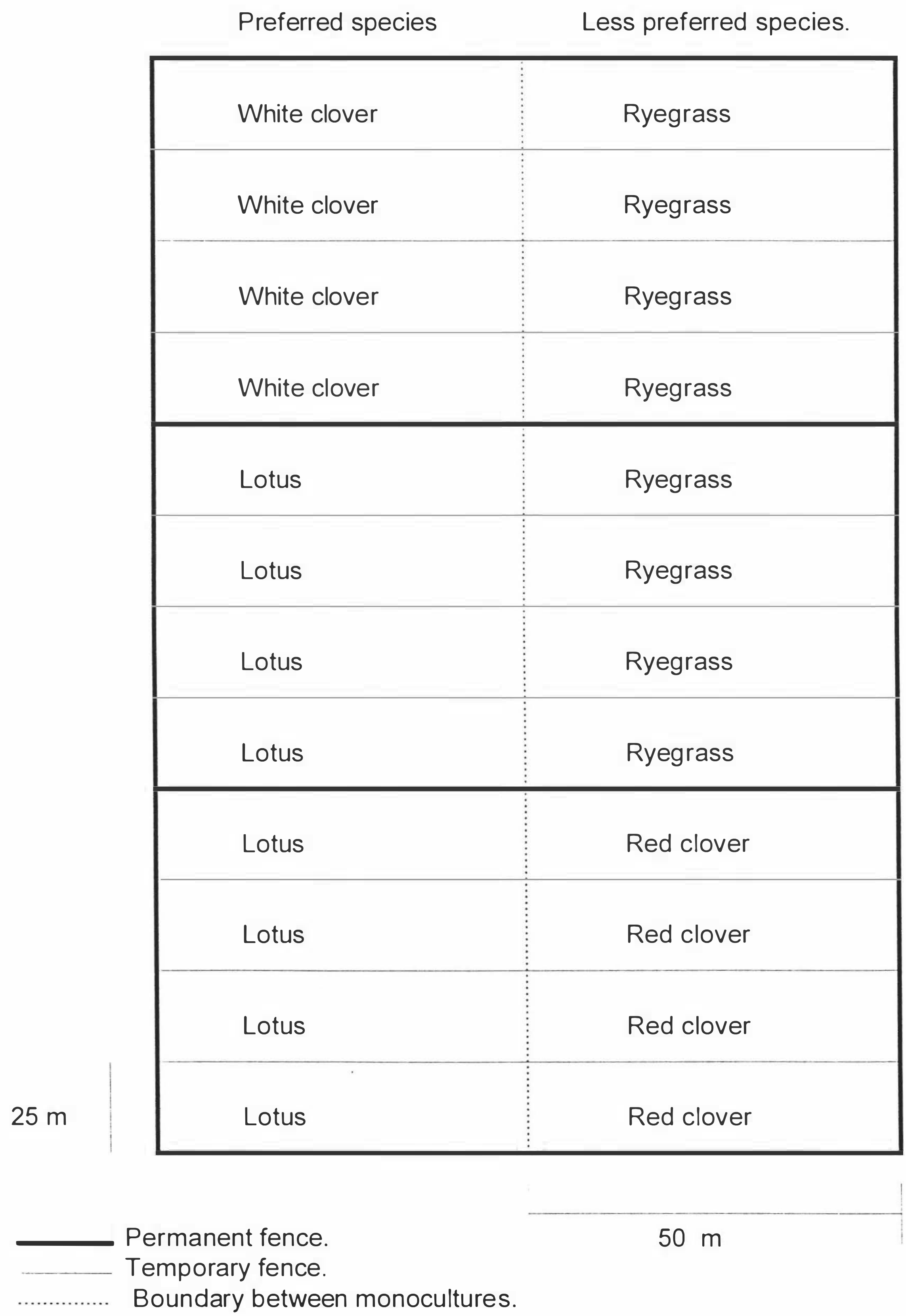
Each plot was prepared by mowing or grazing before the beginning of each of two grazing periods (period 1 and 2, respectively) in both Summer and Autumn, in order to obtain the nominal height.

Period 1 in Summer ran from 5 to 8 December 1995, and period 2 from 9 to 22 January 1996. Periods 1 and 2 in Autumn ran from 15 to 18 April and from 30 April to 3 May 1996, respectively. Observations for grazing activity were made throughout as described below.

During the summer, the animals were kept on the experimental plots for a total of two weeks for each period. During the second week, diet composition and herbage dry matter intake were estimated through the alkane technique (Dove, 1992; 1993). Observations for grazing activity were also made in these phases. Hereafter the second week of periods 1 and 2 in summer are referred to as intake phases 1 and 2. Herbage intake and diet composition were not estimated in autumn.

Water troughs were provided to each plot on the boundary between monocultures so that water location did not bias grazing preference.

Figure 1. Experiment layout (not to scale).



3.4 Animals and management.

Thirty-six 16-month-old heifers with an average bodyweight of 284 (± 17.2) kg were allocated at random to 12 groups of 3, prior to the beginning of the first grazing period in Summer.

For Autumn, 36, 14-month-old Friesian heifers, this time stratified in three sub-sets due to a large range in bodyweight (143 to 249 kg) were allocated at random prior to the beginning of each grazing period, three per plot. The sub-sets were of 179 (± 19.0), 212 (± 8.9) and 235 (± 7.7) kg mean liveweight respectively.

The animals grazed ryegrass-white clover dominant mixed pasture prior to the start of the trial, and between periods 1 and 2 in Summer. The animals used in the Autumn had been grazing ryegrass-white clover dominant pasture prior to commencing the trial, and grazed a mixed pasture, which included cocksfoot, ryegrass, white and red clover between periods 1 and 2.

The animals used in Summer were all dosed with an intra-ruminal antibloat capsule (Rumensin) before being put on the plots. For the Autumn periods, no bloat precautions were taken.

3.5 Grazing activity.

Recordings were made of distribution of grazing activity on preferred and less preferred species, as grazing or not grazing, at 10-minute intervals during daylight hours for three consecutive days during the observation periods and intake phases. Total grazing time (GTt), expressed in hours was calculated from the total sum of observations recorded as 'grazing', divided by the number of observations per hour (e.g. 6). Grazing time (hours) on the preferred (GTp), and less preferred species (GTl), were calculated by dividing the sum of observations made as 'grazing' on the preferred or less preferred species, divided by 6. The proportion of GTt allocated to the preferred species was calculated from the ratio of GTp to GTt. In all cases, group averages were used for statistical analyses.

3.6 Biting rate (BR).

The rate of biting (BR) was recorded twice a day for each animal when grazing each of the two forage species by recording the time spent in taking 20 bites, and expressed as number of bites per minute (Forbes, 1988).

3.7 Herbage measurements.

3.7.1 Sward surface height.

Height of the canopy surface was measured with a modified rising plate meter in which a perspex plate (30 x 30 cm) was lowered on to the canopy and the height recorded when the plate touched the majority of leaves within its perimeter. Fifty readings were taken along plot diagonals prior to introduction of the animals. These readings were taken by the same person on each occasion in order to avoid among-operator variation. Average sward surface height was calculated.

3.7.2 Herbage mass.

Two random, 5 m x 0.089 m strips were cut to ground level in each species within each plot (48 samples in total), prior to the introduction of the animals, for periods 1 and 2 in summer and autumn, and prior to the commencement of recordings for the grazing activity during the intake phases. The herbage samples were oven-dried at 70°C for 24 h. Herbage mass was calculated from the area of the strip cut and expressed as kg DM ha^{-1}.

3.7.3 Botanical composition.

Two samples from each pasture species within each plot were taken to characterise the sward-canopy structure. Sites were selected with a sward surface height similar to that of the average for the plot and the canopy partitioned into upper, and lower strata. The samples (0.315 m x 0.30 m) were cut using hand shears, at approximately half the average height for that particular plot (upper stratum). A ruler was used to indicate the level of cutting.

The samples were weighed and subsampled for dry matter determination. Botanical composition of the upper stratum was determined by dividing cut samples into leaf, stem, flower/seedhead of the sown species, and unsown species where necessary. Tips of *Lotus corniculatus* plants and petioles of clovers were classified as leaf. Ryegrass was divided into lamina and pseudostem. No separation of plant parts was conducted for unsown species. All values were expressed as percentage of DM of the upper stratum subsample.

Sample weights from the upper stratum samples were used for calculating bulk density (BD) of the upper half of the sward canopy as kg DM ha^{-1} cm^{-1}.

Neither separation for botanical composition, nor plant parts separation were performed on the bottom stratum samples.

3.7.4 Herbage quality.

Herbage pluck samples were obtained from the plots in periods 1 and 2 in summer and in autumn, for use in estimating diet composition.

The samples were obtained to simulate grazing by carefully watching what the animals were eating at the time of sampling.

The samples were freeze-dried and ground to 1 mm size. Those samples from the less preferred species within contrasts from each week were bulked since they all were expected to have similar quality because they had similar canopy height.

Estimates for several parameters of quality such as protein, neutral detergent fibre (NDF), acid detergent fibre (ADF), carbohydrates (soluble sugars plus starch), ash and lipid content were determined by Near Infrared Reflectance Spectroscopy (NIRS) (Shenk and Westerhaus, 1994). Estimates of energy (megajoules of metabolizable energy; ME) concentration and energy digestibility were derived from the parameters previously mentioned.

3.8 Diet composition and dry matter intake.

The alkane technique was used for estimation of diet composition (Dove, 1992; 1993), and herbage dry matter intake (Dove and Mayes, 1991).

The estimation of diet composition and herbage dry matter intake was conducted during the second week of grazing following periods 1 and 2 in summer, to allow a 7-day period for faecal alkane appearance to stabilise before faecal sampling started (Dove et al, 1994).

Herbage samples were taken for alkane determination during the intake phases. Herbage samples were obtained by taking pluck samples from both pasture species within each plot. Prior to sample collection, the animals were carefully observed with the help of binoculars. Pluck-samples were then taken attempting to simulate the diet in terms of plant parts eaten. The pluck samples, collected on the first day and last day of the intake phase, were freeze-dried and ground for subsequent alkane determination.

For the herbage dry matter intake estimation, intra-ruminal alkane controlled-release devices (CRD) with a daily release rate of 385 mg of each of C32 and C36 alkanes for a period of approximately 20 days (CSIRO, Australia) were used. Due to the short-term nature of the trial, alkane release rate was not determined, and rather, the release rate supplied by the manufacturer was used. CRDs were inserted prior to the animals commencing grazing on the species-contrast plots allowing a week prior to faecal sampling (Dove et al, 1994).

Faecal samples were collected by rectal stimulation, at around midday of the first two, and the last three days of the second week of periods 1 and 2 in Summer. This allowed for observation on 3 consecutive days, without disturbance of grazing behaviour, between these faecal collection periods. The samples from each animal were freeze-dried individually and then bulked for subsequent alkane determination (Vulich and Hanrahan, 1995).

No samples were collected for alkane determination in Autumn, therefore, both dry matter intake and diet composition were estimated only in Summer.

The experimental units (animals) in this phase were as follows; three animals from each of the 4 and 10 cm treatment heights on the W_Rye and two from each of the 4 and 10 cm treatment heights on both the L_Rye and L_Red contrasts making a total of 14 for the period 1. For period 2, 3 animals were dosed on each of 4 and 10 cm treatment in W_Rye and L_Rye contrasts, and 2 animals in each of the 4 and 10 cm treatment in L_Red, summing to16 in total. Intake and diet composition estimates were confined to summer, and to the extreme treatment heights only because of constraints.

Diet composition was calculated using the linear optimisation program (EatWhat) kindly provided by Dove and Moore (1995), and expressed as percentage of pasture species in a dry matter basis.

Dry matter intake estimation was obtained by following the alkane method described by Dove et al (1989a,b; 1990).

3.9 Statistical analyses.

3.9.1 Observation data.

Experimental unit refers to the group of three animals within a plot. There was no spatial replication of plots. Grazing observations were repeated in each season (period 1 and period 2), and these data sets used as replicates.

Separate analyses of variance using GLM procedure (SAS Institute, 1990) were performed for activity, expressed as total grazing time (GTt), grazing time on the preferred species (GTp), grazing time on the less preferred species (GTl); and proportion of GTt on the preferred species. Where appropriate, relationships were established by regression analysis of GTt, GTp, and GTl on actual sward surface height. The regression analyses were performed using weekly averages. Statistical analysis of the observation data was based on group average daily behaviour. The GLM procedures included season and the interactions between this and species-contrast, and height, tested against the replicate (period) nested within season. The nested effect of replicate was tested against day nested within replicate within season. Main effects of contrast and height of the preferred species were tested against the residual.

3.9.2 Biting rate (BR).

The rate of biting data was unbalanced because no records were available for the first day of the first period of Summer. Therefore, a single daily average value was obtained for each animal and analysed by PROC GLM (SAS Institute, 1990) using a similar model structure to that used for the observation data.

3.9.3 Herbage mass and Bulk density.

Analysis of variance (PROC GLM) was used to analyse herbage mass data with contrast and season as main effects, and species nested within contrast, and height nested within species within contrast, replicate nested within season, and the interactions between season and species within contrast, and season and height within species within contrast.

Bulk density of the sward upper stratum was analysed in similar way to herbage mass.

3.9.4 Pluck samples.

Since the hand-plucked samples from the less preferred species were bulked together for NIRS analyses and those from the preferred species were analysed by individual plot, analyses of variance for preferred, and less preferred species, were performed separately.

3.9.5 Botanical composition.

Percentage of leaf, stem, dead matter, seedhead or flower, and other species were averaged and used for describing herbage conditions of the experimental plots.

3.9.6 Diet composition and dry matter intake.

Grazing time recordings and herbage mass, botanical composition, bulk density and rate of biting data, obtained from the intake phase 1 and 2 in summer, when samples for alkane determination were also collected, were analysed as described before in 3.9.1, except that the variable season was absent since no comparable data was collected in autumn.

4. Results.

4.1 Herbage measurements.

4.1.1 Sward surface height (SSH).

The average SSH by treatment, averaged across seasons is given in Table 1. The height of the less preferred species was attained evenly across plots within species-contrast. The SSH by period within season is given in Appendix 2.

Table 1. Average sward surface height (cm) of experimental plots.

Species-contrast	Species	Treatment-height (cm). 4	6	8	10	Average
W_Rye	White clover	6.2	7.2	9.0	9.9	8.1
	Ryegrass*	11.8	12.0	12.0	11.7	11.9
L_Rye	Lotus	6.5	6.6	9.2	10.0	8.1
	Ryegrass*	10.4	10.4	10.6	10.5	10.5
L_Red	Lotus	6.0	7.7	9.4	10.7	8.4
	Red clover*	10.0	10.1	10.3	9.9	10.1
Std. Err. Preferred species						0.13
Std. Err. Less Preferred species						0.15

* Sward surface height targeted as 10 cm across treatments.

4.1.2 Herbage mass.

Average herbage mass was significantly influenced by species-contrast ($P<0.001$), with L_Red having the lowest herbage mass (1586 kg DM ha^{-1}), followed by L_Rye (1803 kg DM ha^{-1}) and W_Rye with the highest mass (2100 kg DM ha^{-1}). Pasture species (nested within contrast) also differed ($P<0.001$), as shown in Table 2, with ryegrass (Rye) having higher herbage mass than the legumes. There were no differences in herbage mass between lotus (L), white clover (W) and red clover (Red) ($P>0.05$).

Herbage mass decreased as height decreased ($P<0.05$) (Table 2).

Herbage mass was higher in summer than in autumn (P<0.001), and a significant effect (P<0.01) due to replicate, where the first period had greater herbage mass than the second period for each season, although in summer the difference between periods was not significant (P>0.05).

There was evidence (P<0.001) for an interaction between pasture species (nested within contrast) and season, due to an increase in herbage mass from summer to autumn for the Rye in L_Rye.

Table 2. Total herbage mass (kg DM ha^{-1}) of the preferred and less preferred species, as influenced by height, and season.

Species-contrast	Season	Height (cm) of the preferred species. 4	6	8	10	Average	Less preferred species
W_Rye[1]	Summer	1619	2058	2239	2275	2048	2796
	Autumn	1032	1105	1260	1237	1158	2399
	Average	1325	1582	1749	1756	1603	2597
L_Rye[2]	Summer	1396	1373	1684	2005	1614	1803
	Autumn	1287	1448	1460	1480	1418	2380
	Average	1341	1411	1572	1742	1516	2091
L_Red[3]	Summer	1479	1808	1539	2164	1748	1950
	Autumn	978	1036	1560	1881	1431	1216
	Average	1228	1557	1550	2023	1589	1583
	Std. Err.					158	79

Contrast	***
Species(Contrast)	***
Season	***
Replicate(season)	**
Height (species contrast)	*
Season x Species(Contrast)	***
Season x Height(Species contrast)	ns

[1], [2], [3] White clover-Ryegrass, Lotus-Ryegrass, Lotus-Red clover, respectively.
*, **, *** P<0.05, P<0.01, P<0.001, respectively.
ns non-significant (P>0.05)

4.1.3 Bulk density (BD).

The density of herbage dry matter (DM) in the sward upper stratum was similar for each species-contrast, and for each height treatment (P>0.05). However, bulk density (BD) did differ among pasture species (P<0.001), being highest for W and L, intermediate for Red, and lowest for Rye (Table 3).

Bulk density was higher in summer than in autumn (P<0.001), and there were no species x season, or height x season interactions (P>0.05).

Table 3. Bulk density (kg DM ha^{-1} cm^{-1}) of the preferred and less preferred species, as influenced by height, and season.

Species-contrast	Season	Height (cm) of the preferred species. 4	6	8	10	Average	Less preferred species
W_Rye[1]	Summer	187	162	182	171	176	119
	Autumn	120	106	99	109	108	53
	Average	153	134	140	140	142	86
L_Rye[2]	Summer	160	171	155	143	157	97
	Autumn	114	127	96	108	111	52
	Average	137	149	126	125	134	74
L_Red[3]	Summer	160	161	136	187	161	119
	Autumn	129	110	113	86	110	96
	Average	145	136	124	137	135	107
	Std. Err.					15	7

Contrast	ns
Species(Contrast)	***
Season	***
Replicate(season)	ns
Height (species contrast)	ns
Season x Species(Contrast)	ns
Season x Height(Species contrast)	ns

[1], [2], [3] White clover-Ryegrass, Lotus-Ryegrass, Lotus-Red clover, respectively.
*, **, *** P<0.05, P<0.01, P<0.001, respectively.
ns non-significant (P>0.05)

4.1.4 Botanical composition.

4.1.4.1 Leafiness.

Leafiness of the sward upper stratum varied among pasture species with W and Rye having the highest average values, L the lowest and Red being intermediate (Table 4). Leafiness in L, particularly in L_Red tended to decrease with decreases in height, whereas W which appeared more consistent across treatment heights.

Also, W in W_Rye, and L in L_Rye had greater leafiness in autumn than in summer, but the opposite appeared to occur for L and Red in L_Red (Table 4).

Table 4. Leafiness (%) in the sward upper stratum as affected by height and season.

Species-contrast	Season	Height (cm) of the preferred species. 4	6	8	10	Average	Less preferred species*
W_Rye	Summer	68.3	68.0	55.6	62.2	63.5	57.0
	Autumn	91.2	94.4	91.6	90.5	91.9	86.1
	Average	79.8	81.2	73.6	76.3	77.7	71.5
L_Rye	Summer	37.6	34.4	37.6	40.5	37.5	59.0
	Autumn	45.5	33.9	46.8	52.0	44.6	86.5
	Average	41.5	34.1	42.2	46.3	41.0	72.7
L_Red	Summer	22.3	27.8	33.3	47.3	32.7	62.1
	Autumn	13.3	17.7	28.2	37.8	24.3	43.8
	Average	17.8	22.7	30.7	42.5	28.4	53.0
	Std. Err.					9.8	4.9

* Set at 10 cm height across plots; therefore, values were pooled together across plots within contrast.

4.1.4.2 Stemminess.

In general, both, W and Red showed very low stem percentage (1.4 and 2.6 % respectively), followed by Rye in both W_Rye and L_Rye (6.1 and 6.6 %, respectively), with both L having high proportion of stem (24.5 and 25.4 % for L_Rye and L_Red, respectively). There was more stem in the upper stratum in summer than in autumn for all the species-contrasts (Table 5).

Table 5. Stemminess (%) in the sward upper stratum as affected by height and season.

Species-contrast	Season	Height (cm) of the preferred species. 4	6	8	10	Average	Less preferred species*
W_Rye	Summer	3.7	0.0	7.8	0.0	2.9	11.6
	Autumn	0.0	0.0	0.0	0.0	0.0	0.7
	Average	1.8	0.0	3.9	0.0	1.4	6.1
L_Rye	Summer	40.1	38.1	43.8	25.7	36.9	12.5
	Autumn	9.0	10.0	10.3	18.9	12.1	0.7
	Average	24.5	24.0	27.0	22.3	24.5	6.6
L_Red	Summer	41.0	45.7	43.6	40.6	42.7	5.0
	Autumn	15.5	4.3	5.2	7.6	8.2	0.2
	Average	28.2	25.0	24.4	24.1	25.4	2.6
	Std. Err.					3.7	1.9

* Set at 10 cm height across plots; therefore, values were pooled together across plots within contrast.

4.1.4.3 Dead matter.

In general, there was more dead matter in summer than in autumn, and in the less preferred species than in the preferred species, except for L_Red in autumn (Table 6), where percentage of dead matter in L at the 4 cm treatment height was high.

Table 6. Dead matter (%) in the sward upper stratum as affected by height and season.

Species-contrast	Season	Height (cm) of the preferred species. 4	6	8	10	Average	Less preferred species*
W_Rye	Summer	16.4	11.0	13.3	10.2	12.7	24.9
	Autumn	4.0	2.0	1.4	1.1	2.1	12.0
	Average	10.2	6.5	7.3	5.6	7.4	18.4
L_Rye	Summer	16.2	13.6	16.0	10.0	14.0	16.6
	Autumn	10.7	10.3	4.7	5.7	7.9	9.0
	Average	13.4	11.9	10.3	7.8	10.9	12.8
L_Red	Summer	19.8	14.9	15.8	11.1	15.4	23.2
	Autumn	17.7	4.7	8.6	3.1	8.5	5.5
	Average	18.7	9.8	12.2	7.1	11.9	14.3
	Std. Err.					3.5	1.8

* Set at 10 cm height across plots; therefore, values were pooled together across plots within contrast.

4.1.4.4 Seedheads/flowers.

There was in general, a low proportion of seedheads/flowers, particularly in the legume components, except for W in summer. Also, this proportion was lower in autumn than in summer, when no seedheads/flowers were detected (Table 7).

Table 7. Seedheads/flowers (%) in the sward upper stratum as affected by height and season.

Species-contrast	Season	Height (cm) of the preferred species. 4	6	8	10	Average	Less preferred species*
W_Rye	Summer	4.4	10.0	11.6	14.2	10.1	4.5
	Autumn	0.0	0.0	0.0	0.0	0.0	0.0
	Average	2.2	5.0	5.8	7.1	5.0	2.3
L_Rye	Summer	1.0	0.6	0.2	11.7	3.4	9.0
	Autumn	0.0	0.0	0.0	0.0	0.0	0.0
	Average	0.5	0.3	0.1	5.9	1.7	4.5
L_Red	Summer	1.7	0.5	1.6	0.7	1.1	0.7
	Autumn	0.0	0.0	0.0	0.0	0.0	0.0
	Average	0.9	0.3	0.8	0.4	0.6	0.3
	Std. Err.					3.0	1.5

* Set at 10 cm height across plots; therefore, values were pooled together across plots within contrast.

4.1.4.5 Unsown species.

Unsown species identified for the W and L plots were dock (*Rumex* spp), and scotch thistle (*Cirsium vulgare*); white clover and dock in the Red plots; and barley grass (*Hordeum murinum*) in the Rye plots. Two of the L height treatment plots in L_Red had also barley grass and ryegrass.

The proportion of unsown species in the plots was not consistent. Both ryegrass contrasts and white clover showed little presence of unsown species, whereas both L contrasts and red clover showed an increased presence of unsown species from summer to autumn, when values were close to 50 percent, particularly for the L_Red contrast (Table 8).

Table 8. Unsown species (%) in the sward upper stratum as affected by height and season.

Species-contrast	Season	Height (cm) of the preferred species.					Less preferred species*
		4	6	8	10	Average	
W_Rye	Summer	7.3	11.2	11.9	13.5	11.0	2.0
	Autumn	4.9	3.6	7.1	8.5	6.0	1.3
	Average	6.1	7.4	9.5	11.0	8.5	1.6
L_Rye	Summer	5.3	13.4	2.4	12.2	8.3	3.0
	Autumn	34.9	46.0	38.3	23.5	35.7	3.9
	Average	20.0	29.7	20.4	17.8	22.0	3.4
L_Red	Summer	15.3	11.1	5.9	0.3	8.2	9.1
	Autumn	53.7	73.3	58.0	51.6	59.2	50.6
	Average	34.5	42.2	32.0	26.0	33.6	29.8
	Std. Err.					8.2	4.1

* Set at 10 cm height across plots; therefore, values were pooled together across plots within contrast.

4.1.5 Herbage quality.

4.1.5.1 Preferred species.

Height of the preferred species had no influence ($P>0.05$) on any of the parameters of herbage quality measured except for lipid content ($P<0.01$). Differences were observed for pasture species ($P<0.05$) and season ($P<0.01$) in most cases, except for carbohydrate concentration which was similar among species and across seasons ($P>0.05$). The influence of season on herbage quality differed with pasture species as indicated by pasture species x season interaction ($P<0.05$) for most parameters, except for NDF and carbohydrates content ($P>0.05$). Table 9 shows the average values for each of these parameters for the preferred species as influenced by season.

4.1.5.2 Less preferred species.

The less preferred species were kept at similar SSH across plots. Thus, the samples taken from the less preferred species within season were bulked across treatment heights prior to analysis for quality.

The less preferred species showed few significant effects and only season appeared consistently ($P<0.05$) to influence lipid, ADF, carbohydrate contents, and ME and digestibility. Pasture species differed in terms of NDF ($P<0.001$), and carbohydrate ($P<0.05$) contents. Table 10 shows the average values corresponding to the parameters measured for each of the less preferred species within species-contrast, as influenced by season.

Table 9. Near infrared reflectance spectroscopy (NIRS) analyses for samples of preferred species as influenced by season and species within contrast. Values are expressed as g/100 g DM, except for energy (Megajoules of metabolizable energy per kg DM) and digestibility (% of the DM).

Contrast	Species	Season	Protein	ME	Carbohydrates	NDF	ADF	Lipid	Ash	Digestibility
W_Rye	W. clover	Summer	27.4	12.43	9.5	29.0	20.8	3.16	10.42	78.6
		Autumn	32.0	12.40	6.2	26.8	21.0	3.42	11.23	78.4
L_Rye	Lotus	Summer	19.7	11.46	8.6	36.3	27.4	3.15	9.22	72.7
		Autumn	31.7	12.49	9.2	27.8	20.4	4.03	11.15	78.9
L_Red	Lotus	Summer	22.3	11.93	10.7	32.2	24.2	3.56	9.74	75.5
		Autumn	30.1	12.37	9.4	28.1	21.2	3.97	10.97	78.3
	Std. Err.		0.95	0.15	0.96	1.39	1.02	0.08	0.16	0.92

Table 10. Near infrared reflectance spectroscopy (NIRS) analyses for samples of less preferred species within contrast. Values are expressed as g/100 g DM, except for ME (metabolizabe energy; Megajoules/kg DM) and digestibility (%).

Contrast	Species	Season	Protein	ME	Carbohydrates	NDF	ADF	Lipid	Ash	Digestibility
W_Rye	Ryegrass	Summer	22.7	11.86	7.82	48.4	24.7	3.02	10.2	75.2
		Autumn	27.6	11.72	4.04	47.6	25.7	3.68	11.2	74.3
L_Rye	Ryegrass	Summer	22.6	11.99	8.92	46.2	23.8	3.05	9.7	75.9
		Autumn	24.2	11.47	4.36	50.8	27.4	3.61	10.6	72.7
L_Red	Red clover	Summer	29.4	12.41	12.95	28.4	21.0	3.41	10.9	78.5
		Autumn	30.2	11.96	10.20	32.5	24.0	3.44	11.2	75.7
	Std. Err.		2.19	0.18	1.36	1.54	1.20	0.20	0.42	1.08

4.2 Grazing activity.

Analysis of variance was the first approach used for behaviour parameters (see Appendix 1 for program and structure of analysis). Nevertheless, since the heights attained deviated from those originally targeted in some plots, regression analysis using weekly average for each parameter, and actual height of the preferred species was also used. Also, because the variation due to actual heights was taken into account in the ANOVA, interaction effects were not interpreted in detail, and more emphasis was put on the regression equations derived.

Figures depicting general trends in behavioural parameters were made using the residuals from regression analyses. Figures were made by species contrast and season.

4.2.1 Total Grazing Time (GTt).

Species-contrast strongly influenced GTt ($P<0.001$) with W_Rye (6.57 hr) having the shortest GTt, followed by L_Red (6.79 hr) and L_Rye (7.44 hr) (Table 11).

GTt within species-contrast tended to decrease from summer to autumn (7.01 vs. 6.15, 7.52 vs. 6.06, and 7.85 vs. 7.03 hr for W_Rye, L_Red and L_Rye in summer and autumn, respectively), although differences between season were not significant ($P>0.05$).

Table 11. Total grazing time (GTt; hours) as affected by height of the preferred species, species-contrast and season.

Species-Contrast	Season	Height (cm) of the preferred species. 4	6	8	10	Average
W_Rye[1]	Summer	7.30	6.95	7.25	6.53	7.01
	Autumn	6.30	6.20	6.25	5.83	6.15
	Average	6.80	6.57	6.75	6.18	6.58
L_Rye[2]	Summer	7.67	8.83	7.88	7.03	7.85
	Autumn	7.10	7.27	6.70	7.07	7.03
	Average	7.38	8.05	7.29	7.05	7.44
L_Red[3]	Summer	7.17	7.47	7.73	7.73	7.53
	Autumn	6.20	5.78	6.23	6.02	6.06
	Average	6.68	6.63	6.98	6.88	6.79
	Std. Err.					0.16

Contrast	***
Season	ns
Replicate	*
Day	***
Height	*
Contrast x Height	**
Contrast x Season	**
Season x Height	ns
Contrast x Season x Height	ns

[1], [2], [3] White clover-Ryegrass, Lotus-Ryegrass, Lotus-Red clover, respectively.
*, **, *** P<0.05, P<0.01, P<0.001, respectively.
ns non-significant (P>0.05)

Interactions between height of the preferred species and species-contrast, and between species-contrast and season occurred (P<0.01), suggesting differences in response to height between species-contrast and season, for which regression analyses were performed.

Individual regressions for each species contrast by season showed no significant slopes (P>0.05); therefore, a common slope for all species-contrasts and seasons was estimated. The common slope indicated a decrease in GTt with increases in height of the preferred species (slope = -0.14 ± 0.07, P<0.05) (Figure 2). The different intercepts computed for each species contrast and season are shown in Table 12.

Table 12. Species-contrasts intercepts computed for the regression of total grazing time on actual height by season.

Contrast	Season	Intercept	(±)
W_Rye	Summer	8.2	0.61
	Autumn	7.3	0.59
L_Rye	Summer	9.1	0.66
	Autumn	8.0	0.55
L_Red	Summer	8.7	0.63
	Autumn	7.2	0.61

4.2.2 Grazing Time on the Preferred Species (GTp).

The time spent grazing L (5.23 hr) in the L_Rye contrast was higher (P<0.001) than that for white clover (W) (4.47 hr) in W_Rye contrast, and L (3.74 hr) in L_Red contrast (Table 13).

In a similar fashion to GTt, the GTp tended to be lower in autumn than in summer (5.42 vs. 3.51, 4.36 vs. 3.12, and 6.48 vs. 3.99 h for W_Rye, L_Red and L_Rye in summer and autumn, respectively) (Table 13), although season just failed to reach significance (P=0.0574).

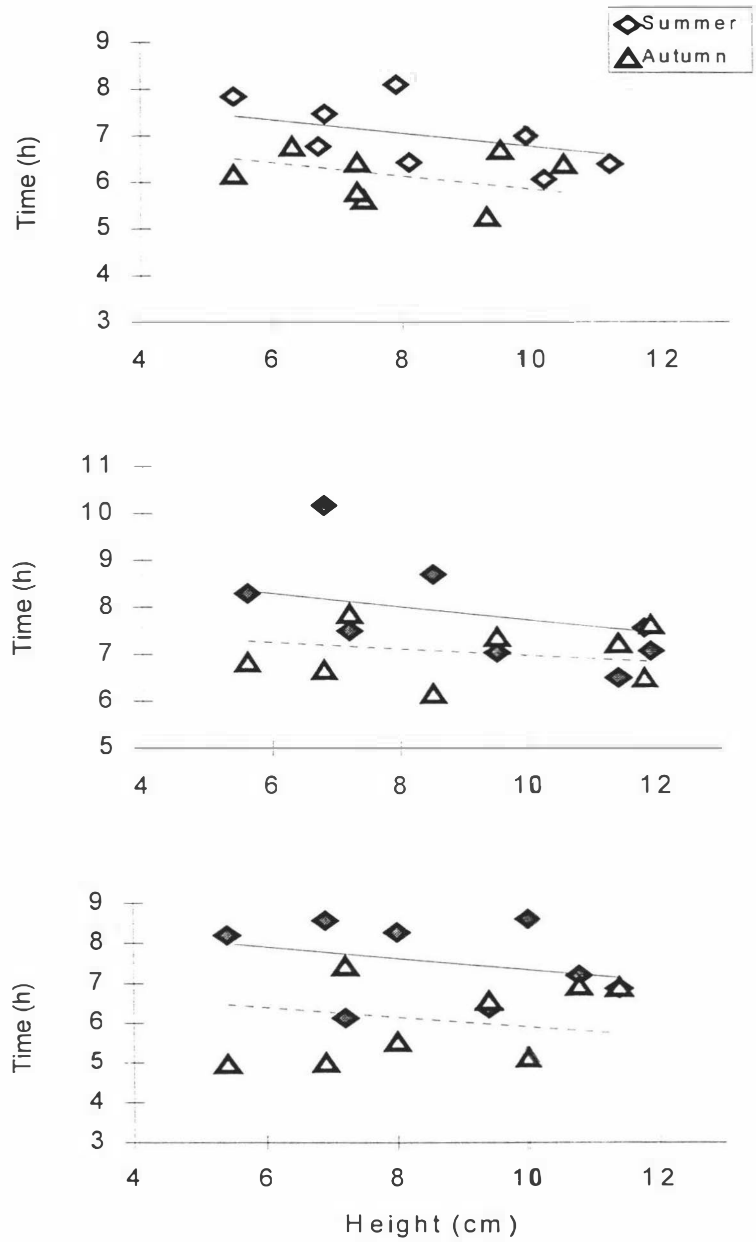


Figure 2. Trends in total grazing time as influenced by height and season. **a**. W_Rye, **b**. L_Rye, and **c**. L_Red species-contrast. Solid line: Summer. Broken line: Autumn.

Table 13. Grazing time on the preferred species (GTp; hours) as affected by height, species-contrast and season.

Species-contrast	Season	Height (cm) of the preferred species. 4	6	8	10	Average
W_Rye[1]	Summer	5.57	5.63	5.43	5.05	5.42
	Autumn	3.50	3.17	3.70	3.68	3.51
	Average	4.53	4.40	4.57	4.37	4.47
L_Rye[2]	Summer	6.70	6.08	6.75	6.37	6.48
	Autumn	3.50	3.90	4.20	4.37	3.99
	Average	5.10	4.99	5.48	5.37	5.23
L_Red[3]	Summer	4.20	4.60	4.28	4.35	4.36
	Autumn	2.28	3.08	3.30	3.80	3.12
	Average	3.24	3.84	3.79	4.08	3.74
	Std. Err.					0.15

Contrast	***
Season	ns
Replicate	ns
Day	***
Height	*
Contrast x Height	*
Contrast x Season	***
Season x Height	***
Contrast x Season x Height	ns

[1], [2], [3] White clover-Ryegrass, Lotus-Ryegrass, Lotus-Red clover, respectively.
*, **, *** P<0.05, P<0.01, P<0.001, respectively.
ns non-significant (P>0.05)

The interactions between species-contrast and season, and season and height (P<0.001) indicated different responses in GTp between species-contrasts. Regression equations were estimated to examine general trends.

With the exception of W_Rye in summer, the other species contrasts showed a positive slope (Table 14) indicating increases in time allocated to grazing the preferred species with increases of height (Figure 3). Replicates within season for W_Rye and L_Red had similar slopes (P>0.05) whereas the replicates within season for L_Rye in autumn were significantly different from one another (P<0.01).

The response to height seemed to be greater in autumn than in summer (Figure 3) as indicated by greater slopes found in the former than in the latter (P<0.01). For L in L_Rye in period 2 in autumn (P<0.001), and L in L_Red in autumn (P<0.01) slopes were significantly different from zero, whereas that for W was not different from zero (P>0.05), indicating that GTp on W tended to be similar for each treatment height.

Table 14. Regression of grazing time on the preferred species (GTp) on actual height.

Contrast	Season	Period	Intercept	(±)		Slope[a]	(±)	
W_Rye	Summer	1 & 2	6.4	0.61	***	-0.11	0.07	ns
	Autumn	1 & 2	2.5	0.56	***	0.13	0.07	ns
L_Rye	Summer	1	5.8	0.60	***	0.03	0.06	ns
		2	6.6	0.50	***			
	Autumn	1	4.1	0.42	***	0.05	0.06	ns
		2	0.9	0.22	***	0.38	0.03	***
L_Red	Summer	1	3.8	0.63	**	0.02	0.06	ns
		2	4.7	0.50	***			
	Autumn	1	1.0	0.37	*	0.28	0.04	**
		2	0.6	0.35	ns			

*, **, *** P<0.05, P<0.01, P<0.001, statistically different from zero.

Ns non-significant (P>0.05).

[a] Blank cells indicate common slope between periods.

4.2.3 Grazing Time on the Less Preferred Species (GTl).

Grazing time on the less preferred species (GTl) differed significantly (P<0.001) among species contrasts, and was highest for Red (3.05 hr), followed by Rye in L_Rye (2.21 hr) and Rye in W_Rye (2.11 hr) (Table 15).

Height of the preferred species significantly (P<0.001) influenced GTl. Likewise, there was evidence for contrast x height, contrast x season, and season x height interactions (P<0.001) resulted because average grazing time on Red was lower in autumn than summer, whereas GTl on Rye in L_Rye and W_Rye was higher in autumn. Rye in L_Rye showed high GTl value on the 6 cm treatment in summer, compared to the other treatment heights within the same species-contrast.

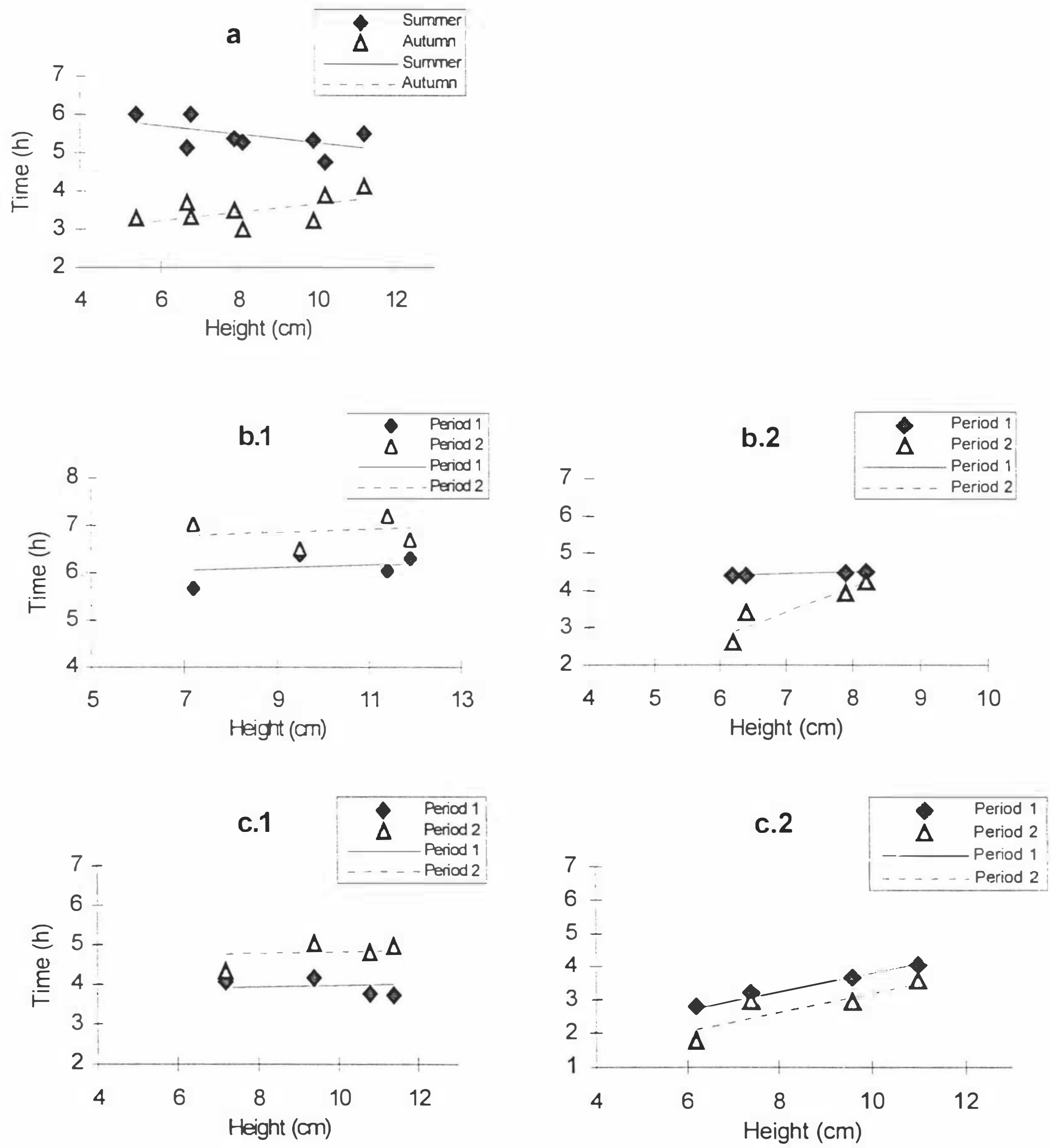


Figure 3. Trends in grazing time on the preferred species as influenced by height. **a**. W_Rye, summer and autumn; **b**. L_Rye, b.1 Summer, Period 1 & 2; b.2, Autumn, Period 1 & 2; **c**. L_Red, c.1 Summer, Period 1 & 2; c2, Autumn, Period 1 & 2.

Table 15. Grazing time on the less preferred species (GTl; hours) as affected by height, contrast and season.

Species-contrast	Season	4	6	8	10	Average
		Height (cm) of the preferred species.				
W_Rye[1]	Summer	1.73	1.33	1.83	1.45	1.59
	Autumn	2.80	3.03	2.57	2.15	2.64
	Average	2.27	2.18	2.20	1.80	2.11
L_Rye[2]	Summer	0.95	2.73	1.13	0.66	1.37
	Autumn	3.62	3.35	2.52	2.68	3.04
	Average	2.28	3.04	1.83	1.68	2.21
L_Red[3]	Summer	2.95	2.87	3.43	3.40	3.16
	Autumn	3.90	2.70	2.93	2.20	2.93
	Average	3.43	2.78	3.18	2.80	3.05
	Std. Err.					0.18

Contrast	***
Season	ns
Replicate	ns
Day	***
Height	***
Contrast x Height	***
Contrast x Season	***
Season x Height	***
Contrast x Season x Height	***

[1], [2], [3] White clover-Ryegrass, Lotus-Ryegrass, Lotus-Red clover, respectively.
*, **, *** P<0.05, P<0.01, P<0.001, respectively.
ns non-significant (P>0.05)

The regression analysis indicated that GTI tended to decrease with increases in height of the preferred species (Figure 4). Furthermore, there was evidence for a common slope but different intercepts (P<0.001); therefore, the common slope was estimated as -0.19 (± 0.05; P<0.001). The corresponding intercepts for each species contrast and season are shown in Table 16.

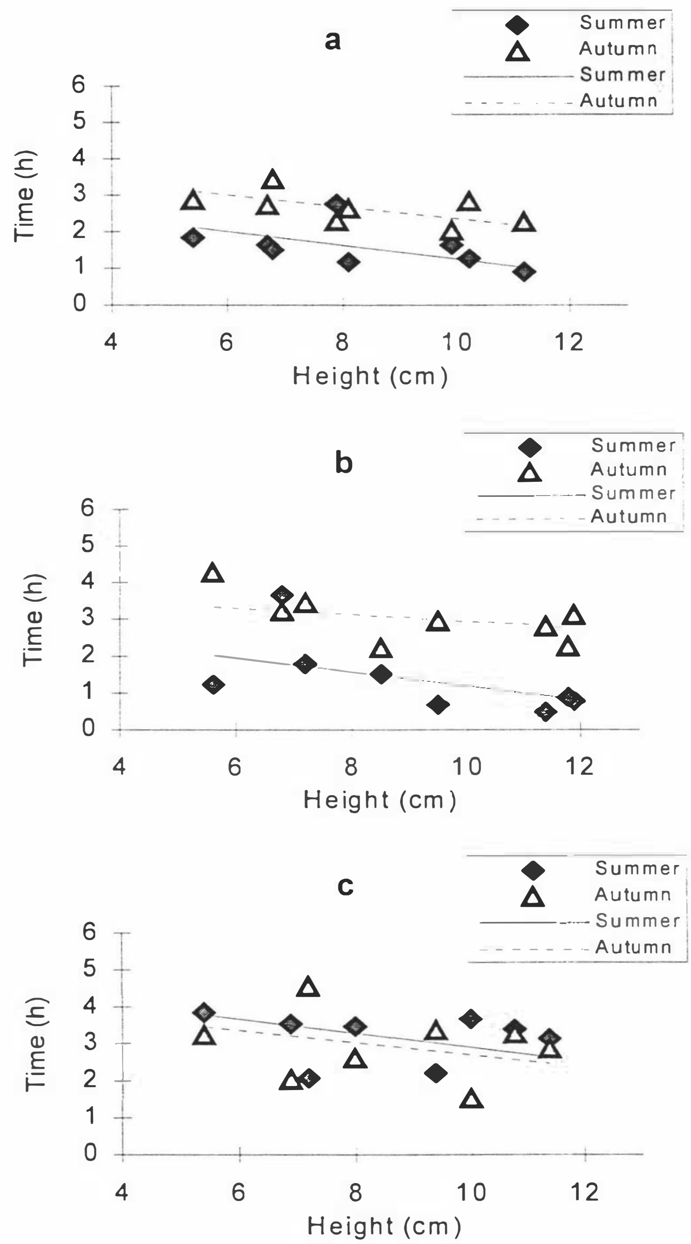


Figure 4. Trends in grazing time on the less preferred species as influenced by height. **a**. W_Rye, **b**. L_Rye, and **c**. L_Red species-contrast.

Table 16. Regression of grazing time on the less preferred (GTl) species on actual height.

Contrast	Season	Intercept	(±)
W_Rye	Summer	3.2	0.48
	Autumn	4.1	0.48
L_Rye	Summer	3.1	0.51
	Autumn	4.4	0.42
L_Red	Summer	4.8	0.49
	Autumn	4.5	0.47

4.2.4 Proportion of GTt allocated to the preferred species.

Overall, the proportion of GTt spent grazing the preferred species was strongly influenced by species-contrast (P<0.001). The animals grazing the legume-grass contrasts showed partial preference for the legume component (70 % for the L in L_Rye and 67 % for W in W_Rye, respectively), whereas those animals grazing the legume-legume contrast showed a weaker preference for Lotus (Table 17) over red clover (55:45 % respectively) although significantly different from 50 % as indicated by the t-statistic (P<0.05).

Partial preference was also influenced by season (P<0.05), where a reduction was observed from summer to autumn (Table 17), although this response was influenced by a contrast x season interaction (P<0.001), with greater differences among species-contrasts in the proportion of GTt spent on the preferred species being noted in autumn than in summer (Figure 5). The t-statistic indicated that, the average proportion of GTt allocated to the preferred species, by species-contrast and by season, were significantly different from neutrality (e.g. 50 %; P<0.05), except for W in autumn which averaged 51.8 % (P>0.05).

Table 17. Proportion of total grazing time (%) spent on the preferred species, as affected by height, species-contrast and season.

Species-contrast	Season	Height (cm) of the preferred species. 4	6	8	10	Average
W_Rye[1]	Summer	76.0	81.5	76.3	77.2	77.8
	Autumn	55.5	51.5	58.5	62.8	57.1
	Average	65.8	66.5	67.4	70.0	67.4
L_Rye[2]	Summer	88.3	70.0	86.2	90.5	83.8
	Autumn	48.0	53.2	63.2	62.0	56.8
	Average	68.2	61.6	74.7	76.3	70.2
L_Red[3]	Summer	59.7	62.3	56.0	56.3	58.6
	Autumn	36.3	53.5	52.8	64.3	51.8
	Average	48.0	57.9	54.4	60.3	55.2
	Std. Err.					2.2

Contrast	***
Season	*
Replicate	ns
Day	***
Height	***
Contrast x Height	**
Contrast x Season	***
Season x Height	***
Contrast x Season x Height	***

[1], [2], [3] White clover-Ryegrass, Lotus-Ryegrass, Lotus-Red clover, respectively.
*, **, *** P<0.05, P<0.01, P<0.001, respectively.
ns non-significant (P>0.05)

The regression equations for the proportion of GTt allocated to grazing the preferred species on actual height indicated a tendency to increase partial preference for the preferred species with increases in height in all cases, except for L in L_Red in summer which had a negative slope, although this slope was not statistically different from zero (P>0.05). The slope for W in W_Rye and L in L_Red in periods 1 and 2, and period 1 of L_Rye all in autumn, were statistically (P<0.05) different from zero (Table 18).

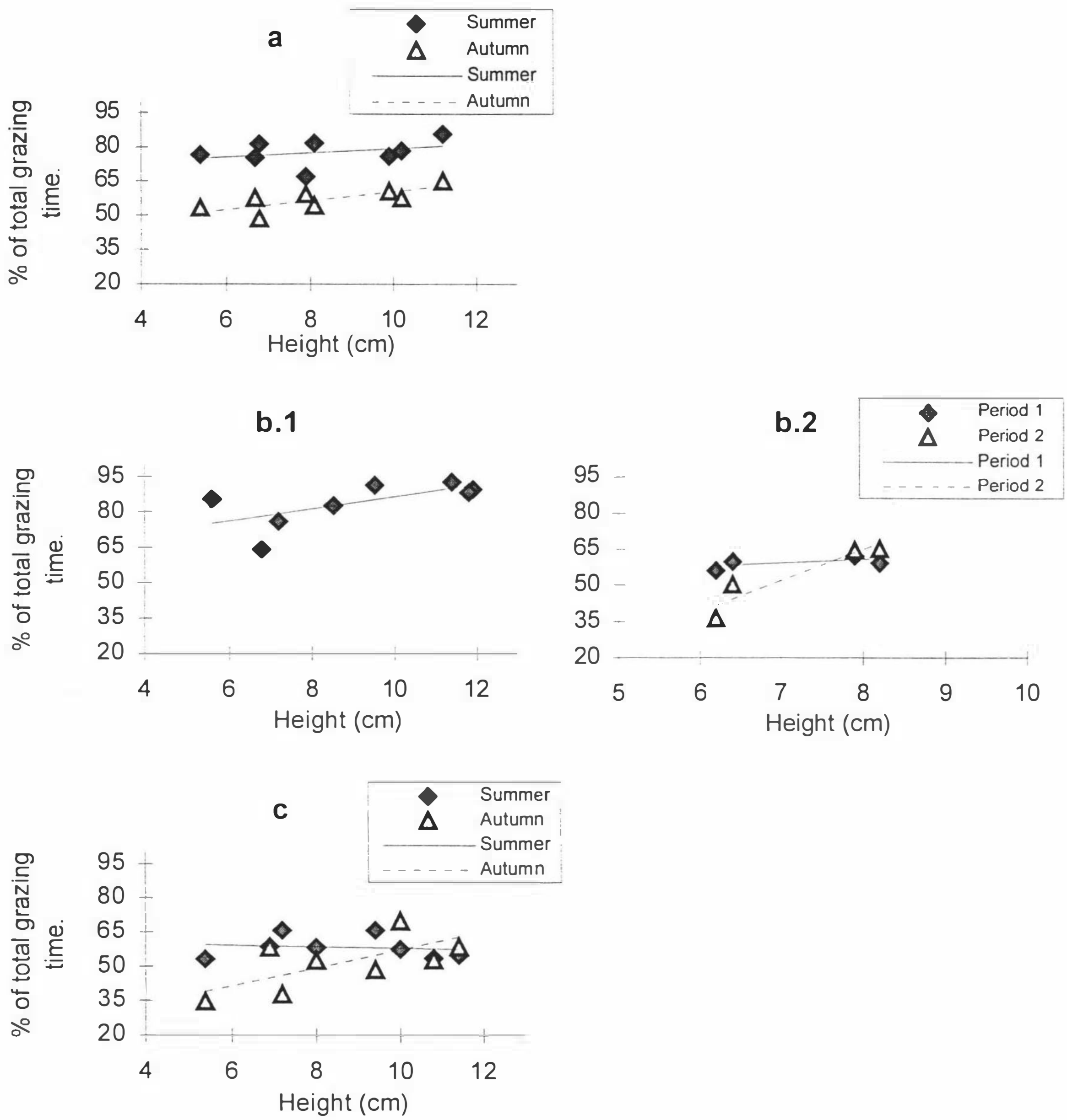


Figure 5. Trends in the proportion of total grazing time allocated to the preferred species as influenced by height. **a**. W_Rye, **b**. L_Rye, b.1 Summer; b.2 Autumn, Period 1 and 2. **c**. L_Red.

Table 18. Regression of proportion of grazing time on the preferred species on actual height.

Species-contrast	Season	Period	Intercept	(±)	Sig.	Slope	(±)	Sig.
W_Rye	Summer	½	69.9	9.1	***	0.94	1.10	ns
	Autumn	½	38.7	5.5	***	2.33	0.69	*
L_Rye	Summer	½	60.5	11.4	**	2.60	1.21	ns
	Autumn	1	48.7	8.23	**	1.50	1.14	ns
		2	4.3	4.40	ns	7.2	0.62	***
L_Red	Summer	1 & 2	61.3	8.60	***	-0.32	0.97	ns
	Autumn	1 & 2	14.1	11.0	ns	4.6	1.3	*

Sig. Significant level for difference from zero *, **, *** P<0.05, P<0.01, P<0.001, respectively.
ns non-significant (P>0.05).

4.3 Rate of biting (BR).

4.3.1 Rate of biting (BR) on the preferred species.

Rate of biting on the preferred species was significantly influenced by species contrast (P<0.001), with the W having the highest value (64.6 bites min^{-1}), followed by L in L_Rye (62.3 bites min^{-1}) and L in L_Red (58.30 bites min^{-1}). The average values for BR by species contrast and height are shown in Table 19. Herbage height influenced the BR (P<0.05), with the BR tending to increase with increases in height of the preferred species in autumn and summer (Table 19). Interactions between height and season (P<0.05), and species-contrast and season (P<0.001) resulted from increased BR for both L contrasts in autumn, but not for W.

Table 19. Rate of biting (bites per min.) on the preferred species, as affected by height, contrast and season.

Species-contrast	Season	Height (cm) of the preferred species. 4	6	8	10	Average
W_Rye[1]	Summer	65.3	65.2	66.4	62.1	64.8
	Autumn	61.8	65.1	67.4	63.4	64.4
	Average	63.5	65.1	66.9	62.7	64.6
	Std. Err.	1.3	1.3	1.3	1.3	
L_Rye[2]	Summer	60.2	55.1	61.0	61.2	59.4
	Autumn	64.1	66.0	64.1	66.7	65.2
	Average	62.2	60.5	62.6	64.0	62.3
	Std. Err.	1.3	1.3	1.3	1.3	
L_Red[3]	Summer	57.3	52.9	57.6	52.5	55.1
	Autumn	57.1	62.2	65.9	61.9	61.9
	Average	57.4	57.5	61.8	57.2	58.5
	Std. Err.	1.3	1.3	1.4	1.3	

Contrast	***
Season	ns
Replicate	ns
Day	***
Height	*
Contrast x Height	ns
Contrast x Season	***
Season x Height	*
Contrast x Season x Height	ns

[1], [2], [3] White clover-Ryegrass, Lotus-Ryegrass, Lotus-Red clover, respectively.
*, **, *** P<0.05, P<0.01, P<0.001, respectively.
ns non-significant (P>0.05)

The regression estimated for BR on the preferred species on actual height indicated a similar trend for the three species-contrasts, with the rate of biting tending to increase slightly with increases in height (slope 0.63 ± 0.26; P<0.05). Different intercepts (P<0.001, Table 20) were observed between species contrasts and season (Figure 6).

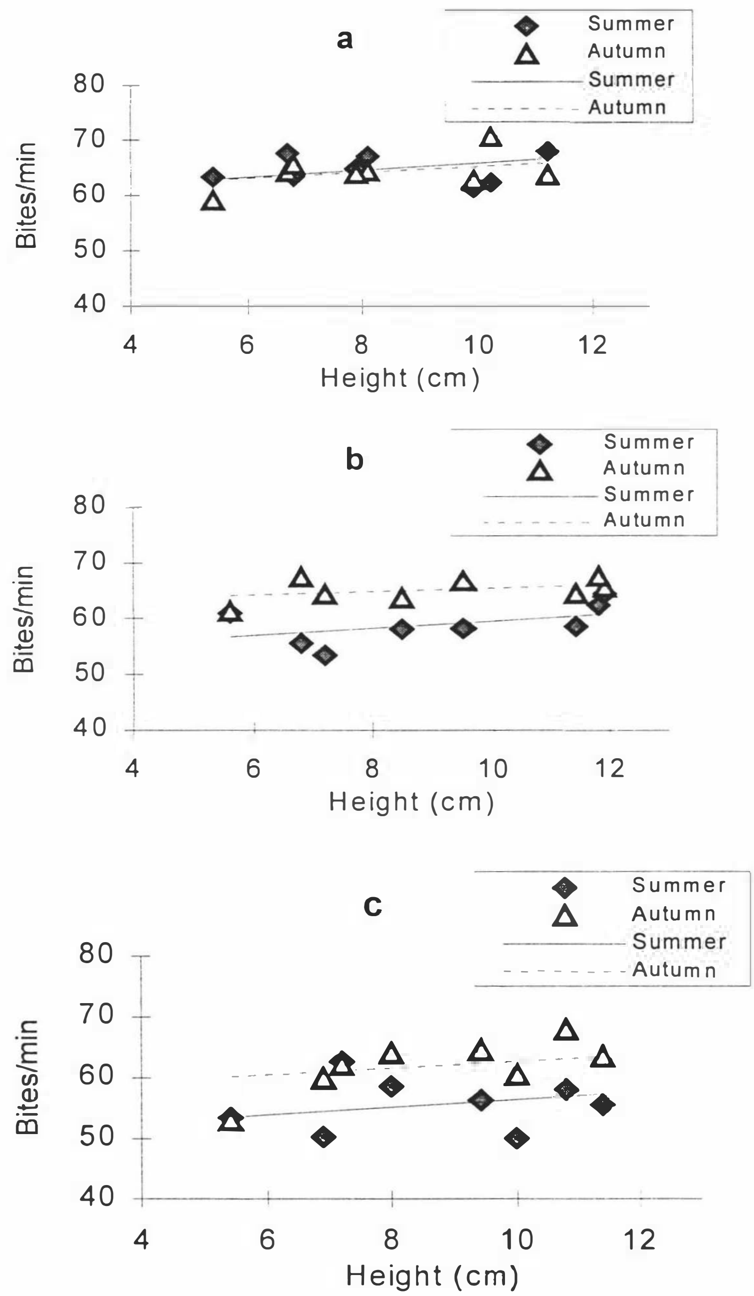


Figure 6. Trends in the rate of biting the preferred species as influenced by height. **a**. W_Rye, **b**. L_Rye, and **c**. L_Red.

Table 20. Intercept for the rate of biting on the preferred species by species contrast and season.

Species-contrast	Season	Intercept	(±)
W_Rye	Summer	59.6	2.4
	Autumn	59.4	2.3
L_Rye	Summer	53.3	2.6
	Autumn	60.8	2.1
L_Red	Summer	50.1	2.5
	Autumn	56.7	2.4

4.3.2 Rate of biting (BR) on the less-preferred species.

There were differences among species-contrasts (P<0.001), with the highest BR recorded on Rye in L_Rye (68.3 bites min^{-1}), followed by Red in L_Red (63.5 bites min^{-1}) and Rye in W_Rye (61.4 bites min^{-1}).

The height of the preferred species did not influence the rate of biting on the less preferred species (P>0.05). A significant interaction between height of the preferred species and species-contrast was observed (P<0.05) due to a different response to height of the preferred species in Red in autumn (Table 21).

The trend observed in the rate of biting with height of the preferred species was different between seasons, increasing with height in autumn and decreasing with height in summer (Figure 7). However, the regression of BR on actual height indicated slopes non significantly different from zero (P>0.05), except for Rye in W_Rye in summer when BR tended to decrease with increases in height of W (P<0.01) (Table 22).

Table 21. Rate of biting (bites per min.) on the less preferred species, as affected by height of the preferred species, contrast and season.

Species-contrast	Season	Height (cm) of the preferred species. 4	6	8	10	Average
W_Rye[1]	Summer	60.8	62.8	55.1	55.5	58.5
	Autumn	63.7	64.2	64.2	65.3	64.3
	Average	62.3	63.5	59.7	60.4	61.4
	Std. Err.	1.4	1.3	1.4	1.3	
L_Rye[2]	Summer	65.1	67.4	68.3	62.5	65.8
	Autumn	68.9	72.2	66.4	75.8	70.8
	Average	67.0	69.8	67.4	69.2	68.3
	Std. Err.	1.3	1.3	1.4	1.5	
L_Red[3]	Summer	67.1	60.0	60.6	62.9	62.8
	Autumn	60.1	61.6	68.3	67.1	64.2
	Average	63.6	60.8	64.4	65.0	63.5
	Std. Err.	1.4	1.4	1.4	1.4	

Contrast	***
Season	ns
Replicate	ns
Day	***
Height	ns
Contrast x Height	*
Contrast x Season	ns
Season x Height	***
Contrast x Season x Height	**

[1], [2], [3] White clover-Ryegrass, Lotus-Ryegrass, Lotus-Red clover, respectively.
*, **, *** P<0.05, P<0.01, P<0.001, respectively.
ns non-significant (P>0.05)

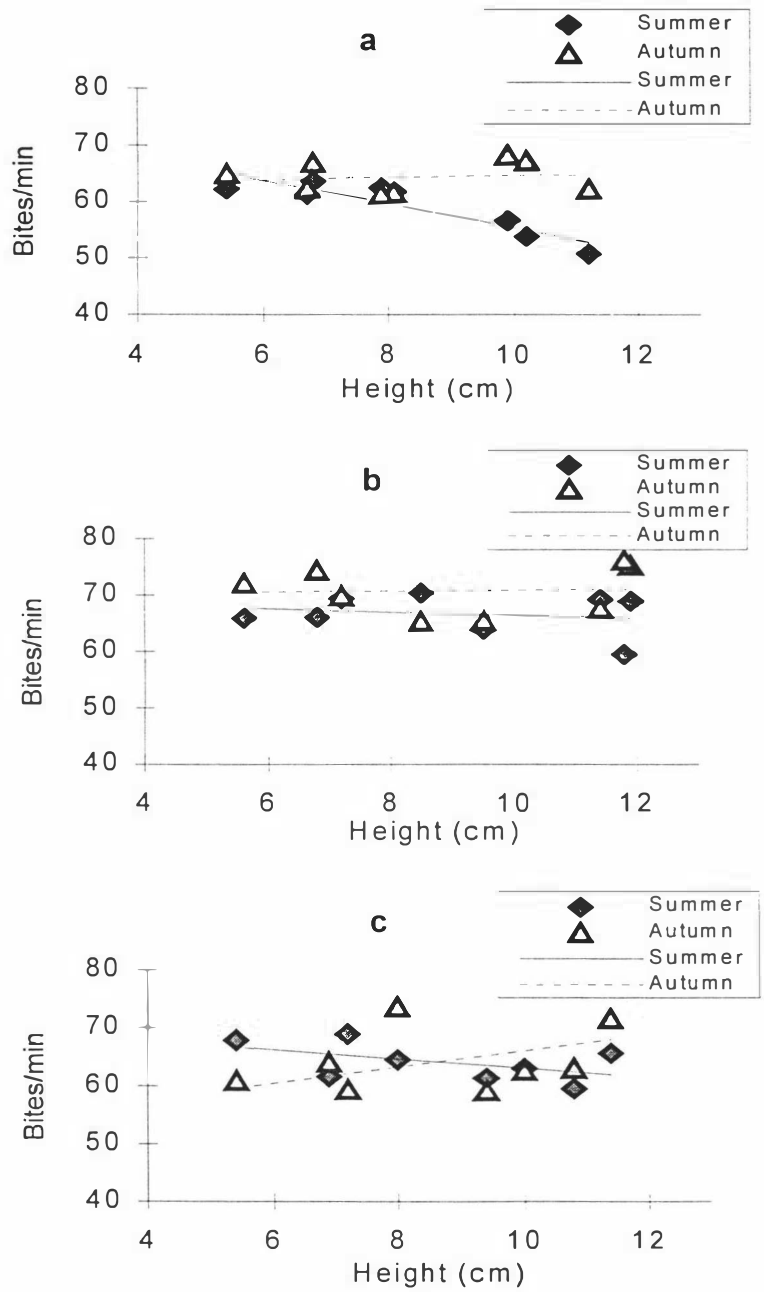


Figure 7. Trends in the rate of biting the less preferred species as influenced by height. **a**. W_Rye, **b**. L_Rye, and **c**. L_Red.

Table 22. Regression of biting rate on the less preferred species on actual height.

Species-contrast	Season	Period	Intercept	(±)	Sig.	Slope	(±)	Sig.
W_Rye	Summer	1 & 2	76.7	3.5	***	-2.13	0.41	**
	Autumn	1 & 2	63.0	5.4	***	0.17	0.67	ns
L_Rye	Summer	1 & 2	69.4	5.6	***	-0.30	0.60	ns
	Autumn	1 & 2	70.0	9.1	***	0.12	1.30	ns
L_Red	Summer	1 & 2	71.0	4.9	***	-0.80	0.56	ns
	Autumn	1 & 2	50.8	7.2	***	1.60	0.85	ns

Sig. Significance level for difference from zero *, **, *** P<0.05. P<0.01, P<0.001, respectively.
ns non-significant (P>0.05).

4.4 Dry matter intake and diet composition.

During the intake and diet composition phases, grazing behaviour parameters were also recorded, but because these observations were made in summer only, it was decided to analyse this data separately from that recorded for periods other than diet composition.

4.4.1 Herbage measurements.

4.4.1.1 Sward surface height (SSH).

The actual heights of the preferred species during the intake phases in summer were higher than planned in the 4 and 6 cm treatments, whereas those for 8 and 10 cm treatment was close to the targeted height, except for W (Table 23).

Table 23. Height (cm) of experimental plots during the intake period.

Contrast	Species	Treatment-height (cm). 4	6	8	10	Average
W_Rye	White clover	6.3	8.2	9.4	10.4	8.6
	Ryegrass*	12.2	13.0	14.0	12.8	13.2
L_Rye	Lotus	6.7	6.4	8.4	10.2	7.9
	Ryegrass*	11.1	10.9	10.7	11.5	11.2
L_Red	Lotus	6.7	8.8	8.3	10.5	8.6
	Red clover*	11.3	10.5	11.9	10.3	11.2
Std Err Preferred species						0.2
Std Err Less preferred species						0.3

* Sward surface height targeted as 10 cm across treatments.

4.4.1.2 Herbage mass.

The analysis of variance carried out for herbage mass of the experimental plots during this phase, indicated significant differences between species-contrasts (P<0.01) and pasture species within contrast (P<0.001), but no differences between treatment heights (P>0.05). W_Rye had the highest herbage mass, followed by L_Rye and L_Red. Among species, Rye in W_Rye had the highest herbage mass, followed by Rye in L_Rye. Both L, Red and W were not significantly different from one another (P>0.05) (Table 24).

Table 24. Total herbage mass (kg DM ha^{-1}) of the preferred and less preferred species, as influenced by height.

Species-contrast	Height (cm) of the preferred species. 4	6	8	10	Average	Less preferred species
W_Rye	1494	1269	1757	1886	1601	3306
L_Rye	1517	1378	1709	1745	1587	2308
L_Red	1733	1919	1274	2363	1822	1879
Std. Err.					258	129

Contrast	**
Species(Contrast)	***
Height (species contrast)	ns
Replicate(season)	***

[1], [2], [3] White clover-Ryegrass, Lotus-Ryegrass, Lotus-Red clover, respectively.
*, **, *** P<0.05, P<0.01, P<0.001, respectively.
ns non-significant (P>0.05)

4.4.1.3 Bulk density (BD).

During this experimental phase, bulk density was not affected by either species contrast or pasture species or treatment height (P>0.05). Values for pasture species by height are shown in Table 25.

Table 25. Bulk density of the sward upper stratum (kg DM cm^{-1} ha^{-1}) of the preferred and less preferred species, as influenced by height.

Species-contrast	Height (cm) of the preferred species. 4	6	8	10	Average	Less preferred species
W_Rye	113	119	116	123	117	125
L_Rye	89	86	125	140	110	114
L_Red	169	99	95	190	138	119
Std. Err.					25	12

Contrast	ns
Species(Contrast)	ns
Height (species contrast)	ns
Replicate(season)	ns

[1], [2], [3] White clover-Ryegrass, Lotus-Ryegrass, Lotus-Red clover, respectively.
*, **, *** P<0.05, P<0.01, P<0.001, respectively.
ns non-significant (P>0.05)

4.4.1.4 Botanical composition of the sward upper stratum.

4.4.1.4.1 Leafiness.

Leafiness percentage was high in the less preferred species and white clover with values over 50 %, whereas those for both L contrasts were below 50 % (Table 26).

Table 26. Leafiness (%) in the sward upper stratum as affected by height.

Species-contrast	Height (cm) of the preferred species. 4	6	8	10	Average	Less preferred species*
W_Rye	91.0	90.1	91.6	90.5	90.8	65.0
L_Rye	34.5	38.4	29.9	38.9	35.4	74.2
L_Red	24.5	32.3	44.0	37.6	34.6	80.7
Std. Err.					8.9	4.5

* Set at 10 cm height across plots; therefore, values were pooled together across plots within contrast.

4.4.1.4.2 Stemminess.

Percentage of stem was high in L with values ranging from 36 to 55.8 %, whereas those for the less preferred species were low, and that for white clover was nil (Table 27).

Table 27. Stemminess (%) in the sward upper stratum as affected by height.

Species-contrast	Height (cm) of the preferred species. 4	6	8	10	Average	Less preferred species*
W_Rye	0.0	0.0	0.0	0.0	0.0	9.6
L_Rye	50.3	46.3	55.8	25.2	44.4	14.2
L_Red	36.0	42.4	46.6	46.4	42.8	3.2
Std. Err.					5.7	2.8

* Set at 10 cm height across plots; therefore, values were pooled together across plots within contrast.

4.4.1.4.3 Dead matter.

Dead matter was at low levels during this phase of the experiment, with values below 20 % in all cases, except for Rye in W_Rye, which reached 22.7 % (Table 28).

Table 28. Dead matter (%) in the sward upper stratum as affected by height.

Species-contrast	Height (cm) of the preferred species. 4	6	8	10	Average	Less preferred species*
W_Rye	7.2	4.0	5.4	4.2	5.2	22.7
L_Rye	13.8	7.4	7.1	2.0	7.6	5.9
L_Red	16.2	18.2	8.1	9.0	12.9	6.9
Std. Err.					5.2	2.6

* Set at 10 cm height across plots; therefore, values were pooled together across plots within contrast.

4.4.1.4.4 Seedheads/flowers.

As can be seen in Table 29, the presence of seedheads or flowers in the experimental plots was lower than 10 % in all cases and nil in some cases.

Table 29. Seedheads/flowers (%) in the sward upper stratum as affected by height.

Species-contrast	Height (cm) of the preferred species. 4	6	8	10	Average	Less preferred species*
W_Rye	1.3	1.2	0.8	1.6	1.2	0.8
L_Rye	0.0	3.2	0.1	2.5	1.5	3.3
L_Red	0.0	0.0	0.0	0.5	0.1	0.8
Std. Err.					1.5	0.7

* Set at 10 cm height across plots; therefore, values were pooled together across plots within contrast.

4.4.1.4.5 Unsown species.

Unsown species were found in low proportions during this experimental phase, with values lower than 10 %, except for that on the 10 cm height for L in L_Rye and 4 cm height for L in L_Red with averages of 31.5 and 23.4 %, respectively (Table 30).

Table 30. Unsown species (%) in the sward upper stratum as affected by height.

Species-contrast	Height (cm) of the preferred species. 4	6	8	10	Average	Less preferred species*
W_Rye	0.7	4.9	2.3	3.8	2.9	1.9
L_Rye	1.5	4.9	7.1	31.5	11.2	2.4
L_Red	23.4	7.2	1.4	6.6	9.6	8.5
Std. Err.					7.2	3.6

* Set at 10 cm height across plots; therefore, values were pooled together across plots within contrast.

4.4.2 Grazing activity.

The grazing behaviour parameters recorded during these experimental phases were included separately from those recorded during periods 1 and 2 in summer, and are described next.

4.4.2.1 Total grazing time (GTt).

The average values for total grazing time, time allocated to grazing the preferred and the less preferred species are shown in Table 31.

The L_Red contrast had the shortest GT (8.97 hr), followed by W_Rye (9.5 hr), and L_Rye (10.69 hr) with the longest, all of them different to one another ($P<0.05$).

There was a significant effect due to replicate ($P<0.01$), due to extremely high GTt registered in the period 2 (average 11.2, 12.3, and 10.6 h for W_Rye, L_Rye and L_Red, respectively) (Table 31).

Height of the preferred species tended ($P=0.0503$) to influence GTt.

Due to the very high grazing times recorded during the intake phase 2, the regression analysis was performed by period to avoid misleading estimates of changes in GT with changes in sward height.

Total grazing time (GT) tended to decrease with increases in height of the preferred species in both Rye contrasts, whereas for L_Red grazing time tended not to change with changes in height of the preferred species (Figure 8). In all cases a common slope was observed between period one and two within species-contrast, but different intercepts for each period (Table 32) due to the high grazing time registered during the period two.

Table 31. Total grazing time, grazing time allocated to the preferred and less preferred species (hr), as influenced by height of the preferred species.

Species-contrast	Species	Height (cm) of the preferred species. 4	6	8	10	Average
W_Rye[1]	W.clover	6.68	6.83	6.55	6.17	6.56
	Ryegrass*	3.07	2.72	2.97	3.05	2.95
	Total	9.72	9.53	9.53	9.23	9.50
L_Rye[2]	Lotus	6.58	6.72	6.40	7.35	6.76
	Ryegrass*	4.05	4.78	4.28	2.62	3.93
	Total	10.67	11.48	10.68	9.95	10.70
L_Red[3]	Lotus	4.60	4.78	4.62	4.45	4.61
	Red clover*	4.25	4.40	4.30	4.47	4.35
	Total	8.87	9.17	8.97	8.90	8.98
Std. Err.		Total Grazing Time				0.30
		Grazing time on Preferred species				0.30
		Grazing time on Less preferred species				0.21

[1], [2], [3] White clover-Ryegrass, Lotus-Ryegrass, Lotus-Red clover, respectively.
* Determined as less preferred species, therefore, set as constant height of 10 cm across plots.

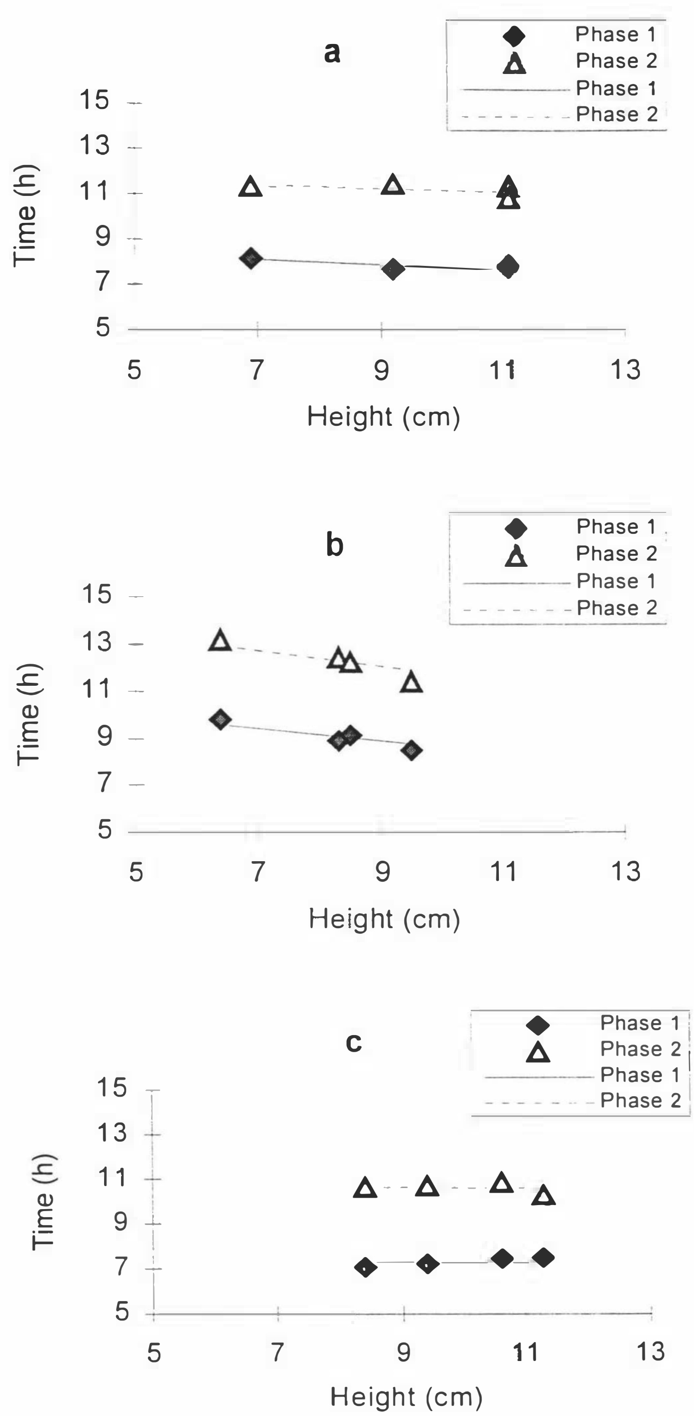


Figure 8. Total grazing time as affected by height. **a**. W_Rye, **b**. L_Rye, **c**. L_Red.

Table 32. Regression of total grazing time on actual height.

Contrast	Period	Intercept	(±)		Slope	(±)	
W_Rye	1	8.84	0.39	***	-0.11	0.04	*
	2	11.99	0.32	***			
L_Rye	1	11.24	0.68	***	-0.26	0.08	*
	2	14.34	0.65	***			
L_Red	1	7.41	0.60	***	-0.01	0.06	ns
	2	10.69	0.45	***			

*, **, *** P<0.05, P<0.01, P<0.001, respectively.
ns non-significantly different from zero (P>0.05).

4.4.2.2 Time spent grazing the preferred species (GTp).

There was a significant effect (P<0.001) for species-contrast, with L in L_Red having the shortest GTp, significantly different from W in W_Rye and L in L_Rye (4.61, 6.56, and 6.76 h, respectively; ± 0.148 std.err) (Table 31). GTp did not differ between treatment heights (P>0.05).

The time spent grazing the preferred species tended to decrease slightly with increases in height in W_Rye and L_Red, whereas it tended to increase for L in L_Rye (Figure 9), although none of the slopes were statistically different from zero (P>0.05; Table 33).

Both W in W_Rye and L in L_Rye showed common slope but different intercepts between periods 1 and 2, whereas L_Red showed a common regression equation for periods 1 and 2 (Table 33).

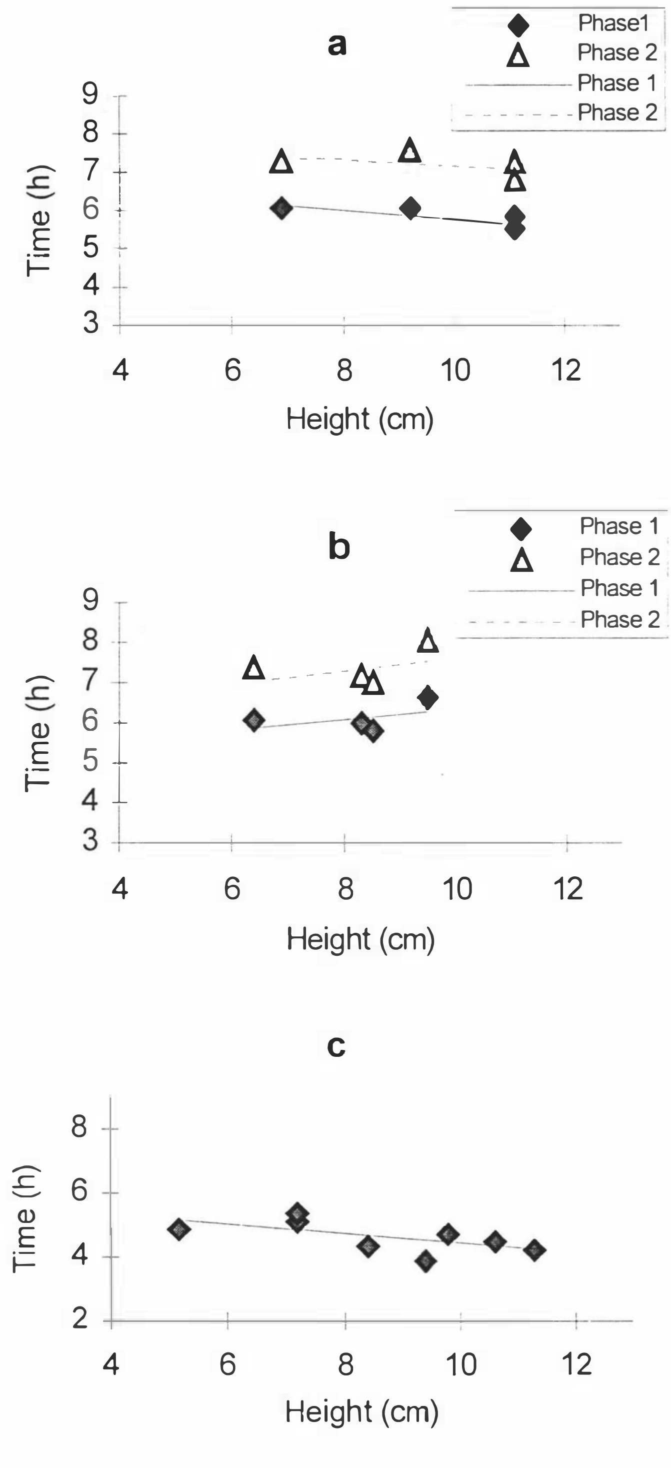


Figure 9. Grazing time on the preferred species as affected by height. **a**. W_Rye, **b**. L_Rye, **c**. L_Red.

Table 33. Regression of grazing time on the preferred species (hr) on actual height.

Species-contrast	Period	Intercept	(±)		Slope	(±)	
W_Rye	1	6.97	0.50	***	-0.12	0.06	ns
	2	8.12	0.41	***			
L_Rye	1	5.04	0.60	***	0.13	0.07	ns
	2	6.37	0.57	***			
L_Red	1 & 2	5.94	0.68	***	-0.15	0.08	ns

*, **, *** P<0.05, P<0.01, P<0.001, respectively.
ns non-significantly different from zero (P>0.05).

4.4.2.3 Time spent grazing the less preferred species (GTI).

GTI was strongly influenced by the species-contrast (P<0.001), being highest for Red, followed by Rye in L_Rye, and Rye in W_Rye (4.35, 3.93, and 2.95 h, respectively, ± 0.105 std err) (Table 31).

Height of the preferred species appeared to influence the allocation of grazing time to the less preferred species (P<0.01). There was evidence for an interaction between height of the preferred species and species-contrast (P<0.001) due to a decline in GTI observed in Rye in L_Rye, but not clearly shown in Rye in W_Rye or Red in L_Red (Table 31).

GTI was not greatly influenced by changes in height of the preferred species, except for Rye in L_Rye where grazing time tended to decrease (P<0.05) with increases in height of the preferred species (Figure 10).

There was evidence for different intercepts between periods within species contrasts, but not for different slopes (P>0.05) indicating common slopes between periods within species contrasts (Table 34).

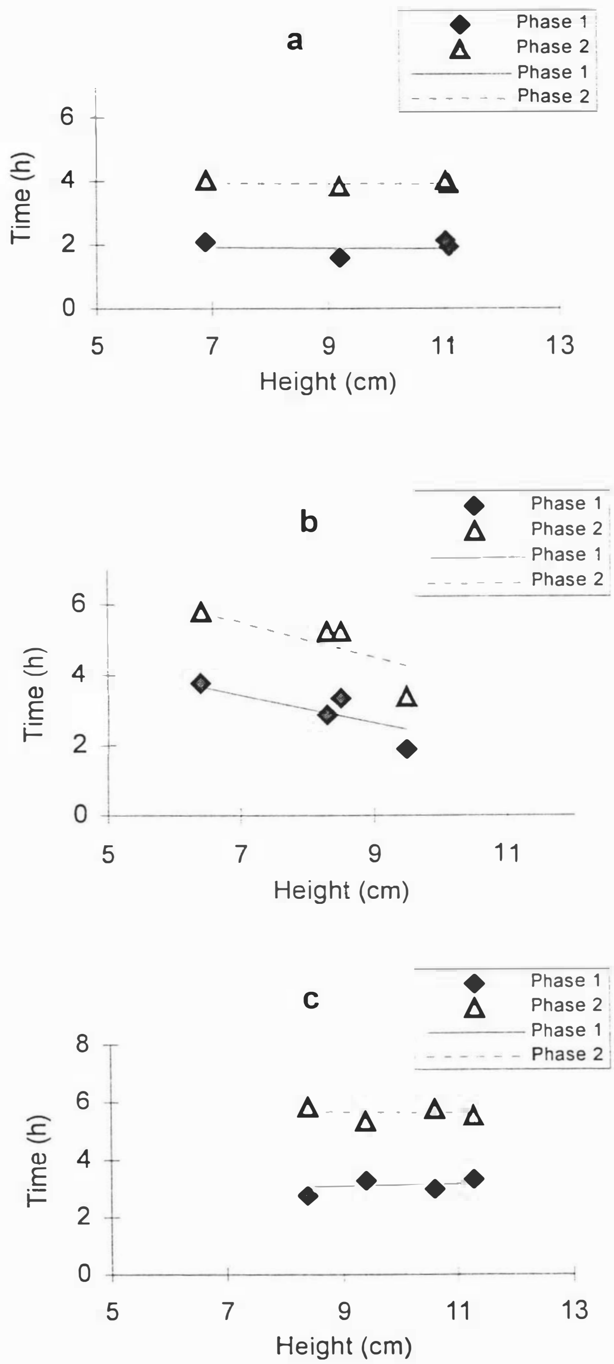


Figure 10. Grazing time on the less preferred species as affected by height. **a.** W_Rye, **b**. L_Rye, **c**. L_Red.

Table 34. Regression of grazing time on the less preferred species on actual height.

Species-contrast	Period	Intercept	(±)		Slope	(±)	
W_Rye	1	1.99	0.44	***	-0.01	0.05	ns
	2	3.99	0.35	***			
L_Rye	1	6.16	0.99	**	-0.39	0.12	*
	2	7.93	0.94	***			
L_Red	1	2.86	0.68	***	0.03	0.07	ns
	2	5.43	0.51	***			

*, **, *** P<0.05, P<0.01, P<0.001, respectively.
ns non-significantly different from zero (P>0.05).

4.4.2.4 Proportion of GT allocated to grazing the preferred species.

Species-contrast highly influenced the proportion of total GT allocated to the preferred species (P<0.001). White clover had the highest proportion of grazing time, followed by L in L_Rye, and L in L_Red, with 69.8, 64.5 and 53.1 %, respectively (Table 35). An interaction between species-contrast and height of the preferred species (P<0.001) indicated that among species-contrasts, animals responded differently to the decrease in herbage availability. In general, animals showed partial preference for the legume over the grass component of the legume-grass species contrast with statistical difference from neutrality (e.g. 50 %), as indicated by the t-statistic (P<0.05), whereas preference in the legume-legume species-contrast was no statistically different from neutrality (P>0.05).

Table 35. Grazing time on the preferred species expressed as a proportion (%) of total grazing time.

Species-Contrast	Species	Height (cm) of the preferred species. 4	6	8	10	Average
W_Rye[1]	W.clover	69.2	72.7	69.5	67.8	69.8
L_Rye[2]	Lotus	62.7	59.3	60.8	75.0	64.5
L_Red[3]	Lotus	54.3	54.2	52.5	51.3	53.1
Std. Err.						2.0

[1], [2], [3] White clover-Ryegrass, Lotus-Ryegrass, Lotus-Red clover, respectively.
* Determined as less preferred species, therefore, set as constant height of 10 cm across plots.

The regression of the proportion of GTt allocated to grazing the preferred species indicated that the animals were not greatly influenced by changes in height of the preferred species. The animals tended to keep similar proportion of grazing time allocated to the preferred species across heights, with exception of the L_Rye contrasts where there was a trend to increase the proportion of grazing time allocated to the preferred species with increasing heights (Figure 11). Also, there was evidence for different intercepts between periods within species contrasts in the case of W in W_Rye and L in L_Red but not for L in L_Rye. In all cases there was evidence for common slopes between periods within species-contrast (Table 36).

Table 36. Regression of the proportion of total grazing time spent grazing the preferred species on actual height.

Species-contrast	Period	Intercept	(±)		Slope	(±)	
W_Rye	1	78.1	5.3	***	-0.3	0.54	ns
	2	66.6	4.3	***			
L_Rye	1 & 2	39.9	9.3	**	3.1	1.14	*
L_Red	1	62.1	7.4	***	-0.4	0.73	ns
	2	51.5	5.6	***			

*, **, *** P<0.05, P<0.01, P<0.001, respectively.
ns non-significantly different from zero (P>0.05).
Blank cells have same value as previous.

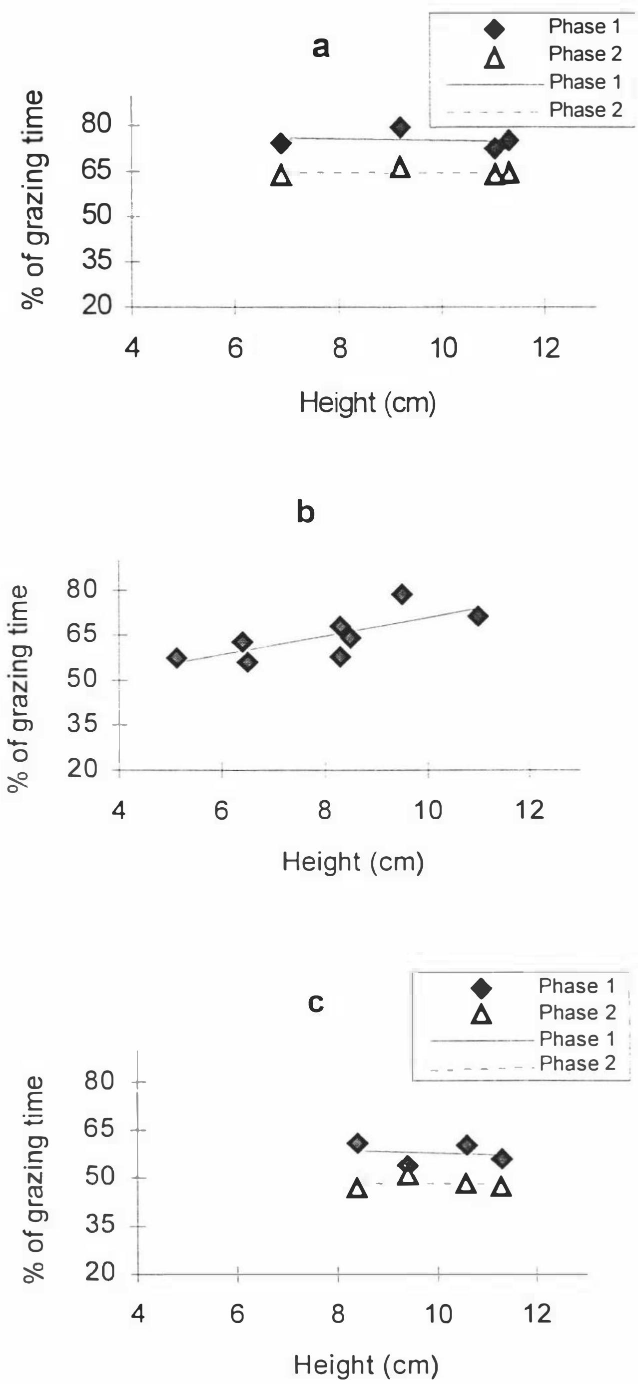


Figure 11. Proportion of grazing time on the preferred species as affected by height. **a**. W_Rye, **b**. L_Rye, **c**. L_Red.

4.4.3 Rate of biting (BR).

4.4.3.1.1 BR on the preferred species.

BR on the preferred species was influenced by species-contrast (P<0.001), but not by height (P>0.05). W had the highest BR (68.5 bites min^{-1}, ± 1.0 S.E.), followed by L in both contrasts (61.0 ± 1.1; and 60.7 ± 1.0, for L_Red and L_Rye, respectively). The regression of BR on actual height did not detect any relationship between these two parameters as indicated by non significant slopes (P>0.05) from each of the species-contrasts. There was evidence for different intercepts (P<0.05), but not for different slopes (P>0.05) among species-contrasts. The common slope indicated a similar response in the rate of biting the preferred species (slope -0.24 ± 0.37 (ns)), to changes in height within the range of this experiment (Figure 12).
The intercepts were 70.1 (± 3.4), 65.6 (± 3.2), and 64.4 (± 3.4) for W_Rye, L_Rye and L_Red, respectively.

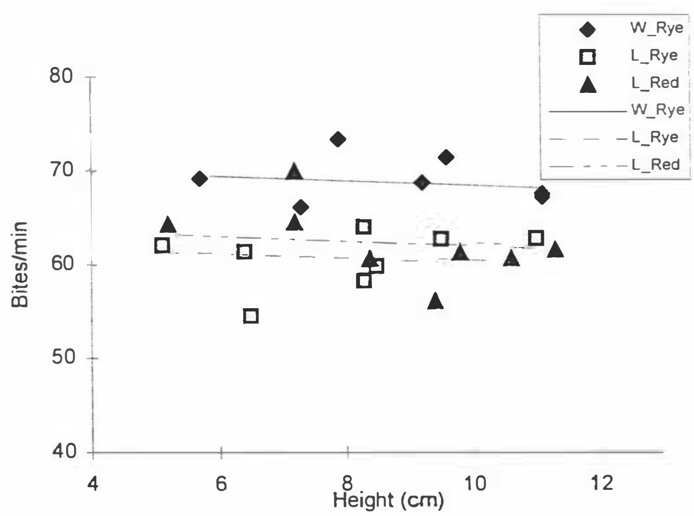


Figure 12. Rate of biting on the preferred species as affected by height.

4.4.3.1.2 BR on the less preferred species.

The BR on the less preferred species was influenced by species-contrast ($P<0.05$) but not by height ($P>0.05$). Rye in L_Rye had the highest BR (70.5 ± 1.1 S.E.), followed by Red (66.7 ± 1.1 S.E.) and Rye in W_Rye (66.1 ± 1.1 S.E.).

Similarly, the regression analysis did not detect any influence of height on BR on the less preferred species ($P>0.05$). There was no difference ($P>0.05$) between periods within species contrasts in either slope or intercept, nor was there between species contrast; this allowed the estimation of a single equation as

$Y = 70.1\ (\pm\ 3.42;\ P<0.001) - 0.25\ (\pm\ 0.4;\ P>0.05)$

with slope not statistically different from zero (Figure 13).

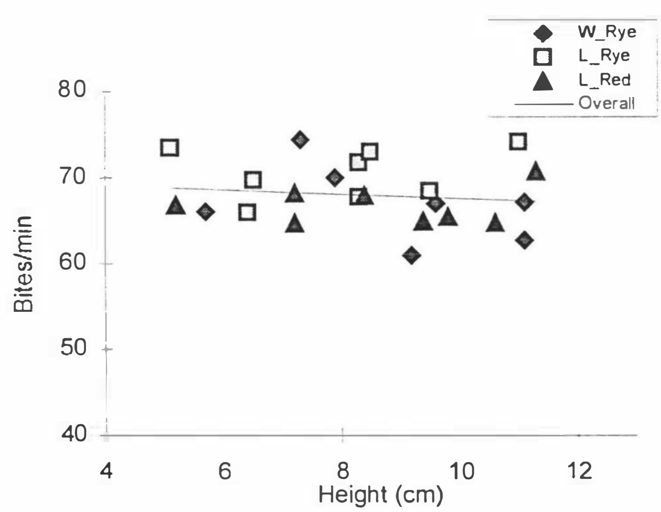


Figure 13. Rate of biting on the less preferred species as affected by height.

4.4.4 Dry matter intake and diet composition.

Dry matter intake estimated from dosed alkanes proved to be unreliable (see discussion), so data are shown only for estimates of diet composition derived from natural alkanes. Diet composition was estimated in summer only; therefore, there was no assessment of seasonal variation.

The estimated averages for the preferred species in the diet selected by experimental animals from treatments 10 and 4 cm on each species contrast are shown in Table 37.

There were significant effects due to contrast ($P<0.001$) and sward surface height ($P<0.01$). Legumes W and L contributed 81.5 and 84.4 % respectively to the diet, significantly ($P<0.001$) higher than the proportion of L in L_Red contrast, with an average of 49.8 %.

Overall, there was a trend to increase the proportion of the preferred component in the diet as sward surface height increased, although this difference was significant for L_Red only ($P<0.01$), largely because of a low estimate for the 4 cm height during intake phase 2.

Table 37. Proportion (%) of the preferred species in the diet selected by experimental animals on treatments 4 and 10 cm during intake phases 1 and 2.

Species-contrast	Period	n	Treatment height (cm)* 4	10	Average
W_Rye	1	3 & 3	82.0	85.7	83.9
	2	3 & 3	76.1	82.2	79.2
	Average		79.1^{a}	83.9^{a}	81.5
L_Rye	1	2 & 2	78.6	87.9	83.3
	2	3 & 3	83.2	88.0	85.6
	Average		80.9^{a}	87.9^{a}	84.4
L_Red	1	2 & 2	53.2	57.1	55.1
	2	2 & 2	27.2	61.6	44.4
	Average		40.2^{b}	59.3^{c}	49.8

* Different superscript within row/column differ $P<0.01$.

4.4.4.1 Relationship between diet composition estimated through alkanes and partial preferences derived from distribution of grazing time.

Estimates for the proportion of the preferred species in the diet consumed, obtained through alkanes, were regressed on the proportion of GTt spent on the preferred species. Individual regressions for each species-contrast gave a significant ($P<0.05$) equation for W_Rye ($Y = 33.7 + 0.7$ b) but equations for both L contrasts were non-significant ($P>0.05$). The comparison of individual regressions indicated a difference between intercepts ($P<0.001$), but not between slopes ($P>0.05$), suggesting a common slope (0.56 ± 0.26), significantly different from zero ($P<0.05$). The intercepts are shown in Table 38, and illustrations are presented in Figure 14.

Table 38. Intercepts for the regression of the proportion in the diet, of the preferred species on the proportion of grazing time spent in the preferred species, by contrast.

Species-contrast	Intercept	(±)	Sig.
W_Rye	43.1	17.7	*
L_Rye	47.7	17.5	*
L_Red	20.7	13.7	ns

Sig. Significance from zero *, **, ***, as P<0.05, P<0.01, P<0.001, respectively. ns non-significantly different from zero, P>0.05

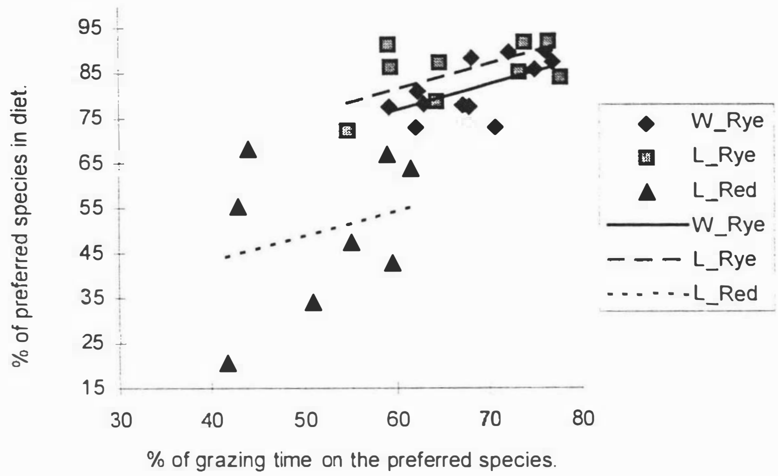


Figure 14. Relationship between proportion of grazing time allocated to the preferred species and the proportion of the preferred species in the diet consumed.

5. Discussion.

There were two main objectives of this work, one regarding the use of paired monocultures to study partial preference, and the second to investigate the effect of relative availability, imposed as differences in sward herbage height, on partial preferences of dairy heifers. A discussion on experimental procedures precedes the discussion on the results.
A final discussion integrates the main points of this work.

5.1 Evaluation of procedures.

5.1.1 Monocultures of pasture species.

The use of monocultures of pasture species in diet selection and grazing preferences of dairy cattle allows the control of factors likely to influence the animals behavioural responses to grazing conditions. This makes testing of preferences more reliable by avoiding the inter-species competition and its effect on species-balance, and by making selection easier (Parsons et al, 1994a), through making searching to locate either of the species on offer unnecessary (Newman et al, 1995a). However, the present work lacked spatial replication due to limited space. Instead, replications in time were used.

5.1.2 Sward herbage height.

The 2 cm intervals between successive height-treatments sought in this experiment was difficult to attain, especially a sward surface height of 4 cm (Table 1, see Appendix 2 for details). Thus, the use of nominal height treatments of 4, 6, 8 and 10 cm did not allow a good approach to accurately describe, through the analysis of variance, the behaviour of the data collected. Regression analyses gave more detailed description of the data since these took account of actual heights.

5.1.3 Observations of grazing behaviour as a measure of preference.

Recording of grazing behaviour was restricted to daylight hours only, therefore the times devoted to grazing may not entirely reflect the grazing activity during a 24 hour period. However, grazing occurs mainly during daylight (Hancock, 1950; Pearson-Hughes and Reid, 1951), with dairy cows allocating up to 85 % of the total grazing time during daylight, distributed in two main grazing bouts (Dulphy et al, 1980).

Increases in night grazing may occur when daylight is not enough to allow animals to meet intake requirements (Hancock, 1950) or when temperatures are beyond thermal neutrality which is influenced by relative humidity (Huber, 1996). Thus, grazing time may not be greatly correlated with temperature within the range between 0° and 34°C, provided the relative humidity is low (Seath and Miller, 1946). Furthermore, an animal rarely spends more than 8-9 hours/day grazing, because this would otherwise interfere with rumination and other behavioural requirements (Hodgson, 1990). However, reports with grazing times of up to 12-14.5 hours in a single day exist (Arnold, 1981). In the present work, the highest grazing times (up to 13.7 h on day 2 in L_Rye, 6 cm treatment-height) were recorded during the second intake-phase in summer. However, GTt recorded for the rest of the experiment was rarely over 9 h per day, similar to the values given as normal grazing activity (Hodgson, 1990).

Continuous observations in behaviour studies are likely to be more accurate than the interval technique, but are more difficult to carry out without automatic equipment (Hodgson, 1982b). This is particularly true for minor behaviour patterns like drinking water and eating concentrates, but less so for major behavioural patters, and in particular, grazing time (Gary et al, 1970). There was no significant difference between continuous recording and point estimates at up to 30-minute intervals (Hull et al, 1960). Thus the 10-minute interval method adopted for this experiment was considered a sufficiently reliable measure of grazing activity.

In addition, whether animals graze during daylight or at night, does not influence diet selection in terms of quality of the herbage eaten (Fernandez-Rivera et al, 1996). Hence, observations during daylight are considered good indicators of grazing behaviour in terms of dietary preferences for the purposes of this experiment.

5.1.4 Dry matter intake and diet composition.

Dry matter intake estimates from dosed alkanes were unreliable, although no conclusive explanation for this could be drawn from the data. However, two observations regarding the use of alkanes in this work point to the dosed alkanes as possible source of error. Dry matter estimation requires both an external marker, an even-chain alkane, and an internal marker, an odd-chain alkane (Mayes et al, 1986), whereas diet composition estimation requires only internal markers, odd-chain alkanes (Dove and Mayes, 1991; 1996; Dove and Moore, 1995; Newman et al, 1995b). Diet composition estimation showed values linearly related to those from the distribution of GTt between the preferred and less preferred species. On the other hand, estimation of dry matter intake rendered, on average, values of 198 % greater than those expected for animals with bodyweight of around 250 kg (NRC, 1978) used in this experiment. Furthermore, this bias in intake estimations was different between periods 1 (136 % over predictions NRC, 1978) and 2 (252 % over predictions NRC, 1978). This difference in reliability of estimates between dry matter intake and diet composition estimates, points to the dosed alkanes as the possible source of error for unreliable estimates of intake. Faulty CRDs could have led to wrong estimates. Unfortunately no test was undertaken for verification of release rate stipulated by the supplier because of time limitations. The plots did not have the carrying capacity to maintain the animals for longer than two weeks without depleting the food resources to a point where intake was compromised, therefore, it was considered not feasible to test release rate.

The diet composition estimated from the concentration of natural alkanes in the herbage and faeces, indicated that the preferred species in the legume-grass species-contrasts had a greater proportion in the diet than that estimated from the proportion of GTt allocated to the preferred species. This suggests that animals had higher rates of intake on the legume component than on the grass, in agreement with the higher BD in the former than in the latter. Animals in the 4 cm treatment of the L_Red species-contrast showed a very low proportion of the preferred species in the diet consumed during the intake phase 2 (Table 37). This may have caused by the lower leafiness and greater proportion of stem in L in intake phase 1 compared to phase 2, whereas Red changed less (see appendix 3.B.3 for details).

It is interesting to note that there was a difference between the distribution of grazing time and the diet composition estimated from the herbage and faecal alkanes. The trend observed in both GTp and the proportion of GTt allocated to the preferred species during the intake phases of the experiment pointed to a decrease in these parameters with increases in height for both W_Rye and L_Red (see Figure 9 and Figure 11). Conversely, the diet composition estimates from alkanes indicated an increase in the proportion of the preferred species in the diet consumed with increases in height (Table 37). The BR was not influenced by differences in height, and thus, it may be that the animals grazing taller swards had been biting deeper into the sward profile with consequent larger bites, a higher rate of intake, and proportion of the preferred species in the diet.

On the other hand, it was interesting to find a common relationship between the time spent grazing the preferred species and the proportion of this in the diet consumed ($r=0.74$, $P<0.01$). This indicates that the diet composition can be estimated to some extent through the distribution of grazing time between the preferred and the less preferred species. However, it must be borne in mind that both techniques, the proportion of GTt between species and the alkane technique applied for both diet composition and dry matter intake, are complementary to one another for analysing grazing preferences and selection in detail.

5.2 Sward characteristics.

5.2.1 Physical characteristics.

Both total herbage mass (kg DM ha^{-1}) and BD (kg DM ha^{-1} cm^{-1}) differed between pasture species. The less preferred species, particularly Rye, had greater total herbage mass, but lower BD in the upper stratum than the other species. Rye in W_Rye had more herbage mass than Rye in L_Rye (Table 2) but there was no difference in BD of the upper stratum (Table 3).

Total herbage mass and BD were greater in summer than in autumn for all pasture species, except for Rye in L_Rye contrast, which had lower herbage mass in summer than in autumn. The changes in herbage mass and BD were not related to differences in height since this was similar between seasons (see Appendix 2 for details).

Total herbage mass declined with decreasing height (Table 2), but BD was not significantly influenced by height (Table 3). The absence of a trend in BD with sward height made it easier to consider responses in grazing activity in relation to height effects within season. However, both herbage mass and BD were lower in autumn than summer in which case comparisons between seasons may be confounded by differences between these two sward characteristics.

The botanical composition of the upper stratum differed between herbage species. White clover was leafy, with little stemminess, followed by Rye and then Red. Lotus was the least leafy and most stemmy among the herbage species (see Table 4 and Table 5).

White clover had less dead matter than the other species (Table 6). Also, W along with Rye appeared as the purest plots with the lowest values for unsown species. In contrast L and Red had the highest proportion of unsown species (Table 8).

Botanical composition of the upper stratum changed with season. In general, leafiness (Table 4) was lower in summer than in autumn, except for L and Red, both in the L_Red contrast. Stemminess (Table 5), dead matter (Table 6), and seedheads/flowers (Table 7) were greater in summer than in autumn. In turn, unsown species were greater in W in summer than in autumn, unlike both L contrasts and Red which had lower proportion of unsown species in summer than in autumn. Both Rye contrasts had a low and constant proportion of unsown species (Table 8).

In general, leafiness tended to decrease with increases in height, except for W where leafiness appeared more consistent across height treatments. In contrast, dead matter tended to decrease with increases in height (Table 6).

5.2.2 Chemical characteristics.

The quality of herbage can help to explain animal responses in preferences (Arnold et al, 1966) and particularly in the case of this experiment, preference responses to changes in height of the herbage. Herbage quality, in terms of chemical composition, was estimated for pluck samples analysed by NIRS procedures (Shenk and Westerhaus, 1994). Determinations, expressed as percentage of the dry matter of herbage, included crude protein, carbohydrates, lipids, ash, and fibre components (ADF and NDF). From these, metabolisable energy (MJ kg^{-1} DM) and digestibility were estimated.

Herbage quality, in terms of chemical composition, differed among herbage species, particularly protein, carbohydrates, fibre components and digestibility, although all species showed digestibility values above 70 % (see section 4.1.5).

Herbage quality of the preferred species improved from summer to autumn, as indicated by increases in digestibility, protein and lipid content and decreases in fibre components, although quality for W did not change significantly (Table 9). In contrast for the less preferred species, fibre components increased as well as protein and lipid, leading to a weak decrease in digestibility from summer to autumn (Table 10).

Height had no influence on herbage quality of either the preferred or less preferred species (see section 4.1.5), except for lipid content which did not influence digestibility. This was an important observation because it allowed similar chemical composition among height treatments within species. Thus, there were no confounding effects between sward herbage height and chemical composition of the herbage, which would affect interpretation of grazing observation data.

5.3 Rate of biting (BR).

The rate of biting differed among the species for both the preferred (Table 19) and the less preferred (Table 21) species. Of the preferred, W had the highest BR, followed by L in L_Rye and lowest L in L_Red (64.5 > 62.3 > 58.5 bites min^{-1} respectively; P<0.05), whereas for the less preferred species, Rye in L_Rye had the highest BR, followed by Red and then Rye in W_Rye (68.3 > 63.5 > 61.4 bites min^{-1} respectively; P<0.05). The differences in BR observed between W and L in both contrasts may be due to ease of prehension (Allden and Whittaker, 1970; Kenney and Black, 1984a,b; Colebrook et al, 1987) due to morphological differences between these species making gathering of leafy material from L more difficult than from W for big mouths like those of cattle (Gordon and Illius, 1988). The difference in BR among the less preferred species is less obvious since the two Rye were placed at the extreme points with Red intermediate between the two. Different maturity stages between the two Rye could explain the different BR found, however, these two Rye swards appeared similar in botanical composition (see section 4.1.4). Another reason for this difference in BR between the two Rye swards may be differences in satiation level between groups of animals which influences the BR (Jung and Koong, 1985; Newman et al, 1994b). This may also explain different BRs observed between the two L contrasts of which L in L_Rye had higher BR than L in L_Red.

The BR on both the preferred and less preferred species was greater in autumn than in summer in all cases except for W, although season was not significant (see Table 19 and Table 21). This may have been caused by a smaller bite size in autumn compared with summer, as Penning et al (1991) have reported for sheep. Decreases in BD, as occurred from summer to autumn in this work (Table 3), are related to smaller bites which in turn induce increases in the BR as a compensation for the reduction in the number of manipulative jaw movements required for small bites (Hodgson, 1985).

White clover increased leafiness from summer to autumn, which may have partly compensated for by its lower BD in autumn compared with summer. Since the BR was maintained by cattle grazing this species across seasons, different grazing strategy to increasing BR must have been used to avoid penalty in the rate of intake (Newman et al, 1994a). In this regard, cattle use the tongue to gather herbage beyond the area encompassed by the open mouth and thus increase bite area (Illius and Gordon, 1987; Laca et al, 1993). Furthermore, if it is considered that bite area might be limited by the forces required to harvest a bite (Burlison et al, 1991) and that W was leafy and soft, cattle in these plot may have increased the bite area to compensate for low BD by sweeping the tongue in an attempt to maintain bite size and rate of intake. This also may apply to the increased BR observed during the intake phases compared to observations made in summer (see summer values in Table 19 and Table 21, and section 4.4.3 for details). There was an increase in leafiness, particularly for the less preferred species from the first to the second week of grazing (see summer values in Table 4 and Table 26 for comparison). Leaves require less force to fracture than pseudostems (Wright and Illius, 1995) which may allow larger bites and/or faster BR when grazing leafy swards as observed in this experiment.

The same principle of fracture properties between plant structures (Wright and Illius, 1995) may apply to account for the explanation for the trend in BR on the preferred species to increase with increases in height (Figure 6), although this was not expected since the literature indicates a negative relationship between BR and SSH (Olson et al, 1989; Newman et al, 1994a). In contrast, height of the preferred species did not exert a significant effect on the BR of the less preferred species. However, interactions between contrast and height, and season and height were observed (see section 4.3.2). BR tended to decrease in summer and increase in autumn with increases in height of the preferred species. The slopes computed were not statistically different from zero, except for that of Rye in W_Rye in summer (Table 22). This relationship is not clear enough since it may be assumed that the BR on one species be independent of the height of another species when these two are spatially separated, however the BR on the less preferred species differed depending on the companion species. An alternative explanation to this observation must then be sought. The higher total herbage mass (1993 vs. 1667 kg DM ha^{-1}), and particularly the higher BD (138 vs. 88 kg DM ha^{-1} cm^{-1}) in summer compared to autumn, may have allowed larger bites, conducive to greater rate of intake in summer than in autumn. The higher rate of intake is conducive to a faster satiety (Jung and Koong, 1985; Newman et al, 1994b). Consequently, the animals may have reached satiety levels earlier in the day in summer than in autumn, hence decreasing BR on the less preferred species with increases in height of the preferred species in summer due to the more favourable sward conditions in terms of herbage availability. Conversely, BR on the less preferred species tended to increase with increases in height of the preferred species in autumn because more effort was required to consume enough herbage to reach satiation.

5.4 Species-contrast effects on preferences.

Partial preference, expressed as the proportion of GTt allocated to the preferred species, differed among species-contrasts (Table 17). The animals in the two legume-grass contrasts showed strong partial preference for the legume component (e.g. W and L). On average, animals in the legume-grass contrasts spent 67 and 70 % of GTt grazing the W and L respectively. In this measure of preference, these contrasts were both significantly ($P<0.01$) different from the 55 % of GTt grazing L in the L_Red species-contrast. When averaged across seasons, partial preference was significantly different from indifference ($P<0.05$) in all three cases. Indifference is defined as the case where animals eat whatever is in front of them, giving equal proportions of grazing time to that of the availability of each of the species on offer (Parsons et al, 1994b).

The partial preference for legumes observed in the 10 cm treatment-height for both legume-grass contrasts in this experiment, particularly those from summer, are higher than the observations by Cosgrove et al (1996) for cattle, and Penning et al (1995b) for sheep, both works comparing ryegrass vs. white clover at similar vertical availability for both herbage species in the choice offered. The lower BD for the ryegrass in the present work compared to that observed by Cosgrove et al (1996) may provide the reason for the stronger preferences for legume reported in this experiment. The partial preference observed for the L_Red species-contrast is in accord with that recorded in a previous experiment (Cosgrove et al, 1997).

The lower preference showed by the L_Red animals compared with that by animals grazing the legume-grass contrasts may be partly due to the alternative species being closely acceptable as the preferred species. When herbage species are equally acceptable the animals are indifferent to differences in availability between species (Parsons et al, 1994b). While red clover had high overall BD (107 kg DM cm^{-1} ha^{-1}) in the sward upper stratum, ryegrass in both contrasts (L_Rye and W_Rye) had the lowest BD (74.4 and 85.8 kg DM cm^{-1} ha^{-1}). Considering that ease of prehension is often related to preference (Allden and Whittaker, 1970; Kenney and Black, 1984a,b; Colebrook et al, 1987), red clover could be expected to be better a alternative to grazing animals than ryegrass particularly when the latter has considerably lower BD than the former.

Lotus had high BD (Table 3) but due to its structure (stemmy compared to clovers), the animals had to spend more time grazing as compensation for smaller bites if selectivity while grazing lotus (eating more leaves than stems) occurs. Indeed, forage plants with different structure from grasses or clovers require different skills to prehend (Flores et al, 1989a), with smaller bites being observed (Flores et al, 1989c).

White clover grows with the younger leaves developing in the lower stratum of the canopy (Thomas, 1980), therefore the leaves are exposed to the surface of the canopy only in an advanced development stage. On the contrary, ryegrass and red clover develop the younger leaves in the upper stratum of the sward (Whyte et al, 1959) and therefore, these are prone to immediate defoliation.

Thus, it can be argued for this experiment, that after mowing, the standing forage left was of high quality in the case of white clover because mainly young (developing) leaves were left, and lower quality in the grass and red clover by cutting away the younger leaves and leaving only the older leaves and dead matter, of lower quality (Hodgson, 1990). This may have altered the preference of the animals used in this experiment. However, partial preference for legumes over grasses as has been reported previously (Penning et al, 1995b; Cosgrove et al, 1996), was still maintained. It is acknowledged though, that this fact of leaf development may have helped to enhance the partial preference observed in the W_Rye contrast.

Partial preference during the intake phases (Table 35) was lower than that recorded during the preceding grazing periods in summer (Table 17). However, preference of grazing animals is influenced by familiarity and novelty of foods too (Provenza, 1996a). Parsons et al (1994a) conducted an experiment with sheep that had grazed either a grass or a clover monoculture or a 50:50 grass/clover mixture for two to three weeks prior to starting the experiment. When the sheep were allowed to freely choose between the two species on offer, they preferred to graze the species they had lacked during the time prior to the experiment, but just for a few days, after which the animals reverted to a preference for their background diet. For the present experiment, the animals used in summer did not have access to pastures containing either lotus or red clover, and only limited white clover, with ryegrass and browntop as the dominant species; therefore, it may be that the animals showed greater preferences for W in W_Rye and L in L_Rye species-contrasts, in the first period of observations for evaluation of preferences, and a decline in that preference towards the second week of grazing when intake and diet composition were estimated. In the works by Cosgrove et al (1996, 1997), the animals were allowed to graze the species-contrasts for a week prior to commencing recording grazing activity. In such case, familiarity and novelty of herbage species used in this experiment may have enhanced the observed partial preferences.

It is not clear why animals choose to graze an alternative species (e.g. ryegrass) even in low amounts, when having shown preference for either white clover or lotus over ryegrass. This question may be further complicated by the higher potential rate of intake offered by W and L compared to that of Rye. Penning et al (1995a) reported greater rates of intake by sheep grazing clover than by sheep grazing ryegrass. On the other hand, Orr et al (1996) found no difference in rates of dry matter intake by cattle when grazing white clover or ryegrass, relating this effect to the high moisture content in the legume compared with the grass.

Pulliam (1975) argues that maximisation of average rate of energy gain, subject to the constraint of adequate nutrient balance can result in partial preferences. The inclusion of different groups of food items in the diet of herbivores to meet requirements of different nutrients has been demonstrated in moose (Belovsky, 1981). In addition, the inclusion of different food items in the diet is not in disagreement with the theory of food aversions in driving dietary preferences of grazing animals (Provenza, 1996b).

In absolute terms, there were differences among species-contrasts in the across-seasons average for GTt (Table 11), GTp (Table 13), and GTI (Table 15). The shortest GTt was registered for W_Rye (6.58 hr), followed by L_Red (6.79 hr) and L_Rye (7.44 hr). The shortest GTp was registered on L in L_Red (3.74 hr), followed by W (4.47 hr), and last L in L_Rye (5.23). Conversely, animals in the L_Red species-contrast showed the longest GTI compared to the two contrasts involving ryegrass (L_Red 3.05 hr; L_Rye 2.21 hr; and W_Rye hr).

Different composition of herbage among contrasts in both chemical and physical terms is likely to influence grazing time by modulating the amount of nutrients consumed per bite (chemical composition of herbage, e.g. nutrient density) and/or the bite size (physical composition, e.g. vertical and horizontal distribution of herbage). Thus, animals respond to plant structure (O'Reagain and Mentis, 1989; Flores et al, 1989c; O'Reagain, 1993), by adopting different strategies reflected in bite parameters and rate of intake first, and eventually in time spent grazing (Stobbs and Hutton, 1974). It is possible that animals grazing W had greater rate of intake than those grazing L due to the greater BR observed in W ($P<0.05$) compared with the two L contrasts (Table 19), as well as the greater leafiness and lower stemminess percentage in the former compared to the latter. Cosgrove and Mitchell (1995) reported higher rates of intake from prostrate legumes than from erect grass or legume species.

It has been reported in sheep (Penning et al, 1991) that animals grazing white clover spend less time eating than animals grazing ryegrass, with dry matter intakes being similar between the species on offer, but greater bodyweight gains from the legume than from the grass (Penning et al, 1991).

The alternative species on offer may have influenced the distribution of GTt. As discussed earlier, Red as the alternative species may allow higher intake rates than ryegrass and thus, decreasing GTp in L_Red by offering similar reward to L in terms of rate of intake.

The modulation of grazing time between species on offer and consequently partial preferences is consistent with a theory that a herbivore controls its intake to maximise long-term 'fitness', rather than to maximise its daily intake (Pyke et al, 1977; McNamara and Houston, 1986; Newman et al, 1995a).

Lower BD of forages generally means less herbage ingested by the animal per bite (Stobbs and Imrie, 1976). However, the importance of BD may differ with animal species, ruminants being energy maximisers (Gordon and Illius, 1996), and feeding optimally but keeping ingestion of toxins under control at the same time (Provenza, 1995; 1996b). In other words, those plant species that offer the highest bulk density of unmixed green foliage with the highest nutrient concentration and lowest content of secondary compounds have the greatest probability of being grazed as the preferred species.

5.5 Season effect on preferences.

Direct comparison of GTt between summer and autumn may be of little value since observations were conducted only during daylight hours. The average difference in daylength between observations made in summer and autumn was 4.4 h (15.5 vs. 11.1 h, respectively), whereas the average difference in GTt between summer and autumn was 0.9 h. It is unlikely that this difference was due to different animals being used for each season since the two groups were of similar age and the difference in bodyweight was only 30 kg between groups of animals (262 vs. 232 kg bodyweight for summer and autumn, respectively). Brumby (1959) and Bao et al (1992), working with dairy cattle, found no significant effect of liveweight on grazing time, whereas milk yield had a greater effect on GTt.

The proportion of GTt allocated to the preferred and less preferred species may give a better indication of any seasonal effect on grazing activity. However, seasonal changes in food intake do occur, particularly between different daylight regimes (Forbes, 1982) as has been reported in deer (Milne et al, 1978), sheep (Forbes et al, 1979; Milne et al, 1978) and cattle (Peters et al, 1981). Thus, higher feed intake in summer compared to autumn, accompanied by different GTts can not be ruled out. Phillips and Leaver (1985) for example, observed a tendency by dairy cows to compress grazing time to mainly daylight hours as daylength decreased from spring to summer.

The partial preferences observed were greater in summer than in autumn (Table 17). This was due to a lower GTp in autumn, accompanied by an increase in GTl (see Table 13 and Table 15). There is no obvious explanation for this observation, though the following points may be relevant.

The difference in herbage mass and BD of the sward upper stratum between summer and autumn may indicate that the animals were not as much limited in expressing their preference for either of the pasture species on offer during summer, as they were in autumn, when they showed a more marked response to changes in height. This may also indicate that factors other than SSH influence preferences (Parsons et al, 1994b). Such factors may have seasonal pattern that can either increase or decrease preference for one over another pasture species on offer.

For example, protein and carbohydrate contents have been reported to be related to dietary preferences (Arnold et al, 1966), and O'Reagain and Mentis (1988) reported that cattle appeared more selective for leaf crude protein (CP) in autumn, than in spring when dietary CP was adequate under the conditions where that experiment was conducted. In this experiment, protein content increased from summer to autumn, but carbohydrate concentration tended to remain similar across seasons except for the W and Rye plots that showed lower values in autumn (Table 9 and Table 10).

Herbage digestibility and fibre components have also been implicated in herbage intake and diet selection (Hanley, 1982; Birrel, 1989; Olson et al, 1989). The indigestible cell wall components, as measured by acid-detergent fibre (ADF), in the less preferred species were greater in autumn than in summer ($P<0.05$), whereas in the preferred species the opposite was observed. Consequently, the *in-vitro* DM digestibility predicted from the NIRS analyses for the less preferred species decreased from summer to autumn ($P<0.05$) whereas that for the preferred species increased ($P<0.05$). Thus, there is not an easy answer to why GTI for both Rye contrasts increased from summer to autumn. It is possible that factors other than the nutritive quality parameters measured were implicated.

Secondary compounds such as condensed tannins in lotus, saponins in white and red clover, phytoestrogens (e.g. formononetin) in red clover, or endophyte metabolites (e.g. ergovaline, lolitrem B) in ryegrass, may also be involved to some degree in influencing preferences. Animals seek to modulate the proportion of a toxic food in the diet (Provenza, 1995; 1996b). For example, alkaloids produced by ryegrass endophytes have been reported to affect preference in cattle (Edwards et al, 1993) and endophyte alkaloids vary seasonally with peak concentration towards autumn (Woodburn et al, 1993). Yatsyn Ryegrass, the variety used in this experiment is considered high endophyte, hence a decrease in preference for this species could be expected towards autumn. This was not observed in the present work and rather the opposite was recorded, with increases in GTI in autumn at expense of GTp (see Table 13 and Table 15). However, levels of alkaloids in the herbage during this experiment were not measured. Besides, Rye showed increased leafiness and decreased stemminess from summer to autumn which may partially explain why animals increased the proportion of grazing time on this less preferred species in autumn at the expense of the preferred species (L and W). Previous work (Cosgrove et al, 1996, 1997) has shown similar trends in GTp between seasons.

Higher BRs were observed in autumn than in summer, except for animals grazing on the W_Rye species-contrast which showed no significant increase in BR (P>0.05; Table 19). An increase in BR occurs with lower herbage mass and BD, as occurred in autumn. Thus, the animals may have changed the ratio bites/chews as a response to the lower herbage availability in autumn, reflected as an increased BR (Hodgson, 1985) on both the preferred and the less preferred species in the L_Rye and L_Red species-contrasts. Conversely, animals in the W_Rye may have maintained BR with little or no penalty to bite mass by modifying their foraging strategies (Newman et al, 1994a). Laca et al (1992) found that bite area and depth in cattle varies with height and BD of the herbage in order to maintain similar bite size. Thus, even though animals were faced with lower BD in autumn, compared with summer, increases in bite area and possibly bite depth, would have been enough to compensate and maintain bite size.

Other possible factors contributing to the observed changes in preference between seasons may be the botanical composition of the sward upper stratum. There was a substantial increase in leafiness from summer to autumn particularly in the Rye plots (Table 4). Hence, despite the lower BD in autumn than in summer, greater leafiness offers easier harvesting opportunities in terms of reduced breaking strength (Evans, 1967).

The proportion of unsown species present at the time of grazing may also influence preference. Intermingling of sown and unsown species may increase the effort required by the animal to prehend plant material by diminishing the horizontal availability of the preferred species in terms of surface area occupied. Horizontal availability influences preferences (Penning et al,1995b) but only when the preferred species is reduced below 20 % of total area available for grazing, and only to the point of indifference for this being the foraging option of lowest cost (Parsons et al, 1994b). Unsown species (Table 8) were low throughout the experiment for Rye and W plots, but increased substantially for the L and Red plots from summer to autumn, particularly for the

L_Red species-contrast. However, the unsown species *per se* do not explain totally the decreased preference observed in autumn compared with summer, otherwise L in L_Rye should have shown a relatively greater decrease in preference from summer to autumn, because Rye in this species-contrast maintained low proportion of unsown species in both seasons.

The partial preference for the preferred species exercised by the animals in this experiment varied from around 80 % in summer to about 57 % in autumn for both legume-grass contrasts, whereas that of animals grazing in the legume-legume contrast was more consistent going from 58 % in summer to 52 % in autumn; the latter being statistically similar to indifference (P>0.05). Animals change diet composition between seasons (O'Reagain and Mentis, 1988). Changes in the acceptability of herbage species between seasons may occur due to changes in availability and or quality of the herbage (O'Reagain and Mentis, 1988; O'Reagain and Schwartz, 1995). It would be interesting to know whether an animal would change its diet with season when both availability and quality of herbage are kept constant throughout the time. This is an issue open to further research.

Also, if animals show nutritional wisdom (Provenza and Balph, 1990; Kyriazakis and Oldham, 1993), and there is a change in metabolism with subsequent adjustments to nutrient demands under short daylight hours (Forbes, 1982), then it is possible that under this situation, animals would increase the proportion of a pasture of lower quality in the diet in order to "balance" a diet to meet lower nutritional requirements. This could account for the observed decrease in partial preference from summer to autumn, it may also partially explain the observed increase in GTl over the same period of time, at the expense of GTp, clearly noticed in the two Rye species-contrasts, even though the quality, as indicated by NIRS analyses, of the Rye tended to decrease, unlike the quality of the W and L which tended to increase from summer to autumn.

It may be too that the animals which prefer a mixed diet, attempt to maintain a constant proportion of both the preferred and less preferred species in the diet (e.g. 70 % legume vs. 30 % grass) (Parsons et al, 1994b; Newman et al, 1995a). To do this, the animals would spend more time in grazing the less preferred species if the intake rate from it declines as a result of, for example, lower BD (Parsons et al, 1994b). Estimations of diet composition during autumn would have answered this point.

5.6 Sward surface height (SSH) effect on preferences.

Partial preference was influenced by height of the preferred species in both seasons but not determined by grazing time during the intake phases. However, the diet composition estimation from alkanes indicated a significant height effect particularly for the L_Red species-contrast. Thus, as height of the preferred species declined, so did the preference of the animals for that preferred species. It has been shown that when the accessibility of a preferred species decreases the animals give up time devoted to that preferred food (Dumont et al, 1995b). However, the decrease in preference with decreasing vertical (e.g. height) availability differed between seasons (see section 4.2.4), being more accentuated in autumn than in summer (Table 5). In fact, judging by the regression analyses for the proportion of GTt spent grazing the preferred species, the animals attempted to maintain partial preferences in summer, as indicated by slopes not significantly different from zero (Table 18). Bite size may have not been significantly affected by SSH of the preferred species or it may be that the cost of grazing the preferred species even as height declined was more rewarding than grazing the taller alternative species (e.g. Rye, Red) in summer, therefore maintaining partial preference. Newman et al (1995a) predicted an increase in consumption of clover when the absolute rate of intake of herbage increases. The intake rates in summer were expected to be higher than those in autumn because of the differences in herbage mass and BD observed between seasons (Table 2 and Table 3).

The GTt declined with increases in height of the preferred species. This response appeared to be stronger in summer than in autumn, although no statistical difference in slopes between seasons was found (see section 4.2.1). The significant interactions between contrast and height, and contrast and season for GTt were related to a different pattern of distribution between species-contrasts. Regressions of GTt on height, however, indicated a common slope for each of the three species-contrasts. Hence, decreases in GTt with increases in height of the preferred species were similar for each species-contrast (Figure 2) and resulted from increases in GTp (Figure 3) and decreases in GTl (Figure 4) with increases in height of the preferred species.

GTp generally increased with increases in height, except for W in period 1 in summer, which showed an inverse relationship between height and GTp (Figure 3), although not statistically different from zero ($P>0.05$). However, the response was different between seasons, with summer showing weak responses in GTp to changes in height, whereas autumn showed significant slopes for changes in GTp in relation to changes in height in both L contrasts but not in W.

As discussed in the previous section, the attainment of satiety faster in summer than in autumn may help to explain the differences in grazing activity in response to height observed between seasons. Also, because of the lower herbage mass and BD available in autumn, bite size may have been restricted. In such case, increasing BR is the only option to maintain rate of intake. If the rate of intake is not maintained, then increased grazing time may occur in order to maintain daily intake (Seman et al, 1991). In this experiment, the animals responded by increasing GTt with decreases in height of the preferred species (Figure 2), which supports the argument that animals use grazing time as a way to compensate for reduced rate of intake (Allden and Whittaker, 1970).

Fisher et al (1995), reported better pasture conditions for one experiment compared to another under different grazing regimes. Significant differences between grazing treatments in dry matter intake and milk yield were found during the experiment where pasture conditions were poorer, but not in that with better pasture conditions. This suggests that the animals were more restricted in their ability to harvest herbage in the experiment with poorer pasture conditions (Chacon and Stobbs, 1976; Fisher et al, 1995; Hepp et al, 1996), therefore allowing detection of smaller differences between grazing treatments.

It may also be that factors other than potential rate of intake were involved in the observed responses in GTp to changes in height between seasons. Bloat is commonly reported in animals grazing legumes (Hall et al, 1988; Bush and Burton, 1994) and it has been hypothesised that sub-clinical bloat may interfere with meal duration (Dougherty et al, 1992). Animals used in summer were all dosed with anti-bloat capsules but none of the animals was dosed with anti-bloat capsules in autumn. No animals were observed suffering from bloat except for one in the L_Red species-contrast with light bloat which did not keep the animal from grazing in autumn. However, Penning et al (1995c) reported no effect of anti-bloat capsules on diet preference of cattle grazing monocultures of white clover and ryegrass.

5.7 Final discussion.

This work does not answer the question of why animals show partial preferences. Rather, it was intended to analyse the effect of different choices and the effect of relative availability, as changes in SSH, on partial preference of cattle, as well as to evaluate the use of monocultures in dietary preference studies.

Cattle responded to species choice by adjusting time spent grazing. Thus, GTt differed among the species-contrasts possibly due to different rates of intake reached among the different herbage species. Hence, improvements to this approach to evaluate dietary preferences of grazing cattle could include a wider arrangement of species-contrasts (e.g. white clover vs. lotus), and the inclusion of different ratios of pasture species on offer by area, in order to discriminate small differences between partial preference from indifference (Parsons et al, 1994a,b).

The estimation of diet composition through the alkane technique gave estimates different from those observed in the distribution of grazing time between pasture species on offer. This implies differences in rate of intake between species available. The overall correlation observed between visual observations and diet composition from alkanes was r = 0.74, indicating that the distribution of grazing time gives a general approach to estimations of relative intake and thus, either methods can be applied to evaluate dietary preferences of cattle. However, care must be exercised, particularly when extrapolating subtle responses in the distribution of grazing time to relative intake. Furthermore, each method can be applied depending on particular circumstances. Visual observations for example may be cheaper than the determination of alkanes although the latter may be less time consuming for the processing of data collected. However, it is important to bear in mind that the number of experimental units considered for the diet composition estimation through alkanes was small, particularly for the L_Red contrast (4 in each phase), for which case it is recommended to carry out further experimentation with an increased number of experimental units to either corroborate or reject the observations made in the present work.

It is interesting to note that even though the trend observed in both GTp and the proportion of GTt allocated to the preferred species during the intake phases of the experiment pointed to a non-significant decrease in these parameters with increases in height for both W_Rye and L_Red, the diet composition estimates from alkanes indicated the opposite, although this was only significant for the L_Red species contrast. This may indicate that adjustments in the foraging strategies to alter the rate of intake may be implicated (Newman et al, 1994a) and thus, the evaluation of factors likely to influence preferences through one single parameter (e.g. GTt) may be misleading, particularly in cases with little grazing behaviour responses to changes in availability as occurred in this experiment. Consequently, when possible, the inclusion of intake estimations should be considered in future experiments.

On the other hand, this work confirms previous reports by Parsons et al (1994a), Penning et al (1995c), and Cosgrove et al (1996, 1997), regarding preference for a mixed diet even though the animals could have met their intake requirements by grazing only one species. In addition, partial preference in favour of the legume over the grass component was observed, in agreement with previous work in cattle (Cosgrove et al, 1996, 1997). Nutritional requirements may be involved in the determination of preference for a mixed diet (Kyriazakis and Oldham, 1993). By including more than one species in the diet, the animal is more likely to meet requirements for several nutrients. The inclusion of different groups of food items in the diet of herbivores to meet requirements of different nutrients has been demonstrated in moose (Belovsky, 1981) and sheep (Kyriazakis and Oldham, 1993).

Sward factors most likely to influence these preferences were height and BD. In general, height exerted a greater effect on preferences in autumn than in summer, although this may be confounded by the effect of lower BD in the sward upper stratum found in autumn (see section 4.1.3). Interactions between SSH and BD influencing ingestive behaviour have been reported in several occasions (Mitchell et al, 1991; Laca et al, 1992; Gong et al, 1996). Effects of variation in total herbage mass may also be important in influencing partial preference since differences in this parameter were also observed between seasons (see section 4.1.2). The influence of total availability on ingestive behaviour has also been documented elsewhere (Arnold et al, 1966; Allden and Whittaker, 1970; Arnold, 1987; Edwards et al, 1996).

The decrease in preferences for legumes, as indicated by the proportion of GTt allocated to the preferred species, over successive weeks of grazing, as observed in the intake phases, may be due to effect of declining novelty of food (Provenza, 1996a). An increase in preference during the first days of introduction to a new or non abundant species, but a decrease to what would be considered as actual preference after a few days of free access to novel or scarce foods has been recorded (Parsons et al, 1994a). However, concomitant changes in other aspects of botanical composition (leafiness, stemminess, etc.) of herbage can not be ruled out, since animals respond differently to different direction of change (e.g. increasing vs. decreasing height) in swards (Armstrong et al, 1995). Longer periods of evaluation would clarify this point.

The trend to decrease GTt with increases in height of the preferred species can have practical implications regarding grazing management strategies, since grazing activity increases energy requirements for maintenance (Graham, 1964; Osuji, 1977). By facilitating foraging activities for the grazing animals, through increasing the proportions of preferred species in the herbage, energy costs for maintenance could be reduced and the spared energy diverted to production (e.g. milk, bodyweight gain). Strategies to offer high proportions of preferred species to grazing animals, such as simultaneous access to different monocultures, or alternate strips of different pasture species have been proposed (Chapman et al, 1996). In this regard, different area ratios between pasture species could be sought out in order to match animal preferences and herbage consumption with herbage growth rates. Future experimental work on this objective would be appropriate.

5.8 Conclusions.

1. The use of monocultures of pasture species is a useful procedure in determination of grazing preferences of cattle.
2. Grazing cattle preferred mixed diets, with partial preference for legumes over grass with an average ratio of about 70:30 respectively. This preference varied between seasons and was higher in the summer compared to autumn.
3. Vertical availability (e.g. height and BD) of herbage influenced preference of cattle. As harvesting the preferred species became more difficult (decreasing height) partial preference declined. However, the effect of height may be confounded with that of BD.
4. Preference between two legumes (e.g. lotus and red clover) was weaker than that observed between legume-grass with an average partial preference of 55 % in favour of the lotus over red clover. Seasonal variation indicates that animals grazed selectively for lotus in summer but not in autumn.
5. Cattle responded to species choice by adjusting the time spent grazing. This may be related to different rates of intake between herbage species.
6. There may be potential benefits to animal performance by offering herbage species in proportion to those preferred by the animals, as indicated by the trend to decrease total grazing time with increases in availability of a preferred species. The potential benefits need to be evaluated in terms of animal performance under long-term grazing trials which may add further information to the current knowledge on dietary preferences of grazing cattle.

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Appendix 1. SAS programs and ANOVA tables.

1.A. SAS programs and ANOVA tables for grazing activity data (GTt, GTp, GTl, Proportion of GTt allocated to the preferred species) and rate of biting (BR) on the preferred and less preferred species, collected from the observations for evaluation of preferences during periods 1 and 2 of summer and autumn.

```
DATA OBSERVS;
INFILE 'A:\observs\RELATIVE.DAT';
INPUT Contrast $ Height Actual Season $ Repl $ Week $ Day $
TTime TiPref TiRyeRed PrefdP BitesP BitesL ;
PROC SORT DATA=OBSERVS;
BY Contrast Height Season Repl Day;
RUN;
PROC GLM DATA=OBSERVS;
CLASS Contrast Height Season Repl Day;
MODEL TTime TiPref TiRyeRed PrefdP BitesP BitesL = Ccontasr
Season Repl(Season) Day(Repl Season) Height Contrast Height
Contrast*Season Season*Height Contrast*Season*Height /SS3;
TEST H=Season E=Repl(Season);
TEST H=Repl(Season) E=Day(Repl Season);
LSMEANS Contrast / PDIFF STDERR;
LSMEANS Season /E=Repl(Season) PDIFF STDERR;
LSMEANS Repl(Season) /E=Day(Repl Season) PDIFF STDERR;
LSMEANS Day(Repl Season) /PDIFF STDERR;
LSMEANS Height /PDIFF STDERR;
LSMEANS Contrast*Height /PDIFF STDERR;
LSMEANS Contrast*Season /PDIFF STDERR;
LSMEANS Season*Height /PDIFF STDERR;
LSMEANS Contrast*Season*Height /PDIFF STDERR;
RUN;
```

NOTE: TTime TiPref TiRyeRed PrefdP BitesP BitesL stand for Total grazing time (GTt), Time spent grazing the preferred species (GTp), Time spent grazing the less preferred species (GTl), proportion of GTt allocated to grazing the preferred species, and BR on the preferred and less preferred species, respectively.

Dependent Variable: TTIME

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	33	175.52666667	5.31898990	16.76	0.0001
Error	110	34.91083333	0.31737121		
Corrected Total	143	210.43750000			
	R-Square	C.V.	Root MSE		TTIME Mean
	0.834104	8.120463	0.56335709		6.93750000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
CONTRAST	2	19.55791667	9.77895833	30.81	0.0001
SEASON	1	39.69000000	39.69000000	125.06	0.0001
REPL(SEASON)	2	61.38472222	30.69236111	96.71	0.0001
DAY(SEASON*REPL)	8	35.59444444	4.44930556	14.02	0.0001
HEIGHT	3	2.94138889	0.98046296	3.09	0.0301
CONTRAST*HEIGHT	6	7.46486111	1.24414352	3.92	0.0014
CONTRAST*SEASON	2	3.13541667	1.56770833	4.94	0.0088
SEASON*HEIGHT	3	1.97500000	0.65833333	2.07	0.1078
CONTRA*SEASON*HEIGHT	6	3.78291667	0.63048611	1.99	0.0736

Tests of Hypotheses using the Type III MS for REPL(SEASON) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SEASON	1	39.69000000	39.69000000	1.29	0.3734

Tests of Hypotheses using the Type III MS for DAY(SEASON*REPL) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REPL(SEASON)	2	61.38472222	30.69236111	6.90	0.0181

Dependent Variable: TIPREF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	33	252.28722222	7.64506734	26.59	0.0001
Error	110	31.63027778	0.28754798		
Corrected Total	143	283.91750000			
	R-Square	C.V.	Root MSE		TIPREF Mean
	0.888593	11.97176	0.53623500		4.47916667

Source	DF	Type III SS	Mean Square	F Value	Pr > F
CONTRAST	2	53.71166667	26.85583333	93.40	0.0001
SEASON	1	126.93777778	126.93777778	441.45	0.0001
REPL(SEASON)	2	15.93805556	7.96902778	27.71	0.0001
DAY(SEASON*REPL)	8	32.03833333	4.00479167	13.93	0.0001
HEIGHT	3	2.60916667	0.86972222	3.02	0.0327
CONTRAST*HEIGHT	6	4.04833333	0.67472222	2.35	0.0359
CONTRAST*SEASON	2	9.26722222	4.63361111	16.11	0.0001
SEASON*HEIGHT	3	5.76833333	1.92277778	6.69	0.0003
CONTRA*SEASON*HEIGHT	6	1.96833333	0.32805556	1.14	0.3436

Tests of Hypotheses using the Type III MS for REPL(SEASON) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SEASON	1	126.93777778	126.93777778	15.93	0.0574

Tests of Hypotheses using the Type III MS for DAY(SEASON*REPL) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REPL(SEASON)	2	15.93805556	7.96902778	1.99	0.1989

Dependent Variable: TIRYERED

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	33	147.69250000	4.47553030	11.93	0.0001
Error	110	41.26305556	0.37511869		
Corrected Total	143	188.95555556			
	R-Square	C.V.	Root MSE		TIRYERED Mean
	0.781626	24.94219	0.61246934		2.45555556

Source	DF	Type III SS	Mean Square	F Value	Pr > F
CONTRAST	2	25.47513889	12.73756944	33.96	0.0001
SEASON	1	24.83361111	24.83361111	66.20	0.0001
REPL(SEASON)	2	15.50361111	7.75180556	20.66	0.0001
DAY(SEASON*REPL)	8	24.58000000	3.07250000	8.19	0.0001
HEIGHT	3	7.99444444	2.66481481	7.10	0.0002
CONTRAST*HEIGHT	6	10.69597222	1.78266204	4.75	0.0002
CONTRAST*SEASON	2	22.52680556	11.26340278	30.03	0.0001
SEASON*HEIGHT	3	6.63638889	2.21212963	5.90	0.0009
CONTRA*SEASON*HEIGHT	6	9.44652778	1.57442130	4.20	0.0008

Tests of Hypotheses using the Type III MS for REPL(SEASON) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SEASON	1	24.83361111	24.83361111	3.20	0.2154

Tests of Hypotheses using the Type III MS for DAY(SEASON*REPL) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REPL(SEASON)	2	15.50361111	7.75180556	2.52	0.1414

Dependent Variable: PREFDP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	33	30078.05555556	911.45622896	15.51	0.0001
Error	110	6462.94444444	58.75404040		
Corrected Total	143	36541.00000000			
	R-Square	C.V.	Root MSE		PREFDP Mean
	0.823132	11.93015	7.66511842		64.25000000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
CONTRAST	2	6122.00000000	3061.00000000	52.10	0.0001
SEASON	1	11953.77777778	11953.77777778	203.45	0.0001
REPL(SEASON)	2	512.50000000	256.25000000	4.36	0.0150
DAY(SEASON*REPL)	8	3291.88888889	411.48611111	7.00	0.0001
HEIGHT	3	1473.38888889	491.12962963	8.36	0.0001
CONTRAST*HEIGHT	6	1303.44444444	217.24074074	3.70	0.0022
CONTRAST*SEASON	2	2588.22222222	1294.11111111	22.03	0.0001
SEASON*HEIGHT	3	1378.38888889	459.46296296	7.82	0.0001
CONTRA*SEASON*HEIGHT	6	1454.44444444	242.40740741	4.13	0.0009

Tests of Hypotheses using the Type III MS for REPL(SEASON) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SEASON	1	11953.77777778	11953.77777778	46.65	0.0208

Tests of Hypotheses using the Type III MS for DAY(SEASON*REPL) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REPL(SEASON)	2	512.50000000	256.25000000	0.62	0.5606

Dependent Variable: BITESP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	32	3515.51799753	109.85993742	6.25	0.0001
Error	98	1721.59101010	17.56725521		
Corrected Total	130	5237.10900763			
	R-Square	C.V.	Root MSE		BITESP Mean
	0.671271	6.770131	4.19133096		61.90916031

Source	DF	Type III SS	Mean Square	F Value	Pr > F
CONTRAST	2	810.45722927	405.22861463	23.07	0.0001
SEASON	1	558.14465461	558.14465461	31.77	0.0001
REPL(SEASON)	2	240.23220549	120.11610274	6.84	0.0017
DAY(SEASON*REPL)	7	982.58998364	140.36999766	7.99	0.0001
HEIGHT	3	161.27352046	53.75784015	3.06	0.0318
CONTRAST*HEIGHT	6	163.75955420	27.29325903	1.55	0.1689
CONTRAST*SEASON	2	328.11289887	164.05644943	9.34	0.0002
SEASON*HEIGHT	3	195.61911023	65.20637008	3.71	0.0141
CONTRA*SEASON*HEIGHT	6	107.41587121	17.90264520	1.02	0.4175

Tests of Hypotheses using the Type III MS for REPL(SEASON) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SEASON	1	558.14465461	558.14465461	4.65	0.1639

Tests of Hypotheses using the Type III MS for DAY(SEASON*REPL) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REPL(SEASON)	2	240.23220549	120.11610274	0.86	0.4651

Dependent Variable: BITESL

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	32	3360.64993688	105.02031053	5.99	0.0001
Error	90	1577.94925011	17.53276945		
Corrected Total	122	4938.59918699			
	R-Square	C.V.	Root MSE		BITESL Mean
	0.680486	6.433983	4.18721500		65.07967480

Source	DF	Type III SS	Mean Square	F Value	Pr > F
CONTRAST	2	984.07647822	492.03823911	28.06	0.0001
SEASON	1	476.31448963	476.31448963	27.17	0.0001
REPL(SEASON)	2	86.94970549	43.47485274	2.48	0.0895
DAY(SEASON*REPL)	7	753.45201653	107.63600236	6.14	0.0001
HEIGHT	3	17.58445818	5.86148606	0.33	0.8005
CONTRAST*HEIGHT	6	232.14394344	38.69065724	2.21	0.0494
CONTRAST*SEASON	2	93.58182567	46.79091284	2.67	0.0748
SEASON*HEIGHT	3	329.19113036	109.73037679	6.26	0.0007
CONTRA*SEASON*HEIGHT	6	362.62116171	60.43686028	3.45	0.0041

Tests of Hypotheses using the Type III MS for REPL(SEASON) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SEASON	1	476.31448963	476.31448963	10.96	0.0804

Tests of Hypotheses using the Type III MS for DAY(SEASON*REPL) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REPL(SEASON)	2	86.94970549	43.47485274	0.40	0.6823

1.B. SAS programs and ANOVA tables for grazing activity data (GTt, GTp, GTl, Proportion of GTt allocated to the preferred species) and rate of biting (BR) on the preferred and less preferred species, collected during the intake and diet composition estimation phases.

```
DATA intake;
INFILE 'A:\intake.dat';
INPUT Contrast $ Height Actual Season $ Repl $ Day $ TTime
TiPref TiRyeRed PrefdP BitesP BitesL;
PROC SORT DATA=intake;
BY Contrast Height Repl Day;
RUN;
PROC GLM DATA=intake;
CLASS Contrast Height Repl Day ;
MODEL TTime TiPref TiRyeRed PrefdP BitesP BitesL = Contrast
Repl Day(Repl) Height Contrast*Height /SS3;
TEST H=Repl E=Day(Repl);
LSMEANS Contrast / PDIFF STDERR;
LSMEANS Repl /E=Day(Repl) PDIFF STDERR;
LSMEANS Day(Repl) /PDIFF STDERR;
LSMEANS Height /PDIFF STDERR;
LSMEANS Contrast*Height /PDIFF STDERR;
RUN;
```

NOTE: TTime TiPref TiRyeRed PrefdP BitesP BitesL stand for Total grazing time (GTt), Time spent grazing the preferred species (GTp), Time spent grazing the less preferred species (GTl), proportion of GTt allocated to grazing the preferred species, and BR on the preferred and less preferred species, respectively.

```
DATA intake;
INFILE 'A:\intake.dat';
INPUT Contrast $ Height Actual Season $ Repl $ Day $ TTime TiPref TiRyeRed
PrefdP RyeRedP BitesP BitesL;
PROC SORT DATA=intake;
BY CONTRAST HEIGHT REPL DAY;
RUN;
PROC GLM DATA=intake;
CLASS CONTRAST REPL DAY height ;
MODEL TTIME TIPREF TIRYERED PREFDP RYEREDP BitesP BitesL = CONTRAST REPL
DAY(REPL) HEIGHT CONTRAST*HEIGHT /ss3;
TEST H=REPL E=DAY(REPL);
LSMEANS CONTRAST / PDIFF STDERR;
LSMEANS REPL /E=DAY(REPL) PDIFF STDERR;
LSMEANS DAY(REPL) /PDIFF STDERR;
LSMEANS HEIGHT /PDIFF STDERR;
LSMEANS CONTRAST*HEIGHT /PDIFF STDERR;
RUN;
```

Dependent Variable: TTIME

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	16	253.15166667	15.82197917	29.66	0.0001
Error	55	29.34333333	0.53351515		
Corrected Total	71	282.49500000			
	R-Square	C.V.	Root MSE		TTIME Mean
	0.896128	7.510758	0.73042122		9.72500000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
CONTRAST	2	37.29083333	18.64541667	34.95	0.0001
REPL	1	195.36055556	195.36055556	366.18	0.0001
DAY(REPL)	4	12.38944444	3.09736111	5.81	0.0006
HEIGHT	3	4.42833333	1.47611111	2.77	0.0503
CONTRAST*HEIGHT	6	3.68250000	0.61375000	1.15	0.3462

Tests of Hypotheses using the Type III MS for DAY(REPL) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REPL	1	195.36055556	195.36055556	63.07	0.0014

Dependent Variable: TIPREF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	16	149.66055556	9.35378472	17.76	0.0001
Error	55	28.96388889	0.52661616		
Corrected Total	71	178.62444444			
	R-Square	C.V.	Root MSE		TIPREF Mean
	0.837850	12.13968	0.72568324		5.97777778

Source	DF	Type III SS	Mean Square	F Value	Pr > F
CONTRAST	2	67.60361111	33.80180556	64.19	0.0001
REPL	1	23.57555556	23.57555556	44.77	0.0001
DAY(REPL)	4	53.61388889	13.40347222	25.45	0.0001
HEIGHT	3	0.60000000	0.20000000	0.38	0.7679
CONTRAST*HEIGHT	6	4.26750000	0.71125000	1.35	0.2510

Tests of Hypotheses using the Type III MS for DAY(REPL) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REPL	1	23.57555556	23.57555556	1.76	0.2554

Dependent Variable: TIRYERED

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	16	230.53833333	14.40864583	54.20	0.0001
Error	55	14.62041667	0.26582576		
Corrected Total	71	245.15875000			
	R-Square	C.V.	Root MSE		TIRYERED Mean
	0.940363	13.76417	0.51558293		3.74583333

Source	DF	Type III SS	Mean Square	F Value	Pr > F
CONTRAST	2	24.92583333	12.46291667	46.88	0.0001
REPL	1	83.85125000	83.85125000	315.44	0.0001
DAY(REPL)	4	105.56666667	26.39166667	99.28	0.0001
HEIGHT	3	3.54486111	1.18162037	4.45	0.0072
CONTRAST*HEIGHT	6	12.64972222	2.10828704	7.93	0.0001

Tests of Hypotheses using the Type III MS for DAY(REPL) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REPL	1	83.85125000	83.85125000	3.18	0.1493

Dependent Variable: PREFDP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	16	12907.22222222	806.70138889	33.35	0.0001
Error	55	1330.55555556	24.19191919		
Corrected Total	71	14237.77777778			
	R-Square	C.V.	Root MSE		PREFDP Mean
	0.906548	7.876647	4.91852815		62.44444444

Source	DF	Type III SS	Mean Square	F Value	Pr > F
CONTRAST	2	3496.02777778	1748.01388889	72.26	0.0001
REPL	1	1586.72222222	1586.72222222	65.59	0.0001
DAY(REPL)	4	6789.72222222	1697.43055556	70.17	0.0001
HEIGHT	3	139.33333333	46.44444444	1.92	0.1371
CONTRAST*HEIGHT	6	895.41666667	149.23611111	6.17	0.0001

Tests of Hypotheses using the Type III MS for DAY(REPL) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REPL	1	1586.72222222	1586.72222222	0.93	0.3884

Dependent Variable: BITESP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	16	1845.99022294	115.37438893	4.76	0.0001
Error	51	1235.51610059	24.22580589		
Corrected Total	67	3081.50632353			
	R-Square	C.V.	Root MSE		BITESP Mean
	0.599054	7.733763	4.92197175		63.64264706

Source	DF	Type III SS	Mean Square	F Value	Pr > F
CONTRAST	2	888.35338751	444.17669376	18.33	0.0001
REPL	1	7.14465534	7.14465534	0.29	0.5895
DAY(REPL)	4	721.57193845	180.39298461	7.45	0.0001
HEIGHT	3	56.11117324	18.70372441	0.77	0.5150
CONTRAST*HEIGHT	6	143.74141037	23.95690173	0.99	0.4427

Tests of Hypotheses using the Type III MS for DAY(REPL) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REPL	1	7.14465534	7.14465534	0.04	0.8520

Dependent Variable: BITESL

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	16	684.15156190	42.75947262	1.52	0.1278
Error	53	1491.84786667	28.14807296		
Corrected Total	69	2175.99942857			
	R-Square	C.V.	Root MSE		BITESL Mean
	0.314408	7.815634	5.30547575		67.88285714

Source	DF	Type III SS	Mean Square	F Value	Pr > F
CONTRAST	2	270.90039259	135.45019630	4.81	0.0120
REPL	1	45.24801368	45.24801368	1.61	0.2104
DAY(REPL)	4	215.42866207	53.85716552	1.91	0.1218
HEIGHT	3	61.54663520	20.51554507	0.73	0.5393
CONTRAST*HEIGHT	6	92.34092358	15.39015393	0.55	0.7702

Tests of Hypotheses using the Type III MS for DAY(REPL) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REPL	1	45.24801368	45.24801368	0.84	0.4112

Appendix 2. Sward surface heights (SSH) throughout the experiment.

2.A. Average sward surface height by period for the grazing observations made for evaluation of preference.

2.A.1. Average sward surface height (cm) for the preferred and less preferred species on Period 1 in Summer.

		Treatment height of the preferred species (cm).			
Contrast	Species	4	6	8	10
W_Rye	White clover	6.7	8.1	11.2	10.2
	Ryegrass	12.4	11.9	12.3	12.5
L_Rye	Lotus	9.5	7.2	11.9	11.4
	Ryegrass	11.1	11.2	11.4	11.5
L_Red	Lotus	7.2	9.4	10.8	11.4
	Red clover	11.5	11.0	11.5	9.8

2.A.2. Average sward surface height (cm) for the preferred and less preferred species on Period 2 in Summer.

		Treatment height of the preferred species (cm).			
Contrast	Species	4	6	8	10
W_Rye	White clover	5.4	6.8	7.9	9.9
	Ryegrass	12.5	12.8	13.2	12.3
L_Rye	Lotus	5.6	6.8	8.5	11.8
	Ryegrass	9.0	9.9	9.7	9.6
L_Red	Lotus	5.4	6.9	8.0	10.0
	Red clover	9.1	9.8	9.4	9.3

2.A.3. Average sward surface height (cm) for the preferred and less preferred species on Period 1 in Autumn.

		Treatment height of the preferred species (cm).			
Contrast	Species	4	6	8	10
W_Rye	White clover	7.4	7.4	9.5	10.1
	Ryegrass	11.8	11.9	11.7	11.8
L_Rye	Lotus	6.4	6.2	7.9	8.2
	Ryegrass	11.2	10.7	11.2	10.6
L_Red	Lotus	6.2	7.4	9.6	11.1
	Red clover	10.2	10.3	11.0	10.6

2.A.4. Average sward surface height (cm) for the preferred and less preferred species on Period 2 in Autumn.

Contrast	Species	Treatment height of the preferred species (cm). 4	6	8	10
W_Rye	White clover	5.4	6.3	7.3	9.3
	Ryegrass	10.4	10.6	10.6	11.0
L_Rye	Lotus	4.6	6.2	8.3	8.6
	Ryegrass	10.3	9.8	10.3	10.2
L_Red	Lotus	5.1	7.3	9.1	10.2
	Red clover	9.4	9.1	9.1	9.9

2.B. Average sward surface height by phase during the dry matter intake and diet composition estimation.

2.B.1. Average sward surface height (cm) for the preferred and less preferred species on Phase 1 during the dry matter and diet composition estimation.

Contrast	Species	Treatment height of the preferred species (cm). 4	6	8	10
W_Rye	White clover	6.9	9.2	11.1	11.1
	Ryegrass	15.5	15.3	16.5	15.7
L_Rye	Lotus	8.3	6.4	8.5	9.5
	Ryegrass	14.2	13.7	13.0	14.1
L_Red	Lotus	8.4	10.6	9.4	11.3
	Red clover	13.1	12.3	14.1	11.0

2.B.2. Average sward surface height (cm) for the preferred and less preferred species on Phase 2 during the dry matter and diet composition estimation.

Contrast	Species	Treatment height of the preferred species (cm). 4	6	8	10
W_Rye	White clover	5.7	7.3	7.9	9.6
	Ryegrass	9.3	11.1	11.9	10.4
L_Rye	Lotus	5.1	6.5	8.3	11.0
	Ryegrass	8.4	8.5	8.7	9.4
L_Red	Lotus	5.2	7.2	7.2	9.8
	Red clover	9.8	9.0	10.1	9.9

Appendix 3. Botanical composition of the sward upper stratum throughout the experiment.

3.A.1 Botanical composition of the sward upper stratum for the W_Rye species-contrast during the periods of summer and autumn.

			Height of the preferred species (cm)							
			4		6		8		10	
Season	Period	Part	W clover	Ryegrass	W clover	Ryegrass	W clover	Ryegrass	W clover	Ryegrass
Summer	1	Leaf	48.1%	49.7%	49.2%	48.8%	40.4%	30.5%	48.1%	30.3%
		Stem	1.0%	21.3%	0.0%	22.0%	14.2%	24.5%	0.0%	16.7%
		Dead	18.4%	29.0%	16.8%	29.2%	16.3%	27.3%	16.9%	23.4%
		Seedhead	6.3%	0.0%	16.2%	0.0%	14.2%	17.7%	17.8%	15.0%
		Unsown spp	10.5%	0.0%	17.9%	0.0%	14.9%	0.0%	17.2%	14.6%
	2	Leaf	88.3%	85.5%	86.7%	68.1%	70.7%	72.4%	76.3%	70.9%
		Stem	5.2%	3.1%	0.0%	1.9%	1.3%	0.6%	0.0%	2.7%
		Dead	13.7%	11.0%	5.2%	27.1%	10.2%	26.7%	3.4%	25.5%
		Seedhead	2.6%	0.0%	3.6%	2.5%	8.9%	0.0%	10.6%	0.9%
		Unsown spp	4.2%	0.4%	4.4%	0.3%	8.9%	0.3%	9.7%	0.0%
Autumn	1	Leaf	98.4%	67.7%	94.9%	89.0%	98.3%	89.5%	94.0%	93.8%
		Stem	0.0%	1.2%	0.0%	1.1%	0.0%	1.1%	0.0%	0.0%
		Dead	1.1%	26.8%	0.7%	8.5%	0.3%	5.3%	1.5%	6.2%
		Seedhead	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Unsown spp	0.5%	4.3%	4.4%	1.4%	1.4%	4.2%	4.5%	0.0%
	2	Leaf	84.0%	84.9%	93.9%	90.2%	84.9%	87.7%	86.9%	85.6%
		Stem	0.0%	0.9%	0.0%	0.6%	0.0%	0.0%	0.0%	0.5%
		Dead	6.8%	14.2%	3.3%	9.2%	2.4%	12.3%	0.6%	13.4%
		Seedhead	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Unsown spp	9.3%	0.0%	2.8%	0.0%	12.7%	0.0%	12.5%	0.5%

3.A.2 Botanical composition of the sward upper stratum for the L_Rye species-contrast during the periods of summer and autumn.

			Height of the preferred species (cm)							
			4		6		8		10	
Season	Period	Part	Lotus	Ryegrass	Lotus	Ryegrass	Lotus	Ryegrass	Lotus	Ryegrass
Summer	1	Leaf	43.2%	42.1%	30.0%	26.7%	36.3%	39.7%	34.0%	37.3%
		Stem	36.4%	18.0%	30.1%	18.7%	39.4%	21.3%	28.3%	26.5%
		Dead	20.4%	23.8%	20.3%	18.9%	24.3%	22.1%	19.3%	19.2%
		Seedhead	0.0%	16.1%	0.0%	15.8%	0.0%	16.9%	0.0%	16.9%
		Unsown spp	0.0%	0.0%	19.6%	19.9%	0.0%	0.0%	18.3%	0.0%
	2	Leaf	31.9%	85.8%	38.8%	88.4%	39.0%	83.8%	47.0%	67.9%
		Stem	43.8%	1.3%	46.0%	2.6%	48.2%	3.7%	23.1%	7.9%
		Dead	11.9%	12.3%	6.8%	7.9%	7.6%	7.9%	0.6%	20.7%
		Seedhead	1.9%	0.0%	1.2%	0.5%	0.4%	2.1%	23.4%	3.6%
		Unsown spp	10.5%	0.6%	7.2%	0.5%	4.8%	2.6%	6.0%	0.0%
Autumn	1	Leaf	68.1%	93.0%	25.0%	95.4%	33.3%	66.3%	47.0%	86.5%
		Stem	8.5%	0.0%	5.7%	0.0%	7.1%	2.4%	27.2%	0.0%
		Dead	3.7%	5.3%	11.3%	4.6%	6.1%	15.4%	1.5%	10.0%
		Seedhead	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Unsown spp	19.7%	1.8%	58.0%	0.0%	53.5%	16.0%	24.3%	3.5%
	2	Leaf	22.8%	88.2%	42.7%	88.1%	60.3%	89.6%	57.0%	85.1%
		Stem	9.5%	0.7%	14.2%	0.5%	13.4%	0.5%	10.5%	1.1%
		Dead	17.7%	9.8%	9.2%	11.4%	3.2%	8.0%	9.9%	7.4%
		Seedhead	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Unsown spp	50.0%	1.3%	33.9%	0.0%	23.1%	1.9%	22.6%	6.3%

3.A.3 Botanical composition of the sward upper stratum for the L_Red species-contrast during the periods of summer and autumn.

			Height of the preferred species (cm)							
			4		6		8		10	
Season	Period	Part	Lotus	Red clover	Lotus	Red clover	Lotus	Red clover	Lotus	Red clover
Summer	1	Leaf	29.0%	48.9%	29.4%	38.4%	39.8%	31.3%	43.1%	78.1%
		Stem	27.3%	15.3%	29.0%	0.0%	35.6%	15.2%	36.9%	0.0%
		Dead	23.1%	20.3%	23.2%	23.3%	24.6%	35.3%	20.0%	21.9%
		Seedhead	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Unsown spp	20.7%	15.5%	18.3%	38.4%	0.0%	18.2%	0.0%	0.0%
	2	Leaf	15.5%	83.3%	26.1%	73.4%	26.7%	63.9%	51.5%	79.7%
		Stem	54.7%	0.0%	62.4%	2.7%	51.5%	4.7%	44.3%	1.8%
		Dead	16.4%	16.7%	6.5%	23.9%	6.9%	30.4%	2.2%	14.0%
		Seedhead	3.4%	0.0%	1.0%	0.0%	3.1%	0.8%	1.4%	4.4%
		Unsown spp	9.9%	0.0%	3.9%	0.0%	11.8%	0.3%	0.6%	0.0%
Autumn	1	Leaf	20.7%	52.3%	13.1%	29.7%	8.3%	42.9%	50.0%	45.2%
		Stem	27.2%	0.0%	3.9%	0.0%	1.4%	0.0%	11.6%	0.0%
		Dead	15.7%	6.0%	3.1%	4.8%	2.9%	0.7%	1.4%	2.6%
		Seedhead	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Unsown spp	36.4%	41.7%	79.9%	65.5%	87.4%	56.4%	37.0%	52.2%
	2	Leaf	5.8%	30.0%	22.3%	64.3%	48.1%	23.4%	25.5%	62.7%
		Stem	3.7%	0.0%	4.7%	0.0%	8.9%	0.0%	3.5%	1.6%
		Dead	19.6%	5.8%	6.3%	8.5%	14.3%	5.4%	4.8%	9.8%
		Seedhead	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Unsown spp	70.9%	64.2%	66.7%	27.3%	28.6%	71.3%	66.2%	25.9%

3.B.1 Botanical composition of the sward upper stratum for the W_Rye species-contrast during the intake/diet composition periods.

		Height of the preferred species (cm)							
		4		6		8		10	
Month	Part	W clover	Ryegrass	W clover	Ryegrass	W clover	Ryegrass	W clover	Ryegrass
December	Leaf	97.0%	46.6%	92.1%	59.6%	98.3%	50.9%	97.8%	72.0%
	Stem	0.0%	19.2%	0.0%	14.7%	0.0%	14.9%	0.0%	15.9%
	Dead	0.9%	32.0%	0.9%	23.2%	0.7%	32.9%	0.4%	10.6%
	Seedhead	0.9%	0.0%	0.3%	0.0%	0.7%	0.0%	0.7%	0.0%
	Unsown spp	1.3%	2.3%	6.7%	2.5%	0.3%	1.2%	1.1%	1.5%
January	Leaf	85.0%	63.5%	88.0%	69.5%	84.8%	89.3%	83.2%	68.7%
	Stem	0.0%	6.6%	0.0%	3.6%	0.0%	1.7%	0.0%	0.0%
	Dead	13.4%	26.6%	7.0%	21.6%	10.0%	6.2%	7.9%	28.2%
	Seedhead	1.6%	1.0%	2.0%	3.0%	0.9%	0.0%	2.5%	2.7%
	Unsown spp	0.0%	2.3%	3.0%	2.4%	4.2%	2.8%	6.5%	0.3%

3.B.2 Botanical composition of the sward upper stratum for the L_Rye species-contrast during the intake/diet composition periods.

		Height of the preferred species (cm)							
		4		6		8		10	
Month	Part	Lotus	Ryegrass	Lotus	Ryegrass	Lotus	Ryegrass	Lotus	Ryegrass
December	Leaf	51.4%	65.9%	47.3%	58.8%	28.6%	74.2%	56.2%	64.1%
	Stem	45.0%	24.2%	41.2%	20.9%	59.0%	14.6%	39.5%	29.1%
	Dead	2.8%	7.9%	2.7%	7.9%	6.2%	7.3%	0.6%	6.8%
	Seedhead	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Unsown spp	0.9%	2.0%	8.8%	12.4%	6.2%	4.0%	3.7%	0.0%
January	Leaf	17.5%	88.1%	29.5%	84.9%	31.1%	82.7%	21.5%	74.9%
	Stem	55.6%	5.1%	51.3%	6.1%	52.6%	5.8%	10.9%	7.4%
	Dead	24.8%	4.0%	12.0%	3.9%	8.0%	2.6%	3.3%	6.9%
	Seedhead	0.0%	1.7%	6.4%	5.0%	0.2%	8.9%	5.0%	10.8%
	Unsown spp	2.1%	1.1%	0.9%	0.0%	8.0%	0.0%	59.3%	0.0%

3.B.3 Botanical composition of the sward upper stratum for the L_Red species-contrast during the intake/diet composition periods.

		Height of the preferred species (cm)							
		4		6		8		10	
Month	Part	Lotus	Red clover	Lotus	Red clover	Lotus	Red clover	Lotus	Red clover
December	Leaf	28.1%	96.2%	47.7%	67.6%	55.6%	82.5%	45.5%	94.2%
	Stem	22.7%	0.0%	41.6%	0.0%	41.7%	0.0%	41.7%	0.0%
	Dead	6.3%	0.4%	4.2%	1.7%	1.7%	0.0%	12.1%	1.0%
	Seedhead	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Unsown spp	43.0%	3.3%	6.5%	30.7%	1.1%	17.5%	0.6%	4.8%
January	Leaf	20.8%	75.4%	16.9%	86.7%	32.3%	70.7%	29.7%	71.9%
	Stem	49.3%	7.3%	43.1%	1.2%	51.5%	10.1%	51.1%	6.6%
	Dead	26.1%	9.0%	32.2%	12.1%	14.5%	18.9%	5.8%	11.8%
	Seedhead	0.0%	1.4%	0.0%	0.0%	0.0%	0.3%	0.9%	4.5%
	Unsown spp	3.8%	6.9%	7.8%	0.0%	1.7%	0.0%	12.5%	5.1%

"And for afters I'll settle for a mouthful or two of *Lotus corniculatus*"

Taken from: Newsletter IGER. No. 35 May 1995. Massey University. New Zealand.