# A STUDY OF SPRING GRAZING MANAGEMENT EFFECT ON SUMMER-AUTUMN PASTURE AND MILK PRODUCTION OF PERENNIAL RYEGRASS x WHITE CLOVER DAIRY SWARDS

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## ABSTRACT

Evidence generated at Massey University demonstrated the importance of the manipulation of ryegrass reproductive growth during spring to pasture production. It showed that lax grazing of pastures during spring followed by hard grazing at the time of anthesis could result in an enhancement of summer-autumn herbage production, associated with an enhanced tillering activity of ryegrass plants. Such grazing management was called "late control", and it was thought to be an option for enhancing pasture production, particularly in dairy farms, where conditions for manipulating reproductive swards would be most favourable. Thus, the objectives of this study were (i) to evaluate the effects of this late control spring grazing management on summer-autumn herbage production and botanical composition of ryegrass-white clover dairy pastures, and (ii) to investigate the consequences of such a grazing management strategy on pasture quality, herbage intake and milk production by dairy cows.

Three field experiments are reported. The first two were sward-based experiments whose results were used to plan and set up the third experiment, which involved evaluation of both sward and animal effects.

The results from Experiment 1 (October 1990 to April 1991) and 2 (October 1991 to April 1992) confirmed the expectations of enhanced spring and summer-autumn herbage accumulation from a late control grazing management over the spring time. An average increase in production of the order of 750 Kg DM/ha (25%) was obtained from October to November, and of 1.0 t DM/ha (20%) was obtained from January to April in both years, with ryegrass accumulation being enhanced in Experiment 1 and white clover accumulation enhanced in Experiment 2. Evidence gathered about tillering activity was inconclusive, although it showed that tillers produced under the late control spring grazing management were bigger than those produced under the conventional hard grazing management. White clover response was variable from year to year. It was concluded that the timing as well as the intensity of execution of the late control were very important. Late control should be executed at the time of anthesis of the reproductive development of ryegrass plants (late November-early December), and the removal of seedheads and reproductive stems should be gradual, over two or three successive grazing cycles.

Simulation of the implementation of this late control grazing management on a farm basis was then performed, based on the results from Experiments 1 and 2, in order to gain an overview about possible practical implications for farm practice. The models showed that the preparation of pastures to achieve the reproductive stage prior to late control was feasible and would not imply any decrease in the feeding level of dairy cows. However, more information was necessary on how to execute late control and whether or not the increased summer-autumn herbage accumulation could be converted to milk production.

Further evaluation of late control grazing in Experiment 3 (October 1992 to April 1993) revealed that increase in spring herbage accumulation by 1000 Kg DM/ha (25%) was a consequence of the reproductive growth of perennial ryegrass plants, which caused a decrease in the digestibility of the herbage consumed from 78% to 75% due to the increased contents of senescent and grass stem material in the sward. On the other hand, increased summer-autumn herbage accumulation (1000 Kg DM/ha, 25%) after late control was due to enhanced accumulation of both ryegrass and white clover. The digestibility of the herbage was restored soon after late control. Despite the lower digestibility of reproductive swards during the control period, no significant reduction in the herbage intake of dairy cows was detected in comparison with animals grazing leafy and vegetative swards. However, the use of forage conservation to augment grazing pressure during the late control phase proved to be more effective than a grazing only strategy, since a large proportion of senescent material was allowed to form under those circumstances. The increase in summer-autumn herbage accumulation was associated with an increase in milk solids yield per cow of the order of 10%, with around 25 Kg milk-fat being obtained from the extra tonne of dry matter accumulated per hectare in late control pastures.

It is concluded that the late control spring grazing management of perennial ryegrass-white clover pastures can be used as an option to enhance pasture production in dairy farms, particularly during the summer-autumn period, and that this increased herbage accumulation can be effectively converted to milk solids yield. The implementation of this grazing strategy into a farm context and its implications for farm practice are briefly discussed.

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# *Chapter 1:*

## INTRODUCTION AND OBJECTIVES

Dairy farming in New Zealand employs unique strategies in comparison to other major dairying areas of the world. The favourable climatic conditions allow almost complete reliance on grazed herbage as the sole diet for livestock throughout most of the year. Recent surveys have shown that grazed pasture comprises around 85% of the total feed consumption in a typical seasonal dairy farm, the balance being completed by other farm grown (crops, hay or silage - 5%) and purchased feeds (hay, silage, feedstuffs - 10%) (Brookes & Holmes, 1988). As a consequence, a strong ecological consciousness and research base have been developed over the years. This has resulted in low cost systems of animal production, which are characterised by very high levels of utilisation of the forage grown.

High levels of animal productivity require high levels of pasture production and utilisation as well as a favourable balance between grasses and legumes. The achievement of such a goal requires the knowledge and understanding of plant responses to varying defoliation regimes and their influence upon animal responses. The pasture response to defoliation and its pattern of production have been the subject of considerable research and of many reviews worldwide and in New Zealand over the years (e.g. Korte & Harris, 1987b; Hunt & Easton, 1989). Much work has been put into understanding sward responses to manipulation by cutting or grazing, with the aim of optimising herbage production. As a consequence, the importance of frequency and intensity of defoliation, carbohydrate reserve levels, light environment, tiller dynamics, tissue turnover and their inter-relationships in determining pasture performance has been well demonstrated.

Recent evidence has highlighted the importance of spring grazing management of pastures in determining sward composition and production. The spring period is critical in terms of grazing management once pasture growth rates exceed animal feed requirements. Lax grazing at this time encourages the production of low quality herbage with subsequent low pasture growth rates, because of poor light environment, high tiller death rates and low tiller density associated with uncontrolled reproductive swards. A series of research papers (Korte, 1982; Korte *et al.*, 1982, 1984, 1985; Korte, 1986; Butler, 1986; Korte & Harris, 1987a; L'Huillier, 1987a) have discussed manipulation of reproductive growth in terms of the ensuing trade off between quantity and quality of the herbage grown. Such manipulation of reproductive growth can cause substantial changes in total and green herbage accumulation, with flow-on effects on the performance of grazing animals, particularly dairy cows (Thomson *et al.*, 1984; Bryant & L'Huillier, 1986; L'Huillier, 1987b,1988; L'Huillier & Aislabie, 1988; McCallum *et al.*, 1991; Hoogendoorn *et al.*, 1988,1992). On the other hand, Matthew *et al.* (1989b), Xia *et al.* (1990), and Matthew (1992) have provided evidence that manipulation of a sward during the reproductive phase can affect subsequent tillering activity and potential pasture production. These studies were all plot trials based on very specific and objective sward targets, and highlight the need for further research which would develop recommendations of spring control of reproductive growth considering tiller dynamics, pasture quality and animal performance.

Generally, research work on the optimum spring/summer grazing management, especially for dairy pastures, has been carried out using grazing management strategies defined in terms of stocking rate and rotation length (e.g. Bryant & L'Huillier, 1986; L'Huillier, 1987b,1988), and it is under those circumstances that animal responses have often been measured. Fixed stocking rates and grazing intervals are characterised by inconsistent effects upon the balance between sward and animal, since changes in sward state are transient and uncontrolled under those circumstances (Hodgson, 1985). A proper understanding of the effects of variation in sward conditions upon plant and animal performance, and of their sensitivity to management interference, can only be achieved in studies based on the control and manipulation of specific sward characteristics either in a state of equilibrium or in some specified pattern of change (Hodgson, 1985).

With this background in mind, the current study sought to bring together understanding of pasture responses to well defined spring grazing management regimes and their impact on dairy cow performance. Accordingly, the experimental objectives were:

(i) To evaluate the effects of contrasting spring grazing management on summer-autumn herbage production and botanical composition in ryegrass-white clover dairy pastures;

(ii) To investigate the consequences of these grazing management policies for summer-autumn milk production by dairy cows.

# *Chapter 2:*

# LITERATURE REVIEW

## 2.1. Introduction and overview

New Zealand systems of animal production are based almost exclusively on grassland farming. Pastures are mainly perennial ryegrass/white clover mixtures which grow all year round as a consequence of favourable climatic conditions. Milk production has long been based on the conversion of pasture into milk by grazing cows, with small quantities of silage and hay fed per cow and very little or no use of concentrate meals (Holmes & Wilson, 1984). This leads to an almost complete reliance on grazed pasture as the sole source of feed to the animals, although seasonality of pasture production has to be accommodated in order to optimise herbage utilisation and animal performance.

Against this background reflecting the importance of pasture production and its seasonality to the pastoral based milk production systems of New Zealand, the following review of literature focuses on the importance of understanding grazing management of pastures and its influence on milk production and dairy cow performance. It establishes a link between grazing management effects, particularly during spring, and dairy cow performance under the seasonal nature of grassland systems in New Zealand. In view of the breadth of the subject matter covered, use has been made of existing authoritative reviews of original material to provide an information base. Original references are cited where they are particularly relevant to the discussion.

## 2.2. Grassland farming systems and seasonality of pasture production

Output from grassland areas in New Zealand has been considerably improved over the last 50 years due not only to the introduction of aerial topdressing and oversowing, but also to improved efficiency of pasture utilisation (proportion of the herbage grown which is harvested by either cutting or grazing) arising from increased understanding of the factors that limit and promote growth (Hunt & Easton, 1989). Herbage growth is understood as the development and increase in size and weight of new leaf and stem tissue. The balance between the rate of growth of new plant material and the rate of loss due to senescence and decomposition correspond to herbage accumulation or the net accumulation of herbage dry matter in the sward (Hodgson, 1979).

Ideally, grassland farming seeks to match pasture growth with animal requirements. Successful husbandry, therefore, depends upon full knowledge of both seasonal distribution of pasture production and the nutritional requirements of animals with changing physiological states throughout the year (Roberts & Thomson, 1984ab). However, complete matching of pasture growth and animal requirements is rarely achieved. The exact pattern of surplus and deficit varies from year to year, and with geographical location of the farming enterprise (Roberts & Thomson, 1984ab). In most farming districts of New Zealand, the production of feed from pastures over the summer frequently falls below stock requirements (Brougham, 1970), probably due to moisture stress (Brock, 1974) and, in dairy pastures, reduced sward tiller density (L'Huillier, 1987b). The other period of feed shortage is in late autumn, winter and early spring (Brougham, 1970), with a surplus period being observed during spring.

Where grazing is practised throughout the year, changes in the seasonal pattern of pasture production can have important consequences on animal production since a continuous supply of food is required. The extent to which seasonality of herbage production is important depends upon whether forage can be conserved or held over, the type of animal production enterprise (such as milk, wool or lamb production), and the degree to which body reserves of grazing animals can act as buffer against variations in food supply (Korte & Harris, 1987b).

The seasonal growth pattern of a pasture is determined largely by the growth rhythms of its dominant species. By manipulating grazing management, the pattern of seasonal pasture growth can be altered and thus synchronised more closely with livestock feed requirements, although the extent to which seasonal pasture production may be modified in this way is limited (Sithamparanathan, 1979). Defoliation at a particular time of the year may change species dominance, since plants may be at different stages in their annual physiological or morphological cycle. This change in botanical composition can further influence the total and seasonal distribution of herbage production and forage quality (Korte & Harris, 1987b). More frequent and intense defoliation of pastures often improves the seasonal pattern of herbage production by reducing the spring growth, although that is usually at the expense of total annual dry matter yield (Korte & Harris, 1987b).

New Zealand pastures consist, basically, of a mixture between perennial ryegrass and white clover. Both species possess quite distinct plant biological characteristics and, for that reason, different grazing managements are likely to generate different patterns of response according to each species. Thus, the morphological and physiological characteristics of ryegrass and white clover plants are outlined in the following section with the objective of providing an understanding of the differences in behaviour when plants are submitted to varying defoliation regimes and, more importantly, opportunities to manipulate them to advantage.

## 2.3. Characteristics of perennial ryegrass and white clover plants

This section deals with aspects of the biology of perennial ryegrass and white clover plants and their response to grazing management. Features of the two species are discussed separately for ease of presentation.

### 2.3.1. Perennial ryegrass (*Lolium perenne* L.)

Perennial ryegrass constitutes the major grass species of mixed pastures in New Zealand. It is well adapted to the environmental conditions in most of the country and is compatible with white clover, its common associate pasture species.

#### 2.3.1.1. Plant biology

According to Hunt & Field (1979), in order to capitalize on the growth potential of a pasture species such as ryegrass, it is necessary to understand both the basic structure of the plant and how the functional organs are affected by the stresses imposed in a pasture environment.

Hunt & Field (1979) also provide a description of perennial ryegrass plants, which will be summarised in this section. According to these authors, the basic unit of production in grasses is the tiller. It is essentially a single growing point encased in the sheaths of the leaves which grow from it, bearing its own root system, and having the capacity to develop new generations of tillers from buds at the bases of individual leaves (Jewiss, 1972; Hunt & Field, 1979; Hodgson, 1990). Before the formation of an adventitious root system, the young tillers are clearly dependent on the parent. After the root system is formed, a tiller may function as an independent unit but revert in times of stress, such as defoliation, to a degree of dependence of the parent plant (Kays & Harper, 1974). The life span of individual tillers varies from a few weeks to more than a year, so the continued production of new tillers which replace senescent or reproductive tillers ensures the perenniality of the plant (Hunt & Field, 1979).

Perennial ryegrass grows well in a range of temperatures varying from 15 to 20 °C (Hunt & Field, 1979; Davies, 1992). Tillers are induced to flower by low winter temperatures followed by increasing day length. About 6 weeks of cold (below about 10 °C) are required to fully vernalize perennial ryegrass (Hunt & Field, 1979). Reproductive tillers are incapable of further leaf or tiller initiation because floral parts are formed at the apical growing points. The previously compact stem elongates during head emergence from the growth of internodes to project the apex above the leaf canopy. The spring period, when a high proportion of tillers are reproductive, is when maximum above-ground growth rates are observed (Davies, 1973). Growth is considerably faster than when all tillers are vegetative even under the same conditions of season and weather. Such a difference in growth rate arises from the more efficient utilisation of light for growth by reproductive swards (Leafe *et al.*, 1974). Several explanations can be offered for such a phenomenon: (a) increasing levels of radiation in spring allow levels of optimum leaf area index (LAI) and ceiling yield to be advanced progressively; (b) during reproductive growth in spring more assimilates are partitioned to the shoot from the root (Ryle, 1970), so that a greater proportion of net synthesis is accessible for harvest during flowering; (c) stem extension, promoted by reproductive growth, results in new leaves emerging and developing higher in the sward where there is more light (Leafe *et al.*, 1974); and (d) a growth response when tillers are transferred from cold to warm environment (Davies *et al.*, 1989).

Perennial ryegrass swards consist of a dynamic population of short-lived tillers of different origins and ages. The survival of an individual plant depends on the balance between the production of new tillers and the death of established tillers, and as there are marked seasonal flushes in tiller production and death, perenniality is not always guaranteed (Colvill & Marshall, 1984). Rates of appearance, growth, and death of tillers in swards determine production, persistence, and in mixed swards, the contribution of grasses to the sward botanical composition (Hunt & Field, 1979; Korte *et al.*, 1985; L'Huillier, 1987b). The knowledge of tiller population dynamics assists interpretation of agronomic studies, and provides basic information for improvement of grassland management (Korte, 1986).

Studies of the life-history of several grasses have consistently revealed a significant turnover in tiller populations and a recurring pattern of high mortality which occurs during each period of active growth (Ong *et al.*, 1978). In perennial ryegrass there are, usually, two periods of active tillering. The first, in spring, continues until internode elongation starts, and the second begins at anthesis and continues until winter (Korte, 1986). At times, either period of rapid tillering may be absent, or suppressed by competition from other species (Garwood, 1969). Under grazing management experiments a more seasonal pattern of tillering has been observed, with rates of tiller appearance being low during autumn, winter and early spring, and increasing to a maximum level during late spring (Korte, 1986; L'Huillier, 1987b; Matthew, 1992). Tiller death is normally greatest during reproductive growth, initially resulting from death of vegetative tillers, and later from death of defoliated reproductive tillers (Korte, 1986).

Recently, vegetative propagation by means of stolon formation has been demonstrated in perennial ryegrass plants, a stolon being defined as a stem with one or more rooted elongated internodes (at least two separated nodes having roots) running on the soil surface or growing in the soil (Korte

& Harris, 1987a). Ryegrass stolons play an important role in tiller replacement (Matthew, 1988), and can develop from the base of procumbent buried tillers in spring, either when vegetative tillers develop elongated internodes and roots, or when reproductive tillers develop subsidiary tillers and roots from buried nodes (Matthew *et al.*, 1989a).

It has been suggested (Matthew *et al.*, 1989a) that ryegrass plants undergo a seasonal cycle of burial and replacement of tillers very similar to that described for white clover plants (Section 2.3.2.1). During winter, earthworm casting, animal treading, and dung deposition result in partial burial of ryegrass plants (Korte & Harris, 1987a; Matthew *et al.*, 1989a). A major seasonal stolon formation event coincides with burial of tillers after the autumn rain and stolon length increases during spring, just before the onset of reproductive growth (Matthew *et al.*, 1989a).

#### 2.3.1.2. Plant responses to grazing management

Grazing management has a major modifying influence on most processes in pastoral systems. Not only does it influence plant growth and morphology, but also the nutrient economy of the pasture growth through changes in the quantity and quality of soil organic matter (Brock *et al.*, 1989). The results of cutting trials which have been designed to provide information on grazing frequency and intensity in pasture rotations have, in both temperate and tropical regions, often shown that lax and infrequent cutting promotes higher dry matter production than does more intensive and frequent cutting (McMeekan, 1960; Anslow, 1967; Agyare & Watkin, 1967), except on prostrate rhizomatous and stoloniferous pastures. These results have, however, seldom been successfully translated into increased animal production in grazing studies where the negative association frequently observed between dry matter production and both herbage quality and its degree of utilisation often negates the increased production resulting from lax and infrequent grazing. Added to this are the longer term effects of spelling interval and grazing intensity on sward density and botanical composition, effects which vary through the season as the morphological condition of the pasture species changes (Tainton, 1974).

Numerous workers have highlighted the close relationship between leaf area index, light interception, and pasture growth (Brougham, 1956, 1957; Anslow, 1965; Brougham & Glenday, 1967; Anslow & Back, 1967; Davies, 1974; Parsons *et al.*, 1988ab). As a result, many pasture management systems have been proposed with the objective of maximizing light interception in order to obtain high annual yields. However, among many other factors that influence pasture production, dry matter losses through tissue death and decay are also important determinants of net pasture productivity. These loss processes restrict dry matter accumulation towards the later stages of regrowth in grass/clover swards (Korte & Harris, 1987b).

The characteristic pattern of dry matter yield on an intensively managed perennial ryegrass sward reflects the annual pattern of radiation, the balance between photosynthesis and losses by respiration and death, and the varying distribution of assimilates above and below ground (Leafe *et al.*, 1974). Net dry matter production, therefore, is ruled by growth of new herbage and death and disappearance of old herbage. Agronomic practices can affect both processes, and thus it is important that both be measured if dry matter accumulation patterns are to be adequately explained (Korte & Sheath, 1979).

More frequent and intense defoliation, whether by cutting or grazing, generally reduces pasture growth (McMeekan, 1960; Anslow, 1967; Agyare & Watkin, 1967), but may not always reduce the amount of forage harvested. Reductions in growth with more frequent and intense defoliation may be wholly or partially compensated for by improved utilisation, and therefore by reduced losses of unharvested herbage (Bircham & Hodgson, 1983; Grant *et al.*, 1983; Korte *et al.*, 1984; Korte & Harris, 1987b; L'Huillier, 1987ac; Xia *et al.*, 1990). This balance between growth and senescence in response to management manipulation provides an 'homeostatic' mechanism which limits change in the net rate of herbage accumulation per unit area (Grant *et al.*, 1985).

Differences in response to defoliation occur because of differences in removal of photosynthetic area and meristems, bud regeneration, flowering, seed production, soil seed reserves and seedling regeneration (Korte & Harris, 1987b). The effect of more frequent and intense defoliation has been attributed to: (1) reduced interception of light by photosynthetic tissue; (2) depletion of metabolic reserves; (3) reduced uptake of nutrients and water; and (4) damage to meristems or depletion of seed reserves. The relative importance of these factors depends on environmental conditions and pasture species (Harris, 1978).

Under favourable environmental conditions, the growth rate of pastures increases with increasing leaf area and associated light interception, the maximum growth rate being reached when 95 to 100% of light is intercepted (Korte & Harris, 1987b). More frequent and intense defoliation reduces leaf area and so reduces light interception and growth (Brougham, 1956).

After defoliation, metabolites for the production of new shoot and root structures come from either current photosynthesis or metabolic reserves accumulated in roots and growing points during the previous regrowth period (Brougham, 1957). Reserves are likely to be of greater importance when the residual leaf area is small, or where the residual leaf area has a low photosynthetic efficiency (Brougham, 1957; Korte & Harris, 1987b). Frequent intense defoliation, by reducing the opportunity for replenishment of reserves, can result in slower pasture growth. The importance of reserves varies considerably with species and environment, reserves being most important where climatic extremes of drought or low temperature seriously reduce growth for prolonged periods (Harris, 1978).

Frequent and intense defoliation could reduce uptake of nutrients and water from soil by three possible mechanisms (Harris, 1978): (i) reduction in root growth following defoliation, so limiting exploitation of nutrients and water; (ii) reduction in transpiration, so restricting absorption of nutrients; and (iii) reduction in assimilate levels, from reserves and photosynthesis, limiting active ion uptake (Korte & Harris, 1987b).

More recently, factors governing the behaviour of tiller populations and the effects of variation in grazing management during sward reproductive growth in spring have been the object of much research work on grassland environment in New Zealand. Among the findings are the importance of stocking rate in determining pasture and animal production by effectively balancing pasture growth rates and animal demand, and the manipulation of tiller populations as a mean of fine-tuning grazing management systems. Such topics are reviewed in more detail in Section 2.4.

### 2.3.2. White clover (*Trifolium repens* L.)

White clover is recognised as perhaps the most important forage legume in the temperate zones of the world (Davies, 1992). New Zealand is particularly fortunate in the sense that its temperate climate is generally conducive to strong white clover growth in most of the intensively farmed regions of the country (Brock *et al.*, 1989). New Zealand pastoral agriculture is based on ryegrass/white clover mixed swards with a small input of nitrogen fertiliser. The main source of the nitrogen element to the soil-plant system is microbial fixation. It has been estimated that biological nitrogen fixation provides an annual input of upwards of one million tonnes of elemental nitrogen to New Zealand soils, equivalent to 98% of the total nitrogen input each year (Syers, 1982).

#### 2.3.2.1. Plant biology

White clover growth depends upon the extension and repeated branching of a series of prostate stems (or stolons) which grow along the soil surface from the crown of the original plant (Hodgson, 1990). Finely rooted daughter plants develop from nodes on the stolons, eventually taking the place of the tap rooted mother plant which dies out (Frame, 1992). Nodes develop at intervals along the stolons and are the sites for the formation of leaves, roots and buds with the potential for new branches (Hodgson, 1990). The stolon branch is therefore the unit of growth most directly analogous to the grass tiller (Hodgson, 1990) and is positively related to the amount of clover production (Frame, 1992). In established pastures white clover grows forward at the apices and dies from the stolon base towards the apex (Hay *et al.*, 1988). Rotting of older basal portions of stolons causes the severance of branch stolons which then form new plants (Chapman, 1983).

Davies (1992) provided a general description of white clover plants which will be summarised in this section. White clover grows well in a range of temperatures varying from 18 up to 30 °C, the optimum being 24 °C. Growth rates drop quite drastically at temperatures below 10 °C (Brock *et al.*, 1989; Davies, 1992). Throughout the summer a succession of flowers is produced. These develop from axillary buds in place of branch stolons when day length and temperature conditions are favourable. Optimum day lengths for flowering in different varieties are normally 14 hours or more. Temperature is particularly important, with differences of only a few degrees having a marked effect on reproductive bud development. Increased temperatures can, to some extent, override the inhibitory effect of short days. By contrast, periods of cold induction may increase the number of reproductive buds, even if such a period is not required for flower initiation (Davies, 1992).

White clover populations in all grazed pastures throughout New Zealand follow a seasonal pattern of death and renewal which can affect persistency. During winter, treading and earthworm activity combine to bury in excess of 90% of clover stolons, and new stolons must be re-established on the soil surface over spring and summer (Hay *et al.*, 1987). At most times of the year the processes of new stolon formation and old stolon death are in balance and the structure of the population of white clover remains relatively constant (Brock *et al.*, 1989). Stolon biomass studies have shown that large quantities of older buried stolon die and decay probably as a result of internal plant stress caused by the demands of increased growth in spring (Hay *et al.*, 1983). Those events induce stolon death to exceed formation, so that plants reduce in size and complexity, larger plants breaking up into several smaller ones, before the equilibrium is re-established over summer. At this point the plant population is fragile and susceptible to mismanagement or environmental stresses such as early drought (Brock *et al.*, 1989). This cycle is thought to be important in the regeneration and persistence of white clover (Hay *et al.*, 1987).

While producing high quality feed, the principal role of white clover lies in its ability to efficiently supply the nitrogen essential to sustain highly productive pastures (Davies, 1992). Recent studies estimate that for developed pastures in New Zealand, annual-fixation inputs range from 100 to 350 Kg/ha (Brock *et al.*, 1989). Fixation is carried out by soil bacteria (*Rhizobium trifolii*) which infect the roots and stimulate the formation of nodules, in which they survive, using the carbon fixed by the clover leaves as a primary energy supply. Fixed nitrogen is transferred to the grass in the urine and dung of the animals grazing the sward and also (but less rapidly) as clover leaves, nodules, roots and stolons decay and release nitrogen to the soil (Davies, 1992).

### 2.3.2.2. Plant responses to grazing management

Like other pasture plants, white clover is well adapted to grazing. The terminal stolon growing points normally remain close to the ground, where they are largely protected from the grazing animal, which consumes the leaflets and part of the petiole. It responds to defoliation by mobilising carbohydrate from the stolons, where it accumulates chiefly in the form of starch (Davies, 1992), and by increasing its specific leaf area (SLA) (leaf area/unit mass) (Chapman *et al.*, 1990). The carbohydrate level in stolons is restored as new leaves develop and photosynthate is once again exported from the leaves (Davies, 1992).

White clover is often perceived as being an unreliable crop because its contribution to total yield in mixtures varies within and between years. This 'unreliability' may result from several factors, including inappropriate management and incorrect choice of cultivars (Collins *et al.*, 1991). Usually, small-leaved varieties are indicated for continuous grazing and larger-leaved varieties for rotational grazing and cutting (Davies, 1992). However, responses to environmental and biotic factors are also implicated in the inconsistency of clover yield in mixtures. Biotic factors with which clover may interact include the companion grass, *Rhizobium* bacterium and grazing management (Collins *et al.*, 1991).

The number of leaves remaining after defoliation is associated with the internal balance of carbon and influences the morphological development of the white clover. Plants under defoliation usually present lower total soluble carbohydrate levels, smaller number of branches produced on the main stolon and lower stolon extension when one leaf rather than two is left per stolon after defoliation, although stolons defoliated continuously to maintain one leaf can sustain growth for considerable period of time. More severe defoliation can affect branch numbers both by reducing the number of nodes on the main stolon and also by reducing the capacity of the axillary buds at each node to develop into branches (Jones & Davies, 1988; Grant *et al.*, 1991). These morphological changes have been found to be closely related to the persistency, production and proportion of white clover in mixed grass/clover swards (Hay *et al.*, 1988; Brock *et al.* 1988).

Several characteristics of stolon material below grazing height such as branching/density, number of growing points, stolon mass, and stolon length have been related to the production and persistence of white clover. Thus conditions for stolon growth have implications for total sward productivity (Hay *et al.*, 1987).

Frequent defoliation (as in a heavily stocked, continuously grazed sward) results in plants with short petioles and small leaves (Wilman & Shrestha, 1985; Davies, 1992). Stolon extension is much reduced and die-back of the older parts of the stolon is increased. Plants which are allowed to grow undisturbed for several weeks between defoliations, as in a rotational grazing system, produce long petioles, large leaves and robust stolons, although the stolon represents a smaller proportion of their dry weight (Davies, 1992).

Less frequent defoliation can enhance white clover production, and that is probably related to the level of reserve carbohydrates in the plants. Under infrequent defoliation petioles extend so that clover laminae are not shaded. The less intense defoliation leads to increased stolon growth and, presumably, under set stocking, mean stolon dry weight per plant presents a more constant pattern, ensuring a more stable white clover presence in the sward, although minimum plant weight and branching complexity are greater in rotational grazed rather than set stocked swards. These facts all indicate that under set stocking compared with rotational grazing, plants have a more limited capacity to exploit favourable conditions, but on the other hand have enhanced stability during periods of stress (Hay *et al.*, 1988).

### 2.3.3. Perennial ryegrass and white clover plants grown in mixtures

Plants growing in mixtures compete above ground for space and light, and below ground for space, water, and nutrients. When such mixtures are grazed, the type of animal, its treading and excretal patterns, and its preference or rejection of one or other partners can markedly influence the balance of species (Frame & Newbould, 1986). Man can influence the dynamics of grass/white clover swards by choice of grazing severity and pattern (timing of grazing in relation to plant species differences in their seasonality of growth and position in the canopy), and by addition of lime and fertiliser (especially nitrogen and phosphorus). Since grasses are usually taller, have a greater mass of fine roots, and have less precise requirements of climate and soil nutrition for growth, it would be expected that white clover could be at a competitive disadvantage when grown with most pasture grasses (Wolton *et al.*, 1970; Frame & Newbould, 1986). However, that is balanced by differences in leaf laminae orientation (horizontal for clover and vertical for grasses) (Barthram & Grant, 1993a) and rate of photosynthesis per unit area during the summer (higher for clover than for ryegrass) (Woledge, 1988), causing the amount of clover in the sward to increase at that time of the year. Furthermore, white clover plants have been demonstrated to possess two physiological attributes (higher specific leaf area and slower pattern of unfolding of leaves than grass) which in combination increase their capacity of growth and, under certain grazing management conditions, work to the advantage of the clover plants over the companion grass species (Parsons *et al.*, 1991ab). This lower investment of carbon per unit of leaf area (higher SLA) would place white clover at an advantage with respect to current and future carbon acquisition relative to ryegrass and, therefore, a higher degree of defoliation or selectivity for that component would be the way to ensure that white clover does not dominate. the sward (Parsons *et al.*, 1991ab).

Although there is evidence that defoliation of ryegrass/white clover swards at a late stage of growth (i.e. conservation cuts) and by long growth intervals (i.e. rotational grazing) can increase the amount of clover in the sward, results can depend on timing (Wolton *et al.*, 1970; Barthram & Grant, 1993a). The timing of the defoliation is likely to affect the balance between clover and ryegrass because of differences in their seasonality of growth (Davies, 1992). Barthram & Grant (1993a) suggested that the amount of clover in a sward will only increase as a result of less intense defoliation regimes when the clover is able to elevate its leaves sufficiently to avoid shading by the companion grass. The amount of white clover in a sward increases substantially with infrequent defoliations during the first part of the growing season when day length is increasing and total hours of sunlight are high (Wolton *et al.*, 1970; Barthram & Grant, 1993a). Lenient rotational grazing during that time causes the accumulation of ungrazed leaves on the stolons which leads to increases in the size of leaves and petioles, allowing stolons to extend and recolonize the sward at some extent. Removal of the resulting elongated reproductive stems by a silage cut or hard grazing would remove most of the grass leaf blade as well as most of the clover leaves. Although the regrowing petioles would be short, the regrowing leaflets would remain as large as they were before. The result would be an increase in the clover leaf area relative to the grass leaf area, and a short-term increase in clover content which could lead to longer-term changes in populations of grass tillers and clover growing points (Davies, 1992). In the later part of the season, with declining day length and less sunshine, clover performance seems to be more variable in grass/clover swards (Wolton *et al.*, 1970). It has been argued that this effect is a consequence of the different growth responses of ryegrass and clover to temperature and seasonal factors (Barthram & Grant, 1993a). Thus, the persistence, productivity and proportion of any one plant species in a mixed sward seems to be a function of its ability to compete for survival, which is a consequence of the plants' morphological and/or physiological state as well as their differential pattern of response to varying seasonal factors (e.g. temperature, rainfall, soil nutrient status).

## 2.4. Spring grazing management of perennial ryegrass/white clover pastures

The wide adoption of year-round rotational grazing in New Zealand, particularly with dairy cattle makes it important to determine the optimum stage of regrowth to graze pasture and the optimum grazing intensity (Korte *et al.*, 1982). Basically, grazing management comprises balancing animal intake and pasture growth in order to optimise herbage utilisation and animal production, as well as balancing the physiological effects of defoliation on plants and pasture production. Those are quite distinct objectives and may or may not be compatible with each other.

During spring, temperature, day length and total hours of sunlight increase, pushing pasture growth rate up to a point when it exceeds animal requirements. This usually coincides with the onset of reproductive growth in perennial ryegrass, further aggravating the seasonality of pasture production in grassland areas (Section 2.2). Because of the surplus of growth over animal demand and the substantial physiological effects of reproductive growth, the spring time has to be the major opportunity if there is going to be any successful physiological manipulation of plants under grazing.

The quality and pattern of herbage accumulation can be greatly influenced by grazing management, particularly during late spring/early summer (Korte, 1982; Korte *et al.*, 1982). A poor light environment and low quality herbage have normally been associated with reproductive swards (Korte, 1982), highlighting the importance of spring grazing management in regulating pasture and animal production. It is usually claimed that more intensive grazing often improves the seasonal pattern of herbage production by preventing reproductive growth and diminishing the spring surplus, and a decrease in total dry matter yield is observed in most cases under those circumstances (Korte & Harris, 1987b). Therefore, control of spring growth basically aims to prevent ryegrass from flowering by removing the apical meristem from reproductive tillers (Korte, 1982).

Higher green herbage accumulation during summer/autumn is obtained when control of late spring growth is achieved by close grazings resulting in significantly smaller amounts of dead herbage and, consequently, lower senescence losses (Korte, 1982; Korte *et al.*, 1982,1984). This constitutes the basis of the conventional spring grazing management of pastures in New Zealand ('early control'), by which early removal of seedheads as close to the ground as possible is recommended (Hughes, 1983) as a means of obtaining leafy vegetative swards in the summer and higher levels of pasture utilisation.

### 2.4.1. Tiller populations and sward productivity

Several factors can influence pasture productivity, and amongst the most important are soil moisture and fertility, rainfall, temperature, and light environment. However, there may be periods when productivity is limited by a low sward tiller population.

Recent work on spring grazing management has highlighted the importance of factors governing tiller populations and the effects of contrasting defoliation regimes during sward reproductive growth. Well-grazed short vegetative swards develop high population densities of small tillers while taller swards develop lower population densities of larger tillers. This differentiation occurs in response to competition between tillers for light. In vegetative swards which have had time to reach equilibrium with their defoliation regime and level of incident light, the relationship between tiller weight and population density conforms to the -3/2 self-thinning law described by Yoda *et al.* (1963) and Westoby (1984). Very short over-grazed swards, however, do not conform to the rule and have fewer tillers than would be expected because of frequent uprooting and possibly also a depressed rate of tiller formation (Grant & King, 1983).

The -3/2 self-thinning rule describes the relationship between mean plant size and mean plant density in a stand of plants increasing in size, and hence subjected to a density dependent mortality or a size/density compensation mechanism (Matthew *et al.*, in prep.). According to Matthew *et al.* (in prep.), in grazed swards the size/density compensation mechanism comprise four phases: (1) Low herbage mass (small tiller size): tiller carbohydrate status is low and the sward has insufficient tiller appearance to reach the self-thinning line by increasing tiller numbers; (2) Variable leaf area (regrowth phase): self-thinning at a slope close to -5/2; (3) Constant leaf area: self-thinning at a slope of -3/2; and (4) Constant herbage mass (hypothetical): self-thinning at a slope of -1. The point of transition from (2) to (3) can be considered as an indicator of the ideal grazing height for a particular species or cultivar, since if regrowth proceeds beyond this point loss of tillers is more rapid for a proportionate increase in herbage mass.

In practice tiller population densities are continually adjusting. The herbage mass in relation to the seasonal variation of incoming radiation determines the potential tiller density and factors which influence growth rate such as temperature, moisture and nutrients influence the rate at which the sward adapts (Grant & King, 1983). Differences in sward morphology which result from differences in management can have an important effect on growth rate by influencing the ability of the sward to produce new leaf (Grant & King, 1983). Tiller density, if too low, could limit pasture growth potential by limiting the number of growing leaves (leaf area). Where tiller densities are sufficient to induce tiller competition, differences in tiller density tend to be compensated by differences in growth per tiller (Hunt & Field, 1979).

A tillering flush follows defoliation and that is one mechanism leading to the commonly observed high tiller populations in frequently cut and continuously grazed swards, and low populations in infrequently cut or high-yielding swards. Another determinant of tiller density is the tiller death rate, which increases regardless of density if swards are undefoliated for long periods. Thus ryegrass tiller populations are characteristically dynamic and capable of major changes in response to season and management. No individual tiller survives indefinitely, as those surviving inter-tiller competition are eventually induced to flower and to complete their life cycle (Hunt & Field, 1979).

Tiller populations represent a balance between rates of tiller appearance and death throughout the year (Korte, 1986). As seen in Section 2.3.1.1, there are different patterns of tiller demography in ryegrass plants. However, for the current New Zealand dairy farm cultivars, such pattern seems to be rather seasonal. The highest tiller appearance rates occur in late spring/early summer, during the regrowth immediately after defoliation of the apices of the main group of reproductive tillers, followed by a decline through summer-autumn, and an increase again during winter. The highest tiller death rates also occur in late spring/early summer, followed by a decline during autumn to lowest rates in winter, and an increase again during spring. As a consequence, peaks of tiller density usually occur during late spring/early summer, when rates of tiller appearance and death are at their maximum (Davies *et al.*, 1981; Korte *et al.*, 1984,1985; Korte, 1986; L'Huillier, 1987b; Matthew *et al.*, 1989a). These facts emphasize the importance of tillering after interruption of reproductive development in determining sward persistency and production (Thom, 1991).

This mechanism of tillering is very important to the perennation of grass swards (Matthew *et al.*, 1993). There are two possible pathways for perennation by tillering. One involves production of daughter tillers by flowering tillers (reproductive pathway) and the other involves tillering by surviving non-flowering tillers (vegetative pathway). The reproductive pathway plays a major role in the perennation of perennial ryegrass and prairie grass swards, once tillers generated through the reproductive pathway produce the majority of the post-flowering tillers in the following year (Matthew *et al.*, 1993) .

Since ryegrass accumulation has been found to be significantly and positively correlated with tiller density from early summer onwards (Korte *et al.*, 1984), it can be suggested that manipulation of the tillering process through controlled spring grazing management in order to generate higher summer tiller densities could improve summer performance of both pasture and grazing animal (L'Huillier, 1987b).

There have been few studies aimed at understanding the origin of those early-summer tillers formed after the reproductive growth of perennial ryegrass plants. Available evidence from a study primarily aimed at defining root demography of a ryegrass pasture is that the majority of the new tillers form from stubs of dead tillers which have tried to flower, but have had seedheads removed, either by grazing or mowing (Matthew *et al.*, 1989a). In that study a treatment comprising a lax/hard spring grazing, allowing greater seedhead development, appeared to enhance tillering, and it was proposed that seedheads would have stimulated the appearance of daughter tillers by providing photosynthates to subsidise or encourage the early growth of young tillers (Matthew *et al.*, 1989b). Further investigation (Matthew, 1990) using a radioactive carbon tracer technique confirmed that supposition, revealing that many daughter tillers presented concentrations of radioactivity similar to that originally supplied to their parent seedheads, especially in the leaf elongation zones of the youngest tillers. This result is consistent with patterns of translocation previously reported by Colvill & Marshall (1984). Both the number and size of tillers formed are increased when greater translocation, whether of products from current photosynthesis or from mobilisation and redistribution of stored carbohydrate, from parent to daughter tillers occurs. In cases where the parent tiller is removed entirely, or translocation from parent to daughter tiller is reduced by allowing competition from developing seedheads, the number and size of daughter tillers formed is reduced (Matthew *et al.*, 1991). Therefore, increased tillering in early-summer can be expected where seedhead growth is allowed to occur, providing that the seedheads are not left too long, in which case a lot of the young tillers would die. Timing for removal of seedheads should be at anthesis in such a way as to leave stubs and some leaf (Matthew, 1991a).

Ryegrass plants are also capable of vegetative spread (Harris *et al.*, 1979). Recent evidence (Korte & Harris, 1987a; Matthew *et al.*, 1989a) shows that this vegetative spread is based on stolon formation and might be encouraged by trampling, or other factors causing burial of stolons.

Stolons can develop from vegetative or reproductive tillers (Korte & Harris, 1987a). Normal vegetative tillers elongate during spring below the soil surface with subsequent root development and daughter tiller production resulting in stolon formation in the late spring. Most tillers forming stolons over the winter flower in the following spring, and after grazing has interrupted reproductive development in late spring, reproductive tillers die and a flush of tillering and root growth occurs resulting in stolons soon after that (Korte & Harris, 1987a; Matthew *et al.*, 1989a). The highest stolon density is normally observed in late spring/early summer although grazing treatments exert little effect on number of stolons. Stolon density increases during culm elongation (flowering time) and achieves a peak after grazing has decapitated and killed reproductive tillers. Lax grazing and long regrowth periods can increase the length of stolons, and bigger numbers of internodes per stolon are usually observed in lax grazed swards (Korte & Harris, 1987a). Stolon formation is reduced by increased intensity of defoliation revealing a possible influence of carbohydrate levels within the plant on the degree of internode elongation (Matthew *et al.*, 1989a).

Vegetative spread from stolons can be responsible for a significant tiller production in late spring/early summer. Most of the tillers present in the swards at that time of the year are primary or secondary daughter tillers arising from nodes on winter-formed stolons of previously reproductive tillers, which are able to produce two or three times more daughter tillers from their stolons in the following summer than tillers originated during autumn (Matthew, 1988; Matthew *et al.*, 1989a). High peaks of tiller appearance rates in early-summer have also been previously reported (Korte, 1986; L'Huillier, 1987a), those results probably reflecting a period of tiller production from underground stolons too (Matthew *et al.*, 1989a).

Grazing management which encourages daughter tiller formation from stolons in early summer is, therefore, likely to improve persistence and summer-autumn pasture growth rates of perennial ryegrass swards (Matthew *et al.*, 1989a). Higher herbage accumulation in late summer-early winter has been reported for pastures laxly grazed in spring in comparison to those hard grazed and topped (Matthew *et al.*, 1989b; Xia *et al.*, 1990), supporting the conclusion that a lax grazing, which allows reproductive growth to take place until near anthesis, followed by a hard grazing killing the majority of the reproductive tillers, results in a further increase in summer and early-autumn production since a rapid development of new vegetative tillers from the stubs of dead reproductive tillers is encouraged (Matthew, 1991a). Such a spring defoliation regime, which gives higher tiller density before the usual water deficit period in summer, can be expected to result in a higher tiller density after drought, resulting in better persistency and herbage production during late summer and autumn (Barker *et al.*, 1985). However, by allowing some early seedhead development, it is likely that the nutritive value of the herbage being grown under those circumstances will decrease, and that could have negative implications for animal performance.

## 2.5. Sward conditions and herbage utilisation by the grazing animal

Animal output from grazing systems is the product of output per animal and the number of animals grazed per hectare (stocking rate). On the one hand, performance per animal may be limited by genetic potential of the animals concerned, the relative proportions of productive and non-productive animals and, in some cases, worm parasite infestation. It is also very much a function of nutrient intake per animal, which can be markedly influenced by the characteristics of the sward upon which the animals are grazing (Hodgson & Maxwell, 1981). On the other hand, stocking rate is limited by the potential of pasture production, which is basically a function of soil fertility, species composition, and defoliation regime or grazing management as previously reviewed. Grassland management, therefore, is a matter of achieving a balance between animal production objectives, maintenance of sward productivity and utilisation of the herbage produced before it enters the stages of death and decay (Hodgson & Maxwell, 1981).

### 2.5.1. Herbage intake under grazing

Livestock productivity from a pasture-based system depends largely on growth of herbage and its subsequent utilisation by stock (Fulkerson & Michell, 1987). Although animals usually select herbage with a higher digestibility than that of the whole sward (Hodgson, 1990), the digestibility of the diet and, hence, the potential level of intake, is clearly influenced by the maturity of the sward and the distribution of components of different digestibility within it (Hodgson & Maxwell, 1981).

Animals grazing pastures rarely approach their genetic potential for meat, milk or wool production because of differences between plant species and components in their capacity to sustain animal performance. The levels of nutrients available to the tissues of the grazing animals vary widely and are often less than required for maximum production (Black, 1990).

The supply of nutrients to the tissues of a ruminant animal grazing on pastures and the efficiency with which the nutrients are utilised for body functions depend on: (1) the nutrient contents of the forage components available; (2) the actual components eaten by the animal; (3) the amount of each selected component eaten; and (4) the efficiency of biochemical reactions metabolising the absorbed nutrients within the animal (Black, 1990).

Variation in the intake of pasture by grazing ruminants has a major influence on animal performance. Many factors influence pasture intake and can be broadly classified as nutritional and non-nutritional (Poppi *et al.*, 1987). Nutritional factors such as digestibility, the time feed stays in the rumen and concentration of metabolic products appear to be important in controlling intake only if accessability and availability of herbage are unlimited, i.e. the animal's harvesting capacity is not limited by allowance, pasture height, mass or density. In situations where these do apply, non-nutritional factors play a more important role in determining intake (Poppi *et al.*, 1987).

The major nutritional factor influencing intake of temperate pastures is the digestibility of the pasture eaten (Poppi *et al.*, 1987). Herbage intake has been shown to be linearly related to the digestibility of the herbage eaten under both grazing and indoor feeding conditions and the indications are that intake will continue to increase at a constant rate up to the highest levels of herbage digestibility which can be achieved in practice (Hodgson & Maxwell, 1981). The digestibility of the herbage eaten by grazing animals is a direct reflection of its morphological composition (Hodgson & Maxwell, 1981). As a herbage plant matures it becomes more fibrous and less rich in pepsin-digestible materials. As fibre content increases the fibre digestibility decreases, so that the total content of digestible material (digestible fibre plus pepsin-digestible material) decreases (Terry & Tilley, 1964). Therefore, the digestibility of new and expanding leaf lamina is likely to be of the order of 0.80-0.90 at all times of the year, falling steadily to 0.70 in senescent leaves, while changes in the digestibility of leaf sheaths are similar. The flowering stem also has an initially high digestibility but this falls rapidly to about 0.50 at maturity, as a consequence of the rapid development and lignification of structural tissue. Variations in the digestibility of herbage down the sward canopy and throughout the year reflect changes in the relative proportions of these morphological components (Hodgson & Maxwell, 1981).

The sensation of physical satiety is an associated factor to digestibility in influencing herbage intake. It is a function of the degree of distension of the alimentary tract caused by the volume of digesta in the rumen. The volume of digesta is a function of the amount of food eaten recently, its digestibility and the rates of digestion and of passage of undigested residues down the digestive tract (Poppi *et al.*, 1987; Hodgson, 1990).

Grazing animals are often forced to graze down to low post-grazing pasture mass in order to maximize the quantity of herbage eaten per hectare, or because pasture is being rationed over times of shortage. As a consequence intake is depressed. It follows that non-nutritional factors (Poppi *et al.*, 1987) or behavioural constraints (Hodgson, 1990) are the most important factors influencing intake of grazing animals throughout most of the year.

The important behavioural variables are the rate of herbage intake, itself the product of the rate of biting and the weight of individual mouthfuls of herbage, and the time spent grazing. The rate of biting and intake per bite are sensitive to variations in herbage mass and sward height, but the ability of the animal to make compensating changes in grazing time may be limited and appears to be dependent in part upon the system of grazing management adopted (Hodgson, 1981).

### 2.5.2. Animal behaviour under grazing

Variations in the mechanics of the grazing process in response to variations in sward conditions can exert an important influence on the herbage intake of grazing animals. Intake per bite is very sensitive to variations in sward conditions, particularly to variations in sward height, with intake per bite declining progressively with decreasing sward height or herbage mass (Hodgson,1981). When intake per bite is reduced there is usually a corresponding fall in the rate of intake unless there is a compensatory increase in the rate of biting. Daily herbage intake is also adversely affected unless any reduction in rate of intake can be offset by an increase in grazing time. In practice, both biting rate and grazing time frequently do tend to increase when intake per bite falls, but these changes are seldom large enough to prevent a fall in daily herbage intake. On extremely short swards intake per bite, rate of biting and grazing time may all decline together (Hodgson, 1990).

Under rotational grazing, herbage intake and animal performance have often been related to variations in the daily allowance of herbage dry matter (kilograms per animal or per cent of animal weight daily) (Combellas & Hodgson, 1979; Le Du *et al.*, 1979; Bryant, 1980b; Glassey *et al.*, 1980). They increase at a declining rate with increasing allowance, usually reaching a plateau at an allowance equal to 10-12% of the animal's body weight for most classes of stock. Since this allowance is between two and three times the maximum daily herbage intake of the animals concerned, it inevitably involves a relative low utilisation of the herbage at one grazing (Bryant, 1980b; Glassey *et al.*, 1980; Hodgson, 1990).

The intake of digestible organic matter of grazing cattle is positively related to pasture herbage mass. That seems to be more related to an enhanced intake per bite rather than to rate of biting, since there is a very little compensatory effect upon intake with changing herbage masses for this last behavioural feature (Forbes & Coleman, 1985). Increases in herbage allowances have been reported to increase herbage intake of dairy cows by up to 20% when changing from severe to lax grazing regimes (Kristensen, 1988). Under those circumstances the herbage eaten had a higher nutritive value than the sward as a whole and presented a clear and linear relationship between degree of defoliation and utilisation of individual nutrients. The highest degree of selection was for green leaf (Hoogendoorn *et al.*, 1985; Kristensen, 1988), a primary consequence of the position of green leaf laminae in the grazing horizon, which makes leaves easier to prehend and masticate. Nutrient content of ingested herbage was increased at the lower degrees of defoliation, this relationship being explained by the fact that non-structural, highly digestible carbohydrates and protein usually are in the highest concentration in the upper part of the sward, while the structural carbohydrates (fibres) are in the highest concentration in the lower part (Kristensen, 1988).

Grazing animals normally divide their working day into alternating periods of grazing, rumination and rest. There are usually between three and five periods of grazing during the day, the longest and most intensive being after dawn and before dusk. Most grazing activity occurs during daylight hours in temperate climates, though short periods of night grazing are common for dairy cows. There is usually a period of ruminating activity after each grazing period, but much of the rumination occurs at night. This characteristic pattern can be affected by routine activities like milking or moving animals to fresh pasture and, exceptionally, by extreme weather conditions, but in most circumstances it is very stable and all members of the flock or herd tend to follow the same pattern. On average, work involved in grazing and ruminating is likely to take between 6 and 8 hours daily for each of those activities, with grazing time in excess of 8 to 9 hours/day being indicative of limiting sward conditions (Hodgson, 1990).

## 2.6. Pasture production and the productivity of dairy systems

Previous sections have dealt with results and trends obtained from very carefully controlled experiments, using them to develop and clarify some general concepts involving pasture and animal responses to different defoliation regimes and sward characteristics. It has been shown that animal production and herbage utilisation and productivity objectives may not be compatible, and that a compromise between them has to be found in order to optimise the overall productivity levels of grassland based systems. Results from management studies are not so numerous but seem to maintain a great degree of similarity with those previously discussed in terms of patterns of tillering and herbage production in response to varying defoliation regimes. However, animal performance has seldom been evaluated under those circumstances, leaving a restricted knowledge base for planning and developing more efficient and adequate grazing systems.

As mentioned previously, seasonality of pasture production is a key issue for efficient grassland productivity (Section 2.2). More frequent and intense defoliation of ryegrass/white clover pasture in late spring-early summer often helps to control it by suppressing the development of reproductive tillers (reduced growth rates) and encouraging growth of grass leaf and white clover (Korte, 1982; Korte *et al.*, 1982, 1984; Thomson *et al.*, 1984; Butler, 1986; L'Huillier, 1987b, 1988; L'Huillier & Aislabie, 1988). That, associated with a positive effect on sward quality, gave rise to the recommendation that an important objective of spring management is the maintenance of sward quality going into summer (Bryant, 1984; Thomson *et al.*, 1984). In practice this involves hard and/or frequent grazing, topping and silage conservation (L'Huillier & Aislabie, 1988; Carton *et al.*, 1989ab), these being very characteristic features of the conventional spring grazing management system being adopted in New Zealand for several decades (McCallum *et al.*, 1991).

### 2.6.1. Pasture control and feeding level of dairy cows

Grazing managements designed to maintain near maximal levels of herbage intake and animal performance (management of spring swards for dairy cows at peak production) usually involve grazing efficiencies of only 25 to 30% (proportion of the herbage offered actually consumed by the grazing animal) with the consequent high levels of herbage wastage (herbage senescence and decay), declining nutritive value and reduced sward vigour (Bryant, 1980b; Glassey *et al.*, 1980; Holmes & McMillan, 1982; Hodgson, 1984), pointing to the fact that there should be a critical pasture allowance which should be offered to cows in early lactation if both milk fat and pasture utilisation are to be optimised (Bryant, 1980ab; Thomson *et al.*, 1984).

Variations in sward conditions and in herbage allowance both influence animal performance through their effects on the amount and nutritive value of the herbage consumed. The need for compromise between animal and sward requirements in order to maintain whole-system viability is no doubt well appreciated (Hodgson, 1984). However, objectivity in determining the appropriate compromises is limited by the shortage of data from studies involving measurements on both sward and animal, particularly in a systems context (Hodgson, 1984). As a consequence, dairy farmers often face a management dilemma in spring: whether to feed cows at a generous herbage dry matter allowance and risk consequent decreases in sward quality and milk yield in summer, or to restrict cows in spring in order to maintain sward quality and risk an immediate decrease in cow performance (Hoogendoorn *et al.*, 1988, 1992).

This conflict on how to maintain high intakes, achieve adequate pasture control and conserve sufficient pasture to meet subsequent feed deficits makes the decision about when and how much pasture to conserve very complex (Thomson *et al.*, 1984). During recent years, conservation has been regarded primarily as an aid to pasture control, its role of providing supplementary feed being of secondary importance, although this has been the subject of re-appraisal since an increase in levels of milk production per cow has been actively promoted recently. Effectiveness in fulfilling its primary role, though, requires the early prediction of the area to set aside for conservation and when this is to happen (Bryant, 1984).

Different systems of grazing management can influence both the amount of pasture eaten per cow daily, and the way in which the pasture is grazed. These can, in turn, influence the subsequent production of the animals and of the pastures. Grazing management is, therefore, an important aspect of nutritional management of dairy herds (Holmes & McMillan, 1982).

### 2.6.2. Grazing management systems and dairy grasslands productivity

The achievement of high levels of production from the herd in early lactation through the combined effects of adequate preparation for calving and full feeding in early lactation is very important (Bryant & Cook, 1977). It ensures, more than any other input, the full and efficient use of pasture at a time when cow efficiency, pasture growth rate and quality are at or near maximum. It ensures that cows are capable of capitalising on good summer growth, should this occur; and it provides the best and least expensive insurance against the possibility of it not occurring (Bryant, 1980a). Thus, much recent work has been focused on spring grazing management of pastures aiming to develop high producing and efficient dairy grazing systems.

Grazing management, during winter, of ryegrass/white clover mixed pastures have repeatedly been reported to have little effect on herbage production and dairy cow performance (Bryant & L'Huillier, 1986; Fulkerson & Michell, 1987; L'Huillier, 1987b), even though increased herbage accumulation through long regrowth interval and high herbage mass is likely to occur (Santamaria & McGowan, 1982; Holmes *et al.*, 1992). However, grazing management during spring can change quite substantially the amount and quality of the herbage produced, to which dairy cows are particularly sensitive (Thomson *et al.*, 1984; L'Huillier, 1987b).

Manipulation of herbage allowances in spring through changing grazing frequency and intensity, timing of forage conservation and stocking rate can substantially alter pasture and milk production (Bryant, 1980b; Glassey *et al.*, 1980; Thomson *et al.*, 1984; Baker & Leaver, 1986; Bryant & L'Huillier, 1986; L'Huillier, 1987b,1988; L'Huillier & Aislabie, 1988; Thomson & McCallum, 1989; Hoogendoorn *et al.*, 1988,1992). During the first half of the lactation (spring), the offer of higher herbage allowances to dairy cows whether by delaying conservation cuts or less intensive defoliation regimes usually results in higher milk fat production per cow (Combellas & Hodgson, 1979; Le Du *et al.*, 1979; Thomson *et al.*, 1984; L'Huillier, 1987b,1988; Thomson & McCallum, 1989), with maximum levels of production being commonly observed at herbage allowance of 33 to 35 Kg DM/cow/day. Under those circumstances only 50% of the herbage on offer is utilised by the cows, with herbage intake and, consequently, milk yield being depressed at lower allowances (Le Du *et al.*, 1979). More intense defoliation as characterized by early conservation (conventional grazing system), spring fast rotation (8-10 day-rounds) or even set stocking result in lower milk fat production and productivity when compared to less intensive defoliation regimes (Thomson *et al.*, 1984; L'Huillier, 1987b,1988; Thomson & McCallum, 1989), despite an improvement in the seasonal profile of pasture production by diminishing the disparity between spring/summer and autumn/winter production and maintaining swards in a leafy vegetative state. Generally, this improved profile of seasonal pasture production is obtained by reducing spring growth rates and, consequently, spring surplus. Under those circumstances the delay in forage conservation or the less intensive defoliation regimes used to generate the higher herbage allowances during spring, normally resulted in faster pasture growth rates which may, eventually, generate more feed being conserved that could be used later in the season (Thomson & McCallum, 1989). Animals maintained under more intensive grazing normally lose more weight, probably reflecting the underfeeding associated with lower herbage allowances and pasture growth rates of early controlled swards or even simply due to lower intake, indicating that production is sustained at the expense of body reserves (Thomson *et al.*, 1984; L'Huillier, 1987b,1988). Short, light swards are characterised by a greater proportion of the total herbage situated close to ground level than tall, heavy ones, making the prehension of feed more difficult for the animals (Combellas & Hodgson, 1979). Under less intensive grazing, the stem content of the herbage on offer in the sward has been demonstrated to increase as some reproductive growth occurs but, in cases where it is controlled when stem material is still green, no negative effect on animal productivity has being reported (Thomson *et al.*, 1984; L'Huillier, 1987b,1988). That supports the conclusion that green stem could make a worthwhile contribution to the intake of dairy cows without any apparent loss in animal performance (Thomson *et al.*, 1984), highlighting the potential benefits to animal production from the adoption of a less intensive grazing policy during spring (Thomson & McCallum, 1989).

During the second half of the lactation (summer-autumn) the residual effects of grazing management of pastures during spring exert a strong impact on summer pasture and animal production. Usually, grazing managements that have failed to control pastures during the reproductive phase of growth result in swards of poor quality and low tiller density going into the summer, causing poor pasture growth rates and milk fat production (Thomson *et al.*, 1984; Baker & Leaver, 1986; L'Huillier, 1987b,1988; Thomson & McCallum, 1989; Hoogendoorn *et al.*, 1988,1992). That is normally the case for those less intensively grazed pastures during spring, in which the increases in milk fat yield during the first half of the lactation were compensated for by a reduction in production during the second half, resulting in no differences on total lactation production at the end of the whole milking season (Thomson *et al.*, 1984; L'Huillier, 1987b,1988).

Any attempt to graze pastures more laxly during spring has the potential to impact negatively on animal production because of the lower nutritive value of seedheads and because of difficulties in removing seedheads once they are allowed to form. In general, previous experiments where increased seedhead growth has been observed, this has occurred as a by-product of experimental treatments in which a longer rotation length reduced animal intake. Continuation of such treatments through the summer only tends to compound problems of poor herbage quality. On the other hand, deliberate encouragement of early seedhead growth, followed by a change in grazing management designed to remove accumulated growth has never been experimentally tested. Such grazing management would produce the benefits from a laxer grazing during spring and of a harder grazing later in the season. As seedheads develop, digestibility falls rapidly (Hodgson & Maxwell, 1981), so that there is probably a fairly narrow 'time window' in late spring for the control of reproductive growth. If this time window were missed, negative results could be expected from a lax grazing policy during spring, due to loss of pasture quality, and also because maturing seedheads compete strongly for carbohydrate with any young tillers being formed, resulting in death of those young tillers (Ong *et al.*, 1978; Carton *et al.*, 1989b; Matthew, 1991a; Matthew *et al.*, 1991; Thom, 1991).

Dairy cow performance has a positive relationship with herbage accumulation during the summer/autumn period (L'Huillier, 1987bc,1988), which is also positively correlated to sward tiller density (Korte *et al.*, 1984). Therefore, grazing management strategies during spring that increase tiller density of pastures can be expected to improve the summer performance of dairy pastures and of the grazing animals (L'Huillier, 1987a). Despite the small overall differences mentioned previously, grazing managements that generated higher sward tiller densities and herbage quality going into the summer were associated with higher herbage accumulation rates and consequent improvements on milk fat and milk protein yields (L'Huillier, 1987b), this last component of milk composition being positively related to the white clover content of pastures (L'Huillier, 1988).

The effect of spring grazing management on the quality of early summer pasture as measured by the *in vitro* digestibility technique has been reported to be quite variable, probably reflecting different stages of maturity and reproductive stem content of the pasture material analysed, since no well defined and objective grazing management has been described in terms of sward characteristics. Generally, grazing management in spring has little effect on the digestibility of early summer pasture, with values of at least 70% in late spring being observed. Season of the year seems to have a larger influence on pasture quality than does grazing management (L'Huillier, 1987b). Levels of *in vitro* digestibility of early spring herbage of around 73-76% have been observed, declining to 70-73% in late spring and 68-69% in mid-summer for grazing managements varying from hard to lax (L'Huillier, 1987b), despite changes in botanical composition which normally result in decreased proportions of ryegrass leaf and white clover associated with increased ryegrass reproductive stem and dead material (Davies, 1973; L'Huillier & Aislabie, 1988).

On the other hand, there is also evidence that less intensive grazing strategies during spring could cause herbage digestibility to drop drastically to levels which impair milk production. Digestibility values of around 67% have been reported to cause reduction in milk production of dairy cows as opposed to those grazing more intensively and well controlled swards (72% digestibility). However, the negative effect of low quality herbage from laxly grazed swards on milk yield can be overcome by offering cows an allowance of green leaf dry matter equivalent to that of cows grazing well controlled pastures (Hoogendoorn *et al.*, 1988,1992). Because of this potential negative effect of the reproductive phase of perennial ryegrass growth on sward tiller density and herbage quality and its influence on dairy cow performance, more intensive grazing managements are widely adopted during spring, despite the potential benefits of a less intensive defoliation regime to dairy cow performance in the first half of the lactation, a period when around 65% of the total lactation yield is produced (Bryant, 1984). Intensive grazing during the period of reproductive growth in spring can be achieved only by the adoption of high stocking rates and/or adequate conservation policies in order to cope with the increased herbage growth at this time (Hoogendoorn *et al.*, 1988; Carton *et al.*, 1989a).

Another important feature that arises from swards grazed by cattle, particularly when less severely grazed, is the high percentage of the sward area that is infrequently grazed, leading to the development of large areas of rejected herbage or tall grass, particularly in association with the maturity of flowering heads (Fitzgerald & Crosse, 1989; Gibb & Baker, 1989; Gibb, 1991). This tall grass represents a sizeable proportion of the sward grazed by dairy cows, averaging about a third of the total area, and increasing from 20 to 40% in late summer/autumn. Tall grass represents an even greater proportion of the herbage mass available to cows than that indicated by its area and can increase to over 50% of the sward in late summer/autumn. Although it is less well utilised, it represents a sizeable proportion (38-43%) of the total herbage consumed by cows, particularly in autumn when growth of short grass is reduced. Better utilisation and a lower proportion of tall grass in the sward can be achieved by tighter grazing in spring/early summer, occasional topping or grazing after cows with other stock (Fitzgerald & Crosse, 1989).

## 2.7. Implications of the agronomic data for dairy production systems

The previous discussion clearly highlighted how significant spring grazing management is in determining pasture and milk production in the seasonal dairy production system adopted throughout New Zealand. The search for the most appropriate grazing system is reflected in the intensive research on spring grazing management during the last 5 or 10 years. In general, animals offered generous herbage allowances during the first half of lactation through either fast rotation or delayed conservation, respond positively in terms of milk solids yield as well as liveweight changes. During the second half of lactation the positive effects observed during the previous phase are usually offset by decreased animal performance either by lower herbage quality, reduced growth rates, shortage of feed or a combination of these factors, basically residual effects of previous grazing regimes during spring which failed to control the reproductive growth or had adverse effects on pasture composition and sward tiller density going into the summer period (Section 2.6.2).

Both prevention of reproductive growth or absence of control either by spring fast rotation or by deferred grazing (conservation *in situ* of surplus grass), respectively, could result in reduced tillering during a key tiller replacement period in late spring, even though an initial increase in pasture tiller population under the spring-summer fast rotation would be seen through the existing size-density compensation mechanism (Matthew, 1991a). Sensitivity to feed shortage periods or unusual growth patterns is also likely to be a complicating factor, since little or no conserved feed is produced under those circumstances. As a consequence, shorter lactation periods (Thomson & McCallum, 1989) and very poor cow performance with poor spring growth (Bryant & L'Huillier, 1986) are likely to occur.

Evidence found in the literature suggests that pasture production in summer and autumn can be enhanced by a grazing management that allows a high tiller density going into the summer (Section 2.4.1). Such management might be achieved in a farm context by lax grazing in early spring, allowing reproductive growth to take place, then switching to a hard grazing in late spring/early summer. This would decapitate and kill the majority of the flowering tillers, and would allow greater carbon assimilation and redistribution of assimilates to the new tillers, and favour greater clover and ryegrass stolon formation which would increase new tiller numbers, increasing summer and autumn pasture production. Such grazing management would create suitable conditions for improved dairy cow performance during both the first and the second half of the lactation, resulting in higher total lactation production. This management is fundamentally different from that normally practised in New Zealand.

It has also been shown that the amount of conserved feed produced is, eventually, increased by the delay in shutting paddocks up for conservation, and that this conserved feed could be in excess of winter requirements (Thomson & McCallum, 1989), which would allow it to be fed back into the system to enhance feeding level and animal productivity during the summer-autumn period (Section 2.6.2). In general, the supply of extra feed should result in the production of extra milk. However the response is affected by many factors (Holmes & Brookes, 1991). When extra feed is available to be fed at any time of the year, then the efficiency with which it would be converted into milk fat would clearly be greatest if fed in early lactation, followed by late lactation and finally the dry period (Holmes & McMillan, 1982). Feeding of extra conserved feed to increase the feeding level of cows could either result in extra milk or extra liveweight, since none of the extra feed would be used for maintenance (Holmes & Brookes, 1991), although the decision in doing so would be very much based on the market driven milk solids price/conserved feed cost relation (Ahlborn & Bryant, 1992).

It may not be possible or sensible to try and close graze the whole farm in late spring. Even on highly stocked dairy farms, cows are unable to consume all late spring/early summer growth. However, spring growth can be controlled by a combination of close grazing, conservation and topping to achieve dense leafy nutritious pasture for summer. Closing paddocks for conservation forces livestock to graze more closely on the rest of the farm. Also regrowth from hay and silage paddocks is normally leafy with few reproductive tillers (Korte, 1982). Further research is required to integrate these principles into farm systems and to establish the extent to which swards can be allowed to become stemmy before the advantages of leafy swards are lost, since failure to control late spring growth in ryegrass dominant pasture reduces herbage quality and production subsequently (Korte *et al.*, 1984).

## 2.8. Conclusion

There are clear theoretical reasons to expect advantages in adopting less intensive grazing policies during spring time for pasture production, dairy cow performance, and overall dairy systems productivity. Such grazing management would be associated with the occurrence of some reproductive growth, bringing about the potential risks to animal and pasture productivity under those circumstances. Success in exploiting the enhanced pasture and milk production from such systems would have to be based on a very well defined set of rules considering sward characteristics, since deficient pasture control would cause the benefits from less intensive defoliation on dairy cow and pasture performance to be lost. Provision of answers to these questions is very important for planning more efficient dairy grazing systems and further research is, therefore, necessary to integrate these principles into a systems context.

# *Chapter 3:*

## THEORETICAL HYPOTHESIS AND EXPERIMENTAL PROGRAMME

The preceding review sought to establish the links between grazing management effects, particularly during spring, and dairy cow performance within the seasonal framework of grassland systems in New Zealand. Evidence gathered under very controlled conditions suggests that there may be benefits in adopting a lax spring grazing regime which allows some early seedhead development and controlling it prior to the ripening of seeds or, more specifically, at anthesis ('late control'). Such a grazing management would enhance herbage accumulation in spring due to the on-going reproductive development and in summer-autumn due to enhanced ryegrass tillering activity and white clover performance. Because late control allows reproductive growth and increases the spring surplus of pasture, such grazing management is thought to be more compatible with dairy systems, where the increased spring surplus could be accommodated more easily since some topping and forage conservation are a common practice in those enterprises. The less intensive grazing during spring in order to allow early seedhead development would favour individual cow productive and reproductive performance in the first half of lactation by increasing levels of feeding, and in the second half by increasing herbage accumulation rates and white clover content of pastures providing that seedheads are not allowed to become overmature.

Implementation of a late control grazing strategy on a farm basis would have to rely on efficient control of reproductive stems in order to capitalise on potential benefits, and that would imply some degree of re-thinking of the conventional role of forage conservation practices and conserved feed use in New Zealand. Furthermore, some questions about the practical logistic of it all would have to be evaluated, such as: (i) the possibility of repeating the same pattern of response observed under very controlled environmental conditions in a large scale basis; and if so, (ii) how best to achieve such late control; (iii) how stemmy swards can be allowed to become before potential benefits would be lost; (iv) whether or not the extra growth, especially in the second half of the lactation, could be used to enhance the performance of dairy cows.

In order to deal with those issues a series of field experiments was carried out at No 4 Dairy Farm, Massey University. Experiments 1 (October 1990 to April 1991) and 2 (October 1991 to April 1992) were plant-based studies which investigated the effects of contrasting spring grazing managements on pasture production and sward dynamics on a dairy cow paddock scale, gathering information and setting up a knowledge base for a combined plant/animal study in Experiment 3. In Experiment 1 the timing of late control was studied and in Experiment 2 the intensity of late control was evaluated. The results from these two experiments are presented and discussed together in Chapter 4. Experiment 3 (October 1992 to April 1993) investigated different grazing strategies for achieving late control and their impact on summer-autumn pasture and milk production. Results from Experiments 1 and 2 were used to plan and define the set of pasture based targets and management guidelines that characterised the different grazing strategies tested in Experiment 3, and a summary of those considerations is reported in Chapter 5. The results from Experiment 3 are presented and discussed in Chapter 6. A more detailed analysis carried out on a pooled data set for the three year study dealing with possible year and year x treatment effects is presented in Chapter 7. Finally, a general overview of the results and their practical implications for dairy farming systems in New Zealand is presented in Chapter 8.

# Chapter 4:

## INFLUENCE OF SPRING GRAZING MANAGEMENT ON SUMMER-AUTUMN PRODUCTION OF PERENNIAL RYEGRASS/WHITE CLOVER DAIRY PASTURES

### 4.1. Introduction

Traditionally in New Zealand, pastures have been grazed very intensively throughout spring and summer with the objective of interrupting ryegrass stem elongation at an early stage and, therefore, preventing it from becoming reproductive. Such an intense defoliation regime aims to reduce the accumulation of grass surplus to animal requirements and to ensure that pastures are kept leafy and dense. Evidence gathered under very controlled conditions has demonstrated that there is a very important period of turnover in tiller population in late spring-early summer. This tiller replacement process is related to the reproductive development of perennial ryegrass plants and it is likely to be diminished by the conventional intensive spring grazing of pastures. A less intense grazing management during spring can enhance tillering activity, resulting in higher tiller populations going into the summer (Matthew, 1991a). This enhanced tiller population has been related to increased resistance to summer water deficit (Barker *et al.*, 1985), a common climatic phenomenon in New Zealand, and higher herbage accumulation rates (Matthew *et al.*, 1991), resulting in enhanced pasture performance over the summer-autumn period. Less intensive spring grazing management is also likely to enhance white clover accumulation by allowing the formation of heavier stolons which contain more reserve carbohydrates (Grant & Barthram, 1991; Barthram & Grant, 1993b), increasing plant resilience and performance.

Such management has been described as involving lax grazing in early spring, allowing reproductive growth to take place, then switching to hard grazing in late spring/early summer, to decapitate and kill the majority of the flowering tillers ('late control'). Fundamentally, this is quite the opposite of the conventional spring grazing management of pastures adopted in New Zealand ('early control'). Because of the need for rapid control of reproductive grass swards in late spring/early summer and the need for some topping or forage conservation as means of achieving it, such a grazing management has been thought to be most compatible with the seasonal dairy systems of New Zealand.

In order to test the impact of this alternative spring grazing management on pasture production at a paddock scale, and to evaluate the practical implications of implementing it into a farm context, comparisons of contrasting 'early control' (conventional) and 'late control' (alternative) managements were carried out at No 4 Dairy Farm, Massey University, during the 1990/91 and 1991/92 dairying season. The present chapter reports those experiments and their results.

## 4.2. Experimental

### 4.2.1. Objectives

The experimental objectives were:

(i) To study the response of perennial ryegrass and white clover plants to lax defoliation regimes during spring ('late control') at a paddock scale under dairy cow grazing;

(ii) To gather information on ryegrass tiller and white clover stolon population dynamics under contrasting spring grazing managements;

(iii) To confirm the theoretical expectation of improved summer-autumn production from pastures managed according to the late control grazing approach.

### 4.2.2. Site

Experiments were conducted over two consecutive milking seasons (August to April) at No 4 Dairy Farm, Massey University, at an altitude of approximately 40 m above sea level. Pastures were three to six years old and comprised a mixture of perennial ryegrass (*Lolium perenne* L. cv. 'Ellett') and white clover (*Trifolium repens* L. cv. 'Grasslands Pitau') sown on a Tokomaru silt loam soil (Typic Fragiaqualf), a poorly drained compact clay loam with a compact subsoil and tendency for drying out in summer. Pastures were sown following a maize crop used for green feed and silage making, as part of the farm's pasture renovation programme. Although the natural fertility of the soil is moderate to low, soil nutrient status was medium/high (25 ppm Olsen-P and

0.37 meq exchageable K/100g soil). The area received an application of 2 tonnes of lime and 350 Kg of a 30% longlife superphosphate (0.7.15.5) per hectare in April/90 and April/91 as part of the annual maintenance fertilisation policy adopted in the farm.

The area is characterised by an average annual rainfall of approximately 1000 mm with prevailing westerly winds. Weather data over the experimental period were assumed similar to those for the Crown Research Institute (CRI) meteorological station, approximately 2 km distant. Air and soil (10 cm depth) temperatures and rainfall and pan evaporation (monthly totals) are presented in Figures 4.1 and 4.2, respectively. The 1990/91 season was a little warmer and drier than 1991/92, with periods of soil moisture stress being more likely to have occurred in 1990/91 (Figure 4.2).

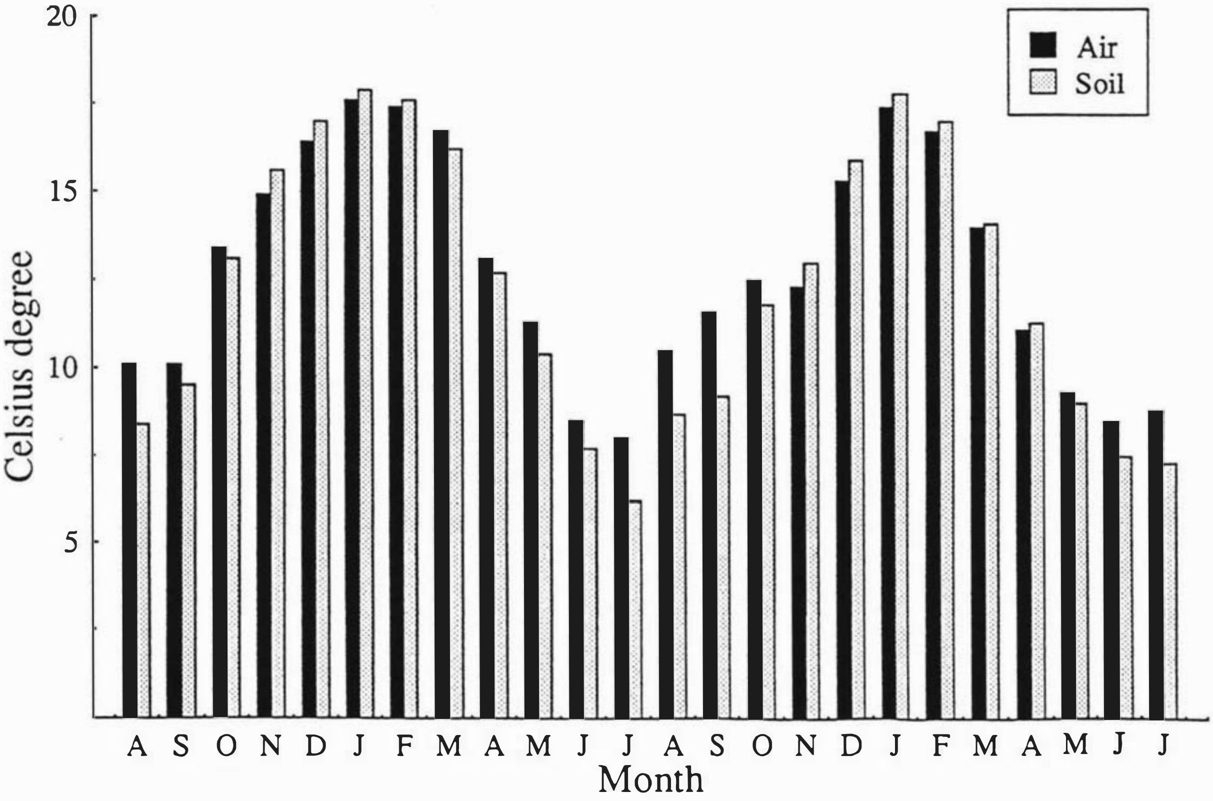

Figure 4.1. Mean air and soil (10cm) temperatures for the 1990/91 and 1991/92 seasons

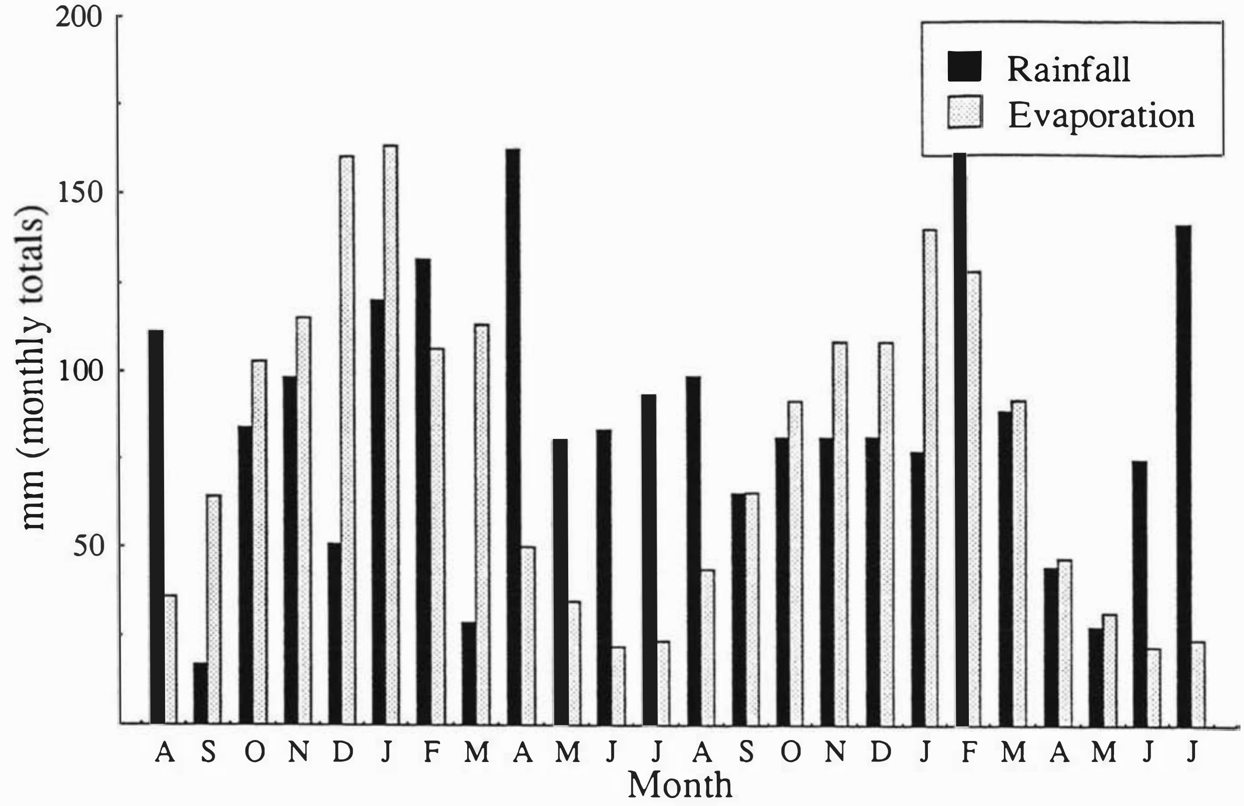

Figure 4.2. Total monthly rainfall and pan evaporation for the 1990/91 and 1991/92 seasons

### 4.2.3. Experimental design

In the 1990/91 season (Experiment 1) five paddocks (2.6 ha/paddock) were selected and each was divided into three strips (plots) by electric fencing. Three grazing treatments were randomly allocated per paddock (block), one per strip, giving a complete randomised block design (CRB) with five replicates (blocks). In the 1991/92 season (Experiment 2), due to the occurrence of patchy or uneven grazing on the late controlled treatments during the previous season, plots were further sub-divided into six sampling areas which were consistently used for the sampling procedures performed throughout the experimental period. Figure 4.3 shows a diagram of one of the experimental paddocks (blocks), and the arrangement of the sampling areas (S) within strips (treatments). Three of the five experimental paddocks used in 1991/92 had been used during the 1990/91 season, and so analogous treatments for both seasons were assigned to the same strips.

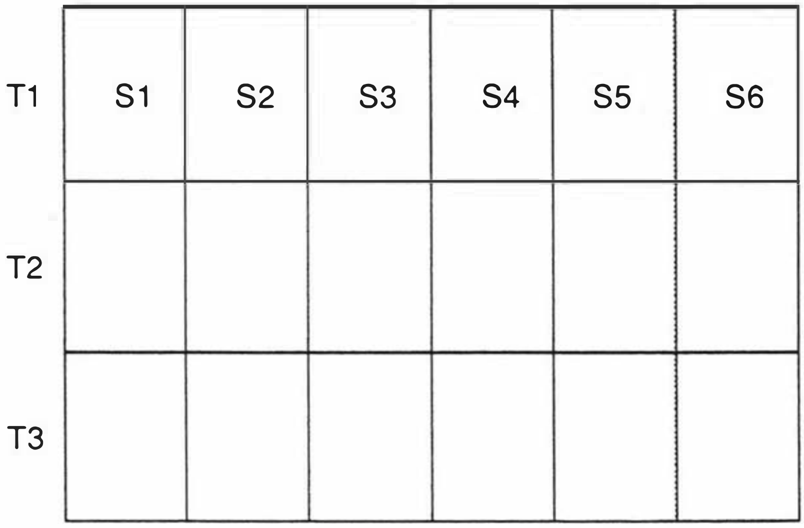

Figure 4.3. Experimental plots layout for the 1991/92 season

### 4.2.4. Experimental treatments

Based on the results of earlier detailed studies (Matthew *et al.*, 1989b; Matthew, 1990) the following three treatments were applied in Experiment 1 to the experimental plots:

(i) EC (early control) - Hard grazing during the entire spring and summer period to a residual pasture height of 30-50 mm (1400-1500 Kg DM/ha);

(ii) LHC (late hard control) - Lax grazing during spring to a residual pasture height of 80-100 mm (1800-2000 Kg DM/ha), switched to a hard grazing (residual height of 30-50 mm) at the time of anthesis (20 November);

(iii) VLHC (very late hard control) - As LHC but the switch to hard grazing made on 18 December.

Plots were rotationally grazed by dairy cows under a controlled herd (250 cows) grazing system. Three distinct phases were distinguished during the grazing season using the switch in defoliation regime from lax to hard as a reference point: (a) pre-control - prior to the switch (October-November) with plots being grazed at 3 week intervals; (b) control - at the time of the switch (December) and still at 3 week grazing intervals; (c) post-control - after the switch (January-April) with plots grazed at 4 week intervals. Treatments based on less intense defoliation regimes (LHC and VLHC) during the pre-control phase allowed some seedhead development, which was controlled during the control phase.

At the time of grazing, animals were allowed into single strips and the grazing monitored. Once residual pasture targets were achieved for different treatments as specified above (usually within a few hours), the cows were shifted to another strip until the grazing of the experimental area was finished. During the post-control phase grazing management for all plots was similar, with paddocks being grazed under the same grazing frequency (4 week interval) and intensity (30-50 mm residual pasture height). Control of the reproductive growth during the late control phase was achieved by mowing to the appropriate heights before grazing, with cows used to harvest the cut herbage.

In Experiment 2 the VLHC treatment was substituted by a late lax control (LLC), with an initial control grazing to a residual height of 75-100 mm and return to a residual height of 30-50 mm over three successive grazings. Control grazings were initiated on 4 December for both LHC and LLC, and were again preceded by mowing to the desired heights.

### 4.2.5. Measurements

#### 4.2.5.1. Herbage accumulation and components

Herbage accumulation was determined from 10 random quadrat areas (0.1 m$^2$) per plot in Experiment 1 (1990/91) and 12 (2 from each sampling area) in Experiment 2 (1991/92) before and after each grazing. Samples were cut to ground level with an electric shearing hand-piece (Table 4.1). Cut herbage was washed and then dried at 80 °C for 24 hours in a forced-draught oven. Samples were taken for determination of botanical composition by cutting a hand-piece wide strip (75 mm) alongside each quadrat. Bulked samples for each strip were then taken to the laboratory, washed, sub-sampled and the herbage from each of the two resulting sub-samples separated by hand into ryegrass leaf and stem, other grass leaf and stem, white clover leaf and stolon, weeds and senescent material. After drying, samples were weighed and the proportion (%) of species components determined and herbage accumulation (Kg DM/ha) calculated based on the difference between pre-grazing and post-grazing herbage mass for successive grazings.

#### 4.2.5.2. Ryegrass tiller demography and dynamics

In Experiment 1 the origin, number and weight of new tillers produced were monitored by detailed observation of individual tillers. For each of the three treatments in each of the five paddocks, six transects of 15 tillers (90 tillers/treatment/paddock) were tagged with split plastic rings between 9 and 24 October, 1990. The tillers marked were selected as being adult overwintered tillers about to flower, and any daughter tillers already present (on average approximately 2 daughter tillers per flowering tiller) were tagged period (TAR);

- Relative tiller death rates - number of tagged tillers that died out of the original population during a regrowth period, divided by the existing number of tillers at the start of the period (TDR); and

- Relative tiller survival rates - percentage of the original population of tillers at the start of a regrowth period alive at the end of the same period (TSR).

At the time of the last grazing of the experimental paddocks all tagged tillers were dug up prior to grazing and removed to the laboratory where they were counted, dried and weighed.

Table 4.1. Grazing dates[1] of the experimental plots for Experiments 1 and 2

| Grazing | experiment 1 | experiment 2 |
|---|---|---|
| $G_0$ | 09.10.90[2] | 27.09.91[2] |
| $G_1$ | 31.10.90 | 23.10.91 |
| $G_2$ | 25.11.90 | 13.11.91 |
| $G_3$ | 18.12.90 | 04.12.91 |
| $G_4$ | 15.01.91 | 01.01.92 |
| $G_5$ | 18.02.91 | 23.01.92 |
| $G_6$ | 12.03.91 | 19.02.92 |
| $G_7$ | 11.04.91[3] | 17.03.92 |
| $G_8$ | - | 13.04.92[3] |

1) Initial dates of successive grazing cycles
2) Post-grazing cuts only
3) Pre-grazing cuts only

#### 4.2.5.3. Species population densities

In Experiment 1 the ryegrass tiller and white clover stolon population densities were monitored through collection of 40 tiller plugs (53 mm diameter) from random locations within strips at the conclusion of the experiment (1 April, 1991), and the total grass tillers (tillers/m$^2$) and clover stolon densities (m/m$^2$) for the three control treatments determined by counting the number of tillers and measuring stolon length in each plug. In Experiment 2 the species populations were monitored more frequently with four tiller plug harvests spread out throughout the experimental period as follows:

Harvest 1 - At the start of the experiment (October/91)
Harvest 2 - At the switch from lax to hard grazing (December/91)
Harvest 3 - On March/92
Harvest 4 - At the end of the experiment (April/92)

At each of the four harvests 60 tiller plugs were collected per plot, ten from each sampling area, and grass tiller, clover stolon/node and weeds population densities determined. An estimate of internode length (cm) was obtained by dividing the stolon density (m/m$^2$) by the node density (nodes/m$^2$) estimates.

#### 4.2.5.4. Soil fertility

In Experiment 2, five soil samples per sampling area were collected from the experimental site at a depth of 0-10 cm and bulked, resulting in one composite soil sample per sampling area or six per strip. Samples were analyzed for pH, phosphorus and potassium levels. Level of pH on soil samples was determined by readings of hydrogen-ion activity in a 1:25 soil-water solution with a radiometer pH meter. Labile phosphorus (Olsen-P) was determined by the sodium bicarbonate extraction method of Olsen *et al.* (1954), and soil sample solutions for determination of exchangeable potassium (exch-K) were obtained by the semi-micro leaching procedure described by Blackemore *et al.* (1980), in which potassium concentrations were determined by flame emission. Experimental treatments did not differ in either pH, Olsen-P or exch-K (Table 4.2) whereas blocks did, particularly for pH (P = 0.025) and Olsen-P (P = 0.005) levels.

Table 4.2. Levels of pH, labile phosphorus (ppm) and exchangeable potassium (meq/100 g soil) of experimental plots in Experiment 2

| | Treatments | | | | |
|---|---|---|---|---|---|
| Feature | EC | LHC | LLC | SEM | Signif.[1] |
| pH | 5.71 | 5.67 | 5.72 | 0.03 | ns |
| Olsen-P | 26.00 | 26.60 | 28.10 | 1.74 | ns |
| Exch-K | 0.39 | 0.34 | 0.36 | 0.04 | ns |

1) In this and subsequent tables, ns = P > 0.10, + = P < 0.10, * = P < 0.05, ** = P < 0.01, and *** = P < 0.001

### 4.2.6. Statistical analysis

All data were initially tested for normality and homogeneity of variance. In cases where these assumptions were not valid, data were appropriately transformed. Statistical analysis was performed in accordance with the randomised complete block design (8 degrees of freedom for error) and standard errors derived from strip means (n=5). Results generated from sequential harvests were analyzed using the 'repeated measures' option of the SAS general linear models procedure. In order to gain an overview of the way in which measured variables related to each other, exploratory multivariate analysis was performed by Canonical Discriminant Analysis (CDA).

## 4.3. Results

### 4.3.1. Ryegrass tiller demography and dynamics

In Experiment 1 the newly formed tillers were classified by their site of origin on the axis of originally tagged tillers (Table 4.3). On a per flowering tiller basis there was no difference in numbers of newly formed daughter tillers for different sites of origin or in tiller survival rates (TSR) at the two harvest dates. The only exception was the higher number of new primary daughter tillers (NT) at the December harvest produced under the VLHC treatment. Excepting that EC plots produced heavier NT tillers than did LHC and VLHC plots at the December harvest, no difference among treatments was observed in individual tiller weight (Table 4.4), the same trend being observed for weight of tillers produced per flowering tiller (Table 4.5). Tillers belonging to the original group of tagged tillers represented, overall, 32% and 20% of the population at the December and February harvests respectively, indicating that an intense turnover of tillers occurred during late spring-early summer, which dramatically changed the profile of the originally selected tiller population going into summer.

In Experiment 2 the new formed tillers were classified by their time of appearance throughout the season (cohorts) (Table 4.6). On a tiller per parent tiller basis, the only difference observed was for the first group of new formed tillers tagged soon after the first grazing, when the LHC treatment presented the highest number of surviving new daughter tillers produced per originally tagged tiller comprising the final tiller population in April/92. Daughter tillers produced by the late control treatments (LHC and LLC) tended to be heavier than those under the early control treatment (EC), particularly during the summer/autumn period after the control of the reproductive growth in early December (Table 4.7). Weight of new formed daughter tillers per parent tiller followed the same trend (Table 4.8).

Table 4.3. Number of new tillers formed per flowering tiller and tiller survival rate (TSR)(%) of the original population of tagged tillers at each of the two tiller harvest dates of Experiment 1

| | Harvest 1 (11 to 14 December, 1990) | | | | | Harvest 2 (4 to 7 February, 1991) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | NT | SFNT | SFTAG | TOTAL | TSR | NT | SFNT | SFTAG | TOTAL | TSR |
| EC | 0.89 | 0.21 | 1.17 | 2.45 | 27.2 | 0.62 | 0.67 | 1.85 | 3.25 | 19.9 |
| LHC | 0.81 | 0.21 | 0.71 | 1.83 | 31.3 | 0.48 | 0.45 | 1.21 | 2.19 | 19.9 |
| VLHC | 1.26 | 0.18 | 0.99 | 2.75 | 37.8 | 0.52 | 0.35 | 1.26 | 2.37 | 21.3 |
| | | | | | | | | | | |
| SEM | 0.08 | 0.19 | 0.23 | 0.40 | 6.00 | 0.09 | 0.11 | 0.33 | 0.48 | 3.82 |
| Signif. | ** | ns | ns | ns | ns | ns | ns | ns | ns | ns |

Table 4.4. Individual tiller weight (mg) of new formed tillers at each of the two tiller harvest dates of Experiment 1

| | Harvest 1 (11 to 14 December, 1990) | | | | Harvest 2 (4 to 7 February, 1991) | | | |
|---|---|---|---|---|---|---|---|---|
| Treat. | NT[1] | SFNT | SFTAG | SURV | NT | SFNT | SFTAG | SURV |
| EC | 35.6 | 8.7 | 12.5 | 68.2 | 21.1 | 15.7 | 17.9 | 41.8 |
| LHC | 24.9 | 7.5 | 10.6 | 56.5 | 20.1 | 10.6 | 16.8 | 29.0 |
| VLHC | 21.2 | 12.2 | 14.0 | 45.6 | 29.1 | 9.6 | 15.9 | 35.6 |
| SEM | 2.5 | 1.6 | 1.5 | 13.9 | 6.8 | 2.3 | 2.4 | 6.4 |
| Signif. | * | ns | ns | ns | ns | ns | ns | ns |

1) Means from vegetative tillers only

Table 4.5. Total weight (mg) of new formed tillers per flowering tiller at each of the two tiller harvest dates of Experiment 1

| | Harvest 1 (December/90) | | | Harvest 2 (February/91) | | |
|---|---|---|---|---|---|---|
| Treatment | NT | SFNT | SFTAG | NT | SFNT | SFTAG |
| EC | 31.5 | 2.2 | 14.7 | 12.4 | 10.2 | 36.7 |
| LHC | 20.5 | 1.5 | 8.5 | 9.2 | 4.6 | 20.3 |
| VLHC | 27.0 | 2.3 | 13.1 | 14.0 | 3.4 | 23.9 |
| SEM | 3.7 | 0.7 | 3.5 | 3.7 | 2.0 | 9.2 |
| Signif. | + | ns | ns | ns | + | ns |

Table 4.6. Average number of new tillers formed per parent tiller at the final harvest of Experiment 2 (14 to 23 April, 1992)

| | Tiller cohorts tagging dates | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Treatment | 26-31/10 | 15-26/11 | 11-17/12 | 07-11/01 | 01-05/02 | 24-28/02 | 24-30/03 | 14-23/04 | Total |
| EC | 0.04 | 0.24 | 0.42 | 0.27 | 0.51 | 0.68 | 0.66 | 1.27 | 4.09 |
| LHC | 0.13 | 0.17 | 0.35 | 0.32 | 0.47 | 0.59 | 0.73 | 1.29 | 4.06 |
| LLC | 0.06 | 0.16 | 0.27 | 0.29 | 0.49 | 0.74 | 0.77 | 1.22 | 4.00 |
| SEM | 0.02 | 0.04 | 0.04 | 0.05 | 0.07 | 0.08 | 0.09 | 0.16 | 0.39 |
| Signif. | ** | ns | ns | ns | ns | ns | ns | ns | ns |

Table 4.7. Individual tiller weight (mg) of new formed tillers at the final harvest of Experiment 2 (14 to 23 April, 1992)[1]

| | Tiller cohorts tagging dates | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment | 26-31/10 | 15-26/11 | 11-17/12 | 07-11/01 | 01-05/02 | 24-28/02 | 24-30/03 | 14-23/04 |
| EC | 27.8 | 34.5 | 30.9 | 28.7 | 22.7 | 19.7 | 16.6 | 4.8 |
| LHC | 31.5 | 45.2 | 38.9 | 29.2 | 31.0 | 31.1 | 20.5 | 6.2 |
| LLC | 28.5 | 36.4 | 33.6 | 31.4 | 34.6 | 27.4 | 19.6 | 6.4 |
| | | | | | | | | |
| SEM | 9.1 | 6.7 | 2.6 | 3.7 | 3.0 | 3.7 | 1.3 | 0.7 |
| Signif. | ns | ns | + | ns | * | + | + | ns |

1) Statistical analysis performed on transformed data: square root

Table 4.8. Total weight (mg) of new formed tillers per parent tiller at the final harvest of Experiment 2 (14 April, 1992)[1]

| | Tiller cohorts tagging dates | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment | 26-31/10 | 15-26/11 | 11-17/12 | 07-11/01 | 01-05/02 | 24-28/02 | 24-30/03 | 14-23/04 |
| EC | 5.0 | 9.6 | 13.4 | 8.6 | 13.8 | 14.0 | 11.3 | 6.5 |
| LHC | 9.3 | 8.9 | 15.1 | 10.4 | 15.0 | 17.2 | 14.5 | 8.7 |
| LLC | 4.1 | 8.5 | 9.5 | 10.5 | 16.6 | 21.4 | 15.3 | 8.9 |
| SEM | 2.3 | 2.0 | 2.2 | 1.8 | 2.6 | 2.4 | 2.9 | 1.5 |
| Signif. | ns | ns | ns | ns | ns | + | ns | ns |

1) Statistical analysis performed on transformed data: square root

Although a similar number of new formed tillers per parent tiller was observed at the end of Experiment 2, more detailed measurements of the tillering process revealed that swards subjected to different treatments exhibited different tiller demographic patterns (Figure 4.4). Swards had similar numbers of tagged tillers during the pre-control phase (October-November), with numbers decreasing significantly at the time of control of the reproductive growth on LHC and LLC (December), and recovering soon after the control and throughout the post-control phase (January-April) (Table 4.9). Again a high turnover in tiller population was observed with only 24% of the originally tagged tillers present in early January/92.

During the pre-control phase the LHC and LLC plots showed lower tiller appearance rates (TAR), lower tiller death rates (TDR) and higher tiller survival rates (TSR) than did EC plots (Table 4.10). Rates of death and survival of tillers were similar throughout the control and post-control phases, with treatments under the laxer spring grazing regime presenting the highest TAR, particularly the LLC treatment.

### 4.3.2. Grass tiller and clover stolon/node population

In Experiment 1, due to problems of identification between ryegrass and other grass species, results for the grass component of the sward are presented as total grass tillers (ryegrass + other grasses). However, the proportions of ryegrass and other grasses in the herbage being accumulated from grasses (Table 4.17) indicate that ryegrass was the major grass species present. Plots under the laxer spring grazing management (LHC and VLHC) had a higher total grass tiller population (Table 4.11) and higher white clover stolon density than did EC (Table 4.12) at the end of the experimental period.

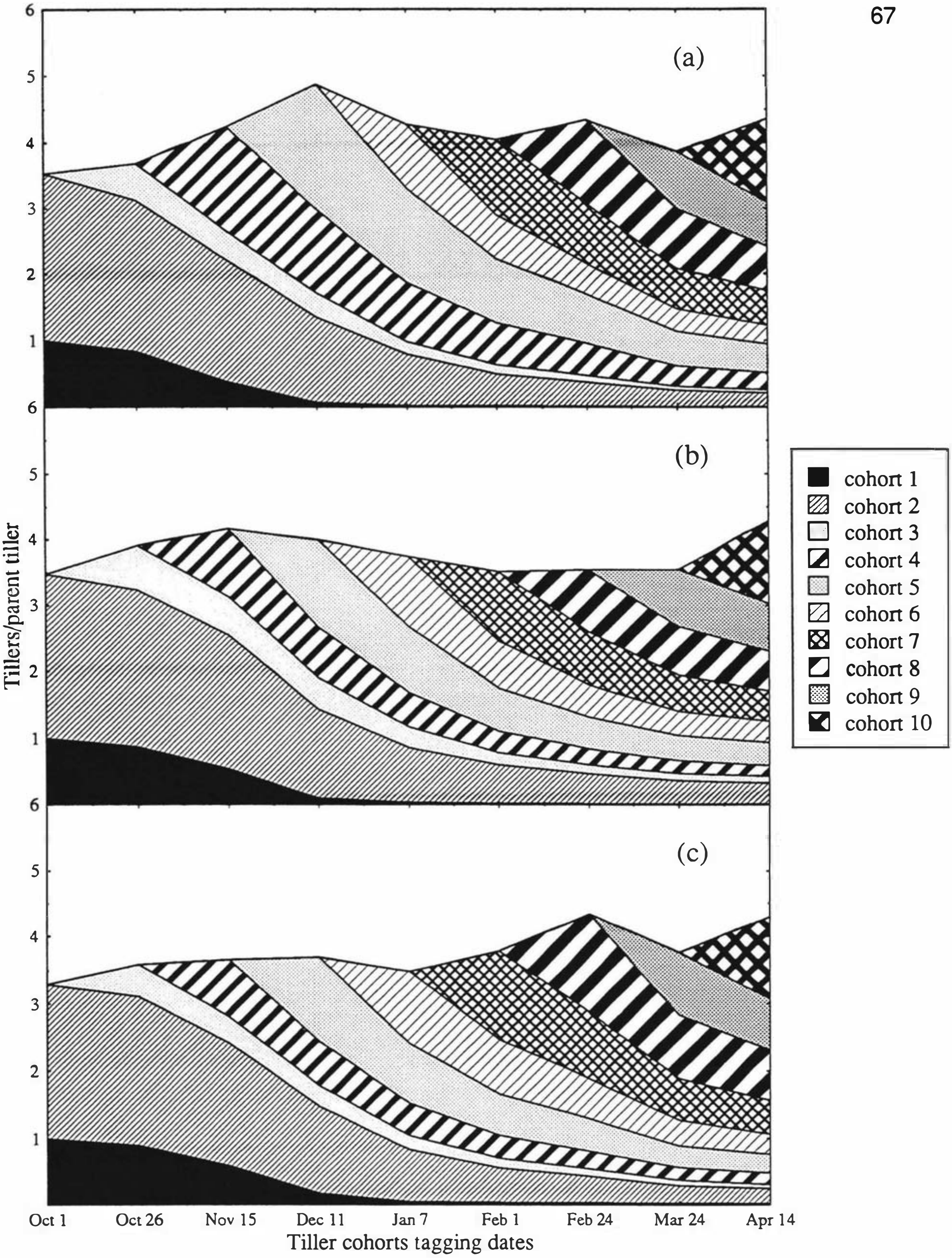

Figure 4.4. Ryegrass tillering pattern throughout the 1991/92 season for (a) EC; (b) LHC; and (c) LLC

Table 4.9. Average number of tagged tillers per parent tiller throughout Experiment 2

| | Tagging dates | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Treatment | 01-10/10 | 26-31/10 | 15-26/11 | 11-17/12 | 07-11/01 | 01-05/02 | 24-28/02 | 24-30/03 | 14-23/04 |
| EC | 3.5 | 3.7 | 4.2 | 4.9 | 4.3 | 4.0 | 4.3 | 3.9 | 4.4 |
| LHC | 3.5 | 3.9 | 4.2 | 4.0 | 3.7 | 3.5 | 3.5 | 3.5 | 4.3 |
| LLC | 3.3 | 3.6 | 3.7 | 3.7 | 3.5 | 3.8 | 4.3 | 3.8 | 4.3 |
| SEM | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.3 | 0.4 |
| Signif. | ns | ns | ns | * | ns | ns | ns | ns | ns |

Table 4.10. Rates of ryegrass tiller appearance, death and survival for the different experimental phases in Experiment 2

| | Experimental Phase[1] | Treatments | | | SEM | Signif. |
|---|---|---|---|---|---|---|
| | | EC | LHC | LLC | | |
| | Pre | 33.7 | 25.8 | 23.9 | 2.4 | * |
| TAR | Control | 17.3 | 23.8 | 27.0 | 1.3 | *** |
| (tillers/100 tillers) | Post | 27.3 | 28.9 | 35.0 | 1.6 | ** |
| | Pre | 25.7 | 23.7 | 22.3 | 0.9 | * |
| TDR | Control | 38.0 | 38.3 | 40.3 | 2.1 | ns |
| (tillers/100 tillers) | Post | 29.1 | 28.5 | 30.0 | 1.4 | ns |
| | Pre | 74.3 | 76.3 | 77.7 | 0.9 | * |
| TSR | Control | 62.0 | 61.4 | 59.7 | 2.2 | ns |
| (%) | Post | 70.9 | 71.1 | 70.0 | 1.5 | ns |

1) Pre = Oct-Nov/91, Control = Dec/91, Post = Jan-Apr/92

Table 4.11. Grass tiller population density (tillers/m$^2$) at the end of Experiment 1 (April/91) and throughout Experiment 2

| Treat. | Ryegrass[1] | | | | | Other grasses | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Apr/91[2] | Oct/91 | Dec/91[3] | Mar/92 | Apr/92 | Apr/91 | Oct/91 | Dec/91[3] | Mar/92 | Apr/92 |
| EC | 3970 | 3820 | 3030 | 3480 | 4240 | - | 2350 | 3990 | 5180 | 4730 |
| LHC | 4930 | 3780 | 2040 | 3480 | 3720 | - | 2880 | 2590 | 5250 | 5010 |
| VLHC[4] | 4740 | 4210 | 2020 | 3930 | 3940 | - | 2680 | 2200 | 4940 | 4010 |
| SEM | 313 | 142 | 216 | 305 | 316 | - | 303 | 294 | 298 | 233 |
| Signif. | * | + | ** | ns | ns | - | ns | ** | ns | * |

1) For 1990/91 it represents total grass tiller population (ryegrass + other grasses)
2) Statistical analysis performed on transformed data: cosin
3) Time of control of the reproductive growth on "late control" plots
4) Replaced by LLC in the 1991/92 season

Table 4.12. White clover stolon population at the end of each experiment and clover nodes density throughout Experiment 2

| | Clover stolon ($m/m^2$) | | Clover nodes ($nodes/m^2$) | | | | Internode length (cm/node) |
|---|---|---|---|---|---|---|---|
| Treat. | Apr/91 | Apr/92 | Oct/91 | Dec/91[1] | Mar/92 | Apr/92 | Apr/92[2] |
| EC | 41.4 | 109.6 | 1370 | 3190 | 3600 | 4520 | 2.5 |
| LHC | 61.6 | 112.4 | 1600 | 2330 | 3850 | 4360 | 2.6 |
| VLHC[3] | 59.4 | 113.8 | 1430 | 1980 | 3400 | 4230 | 2.8 |
| SEM | 5.3 | 6.4 | 141 | 242 | 225 | 354 | 0.1 |
| Signif. | * | ns | ns | ** | ns | ns | * |

1) Time of control of the reproductive growth on "late control" plots
2) Statistical analysis performed on transformed data: sin
3) Replaced by LLC in the 1991/92 season

In Experiment 2 the species population changes were monitored more often, revealing that there was a significant reduction in tiller numbers and white clover nodes by the time of the late control of the reproductive growth on the lax grazed plots (Tables 4.11 and 4.12). Grass tiller and clover node populations of the LHC and LLC plots were restored during the control and post-control phases, and were similar to those of the EC plots at the end of the season. These changes in the ryegrass tiller population followed closely the changes observed in the total number of tillers formed per parent tiller during measurements of tiller dynamics (Table 4.9). Other grass tiller populations tended to follow the same pattern as ryegrass tillers, although treatments had no effect on weed population densities (Table 4.13).

Lax grazing during spring (LHC and VLHC swards) resulted in the highest white clover stolon density at the end of experiment 1 (April/91), but the same difference was not observed at the end of experiment 2 (April/92), although plants grown under the lax spring grazing regimes (LHC and LLC), particularly LLC, showed longer internode length than those under EC (Table 4.12).

Table 4.13. Weed population densities (plants/m$^2$) throughout Experiment 2

| Treatments | Oct/91 | Dec/91[1] | Mar/92 | Apr/92 |
|---|---|---|---|---|
| EC | 65 | 53 | 67 | 80 |
| LHC | 56 | 38 | 89 | 89 |
| LLC | 41 | 36 | 79 | 42 |
| | | | | |
| SEM | 15 | 20 | 32 | 30 |
| Signif. | ns | ns | ns | ns |

1) Time of control of the reproductive growth on "late control" plots

### 4.3.3. Dry matter production and herbage accumulation rates

In this section results are presented for each separate year, but an overall analysis dealing with year and treatment x year effects is presented in Chapter 7. In Experiment 2, treatments LHC and LLC were expected to perform similarly during the pre-control phase. Instead, LHC swards had lower herbage accumulation rates, and their poorer performance extended throughout the rest of the season. The fact that herbage accumulation rates were depressed on LHC relative to LLC plots before the commencement of differential treatments is unexplained (Table 4.14), but needs to be borne in mind when interpreting results for this treatment.

In general, treatments involving lax defoliation regimes during spring (LHC/VLHC in Experiment 1 and LHC/LLC in Experiment 2) tended to accumulate herbage at a faster rate than the conventional hard grazing ones (EC) during both pre-control and post-control phases (Table 4.14). In Experiment 1 a substantial degree of variation was associated with the measurements (average coefficient of variation from January to April of about 63.5%), resulting in differences being non-significant for most regrowth intervals. In Experiment 2, with the further sub-division of experimental strips into sampling areas, variation was better controlled but still of considerable size (average coefficient of variation from January to April of about 21.9%). Higher total herbage accumulation rates were most evident towards the end of the post-control phase, particularly March and April in both seasons. The trends (Experiment 1) and/or differences (Experiment 2) in herbage accumulation rates were reflected in total herbage accumulation for each of the experimental phases concerned and for the total production of the whole period (Table 4.15). During the pre-control phase the increased total dry matter accumulation for the late control treatments was a consequence of higher green and senescent dry matter accumulation (Table 4.16). Green

Table 4.14. Monthly herbage accumulation rates for Experiments 1 and 2 (Kg DM/ha/day)

| | Experiment 1 | | | | | Experiment 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Month | EC | LHC | VLHC | SEM | Signif. | EC | LHC | LLC | SEM | Signif. |
| Oct | 55.0 | 64.0 | 64.0 | 8.6 | ns | 44.0 | 39.0 | 44.0 | 5.1 | ns |
| Nov | 49.0 | 73.0 | 94.0 | 7.0 | * | 35.0 | 45.0 | 53.0 | 4.3 | * |
| Dec | 67.0 | 72.0 | 75.0 | 9.3 | ns | 46.0 | 44.0 | 54.0 | 3.2 | * |
| Jan | 55.0 | 49.0 | 53.0 | 9.1 | ns | 62.0 | 60.0 | 71.0 | 5.5 | ns |
| Feb | 27.0 | 30.0 | 23.0 | 7.8 | ns | 49.0 | 53.0 | 54.0 | 3.5 | ns |
| Mar | 22.0 | 46.0 | 29.0 | 10.8 | ns | 38.0 | 31.0 | 45.0 | 4.5 | * |
| Apr[1] | 20.0 | 27.0 | 39.0 | 9.6 | ns | 40.0 | 47.0 | 51.0 | 5.6 | * |

1) Statistical analysis performed on transformed data (sin) for the 1991/92 season

Table 4.15. Total herbage dry matter accumulation in Experiments 1 and 2 (Kg DM/ha)

| | Experiment 1 | | | | | Experiment 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Phase[1] | EC | LHC | VLHC | SEM | Signif. | EC | LHC | LLC | SEM | Signif. |
| Pre | 3190 | 4180 | 4820 | 386 | * | 2430 | 2570 | 2960 | 210 | ns |
| Control | 2080 | 2240 | 2330 | 288 | ns | 1430 | 1350 | 1680 | 100 | * |
| Post | 3740 | 4580 | 4330 | 678 | ns | 5600 | 5670 | 6590 | 299 | * |
| Season | 9010 | 11000 | 11480 | 803 | ns | 9460 | 9590 | 11230 | 275 | ** |

1) Pre = Oct-Nov; Control = Dec; Post = Jan-Apr

Table 4.16. Herbage components accumulation (Kg DM/ha) in Experiments 1 and 2

| | | Pre[1] | | Control[1] | | Post[1] | |
|---|---|---|---|---|---|---|---|
| Experiment | Treatments | green | senescent | green | senescent | green | senescent |
| | EC | - | - | 2310 | -230 | 4030 | -290 |
| 1 | LHC | - | - | 1830 | 410 | 4730 | -150 |
| | VLHC | - | - | 1810 | 520 | 4880 | -550 |
| | SEM | - | - | 165 | 259 | 601 | 348 |
| | Signif. | - | - | + | + | ns | ns |
| | EC | 1070 | -10 | 1460 | -30 | 5640 | -40 |
| 2 | LHC | 1310 | 70 | 1190 | 160 | 5570 | 100 |
| | LLC | 1380 | 220 | 1170 | 510 | 6210 | 380 |
| | SEM | 135 | 56 | 176 | 160 | 380 | 192 |
| | Signif. | ns | * | ns | * | ns | ns |

1) Pre = Nov only; Control = Dec; Post = Jan-Apr

herbage accumulation was reduced during the control phase, and senescent herbage accumulation significantly increased. After the control of the reproductive growth on the lax spring grazed plots had taken place and the swards had been re-established in their vegetative state, the accumulation of green dry matter increased again, resulting in higher green and total herbage accumulation for the late rather than early control treatments during the post-control phase. Despite some sizeable differences between treatments in relation to herbage component accumulation, none of the differences was significant due to the high variability associated with the data set.

The trend for increased green dry matter production during the pre-control phase for the late control treatments was associated with increases in other grass and perennial ryegrass stem components of herbage accumulation, as the reproductive growth progressed (Tables 4.17, 4.18, 4.19; Figure 4.5). During the control phase, the reduced green dry matter production for the late control treatments was due chiefly to the reduction in ryegrass accumulation, probably reflecting the reduced ryegrass tiller density of those swards at that time of the year (Table 4.11). Herbage components accumulation was quite variable during the post-control phase for different seasons. In Experiment 1, the increased green dry matter accumulation for the late control treatments came, basically, from enhanced ryegrass accumulation (Table 4.17), but in Experiment 2, bearing in mind the limitations of the LHC treatment in that year, it appeared to come primarily from enhanced white clover accumulation (EC vs LLC; Tables 4.18 and 4.19). No effect on weed dry matter accumulation was detected at any season or experimental phase (Tables 4.17 and 4.18). The ryegrass:white clover balance of all experimental swards was characterised by a seasonal pattern (Figure 4.6), probably a consequence of the different plant species characteristics and environmental requirements.

No direct evaluation of the nutritive value of the pasture grown was carried out, but inferences can be drawn from the morphological changes caused in the swards by different grazing treatments in Experiment 2. No significant changes in the live:senescent material ratio of the swards were observed throughout the experimental period (Table 4.20). On the other hand, the quality of the green material produced was quite variable and reflected the physiological state of the swards. During the pre-control phase the leaf:stem ratio of the grass component in the late controlled swards (LHC and LLC) was significantly reduced. Subsequently, leaf:stem ratios for late controlled swards were re-established to levels similar to that of early controlled swards (Table 4.21).

Table 4.17. Green dry matter accumulation components[1] during Experiment 1 (Kg DM/ha)

| | | Ry | | | | | |
|---|---|---|---|---|---|---|---|
| Phase[2] | Treatment | leaf | stem | leaf+stem | Og | Wc | Wd |
| Control | EC | 1090 | 440 | 1530 | 110 | 650 | 20 |
| | LHC | 1030 | -50 | 980 | 60 | 800 | -10 |
| | VLHC | 1060 | -160 | 900 | -10 | 840 | 80 |
| | SEM | 100 | 90 | 154 | 63 | 142 | 41 |
| | Signif. | ns | ** | * | ns | ns | ns |
| Post | EC | 2190 | 0 | 2190 | 550 | 1190 | 100 |
| | LHC | 2950 | -10 | 2940 | 290 | 1420 | 80 |
| | VLHC | 2940 | 280 | 3220 | 330 | 1190 | 140 |
| | SEM | 334 | 209 | 359 | 274 | 349 | 113 |
| | Signif. | ns | ns | + | ns | ns | ns |

1) Ry = ryegrass; Og = other grasses; Wc = white clover; Wd = weeds
2) Control = Dec/90; Post = Jan-Apr/91

Table 4.18. Species dry matter accumulation during Experiment 2 (Kg DM/ha)

| Phase[1] | Treatment | Ryegrass | Other grasses | White clover | Weeds |
|---|---|---|---|---|---|
|  | EC | 550 | -30 | 540 | 10 |
| Pre | LHC | 630 | 210 | 480 | -10 |
|  | LLC | 570 | 190 | 640 | -20 |
|  | SEM | 159 | 139 | 107 | 21 |
|  | Signif. | ns | ns | ns | ns |
|  | EC | 400 | 60 | 980 | 20 |
| Control | LHC | 260 | -100 | 960 | 70 |
|  | LLC | -90 | 30 | 1210 | 20 |
|  | SEM | 90 | 61 | 153 | 39 |
|  | Signif. | ** | ns | ns | ns |
|  | EC | 3080 | 440 | 1970 | 150 |
| Post | LHC | 3130 | 440 | 1900 | 100 |
|  | LLC | 3200 | 370 | 2440 | 200 |
|  | SEM | 293 | 358 | 364 | 123 |
|  | Signif. | ns | ns | ns | ns |

1) Pre = Nov/91 only; Control = Dec/91; Post = Jan-Apr/92

Table 4.19. Species components accumulation[1] (Kg DM/ha) in Experiment 2

| | | Ry | | Og | | Wc | |
|---|---|---|---|---|---|---|---|
| Phase[2] | Treatment | L | S | L | S | L | S |
| | EC | 450 | 100 | -30 | 0 | 490 | 50 |
| Pre | LHC | 270 | 360 | -40 | 250 | 410 | 70 |
| | LLC | 240 | 330 | -40 | 230 | 560 | 80 |
| | SEM | 79 | 107 | 35 | 111 | 78 | 49 |
| | Signif. | + | ns | ns | ns | ns | ns |
| | EC | 410 | -10 | 80 | -20 | 790 | 190 |
| Control | LHC | 280 | -20 | 20 | -120 | 780 | 180 |
| | LLC | 170 | -260 | 120 | -90 | 1000 | 210 |
| | SEM | 63 | 68 | 21 | 57 | 112 | 84 |
| | Signif. | * | * | * | ns | ns | ns |
| | EC | 2730 | 350 | 520 | -80 | 2330 | -360 |
| Post | LHC | 2780 | 350 | 520 | -80 | 2190 | -290 |
| | LLC | 2800 | 400 | 400 | -30 | 2740 | -300 |
| | SEM | 190 | 145 | 230 | 171 | 285 | 148 |
| | Signif. | ns | ns | ns | ns | ns | ns |

1) Ry = ryegrass; Og = other grasses; Wc = white clover; L = leaf; S = stem/stolon

2) Pre = Nov/91 only; Control = Dec/91; Post = Jan-Apr/92

Table 4.20. Pre-grazing live:senescent material ratio for the three experimental phases of Experiment 2

| | Treatments | | | | |
|---|---|---|---|---|---|
| Phase | EC | LHC | LLC | SEM | Signif. |
| Pre | 3.80 | 4.41 | 4.05 | 0.24 | ns |
| Control | 3.73 | 2.64 | 2.26 | 0.48 | ns |
| Post | 3.58 | 3.22 | 2.81 | 0.25 | ns |

Table 4.21. Pre-grazing leaf:stem ratio of the grass component of the sward for the three experimental phases of Experiment 2

| | Treatments | | | | |
|---|---|---|---|---|---|
| Phase | EC | LHC | LLC | SEM | Signif. |
| | | Ryegrass: | | | |
| Pre | 1.19 | 0.91 | 0.84 | 0.05 | ** |
| Control | 2.01 | 2.86 | 1.81 | 0.45 | ns |
| Post | 2.94 | 2.79 | 2.87 | 0.21 | ns |
| | | Other grasses: | | | |
| Pre | 0.74 | 0.85 | 0.70 | 0.52 | ns |
| Control | 1.28 | 1.50 | 0.92 | 0.19 | ns |
| Post | 1.84 | 1.65 | 1.34 | 0.17 | ns |
| | | Overall: | | | |
| Pre | 0.94 | 0.86 | 0.77 | 0.04 | * |
| Control | 1.73 | 2.11 | 1.19 | 0.23 | + |
| Post | 2.53 | 2.17 | 2.09 | 0.20 | ns |

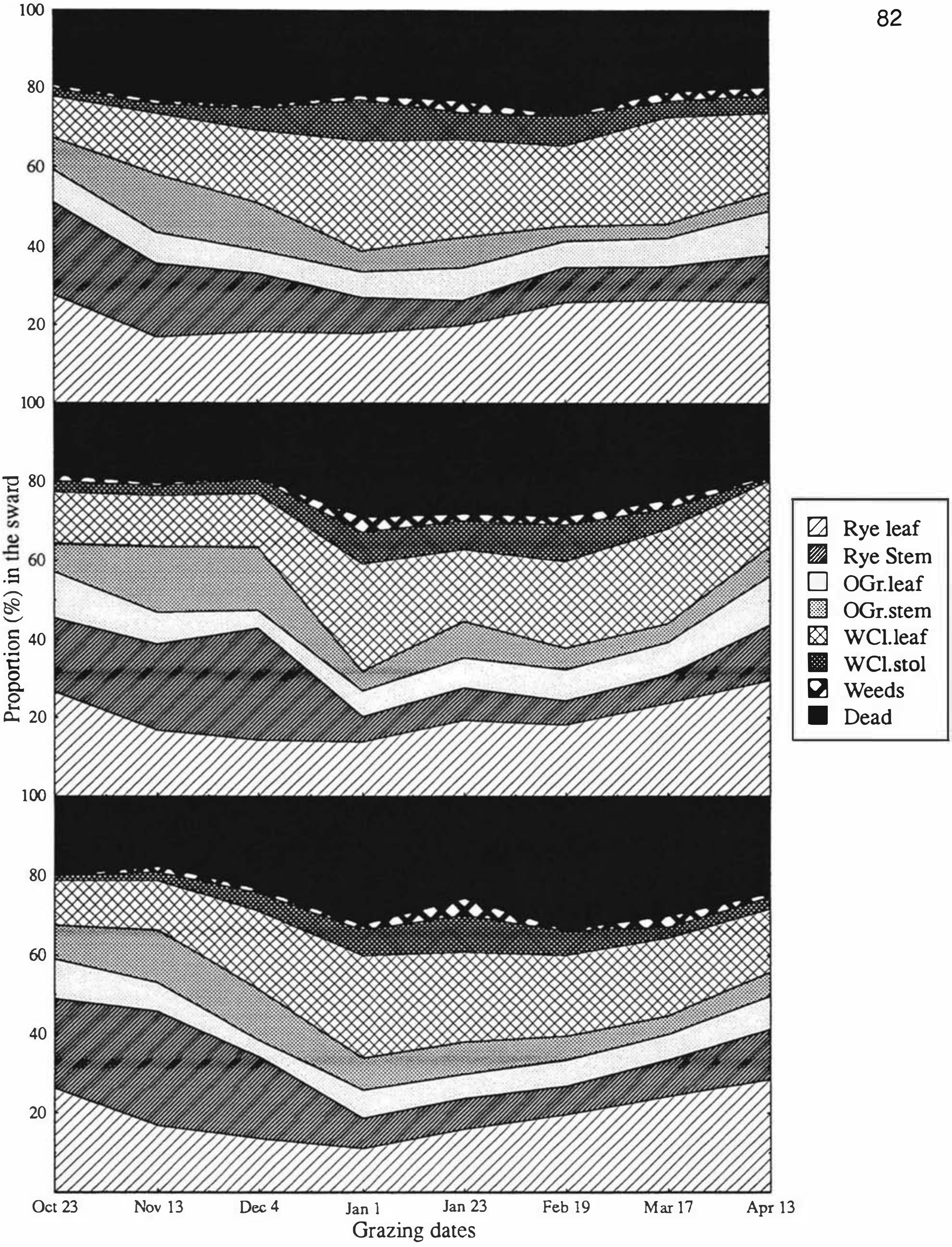

Figure 4.5. Botanical composition of EC (top), LHC (middle), and LLC (bottom) swards at pre-grazing throughout the 1991/92 season

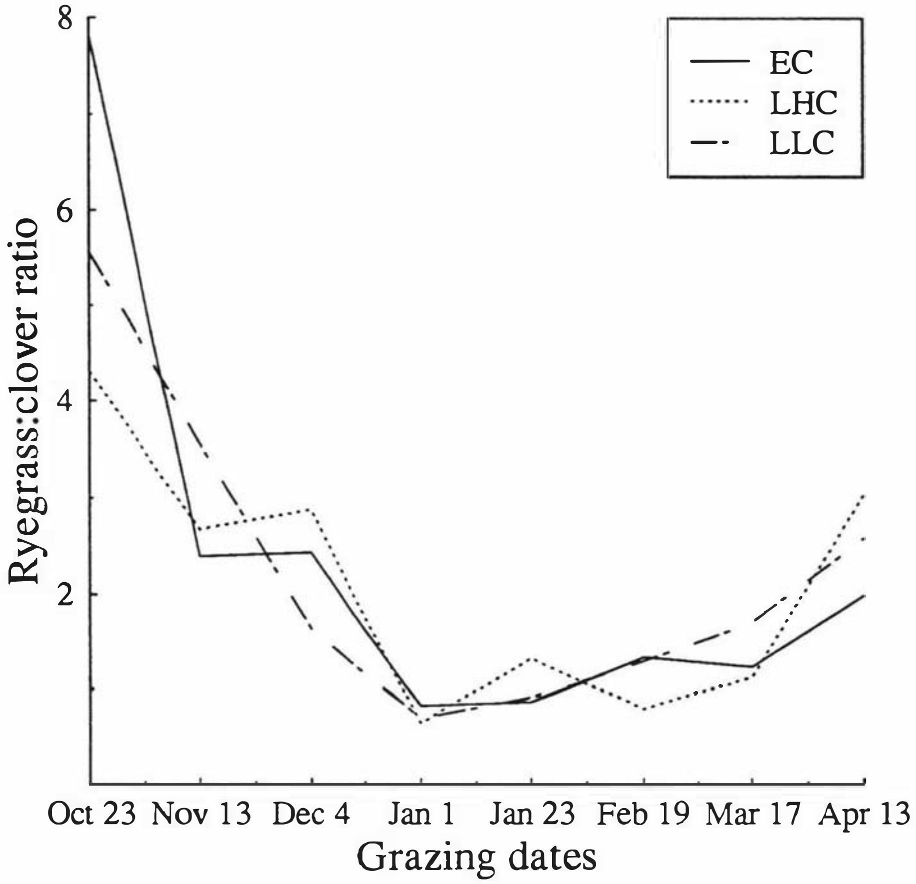

Figure 4.6. Ratio between perennial ryegrass (%) and clover (%) at pre-grazing masses in Experiment 2

### 4.3.4. Relationship between the measured variables according to Canonical Discriminant Analysis (CDA)

Since all the variables measured influence pasture production, they would be expected to be correlated to each other. This is the type of correlation which is assessed in multivariate analysis and can be used to study the interrelationships between data sets of measurements made on the same subjects (Cooley & Lohnes, 1971). Canonical correlation identifies the maximum correlation between linear functions of two vector variables generated from the original data set, the canonical factors or discriminant functions. Each canonical factor accounts for some of the variation in the original data set, and their relative importance within the overall data set is given by the proportion of the multivariate dispersion explained. Often one or two of these canonical factors account for much of the variation in a larger data set (Cooley & Lohnes, 1971). Preliminary CDA analysis on soil fertility results revealed that the most significant discriminant function for paddocks was based on a contrast between pH and combined levels of P and K. In addition, for the ryegrass tillering results, the most significant discriminant function for treatments was based on spring and summer/autumn tiller appearance rates. Thus 90 observations on 5 variables measured in Experiment 2 were used in a CDA as follows: (i) soil fertility: pH, combined levels of P and K (P+K); (ii) ryegrass tiller appearance: spring and summer/autumn rates; and (iii) herbage accumulation: summer/autumn rates, where the discrimination was performed for both experimental paddocks and treatments.

The results obtained demonstrated quite clearly that experimental paddocks did differ from each other in soil fertility status, as previously found from the univariate analysis of variance (Section 4.2.5.4), and that such differences were associated with the contrasting tillering patterns observed during the experimental period ($r^2 = 0.9331$; P = 0.0082). The first and second canonical factors accounted for 64% and 27% of the overall variance respectively, and revealed that paddocks that had high levels of phosphorus and potassium in the soil had high summer/autumn tiller appearance rates (Table 4.22, Figure 4.7). In particular, inspection of paddock means (Figure 4.7) shows that paddock 1 had lower fertility and lower summer-autumn tillering than the other paddocks. Additionally, there was a marginally significant treatment effect on tiller production (P = 0.0920), with the first canonical factor accounting for 97% of the multivariate dispersion. The multivariate analyses indicate that treatments that had high summer/autumn herbage accumulation rates also had low spring but high summer/autumn tiller appearance rates ($r^2 = 0.9231$). This is illustrated by plotting treatment means for herbage accumulation and tiller appearance rates (Figure 4.8), and was consistent with the theoretical hypothesis being tested. Furthermore, in this canonical factor soil fertility also appeared as a very strong feature with a coefficient of 0.9999 (Table 4.22). This result is somehow surprising, since the results from the univariate analysis on the soil fertility results revealed no significant difference between treatments for any of the soil fertility traits measured (Table 4.2 in Section 4.2.5.4). However, levels of labile phosphorus were slightly higher for the LLC treatment than for EC and LHC, the treatment that also showed the highest tiller appearance and herbage accumulation rates during the summer-autumn period. On this basis, the possibility that these small and non-significant differences in fertility status between strips within paddocks contributed to the observed differences between treatments can not be ruled out.

Table 4.22. First canonical factor for analysis of (1) paddock and (2) treatment effects in CDA of five variables.

| Variable | Canonical 1 (Paddock) | Canonical 1 (Treatments) |
|---|---|---|
| Soil fertility: | | |
| pH | 0.7531 | 0.4201 |
| P+K | -0.8383 | 0.9999 |
| Tillering: | | |
| spring | 0.2119 | -0.8353 |
| summer/autumn | -0.5958 | 0.9977 |
| Herbage accum. | -0.4461 | 0.9756 |
| Canonical $r^2$ | 0.9331 | 0.9231 |
| Proportion[1] | 0.6391 | 0.9668 |
| Probability | 0.0082 | 0.0920 |

[1] Proportion of multivariate dispersion explained

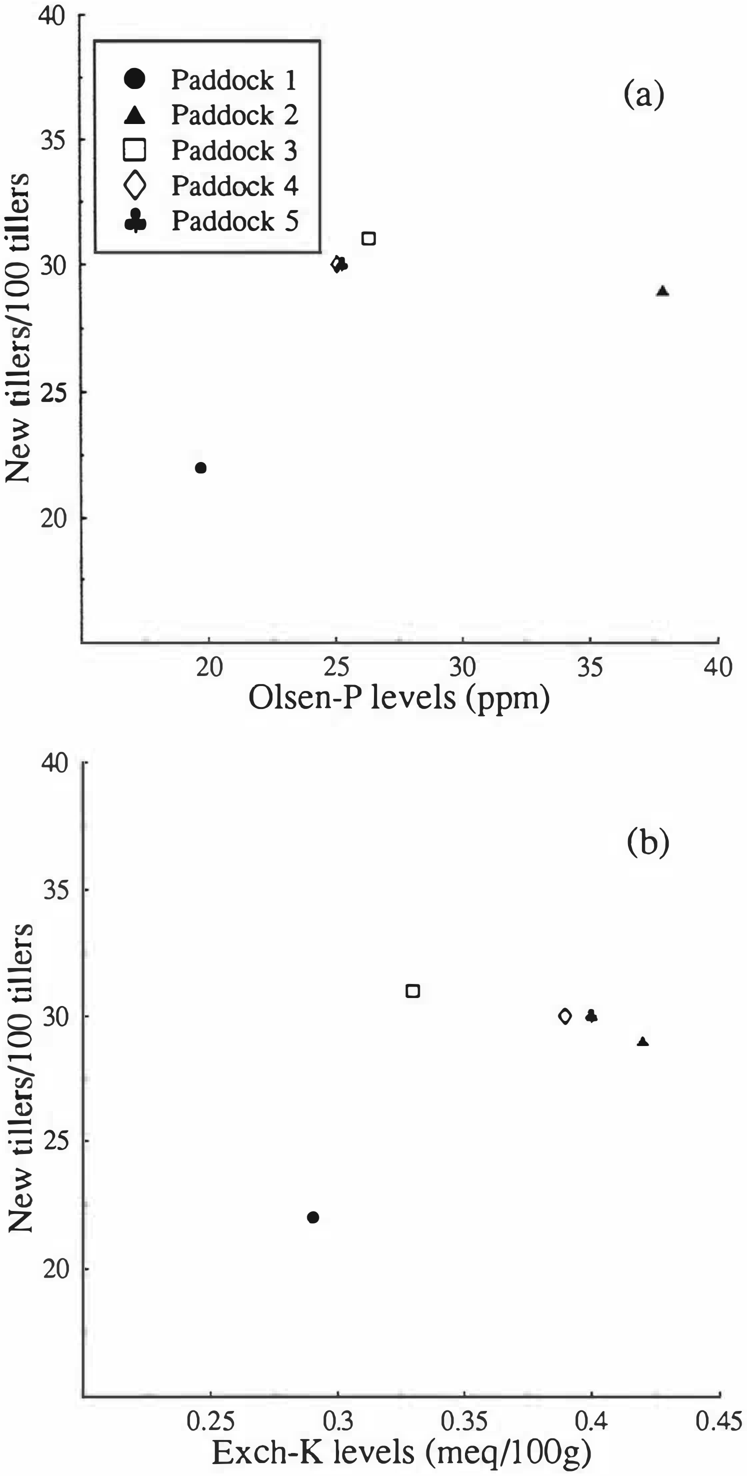

Figure 4.7. Relationship between summer-autumn tillering and soil fertility as represented by Olsen-P (a) and Exch-K (b) levels.

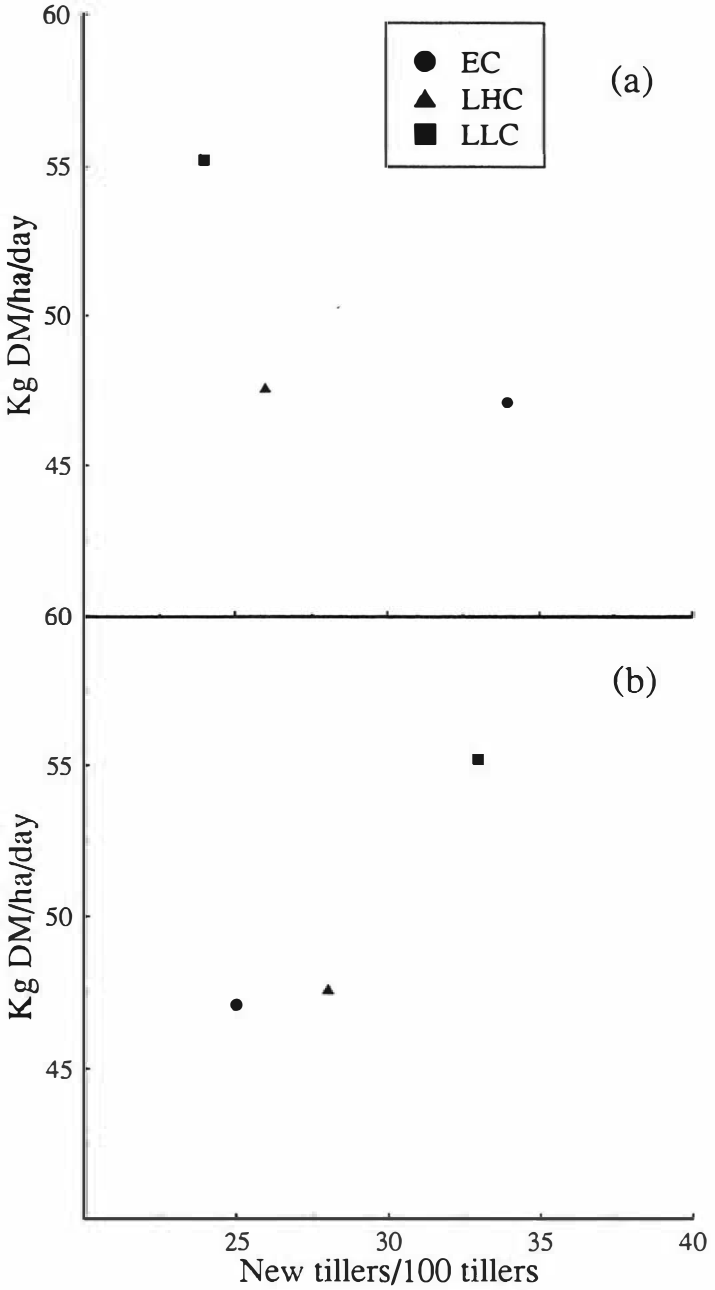

Figure 4.8. Relationship between summer-autumn herbage accumulation rates and the spring (a) and summer-autumn (b) tillering

## 4.4. Discussion

### 4.4.1. Research techniques

Experimental areas used in either Experiment 1 or 2 were large and therefore likely to present problems of substantial variability between and within paddocks (blocks). In Experiment 1, random sampling (quadrat cuts) of each strip (Frame, 1981) was used in association with a completely randomised block (CRB) design. Results obtained during that experiment revealed that the CRB design was effective in eliminating the noise coming from the differences between paddocks in the analysis of variance, but the number of samples harvested within each strip was not big enough to cope with the within treatment variability. As a consequence, the intensity and structure of the sampling procedures used in Experiment 2 were altered in order to increase the precision of the measurements being carried out. Strips were sub-divided into sampling areas and the total number of samples per strip increased, with samples now being harvested randomly within each sampling area (Frame, 1981).

This re-structuring in sampling procedures proved to be effective in dealing with the between and within paddock variability, and coeficients of variation (CV) of around 65% in Experiment 1 were reduced to values of around 20%, which were within the 10-40% range presented by Frame (1981) for typical plot sub-sampling techniques. Estimates of tiller density and demography presented CV varying from 8 to 22%, which were also within the range of 10-45% presented by Jewiss (1981) for a wide range of techniques used to determine these pasture traits. Therefore, the changes carried out in sampling procedures were effective in reducing variability and increasing experimental precision to acceptable levels. Further improvements in precison might be achieved by the adoption of double sampling procedures (Frame, 1981; Thom *et al.*, 1986) and/or ranked sampling methods (McIntyre, 1952).

### 4.4.2. Ryegrass tiller demography, dynamics and population

A considerable amount of variability occurred in the results of individual tiller observations in Experiment 1, mainly due to variation within experimental plots (transects). This effect was probably due, in part, to the fact that several people worked on the tiller tagging procedure, possibly introducing differences in interpretation in some cases. Balancing operators across plots and treatments was not possible at that time. As a consequence, no overall differences among treatments were detected (Tables 4.3, 4.4, and 4.5), although the results from grass tiller population measurement at the end of the trial (Table 4.11) and of herbage accumulation components during the post-control phase (Table 4.17) suggested otherwise. The trend for lower tillering on the LHC treatment was not expected. If this was a real effect, a possible reason could be that removal of seedheads immediately after stem elongation, before there has been time for appreciable photosynthesis, actually leaves the plant more depleted of reserves than not allowing the seedheads to form in the first place (Matthew, 1990). It is possible that control treatments could have had a more marked effect on tillering if mowing height had been a little higher for the LHC and VLHC treatments, since reduced stubble heights are likely to reduce the formation of new tillers from the cut stubs of reproductive tillers (Davies, 1977,1988; Matthew *et al.*, 1991). The individual weight of new primary tillers (NT) at the February harvest was smaller than that at the December harvest (Table 4.4), the probable reason being that numbers of early formed NT also flowered, and that NT recorded at the February harvest were newly formed. Only vegetative tillers were included in the means presented in Table 4.4.

In Experiment 2, tillers in swards grazed laxly during spring with consequent early seedhead development (LHC and LLC), tillered and died at a slower rate than did those in hard grazed swards (EC) during the pre-control phase (Table 4.10), resulting in lower ryegrass tiller populations at the time of control for the LHC and LLC treatments (Table 4.11). Poor tillering activity and reduced tiller population have previously been associated with ryegrass swards allowed to go through their reproductive growth phase (Korte, 1982; Korte *et al.*, 1982). Reproductive swards are characterised by a poor light environment which adversely affects the tillering process (Korte, 1982), an effect which is exacerbated by the ability of maturing seedheads to compete strongly with young tillers for carbohydrate (Ong *et al.*, 1978; Carton *et al.*, 1989b; Matthew, 1991a; Matthew *et al.*, 1991; Thom, 1991). Such competition is known to result in reduced number and size of new tillers formed, and also increased death of young tillers if seedheads are allowed to pass the stage of anthesis (Matthew, 1991a).

Rates of tiller appearance under the LHC and LLC treatments became higher than those under EC during the control phase and remained higher for the LLC treatment during the post-control phase (Table 4.10). That effect, in association with similar rates of tiller death and survival for all treatments, allowed the number of tillers formed per parent tiller and tiller population to be re-established in late control treatments by the end of Experiment 2 in April/92 (Tables 4.9 and 4.11). Tillers formed after the control phase on swards laxly grazed during spring were heavier than those on hard grazed swards (Table 4.7). The high tiller appearance rates for LHC and LLC during the control phase were probably due to a more open sward that allowed ryegrass plants to tiller freely under a situation of reduced intra-specific or self-competition. The same explanation does not apply to the post-control phase, when tiller populations for those treatments were essentially the same (Table 4.9) but LLC swards continued to tiller at a much faster rate than EC plots (Table 4.10).

Enhanced tillering activity following delay of interruption of reproductive growth until anthesis has been reported previously (Matthew, 1988; Matthew *et al.*, 1989ab; Matthew *et al.*, 1993; Xia *et al.*, 1990). Although some evidence of such enhancement of tillering activity obtained from the results of the two field experiments reported, the differences between treatments in ryegrass tiller densities at the end of the measurement periods were not significant (Table 4.11). However, there was a trend for tillers being produced in late controlled swards to be heavier than those produced from EC swards (Table 4.7), and such an increase in tiller size could be equivalent to an increase in tiller numbers according to the size/density compensation mechanism described by Matthew *et al.* (in prep.).

In both Experiments 1 and 2 a high turnover of tillers was observed during the pre-control and control phases for all treatments, with only 20-25% of the original population of tagged tillers being present in early January. That indicates that most of the early spring daughter tillers from flowering tillers are short lived, and pastures need to rely on the late spring-early summer tillering to ensure adequate tiller numbers going into the summer period. The importance of tiller replacement and tillering during late spring-early summer has also been highlighted in earlier studies (Korte *et al.*, 1982,1984,1985,1986; L'Huillier, 1987b; Matthew, 1991a,1992; Thom, 1991), and it also seems to play an important role in determining tiller population density during the summer-autumn period.

### 4.4.3. White clover stolon/node population

Responses of white clover stolon populations were variable for different seasons (Table 4.12). At the end of Experiment 1, plots which had been laxly grazed during spring (LHC and VLHC) presented higher clover stolon densities than did those hard grazed (EC), but this result was not repeated at the end of Experiment 2. In addition, values of white clover stolon density measured in Experiment 2 were almost twice as large as those measured in Experiment 1, probably a consequence of some degree of inter-specific competition going on within the sward (Section 4.4.5) which may have caused the differences in patterns of response of herbage accumulation (Section 4.3.3) for different seasons. White clover node populations tended to follow the same pattern of changes observed for ryegrass tiller populations, with numbers being significantly decreased for the LHC and LLC treatments during the pre-control phase, but recovering again during the post-control phase and reaching the same level as EC plots by the end of Experiment 2 in April/92. An indirect measurement of plant size (internode length) indicated that, although stolon and node populations were essentially the same at the end of Experiment 2, white clover plants in the LHC and LLC swards must have undergone a morphological transformation that resulted in plants comprised of bigger units than those in EC swards. This increase in plant size could be equivalent to an increase in the number of plants (density) (size/density compensation mechanism - Section 2.4.1).

Lax defoliation regimes during spring are likely to lead to increased stolon growth and, presumably, increased energy reserve levels in white clover plants (Grant & Barthram, 1991; Barthram & Grant, 1993). The resulting longer internodes, with their higher content of reserve carbohydrates, would greatly increase the energy available to support axillary bud development at each node, resulting in higher leaf appearance and branching rates (Grant & Barthram, 1991; Barthram & Grant, 1993) and probably improving the plant's ability to regrow after defoliation at that time of the year. White clover plants also undergo a process of separation into smaller units which results in simpler plants in terms of branching complexity during spring. These smaller plants usually have a rapid growth over the summer period, in which they increase plant weight and branching complexity again (Hay *et al.*, 1988; Brock *et al.*, 1988). Therefore, spring conditions that allow clover plants to accumulate high levels of reserve carbohydrates, as the late control treatments would, are likely to favour the recovery process of plant weight and branching complexity. This would enhance the subsequent presence and production of white clover in those swards (Hay *et al.*, 1988), since small plant size can lead to decreased survival and productivity in many plant communities (Harper, 1977; cited by Hay *et al.*, 1988).

Clover stolon length was measured only at the end of Experiment 2, but it seems that, although clover node density was lower for LHC and LLC swards than for EC at the time of the late control grazing, plants in the former swards were probably bigger and had higher reserve carbohydrates levels than those in the EC sward. That probably caused an enhancement in the recovery process and degree of competitiveness of clover plants during summer, resulting in the similar stolon and node densities for all treatments at the end of the season, the difference being the size of the morphological units comprising those plants.

#### 4.4.4. Herbage dry matter accumulation

Despite the considerable within-treatment variation observed during both seasons, particularly in Experiment 1, a consistent trend of higher herbage accumulation rates for laxly grazed swards was obtained for both pre-control and post-control phases, with the exception of the LHC treatment during the post-control phase of Experiment 2 (Table 4.14). Differences in accumulation were particularly noticeable towards the end of each season. Cumulative total summer-autumn pasture production measured for the LHC treatment in 1990/91 and LLC in 1991/92 was 22% (840 Kg DM/ha) and 18% (990 Kg DM/ha) higher, respectively, than the conventional EC treatment (Table 4.15). Late control plots performed better than early control plots in three out of the four comparisons carried out in Experiments 1 and 2, with the

LHC plots in Experiment 2 (1991/92) being the only case in which that was not observed. Those plots had performed poorly in a pre-treatment phase during spring (Section 4.3.3), when all the others were accumulating herbage more quickly than EC plots. Similar patterns of response have been reported previously by Matthew *et al.* (1989b) and Xia *et al.* (1990) working with pure ryegrass swards grazed by sheep under very controlled conditions. Therefore, ryegrass swards submitted to similar grazing regimes seem to respond consistently through increasing herbage dry matter accumulation during the summer-autumn period. In Experiment 1, despite the higher total season herbage dry matter production from LHC and VLHC in comparison to EC swards, those subjected to a late control grazing at anthesis (LHC) tended to produce more of the extra dry matter during the summer-autumn period as opposed to those swards controlled two weeks later (VLHC), in which most of the extra dry matter was produced during spring (Table 4.15).

### 4.4.5. Herbage components accumulation

Since the components of the accumulated herbage were essentially sub-sets of the main data set of total herbage accumulation, variability associated with them was substantially higher, with statistically significant differences seldom being observed. Results for the pre-control phase of Experiment 1 are not presented because separation of botanical components of harvested herbage was not performed until the first control treatment on LHC took place on November, 20. The increased levels of total herbage accumulation observed during the pre-control phase of Experiment 2 for the LHC and LLC treatments were mostly due to increased accumulation of senescent material, and to a lesser extent, the accumulation of green material (Table 4.16), although the ratio live:senescent material of the pasture grown did not change substantially (Table 4.20). Basically, the component contributing to the slightly higher green dry matter accumulation over that period was grass stem as opposed to leaf material, a consequence of the on-going reproductive development (Figure 4.5) that caused leaf:stem ratio of the grass component in the sward to decrease significantly (Table 4.21). The higher accumulation of senescent material on lax grazed treatments in spring reflected reduced levels of herbage utilisation which, when associated with the reduced leaf:stem ratio of the pasture grown, could have negative effects on the quality of the herbage for purposes of feeding dairy cows. Similar results have being reported in earlier studies (Korte, 1982; Korte *et al.*, 1982,1984; Thomson *et al.*, 1984; Butler, 1986; Bryant & L'Huillier, 1986; L'Huillier, 1987b,1988; L'Huillier & Aislabie, 1988), and have been one of the reasons for the conventionally wide spread hard grazing of pastures throughout spring and summer in New Zealand.

During the control phase of Experiment 2, the trend observed during the pre-control phase for senescent material accumulation on lax grazed swards continued, but the opposite occurred for the green material component (Table 4.16), causing a slight, but not significant, reduction in the live:senescent material ratio in the sward (Table 4.20). The reason for that was a reduction in accumulation of the grass component, particularly of stem material (Tables 4.17, 4.18, and 4.19), following the control of the ryegrass reproductive growth (Figure 4.5). As a result the leaf:stem ratio of the sward increased to a level similar to that of the early controlled swards (Table 4.21). In Experiment 2, a reduction in ryegrass leaf accumulation was also observed for the late control treatments, as in the previous phase, possibly related to the low tiller density of those swards. The differences in sward morphology generated by differences in management have been reported to have an important effect on pasture growth rate by influencing the ability of the sward to produce new leaf (Grant & King, 1983). Low tiller density is one of those morphological differences and could limit pasture growth potential by limiting the number of growing leaves (Hunt & Field, 1979) and the plant's ability to compete for space, light and nutrients.

Bearing in mind the limitations occurred with the LHC treatment in Experiment 2, the increased total herbage accumulation for the late control treatments during the post-control phase in both seasons can be attributed mainly to enhanced green dry matter accumulation (Table 4.16). In Experiment 1 the increased green material accumulation was chiefly a consequence of increased ryegrass growth, particularly the leaf fraction, probably reflecting the enhanced grass tiller density of those treatments (Table 4.11). On the other hand, in Experiment 2 (LLC), the increase came mainly from increased white clover accumulation on the LLC plots, probably due to plants comprised of heavier units since no difference was observed in either stolon or node population at the end of the trial. There was solid evidence of larger ryegrass tiller size in Experiment 2, and this increase in size of a tiller population is expected to enhance sward productivity as much as an increase in density according to the size/density compensation mechanism described by Matthew *et al.* (in prep.). During the post-control phase, in either season, the quality of the pasture grown on late control swards (LHC and LLC) as measured by the live:senescent material and leaf:stem ratios returned to levels similar to those of EC swards Tables 4.20 and 4.21).

### 4.4.6. Ryegrass:clover balance

Results regarding late control of the reproductive growth of perennial ryegrass plants were originally obtained from small plots and glasshouse experiments on pure ryegrass swards (Matthew *et al.*, 1989ab; Matthew, 1990; Xia *et al.*, 1990). Similar response patterns but of smaller magnitude were obtained from ryegrass-white clover mixed swards under the less controlled conditions of the two field experiments described. In Experiment 1 late control plots showed an increase in summer-autumn herbage accumulation mainly due to enhanced ryegrass accumulation, and that was associated with an increased grass tiller and clover stolon density. In Experiment 2 the increased summer-autumn herbage accumulation was mainly due to enhanced white clover accumulation, and that was associated with bigger ryegrass tillers and greater clover internode length. There were no differences in either grass tiller or clover node/stolon densities, but a clear seasonal ryegrass:clover balance effect influencing the summer-autumn herbage accumulation of pastures was observed for all treatments (Figure 4.6), probably a consequence of the different morpho-physiological characteristics of the plants and their response patterns to seasonal climatic conditions. These results show a quite variable pattern of response to late control treatments for different years, but offer little opportunity to explain them. It seems that a more complex mechanism inter-relating the different morpho-physiological characteristics and the differential patterns of response to varying defoliation regimes and seasonal factors (e.g. temperature, rainfall, soil nutrient status, etc) would be involved in determining the ryegrass:clover balance and sward performance of mixed pastures subjected to late control spring grazing management, and that could be the subject of future research.

Plants growing in mixtures tend to compete for space, light, water and nutrients (Frame & Newbould, 1986), with factors affecting the plant's ability to compete probably exerting a decisive role in determining the proportion and productivity of any one species in the sward. The responses of different pasture species to different defoliation regimes, particularly ryegrass and white clover, have been attributed to their differences in growth response to temperature and seasonal factors (Barthram & Grant, 1993a) and differences in the physiological responses to stress of plants conditioned by different defoliation patterns (Brock *et al.* 1981). Perennial ryegrass and white clover plants have different temperature requirements for optimum growth, with warmer conditions suiting the legume best. White clover plants when submitted to lax defoliation regimes tend to accumulate ungrazed leaves on the stolons causing the size of the leaves and petioles to increase and allowing stolons to extend and recolonize the sward to some extent (Davies, 1992). The resulting bigger stolons are probably associated with increased energy reserves which would greatly increase the ability of plants to grow and establish in a plant community (Grant & Barthram, 1991; Barthram & Grant, 1993b). By controlling reproductive swards, most of the grass leaf blade as well as most of the clover leaves are removed. Although the regrowing petioles are short, the regrowing leaflets remain as large as they were before the control cut/grazing, resulting in an increase in the clover leaf area relative to the grass leaf area, and a short-term increase in clover content which may lead to longer-term changes in populations of grass tillers and clover growing points (Davies, 1992). In addition, a higher specific leaf area (lower investment of carbon per unit area of leaf produced) and a slower pattern of unfolding of leaves when compared to grasses, would place white clover plants in advantage over the companion grasses with respect to current and future carbon acquisition during the regrowth process in summer time (Parsons *et al.*, 1991ab).

At the time of late control it is likely that white clover had already undergone the seasonal process of re-establishment and sub-division into smaller plants that usually takes place in spring (September/October), during which plants are fragile and susceptible to any environmental or management stress (Brock *et al.*, 1988,1989). However, the hard control used for both the late control treatments in Experiment 1 may well have interfered with the recovery process of white clover plants in weight and branching structure over the summer which, in association with the low precipitation in December (Section 4.2.2 - Figure 4.2), resulted in no enhanced production despite the likely bigger size of the morphological units comprising the plants at that time. Under those circumstances a higher grass tiller population was observed instead, and the positive differential in summer-autumn herbage accumulation in favour of the late controlled swards was mainly due to enhanced ryegrass accumulation. In Experiment 2 the less intensive control of the reproductive growth (LLC) does not seem to have interfered with the recovery process of clover plants, and resulted in the formation of bigger stolons and enhanced tillering activity in ryegrass plants over the summer-autumn period. Because of the high temperatures during summer, the more vigorous white clover plants in the LLC swards were probably able to compete more efficiently with their companion species causing pasture dry matter accumulation over the post-control phase to be higher than that for EC swards. The proportion of ryegrass in the sward started to increase as temperatures started to decrease, swinging the competitive balance away from the clover component (Figure 4.6). Although such a trend could be observed (Figure 4.5), it was not reflected in increased ryegrass accumulation, with the overall increased summer-autumn pasture production of the LLC treatment being a result of the enhanced white clover production.

## 4.5. Summary

1. Dry matter production during spring and summer-autumn periods was enhanced by a grazing regime involving lax grazing of pastures during spring switched to hard grazing at the time of anthesis of the reproductive growth of ryegrass plants (late November-early December) (late control) in three out of four comparisons.

2. Timing as well as intensity of late control were important in determining pasture yield. For maximum increase in dry matter production, late control should be executed at anthesis (late November/early December) and the return to conventional post-grazing residuals (30-50 mm or 1400-1500 Kg DM/ha) reached gradually over 2 or 3 successive grazing cycles.

3. The data shows some evidence of increased ryegrass tiller density in Experiment 1 and increased tiller size in Experiment 2, but the evidence that this caused the increase in pasture production is inconclusive.

4. Although white clover responses appeared to differ between years, there was some evidence that late control increased growth of white clover also.

5. If an alternative grazing system is to be built upon these principles of defined plant physiological state and objective pasture targets, further research including animal responses and herbage quality is necessary to study the feasibility of implementing such a grazing management into a farm context.

# Chapter 5:

# FEASIBILITY OF THE LATE CONTROL SPRING GRAZING MANAGEMENT FOR SEASONAL DAIRY SYSTEMS

## 5.1. Introduction

The pattern of increased herbage accumulation during the summer-autumn period after a previous period of controlled reproductive growth ('late control') seems to be consistent and could be used as an option to enhance feeding levels of dairy cows during the second half of lactation, a period of the year when farmers usually can not feed cows to their full requirements. However, some important practical questions must be answered before considering the implementation of such a grazing management in a farm context. The first comprises how to allow ryegrass plants to become reproductive without restricting cow intake in the spring. In order to accomplish that, there should be a relaxation in grazing pressure over the spring (higher post-grazing residuals - Section 4.2.4). Because pasture growth rates normally start to exceed animal feed requirements only from mid-spring onwards, that could imply that less of the forage grown is available for consumption in early spring, resulting in a likely restriction to the feed intake of cows in early lactation. Secondly, accumulation of pasture cover in spring may lead to a reduction in nutritive value of the herbage associated with reproductive development. That could jeopardise current and future milk production. In addition, less grazing pressure usually implies increased herbage intake (Section 2.6.2), which could have consequences for the overall farm stocking rate since the farm would have to carry fewer cows in order to generate the extra pasture cover, unless conserved feed was used during early lactation.

Supposing that it would be possible to create the sward conditions necessary for executing late control of the reproductive growth without sacrificing animal performance during spring, the second question would be how to achieve such control, since it is very difficult to remove seedheads from reproductive swards using only generously fed grazing animals. That problem is further aggravated since, at the time of late control, pastures are usually accumulating herbage much more quickly than the cows are eating it. Inadequate control of pastures can reduce tiller populations and pasture production and quality (Section 2.6.2). Assuming that late control could be effectively achieved and the increased summer-autumn pasture production obtained, the final question would then be if the extra herbage would be eaten and converted into extra milk production.

## 5.2. Simulations of late control grazing in a farm condition

In order to perform a preliminary feasibility test of the late control spring grazing management, a series of feed budgets was performed using computer spreadsheets designed to calculate the feed requirements of dairy cows and use them in feed budget calculations for dairy farms (Brookes, 1993). These spreadsheets require input of farm size, stocking rate, calving date, drying-off date, liveweight and body condition score of cows, level of milk fat production, lactation period, pasture growth rates and average pasture cover. Figures of herbage intake obtained are based on the concentrations of metabolizable energy of the pasture. Pasture growth rate figures were based on a set of data collected over a period of 19 years for the experimental site (Massey University Farms Administration, unpublished internal report), and over 8 years for the Manawatu downland areas (mainly dairying areas) (McCrone - Ministry of Agriculture and Fisheries, unpublished internal report). During the exercise two situations were simulated for each site, a conventional and a late control spring grazing management.

Since deliberate encouragement of early seedhead development followed by a change in grazing management designed to remove accumulated growth (late control) had never been experimentally tested before, some assumptions had to be made in order to simulate late control conditions. Based on the results of the two field experiments reported in Chapter 4 (Experiment 1 and 2) and on other research work involving spring grazing management (e.g. L'Huillier, 1987bc), it was assumed that pastures under the late control grazing management would have herbage accumulation rates increased by 20% in late spring (November) and by 25% in mid-summer/early-autumn (February to April). Feed requirements were predicted considering a Friesian dairy cow weighing 500 Kg and producing 160 Kg of milk fat in 260 days (average cow of the experimental herd). Targeted body condition scores were 5.0 at calving (early August), 4.5 at drying-off date (late April), and reaching 5.0 again at the start of next calving. Targeted average pasture covers for the late control grazing strategy were 2000 Kg DM/ha at start of calving, 2500-2600 Kg DM/ha at late control time (early December), returning to 2000 Kg DM/ha at the end of the late control period (early January), which was the target average pasture cover for the conventional grazing strategy throughout the spring and summer periods. Feed budget calculations were made considering a stocking rate of 2.7 and 2.5 cows/ha for the Manawatu downland areas and the experimental site, respectively. Those were the optimum stocking rates for those sites in relation to the standard herbage accumulation rates provided, since the total amount of pasture grown in a year was very similar to the total feed requirements under those circumstances. Cows were fed at their full requirements at all times.

### 5.2.1. Manawatu downland areas

At this site a feed surplus was predicted from early October onwards, since pasture growth rates (feed supply) started to exceed animal requirements (feed demand) under both the conventional and the late control grazing managements (Tables A1.1 and A1.2 - Appendix 1). Under the simulated conventional grazing strategy, 30% of the area had to be shut up for conservation from mid November to late December (6 week period), in order to maintain pasture in a vegetative state and to avoid the average pasture cover target of 2000 Kg DM/ha being exceeded (Figure 5.1). This conservation process resulted in an average of 680 Kg DM/ha of conserved feed over the whole area, from which 347 Kg DM/ha (51%) would have to be fed back into the system to meet the target pasture cover of 2000 Kg DM/ha at the start of the next calving.

On the other hand, under the simulated late control grazing strategy, the target pasture cover of 2500-2600 Kg DM/ha was not achieved until early December, when 60% of the area was taken for conservation and the extra 500-600 Kg DM/ha removed (4 week period), in order to obtain the pasture cover of 2000 Kg DM/ha by early January (Figure 5.1). Such a large proportion of the farm area being taken for conservation could have a negative effect on herbage intake and milk production, since it would correspond to a large increase in grazing pressure and force animals to graze into the lower strata of reproductive swards. An average of 840 Kg DM/ha of conserved feed over the whole area was produced, all of which was in excess of the total annual animal feed requirements and corresponded to the 500-600 Kg DM/ha of extra pasture cover removed plus the additional feed surplus accumulated over the control period.

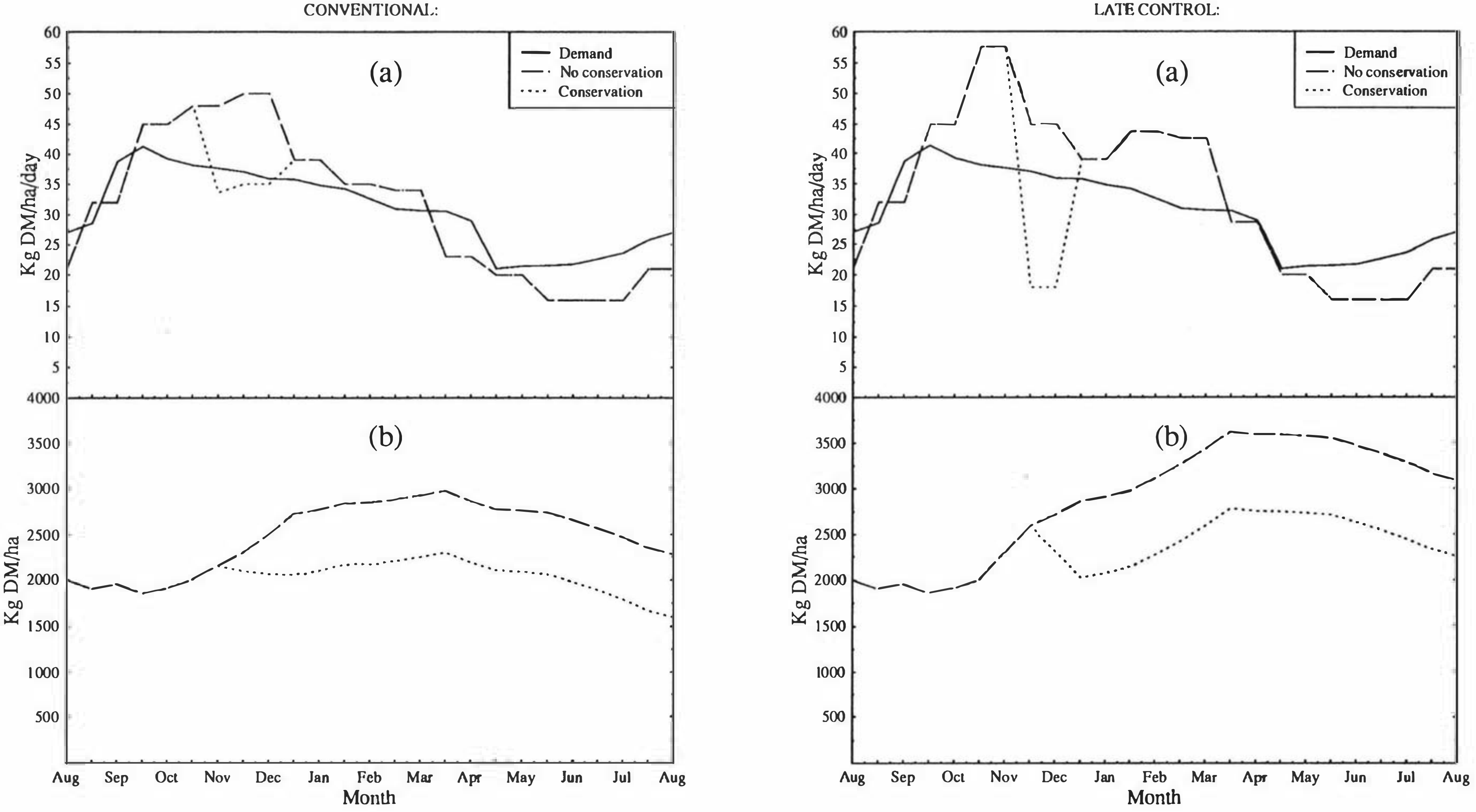

Figure 5.1. Predicted curves of (a) feed demand and supply, and (b) average pasture cover for downland areas under the conventional and the late control spring grazing managements.

### 5.2.2. Experimental site

Although the No 4 Dairy Farm is also situated within the Manawatu region, its pattern of pasture growth is quite distinct from that of the downland areas in the same region, with feed supply being always higher than animal demand during a normal spring (Tables A1.3 and A1.4 - Appendix 1). As a consequence, the need for shutting up areas for conservation occurred much sooner for both the conventional and the late control grazing management. Under the conventional grazing strategy, 30% of the area had to be shut up from early October to late November (6 week period) (Figure 5.2). An average of 880 Kg DM/ha of conserved feed over the whole area was produced, from which 475 Kg DM/ha (54%) would have to be fed back into the system in order to meet the target pasture cover of 2000 Kg DM/ha at the start of the next calving. However, feed supply started to become short in relation to feed demand from late February onwards, when the average pasture cover declined below 1800 Kg DM/ha, the minimum pasture cover limit allowed during lactation for that particular farm. In that situation, the 475 Kg DM/ha of conserved feed would have to be used to maintain the feeding level of cows during the remainder of the lactation.

Under the late control grazing strategy the target pasture cover of 2500-2600 Kg DM/ha was reached in late October and maintained until early December by shutting up 30% of the area for conservation from mid October to end of December (10 week period), when the extra 500-600 Kg DM/ha were removed in order to achieve the 2000 Kg DM/ha pasture cover target set out for early January. An average of 1030 Kg DM/ha of conserved feed over the whole area was produced, all of which was in excess of the total annual feed requirements of the cows and corresponded to the extra pasture cover removed plus the feed surplus occurred over the control period. There was no need for using conserved feed over the autumn under this grazing strategy.

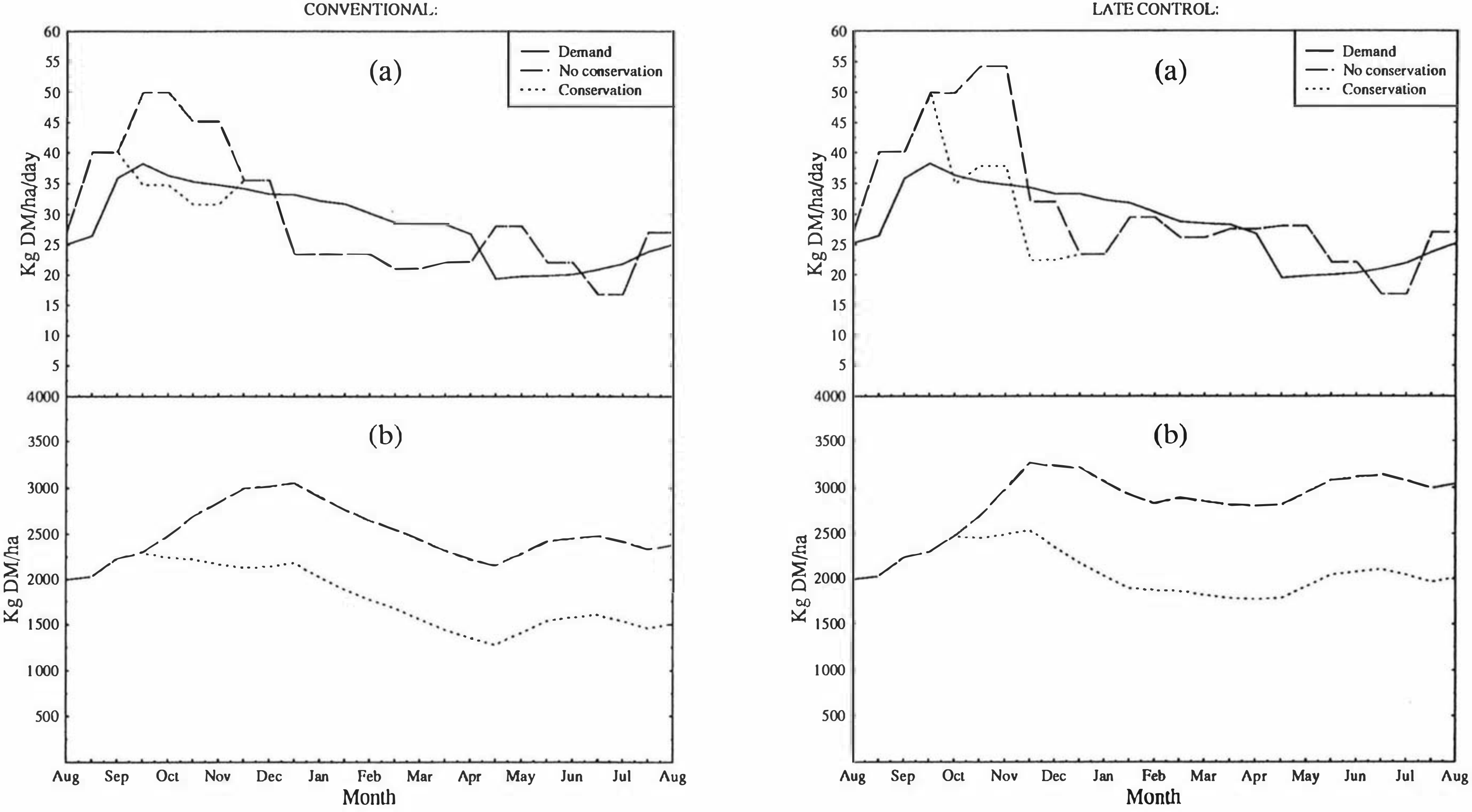

Figure 5.2. Predicted curves of (a) feed demand and supply, and (b) average pasture cover for the experimental site under the conventional and the late control spring grazing managements.

## 5.3. Discussion

Although for this type of computer simulation work a more detailed model such as UDDER (Larcombe, 1990) would be more suitable, it was not used due to unavailability. Later evaluations using UDDER produced similar results to those obtained from Brookes' spreadsheet model. These results showed that the relaxation in grazing pressure over the spring simply by manipulating grazing management (no conserved feed used) would not interfere with the feeding levels of the cows, since herbage accumulation rates were usually higher than feed requirements. Simple manipulation of the timing and proportions of area to be set aside for conservation allowed higher post-grazing residues to be obtained and the targeted 500-600 Kg DM/ha of extra pasture cover to accumulate without causing a restriction on the feed intake of cows, particularly at the experimental site, where growth rates over the spring normally exceed feed requirements (Figures 5.1 and 5.2). In fact there could be some benefits, since animals would be offered a higher daily herbage allowance and pre-grazing herbage mass, which could result in enhanced levels of herbage intake (Sections 2.6.1 and 2.6.2).

According to these simulations, the conserved feed produced under the late control grazing strategy in both sites would be in excess of animal requirements and could be used to raise feeding levels of cows at different times of the year, or even used to decrease grazing pressure on pastures in years of cold and wet springs, when herbage accumulation rates are slow and it is difficult to generate the extra pasture cover without causing some degree of restriction to the dairy cows. However, it was not possible to obtain milk yield responses to the increased herbage production, since milk production was an input to the spreadsheet model used to calculate feed requirements.

It was concluded that setting the sward conditions for late control did not constitute a problem in normal spring years, but further information was necessary on how best to achieve effective control of the reproductive growth without excessive reduction in herbage allowance for the cows, and how effectively the extra growth during the summer-autumn period would be converted into extra milk production. Furthermore, from an experimental point of view, it would be interesting to have a comparison between a late control treatment that would use no conservation (only grazing animals) to control pastures and a late control treatment that would rely on forage conservation to augment grazing and control pastures. Under those circumstances it would be possible to determine the effectiveness of the expected increase in herbage intake, due to enhanced allowance, in controlling reproductive swards relative to an optimum use of forage conservation to achieve the same goal.

In practical terms, late control could be implemented on a farm scale by either a delay in shutting up paddocks for conservation, or strategic use of supplementation (conserved feed) in early spring in order to decrease grazing pressure on pastures and allow early seedhead development. Under those circumstances, post-grazing residuals would be around 500 Kg DM/ha higher than those conventionally used, and the normal average pasture cover over the whole farm would increase by the same amount. Late control of the reproductive growth of pastures would be executed later, at anthesis, with silage being made in December rather than in November. Such a grazing management could improve animal performance in early lactation through higher herbage allowances, and in late lactation through increased herbage accumulation which could be used either for increased milk production or to extend lactation. The incorporation of such a grazing practice into a farm system context is dependent upon further research to integrate all these principles and provide a strong knowledge base to support the decision making process.

# *Chapter 6:*

# SPRING GRAZING MANAGEMENT EFFECT ON SUMMER-AUTUMN PASTURE AND MILK PRODUCTION OF MIXED DAIRY SWARDS

## 6.1. Introduction

Animal production systems based on grassland areas are extremely dependent upon the quality and efficient harvesting of the pasture grown. New Zealand systems of animal production, particularly dairy systems, have been recognized worldwide for their efficiency and levels of productivity. Such successful animal husbandry enterprises are based on closely matching feed supply (pasture growth) to feed demand (animal requirements), conferring the characteristic seasonal pattern of production to New Zealand grassland systems. The levels of productivity of such systems are mainly determined by manipulation of factors like stocking rate, cow quality, calving date, body condition or liveweight at calving, and level of feeding in early lactation (Bryant, 1980a).

Recent evidence has highlighted the importance of the spring grazing management of pastures as a means of optimising the performance of seasonal dairying systems. Late control of the reproductive growth of pastures in spring (Matthew, 1992) results in enhanced spring and summer-autumn herbage accumulation (Experiments 1 and 2 - Chapter 4), which could be used to raise feeding levels and enhance milk production of dairy cows. Although the feasibility of such a grazing management strategy has been partially assessed by simulation exercises, it has not been tested experimentally yet. The available evidence shows that the preparation of pastures during spring in order to develop the extra pasture cover required to allow early seedhead development would not imply any sacrifice to the nutrition of dairy cows (Chapter 5). However, no information is available on how to execute the late control of the reproductive growth and, furthermore, what the consequences would be to pasture quality and animal performance under those circumstances.

In order to deal with those issues, a third field experiment was planned to test the impact of a late control grazing strategy on pasture and animal responses. The main objectives were:

(i) (a) To further study the impact of late control of ryegrass reproductive growth on herbage production and quality;

(b) To measure the effects of such a grazing practice on the herbage intake and milk production of dairy cows during the summer-autumn period;

(ii) To test two different grazing strategies for achieving late control of reproductive swards;

(iii) To evaluate the implications of such grazing management in a dairy systems context.

The present chapter reports that experiment, its results, and draws attention to eventual implications for dairy systems.

## 6.2. Experimental

### 6.2.1. Site

The experiment was conducted at No 4 Dairy Farm, Massey University, during the 1992/93 dairying season. Pastures were two to three years old and comprised a mixture of perennial ryegrass (*Lolium perenne* L. cv. 'Grasslands Nui'), white clover (*Trifolium repens* L. cv. 'Grasslands Pitau') and red clover (*Trifolium pratense* L. cv. 'Grasslands Pawera') sown on a Ohakea silt loam soil (Aeric Ochraquept), a moderate clay alluvial with overlaying gravel and stones about a metre below the surface. This soil is imperfectly drained and dries out in summer. Original soil nutrient status was medium/low (15 ppm Olsen-P and 0.25 meq Exch-K/100g soil). The area also received an application of 2 tonnes of lime and 350 Kg of a 15% longlife superphosphate (0.9.8.7) per hectare in May/92 as part of the annual maintenance fertilisation policy adopted in the farm, and 30 Kg/ha of nitrogen were applied as urea in October 23 on two of the experimental blocks due to signs of nitrogen deficiency (yellowing and patchy urine responses).

Air and soil (10 cm depth) temperatures and rainfall and pan evaporation (monthly totals) are presented in Figures 6.1 and 6.2, respectively. The spring was considerably wetter than the previous two seasons but that changed during the summer and autumn, when rainfall was considerably reduced (especially January and February) and temperatures were not as high as those observed during the 1990/91 and 1991/92 seasons (Figures 4.1 and 4.2, Section 4.2.2). Further details of site are described in Chapter 4.

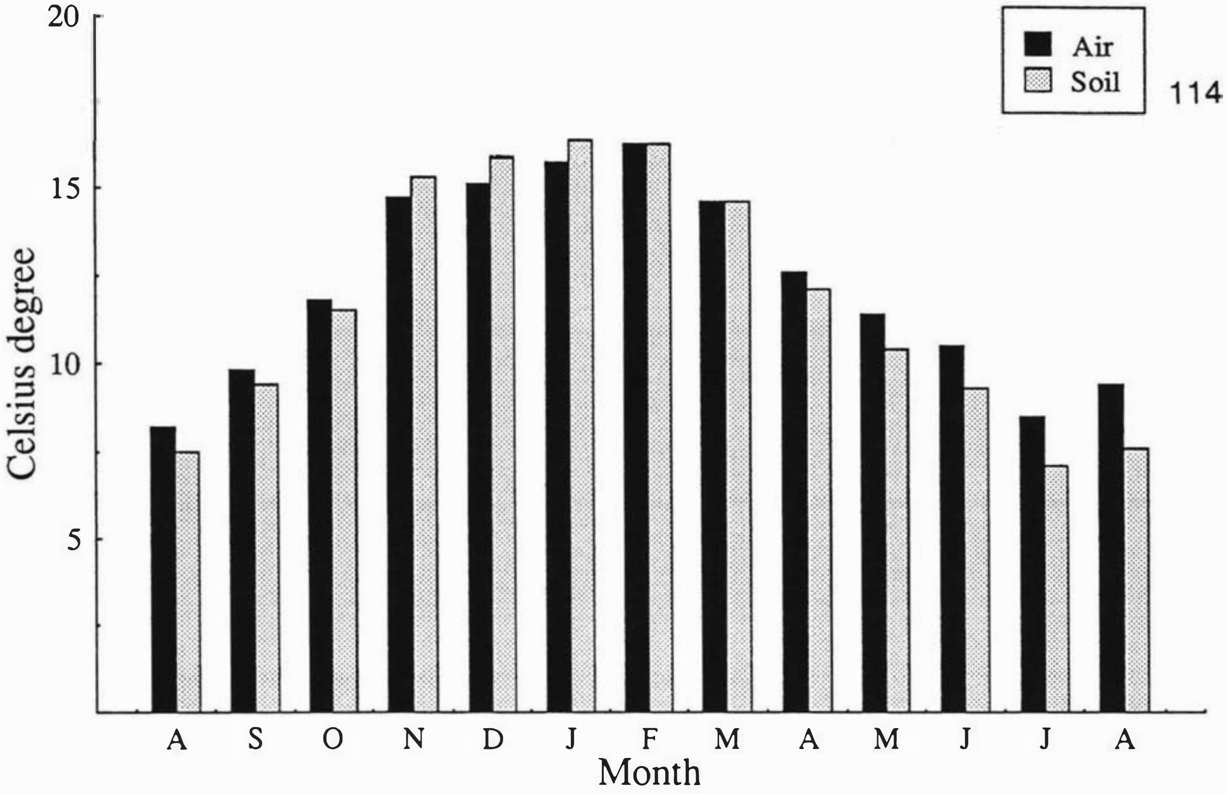

Figure 6.1. Mean air and soil (10cm) temperatures for the 1992/93 season

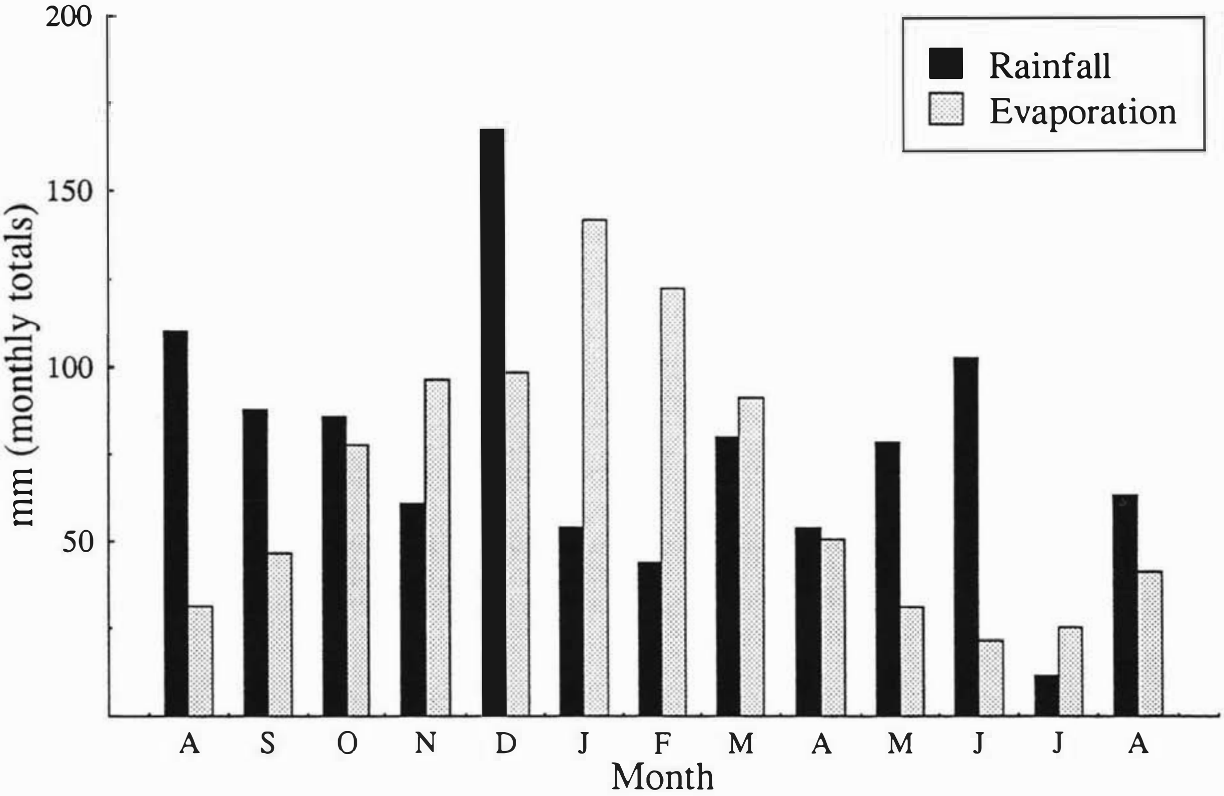

Figure 6.2. Total monthly rainfall and pan evaporation for the 1992/93 season

### 6.2.2. Experimental design

#### 6.2.2.1. Pasture evaluations

The layout of the experimental area regarding pasture measurements was the same as that used during the previous season and described in Section 4.2.3. Briefly, a new set of five 1.7 ha paddocks were selected and each divided into three strips (plots) by electric fencing. Three grazing treatments were randomly allocated per paddock (block), one per strip, in a completely randomised block (CRB) design with five replicates (blocks). As before, six sampling areas were identified within each strip and used consistently for the sampling procedures performed throughout the experimental period.

#### 6.2.2.2. Animal evaluations

Three selected groups of seven Friesian dairy cows were assigned to three experimental grazing treatments for the period of measurements of animal responses (December 4 to April 29). Cows were first drafted from the main herd (250 cows) according to their age, production index (PI) and breeding index (BI), lactation days, pregnancy status, levels of milk-fat and milk-protein production in the current lactation and, finally, liveweight and body condition score at the time of grouping. Cows were then randomly drawn to comprise the final experimental groups, which were balanced for age in order to get the same age structure as that of the main herd. Experimental animals had an average initial liveweight of 490 Kg and body condition score of 4.4. Each cow was considered as an experimental unit, giving a completely randomised design (CRD) with seven replicates (the number of cows per group).

### 6.2.3. Experimental treatments

Planning of the grazing treatments to be tested was based on the results of field experiments in the previous seasons (Experiments 1 and 2 - Chapter 5), and on earlier detailed studies (Matthew *et al.*, 1989b; Matthew, 1990). Basically, it involved a comparison between an early control or conventional grazing treatment (EC) and two late control treatments (LC). For analytical reasons, the trial was divided into three experimental phases and three treatments were assigned to strips (plots) as follows:

(i) Pre-control or preparation phase (15 September - 03 December/92) - Throughout this phase plots were rotationally grazed by a herd of 250 dairy cows at approximately 3 week intervals, in order to allow the development of sward differences and establish an average pasture cover over the experimental area as specified for the following treatments:

(a) EC → One strip of each paddock was grazed intensively to a residual pasture height of 30-50 mm (1400-1500 Kg DM/ha) maintaining an average pasture cover of around 2000-2100 Kg DM/ha on all five paddocks;

(b) LC → The other two strips of each paddock were grazed laxly to a residual pasture height of 80-100 mm (1800-2000 Kg DM/ha) maintaining an average pasture cover of around 2500-2700 Kg DM/ha on all five paddocks.

During this time paddocks (blocks) were sequentially grazed by the dairy herd with a difference of three to four days between them. Lax grazing treatments (LC) allowed some early seedhead development. Grazing was closely monitored, and cows were removed as soon as residual pasture targets were achieved for the different treatments as specified above. By the end of this phase a difference of around 500-700 Kg DM/ha in average pasture cover between EC and LC treatments had been created. Plots under the EC treatment were in a vegetative stage with few reproductive tillers while those under LC were in a reproductive (anthesis) stage, setting up the differences in sward characteristics for the next phase.

(ii) Control phase (04 December/92 - 02 January/93) - During this phase the selected groups of cows were transferred to the experimental areas (December 4) and randomly assigned to the three experimental treatments. From December 4 onwards, each of the three replicated sets of treatments (2.8 ha) was transformed into a self-contained unit. The initial difference of 500-700 Kg DM/ha in average pasture cover between EC and the LC treatments (created during the pre-control phase) had to be removed by the end of this phase, in order to have the three farmlets running at a common average pasture cover of around 2000 Kg DM/ha in early January/93. Two contrasting grazing strategies were used to control seedheads and reduce pasture cover on the LC farmlets to the same level as that for the EC farmlet:

(a) No forage conservation - Maintenance of the same level of stocking rate as on the EC farmlet (2.5 cows/ha or 7 cows/2.8 ha), but increasing the speed of the rotation from a 20 to a 10-day round (very fast rotation - VFR);

(b) Simulating forage conservation on 30% of the farmlet area - Since the effectiveness of mowing in controlling reproductive grass growth was demonstrated in previous trials (Experiments 1 and 2 - Chapter 4) and the main interest was on the consequences of such a grazing policy on the grazed part of the farm, the 30% area of forage conservation (defined in Chapter 5) was simulated by an equivalent increase (43%) in stocking rate on the grazed area. Three more cows were therefore added to this treatment during the control phase, giving an effective stocking rate of 3.6 cows/ha or 10 cows/2.8 ha (high stocking rate approach -HSR). Rotation length was slightly shortened from a 20 to a 15-day round in order to allow cows to graze around the entire farmlet twice before the beginning of the next phase.

During this phase each of the five strips was sub-divided into 2 (VFR), 3 (HSR) or 4 (EC) breaks by electric fencing in order to generate the different rotation lengths specified above (10, 15 and 20 days, respectively). Residual pasture heights or herbage masses and average pasture covers became a function of the rates of herbage intake and accumulation, since a fresh area of pasture was offered daily to the animals after the afternoon milking. Water was available to each group of cows at all times from portable troughs.

(iii) Post-control phase (03 January - 29 April/93) - This phase was scheduled to start in early January, when the three experimental farmlets were expected to be running at a very similar average pasture cover, and in fact started on January 3. Stocking rate on the HSR farmlet (previously 3.6 cows/ha) was reduced to the same level as that for EC and VFR (2.5 cows/ha) and all three farmlets were grazed at a 20-day rotation interval (4 breaks per strip) until January 31, when they were shifted to a 30-day interval (6 breaks per strip) for the rest of the post-control phase.

During this phase all three treatments (farmlets) were managed under the same stocking rate (2.5 cows/ha) and grazing interval (20-day increasing to a 30-day round), the only difference being the residual effects of contrasting spring grazing managements and late control strategies implemented during the control phase. Each group of cows received a fresh area of pasture after the afternoon milkings. A schematic representation of the treatments is presented in Figure 6.3.

| | **Pre** | **Control** | **Post** | |
|---|---|---|---|---|
| **EC** | 1500 Kg DM/ha<br>20d rotation | 2.5 cows/ha<br>20d rotation | 2.5 cows/ha<br>20→30d rotation | **EC** |
| **LC** | 1800 Kg DM/ha<br>20d rotation | 2.5 cows/ha<br>10d rotation | 2.5 cows/ha<br>20→30d rotation | **VFR** |
| | | 3.6 cows/ha<br>15d rotation | 2.5 cows/ha<br>20→30d rotation | **HSR** |
| | **(Sep 15 - Dec 3)** | **(Dec 4 - Jan 2)** | **(Jan 3 - Apr 29)** | |

Figure 6.3. Layout of the experimental treatments during the 1992/93 season

### 6.2.4. Measurements

### 6.2.4.1. Pasture responses

### 6.2.4.1.1. Herbage accumulation and components

Measurements were carried out as in Experiments 1 and 2 (Chapter 4). Herbage accumulation was determined from 12 randomly placed quadrat areas (0.1 $m^2$) per plot (2 from each sampling area) before and after each grazing. Samples were cut to ground level with an electric shearing hand-piece. Cut herbage was washed to remove soil contamination and then dried at 80 °C for 24 hours in a forced-draught oven. Samples were taken for determination of botanical composition by cutting a hand-piece wide (75 mm) strip alongside each quadrat. Bulked samples for each strip were then taken to the laboratory, washed, sub-sampled and the herbage from each of two sub-samples separated by hand into ryegrass leaf and stem, other grass leaf and stem, clover leaf and stolon, weeds and senescent material. Since the proportion of red clover in the samples was low, both white and red clover were put together into the same botanical category of clover. After drying, samples were weighed and the proportion (%) of species components determined. Herbage accumulation (Kg DM/ha) was calculated based on the difference between pre-grazing and post-grazing herbage masses for successive grazings. Herbage accumulation rates during the first regrowth period (mid-August to mid-September/93) following a common winter grazing management after experimental paddocks had been re-incorporated into the farm area were also determined. During the control and post-control phases, post-grazing cuts were usually taken on a strip when the last break containing a sampling area within it was grazed.

#### 6.2.4.1.2. Average pasture cover

Measurements of average pasture cover over the experimental area commenced on December 4 at the beginning of the control phase, when experimental farmlets were set out, and continued on a weekly basis throughout the control and post-control phases (Section 6.2.4). Since the direct estimate of herbage mass is time consuming, determination of herbage mass on the farmlets was carried out indirectly by the use of a rising plate meter. Although this method relies on a calibration curve (linear equation) which might be affected by the differing sward structures, no calibration curves were made for the experimental treatments. Measurements were made by taking 50 random rising plate meter readings from a zig-zag line across each experimental strip (plot). Average herbage mass for each strip was calculated using the following calibration equation supplied by the manufacturer of the equipment:

$$HM = 158(RPR)+200;$$

where HM = herbage mass and RPR = average rising plate reading. The average pasture cover for each farmlet was determined by simple arithmetic mean of herbage masses across strips. These measurements were used in making day to day grazing management decisions, but not for calculation of herbage accumulation data.

#### 6.2.4.1.3. Tiller dynamics

Tiller population dynamics was monitored by detailed observation of individual tillers. For each of the three treatments in each of the five paddocks, six transects of ten tillers (60 tillers/treatment/paddock) were tagged with split plastic rings between 1 and 18 October, 1992. The tillers marked were selected as being adult overwintered tillers about to flower, and any daughter tillers already present (on average approximately 2.5 daughter tillers per flowering tiller) were tagged with a different colour from that used to tag the main tiller axis. Tagging of new tillers and counts of dead ones was performed at three different times throughout the experimental period as follows:

Tagging 1 - At the start of the control phase (early-December/92)
Tagging 2 - A month after beginning of post-control phase (early-February/93)
Tagging 3 - At the end of the experiment (April/93)

For each tagging procedure a different colour was used, allowing the identification of different tiller cohorts and their time of appearance. From the recorded observations, some tiller dynamics parameters like tiller appearance rate (TAR), tiller death rate (TDR) and tiller survival rate (TSR) (Section

4.2.5.2) were calculated for the three experimental phases (Section 6.2.4). At the time of the last grazing of the experimental paddocks all tagged tillers were dug up prior to grazing and removed to the laboratory where they were separated into their respective cohorts which were counted, dried and weighed.

#### 6.2.4.1.4. Species population densities

Grass tiller and white clover stolon/node population densities were monitored with four tiller plug (53 mm diameter) harvests spread out throughout the experimental period as follows:

Harvest 1 - At the start of the experiment (October/92)
Harvest 2 - At the switch from the pre-control to control phase (early-December/92)
Harvest 3 - At the end of the experiment (April/93)
Harvest 4 - At the time of the first grazing following a common winter rotation management after experimental paddocks had been re-incorporated into the farm area (mid-August/93)

At each of the four harvests 60 tiller plugs were collected per plot, ten from each sampling area, and grass tillers and clover stolon/node densities determined by counting tillers and nodes and measuring stolon length in each plug. Again red clover plants constituted a small proportion of the plants in the samples and, for that reason, the clover component comprises mainly white clover plants. An estimate of internode length (cm) was obtained by dividing the stolon density ($m/m^2$) by the node density ($nodes/m^2$) estimates.

### 6.2.4.2. Animal responses

#### 6.2.4.2.1. Milk yield and composition

Milk yield was measured electronically for each cow every day by means of the Ruakura Milk Harvest system installed on the 36 bail twin-style rotary platform used to milk the herd. Cows were milked twice daily at 7:00 am and 4:30 pm. Milk samples were taken on the following dates using a proportioning Milk Meter (Tru Test Co. N.Z.) and composition of representative milk samples was determined at the Livestock Improvement Corporation laboratory (Hamilton) by infra-red absorption (Milk-O-Scan; A/S N Foss, Denmark):

9, 14, 20 December 1992
7, 17, 27 January 1993
11, 24 February 1993
11, 21 March 1993
14 April 1993

Results from different milk tests were combined to generate mean values for milk-volume and milk-solids yields during the control (9,14,20 December) and post-control (remaining milk test results) phases of the experimental period. Prior to the commencement of the farmlet study period, during the preparation phase, milk yield and composition of each cow in the whole herd were measured at monthly intervals, and those results were used as covariates during the statistical analysis of the data.

### 6.2.4.2.2. Liveweight and body condition score of cows

Changes in liveweight and body condition score were monitored by weighing and condition scoring experimental cows at monthly intervals. These measurements were carried out consistently after the morning milking, before the cows went back to the experimental area, and performed by the same person at the beginning of each month. The liveweight of cows was measured by an electronic scale and body condition scores assessed according to a visual 0 to 10 scale developed at Massey University, which is based on the degree of body fatness of the animals (0 = thin and 10 = fat).

### 6.2.4.2.3. Herbage intake and sward quality

Levels of herbage intake were calculated from estimates of total faecal output and herbage digestibility as described by Le Du & Penning (1982). Faecal output was estimated indirectly by the use of intra-ruminal chromium controlled release capsules (65% $Cr_2O_3$ matrix, 46.6 mm$^2$ orifice, 4.1 cm core, Mark II wing design, CAPTEC New Zealand Ltd); (Parker *et al.*, 1990).

Measurements of herbage intake were carried out in the periods 14-23 December/92 and 18-27 January/93, during the control and post-control phases, respectively. Capsules were administered to the cows and a period of seven days allowed in order to achieve an uniform concentration of $Cr_2O_3$ in the rumen. Faecal samples were collected from each cow once a day in the morning during days 8 to 17 after cows had received the capsules. Samples were bulked over five day periods (day 8 to 12 and 13 to 17) and stored at -4 °C, prior to being thawed, dried (80 °C to constant weight for at least 72 hs) and ground in preparation for chromium analysis by atomic absorption spectrophotometry according to the method described by Costigan & Ellis (1987) and modified by Parker *et al.* (1989). During each of the five-day periods of faecal sample collection, four oesophageal fistulated cows were used for collection of herbage samples at the beginning and end of grazing. Fistulated animals were maintained on similar pastures adjacent to the experimental area and used in pairs, rotating across treatments, in order to allow a sample to be collected for each treatment from each cow. Samples were place in crushed ice immediately after collection and taken to the laboratory for storage at -18 °C. These extrusa samples were subsequently freeze-dried, ground, subsampled and submitted to digestibility analysis. The digestibility of the grazed herbage was determined by an *in vitro* cellulose solubility technique using a method slightly modified from Roughan & Holland (1977).

Additional procedures of herbage intake measurement and sampling of herbage as grazed were used during the December measurement period. Estimates of apparent herbage intake were obtained through differences between pre and post-grazing herbage masses, and digestibility of grazed herbage estimated on samples harvested by hand plucking simulating grazing activity from areas left ungrazed by exclosure cages (2 x 1 m). Because cows were being offered a different area of pasture daily during that period as a consequence of the different treatments, the number of quadrat cuts (0.1 $m^2$) and exclosure cages used was planned on a per strip basis. Thus, a total of 16 quadrat cuts and 8 exclosure cages were used for sampling the EC and VFR treatments (4 cuts and 2 cages per break for EC, 8 cuts and 4 cages per break for VFR) and 15 quadrat cuts and 9 exclosure cages for sampling the HSR treatment (5 cuts and 3 cages per break). Bulked samples of hand plucked herbage per strip were sub-sampled into four pairs of samples, with one of them being hand dissected into botanical components and the other freeze dried, ground and analysed for *in vitro* digestibility and nitrogen content (standard procedure of Kjeldahl nitrogen with a Kjeltec auto system).

#### 6.2.4.2.4. Grazing behaviour

In each of the four 5-day periods of herbage intake assessment, a 24-hour period of observation on the grazing activity of the animals was performed (15 and 22.12.92, 23 and 29.01.93). Recording of activities was performed at 10 minute intervals and was based on counting the number of animals demonstrating specific activity in each group or farmlet. The activities monitored were grazing, rumination or neither. Estimates of rate of biting were made during the periods of major grazing activity by recording the amount of time taken for animals to make 20 uninterrupted bites (Hodgson, 1982). Because observations of activities were performed on a group rather than individual animal basis, statistical analysis could not be performed due to lack of replication. Therefore, the records generated are presented only as an indication of possible effects of treatments on grazing behaviour.

### 6.2.5. Statistical analysis

All data were initially tested for normality and homogeneity of variance. In cases where these assumptions were not valid, data were appropriately transformed. Statistical analysis on the pasture response data was performed in accordance with the randomised complete block design (8 degrees of freedom for error) and standard errors derived from strip means (n=5). Results generated from sequential harvests were analysed using the "repeated measures" option of the SAS general linear models procedure. Statistical analysis was performed on the animal response data according to the completely randomised design (18 degrees of freedom for error) and standard errors derived from cow means (n=7). Data for yields of milk and milk-solids, liveweight and body condition score were subjected to a pre-treatment covariance adjusted repeated measures analysis. The covariates were the accumulated yield for each cow from calving until one week before the control phase began, and liveweight and body condition score at the start of the control phase, when all cows were grazing together in one herd.

As in Experiment 2 (Section 4.2.6), it was of interest to examine associations between variables, in particular herbage accumulation and milk production. Since CDA was ruled out by the different structures of the two data sets (5 paddocks compared with 7 cows) a small principal component analysis (PCA) was used to achieve this, and analysis of variance performed on PC scores (Jolliffe, 1986). Further details are given in Section 6.3.8.

## 6.3. Results

### 6.3.1. Tiller dynamics

During the pre-control or preparation phase, late control swards (VFR and HSR) were characterised by lower tiller appearance (TAR) and death rates (TDR) and higher tiller survival rates (TSR) than those observed for the EC swards (Table 6.1). That pattern changed during the control and post-control phases, when TDR and TSR were essentially the same for all treatments. During the control phase, no significant difference was observed between treatments in TAR, although HSR swards tended to tiller considerably faster than VFR swards, and slightly faster than the EC swards. The same trend continued during the post-control phase.

Table 6.1. Rates of ryegrass tiller appearance (TAR), death (TDR) and survival (TSR) throughout the experimental period

| | Experimental | Treatments | | | | |
|---|---|---|---|---|---|---|
| | Period | EC | VFR | HSR | SEM | Signif. |
| | Oct-Nov | 64.9 | 44.5 | 49.2 | 6.1 | * |
| TAR | Dec-Jan | 101.6 | 76.9 | 104.9 | 17.5 | ns |
| (tillers/100 tillers) | Feb-Apr | 46.8 | 49.3 | 58.9 | 4.8 | ns |
| | Oct-Nov | 63.2 | 52.4 | 54.4 | 3.1 | * |
| TDR | Dec-Jan | 50.3 | 52.5 | 50.5 | 2.3 | ns |
| (tillers/100 tillers) | Feb-Apr | 37.1 | 32.5 | 31.5 | 2.8 | ns |
| | Oct-Nov | 36.8 | 46.2 | 45.6 | 2.7 | * |
| TSR | Dec-Jan | 49.7 | 47.5 | 49.5 | 2.3 | ns |
| (%) | Feb-Apr | 62.9 | 67.5 | 68.5 | 2.8 | ns |

The records of tiller appearance at different tagging dates revealed a smaller number of new daughter tillers being formed throughout the season for the VFR treatment as opposed to the EC and HSR treatments (Table 6.2). Tillering was reduced during the period of lax grazing on both late control treatments (VFR and HSR). Soon after the control of the reproductive growth of the swards took place, tillering was considerably enhanced on the HSR swards, but not in the VFR swards (Figure 6.4), resulting in a lower number of newly formed daughter tillers being produced per parent tiller in VFR swards at the end of the trial. A high turnover in tiller population was observed for all treatments with only 25% of the originally tagged tillers remaining in the tiller population of the experimental swards in early February/93.

Table 6.2. Average number of tagged tillers per parent tiller throughout the season

| | Tagging dates | | | |
|---|---|---|---|---|
| Treatments | 01-18/10 | 01-16/12 [1] | 10-26/02 | 18-30/04 |
| EC | 3.3 | 4.5 | 8.5 | 9.1 |
| VFR | 3.4 | 3.6 | 5.8 | 6.9 |
| HSR | 3.5 | 3.8 | 8.4 | 10.2 |
| | | | | |
| SEM | 0.1 | 0.1 | 0.1 | 0.1 |
| Signif. | ns | ** | ns | + |

1) Time of control of the reproductive growth on late control farmlets

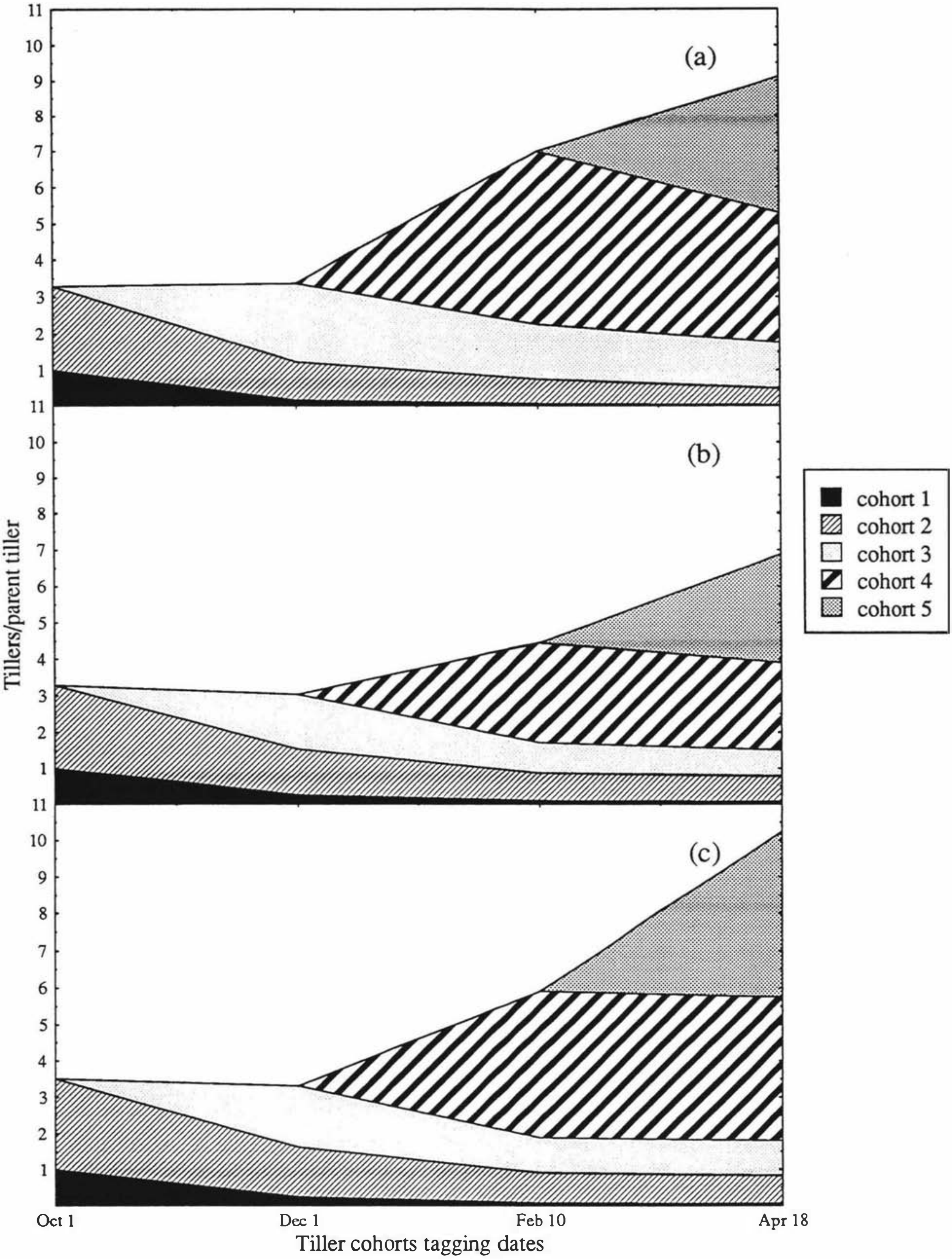

Figure 6.4. Ryegrass tillering pattern for (a) EC; (b) VFR; (c) HSR

Numbers of daughter tillers per parent tiller formed during the observation period and still alive at the time of the final harvest of tillers in April/93 were similar for the EC and HSR treatments, and lower ($P < 0.10$) for the VFR treatment (Table 6.3). The only difference observed in the weight of individual tillers produced per parent tiller at different tagging dates, was that tillers belonging to the last cohort were significantly heavier for the EC treatment when compared to those produced under the VFR and HSR treatment conditions (Table 6.4). As a consequence, the total weight of new formed daughter tillers per parent tiller produced by the VFR swards was consistently smaller than that for EC and HSR swards (Table 6.5), though differences were significant only for cohorts tagged during the control phase.

Table 6.3. Average number per parent tiller of tillers formed during the observation period and still alive at the final harvest of the season (18 to 30 April, 1993)

| | Tiller cohorts tagging dates | | | |
|---|---|---|---|---|
| Treatments | 01-16/12[1] | 10-26/02 | 18-30/04 | Total |
| EC | 1.27 | 3.55 | 3.81 | 8.63 |
| VFR | 0.75 | 2.40 | 2.96 | 6.11 |
| HSR | 0.98 | 3.95 | 4.49 | 9.41 |
| | | | | |
| SEM | 0.13 | 0.43 | 0.49 | 0.87 |
| Signif.[2] | * | ns | + | ns |

1) Time of control of the reproductive growth on late control farmlets

2) In this and subsequent tables: ns = $P > 0.10$; + = $P < 0.10$; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$

Table 6.4. Individual tiller weight (mg)[1] of new formed tillers at the final harvest of the season (18 to 30 April, 1993)

| | Tiller cohorts tagging dates | | |
|---|---|---|---|
| Treatments | 01-16/12[2] | 10-26/02 | 18-30/04 |
| EC | 33.9 | 33.4 | 14.3 |
| VFR | 35.1 | 29.3 | 10.3 |
| HSR | 29.3 | 30.4 | 10.0 |
| SEM | 0.1 | 0.1 | 0.1 |
| Signif. | ns | ns | ** |

1) Statistical analysis performed on transformed data: logarithm
2) Time of control of the reproductive growth on late control farmlets

Table 6.5. Total weight (mg)[1] of new formed tillers per parent tiller at the final harvest of the season (18 to 30 April, 1993)

| | Tiller cohorts tagging dates | | | |
|---|---|---|---|---|
| Treatments | 01-16/12[2] | 10-26/02 | 18-30/04 | Total |
| EC | 41.9 | 121.8 | 50.4 | 214.2 |
| VFR | 24.3 | 76.1 | 34.2 | 134.7 |
| HSR | 33.1 | 120.9 | 49.0 | 203.0 |
| SEM | 5.1 | 17.7 | 7.7 | 26.1 |
| Signif. | * | ns | ns | ns |

1) Statistical analysis performed on transformed data: square root
2) Time of control of the reproductive growth on late control farmlets

### 6.3.2. Grass tiller and clover stolon/node population

At the start of the preparation period EC swards presented slightly higher ryegrass population density than HSR swards, and slightly lower clover nodes/stolon densities than VFR and HSR (Table 6.6 and 6.7). At the time of the late control of the reproductive growth, the population of ryegrass tillers on the lax grazed plots (VFR and HSR) was slightly lower than on EC ($P < 0.10$) (Table 6.6), with other grasses following the same trend only in swards under the HSR treatment. The VFR treatment presented slightly higher tiller population of other grasses than EC, both being significantly more dense ($P < 0.05$) than the HSR swards. Total grass tiller populations followed the same pattern as other grasses tiller populations. During the control and post-control phase, tiller population densities of ryegrass and other grasses on HSR swards were restored to the same levels as those of the EC swards by the end of the trial (April/93). The VFR swards had lower ryegrass tiller density but similar other grasses tiller density to EC and HSR swards. Results from the plug samples immediately after the winter rotation management (Aug/93; Table 6.6) revealed that all the experimental swards started the following spring with similar populations of ryegrass and other grasses tillers.

Little difference between treatments was observed in clover node population densities throughout the season (Table 6.7). On the other hand, clover stolon density and internode length changed substantially by the time of the late control of the reproductive growth on lax grazed swards during spring, with VFR and HSR swards presenting higher stolon densities and internode length than EC swards ($P < 0.05$ and $P < 0.01$, respectively). The same trend was observed at the end of the post-control phase for stolon density and internode length, with the exception that VFR swards tended to show reduced clover stolon densities at that time. Overall, clover node and stolon populations were diminished during the winter, but experimental swards

Table 6.6. Grass tiller population densities (tiller/m$^2$) throughout the season

| Grass sp. | Treatments | Oct/92 | Dec/92[1] | Apr/93 | Aug/93 |
|---|---|---|---|---|---|
| Ryegrass | EC | 2550 | 2080 | 2700 | 3260 |
| | VFR | 2230 | 1540 | 1820 | 3360 |
| | HSR | 2010 | 1570 | 2860 | 3290 |
| | SEM | 182 | 168 | 102 | 255 |
| | Signif. | + | + | *** | ns |
| Oth.grass | EC | 3030 | 3960 | 5580 | 4340 |
| | VFR | 3740 | 4780 | 5360 | 4850 |
| | HSR | 2860 | 3290 | 5160 | 4880 |
| | SEM | 277 | 444 | 489 | 262 |
| | Signif. | + | * | ns | ns |
| Total | EC | 5580 | 6040 | 8280 | 7600 |
| | VFR | 5970 | 6320 | 7180 | 8210 |
| | HSR | 4870 | 4860 | 8020 | 8170 |
| | SEM | 298 | 437 | 457 | 366 |
| | Signif. | * | * | ns | ns |

1) Time of control of the reproductive growth on late control farmlets

Table 6.7. Clover stolon/node population densities throughout the season

| Unit | Treatments | Oct/92 | Dec/92[1] | Apr/93 | Aug/93 |
|---|---|---|---|---|---|
| | EC | 2190 | 2750 | 4780 | 2120 |
| Nodes | VFR | 2530 | 2180 | 4360 | 1750 |
| (nodes/$m^2$) | HSR | 2560 | 2760 | 4570 | 1790 |
| | SEM | 155 | 240 | 303 | 153 |
| | Signif. | ns | ns | ns | ns |
| | EC | 84.4 | 65.1 | 87.7 | 57.2 |
| Stolon | VFR | 89.2 | 70.6 | 80.8 | 46.4 |
| ($m/m^2$) | HSR | 87.4 | 79.6 | 89.0 | 53.0 |
| | SEM | 3.9 | 4.2 | 3.7 | 2.9 |
| | Signif. | ns | * | ns | * |
| | EC | 4.0 | 2.8 | 1.9 | 2.8 |
| Internode | VFR | 3.7 | 3.7 | 2.0 | 2.8 |
| (cm) | HSR | 3.7 | 3.2 | 2.2 | 3.0 |
| | SEM | 0.2 | 0.2 | 0.1 | 0.1 |
| | Signif. | ns | ** | ns | ns |

1) Time of control of the reproductive growth on late control farmlets

came out of the winter rotation period basically with the same levels of node and stolon density, the only exception being the VFR treatment which showed a lower clover stolon density than did the EC and HSR treatments ($P < 0.05$). Clover stolons produced by HSR swards maintained the trend of longer internode length, with those produced by VFR swards reverting to levels similar of those observed for EC swards.

In general, no significant changes in weed population density were observed either during the experimental period or after the winter rotation management. There was a trend for HSR swards to show a higher weed population than EC and VFR by the time of the late control (Table 6.8).

Table 6.8. Weed population densities (plants/$m^2$) throughout the season

| Treatments | Oct/92 | Dec/92[1] | Apr/93 | Aug/93 |
|---|---|---|---|---|
| EC | 150 | 120 | 240 | 190 |
| VFR | 220 | 100 | 270 | 190 |
| HSR | 200 | 190 | 240 | 160 |
| | | | | |
| SEM | 33 | 31 | 29 | 36 |
| Signif. | ns | + | ns | ns |

1) Time of control of the reproductive growth on late control farmlets

### 6.3.3. Herbage accumulation and average pasture cover

A high degree of variability was observed in the data for herbage accumulation, especially after the farmlet study started and post-grazing sampling had to be carried out after a one-day or two-day regrowth period for some sampling areas within each experimental strip (coefficient of variation of around 64%). As a result, few significant differences were observed. Nevertheless, late control swards (VFR and HSR) accumulated herbage dry matter at a faster rate than did early control swards (EC) during the pre-control or preparation phase ($P < 0.10$; Table 6.9). That trend changed with the implementation of different reproductive growth control strategies during the control and post-control phases, basically reflecting the degree of intensity of control being imposed (Table 6.10). Under those circumstances, VFR swards showed the highest rates of herbage accumulation which continued to be observed during the first month of the post-control phase (January) (Table 6.9). On the other hand, swards controlled under a more intensive grazing approach (HSR), resulted in a faster control and reduction of the average pasture cover over the farmlet (Table 6.10). Such a control policy caused a reduction in rates of herbage accumulation which could still be observed during the first month of the post-control phase (January) (Table 6.9). During this period HSR swards performed poorly, with rates of herbage accumulation tending to be slower than those observed on the EC swards. That pattern of response changed again in February, soon after the rain following a dry spell which started in mid January and continued until late February (Figure 6.2), with both late control treatments (VFR and HSR) performing better than EC during the remainder of the experimental period. This was particularly the case for HSR swards, which showed the highest rates of herbage accumulation during March and April (Table 6.9). Consequently, the average pasture cover over the late control farmlets (VFR and HSR) was slightly higher than that for the early control farmlet (EC) in March and April, although by the time the cows were dried-off, all three experimental farmlets had essentially the same average pasture cover (Table 6.11; Figure 6.5).

Table 6.9. Monthly herbage accumulation rates (Kg DM/ha/day) throughout the season

| | Treatments | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | EC | VFR | HSR | | | SEM | Signif. |
| Oct | 55.0 | 69.0 | 61.0 | 80 | 20 | 3.8 | * |
| Nov | 56.0 | 77.0 | 71.0 | 73 | 25 | 7.6 | + |
| Dec | 65.0 | 85.0 | 53.0 | 76 | 25 | 13.3 | ns |
| Jan | 64.0 | 86.0 | 56.0 | 74 | 25 | 11.4 | + |
| Feb | 35.0 | 55.0 | 49.0 | 63 | 35 | 9.2 | ns |
| Mar | 21.0 | 29.0 | 38.0 | 72 | 25 | 6.1 | + |
| Apr | 9.0 | 11.0 | 20.0 | 80 | 20 | 8.9 | ns |
| Aug/Sep | 52.0 | 65.0 | 67.0 | 80 | 20 | 2.6 | + |

Table 6.10. Average pasture cover over the experimental farmlets during the four weeks of the control phase (Kg DM/ha)

| | Treatments | | | | |
|---|---|---|---|---|---|
| Date | EC | VFR | HSR | SEM | Signif. |
| Dec 4 | 2090 | 2770 | 2830 | 139 | ** |
| Dec 11 | 2150 | 2400 | 2500 | 165 | ns |
| Dec 18 | 2240 | 2440 | 2250 | 129 | ns |
| Dec 26 | 2590 | 2640 | 2360 | 142 | ns |
| Jan 2 | 2300 | 2330 | 2150 | 161 | ns |

Table 6.11. Average pasture cover over the experimental farmlets during the post-control phase and at drying-off date (28 April, 1993) (Kg DM/ha)

| | Treatments | | | | |
|---|---|---|---|---|---|
| Month | EC | VFR | HSR | SEM | Signif. |
| Jan | 2210 | 2430 | 2180 | 81 | ns |
| Feb | 2150 | 2190 | 2150 | 55 | ns |
| Mar | 2070 | 2220 | 2160 | 49 | + |
| Apr | 1880 | 1970 | 1900 | 37 | ns |
| Apr 28 | 1800 | 1780 | 1770 | 99 | ns |

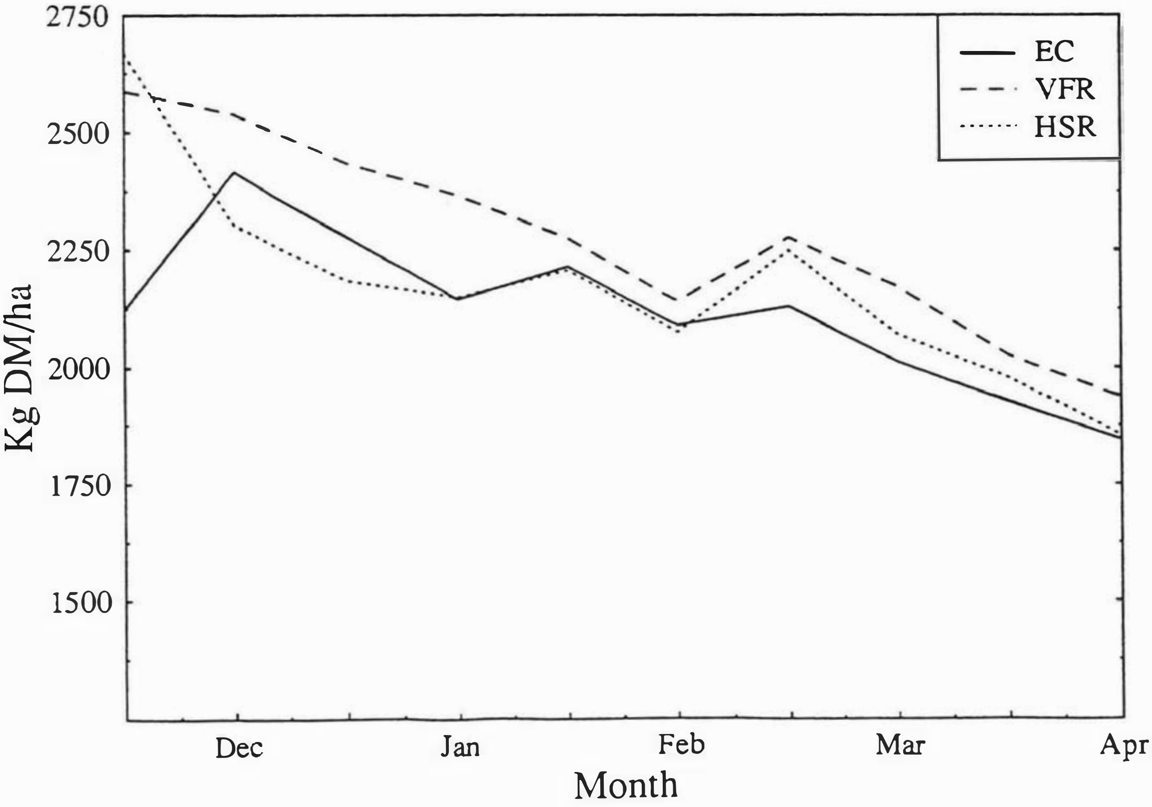

Figure 6.5. Average pasture cover for the three experimental treatments throughout the farmlet study period

The pattern of response of total herbage accumulation for different experimental phases and overall season pasture production reflected the same trend as observed for the monthly herbage accumulation rates (Table 6.12). A more comprehensive analysis including the three years data (years 1 and 2 - Section 4.3.3; and year 3) is presented in Chapter 7. During the pre-control or preparation phase the late control treatments produced more dry matter than the early control (EC) due to higher green and senescent material accumulation under those circumstances (Table 6.12), although no significant differences were observed in live:senescent material ratio of the herbage grown in different swards (Table 6.13). After the control phase was implemented with the late control treatments being differentiated into two different farmlets, the accumulation of senescent material followed the same pattern as in the previous phase but at different intensities, with VFR swards accumulating a larger amount of senescent material than HSR. Both VFR and HSR accumulated more senescent material than did EC, while accumulation of green material was reversed and VFR and HSR tended to accumulate less live herbage material than did EC over the four weeks of the control phase. This was particularly so for the HSR treatment, that being the main cause for the different trends of response observed in total herbage accumulation during that period. This decrease in green herbage accumulation associated with a higher accumulation of senescent material caused the live:senescent material ratio in the sward to drop substantially.

Table 6.12. Herbage dry matter accumulation (Kg DM/ha) during the three experimental phases[1]

| | Pre | | | Control | | | Post | | | Season |
|---|---|---|---|---|---|---|---|---|---|---|
| Treat. | Green | Senescent | Total | Green | Senescent | Total | Green | Senescent | Total | Total[2] |
| EC | 3320 | 80 | 3400 | 2010 | 10 | 2020 | 4210 | -300 | 3910 | 9330 |
| VFR | 3920 | 520 | 4440 | 1700 | 950 | 2650 | 5060 | 360 | 5420 | 12510 |
| HSR | 3630 | 400 | 4030 | 1360 | 290 | 1650 | 5430 | -530 | 4900 | 10580 |
| SEM | 303 | 84 | 317 | 334 | 202 | 414 | 673 | 375 | 561 | 640 |
| Signif. | ns | ** | * | ns | ** | ns | ns | ns | + | + |

1) In this and subsequent tables: Pre = Oct-Nov/92; Control = Dec/92; Post = Jan-Apr/93

2) October 1 to April 30 (212 days)

Table 6.13. Pre-grazing live:senescent material ratio for the three experimental phases

| | Treatments | | | | |
|---|---|---|---|---|---|
| Phase | EC | VFR | HSR | SEM | Signif. |
| Pre | 7.87 | 6.52 | 7.33 | 0.43 | ns |
| Control | 5.77 | 2.67 | 3.35 | 0.69 | * |
| Post | 3.53 | 2.97 | 3.69 | 0.20 | + |

Accumulation of green material by the late control treatments (VFR and HSR) increased again after swards had been re-established in their vegetative state by the end of the control phase, causing the live:senescent material ratio of the herbage in the experimental swards to become similar again. Despite that, VFR swards were still accumulating a considerable amount of senescent material when compared with either EC or HSR swards, that being reflected in a trend for lower live:senescent material ratio during the control period (Table 6.13). Although a considerable variation among plots for herbage components accumulation was observed during the post-control phase, statistical analysis of the data did not reveal significant treatment differences. As a consequence, only the trends for a higher accumulation of total and green dry matter during the summer-autumn period for the VFR and HSR farmlets as opposed to the EC can be reported. The overall seasonal pasture production tended to be higher for the late controlled swards (VFR and HSR) ($P < 0.10$; Table 6.12).

The enhanced green dry matter accumulation of the late control treatments during the pre-control or preparation phase was mainly due to an increased accumulation of grasses in the sward (ryegrass and other grasses), particularly of the stem component, a likely consequence of the reproductive state of such swards (Tables 6.14, 6.15; Figure 6.6), causing a trend for reduced leaf:stem ratio in the grass component of the herbage produced when compared to EC swards (Table 6.16). The same component (grass stem) also

Table 6.14. Species dry matter accumulation (Kg DM/ha) during the three experimental phases

| Phase | Treatment | Ryegrass | Other grasses | Clover | Weeds |
|---|---|---|---|---|---|
| Pre | EC | 900 | 690 | 1380 | 350 |
| | VFR | 1360 | 760 | 1280 | 520 |
| | HSR | 940 | 930 | 1370 | 390 |
| | SEM | 279 | 265 | 327 | 106 |
| | Signif. | ns | ns | ns | ns |
| Control | EC | 860 | 130 | 830 | 190 |
| | VFR | 660 | -70 | 1120 | -10 |
| | HSR | 200 | -30 | 1230 | -40 |
| | SEM | 195 | 307 | 404 | 274 |
| | Signif. | * | ns | ns | ns |
| Post | EC | 1750 | -260 | 1950 | 770 |
| | VFR | 2360 | 220 | 2200 | 280 |
| | HSR | 2300 | -110 | 2980 | 260 |
| | SEM | 537 | 428 | 619 | 172 |
| | Signif. | ns | ns | ns | + |

Table 6.15. Species components accumulation[1] (Kg DM/ha) during the three experimental phases

| | | Ry | | Og | | Clv | |
|---|---|---|---|---|---|---|---|
| Phase | Treatment | L | S | L | S | L | S |
| Pre | EC | 890 | 10 | 420 | 270 | 1360 | 20 |
| | VFR | 840 | 520 | 490 | 270 | 1090 | 190 |
| | HSR | 600 | 340 | 390 | 540 | 1210 | 160 |
| | SEM | 123 | 107 | 99 | 182 | 244 | 108 |
| | Signif. | ns | + | ns | ns | ns | ns |
| Control | EC | 680 | 180 | 240 | -110 | 940 | -110 |
| | VFR | 750 | -90 | 230 | -300 | 1110 | 10 |
| | HSR | 370 | -170 | 90 | -120 | 1210 | 20 |
| | SEM | 127 | 188 | 194 | 158 | 243 | 218 |
| | Signif. | + | ns | ns | ns | ns | ns |
| Post | EC | 1700 | 50 | 290 | -550 | 1780 | 170 |
| | VFR | 2290 | 70 | 350 | -130 | 2410 | -210 |
| | HSR | 2370 | -70 | 470 | -580 | 2660 | 320 |
| | SEM | 340 | 251 | 181 | 271 | 380 | 297 |
| | Signif. | ns | ns | ns | ns | ns | ns |

1) Ry = ryegrass; Og = other grasses; Clv = clover; L = leaf; S = stem/stolon

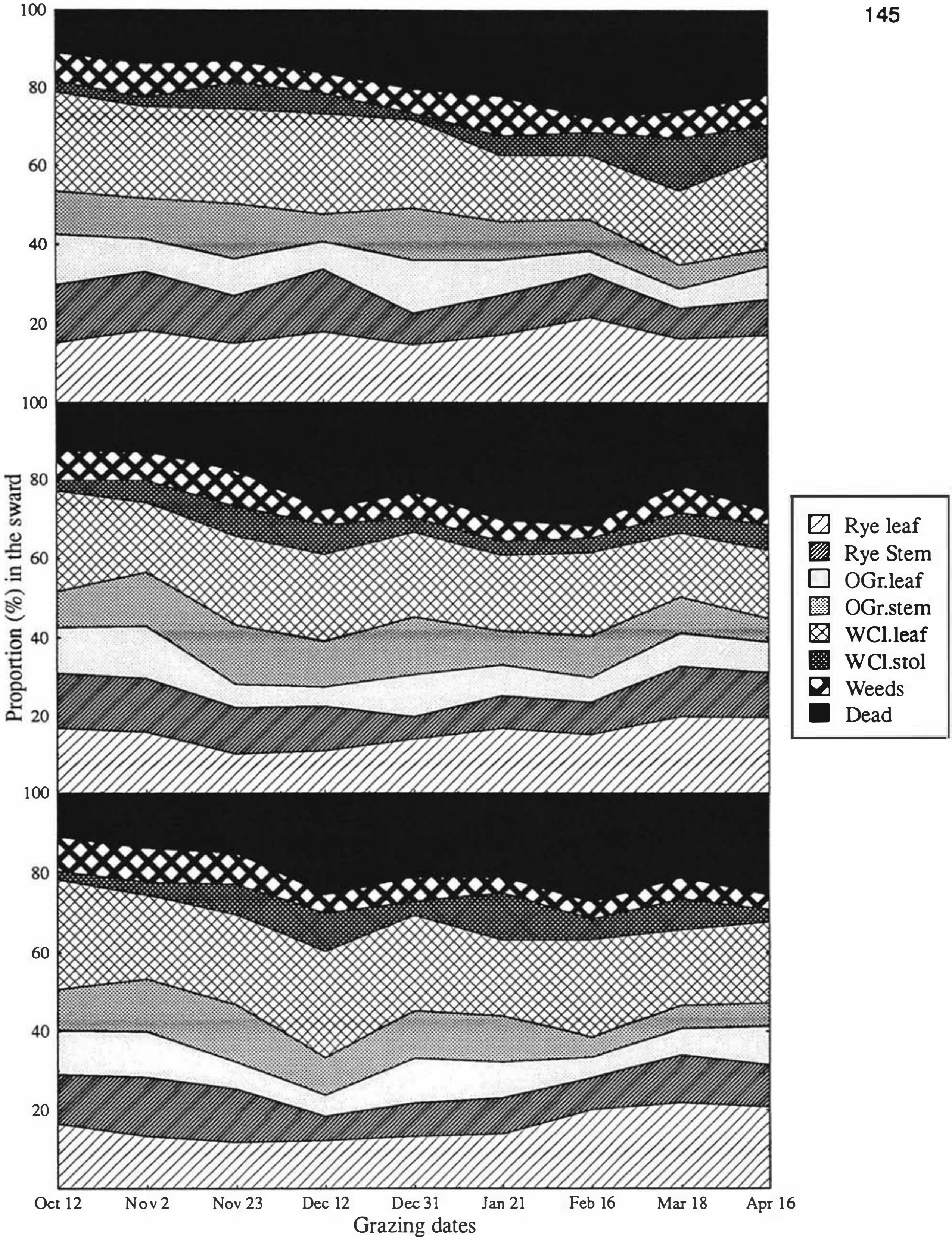

Figure 6.6. Botanical composition of EC (top), VFR (middle), and HSR (bottom) swards at pre-grazing throughout the 1992/93 season

Table 6.16. Pre-grazing leaf:stem ratio of the grass component of the sward for the three experimental phases

| Phase | Treatments | | | SEM | Signif. |
|---|---|---|---|---|---|
| | EC | VFR | HSR | | |
| | Ryegrass: | | | | |
| Pre | 1.31 | 1.22 | 1.17 | 0.09 | ns |
| Control | 1.19 | 1.27 | 2.34 | 0.44 | ns |
| Post | 2.13 | 2.01 | 2.21 | 0.14 | ns |
| | Other grasses: | | | | |
| Pre | 1.06 | 1.02 | 0.81 | 0.11 | ns |
| Control | 1.01 | 0.45 | 0.66 | 0.12 | * |
| Post | 1.17 | 0.94 | 1.20 | 0.12 | ns |
| | Overall: | | | | |
| Pre | 1.13 | 1.09 | 0.96 | 0.09 | ns |
| Control | 1.14 | 0.81 | 1.27 | 0.18 | ns |
| Post | 1.56 | 1.35 | 1.60 | 0.07 | + |

accounted for the differences observed in green herbage accumulation during the control period. As the control phase progressed and seedheads and reproductive stems were controlled, there was a considerable reduction in the accumulation of grass stem material causing the overall green dry matter accumulation to be diminished. No significant differences in leaf:stem ratio were observed for different experimental swards at this time. During the post-control phase the increased green dry matter accumulation in the late control swards (VFR and HSR) was mainly due to an enhanced ryegrass and clover accumulation, particularly of the leaf component. The leaf:stem ratio of the grass component in the swards was maintained at similar levels throughout the summer-autumn period. The late control treatments (VFR and HSR) tended to accumulate less weed dry matter than did EC. Herbage accumulation rates soon after the winter rotation management tended to be higher for the late control treatments (VFR and HSR) (Table 6.9).

### 6.3.4. Sward quality and herbage intake

During weeks 2 and 3 of the control phase (14 to 23 December, 1992) samples of herbage as grazed were collected by hand plucking from areas protected from grazing by exclosure cages. Hand separation of that herbage into botanical components revealed a similar live:senescent material ratio for all the treatments despite their different physiological states of development. However, in the late controlled swards (VFR and HSR) the live component of the herbage was characterised by a smaller grass leaf:stem ratio for the VFR treatment, and there was a higher proportion of clover for the HSR treatment (Table 6.17). These differences were reflected in the differences observed between treatments in nutritive value of the sampled herbage as measured by its nitrogen content (%N), dry matter digestibility (%DMD) and organic matter digestibility (%OMD). The HSR treatment showed the highest content of nitrogen and the late controlled treatments (VFR and HSR) the lowest levels of digestibility (Table 6.18).

Table 6.17. Main botanical features of herbage sampled by hand plucking simulating grazing in areas protected from grazing by exclosure cages from 14 to 23 December

| | Treatments | | | | |
|---|---|---|---|---|---|
| Feature | EC | VFR | HSR | SEM | Signif. |
| live:senescent | 14.1 | 10.7 | 11.7 | 1.6 | ns |
| leaf:stem | 3.2 | 1.5 | 2.7 | 0.3 | * |
| %clover | 37.2 | 39.2 | 49.8 | 1.0 | ** |

Table 6.18. Nutritive value of the herbage sampled by hand plucking of areas protected from grazing by exclosure cages from 14 to 23 December

| | Treatments | | | | |
|---|---|---|---|---|---|
| Parameter | EC | VFR | HSR | SEM | Signif. |
| N(%) | 3.25 | 3.21 | 3.39 | 0.03 | ** |
| DMD(%) | 78.6 | 77.5 | 76.8 | 0.15 | *** |
| OMD(%) | 80.7 | 79.9 | 79.5 | 0.10 | *** |

Oesophageal fistulated (OF) dairy cows were used concomitantly with the hand plucking procedure to harvest samples of herbage as grazed during the first period of herbage intake assessment. The results of the digestibility analysis of the OF samples were very similar to those of pasture from the exclosure cages, and must have been a consequence of the morphological differences of plants in the swards at that time (Table 6.19). Despite such differences in nutritive value, morphology and structure of the swards at that time of the year, estimates of herbage intake were similar for all three experimental treatments (Table 6.20), although animals grazing late control swards (VFR and HSR) tended to show lower levels of intake than those grazing EC swards. During the second period of herbage intake assessment soon after the end of the control phase, in January, no difference was observed in the digestibility of the OF samples or in levels of herbage intake (Tables 6.19 and 6.20). Estimates of herbage intake obtained either by the difference between pre-grazing and post-grazing herbage masses or the chromium oxide technique were unrealistically high and, as a consequence, only the relative differences between treatment means should be considered. The digestibility of the herbage consumed at the beginning of grazing was consistently higher than that at the end of the grazing (Table 6.19).

Table 6.19. Values of estimated *in vivo* digestibilities (%) for the dry matter and organic matter of extrusa samples collected by oesophageal fistulated cattle at either the beginning and end of grazing

| | 14 to 23 December | | | 18 to 27 January | | |
|---|---|---|---|---|---|---|
| Treatments | beginning | end | average | beginning | end | average |
| DMD(%): | | | | | | |
| EC | 79.8 | 75.7 | 77.8 | 80.6 | 75.3 | 78.0 |
| VFR | 76.5 | 74.5 | 75.5 | 81.3 | 75.0 | 78.2 |
| HSR | 77.5 | 72.7 | 75.1 | 81.8 | 75.6 | 78.7 |
| SEM | 0.42 | 0.66 | 0.36 | 0.62 | 0.98 | 0.47 |
| Signif. | *** | ** | *** | ns | ns | ns |
| OMD(%): | | | | | | |
| EC | 83.3 | 78.9 | 81.1 | 83.1 | 77.2 | 80.2 |
| VFR | 80.0 | 77.2 | 78.6 | 83.5 | 77.7 | 80.6 |
| HSR | 80.9 | 75.5 | 78.2 | 84.4 | 78.2 | 81.3 |
| SEM | 0.49 | 0.56 | 0.33 | 0.90 | 1.04 | 0.59 |
| Signif. | *** | *** | *** | ns | ns | ns |

Table 6.20. Estimates of herbage intake (Kg/cow/day) by the experimental groups of cows at both periods of measurement as determined using the chromium oxide technique

| Treatments | Measurement period | |
|---|---|---|
| | 14 to 23 December[1] | 18 to 27 January |
| | Dry matter: | |
| EC | 27.7 (25.6) | 27.7 |
| VFR | 25.5 (21.0) | 26.2 |
| HSR | 23.6 (18.4) | 28.2 |
| SEM | 1.42 (11.0) | 2.27 |
| Signif. | ns ( ns ) | ns |
| | Organic matter: | |
| EC | 24.2 | 22.7 |
| VFR | 22.7 | 22.5 |
| HSR | 20.7 | 23.0 |
| SEM | 1.34 | 1.63 |
| Signif. | ns | ns |

1) Numbers in parenthesis correspond to estimates of dry matter intake from the pre-grazing/post-grazing cut technique

### 6.3.5. Patterns of grazing behaviour

The dairy cows spent 19.5% of the day engaged in activities related to the twice daily milkings, since the experimental area was approximately 1000 metres distant from the milking shed and animals from different treatments had to be moved back and forward as a single mob, causing the need for sorting out experimental groups twice daily before the cows were allowed back into their farmlets. The remaining 80.5% of the day was spent on the paddocks in grazing and ruminating activities, with the major periods of grazing and rumination occurring approximately at the same time for all treatments. During the control phase animals in the late control farmlets (VFR and HSR) tended to spend slightly more of their time grazing than did those in the EC farmlet (Table 6.21), a likely consequence of the higher pre-grazing herbage masses on these treatments and the different structure of those swards when compared to EC. VFR and HSR swards had a higher proportion of stem material in the grazing stratum that may have caused increased difficulties for prehension of the herbage. Time spent in rumination was somewhat longer for the HSR group than for animals in the EC and VFR groups, probably a result of a higher intake of fibrous material that had to be chewed further in order to be digested. Such trends in grazing and rumination times caused VFR and HSR groups to spend a smaller proportion of their time on other activities (neither grazing nor ruminating). The same pattern of behavioural activities was observed during the second period of observation in late January, the first month of the post-control phase. Little difference was observed between treatments in relation to rate of biting in either period of observation (around one bite per second), although the rates observed in late January tended to be slightly higher than those observed in December (Table 6.21), probably reflecting the lower average pasture cover over the farmlets during the second period of observation.

Table 6.21. Time spent in specific activities by dairy cows grazing the experimental swards (hours) and their rates of biting (bites/minute)

| Activities | Treatments | | |
|---|---|---|---|
| | EC | VFR | HSR |
| | | 14 to 23 December: | |
| Milking: | 4.8 | 4.8 | 4.8 |
| On pastures: | 19.2 | 19.2 | 19.2 |
| . grazing | 7.7 | 8.5 | 8.3 |
| . ruminating | 5.9 | 5.6 | 6.4 |
| . neither | 5.6 | 5.1 | 4.5 |
| Biting rate: | 62.3 | 63.5 | 59.0 |
| | | 18 to 27 January: | |
| Milking: | 4.5 | 4.5 | 4.5 |
| On pastures: | 19.5 | 19.5 | 19.5 |
| . grazing | 8.1 | 8.6 | 8.3 |
| . ruminating | 5.7 | 5.9 | 6.1 |
| . neither | 5.7 | 5.0 | 5.1 |
| Biting rate: | 69.3 | 68.6 | 66.5 |

### 6.3.6. Milk yield and composition

No significant difference between treatments was observed in volume of milk produced per cow at any stage throughout the farmlet study period (Table 6.22). During the control phase (December), particularly during the last two weeks of that period, cows belonging to the VFR and HSR groups tended to produce a smaller volume of milk than did those in the EC group. That pattern of response changed soon after the control of the reproductive growth had been completed in early January with the cows in the VFR treatment producing the same volume of milk as those in the EC group. The cows in the HSR group continued to produce slightly less milk during January, until catching up with the other two groups in February. Subsequently, cows in the VFR and HSR farmlets tended to show slightly higher milk production than cows in the EC farmlet when herbage accumulation rates for VFR and HSR treatments tended to become bigger than those for EC towards the end of the season (Table 6.9). Such patterns of response were reflected in the total milk production per cow during both control and post-control phases (Table 6.22).

Despite the trend for reduced milk production per cow during the control phase for animals in the VFR and HSR groups (Table 6.22), the concentrations of solids (fat, protein and lactose) in their milk was slightly higher than that for animals in the EC group (Table 6.23), causing levels of milk fat, protein, lactose and total solids per cow to be very similar during the control phase (Tables 6.24, 6.25, 6.26, and 6.27). Significant differences were observed in March and April ($P < 0.05$ and $P < 0.10$, respectively), the time of the biggest differences in herbage accumulation rates for the VFR and HSR treatments, when animals in the late control farmlets produced more milk solids than those in EC (Table 6.27). Such a significant increase in milk solids during the last two months of the experiment was reflected in the trend for the overall increased total milk solids production during the summer-autumn period

(P = 0.1750), particularly milk fat (P < 0.10) (Table 6.24).

### 6.3.7. Changes in liveweight and body condition score

Animals grazing late control swards were lighter than those grazing EC swards at the end of the control phase (December) (Table 6.28). In general, cows gained weight during most of the farmlet study period, though cows in the HSR group to lost some weight in January, the time when that treatment showed the lowest herbage accumulation rate in comparison with EC and VFR (Table 6.9), but cows were still producing the same level of milk solids (Tables 6.24, 6.25, 6.26, 6.27). The differences in liveweight generated during the control phase persisted during most of the post-control phase, and disappeared only at the end of this period. Changes in body condition score of the animals were minor, and tended to follow the same pattern as the liveweight changes (Table 6.29).

Table 6.22. Daily milk yield during the farmlet study period (litres/cow/day) and the cumulative total yields for the control and post-control phases (litres/cow)

| | Treatments | | | | |
|---|---|---|---|---|---|
| Month | EC | VFR | HSR | SEM | Signif. |
| Dec | 19.3 | 18.9 | 18.8 | 0.46 | ns |
| Jan | 19.7 | 19.4 | 18.9 | 0.52 | ns |
| Feb | 17.1 | 17.4 | 17.7 | 0.38 | ns |
| Mar | 14.2 | 14.9 | 15.3 | 0.57 | ns |
| Apr | 10.9 | 12.2 | 12.0 | 0.64 | ns |
| | | Phase: | | | |
| Control | 600 | 590 | 580 | 10 | ns |
| Post | 1860 | 1920 | 1920 | 50 | ns |

Table 6.23. Milk composition for the three experimental treatments during the control and post-control phases (%)

| Month | Treatments |  |  | SEM | Signif. |
|---|---|---|---|---|---|
|  | EC | VFR | HSR |  |  |
|  |  | Fat: |  |  |  |
| Dec | 4.47 | 4.62 | 4.68 | 0.22 | ns |
| Jan | 4.51 | 4.71 | 4.91 | 0.22 | ns |
| Feb | 4.89 | 4.89 | 5.01 | 0.22 | ns |
| Mar | 4.89 | 5.19 | 5.66 | 0.21 | + |
| Apr | 5.19 | 5.07 | 5.55 | 0.28 | ns |
|  |  | Protein: |  |  |  |
| Dec | 3.46 | 3.52 | 3.44 | 0.09 | ns |
| Jan | 3.26 | 3.25 | 3.20 | 0.08 | ns |
| Feb | 3.58 | 3.58 | 3.51 | 0.10 | ns |
| Mar | 3.66 | 3.85 | 3.79 | 0.12 | ns |
| Apr | 3.68 | 3.81 | 3.83 | 0.13 | ns |
|  |  | Lactose: |  |  |  |
| Dec | 5.16 | 5.26 | 5.17 | 0.06 | ns |
| Jan | 4.73 | 4.86 | 4.73 | 0.06 | ns |
| Feb | 5.07 | 5.28 | 5.20 | 0.06 | ns |
| Mar | 4.77 | 4.96 | 4.84 | 0.09 | ns |
| Apr | 4.70 | 4.73 | 4.70 | 0.07 | ns |

Table 6.24. Daily milk-fat yield during the farmlet study period (Kg/cow/day) and the cumulative total yields for the control and post-control phases (Kg/cow)

| | Treatments | | | | |
|---|---|---|---|---|---|
| Month | EC | VFR | HSR | SEM | Signif. |
| Dec | 0.87 | 0.87 | 0.86 | 0.03 | ns |
| Jan | 0.89 | 0.91 | 0.91 | 0.04 | ns |
| Feb | 0.84 | 0.85 | 0.87 | 0.03 | ns |
| Mar | 0.70 | 0.77 | 0.86 | 0.03 | ** |
| Apr | 0.57 | 0.61 | 0.66 | 0.03 | + |
| | | Phase: | | | |
| Control | 27.0 | 27.0 | 27.0 | 1.1 | ns |
| Post | 90.0 | 94.0 | 99.0 | 3.5 | + |

Table 6.25. Daily milk-protein yield during the farmlet study period (Kg/cow/day) and the cumulative total yields for the control and post-control phases (Kg/cow)

| | Treatments | | | | |
|---|---|---|---|---|---|
| Month | EC | VFR | HSR | SEM | Signif. |
| Dec | 0.67 | 0.66 | 0.65 | 0.02 | ns |
| Jan | 0.64 | 0.62 | 0.61 | 0.02 | ns |
| Feb | 0.61 | 0.61 | 0.62 | 0.02 | ns |
| Mar | 0.52 | 0.57 | 0.58 | 0.02 | + |
| Apr | 0.40 | 0.46 | 0.46 | 0.02 | * |
| | | Phase: | | | |
| Control | 21.0 | 20.0 | 20.0 | 0.7 | ns |
| Post | 65.0 | 68.0 | 68.0 | 2.1 | ns |

Table 6.26. Daily milk-lactose yield during the farmlet study period (Kg/cow/day) and the cumulative total yields for the control and post-control phases (Kg/cow)

| | Treatments | | | | |
|---|---|---|---|---|---|
| Month | EC | VFR | HSR | SEM | Signif. |
| Dec | 1.00 | 0.98 | 0.98 | 0.03 | ns |
| Jan | 0.94 | 0.93 | 0.90 | 0.03 | ns |
| Feb | 0.87 | 0.91 | 0.92 | 0.03 | ns |
| Mar | 0.69 | 0.74 | 0.74 | 0.04 | ns |
| Apr | 0.52 | 0.58 | 0.57 | 0.03 | ns |
| | | Phase: | | | |
| Control | 31.0 | 30.0 | 30.0 | 1.0 | ns |
| Post | 90.0 | 95.0 | 94.0 | 3.5 | ns |

Table 6.27. Daily milk-solids yield during the farmlet study period (Kg/cow/day) and the cumulative total yields for the control and post-control phases (Kg/cow)

| | Treatments | | | | |
|---|---|---|---|---|---|
| Month | EC | VFR | HSR | SEM | Signif. |
| Dec | 2.54 | 2.52 | 2.48 | 0.07 | ns |
| Jan | 2.47 | 2.48 | 2.42 | 0.07 | ns |
| Feb | 2.32 | 2.37 | 2.41 | 0.06 | ns |
| Mar | 1.91 | 2.08 | 2.18 | 0.08 | * |
| Apr | 1.49 | 1.64 | 1.69 | 0.08 | + |
| | | Phase: | | | |
| Control | 79.0 | 78.0 | 77.0 | 2.2 | ns |
| Post | 245.0 | 257.0 | 261.0 | 7.6 | ns |

Table 6.28. Average liveweight (Kg) throughout the farmlet study period (control and post-control experimental phases)

| | Treatments | | | | |
|---|---|---|---|---|---|
| Period | EC | VFR | HSR | SEM | Signif. |
| Dec | 511 | 495 | 502 | 4.9 | * |
| Jan | 514 | 500 | 494 | 7.1 | + |
| Feb | 527 | 514 | 507 | 5.9 | * |
| Mar | 535 | 516 | 506 | 5.9 | * |
| Apr | 540 | 529 | 529 | 7.3 | ns |

Table 6.29. Average body condition score throughout the farmlet study period (control and post-control experimental phases)

| | Treatments | | | | |
|---|---|---|---|---|---|
| Period | EC | VFR | HSR | SEM | Signif. |
| Dec | 4.7 | 4.6 | 4.6 | 0.1 | ns |
| Jan | 4.5 | 4.5 | 4.3 | 0.1 | ns |
| Feb | 4.5 | 4.6 | 4.3 | 0.1 | * |
| Mar | 4.5 | 4.7 | 4.3 | 0.1 | * |
| Apr | 4.5 | 4.6 | 4.5 | 0.1 | ns |

### 6.3.8. Relationship between pasture and animal responses according to Principal Components Analysis (PCA)

In order to gain some objective assessment of the relationship between milk solids production and herbage accumulation, principal components analysis was performed on a small combined data set of animal and pasture measurements. These consisted of 3 treatments (EC, VFR and HSR) and 3 months (February, March and April). Data from December and January were excluded from the analysis because of the large degree of variability. The variables involved were herbage accumulation rate and/or milk-solids, fat, protein, lactose yield.

The PCA generated two principal components for each combination of herbage accumulation and milk-yield feature, but only the first one is reported, since it accounted for a very high proportion of the overall variation of the data under investigation (Table 6.30). The PC's revealed a close relationship between pasture production and animal performance. Analysis of variance of the PC scores obtained from each of the PCA's revealed a significant effect of treatment ($P < 0.020$) and time of the year ($P < 0.001$), with higher milk-solids yield being obtained from treatments accumulating herbage at a faster rate (HSR > VFR > EC) and decreasing through the season as the overall herbage accumulation rates decreased (February > March > April) (Table 6.9). Since the two sets of data (animal and pasture measurements) were not conformable, it was not possible to determine how much of the association between herbage growth and milk production may have been due to the effect of declining milk yields with advances in lactation stage. Similar results were obtained from an analysis on the same data by simple linear regression. Because for this analyses the herbage accumulation rates and the milk solids yield were averaged across time (February to April), logarithmic transformation was used in order to prevent the large February means having an increased influence on the analyses compared with the smaller March and April means. Again a strong relationship between herbage accumulation and milk solids production was observed, with 98.2% of the variation in milk solids being accounted for by the fitted regression (Figure 6.7).

Table 6.30. Correlations between raw data and PC scores, and the proportion of total variance explained by PCA of the combined data set of animal and pasture responses

| | Data set | | |
|---|---|---|---|
| PCA | Pasture | Animal | Proportion |
| HA[1] x solids | 0.932 | 0.932 | 0.869 |
| HA x fat | 0.973 | 0.973 | 0.946 |
| HA x protein | 0.833 | 0.833 | 0.694 |
| HA x lactose | 0.968 | 0.968 | 0.937 |

1) HA = herbage accumulation

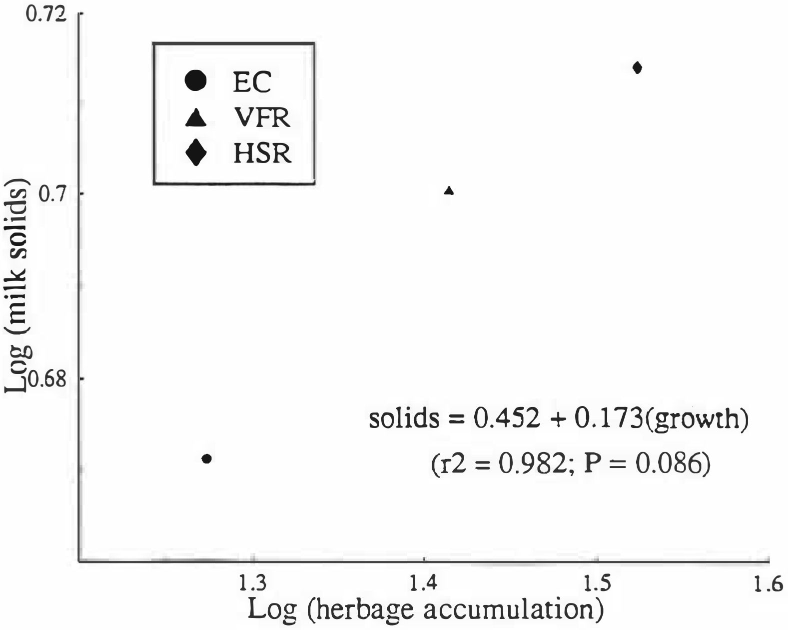

Figure 6.7. Relationship between the average herbage accumulation rate (Kg DM/ha/day) and average milk solids yield (Kg/ha/day) for the February to April period.

## 6.4. Discussion

### 6.4.1. Techniques

In general, measurements of pasture traits were associated with high levels of variability (coefficients of variation of up to 64%). The size of the experimental area was quite large (8.4 ha) and, although a completely randomised block design was used in order to get some control over the between-paddock variability intrinsic to on-farm trials, variability within paddocks was considerable and could not be effectively controlled by the experimental techniques used. As a consequence, the level of precision of the estimates obtained reduced and resulted in only a few significant differences being observed. However, the marginal differences and trends observed in this trial should be considered more carefully since they were consistent with the findings from the previous two grazing seasons (Experiment 1 and 2 - Chapter 4) and could reflect a real treatment effect (Chapter 7).

The same problem of large variability did not occur with the results from the set of animal measurements (coefficients of variation between 5 and 10%), excepting the estimates of the daily herbage intake of dairy cows. Herbage intake measurements were made by two different ways during the study. In December, direct (difference between pre-grazing and post-grazing herbage masses) as well as indirect estimates of herbage intake (from estimates of total faecal output and herbage digestibility of the grazed herbage) were made, and only indirect estimates were made in January (Section 6.2.4.2.3).

The results obtained from both periods were unrealistically high, and may have been a consequence of problems with the techniques employed. Expected values for that time of the year would be around 15 Kg DM/cow/day or 140 MJ of metabolizable energy considering the combined requirements for maintenance and milk production (Chapter 5). During the control phase, when the direct method was used, grazing was quite patchy in both late control and early control pastures. Such a problem was expected to occur with late control pastures because of the high pre-grazing herbage masses and high herbage allowances offered to the cows. On the other hand, December was wetter than in the past two years (Figures 4.2 and 6.2), resulting in higher herbage accumulation rates than expected for the early control areas, which favoured the occurrence of patchy grazing. Consequently, determinations of pre-grazing and post-grazing masses were quite variable, with some very high values being obtained from patches of tall grass due to the random sampling procedure employed.

Estimates of herbage intake from the indirect technique using the chromium controlled release capsules (CRC) were also very high. Estimates of intake according to that technique are based on estimates of the total faecal output and the digestibility of the grazed herbage, which can be calculated by the following expressions:

$$F = \text{CRC release rate (g.day}^{-1}) \;/\; Cr_2O_3 \text{ in faeces (g.g}^{-1})$$

$$I = F \;/\; (1\text{-}D)$$

It follows that measurements of intake (I) are dependent upon the accurate estimation of faecal output (F) and digestibility (D). Any error in estimating F would result in equivalent error in I but, if error occurs in the estimation of D, it would result in a proportionally larger error in I, since values of D are usually greater than 0.50 (Le Du & Penning, 1982). Values of release rate of the CRC used in this trial were those supplied by the manufacturer for animals grazing similar pastures, and it was not possible to check them under the experimental grazing conditions. If, for any reason, the release rate of the CRC's was lower than the value used, the determination of total faecal output would be inflated and so would the estimates of herbage intake. Values of chromium concentration in the faeces are not likely to have been a source of bias, since that sort of analysis is performed routinely at the University laboratory where faecal samples were analysed. Furthermore, values of digestibility of the grazed herbage were quite high for pastures used during both measurement periods when compared to existent values in the literature (Section 2.6.2), and that could also have inflated the estimates of intake.

Although the very high absolute values of herbage intake rule out any possibility of comparison between the results obtained in this trial and other published results, it does not mean that a relative comparison between treatments would not be valid. With these considerations in mind, a discussion of results is presented in the following sections.

### 6.4.2. Tiller dynamics and population

As in the previous seasons (Experiments 1 and 2 - Chapter 4), a considerable amount of variability was observed in the data set. This is not surprising given the between-paddock variation inherent in an on-farm trial. During the preparation period (spring) the lax grazing management (VFR and HSR) caused a significant decrease in the number of new daughter tillers formed per parent tiller in comparison with those formed in the hard grazed swards (EC) (Table 6.2, Figure 6.4), resulting in lower tiller population densities by the time of the start of the experimental farmlet study period (Table 6.6). These differences reflected reduced rates of tiller appearance, which were not compensated by the lower rates of tiller death and higher rates of tiller survival under those circumstances (Table 6.1). Such a pattern of response was very similar to that observed in Experiment 2 (Table 4.10) and is in accordance with several previous reports (e.g. Korte, 1982; Korte *et al.*, 1982). The poor light environment associated with reproductive swards (Korte,

1982) and the strong competition for assimilates between maturing seedheads and young tillers (Ong *et al.*, 1978; Carton *et al.*, 1989b; Matthew, 1991a; Matthew *et al.*, 1991; Thom, 1991) are the most probable causes. The light regime within a sward has long been recognised as a major factor in determining tiller death (Hunt & Field, 1979) and the competition between maturing seedheads and young tillers has been known to cause a reduction in number and size of new formed tillers as well as increased death of young tillers once seedheads are allowed to pass the stage of anthesis (Matthew, 1991a).

During the control phase, the first month of the experimental farmlet study period (December/92), late control treatments (VFR and HSR) showed different patterns of tillering which were a likely consequence of the defoliation regime being applied to those swards at that time (Figure 6.4). The VFR treatment resulted in a more gradual control and reduction in average pasture cover levels, and it was associated with lower tiller appearance rates than those for the remaining treatments (EC and HSR) (Table 6.1). On the other hand, a more intensive defoliation regime which caused a more sudden control and reduction in average pasture cover levels (HSR) resulted in rates of tiller appearance as high as those of the conventionally hard grazed swards (EC), and a faster and more effective recovery of tiller numbers at the start of the summer-autumn period (Table 6.2). Such a contrast in response patterns from the two late control treatments was probably due to the efficacy and timing of the different grazing strategies in returning swards to their vegetative state and reducing their overall average pasture cover to the same level as that on the EC farmlet, the original target for early January. The VFR management took longer to control swards than its counterpart (HSR) and probably allowed animals to selectively graze pastures, causing rejected stem and old herbage material to senesce and accumulate at the base of the sward, and to interfere with the tillering process (Table 6.12). Shading of photosynthetic tissue by dead herbage and ryegrass stems in rank pasture has been reported previously by Korte (1982) and it is believed to cause considerable decreases in tillering under those circumstances (Davies, 1977). Accumulation of senescent material in the HSR swards was not so intense and allowed ryegrass plants to tiller freely since, under those circumstances, there was no intra-specific competition due to reduced tiller population.

The rate of tillering in VFR swards (Table 6.1) during the post-control phase was similar to that of EC swards, and caused an incomplete restoration of tiller numbers in the former, resulting in reduced numbers of new daughter tillers being formed per parent tiller (Table 6.2 and 6.3, Figure 6.4) and reduced tiller population (Table 6.6) at the end of the trial. That may have been a consequence of the unsuitable light environment inherited from the previous phase (control phase), since the shortage of moisture in the soil during most of January and February (Figure 6.2) was likely to have slowed down the decomposition of the senescent material which is believed to have interfered with tillering. However, HSR swards continued to tiller slightly more quickly than EC in the autumn, despite having similar numbers of tillers per parent tiller since the beginning of the post-control phase. That, associated with similar rates of death and survival for all treatments, resulted in a trend for increased numbers of daughter tillers being formed per parent tiller by the end of the experimental period in HSR swards (Table 6.2 and 6.3, Figure 6.4). The EC and HSR swards finished the season with essentially the same ryegrass tiller populations which were significantly higher than that in the VFR swards (Table 6.6).

Tiller populations in other grasses tended to show the same pattern of response, with the exception of VFR swards during the pre-control phase. Those swards started the farmlet study period with higher other grasses tiller population, which was probably a consequence of the slightly higher tiller population present at the outset of the trial (Table 6.6).

The importance of the late spring-early summer tillering in swards comprised mainly of perennial ryegrass plants was highlighted by the high turnover in tiller population observed during that period, with only 25% of the original tiller population tagged in October/92 still present in early-February/93. Such a tiller replacement process has been reported previously by several authors (Korte *et al.*, 1982, 1984, 1985, 1986; Matthew, 1991a,1992; Thom, 1991) and seems to play an important role in determining tiller population during the summer-autumn period. The formation of new tillers from reproductive tillers has been demonstrated to be a very effective way of enhancing such tiller replacement and it is likely to improve the perennation and persistency of perennial ryegrass swards (Matthew *et al.*, 1993).

### 6.4.3. Clover stolon/node population

The initial set of tiller plugs harvested in October/92, at the outset of the trial, revealed that swards had the same clover node and stolon population and, consequently, the same internode length (Table 6.7). Lax grazing during the spring did not have any effect on node population density throughout the experimental period, with only a trend for reduced node numbers being observed in the VFR swards at the beginning of the farmlet study period, the time of the year when those swards were conceptually the same as HSR swards. Such a pattern of response was slightly different from that observed during the previous season in Experiment 2 (Chapter 4), when a significant reduction in node population was observed in the lax grazed swards (LHC and LLC). This discrepancy could be due to the joint presence of white and red clover in the clover component of the swards during the current trial, whereas only white clover was present in the previous season. The overall clover node population was higher at the end than at the start of the trial, probably reflecting the different phases of the seasonal cycle of burial and re-establishment that clover plants undergo during the year (Section 2.3.2.1). An indication of the winter burial of clover plants was obtained from the reduced node population densities observed soon after the winter rotation management, when swards did not differ in node numbers but presented a lower node population than that observed at the beginning of the autumn (Table 6.7).

Clover stolon density was significantly affected by lax grazing over the spring (Table 6.7). Late controlled swards (VFR and HSR) were characterised by higher stolon densities going into the farmlet study period. That was probably a consequence of the defoliation regime adopted on those swards that allowed clover plants to grow bigger stolons which, in association with the similar clover node densities of the experimental treatments, resulted in the longer internode length observed at that time of the year (Table 6.7). Such an effect of lax defoliation regimes on stolon growth was observed during the previous season (Section 4.4.2) and has also been reported elsewhere (Grant & Barthram, 1991; Barthram & Grant, 1993) (Section 2.3.3). Clover stolon densities tended to become similar again by the end of the trial in April/93, with mean values being slightly lower for the VFR swards than for the EC and HSR swards (Table 6.7). Such a trend was maintained after the common winter grazing management, but levels of stolon density on all treatments were lower than those observed in early autumn, probably due to the winter burial of stolons (Hay *et al.*, 1987). Clover plants in the HSR swards tended to show longer internode length throughout the summer, autumn and winter.

### 6.4.4. Herbage dry matter accumulation

The data for herbage accumulation and components were characterised by a considerable level of variation which limited the significance of treatment effects, particularly during the December and January months. From December onwards each set of replicated treatments was managed as a self-contained farmlet at a fixed stocking rate, and a fresh break of pasture was offered to cows every day. The stocking rates had been previously defined based on an average pasture growth rate for the experimental site of around 35 Kg DM/ha/day in December and 25 Kg DM/ha/day in January. Actual growth rates were substantially greater than those expected, which caused cows to leave higher post-grazing residues and led to the occurrence of patchy or uneven grazing. Thus, variability within strips due to patchy grazing was greater than in Experiment 2. Despite that, herbage accumulation rates were consistently higher for the late control treatments (VFR and HSR) during spring (preparation period) and most of the summer-autumn period (experimental farmlet period) (Table 6.9). The rates of herbage accumulation in the VFR and HSR swards during the control phase (December) and the first month of the post-control phase (January) were a direct consequence of the grazing strategy utilised to re-establish those swards into their vegetative state and reduce the average pasture cover on those farmlets back to the same level as that of the conventionally grazed farmlet (EC).

The very fast rotation grazing approach (VFR) achieved control of the reproductive growth of swards by a sequence of three 10-day grazing cycles of increasing grazing intensity, characterised initially by high levels of post-grazing residuals that allowed swards to accumulate herbage more rapidly due, probably, to higher levels of residual leaf area index, even though they had low grass tiller densities (Table 6.6). The importance of the remaining leaf area index in determining rates of regrowth after grazing or cutting has long been recognised (Brougham, 1956,1957; Anslow, 1965; Brougham & Glenday, 1967; Anslow & Back, 1967; Davies, 1974; Korte & Harris, 1987b; Parsons *et al.*, 1988ab; Parsons & Penning, 1988). On the other hand, the high stocking rate approach (HSR) achieved control of the reproductive growth of the swards by a sequence of two 15-day grazing cycles of intensive grazing which eliminated seedheads, reproductive stems and the extra pasture cover more quickly than the VFR approach did (Table 6.10). The resultant swards were open and characterised by low grass tiller densities, resulting in low rates of herbage accumulation. Differences in sward morphology caused by differences in grazing management have been recognised to be important factors in determining herbage accumulation rates by influencing the ability of the sward to produce new leaf (Grant & King, 1983). Reduced tiller density is one of those morphological differences and it is likely to limit herbage accumulation by limiting the number of growing leaves (Hunt & Field, 1979) and the ability of plants to compete for space, light and nutrients.

The increased herbage accumulation rates for the late control swards (VFR and HSR) were more noticeable towards the end of the experimental season (March and April), particularly for the HSR treatment (Table 6.9). Estimates of total herbage accumulation tended to follow the same trend observed for herbage accumulation rates and were reflected in the overall seasonal pasture production (Table 6.12). Late control swards (VFR and HSR) tended to regrow more quickly soon after the first grazing following the standard winter rotation management (Table 6.9). There was no apparent reason for such a trend, since grass tiller and clover node/stolon densities (Tables 6.6 and 6.7) as well as the post-grazing herbage masses were similar on all three treatment areas at the beginning of that regrowth period.

#### 6.4.4.1. Herbage dry matter composition

During the pre-control or preparation phase of the trial the differences observed in total herbage accumulation were a consequence of increased senescent material accumulation and, to a lesser extent, green dry matter accumulation in the lax grazed swards (VFR and HSR) when compared to the hard grazed swards (EC) (Table 6.12). The small increase in green material accumulation was basically a function of the reproductive state of the late control swards (Figure 6.6) and was caused by increased stem material accumulation in the grass component (Tables 6.14 and 6.15). Because of that, there was a slight reduction in the ratios of live:senescent material and leaf:stem in the VFR and HSR swards, although those changes were not statistically significant (Table 6.13 and 6.16). Rapid accumulation of senescent material usually indicates reduced levels of herbage utilisation which in association with an increased proportion of stem material in the sward could interfere with the quality of the herbage grown and the nutrient intake of grazing animals. Such a pattern of response was observed during the previous season (Section 4.4.4) and has repeatedly been reported in New Zealand (Korte, 1982; Korte *et al.*, 1982,1984; Thomson *et al.*, 1984; Butler, 1986; Bryant & L'Huillier, 1986; L'Huillier, 1987b,1988; L'Huillier & Aislabie, 1988; Hoogendoorn *et al.*, 1992).

The increased herbage production in the VFR treatment during the control phase was mainly due to increased senescent material accumulation, which was probably caused by the gradual process of control and reduction in levels of pasture cover for that treatment (Table 6.10) (section 6.4.3). Both late controlled swards (VFR and HSR) accumulated rather less green material than EC swards. The reduction in green herbage accumulation in VFR swards seemed to be due mainly to reduced grass stem accumulation, while in the HSR swards there was reduced grass stem as well as leaf accumulation (Tables 6.14 and 6.15). The results suggest that reproductive stems in the VFR swards were not consumed by the animals and underwent a process of senescence, increasing the size of the pool of senescent material under those circumstances which caused a significant drop in the live:senescent material ratio of those swards (Table 6.13). The removal of reproductive stems was more effective in those swards where the grazing animals were forced to graze more intensively due to the increased stocking rate (HSR). Under those circumstances most of the leaf material was being consumed and tiller densities were rather low, that probably being the reason for those swards not being able to produce new leaf material at the same rate as it was being consumed (Hunt & Field, 1979; Grant & King, 1983) (Section 6.4.2). The increased intensity of defoliation was reflected in the intermediate live:senescent material and higher leaf:stem ratio observed in HSR swards when compared to those for EC and VFR (Tables 6.13 and 6.16).

During the post-control phase the patterns of response in terms of herbage accumulation were similar to those observed in Experiments 1 and 2 (Section 4.4.4). Late control treatments (VFR and HSR) tended to accumulate more dry matter than EC did. The increased dry matter accumulation was mainly due to green material accumulation, although VFR swards tended to accumulate slightly larger amounts of senescent material than EC and HSR swards (Table 6.12). The higher green dry matter accumulation for VFR and HSR than for EC swards was mainly due to enhanced production of perennial ryegrass and clover leaf material, particularly for HSR swards (Tables 6.14 and 6.15). The leaf:stem ratios of swards under the three grazing treatments were similar throughout the summer-autumn period. Such a pattern of response was probably a consequence of the enhanced ryegrass tillering activity (Table 6.5) and clover morphological structure (Table 6.7) of the late controlled swards during the summer-autumn period.

### 6.4.5. Ryegrass:clover balance

During the current trial, grass and clover plants presented a pattern of response very similar to that observed during the first two years of this study (Experiments 1 and 2). A theoretical mechanism to explain the responses of grass and clover plants to defoliation regimes similar to those used in this trial was proposed in Section 4.4.5 and can be used here to facilitate the understanding of the ryegrass:clover balance of swards subjected to late control grazing management during spring time.

The lax grazing regime imposed on the late control swards (VFR and HSR) caused a reduction in tiller number.Despite that, such tillers were bigger and, therefore, no detrimental effect was noticed in terms of total herbage accumulation during that period. This tiller size-density compensation event is quite common in grass species (Matthew *et al.*, in prep.). An increased growth of stolons by clover plants was also induced by lax grazing, probably due to the accumulation of ungrazed leaves on stolons (Davies, 1992), which resulted in bigger stolons with a higher level of reserve carbohydrates (Grant & Barthram, 1991; Barthram & Grant, 1993). Such morphological changes in the pasture species contributed to the behaviour of the swards during the control and post-control phases of growth. Soon after the reproductive stems were removed from the swards of the VFR and HSR farmlets, the plant community was quite open and provided plenty of vacant spaces to be colonized. Under those circumstances, plants were able to grow freely at first until intra and inter-specific competition started to impose limits, probably at the beginning of the post-control phase (January). At that time, a reduction in rainfall occurred which was extended until late in February (Figure 6.2). As a consequence of the elongation of grass leaves and sheaths during the reproductive phase, the control of the reproductive growth of the swards probably caused most of the grass leaf blade as well as most of the clover leaves to be removed, particularly in the swards under the HSR treatment. Under those circumstances regrowing petioles are short but the regrowing leaflets remain as large as they were before, which could have caused an increase in the clover leaf area relative to the grass leaf area and a short-term increase in the clover content of the swards (Davies, 1992).

Clover plants are also characterised by having a lower specific leaf area and slower pattern of unfolding of new leaves when compared to grass species, which confers an advantage in terms of current and future carbon acquisition during the regrowth process in summer (Parsons *et al.*, 1991ab). This lower investment of carbon per unit area of leaf, associated with a higher level of reserve carbohydrates in the late control treatments, high temperatures (Figure 6.1) and a probable soil moisture deficit during January and February (Figure 6.2), may have allowed clover plants to perform better than in conventional conditions (EC farmlet). Once rainfall resumed in late February and levels of soil moisture were re-established, ryegrass plants which were already tillering considerably but could not compete efficiently with clover plants due to climatic conditions, were able to increase their contribution to the herbage accumulated (Figure 6.6), particularly during March and April, when temperatures were not as high as in January and February. Therefore, knowledge of the differences between ryegrass and clover plants in response to varying temperatures and other seasonal features (Barthram & Grant, 1993) as well as their physiological responses to stress conditioned by different defoliation regimes (Brock *et al.*, 1981) is very important for an appropriate understanding of the overall response of a mixed pasture submitted to different grazing managements. As a consequence of this ryegrass:clover balance, late control treatments accumulated more total and green dry matter during the summer-autumn period, which was a result of enhanced dry matter production by both plant species.

### 6.4.6. Herbage quality and intake

The changes that occurred in the quality of the herbage of experimental swards were a primary consequence of the different morphological states of plants under those circumstances. Swards allowed to become reproductive

(VFR and HSR) were characterised by a lower leaf:stem ratio than those maintained in a vegetative state (EC) (Tables 6.16 and 6.17). The more gradual control grazing approach (VFR) did not remove the reproductive stems quickly enough, causing them to become overmature and senesce, increasing the pool of senescent material at the base of the sward (Table 6.15). On the other hand, HSR was effective in returning swards quickly to a vegetative state and removing reproductive stems. Such a sequence of events resulted in a decrease in the nutritive value of the herbage present on VFR and HSR swards during most of the control phase in December (Tables 6.18 and 6.19), although the overall levels of digestibility observed at that time of the year were higher than the 67% level reported by Hoogendoorn *et al.* (1988,1992) as likely to interfere with the milk production of dairy cows. At the time of the harvest of the herbage samples for digestibility analysis, stems were still green and likely to be of high digestibility. Similar results have been reported previously (Davies, 1973; L'Huillier, 1987b,1988; L'Huillier & Aislabie, 1988) and revealed the potential value of green stems in mixed reproductive ryegrass-white clover pastures for dairy cow feeding purposes (Thomson *et al.*, 1984; Thomson, 1989). Levels of digestibility of the herbage from VFR and HSR swards were restored to levels similar to those of EC swards by mid-January, after being returned to a vegetative state (Table 6.19).

At individual grazings the quality of the herbage being consumed decreased as the grazing process continued, a likely consequence of the declining grazing heights and morphological differences of the sward strata being grazed (Table 6.19) (Hodgson & Maxwell, 1981). Levels of nitrogen in the consumed herbage reflected the differences in content of clover, with a higher level of clover in the herbage being associated with higher levels of nitrogen (Table 6.17).

Despite the differences in sward quality and structure observed during the control phase, the estimates of herbage intake did not reveal any difference between treatments, although the intake of animals grazing late controlled swards (VFR and HSR) was slightly lower than those grazing EC swards (Table 6.20). The different rotation lengths being used at that time caused cows in the VFR and HSR farmlets to receive a daily area for grazing 2 or 1.33 times larger than cows in the EC farmlet, respectively. Such a larger area associated with higher pre-grazing herbage masses resulted in higher herbage allowances, which must have partially compensated for the adverse sward characteristics of the VFR and HSR swards. Maintenance of levels of intake and milk production of dairy cows grazing reproductive swards by offering a higher allowance of pasture has been reported previously under similar conditions (Hoogendoorn *et al.*, 1988,1992) (Section 2.5.2). Once the control phase had been finished and swards returned to a vegetative state, no differences were observed in levels of herbage intake during the first month of the post-control phase (Table 6.20).

### 6.4.7. Animal performance

The observed pattern of response in animal performance to the three experimental treatments under investigation was a likely consequence of the differences in sward structure, species composition and morphology, rates of herbage accumulation and change in animal liveweight and body condition score. During the control phase (December/92) no difference between treatments was observed in either milk volume or milk solids yield corrected for any pre-experimental differences (Tables 6.22, 6.24, 6.25, 6.26, 6.27). Despite the tendency for decreased milk volume in animals grazing late controlled swards (VFR and HSR), individual daily production of milk solids was very similar to that from EC swards due to the slightly higher content of protein, lactose and, particularly, fat in the milk being produced by the VFR and HSR groups (Table 6.23). Such a trend for enhanced milk solids content was observed again in March and April (end of the post-control phase), the time when VFR and HSR were accumulating herbage at a faster rate than EC.

The content of solids in the milk can be influenced by both the chemical composition of the diet and the nutritional status of the dairy cow (Sutton & Morant, 1989; Coulon & Remond, 1991; Buttery & Beever, 1992). During the control phase the animals grazing VFR and HSR swards received a higher allowance than those grazing EC swards (higher herbage masses and grazing area) and consumed herbage characterised by a higher content of stem material (Section 6.4.5). The stem material of grasses is generally characterised by higher levels of structural components or cell walls which are less digestible to the animals and comprise the fibre portion of the diet, commonly expressed as ADF (acid detergent fibre). The content of milk fat is very closely related to the ADF level of the diet which, in association with levels of dry matter intake, usually explain a very large proportion (90-95%) of the variation observed in concentrations of milk fat in feeding trials (Sutton & Morant, 1989). Milk fat has been demonstrated to be the constituent of the milk that is likely to give the greatest response to defined nutritional changes (Buttery & Beever, 1992). Increases in milk fat concentrations are also likely to occur when animals are in negative balance of energy and are mobilising body fat reserves from adipose tissues to maintain production (Buttery & Beever, 1992). The data suggest that this did not happen during the control phase (Tables 6.28 and 6.29).

Variations in milk fat content can be quite independent of variations in milk production and protein content (Coulon & Remond, 1991). Increases in milk protein content have been reported in feeding trials where an increment in energy supply was accompanied by an increment in protein supply provided that the energy supply was adequate to meet the animal requirements. It was also noted that the increase in dietary protein content could improve diet digestibility, and consequently its energy value (Coulon & Remond, 1991). A reduction in milk protein concentration is likely to occur when animals are in negative balance of nitrogen (Buttery & Beever, 1992). During the control phase and most of the post-control phase, the VFR and HSR swards produced more clover than EC swards and analysis of the herbage as grazed during the first period of herbage intake in December revealed a higher content of nitrogen for samples collected from HSR swards. Such an increase in nitrogen content of the herbage consumed could be related to an improvement of the digestibility of the diet, which may have resulted in the higher milk solids content, particularly fat, during March and April, when swards were all vegetative and had similar leaf:stem ratios (Tables 6.16 and 6.17). Significant increases in concentration of milk protein have been recently reported by Wilkins *et al.* (1991) in dairy cows grazing ryegrass and white clover swards when offered pastures with a high proportion of white clover (1% vs 23%).

During the post-control phase, VFR and HSR treatments showed a consistent trend for higher production of milk solids than did EC, and that must have been a consequence of higher allowance or greater mass, which in turn reflect the higher rates of herbage accumulation and clover content of those swards at that time of the year (Section 6.3.8). Experimental groups of animals grazed equal areas of pasture daily throughout the post-control phase. Under those circumstances, treatments accumulating herbage at faster rates are believed to have provided animals with a higher allowance of good quality feed with a higher content of nitrogen. Such enhanced allowance may have caused increased herbage intake (Combellas and Hodgson, 1979; Le Du *et al.*, 1979; Bryant, 1980b; Glassey *et al.*, 1980; Le Du *et al.*, 1981) and improved the fermentative process of ruminal digestion, increasing the availability of precursors for milk solids synthesis at the mammary gland level, particularly for milk fat. However, animals in the VFR group tended to produce less milk solids than animals in the HSR group, probably a consequence of the higher amount of senescent material in those swards (Table 6.12). The pattern of change in milk solids content throughout the experimental period was consistent with the changes in milk composition which occur normally in late lactation: increases in the concentration of milk fat and protein and a decrease in lactose concentration (Grainger, 1990). Although cows in the HSR group lost some liveweight and body condition in January, changes in liveweight and body condition score were minor and not large enough to have caused any of the changes observed in milk yield and composition. Overall changes in liveweight and condition score were similar between treatments by the end of the experimental period (Tables 6.28 and 6.29).

The EC farmlet started the control period with around 710 Kg DM/ha less pasture cover than VFR and HSR farmlets (Table 6.10), which would correspond to about 28 Kg milk fat (MF) if that extra feed had been eaten by dairy cows, assuming a conversion rate of 25 Kg DM/Kg MF during early lactation (Holmes & Brookes, 1991). Over the control period the milk fat production was 67.5, 67.5, and 97.2 Kg MF/ha for EC (2.5 cows/ha), VFR (2.5 cows/ha), and HSR (3.6 cows/ha), respectively (Table 6.24). Under those circumstances, the HSR farmlet produced about 30 Kg MF/ha more than the EC farmlet, which was very similar to the 28 Kg MF/ha expected given the initial differences in feed reserve on those two farmlets. On the other hand, the same increase in milk fat production was not observed in the VFR farmlet, indicating that an intense process of senescence and decay probably occurred in the pastures subjected to that grazing management strategy.

During the post-control period both VFR and HSR swards accumulated more herbage dry matter than EC swards, 1510 Kg DM/ha and 990 Kg DM/ha respectively, which caused an increase in milk fat yield of 10 and 22.5 Kg MF/ha (4 and 9 Kg MF/cow). These results revealed that the conversion of the extra feed to milk fat production for the VFR treatment (150 Kg DM/Kg MF) was less favourable than that for the HSR treatment (40 Kg DM/Kg MF) and very low when compared to the 40 Kg DM/Kg MF normally expected for animals in late lactation (Grainger, 1990). That may have been due to the higher accumulation of senescent material in those swards during that phase (Table 6.12). Despite its lower efficiency in comparison to HSR, the VFR farmlet would correspond to a very high risk system, since no conserved feed was harvested and it would be forced to rely heavily on purchased feed to operate.

## 6.5. Summary

1. Spring grazing management of perennial ryegrass-clover dairy pastures involving late control of the reproductive development of swards as defined by the late control treatments of this field experiment (Experiment 3) increased pasture production in spring and in the summer-autumn period, confirming the results from previous Experiments 1 and 2 (Chapter 4).

2. The increased pasture production appeared to be associated with enhanced ryegrass and clover accumulation through enhanced tillering activity and more vigorous and resilient clover plants, respectively.

3. Late control of the reproductive growth of swards in late spring-early summer (anthesis in ryegrass plants) was more rapidly and more effectively achieved by augmenting grazing pressure through a temporary increase in stocking rate associated with forage conservation, than by decreasing rotation length to 10 days.

4. Swards allowed to become reproductive suffered a reduction in nutritive value as measured by the digestibility of the herbage being consumed. This reduction in digestibility levels did not interfere with milk yield. This can be attributed to increased herbage allowance and to removal of reproductive stems while they were still green and immature.

5. Late controlled swards accumulated herbage at a faster rate than early control swards and the extra feed was effectively converted into milk by the dairy cows.

# *Chapter 7:*

## OVERALL ANALYSIS OF COMBINED EXPERIMENTS

The overall effects of spring grazing management on pasture accumulation were examined in a final analysis of the pooled data from the three experiments (Sections 4.2.4 and 6.2.3), based on contrast between the early control management (EC) and the two late control managements (LC) in each year. The overall analysis was feasible because similar experimental designs and similar pasture measurements techniques were used in all three years. The results for herbage accumulation (Kg DM/ha) were examined within pre-control, control and post-control phases, as for the individual experiments (Tables 4.15 and 6.12).

The combined analysis was based on 15 observations per treatment (from 5 replicate blocks or paddocks per year). Three of the five replicate paddocks used in Year 1 were also used in Year 2 (Section 4.3). These paddocks were discarded from the data set in order to prevent the introduction of bias to the analysis. Therefore, from the 45 possible observations per phase, only 36 were actually used in the overall analyses. Treatment effects and treatment contrasts (EC vs LC) were evaluated against the treatment x year mean square with four degrees of freedom.

In a preliminary analysis the estimates of pasture production within each of the three phases were adjusted by covariance for differences in herbage accumulation in the first month of each year. This covariate had a significant effect on the data only for the pre-control phase ($P < 0.0001$), and appeared to deal effectively with the relatively poor performance noted for treatment LHC in Year 2 (Section 4.3.3). However, it did not materially affect the assessment of treatment contrasts, and the results shown in Table 7.2 relate to uncorrected plot values drawn from Table 7.1.

Table 7.1. Summary of herbage accumulation results from Experiments 1, 2 and 3.

| Phase | Year | Treatment | | | SEM | Signif. |
|---|---|---|---|---|---|---|
| | | EC | LC1 | LC2 | | |
| pre | 1 | 3190 | 4180 | 4820 | 386 | * |
| | 2 | 2430 | 2570 | 2960 | 210 | ns |
| | 3 | 3400 | 4440 | 4030 | 317 | * |
| control | 1 | 2080 | 2240 | 2330 | 288 | ns |
| | 2 | 1430 | 1350 | 1680 | 100 | * |
| | 3 | 2020 | 2650 | 1650 | 414 | ns |
| post | 1 | 3740 | 4580 | 4330 | 678 | ns |
| | 2 | 5600 | 5670 | 6590 | 299 | * |
| | 3 | 3910 | 5420 | 4900 | 561 | + |

Table 7.2. Results from the combined experiment analysis for Experiments 1, 2, 3.

| Phase | F-test significance level | | |
|---|---|---|---|
| | Year | Year*Treatment | Treatments Contrast (EC vs LC) |
| Pre | 0.0862 | 0.3549 | 0.0265 |
| Control | 0.8432 | 0.4915 | 0.6704 |
| Post | 0.2356 | 0.8879 | 0.0276 |

There were no significant effects of either year x treatment interaction or year on pasture accumulation, but the contrast between LC and EC treatments was significant ($P < 0.05$) in both the pre-control and post-control phases (Table 7.2), with the LC treatments showing higher levels of herbage accumulation in both phases (Table 7.1).

The analysis used is conservative in the sense that it ignores any contribution to variability in LC pasture responses from variation in the details of the LC treatments within and between years. The results therefore consolidate the observations from individual studies (Sections 4.3.3 and 6.3.3), and provide a substantial degree of confidence for the overall evaluation of the effects of contrasting spring grazing managements on pasture production. These effects will be considered further in Chapter 8.

# Chapter 8:

# OVERVIEW AND CONCLUSIONS

## 8.1. Synthesis of results

The present study aimed at evaluating the theoretical potential benefits to pasture production from a less intense defoliation regime than the conventional hard grazing during the spring used to suppress the reproductive growth of perennial rygrass-white clover swards and maintain pastures in a leafy and vegetative state (Chapter 3). Such a defoliation regime was called "late control", and it allowed some early seedhead development followed by hard grazing at the time of anthesis in order to remove the reproductive stems. It was argued that late control of reproductive growth would result in increased pasture production due to an enhancement in the tillering activity of ryegrass plants, and that was associated with increased rates of herbage accumulation during the summer-autumn period (Section 2.4.2). Three field experiments were carried out during three successive grazing seasons in order to study the possibility of repeating the same pattern of increased summer-autumn growth in a dairy cow paddock scale, and the feasibility of incorporating this late control grazing management into a dairy farm context.

The first experiment in 1990/91 (Experiment 1) was designed to compare the late control grazing management with conventional intensive spring grazing, and to study the timing of execution of the late control. The results showed that pastures grazed under the late control grazing management accumulated more herbage dry matter than conventionally grazed pastures during spring and summer-autumn period, and that the increased summer-autumn herbage accumulation was mainly due to enhanced ryegrass accumulation. Measurements of grass tiller density in that year revealed that late control treatments finished the summer with a higher tiller population than the early control treatment, although this effect was not detected by the tiller demography measurements. Generally, variability in the data set was very high causing the level of significance of differences between treatments to be either marginal or not significant. Control of the reproductive growth in late November-early December (anthesis) proved to be more desirable than control two weeks later (mid December), since it resulted in a higher proportion of the extra dry matter being produced during the summer-autumn period.

The second experiment in 1991/92 (Experiment 2) provided a further comparison between the conventional and the late control spring grazing managements, but also the opportunity to further study aspects of the execution of the late control (i.e. intensity of control). Late control treatments generated increased herbage accumulation rates during spring and summer-autumn period again, but in this study the increase in production was mainly due to enhanced white clover accumulation. No difference was observed in either ryegrass tiller or white clover node populations at the end of summer, although the results indicated that ryegrass tillers and white clover plants in the late control swards were bigger than those in early control swards. The level of variability observed during this second trial was reduced due to an improved experimental design, but was still large enough to limit the number of significant differences obtained. A gradual removal of the reproductive stems over 2 or 3 grazing cycles proved to be more effective in increasing summer-autumn production than a more sudden approach which removed reproductive stems at the first control grazing.

Although differences in herbage accumulation over the summer-autumn period were not significant for individual years (seasons), they assume more authority since they were consistent across years (Chapter 7) and match the experimental hypothesis of the study. However, the pattern of species response to the late control spring grazing management was quite variable, with ryegrass production being enhanced in the first year and white clover production enhanced in the second year. In general the results showed some evidence of increased ryegrass tiller density in the first year (Experiment 1) and increased tiller size in the second year (Experiment 2), but the evidence that this caused the increase in pasture production was inconclusive. The response of white clover to the late control grazing management seemed to be the result of an interaction between its morpho-physiological characteristics and climatic requirements, particularly temperature and soil moisture (Section 4.4.5), which would explain the variable responses from year to year. However, these comments are merely speculative and further work under well controlled experimental conditions would be necessary to deal with the issue properly.

Increased herbage accumulation during spring may not be important for New Zealand farming systems since it is during spring that a feed surplus normally occurs. However, during the summer-autumn period farmers usually face a shortage of feed, which results in cows being fed less than their requirements. Under those circumstances an increase in herbage accumulation is potentially important, and could result in enhanced feeding levels and increased milk production. In both Experiments 1 and 2 the increase in summer-autumn herbage accumulation was of the order of 1000 Kg DM/ha. Assuming a conversion rate of extra feed in late lactation to milk fat production of about 40 Kg DM/Kg MF (Grainger, 1990), that would correspond to an increase of 25 Kg MF/ha. Nevertheless, when considering the implementation of this late control spring grazing management into dairying farming systems, some practical issues were raised and the need for some further investigation highlighted (Chapter 5). Thus, a third field experiment (Experiment 3) was set up to evaluate means of achieving the late control of reproductive swards at a farm level, and to study the impact of such a grazing management on dairy cow performance. Once again, the late control pastures accumulated more dry matter than conventionally grazed pastures during both the spring and the summer-autumn period. The increased herbage production in spring was a function of the reproductive development of grass plants, and presented a lower leaf:stem ratio than conventionally grazed pastures at that time of the year. As a consequence, the digestibility level of the diet of the grazing dairy cows was decreased but did not drop below the 67% reported by Hoogendoorn *et al.* (1988,1992) to reduce milk yield. In fact, the extra feed reserve on the HSR farmlet at the beginning of the control phase was effectively converted to milk fat in a ratio of about 25 Kg DM/Kg MF (Section 6.4.7). During the summer-autumn period pasture responded consistently through increased herbage production as in previous years (Experiments 1 and 2), although its composition and origin seemed to depend upon seasonal features that would determine the competitive balance between the two major plant species comprising the sward; perennial ryegrass and white clover. The herbage produced in summer-autumn was of good quality and was converted into milk by the cows. Under those circumstances, 22.5 Kg MF were obtained from an extra pasture production of 990 Kg DM/ha for the HSR treatment (Section 6.4.7), a conversion of 44 Kg DM/Kg MF, which was consistent with values reported elsewhere (Grainger, 1990; Holmes & Brookes, 1991) and confirmed the prediction of increased milk-fat production.

Control of the reproductive swards was better achieved by the grazing strategy which involved forage conservation (HSR) as a means of augmenting grazing pressure (30% of the area destined for silage making). Under those conditions, control of reproductive stems and removal of the extra pasture cover over the whole farm was more rapid and effective, causing swards to be brought back under close control in a shorter period of time.

## 8.2. Implications for farm practice in New Zealand

The potential benefits of a less intense grazing policy than the conventional hard spring grazing of perennial ryegrass-white clover dairy pastures have been demonstrated through the results obtained from the three field experiments reported. Such findings are of particular interest for increasing overall productivity of the seasonal dairying systems of New Zealand.

Late control grazing management during spring on dairy farms would basically imply a delay in the decision to exclude paddocks for forage conservation. Herbage accumulation rates normally exceed animal demand from mid-October onwards, the time of the year that farmers usually set paddocks aside for silage making. Under a late control management approach, exclusion of paddocks from the rotational sequence of grazings would be postponed for about 4 to 6 weeks (e.g. from mid October until late November) (Chapter 5). This relaxation in grazing pressure would allow swards to accumulate increased herbage mass and to become reproductive, with the average pasture cover over the whole farm increasing to levels of 500-700 Kg DM/ha above the usual average pasture cover of conventionally grazed dairy farms. Strategic use of conserved feed can also be considered an option for reducing the grazing pressure on pastures and to allow the build up of the extra pasture cover, particularly in springs of slow herbage accumulation. The extra 500-700 Kg DM/ha in average pasture cover should be removed during the control period in order to return swards to a close control by early January. This control period should start in late November-early December, or more specifically at the time of anthesis of the reproductive growth of ryegrass plants, during which paddocks would be dropped from the grazing sequence for silage making. That would provide the increase in grazing pressure necessary to remove the extra pasture cover accumulated on the farm over the spring, and bring swards back under close control. The proportion of the farm to be set aside for conservation is dependent upon the pasture growth conditions in each season and of the geographical location of each farming enterprise.

Seasons in which low rates of herbage accumulation occur during spring are likely to be unsuitable for implementing the late control grazing because, under those circumstances, feeding restrictions would have to be imposed on the cows in order to allow pasture mass to accumulate. On the other hand, in springs of extremely rapid growth, levels of average pasture cover over the farm might exceed the extra 500-700 Kg DM/ha level set as a management guideline. Under those circumstances paddocks would have to be dropped off the sequence of rotational grazing and set aside for silage before the beginning of the control phase. Furthermore, in years of rapid summer growth additional forage conservation would probably have to be carried out in order to keep control over the pastures and of the grazing pressure. Thus, the late control grazing management should be seen as one more option in a range of managements available to dairy farmers, and could be adopted if seasonal conditions are favourable.

The resulting less intensive grazing during spring is likely to favour milk production and reproductive performance of dairy cows through the consequent higher levels of herbage allowance which would result in higher intakes (Section 2.6.2). Such an increase in feeding level at that time of the year is very desirable, since animals would be at their peak of milk production and energy demand, in the phase of lactation of the highest possible efficiency in terms of utilization of feed. The enhanced milk production would continue during the summer-autumn period as a consequence of the higher rates of herbage accumulation and quality of the herbage produced following the period of late control. Furthermore, the simulation models showed that, in normal years, the conserved feed produced under late control grazing would be in excess of the total annual feed requirement, and could also be used to enhance feeding levels. In Experiment 3, conversion rates of herbage dry matter to milk fat were of about 25 Kg DM/kg MF in mid lactation and 40 Kg DM/Kg MF in late lactation, indicating that if extra feed is available it should be fed during the first half of the lactation (spring), when it would be more efficiently converted to milk fat by the dairy cows (Holmes & Brookes, 1991).

Probably the main general implication to farm practice in New Zealand would be the mental approach to the spring grazing management issue. The present study has provided evidence that, contrary to conventional views, it is not necessarily bad practice to allow some reproductive development in spring pastures. In fact, it has been demonstrated that the spring grazing management of pastures on seasonal dairy farms can be much more flexible than is generally assumed.

## 8.3. Further research

It is not clear what would be the most appropriate way of utilising the extra feed produced from pastures subjected to late control grazing management during the spring. Possible options would include enhancement of herbage intake and milk production per cow in the current lactation, maintenance of the actual levels of milk yield and lengthening of the lactation period, improvement of the body condition score of the cows, carrying pasture reserves forward to improve pasture cover on the farm at start of next calving and, finally, enhancement of milk production by delaying the culling of discarded cows. Therefore, the implementation of this alternative grazing procedure in a farm systems context is dependent upon further research to integrate all these principles and provide a knowledge base strong enough to support the decision making process in a whole farm basis.

Furthermore, an evaluation of the productivity levels is necessary under both the late control and the conventional spring grazing management, since differences are likely to exist in the total amount and the quality of the conserved feed produced because of the different timing and proportions of the farm area being set aside for conservation. That could have important implications on stocking rate and productivity levels (milk yield/ha) of farms, and should be thoroughly studied in order to determine if the agronomic benefits from a less intensive spring grazing approach (i.e. late control) would also be positive in terms of the overall farming enterprise. To accomplish that, further research would have to be based on self-contained system studies, so all the inputs and outputs of the whole operation could be accounted for and practical management guidelines developed.

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# *APPENDIX 1:*

## OUTPUTS OF LATE CONTROL SIMULATION MODELS

The outputs from the computer spreadsheets used to simulate the different grazing strategies in Chapter 5 give results for half month periods, and include the following information: average pasture cover at the start and at the end of each half month period, daily and total feed supply, daily and total feed requirement. These results can be seen in the following tables:

Table A1.1. Predicted values for feed supply and demand (Kg DM/ha/day) and average pasture cover (Kg DM/ha) for downland areas under a conventional spring grazing management situation (2.7 cows/ha)

| | Feed | No conservation | | Conservation[1] | |
|---|---|---|---|---|---|
| Month | Demand | Supply | Cover | Supply | Cover |
| Aug(2) | 27.1 | 21.0 | 2000 | 21.0 | 2000 |
| Sep(1) | 28.6 | 32.0 | 1902 | 32.0 | 1902 |
| Sep(2) | 38.7 | 32.0 | 1952 | 32.0 | 1952 |
| Oct(1) | 41.3 | 45.0 | 1851 | 45.0 | 1851 |
| Oct(2) | 39.2 | 45.0 | 1906 | 45.0 | 1906 |
| Nov(1) | 38.1 | 48.0 | 1999 | 48.0 | 1999 |
| Nov(2) | 37.6 | 48.0 | 2147 | 33.6 | 2147 |
| Dec(1) | 37.0 | 50.0 | 2303 | 35.0 | 2087 |
| Dec(2) | 35.9 | 50.0 | 2499 | 35.0 | 2058 |
| Jan(1) | 35.8 | 39.0 | 2724 | 39.0 | 2043 |
| Jan(2) | 34.8 | 39.0 | 2772 | 39.0 | 2091 |
| Feb(1) | 34.2 | 35.0 | 2839 | 35.0 | 2158 |
| Feb(2) | 32.6 | 35.0 | 2850 | 35.0 | 2169 |
| Mar(1) | 31.0 | 34.0 | 2883 | 34.0 | 2202 |
| Mar(2) | 30.7 | 34.0 | 2928 | 34.0 | 2247 |
| Apr(1) | 30.6 | 23.0 | 2981 | 23.0 | 2300 |
| Apr(2) | 29.0 | 23.0 | 2866 | 23.0 | 2185 |
| May(1) | 21.0 | 20.0 | 2777 | 20.0 | 2096 |
| May(2) | 21.4 | 20.0 | 2762 | 20.0 | 2081 |
| Jun(1) | 21.5 | 16.0 | 2740 | 16.0 | 2059 |
| Jun(2) | 21.7 | 16.0 | 2657 | 16.0 | 1976 |
| Jul(1) | 22.6 | 16.0 | 2571 | 16.0 | 1890 |
| Jul(2) | 23.6 | 16.0 | 2472 | 16.0 | 1791 |
| Aug(1) | 25.8 | 21.0 | 2350 | 21.0 | 1669 |
| Aug(2) | - | - | 2278 | - | 1597 |
| Total | 11247 | 11525 | - | 10844 | - |
| Silage | - | 0 | - | 681 | - |

1) 30% of the area shut from late November to late December

Table A1.2. Predicted values for feed supply and demand (Kg DM/ha/day) and average pasture cover (Kg DM/ha) for downland areas under a late control spring grazing management situation (2.7 cows/ha)

| | Feed | No conservation | | Conservation[1] | |
|---|---|---|---|---|---|
| Month | Demand | Supply | Cover | Supply | Cover |
| Aug(2) | 27.1 | 21.0 | 2000 | 21.0 | 2000 |
| Sep(1) | 28.6 | 32.0 | 1902 | 32.0 | 1902 |
| Sep(2) | 38.7 | 32.0 | 1952 | 32.0 | 1952 |
| Oct(1) | 41.3 | 45.0 | 1851 | 45.0 | 1851 |
| Oct(2) | 39.2 | 45.0 | 1906 | 45.0 | 1906 |
| Nov(1) | 38.1 | 57.6 | 1999 | 57.6 | 1999 |
| Nov(2) | 37.6 | 57.6 | 2291 | 57.6 | 2291 |
| Dec(1) | 37.0 | 45.0 | 2591 | 18.0 | 2591 |
| Dec(2) | 35.9 | 45.0 | 2712 | 18.0 | 2307 |
| Jan(1) | 35.8 | 39.0 | 2857 | 39.0 | 2020 |
| Jan(2) | 34.8 | 39.0 | 2905 | 39.0 | 2068 |
| Feb(1) | 34.2 | 43.7 | 2972 | 43.7 | 2135 |
| Feb(2) | 32.6 | 43.7 | 3105 | 43.7 | 2268 |
| Mar(1) | 31.0 | 42.5 | 3260 | 42.5 | 2423 |
| Mar(2) | 30.7 | 42.5 | 3432 | 42.5 | 2595 |
| Apr(1) | 30.6 | 28.7 | 3621 | 28.7 | 2784 |
| Apr(2) | 29.0 | 28.7 | 3592 | 28.7 | 2755 |
| May(1) | 21.0 | 20.0 | 3588 | 20.0 | 2751 |
| May(2) | 21.4 | 20.0 | 3573 | 20.0 | 2736 |
| Jun(1) | 21.5 | 16.0 | 3554 | 16.0 | 2714 |
| Jun(2) | 21.7 | 16.0 | 3468 | 16.0 | 2631 |
| Jul(1) | 22.6 | 16.0 | 3382 | 16.0 | 2545 |
| Jul(2) | 23.6 | 16.0 | 3283 | 16.0 | 2446 |
| Aug(1) | 25.8 | 21.0 | 3161 | 21.0 | 2324 |
| Aug(2) | - | - | 3089 | - | 2252 |
| Total | 11247 | 12336 | - | 11499 | - |
| Silage | - | 0 | - | 837 | - |

1) 60% of the area shut during December

Table A1.3. Predicted values for feed supply and demand (Kg DM/ha/day) and average pasture cover (Kg DM/ha) for the experimental site under a conventional spring grazing management situation (2.5 cows/ha)

| | Feed | No conservation | | Conservation[1] | |
|---|---|---|---|---|---|
| Month | Demand | Supply | Cover | Supply | Cover |
| Aug(2) | 25.1 | 27.1 | 2000 | 27.1 | 2000 |
| Sep(1) | 26.5 | 40.1 | 2032 | 40.1 | 2032 |
| Sep(2) | 35.9 | 40.1 | 2235 | 40.1 | 2235 |
| Oct(1) | 38.3 | 49.9 | 2299 | 34.8 | 2299 |
| Oct(2) | 36.3 | 49.9 | 2473 | 34.8 | 2247 |
| Nov(1) | 35.3 | 45.2 | 2691 | 31.6 | 2222 |
| Nov(2) | 34.8 | 45.2 | 2839 | 31.6 | 2167 |
| Dec(1) | 34.2 | 35.5 | 2995 | 35.5 | 2119 |
| Dec(2) | 33.3 | 35.5 | 3015 | 35.5 | 2138 |
| Jan(1) | 33.2 | 23.4 | 3050 | 23.4 | 2174 |
| Jan(2) | 32.2 | 23.4 | 2904 | 23.4 | 2028 |
| Feb(1) | 31.7 | 23.4 | 2762 | 23.4 | 1886 |
| Feb(2) | 30.2 | 23.4 | 2647 | 23.4 | 1771 |
| Mar(1) | 28.7 | 21.0 | 2551 | 21.0 | 1675 |
| Mar(2) | 28.4 | 21.0 | 2436 | 21.0 | 1560 |
| Apr(1) | 28.4 | 22.1 | 2317 | 22.1 | 1441 |
| Apr(2) | 26.8 | 22.1 | 2223 | 22.1 | 1347 |
| May(1) | 19.4 | 28.1 | 2152 | 28.1 | 1276 |
| May(2) | 19.8 | 28.1 | 2282 | 28.1 | 1406 |
| Jun(1) | 19.9 | 22.1 | 2415 | 22.1 | 1539 |
| Jun(2) | 20.1 | 22.1 | 2447 | 22.1 | 1571 |
| Jul(1) | 20.9 | 16.8 | 2477 | 16.8 | 1601 |
| Jul(2) | 21.9 | 16.8 | 2415 | 16.8 | 1539 |
| Aug(1) | 23.9 | 27.1 | 2334 | 27.1 | 1458 |
| Aug(2) | - | - | 2382 | - | 1506 |
| Total | 10414 | 10796 | - | 9920 | - |
| Silage | - | 0 | - | 876 | - |

1) 30% of the area shut from early October to late November

Table A1.4. Predicted values for feed supply and demand (Kg DM/ha/day) and average pasture cover (Kg DM/ha) for the experimental site under a late control spring grazing management situation (2.5 cows/ha)

| | Feed | No conservation | | Conservation[1] | |
|---|---|---|---|---|---|
| Month | Demand | Supply | Cover | Supply | Cover |
| Aug(2) | 25.3 | 27.1 | 2000 | 27.1 | 2000 |
| Sep(1) | 26.5 | 40.1 | 2032 | 40.1 | 2032 |
| Sep(2) | 35.8 | 40.1 | 2235 | 40.1 | 2235 |
| Oct(1) | 38.3 | 49.9 | 2299 | 49.9 | 2299 |
| Oct(2) | 36.3 | 49.9 | 2473 | 34.9 | 2473 |
| Nov(1) | 35.3 | 54.2 | 2691 | 37.9 | 2451 |
| Nov(2) | 34.8 | 54.2 | 2974 | 37.9 | 2490 |
| Dec(1) | 34.3 | 39.0 | 3265 | 27.3 | 2536 |
| Dec(2) | 33.3 | 35.5 | 3332 | 24.8 | 2359 |
| Jan(1) | 33.3 | 23.4 | 3212 | 23.4 | 2185 |
| Jan(2) | 32.3 | 23.4 | 3065 | 23.4 | 2039 |
| Feb(1) | 31.8 | 28.1 | 2924 | 28.1 | 1897 |
| Feb(2) | 30.3 | 28.1 | 2824 | 28.1 | 1867 |
| Mar(1) | 28.8 | 25.2 | 2884 | 25.2 | 1857 |
| Mar(2) | 28.5 | 25.2 | 2846 | 25.2 | 1819 |
| Apr(1) | 28.3 | 26.5 | 2810 | 26.5 | 1784 |
| Apr(2) | 26.8 | 26.5 | 2799 | 26.5 | 1772 |
| May(1) | 19.5 | 28.1 | 2810 | 28.1 | 1784 |
| May(2) | 19.8 | 28.1 | 2941 | 28.1 | 1914 |
| Jun(1) | 20.0 | 22.1 | 3074 | 22.1 | 2047 |
| Jun(2) | 20.3 | 22.1 | 3106 | 22.1 | 2079 |
| Jul(1) | 21.0 | 16.8 | 3135 | 16.8 | 2109 |
| Jul(2) | 22.0 | 16.8 | 3074 | 16.8 | 2047 |
| Aug(1) | 23.8 | 27.1 | 2992 | 27.1 | 1966 |
| Aug(2) | - | - | 3041 | - | 2014 |
| Total | 10414 | 11455 | - | 10428 | - |
| Silage | - | 0 | - | 1027 | - |

1) 30% of the area shut from late October to late December