Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

A STUDY ON THE EFFECT OF SWARD CONDITIONS ON HERBAGE ACCUMULATION DURING WINTER AND SPRING.

A thesis presented in partial fulfilment of the requirements
for the degree of Master of Applied Science in Plant Science at
Massey University

FULTON PAUL HUGHES
1999

ABSTRACT

Recently there has been an increased trend for farmers to adopt farm systems that operate at a reduced stocking rate, with the aim to improve per hectare production through achieving higher production per cow. The emphasis of these farming systems is on improving cow intakes and production and increasing herbage accumulation through the maintenance of pasture conditions with emphasis on pasture quality and higher post grazing residuals. A key issue at the centre of such a grazing system is whether the increase in pasture accumulation will outweigh the decrease in pasture utilisation at the time of grazing, thus increasing overall efficiency. The objectives of this study were to measure the effect of herbage mass present after grazing on subsequent net herbage accumulation rate, and to explain these differences through monitoring changes in sward components, as well as discussing the practical implications of these within a dairy farming system.

Two experiments were conducted on a commercial dairy farm near Dannevirke in 1998, Experiment I over winter (June 19 – August 28) and Experiment II in spring (September 18 – October 28). The farm was situated approximately 300m A.S.L, with the soil type being a combination of an Ashhurst stony silt loam and a Dannevirke silt loam, with high soil fertility levels. Treatments involved a range of post-grazing residuals representing cow intake levels from under fed to ad-lib (900, 1200, 1500, 1800, 2100 kg DM/ha in winter and 1200, 1500 1800 2100 kg DM/ha in spring, Treatments 1-5 and 1-4 respectively). The spring experiment also involved nitrogen treatments at rates of 0, 25 and 50 kg N/ha. Heifers and dry cows were used to graze plots with grazing intensities calculated for stock to reach the targeted residuals in 24 hours (Experiment I) and 8 hours (Experiment II). Experiment I was designed as a randomised complete block design, and Experiment II as a randomised split plot design. Both experiments were replicated three times.

In both experiments a range of post-grazing residuals was achieved (870, 1140, 1394, 1635, 1917 in Experiment I, and 1098 1424, 1704, 1913 in Experiment II). Post-grazing residuals in both experiments were significantly different ($P<0.05$).

A post-grazing residual of 1394 and 1704 kg DM/ha in winter and spring respectively resulted in the greatest net herbage accumulation rates (16.3 and 81.7 kg DM/ha/day) from grazing

until a pre-grazing target level of 2600-2700 kg DM/ha was achieved. Net herbage accumulation rates measured in both experiments were higher than those used in practice on the case farm. No statistical differences existed in Experiment I. In Experiment II Treatment 3 (1704 kg DM/ha residual) was significantly ($P<0.05$) higher than the other treatments. The relationship between herbage mass and net herbage accumulation rate showed a positive trend in both experiments. The herbage mass at which pasture accumulation was optimised was greater in spring (2900 kg DM/ha) than winter (2500 kg DM/ha).

In both Experiments tiller density was greater in more intensely grazed swards, and showed a compensation effect with tiller weight. In Experiment I all treatments increased in tiller density with Treatment 1 having a significantly greater ($P<0.05$) increase than the other treatments. In Experiment II tiller density in all swards declined over the entire experiment, being greatest ($P<0.01$) in Treatment 3. Leaf extension rates had a similar trend to tiller weight in Experiment I with the laxer treatments (Treatments 3-5) having a significantly higher ($P<0.01$) extension rate than Treatments 1 and 2. Treatment 3 also had the fastest leaf appearance rate (17.1 days/leaf), although this was only statistically different to Treatment 5. Leaf appearance rates in Experiment II showed no trend, with Treatments 2 and 4 having the fastest appearance rates, and Treatment 3 the slowest. Tiller appearance rates showed some evidence of a trend (although not significant) with more intensely grazed swards tending to have a slightly faster appearance rate compared to more laxly grazed swards.

Tiller weight and leaf extension rate were significantly correlated ($P<0.05$) to net herbage accumulation in winter. In spring all sward components measured were correlated ($P<0.01$) to net herbage accumulation with leaf appearance rate being the most significant ($P<0.001$).

Botanical composition in Experiment I showed that more intensely grazed plots had a greater ($P<0.05$) proportion of leaf, lower proportion of dead material and higher clover content. In Experiment II the trend between variables and grazing level was similar but not significant. The proportion of clover and dead material in spring swards was low (averaging 9.8 and 14.9% respectively) given the herbage mass levels reached. NIR results in general reflected the changes in botanical composition.

It was concluded that there is benefit in the use of sward conditions (targets) in the planning and management of grazing systems in enhancing both pasture and animal performance.

Compensatory effects between sward components resulted in non-significant differences in herbage accumulation rates, and in practice, differences in pasture growth are likely to occur at extreme grazing residuals. Grazing management decisions are therefore more likely to be based on residual dry matter to achieve desired intakes for high per cow production, high pasture utilisation and high pasture quality, rather than to optimise pasture accumulation. It is recommended that residual herbage mass after grazing should be 1200-1300 kg DM/ha and 1500-1600 kg DM/ha in winter and spring respectively. The practical implications of these are discussed.

ACKNOWLEDGMENTS

This thesis brings to a close my study at Massey University. The past two years have been difficult yet very rewarding. Many people have assisted and encouraged me in completing this course, and I would like to acknowledge these people.

I would firstly like to thank my supervisor, Mr Parry Matthews for all his valuable time, guidance, and encouragement in all aspects of the study throughout the past year, and indeed in my two years of post graduate study at Massy University.

Thanks also to Dr Cory Matthew for his comments and technical advice in writing this thesis, and help with statistical analysis. An acknowledgment also to Professor John Hodgson who assisted with the selection and setup of appropriate detailed sward component measurements.

I would like to sincerely thank Russell and Karen Phillips. Without their cooperation in allowing me to base my experiments on their farm, their time and patience, this study would not have been possible.

A considerable amount of field and lab work was required to be completed over the experimental period. The assistance of Mr Reuben Brown and Miss Patricia Salles is very much appreciated. Their help with stock work, data gathering and lab work, which on occasions was very time consuming and laborious is gratefully acknowledged. Their patience and dedication is a credit to them.

Gratitude is also expressed to Professor Colin Holmes of the Institute of Veterinary and Biomedical Sciences for his knowledge and helpfulness.

Gratitude is expressed to Mr Peter McIvor for his interest in the study and useful comments, observations and general support and encouragement throughout most of the experimental period.

I would like to take this opportunity to thank my parents and brothers for their kind support, advice and patience over the last five years of my university career. When times got tough, they were always there, and this thesis is dedicated to them.

Finally, I would like to thank the many other people, fellow students, friends, flatmates and lecturers who have given encouragement and advice over the past two years and who have made my time at Massey an enjoyable one.

Fulton Hughes

Massey University
August 1999

Table of Contents

List of Tables

List of Figures

List of Plates

1.0 INTRODUCTION

In recent times there has been a tangent in the way of thinking by some dairy farmers and advisers. In the early 1960's it was recognised that dairy production on most farms was limited by pasture utilisation, rather than the amount of pasture grown (McMeekan 1961). Subsequently over the next 10 years stocking rate increased from 2.1 to 2.5 cow/ha between 1981 and 1991 (LIC 1997). This higher stocking rate resulted in a higher proportion of the feed grown being harvested (especially over spring), but lead to cows being underfed (Matthews 1995). However the higher stocking rate in general required that the herd calve later to ensure adequate feed (unless large amount of supplements were used), and also resulted in short lactation lengths due to cows having to be dried off progressively over the summer as pasture growth declined. Thomson & Holmes (1995) stated that the average lactation length of 230 days was 75 short of the potential 305 days. Macdonald & Penno (1998) stated that stocking rate is often cited as the cause for poor per cow production. However the reason that farmers do not achieve a long lactation and high per cow production is due entirely to the lack of pasture quality and quantity relative to stock numbers (Penno et al 1996).

Recent trends see farmers adopting systems that operate at a reduced stocking rate, with the aim to improve per hectare production through achieving higher per cow production targets. This means an increase in the strategic use of supplementary feeding to overcome shortfalls in pasture supply, and grazing management which allows high intake of high quality pasture (Cassells & Matthews 1995; Brander & Matthews 1997).

The overall emphasis of these farming systems is on improving cow intake levels and increasing pasture production through maintaining higher post grazing residuals (and hence higher pasture cover levels) throughout the year. It is proposed that these higher levels of pasture cover will allow improved net herbage production through gaining the optimum balance between leaf senescence and leaf growth (Matthew et al 1995). The common objectives of these farmers were stated by Waugh (1998), and are:

- To maintain emphasis on the efficient utilisation of pasture.
- To overcome the limitations in the underlying pasture supply.
- To develop strategies for the strategic use of supplements to improve farm production and profitability.

Research on the relationship between herbage mass and pasture growth has produced variable results, reflecting both negative (Clark et al 1994) and positive (Brougham 1957; Bluett et al 1998) relationships as well as no relationship. Thus, not surprisingly, it is difficult to draw any firm conclusion of the relationship between herbage mass and pasture growth. Yet the key to these reduced stocking rate farming systems targeting higher per cow production, is that the higher grazing residuals resulting from high pasture allowance to achieve high cow intakes will increase pasture production that will outweigh the reduction in pasture utilisation. Some farmers are budgeting on pasture growth rates increases up to 25% over the winter period through operating at lower stocking rates and higher pasture cover (Matthews pers comm). It is important that farmers have a sound knowledge of the changes occurring to their farm systems through changes in management so that efficient low cost farming can continue.

The experiments presented in this thesis were designed to provide further information on the relationship between herbage mass and pasture growth. With a number of farmers adopting a farming system aimed toward reduced stocking rate and improved per cow production, and with a positive relationship between mass and growth being a key variable in terms of the success of these systems, this research is pertinent to the continued success of efficient dairy production.

This study has been designed to test the hypothesis that higher post-grazing levels (and hence higher pasture cover levels) will result in a positive effect on pasture growth rates over winter and early spring. The objectives of this study are therefore:

- To study the effect of herbage mass present after grazing on subsequent net pasture accumulation rate.

- To take detailed sward measurements to explain the effect of post-grazing herbage mass on pasture accumulation rate.

- To discuss the implications of these results to the management of dairy grazing systems.

2.0 REVIEW OF LITERATURE

2.1 Introduction

Economic and environmental factors mean that animal production in New Zealand is largely based on pasture. One of the main limitations to animal production is therefore the production and seasonally of pasture production.

The grazing of dairy stock involves a range of interrelated aspects. Agronomically it involves the growth, defoliation and regrowth of pastures, and how this is affected by the grazing cow, and the grazing strategies used (Matthews 1971).

This review will cover the growth, defoliation and regrowth of pastures. Initially key physiological and morphological aspects will be covered to determine growth potential of pasture plants. This will then extend to more general aspects of pasture production and tissue turnover. With the emphasis of this study being on the relationship between herbage mass and pasture growth, key studies that have covered this will be reviewed and a conclusion of current findings made. Finally a wider approach will be taken investigating system trials where the relationship between herbage mass, pasture growth, cow intake, and milk production is examined, and how such relationships influence management decisions such as rotation length and target sward conditions suitable for the optimum pasture and animal performance.

2.2 Plant Physiology

2.2.1 Overview

It can be taken for granted that if we graze pastures with stock or cut using mechanical equipment that it will regrow to be grazed again at a later date. However plant growth involves both complex physiological and morphological aspects. These, along with environmental conditions, determine plant growth potential and plant responses to defoliation.

Research, in an attempt to be more accurate and quantitative has looked to take a reductionist approach to help with the understanding of plant growth (Wilson 1992).

The growth and productivity of both individual plants and plant communities as a whole can be combined into three areas, being interception, conversion and partitioning. The interaction of both physiological and morphological processes between these three areas combine to determine the productivity of plant communities (Figure 2.1).

The interception of light can be seen as the starting point of growth and is determined by plant morphological characteristics (Kemp, pers comm). The interception of light then determines physiological processes, namely the conversion of the intercepted light into carbohydrates through photosynthesis, and the partitioning of this carbohydrate supply into the morphological units of the plant such as the roots, leaves and stem. These will in turn determine the growth of each component and affect the interception of light. This then highlights the interrelationship between both physiological and morphological aspects of plant growth and also highlights the inherent difficulty and advantage in focusing on only one of the two aspects of plant growth. By concentrating on only one we can better understand the mechanisms that are contributing to plant growth (a more reductionist view), however when we apply these to a field situation the contribution of both aspects means that it becomes more difficult to follow due to the interrelationships that occur. The processes will also be modified by the grazing management decisions made.

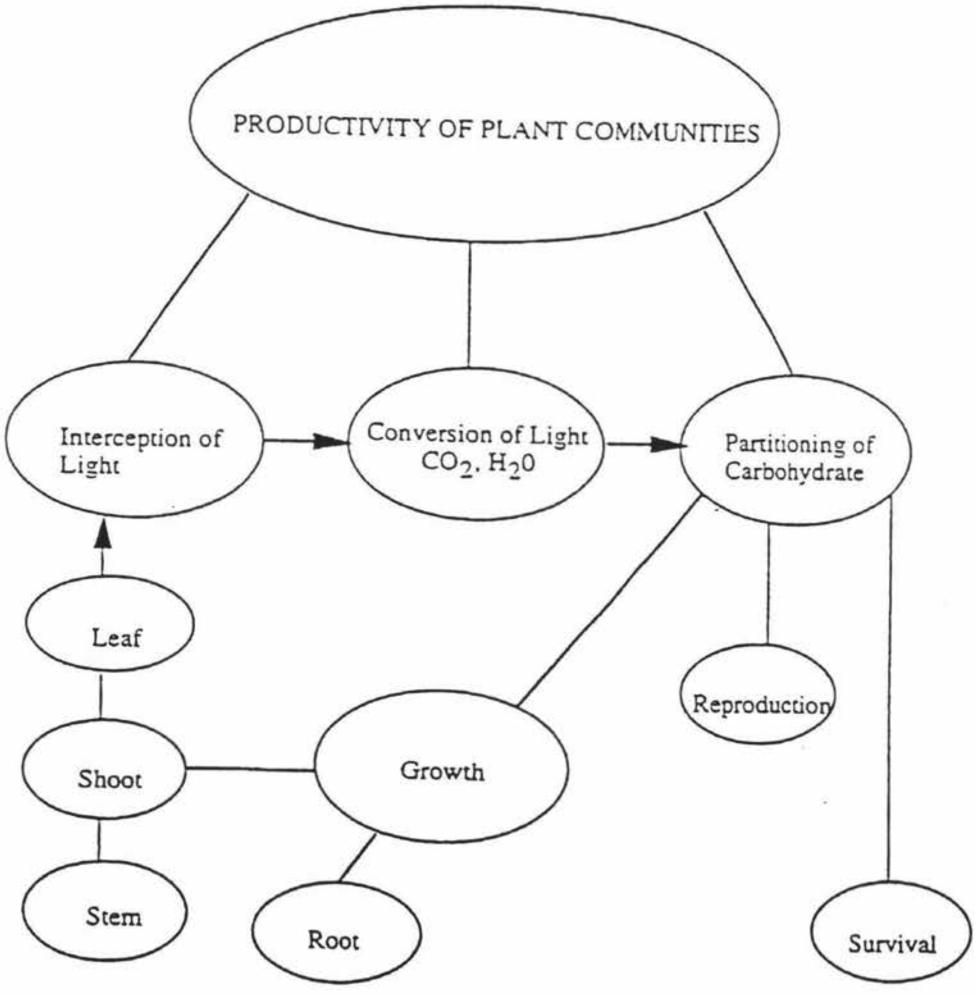


Figure 2.1 The determinants of plant growth.

Plant physiology is concerned with understanding the processes that determine plant yield (Wilson 1992), rather than the final result, (i.e. final dry matter yield). It was stated that there is little to be gained in recording only the end results of experimental variables, by understanding the changes within plants to discover why the final yield result occurred, limitations in plant yield can be recorded and actions taken to overcome this in an effort to increase yield (Richards 1993).

2.2.2 Photosynthesis

Simply put, plant growth is the addition of new tissue and an increase in biomass. This increase in biomass depends on the process of photosynthesis; a process by which sunlight is intercepted by leaves and provides the energy for the plant to convert carbon dioxide (CO_2) into water and carbohydrates (Robson et al 1989). While the uptake of nutrients by plant roots is also important, photosynthate production is the over riding control process, and the primary limitation to biological production.

Perhaps one of the most important physiological factors determining plant growth is the rate of CO_2 assimilation per unit leaf area. This parameter is a measure of the efficiency of the plant to produce carbohydrates for dry matter production. The ability of the leaf area of the plant to convert the intercepted light into stored carbon has long been seen as an important plant physiology process. However, Korner (1991) stated and showed that while this is obviously important, there are many other factors which influence growth, and which may be of equal or even greater importance than the rate of CO_2 assimilation per unit leaf area (Table 2.1). An example was highlighted by Heide et al (1985); who showed that the manipulation of day length could increase relative growth rate by 40% despite a decline in the rate of photosynthesis per unit leaf area. These other important determinants of plant growth are relatively simple to measure, while photosynthetic activity is more complex and sophisticated (Table 2.1).

Figure 2.2 shows the four key variables affecting the conversion of intercepted light into carbohydrate (or more correctly the net assimilation of carbon available for plant growth). It is generally considered that photosynthetic rate is one of the more important variables affecting this conversion rate, as this is effectively the input of carbon into the system. Respiration rate and carbon losses through volatilisation and to a lesser extent exudation are both losses from the system, and canopy conductance is a factor inhibiting the interception of light and thus the increase of carbon in the system. The balance of these results in the net assimilation rate (NAR) which gives an indication of how much growth is being generated per unit area of leaf (Lambers & Poorter 1992).

The photosynthetic rate of leaves is largely dependent on the leaf nitrogen concentration, as photosynthetic capacity decreases with decreasing nitrogen concentration in the leaf (Evans 1989). Slow growing species have a lower photosynthetic nitrogen use efficiency (PNUE) compared to faster growing species, as they partition more nitrogen into non photosynthetic components compared to faster growing species (Lambers & Poorter 1992). Faster growing species also have higher maximum rates of photosynthesis per unit leaf area (Poorter et al 1990).

Respiration is a key factor in determining NAR and thus relative growth rate (RGR), it provides the major driving force for the major energy requiring processes of growth and maintenance (Lambers & Poorter 1992). Studies have shown that faster growing species have a higher rate of photosynthesis per unit leaf dry weight, and a higher relative growth rate (RGR) (Poorter et al 1990; Dijkstra & Lambers 1989), and as a result of having a higher output they also have greater respiration rates per unit leaf weight. Although compared to the total amount of carbon produced per day they use less in respiration compared to slower growing species.

Table 2.1 Plant factors that can influence plant growth.

Metabolic factors
Leaf photosynthesis
Dark respiration of various plant compartments
Developmental factors
Cell division and cell differentiation
Position of active meristems (morphogenetic constraints)*
Ontogenetic status (e.g. leaf plastochron)*
Allometric factors
Leaf weight (and area) ratio*
Plant dry mass compartmentalization*
Specific leaf area*
Maximum plant height (mechanical constraints)*
Plasticity of sink size
Biomass losses
Fine root turnover*
Above-ground mortality*
Allocation of carbon to symbionts and exudation
Time factors
Leaf duration*
Duration of vegetative plant activity*
Total plant life-span*

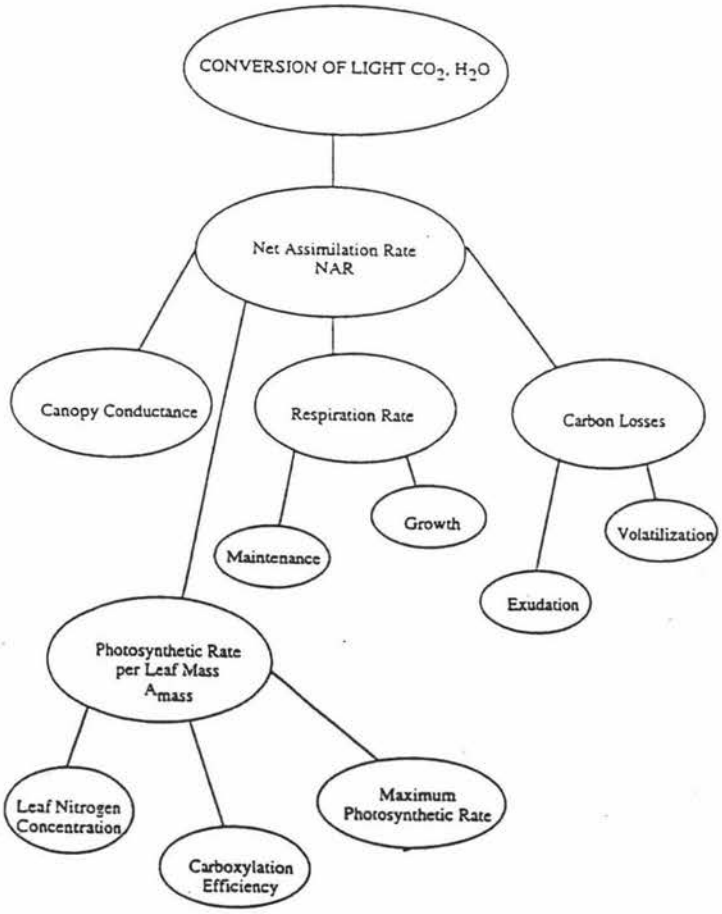


Figure 2.2 Factors affecting the conversion of light into carbon.

Figure 2.3 shows the factors influencing the partitioning of the carbohydrate in plants. Obviously not all the available carbon is used for new growth, some is stored for defence purposes and to aid in recovery from defoliation, and some is used for reproduction when this is of relevance. Carbohydrate allocation can be measured in terms of leaf, stem and root weight (Richards 1993).

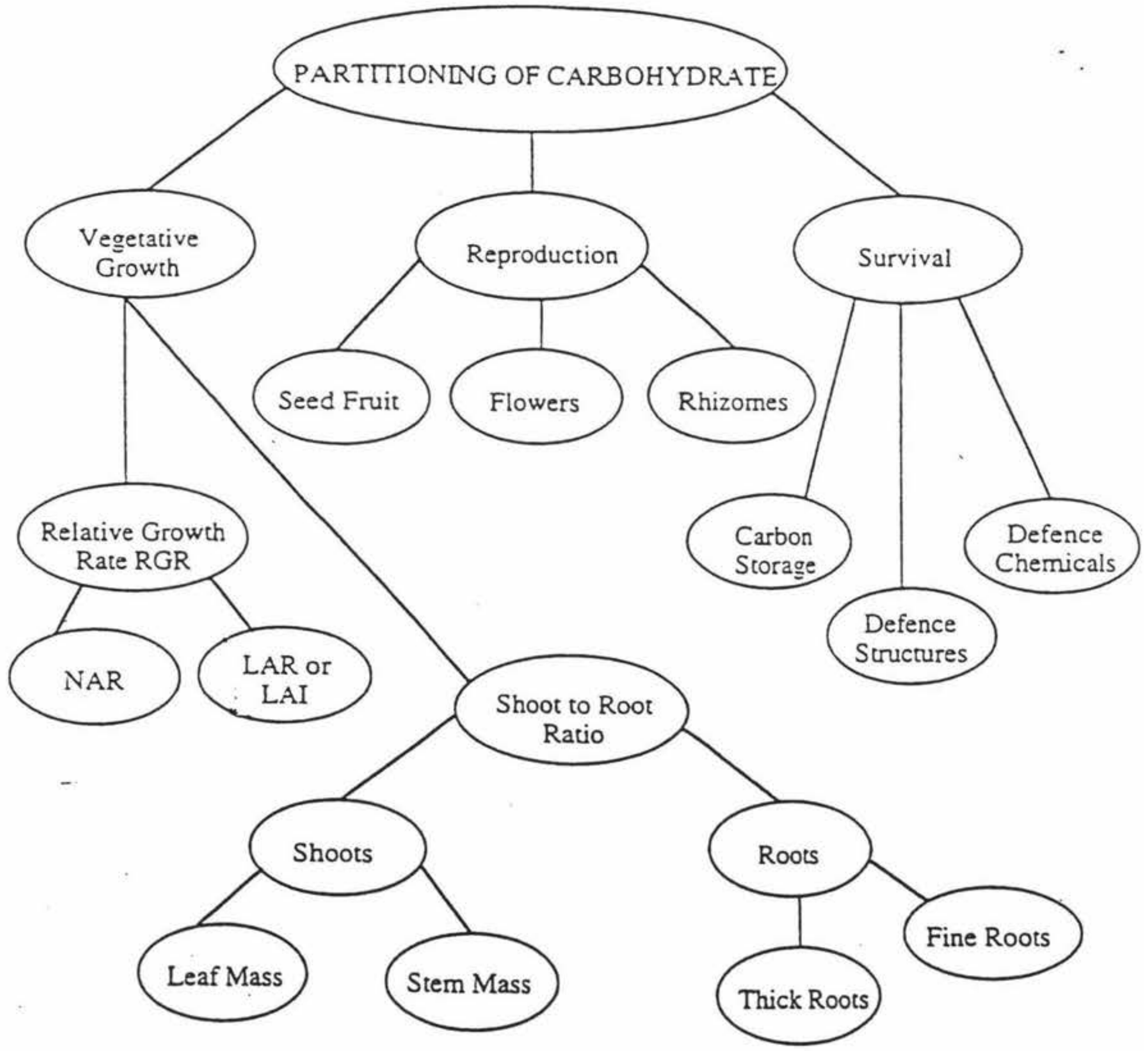


Figure 2.3 Factors affecting the partitioning of carbon within plants.

The majority of carbohydrate is directed towards biomass production, and as shown in the Figure 2.3 NAR and the leaf area ratio (LAR) are the key variables directly influencing RGR. The root to shoot ratio gives an indication of the partitioning between above and below ground components. Thus partitioning will have a large effect on morphological components and their effects on plant growth. Some studies have shown that the level of gibberellins and abscisic acid are factors influencing the root to shoot ratio in plants (Rood et al 1990: Saab et al 1990).

Faster growing species produce more leaf area than slow growing species (Lambers & Poorter 1992), and this is the main reason why faster growing species have a higher RGR. Another reason why faster growing species have a higher RGR is due to the fact that these species allocate less carbohydrate to root mass compared to slower growing species at a optimum supply of nutrient. Although they are able to adjust their carbohydrate allocation when required (e.g. a low availability of nitrogen and phosphorous enhances carbohydrate allocation to roots (Grime et al 1989). Any investment in biomass other than leaf area reduces RGR of plants (Lambers & Poorter).

The amount and type of tissue removed, and when the loss occurs in relation to plant development and the prevailing environment, are important in determining the impact of defoliation on plants (Richards 1993). The age and type of tissue removed also influence how quickly a plant can recover. The youngest leaves have a greater photosynthetic potential than older leaves (Woledge 1979, Gold & Caldwell 1989). Richards & Caldwell (1985) also showed that the loss of meristematic tissue often has a greater effect than the proportional loss of biomass, leaf area or plant resources.

2.3 Plant Morphology

The morphological aspects affecting plant growth are largely to do with the interception of light or carbohydrate production. This implies that plant leaves are the key to maximising light interception and improving plant growth. Factors such as the number, arrangement and life span of leaves will be of relevance. Figure 2.4 shows the two main aspects influencing light interception. Firstly it is the quantity of leaf area present, and secondly it is how the leaves that are present are arranged, so that at a given leaf area index (LAI) the arrangement of leaves will determine the quantity of intercepted light and vice-versa. The LAI is similar to the LAR and is simply another way to reflect the size of the photosynthetic surface. The LAI is a measure of the photosynthetically active tissue in a sward (Robson & Sheehy 1981). Leaf sheaths and clover stolons are also photosynthetically active but contribute very little (<5%) to the gross photosynthesis of the sward (Parsons et al 1983a, b; Korte & Parsons 1984). The leaf mass of a plant will be determined by the amount of carbohydrate partitioned into leaf growth. Korner (1991) stated that it is the location of meristems and their specific activity, and thus the rate of cell production which determines plant morphology and growth rate. The importance of cell production is perhaps underestimated, while carbon allocation to leaf growth may be large, any limitations in cell differentiation and maturation through stress will limit plant growth through reduced leaf area and hence light interception. The specific leaf area (SLA) is another factor influencing LAI, this is largely a function of leaf thickness and mechanical tissue, and is very variable within species (Chiariello et al 1991). Leaf lifespan is more species specific and less variable within species compared to SLA (Chapman & Lemaire 1993). The longer lifespan of leaves will mean that (assuming everything else remains the same) the LAI of plants will remain at the optimum level for longer. Obviously this is determined by many factors, and in terms of pasture plants the influence of grazing animals will have the greatest impact. Defence structures and chemicals, of plants (see Figure 2.3) will thus have an effect of leaf lifespan, and again it can see that the physiological aspect of carbon partitioning will influence the presence of defence structures and chemicals and so have an effect on the morphological factors of leaf lifespan and LAI, which affects the interception of light for carbon production. Again highlighting the interrelationship of physiological and morphological aspects that affect plant growth.

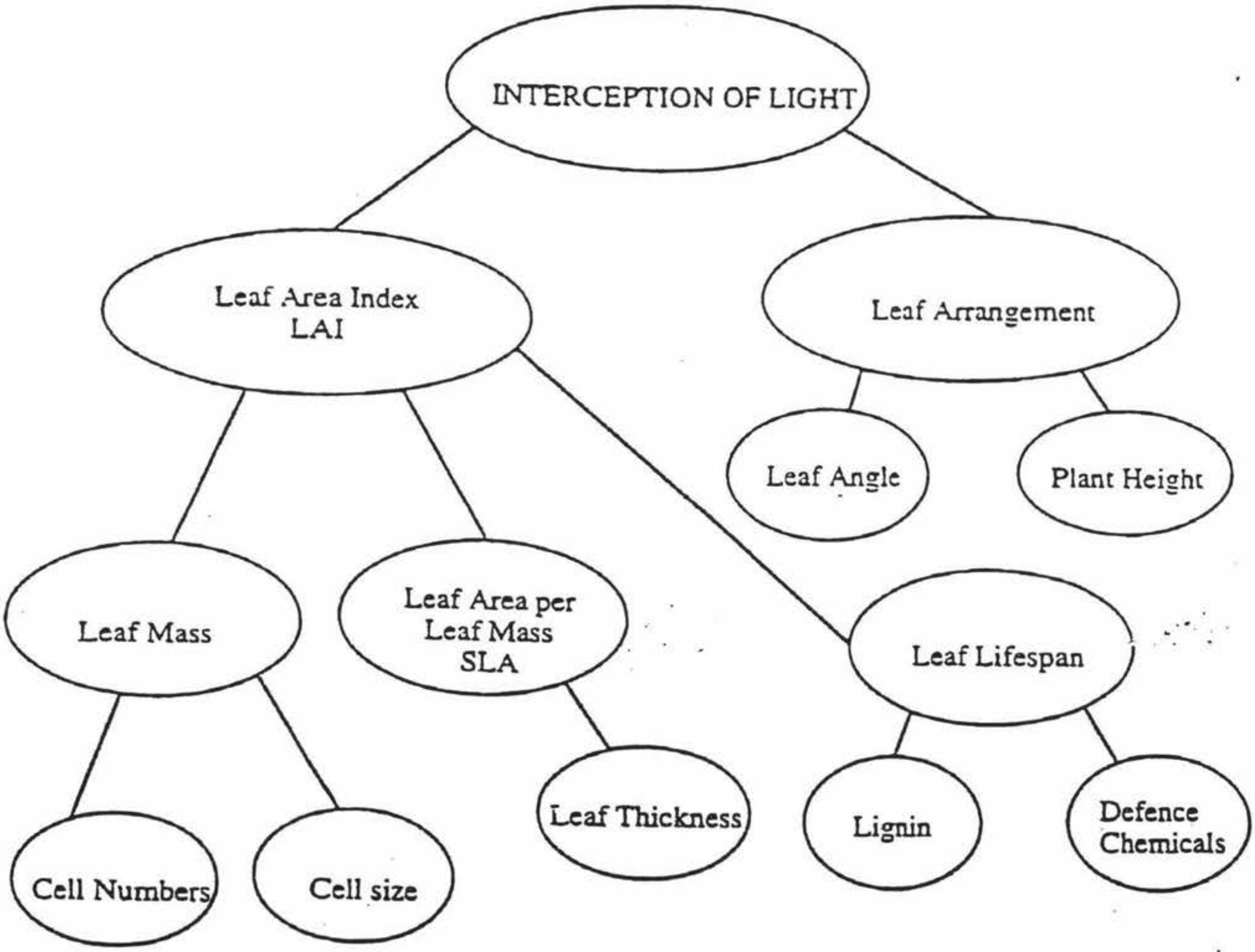


Figure 2.4 Factors affecting the interception of light.

Leaf arrangement deals with leaf angle and plant height. These two factors will determine the amount of light each leaf receives and thus will have an effect on the efficiency of photosynthate production per unit leaf mass (Butler 1986).

Leaf growth per tiller is dependent on the rates of leaf appearance and extension. These usually increase in spring to peak in summer and decline in autumn to a low in winter (Chapman et al 1983), due to their dependence on temperature and water status (Thomas & Norris 1981; Norris 1985; Leafe et al 1977). Grant et al (1981) showed that the effects of defoliation on leaf appearance were largely determined by the interaction of defoliation on leaf extension rates and the length of sheath tube through which the emerging leaf grows. Higher leaf extension rates are found with larger, older tillers (Chapman et al 1983; Agyre & Watkin 1967) with greater lamina area, and therefore less severe defoliation increases leaf extension rates (Wilman & Shrestha 1985). Studies have shown that leaf appearance and leaf extension rates are greater in reproductive swards compared to vegetative tillers (Vine 1983).

Tiller density has been used as an agronomic indicator of swards for many years. However the link between tiller density and pasture production has only recently been fully understood. Tiller populations do not remain constant, they vary with grazing management and environmental conditions. However there is now a basis for determining what tiller population should be present at a particular pasture cover.

An inverse relationship between tiller density and tiller size has been recognised for many years, and analysis of this produced the self-thinning line (-3/2 rule) of plant ecology (Langer 1963). This rule defines a constant leaf area, as pasture cover decreases and tiller size becomes smaller, more of these smaller tillers can fit into a defined area, thus tiller density increases (Table 2.2). However Figure 2.5 shows that at lower pasture cover levels tiller density is unable to compensate for the loss of tiller size, that is instead of following the solid -3/2 line it follows the dotted line, and a loss in productivity occurs. The reason that this occurs is because the increase in tiller density is less than that required to maintain the sward leaf area at the previous LAI (Matthew et al 1996), and this can be related to a loss of 'energy' through herbivores. The actual pasture mass where the LAI falls away from the compensation (-3/2) line is not well defined as it is likely to alter due to environmental and genetic effects. However Matthew et al (1996) stated that it is somewhere in the range of just over 2000-2500 kg DM/ha in winter to near 5000-5500 kg DM/ha in late spring. Herbage accumulation rate should increase with increasing herbage mass until a sward reaches this point.

Because of this relationship herbage growth is insensitive to tiller density over a wide range of herbage mass (Grant et al 1983).

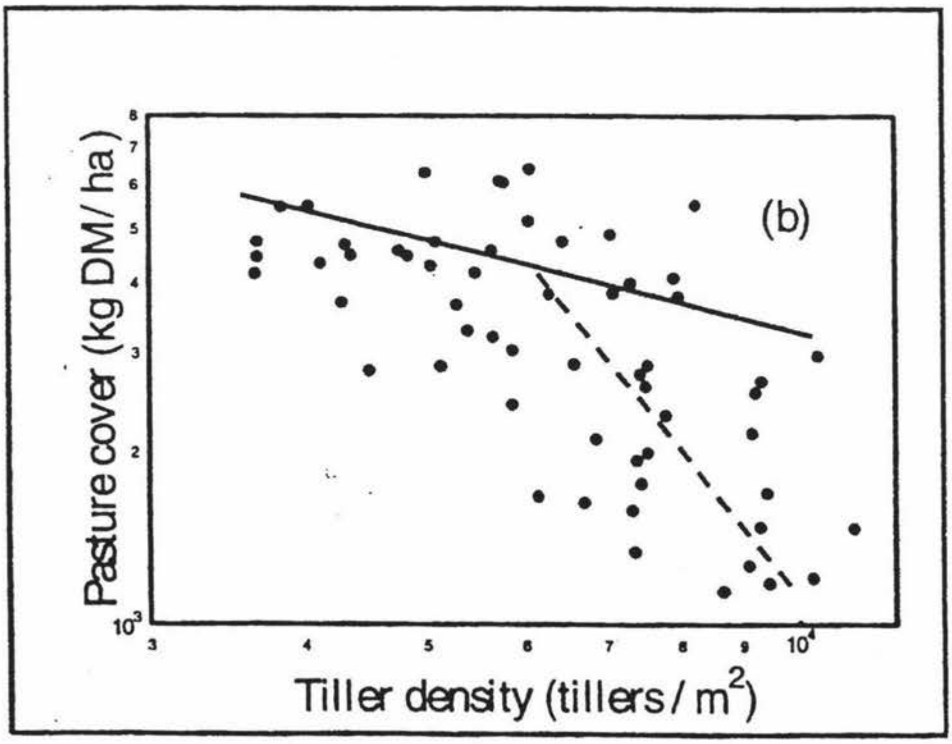


Figure 2.5 The relationship between pasture cover and tiller population density for a ryegrass sward at Palmerston North. The dotted line showing a potential loss in productivity. (Matthew et al 1996)

However in some cases, management can influence tiller density and through tiller density, herbage production. One example was the lax spring grazing of Hernandez-Garay et al (1993, Table 2.2).

Table 2.2 Tiller density (tillers/m^2) and herbage accumulation (kg DM/ha) of ryegrass/white clover swards under contrasting spring grazing management (Hernandez-Garay et al 1993).

Treatment	Oct 20	Dec 1	Jan 1	Jan 25	Jan 25	Herbage accumulation (Dec 1 – 25 Jan)[1]
H-H-H-H	4690	3830	6990	7760	5050	629
H-L-H-H	4530	3280	5840	8820	8050	1994
H-L-L-H	4770	3740	7070	12740	7758	2610

2.4 Tiller Dynamics

2.4.1 The seasonalily of tiller production

The main growth unit of pastures is the grass tiller. The life cycle of these tillers (their appearance, growth and death) effectively determines the production and persistence of grasses in the sward. Davies & Thomas (1983) stated that the potential rate of tiller appearance is determined by the leaf appearance rate. With the success of the New Zealand dairy industry depending largely on the production and utilisation of pasture, it was obvious that a better understanding of the principles and patterns of tiller production were required to highlight any possible avenues for manipulating pasture production and persistence, to allow further increases in farm production.

An experiment by Korte (1986) looked at the tillering of perennial ryegrass

[1] Herbage accumulation of grass component of sward only.

(*Lolium perenne*) swards at different times of the year. Plots were mown at two different mowing frequencies throughout the year to simulate grazing. Tiller numbers are greater over the summer due to the higher light levels (Matthew pers comm). The findings (Figure 2.6) show that the tiller population was greatest directly after reproductive tillers were cut in November (as indicated by the arrows, and is more noticeable in the second year of the two-year experiment). The cause for this increase in population is due to the large increase in tiller appearance rate (Figure 2.6). Tiller death rate is also highest during this same period (Figure 2.7). Approximately 75% of all tillers in the sward die and are replaced over December/January (Matthew et al 1995). The increase in tiller population seen over July, August and September in 1978 was a result of the low tiller death in relation to tiller appearance. Although tiller appearance rate is very high after reproductive tillers are cut or grazed in November/December, it is matched by the high death rate, as a result there is little net change. Other studies (L'Huillier 1987a, Matthew 1988) on the seasonally of tiller appearance, death and survival (with ryegrass) have produced similar results.

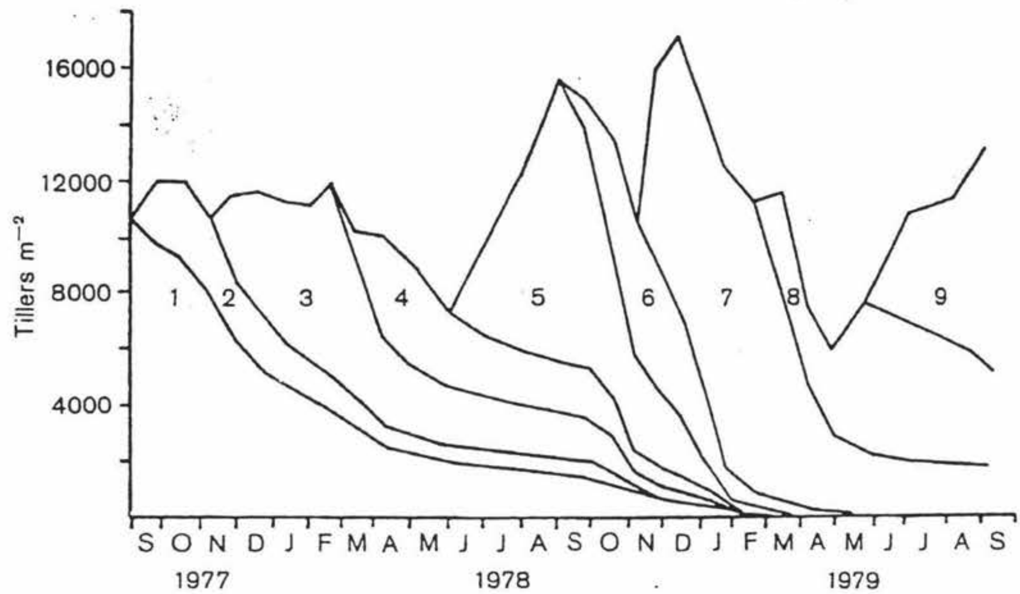


Figure 2.6 Tiller Population turnover in a Nui ryegrass sward at Palmerston North (Korte 1986).

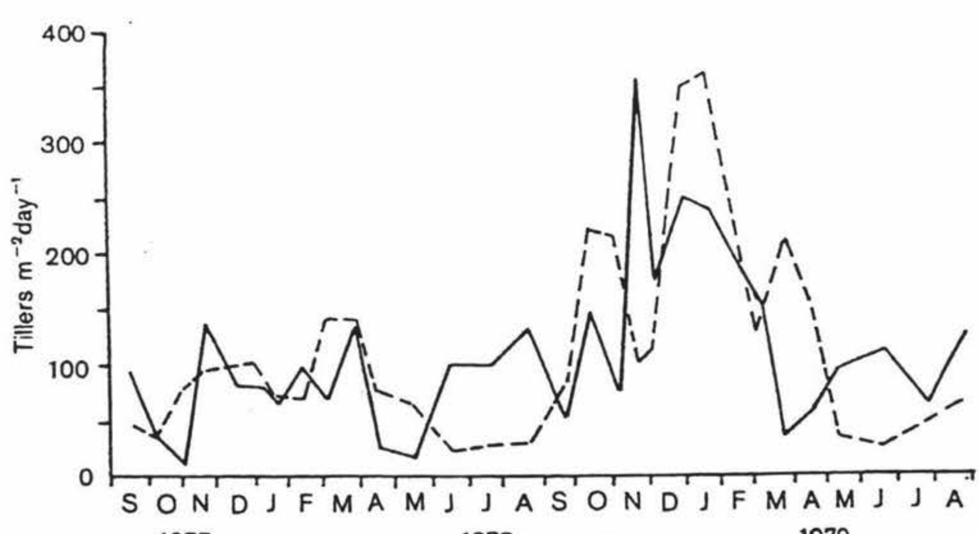


Figure 2.7 Tiller appearance and death rates for a ryegrass sward (Korte 1986).

The high turnover rate in this short period of time would suggest a potential for increasing tiller density in the following period (summer) through optimising tiller appearance rate while minimising death rate, or conversely highlight a period of vulnerability in terms of the stability of the tiller population. It is perhaps more likely that any increase in tiller density will come about through increasing tiller appearance rates. The conflict which may arise though, would be whether conditions which allowed an increase in tiller appearance, also increased tiller death rate, i.e. is there a correlation between tiller appearance and death. Can we manipulate the system so that we can achieve high tiller appearance and while keeping death low? This period of high turnover has been integrated into the late control management strategy that aims to exploit this high tiller appearance rate (Matthew 1991; Matthew et al 1995 - Table 2.2)

Tiller appearance and growth are largely determined by environmental conditions, whereas tiller death is determined by grazing management (L'Huillier 1987a). L'Huillier (1987b) showed that a higher stocking rate over spring increased tiller density in summer (Table 2.3). It was suggested that a high stocking rate or a grazing regime which provided a relatively short rotation length (over this time of high tillering) would minimise tiller death through greater light availability and so would result in a greater tiller density over summer and into the autumn giving higher pasture production (L'Huillier 1987b; Matthew 1991).

Table 2.3 Effects of stocking rate on ryegrass tiller density (000/m^2) (L'Huillier 1987b).

	Stocking rate (cows/ha)	
	2.8	4.3
Spring	5.2	4.8
Summer	3.2	5.0
Autumn	4.7	5.5
Winter	5.0	6.1

2.4.2 Tiller survival

The high turnover rate in December/January is illustrated in Figure 2.6. It can be seen that the tillers in age category 1-5 are just about all dead, heading into summer. The tillers formed over the December to January period, after reproductive tillers have been removed, persisted longer than tillers formed in early spring (this is more noticeable in the second year of the experiment). It would seem pointless to try to encourage tillers that will not last through to summer and autumn. Tallowin (1981) showed that differences in grazing management can affect the percentage of early spring tillers surviving and thus give a wider range of tiller age profiles in the following summer.

It was noted that tillers produced over the winter were important in providing vegetative tillers for rapid growth and tillering after reproductive growth in early summer (Korte 1986). It was also found that tillers formed before winter, including those that survived through the reproductive period in the previous year, were the main contributors to reproductive growth in the following year. This is therefore an important issue in terms of the persistence and productivity of the sward. If the number of new tillers produced during December/January can be maximised and if these can survive through the following summer, into the winter, then there will be more reproductive tillers from which potential new tillers can be formed further improving pasture production in summer and persistence. However the experiment highlighted the fact that pasture swards are made up of short-lived tillers of varying ages. Changes in tiller appearance and death results in changes in tiller density over the year. The logical question resulting from this work is what caused the increased levels of tiller appearance after the seedheads had been removed? And is there any opportunity to take advantage of this within a farming system?

While the efficiency of photosynthesis per unit area has been seen as one of the important factors determining plant growth, many see morphological aspects as being of even more importance. An example by Korner (1991) using data from Korner & Pelaez Menendez-Riedli (1989) highlights this point (Figure 2.8), as a range of plant species grown in the same conditions and CO_2 responses was studied. Two species, one small with a high CO_2 efficiency and a tall species with a low CO_2 efficiency were selected and compared. The efficient dwarf species would be worse off as despite it being more efficient, the taller species would shade the smaller species reducing its competitive physiological advantage. In this actual study, it was found that the species with the least photosynthetically efficient leaves (at the right end of Figure 2.8) would actually be the more dominant plant. This is because the leaves on the plant develop in early spring before competition for light between other plants occurs. From these results it was concluded that under such conditions, timing of leaf emergence, leaf growth and size might be stronger determinants of potential growth than the capacity of leaves to fix carbon. It was suggested that the study of plant communities may provide valuable and important information which laboratory experiments with isolated plants cannot provide.

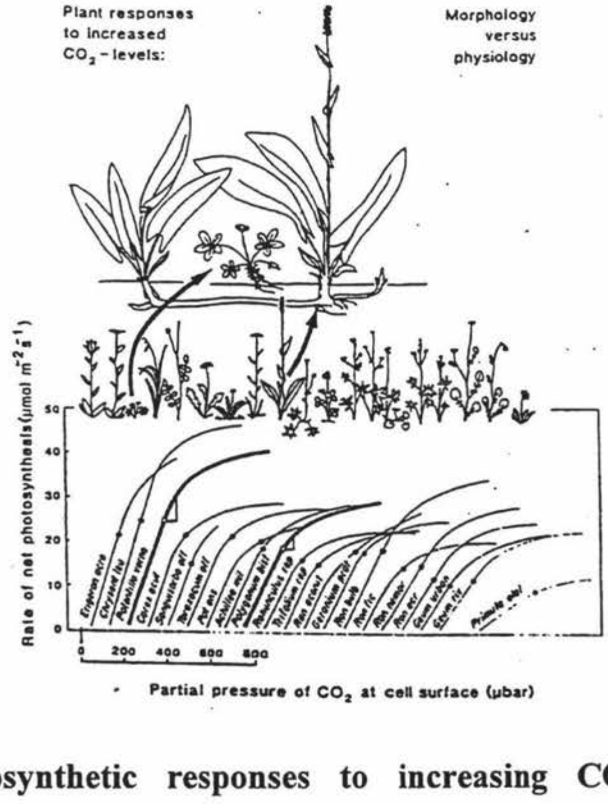


Figure 2.8 Photosynthetic responses to increasing CO_2 supply under competitive situations.

2.5 The Effects of Defoliation

Pasture swards are commonly subjected to defoliation from grazing animals. The recovery of plants from defoliation again involves both physiological and morphological aspects. However in contrast to plant growth potential, the two are not interrelated very much, moreover they are in a more sequential pattern. Physiological responses are generally defined as occurring over short time scales (a few days), whereas morphological responses are generally considered as being longer term (Chapman & Lemaire 1993).

Pasture regrowth is determined by three variables, photosynthesis of existing leaf area, utilisation of carbohydrate reserves, and new growth through cell division and expansion from growing points that are present. The reserves of carbohydrate present after defoliation have been advocated as the main source of carbon for regrowth (Trlica & Singh 1979), however other studies have shown that in some species there is almost no mobilisation of reserves from roots to shoots after defoliation (Davidson & Milthorpe 1966).

2.5.1 Physiology of Defoliation

The immediate effects of defoliation depend on grazing intensity. The reduction in whole plant photosynthesis or daily carbon gain provides a good measure of defoliation intensity (Richards 1993).

At the time of grazing or shortly after a number of processes occur within plants. Davidson & Miltorpe (1966); Culvenor et al (1989) documented a rapid decline in carbohydrate supply of roots and remaining shoot parts during the first 48 hours after defoliation. Root growth, respiration and nutrient absorption in rapidly growing plants rely heavily on a continuing supply of carbohydrates from the shoot system. As a result these three variables are all adversely affected after defoliation.

Root elongation stops within 24 hours after 40-50% or more of the shoot system is grazed (Javis & McDuff 1989), highlighting that root growth and maintenance is very sensitive to defoliation. However Richards (1993) mentioned that root function might be buffered for 2-48 hours by continued translocation of carbohydrates from any shoot tissues remaining. The rapid decline in soluble carbohydrate concentrations of roots after defoliation is a result of reduced, but not complete cessation of, allocation from the root system and continued utilisation of these reserves by root respiration (Richards 1993). Not suprisingly nutrient absorption declines in a similar fashion as root growth as the two are interrelated. With perennial ryegrass, nitrate absorption was shown to decline within 30 minutes after 70% of root dry mass was removed, and declined to less than 40% within two hours (Clement et al 1978).

Resource allocation of available carbohydrates in defoliated plants has a large influence on the speed of regrowth of plants. In defoliation tolerant plants such as perennial ryegrass the supply of photosynthate to roots is reduced immediately after defoliation not only because of reduced photosynthesis, but also because of a greater allocation to shoot meristematic and leaf growth regions (Ryle & Powell 1975). This highlights how important photosynthesis is to biomass production, and indicates the efforts of such plants to increase leaf area as quickly a possible though regrowth of defoliated leaves and the production of daughter tillers.

2.5.2 Morphology of Defoliation

The regrowth of a sward can be described in the terms of the appearance of new organs, their rate of expansion, and their rate of senescence and decomposition (Chapman & Lemaire 1993). Thus following on from this, it was stated that the key morphogenic characteristics of a sward regrowing are: leaf appearance rate, leaf elongation rate and leaf life span, which affect tiller appearance rate and tiller survival (Figure 2.9).

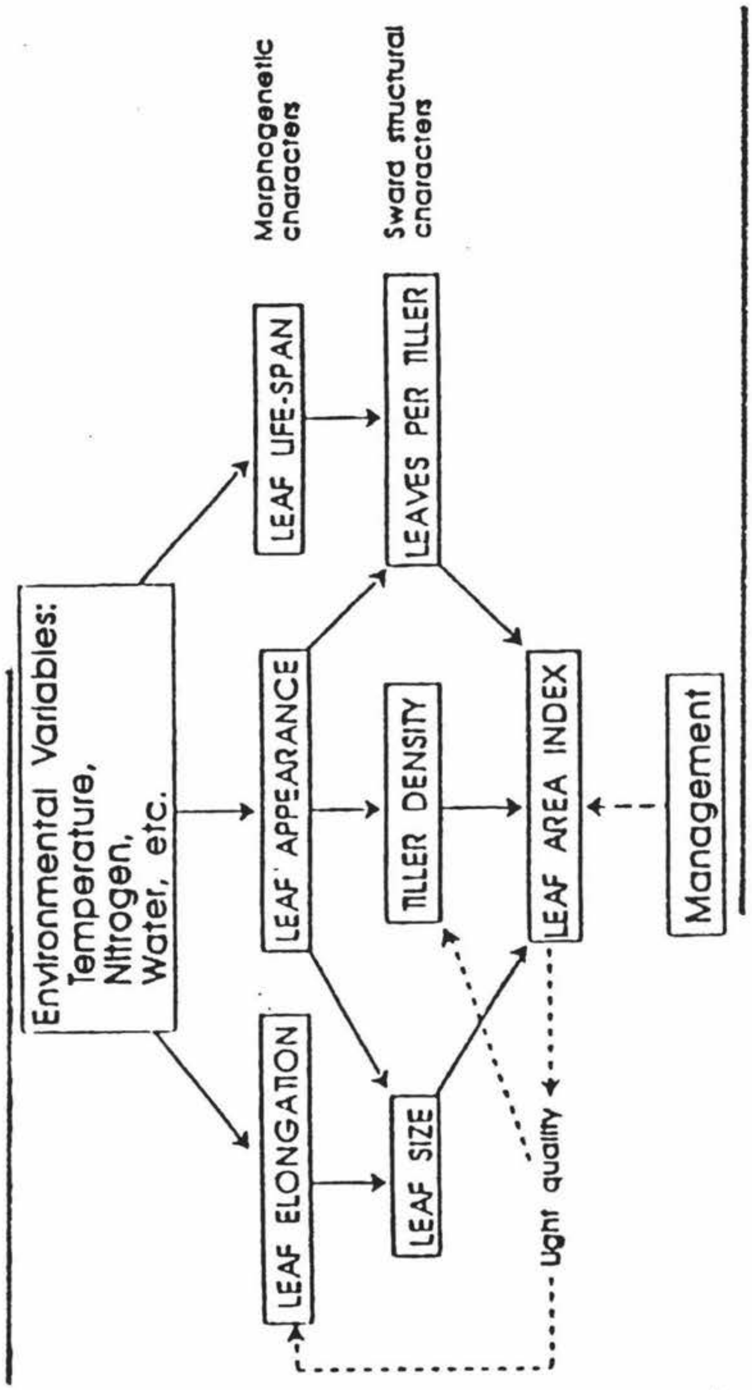


Figure 2.9 The relationship between morphogenetic and sward structural characteristics (Chapman & Lemaire 1993).

These three morphogenic variables influence three structural parameters, leaf size, tiller density, and leaves per tiller. These in turn influence one of the main determinants of pasture growth, the LAI. The LAI effects how much of the available light is intercepted. As LAI increases, pasture growth also increases. The term critical LAI is the LAI required to intercept 95% of the incident light at midday, this is also the LAI at which maximum growth rate is reached (Brougham 1959). Species differences exist in the LAI required to intercept 95% of incident light (Brougham 1956) which appear due to their growth form. The importance of meristem activity and positioning within the sward is often overlooked. In conjunction with grazing management, meristem positioning and activity are important factors determining production and persistence for individual plants and plant communities (Chapman & Lamaire 1993). In Perennial Ryegrass approximately 20-30% of new growth after defoliation is derived from new tiller growth (Kemp pers comm 1998).

2.6 Growth of Pasture

Pasture accumulation is determined by a dynamic balance between two simultaneous but opposing processes (Matthew et al 1995). Many authors have in the past stated that the quantity, seasonality and annual flow of dead herbage in the sward has often been neglected (Campbell 1964; Korte & Sheath 1978; Hay 1987). In some instances leaf senescence may exceed 50 kg DM/ha/day (Wade 1975), highlighting the fact that it requires closer consideration. Thus herbage senescence has a large influence on net herbage accumulation and is a major factor influencing the relative productivity of pasture under different grazing management strategies (Hodgson & Wade 1978).

Table 2.4 shows a set of sward variables measured under two different grazing intensities. Relatively little dead material was present in the hard grazed sward, however in the lax sward dead material accumulated over the five month period. Although there was no difference between the average net herbage growth rates of the two treatments, it can be seen that significant differences in the average rate of live herbage accumulation between the two treatments existed. The consequence of which will have significant effects on pasture quality, animal production and pasture regrowth.

Table 2.4 Average net herbage accumulation rates of a ryegrass/white clover sward from October to mid February (Korte & Sheath 1978).

Treatment	Lax	Hard	L.S.D (5%)
Dead herbage			
Leaf & sheath	8.6	-1.4	9.7
Ryegrass stem	3.8	-1.4	4.1
Total	12.4	-2.8	12.7
Live herbage	61.9	75.8	12.8
Total herbage	74.3	73.0	n.s.

The small diagram below helps to illustrate the simple relationship between herbage growth and disappearance. Dead material that accumulated in spring disappeared from the sward during autumn. So although the growth of live herbage was accumulating at 33 kg/DM/ha/day, the diagram shows that the proportion of dead material declining, as a result, the net herbage growth rate was only 7 kg DM/ha/day.

Work by Matthews (1994) showed that practically, a sound understanding of tissue turnover within the sward can help open opportunities for improvements in per cow and per hectare production in dairy farm systems.

He stated that in the measurement of herbage mass of a sward over time, that it is not pasture growth rate which is being measured, but is (as has been mentioned) the balance between pasture growth and pasture losses over time. Korte et al (1987) showed that net herbage production is equal to the total herbage harvested:

Net herbage production	=	Growth	-	Decay	=	Total herbage harvested

In New Zealand it is generally considered that animal production is limited by pasture production, particularly in the dairy industry where high genetic merit cows seldom reach their production potential. Hodgson (1989) showed that there had been little increase in the total quantities of pasture grown in New Zealand pastoral systems over the previous 40 years. The large and significant gains in dairy production over this period have been through improved grazing strategies allowing improved utilisation of pasture grown (Matthews 1994; 1995). Importantly he stated that in light of Hodgson's (1989) data that it was reasonable to argue that future gains are likely to be less significant unless the total amount of pasture grown can be increased.

Given the simple equation above an increase in pasture production will occur through either an increase in true pasture growth or a decrease in pasture losses through death and decomposition. An increase in pasture growth will require a change in the environment, while an increase in harvesting efficiency will require a change in grazing management (Matthews 1994).

2.7 Herbage Mass and Pasture Growth

There has been much debate and research on the relationship between herbage mass and pasture production. Initial work undertaken by R.W. Brougham who provided information on the change in pasture production from changes in pasture cover over time, and gave an insight into the effects of grazing management on pasture production (Brougham 1955; Brougham 1956; Brougham 1957). He showed that the pattern of pasture regrowth follows a sigmoid shape; having a period of initial slow growth after grazing, followed by a period where the growth is maximised and then the final period where growth slowly declines again (Figure

2.10). From his studies, Brougham was the first to provide sward targets to increase pasture production. It was shown that the optimum herbage mass was 1166 and 747 kgDM/ha following April and May grazings respectively. These figures are masked somewhat by the fact that they are for herbage mass above 25mm. Bluett et al (1998) stated that it could realistically be assumed that the stubble below 25mm would be approximately 1000 kg DM/ha, giving more realistic figures of 2166 and 1747 for April and May grazings.

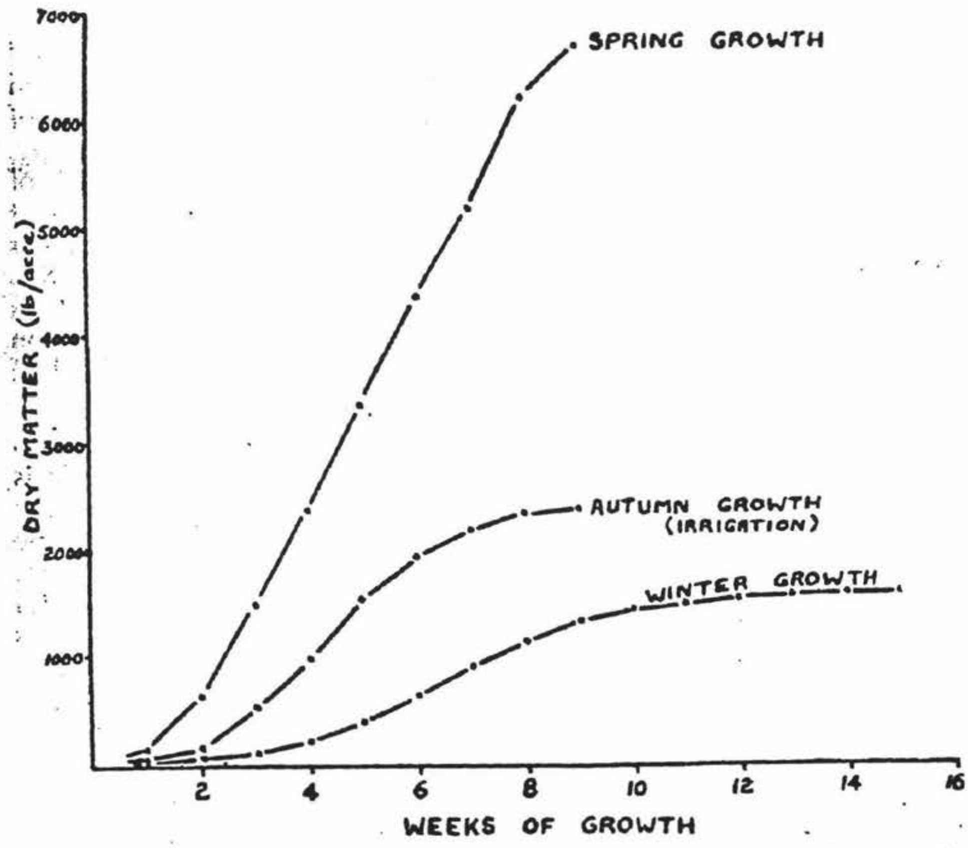


Figure 2.10 Logistic curve for total herbage and ryegrass yields for four dates of spelling (Brougham 1957).

From the study of changes in leaf growth and leaf death (Bircham & Hodgson 1983) came grazing management recommendations for optimising pasture production. These authors stated that maximum accumulation rates for British swards were achieved at a herbage mass of 1200-1250 kg DM/ha. Matthew et al (1995) stated that for dairy pastures in New Zealand the range in pasture cover over which management has minimal effect on net herbage production is approximately between 1200 – 3000 kg DM/ha although this range is ambiguous as there are no clear boundaries as Figure 2.11 shows. At levels below 1200 kg DM/ha pasture growth is slow because of the reduced leaf area available to intercept light, at covers higher than 3000 kg DM/ha net production is reduced because while true growth is high senescence and decay are also high and are usually greater than growth meaning that net herbage production is declining (Figure 2.12). Recently, Brander & Matthews (1997) suggested that a winter grazing regime that resulted in a 2200 kg DM/ha average herbage mass resulted in increased winter pasture growth and improved nitrogen responses.

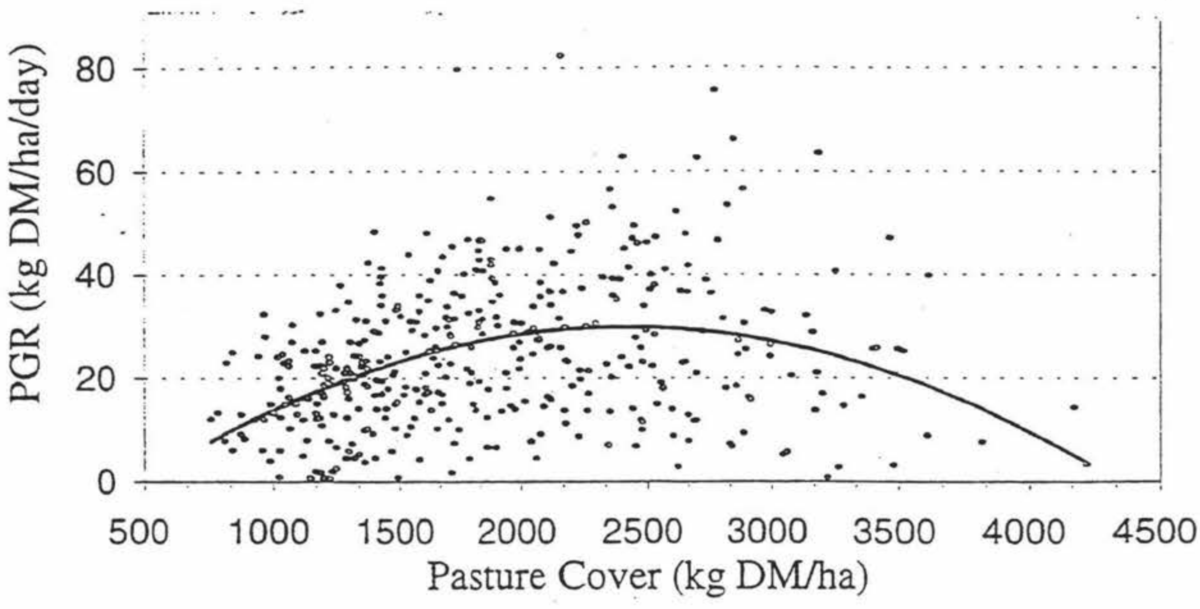


Figure 2.11 The relationship between herbage accumulation rate and pasture cover, May to August, No 4 Dairy, Massey University (Matthew et al 1995).

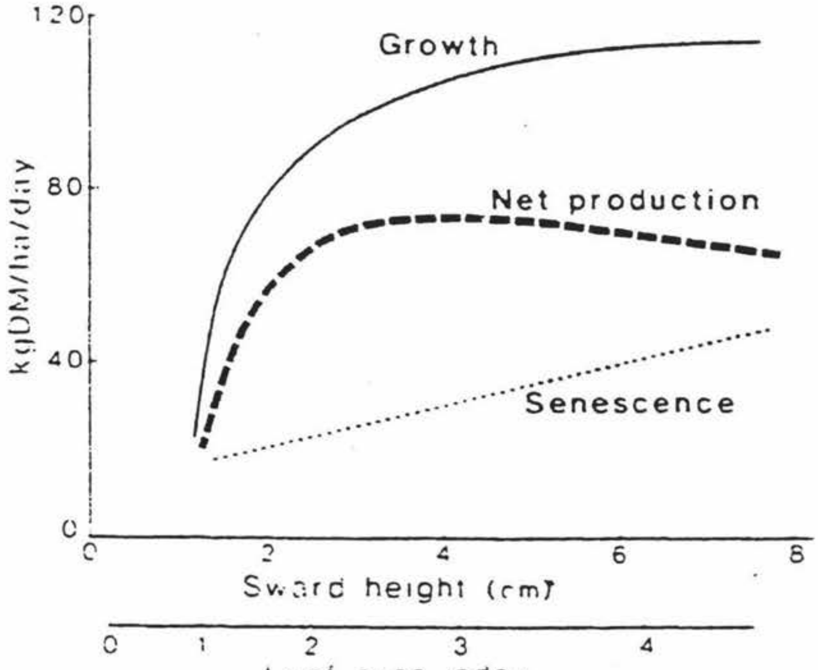


Figure 2.12 Herbage growth, net herbage production and decay versus pasture mass (Bircham & Hodgson 1983).

In practice farmers would want all paddocks to be within the 1200 – 3000 kg DM/ha range, this would give an average cover of 2100 kg DM/ha. However if the goal is to feed the herd generously then a compromise must be made. For high quality herbage and high cow intakes to be achieved, pre-grazing and post-grazing masses must decrease and increase respectively. Thus farmers would be operating somewhere in the range of 1500 – 2500 kg DM/ha, giving an average cover of 2000 kg DM/ha. Matthews (1994) stated that the extent to which average pasture cover could alter to accommodate variations in pasture growth, without affecting net herbage production is approximately 400 kg DM/ha, between 1700 – 2100 kg DM/ha in winter and 2000 - 2400 kg DM/ha in late spring-summer.

In recent times many dairy farmers are increasing pasture cover levels (mainly through increases in post grazing residuals) as part of their endeavour to improve cow intake levels and ultimately milksolids production and farm profitability. If we take Figure 2.11 we can see a clear relationship, however if we analyse it more closely, one of the first things to notice is the extreme variability, as acknowledged by Bluett et al (1998), although pasture growth is by its own inherent nature extremely variable. The second main point, which is of practical interest, is that if we take the range in pasture cover levels over which dairy farmers are likely to realistically operate within (between 1200 – 3000 kg DM/ha) then there is less of a relationship, it is almost a straight line. The data is also confounded by environmental conditions, for example in poor environmental conditions, a sward with a high herbage mass may have a low growth rate, and conversely in favourable climatic conditions a sward with a low herbage mass may have a high growth rate.

This less than ideal relationship means that farmers should be cautious in the emphasis that they place on this data, the way they interpret it, and the grazing strategies which have been recommended from such data.

Santamaria & McGowan (1982) support the findings of Matthew et al (1995). They found that the optimum range in pasture cover for maximum growth was between 1000 – 3000 kg DM/ha. The authors showed that an increase of 100 kgDM/ha in pasture cover gave a positive increase in pasture growth rates by 5%. Coutinho (1998) also showed a 33% increase in pasture production (as well as an increase in animal performance and decrease in supplement feed) on farmlets where grazing management was based on target sward conditions rather than on animal performance targets over winter. However Ryan (1986) showed with extremes in post grazing residuals of 978 kg DM/ha and 1925 kg DM/ha over winter, that the lower residual gave the faster growth rate during the three week period following defoliation (76 kgDM/ha versus 57 kg DM/ha respectively). In fact L'Huillier (1987b) concluded from his trial work that green herbage accumulation was not affected by the degree defoliation intensity at any time of the year, a result previously reported by Wade (1979). However, the rate of total herbage accumulation was greater in lax than hard grazed swards, but net production was reduced by the significant influence of dead herbage accumulation resulting in these (L'Huillier 1987b).

In an experiment (Holmes & McLenagham 1980) in which treatment swards were grazed down to one of three intensities (hard, medium and lax) and grazed at one of two frequencies (frequent and infrequent). The results (Figure 2.13) clearly show that the hard grazed plots had a higher pasture growth compared to medium and lax treatments. Pre and post-grazing sward levels are shown in table 2.5.

Table 2.5 Average pre and post gazing levels and pasture growth rates. (Holmes & McLenagham 1980)

Treatment	Hard	Medium	Lax
Pre grazing (kg DM/ha)	2110	2465	3095
Post grazing (kg DM/ha)	1095	1715	1985
Pasture growth rate (kg DM/ha/d)	38.5	33.9	32.8

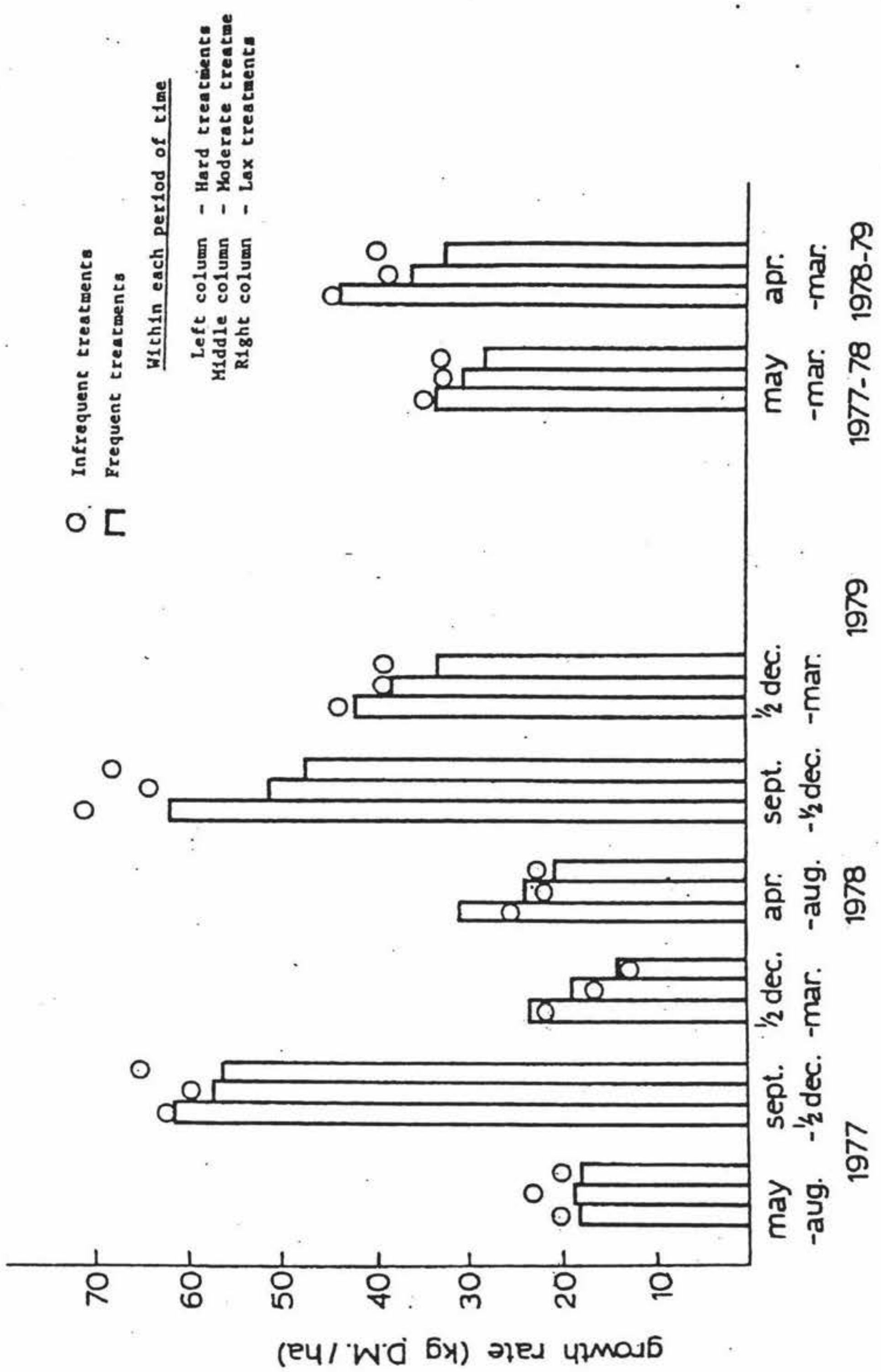


Figure 2.13 Growth rate of treatment swards over time (Holmes & McLenaghan 1980).

The grazing frequency of the infrequent treatment was exactly double that of the frequent treatment, which was a grazing twice every eight weeks in winter, twice every three weeks in spring, and twice every five weeks in summer. It could be argued that in the lax grazing intensity treatment a rotation of greater then 30 days argued that in the lax grazing intensity treatment a rotation of greater then 30 days (average between the two grazing frequencies) was too long for the grazing intensity implemented. This treatment would have reached ceiling herbage mass sooner than the other grazing intensity treatments. Parsons & Penning (1988) have modeled a situation such as this showing the theoretical effects on sward components (Figure 2.14).

It seems evident from some of these reviewed studies that the full relationship between growth and death within a sward over varying herbage mass and environmental conditions is still not fully understood. The theoretical model of Parsons & Penning (1988) has aided in the understanding of the relationship better. The effect of the duration of regrowth on average growth rate is shown in Figure 2.14. It can be seen that after defoliation the average growth rate increases in association with the marked increase in the instantaneous growth rate which it is derived from, but during later stages of regrowth the average growth rate is affected by the initial accumulation of high values of instantaneous growth rate. "Thus, even assuming that all accumulated herbage is harvested (ie the sward returned to W_o), the average growth rate will be insensitive to variations in the length of period of regrowth beyond a given minimum duration (Parsons & Penning 1988). After defoliation the maximum average growth rate occurs after the maximum instantaneous growth rate but before the ceiling yield is reached (Figure 2.14).

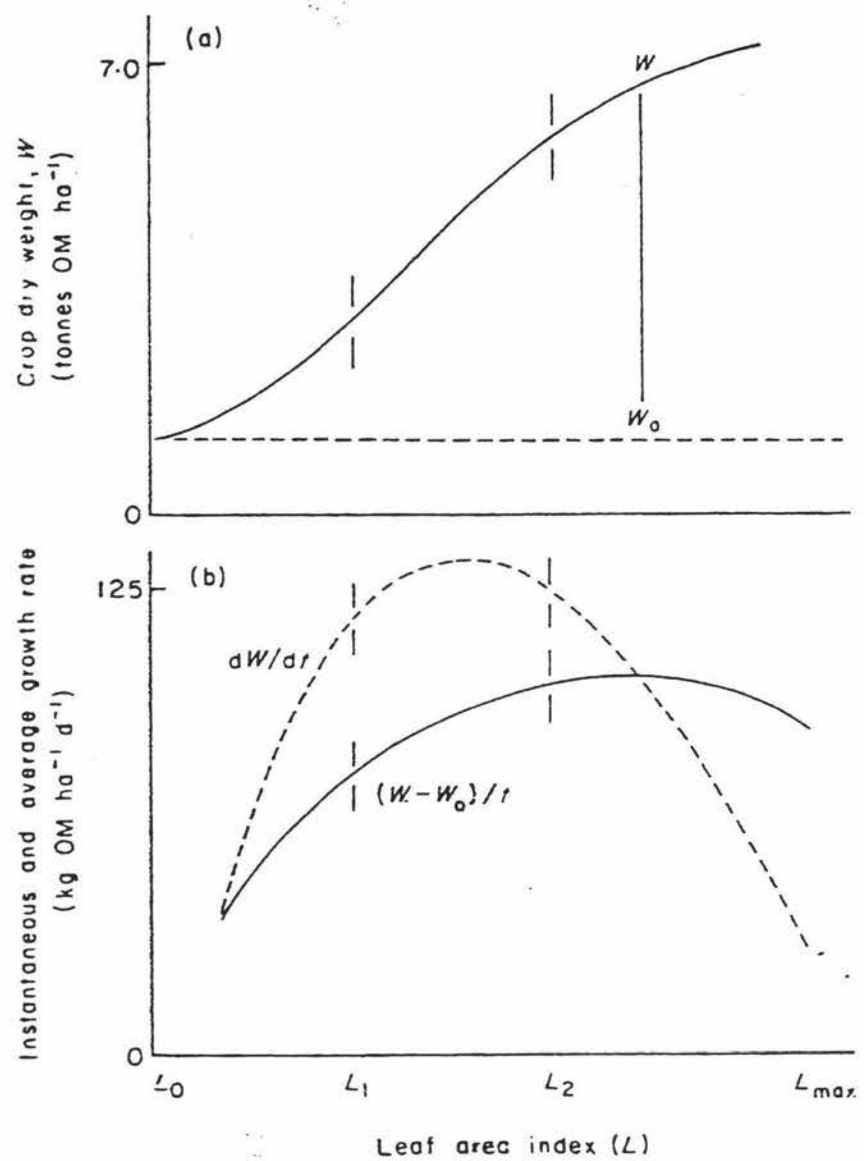


Figure 2.14 A model which illustrates the corresponding changes in the instantaneous growth rate (dW/d*t*), the weight of the crop (W) and the average growth rate (($W-W_0$)/*t*) (Parsons & Penning 1988).

Clark et al (1994) tested the effect of winter pasture residuals on pasture performance. Three farmlets were deigned to have an average pasture cover at calving of 2000 kgDM/ha, but with pastures grazed to either 900, 1400, 1800 kgDM/ha by using winter rotation lengths of 112, 80 and 40 days respectively. Previous defoliation treatments had no consistent effect on subsequent pasture regrowth in either the immediate regrowth period (0-3 weeks) or the later regrowth period (3-6 weeks) as shown in Table 2.6.

Table 2.6 The effect of winter grazing treatment on pasture regrowth (kgDM/ha in weeks 0-3 and 3-6. (Clark et al 1994).

	Winter treatment		
Week 0-3	900	1400	1800
July	546	241	300
August	151	577	408
September	1515	1397	861
October	2195	1785	2052
November	589	1021	964
Week 3-6			
July	940	814	780
August	1129	1051	1107
September	1617	1853	2189
October	1303	2156	3195
November	3198	3816	2917

Milk production data was also recorded from calving to mid December (Table 2.7). As with pasture production data, results showed no consistent effect. As a result the authors concluded that a range of wintering options could be adopted without concern that subsequent lactation performance will be compromised.

Table 2.7 The effect of winter grazing management on milksolids, liveweight change and average farm cover for period 1 (16 July-3 Sept) and period 2 (3 Sept-22 Oct), (Clark et al 1994).

	900	1400	1800
Milksolids (kg cow/d)			
Period 1	1.62	1.48	1.58
Period 2	1.80	1.79	1.78
Liveweight change (kg/cow)			
Period 1	-87	-66	-62
Period 2	39	30	11
Average farm cover (kg DM/ha)			
Period 1	1910	2000	1960
Period 2	2370	2390	2360

In summary, it can be seen that there are many conflicting results and conclusions. While some have rational explanations, many are not obvious or clear, yet grazing management strategies have been formulated from some of these results. Clearly more evidence is required to provide a better understanding of the relationship between herbage mass and pasture growth, and how this can influence grazing management decisions and provide opportunities to improve farm productivity. Perhaps authors need to better explain the dynamics of growth and death within pastures to enable improved management strategies to be formulated.

2.8 Systems Trials

This section will look at the effects of grazing levels and stocking rate on parameters such as milk production, cow intake, supplement use and pasture production. It is intended to show the effects of different grazing strategies on farm performance to allow an evaluation of some likely effects from achieving different sward targets and conditions.

In dairy production systems stocking rate is considered that main variable which effects output per unit area of land (McMeekan 1956). Indeed in 1961 he stated that "no more important force exists for good or evil that the control of stocking rate in grassland farming". It is a large determinant on the balancing of pasture growth with herd requirements, an aspect that has been seen as critical in achieving an efficient low cost production. Dillon et al (1995) highlighted the advantage of better matching pasture growth with cow requirements through having the right calving date/stocking rate combination. Their results (Table 2.8) showed that relatively high production yields can be achieved with minimal supplementary feed inputs.

Table 2.8 Milk production and use of supplements fed and conserved for thee different farmlet systems (Dillon et al 1995).

Treatment		Early calving 2.9 cows/ha	Late calving 2.9 cows/a	Late calving 2.6 cows/ha
Milk yield	kg/cow	5872	5444	5584
	MS/cow	397	391	404
	MS/ha	1151	1123	1049
Concentrates fed (kg/cow)		620	185	80
Silage made/fed (kg/cow)		7.2	7.0	8.8

In the short term, stocking rate affects cow performance through its influence on daily herbage allowance per cow. Bryant et al (1980) showed that the intake and performance of dairy cows was reduced as daily herbage allowance was decreased. This information agrees with other findings (Glassey et al 1980). The performance of cows offered a high allowance is due entirely to the subsequent increase in intake (Table 2.9). Hodgson (1975) suggested that that herbage intake and milk production of dairy cows is maximised when the daily herbage allowance on offer is equivalent to four times the amount eaten. However, 90% of a cow's intake is obtained by offering a pasture allowance 50% less than that required to achieve maximum intake (Ryan 1986), suggesting that maximum per hectare performance will occur at pasture allowances below those required to maximise per animal performance.

Table 2.9 Average herbage allowance, intakes and residual herbage yields (Glassey et al 1980).

	High	Moderate	Low
Herbage allowance (kg DM/cow/day)	53	33	14
Intake (kg DM/cow/day)	16	14	10
Residual yield (kg DM/ha)	1850	1550	750

Glassey et al (1980) showed that post grazing residual is strongly related to herbage allowance and intake (Table 2.9), thoughts advocated by Matthews (1995). There appears to be an asymptotic relationship existed between pasture allowance, grazing residual and intake (Greenhalgh et al 1967; Holmes 1987). Milk production from the three herbage allowances was 16.7, 16.2 and 12.8 litres/cow/day for the high, moderate and low treatments respectively. Although per cow production is high when herbage allowance is high, the fact that utilisation of pastures decreases will mean that production per hectare is likely to decline. Farmers have to make a compromise between maximum output per hectare and maximum output per cow.

In a short term grazing experiment by Combellas & Hodgson (1979) the variations in herbage mass and herbage allowance were examined to determine the effects of interactions between them on intake and milk production. The interaction between allowance and intake was not significant, although there was some evidence that intake continued to increase to a higher allowance on the high herbage mass treatment than the low herbage mass treatment. Herbage mass had no significant effect on milk yield or composition, however milk yield was significantly lower at low than high herbage allowance.

Similar results using different stocking rates were achieved by Baker & Leaver (1986). Using low (3.98), medium (4.26) and high (4.54) stocking rates (cows/ha), which effectively lead to different pasture allowances. The greater stocking rate was associated with a decrease in sward height, this led to an increase metabolisable energy content and crude protein content, and to an increase in tiller density. Over the 147 days of the experiment average milk yields were 20.5 21.5 and 21.6 kg/day respectively with milksolids production yields 1.50, 1.54 and 1.57 kg/day respectively. However milk and milksolids yields were not significantly different. Average concentrate intakes were 4.3, 4.7 and 3.9 kg DM/day respectively. Baker & Leaver (1986) concluded that their results indicated that high stocking rates in the spring were not necessarily detrimental to overall summer performance. The high stocking rates in the early spring ensued a high level of herbage utilisation and milk production per hectare. Pasture production was not measured in the trial, and results showed that sward height was reduced in mid spring, the question to be asked, is whether this reduced sward height (herbage mass) is restricting pasture production and hence potential milk production? Mayne et al (1987) showed that a 30% reduction in net herbage accumulation resulted from a low herbage allowance compared to a laxer grazed treatment, and was due to treading damage during the early season.

The trade off between increasing sward height (through a reduced stocking rate) in spring will be between pasture quality and cow intakes levels from pasture. Hughes (1998) showed that a grazing system based on achieving desirable sward targets to obtain a desirable compromise between animal and pasture production levels to ultimately improve per hectare production can be achieved. However the level and timing of supplement input along with effective monitoring is seen and critical. Le Du et al (1981) quoted a sward height of 7 cm being the level below which levels of milk production are rapidly depressed, although Mayne et al (1987) stated a minimal residual sward height of 8 cm. While the general rule is that laxer grazing over spring results in pastures of lower quality, the effect over the early spring period is less evident as shown by Mayne et al (1987) and Hoogendoorn et al (1987). With effective monitoring and sensible pasture control through conservation techniques it may well be possible to combine a laxer grazing in early spring to enhance pasture growth rates and still maintain pasture quality in late spring and into summer.

2.9 Conclusion

This chapter has attempted to give a review of the some of the important physiological and morphological characteristics that influence the growth and structure of ryegrass/white clover swards. It has attempted to link this knowledge to help explain the relationship between herbage mass and pasture growth and the fundamentals of the relationships that exist, and then apply this to dairy farming systems to help with a formal understanding of the grass sward to management. And also to evaluate the effectiveness of alternate grazing systems, in terms of pasture and animal production.

In general while there is an abundance of literature on individual plant processes and structure. This is much less which incorporates all these processes and describes these in relation to pasture production and survival, and the effect of management on the ryegrass/white clover sward.

The experiments reported in this thesis have attempted to provide further information on the relationship between herbage mass and pasture growth. And to add to the present content of knowledge on the components of grasses which influence pasture growth.

Developments and changes in the way of thinking in grazing management have resulted from research reported in this review. One such example is the dairy farm of Russell and Karen Phillips. Over the past 6-8 years their farming system has undergone some large changes. The traditional system of high stocking rates and short lactation's has changed to one focused on achieving higher per cow, and per hectare production through reduced stocking rate and a greater focus on grazing management. This was the reason why this farm was chosen as the experimental site.

Sward targets for the case farm over winter and spring are presented in Table 2.10. The targets reflect the emphasis placed on optimising pasture production and maintaining high cow intakes through appropriate post-grazing residuals as a means of improving per cow and per hectare productivity.

Table 2.10 Sward targets (kg DM/ha) for case farm from winter through to late spring (Phillips & Matthews 1994).

	Average cover	Pre-grazing	Post grazing
Winter	2000	2600	900
Early Spring	1950	2700	1400
Late Spring	2100	2600	1600

This study will help to provide evidence on the effect of these targets on pasture production and utilisation, and hopefully support the changes that have been made and to help refine them. Overall it is hoped that this research will add to the present knowledge to better develop plans for pasture and animal management to further develop farm efficiency and sustain profitable and viable dairy farming systems.

3.0 EXPERIMENTAL OUTLINE AND METHODS

3.1 Experimental Sites

Two experiments were undertaken in the winter and spring of 1998 on a 155 hectare commercial dairyfarm situated on Te Kumeti Road, Te Ruhunga, approximately 8 km SW of Dannevirke (Appendix 1)

The soil type varied within the farm, but came under two main soil types; an Ashhurst stony silt loam and a Dannevirke silt loam. Both are classed as a moderately to strongly gleyed soil related to yellow grey earths and yellow brown earths (Soil map from Dept. of Lands & Survey NZ).

Each experimental area covered a total of approximately three hectares, made up of three, one hectare paddocks, with (Figure 3.1). The predominant pasture species were perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*), with small quantities of cocksfoot (*Dactulis glomerata*) and weeds such as clustered dock (*Pumex conglomeratus*), creeping buttercup (*Ranunculus repens*), and various flat weeds.

3.2 Experimental Outline

The first of the two experiments was undertaken over winter from June 19 to August 28 (Experiment I), and the second experiment in spring from September 28 to October 28 (Experiment II). The two experiments were carried out to compare growth rates at a time of low pasture growth and of high pasture growth. A farm walk was undertaken prior to each experiment to select pre-grazing paddocks that had an appropriate herbage mass, were close to each other and of good quality (ie had a high leaf to stem proportion) as judged by eye.

3.3 Experiment I: Experimental Design

3.3.1 Treatments

In this experiment five target post-grazing residual treatments were studied (900 1200 1500 1800 and 2100 kg DM/ha). While these target grazing levels were specified, the main aim was to achieve a range of grazing residuals which represented a range of cow intake levels ranging from underfed cows, to cows that were well fed (ad lib). Treatments were replicated three times. Each replicate (block) encompassed one paddock. Pre -grazing sward levels were targeted to be in the range of 2600 – 2800 kg DM/ha

3.3.2 Treatment Layout

Each replicate was divided into six equal plots (0.17 ha) using electric fences (Figure 3.2), pegs were put in along the fence line to mark the plot after treatments had been imposed and electric fences removed.

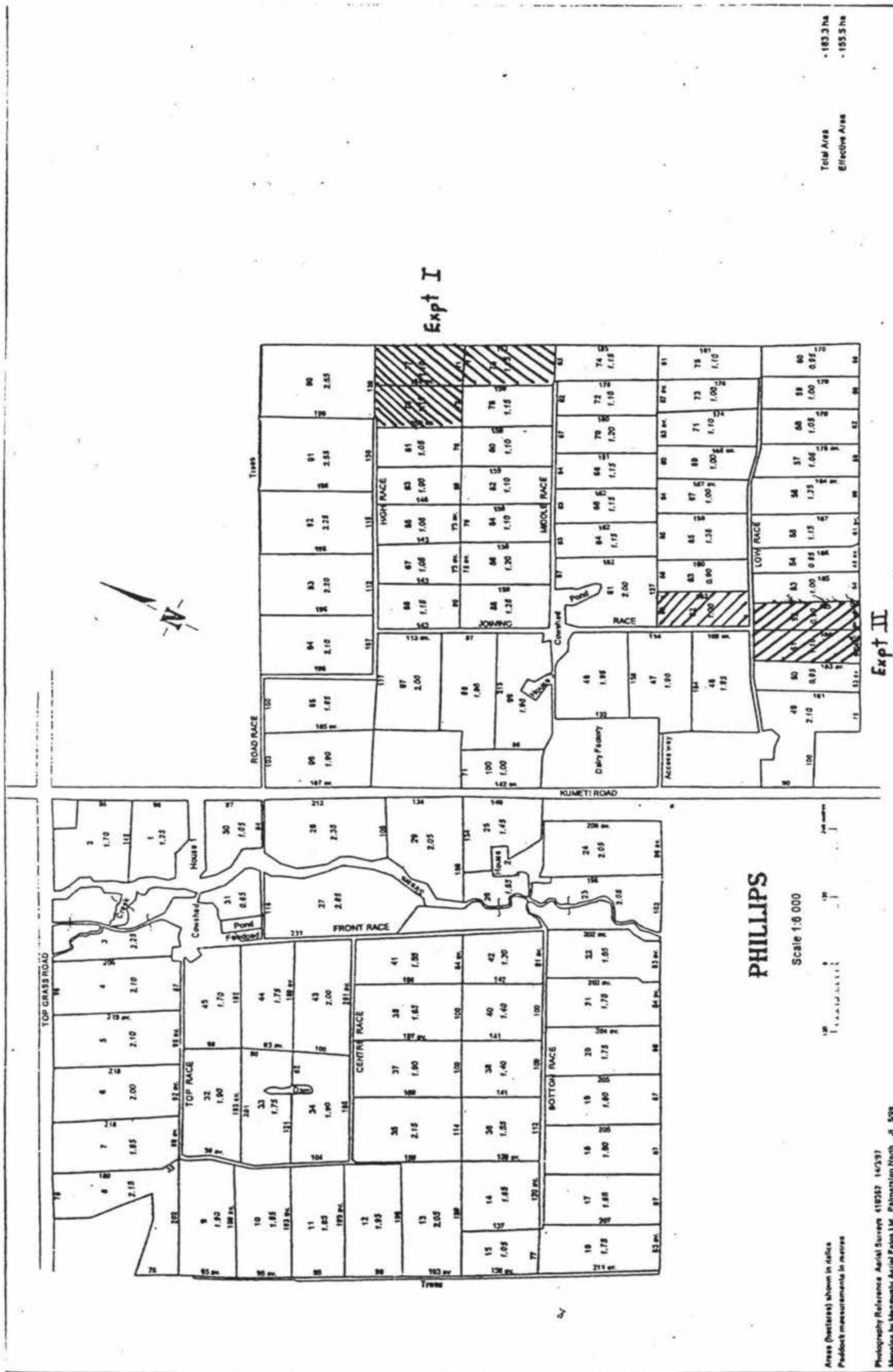


Figure 3.1 Location of experimental site.

One of the plots in each replicate provided a holding area for surplus stock, or for stock that had achieved the target residual in their plots sooner than had been expected. Treatments were randomly allocated to plots within each block. The areas around troughs were excluded due to likely soil fertility gradients. A 6m strip along a line of trees at one end of each of the paddocks was fenced off. Plot dimensions were such that each grazed plot was essentially square, minimising treading damage that can occur in strip feeding compared to block feeding (Judd et al 1994). Approximately 90 Holstein-Friesian two year old heifers and 30 Holstein-Friesian dry cows were used to apply the grazing treatments. Cow numbers (Table 3.1) were calculated (Appendix 2a) to achieve the desired post-grazing level so that each treatment level was achieved over a 24 hour period. This was done to represent what occurs in practice in farming systems and to reduce the effect of an on-off grazing system where nutrient transfer is likely to occur. It was assumed that the heifers could consume a maximum of 14 kg DM.

Table 3.1 Cow numbers and grazing intensities for Experiment I

Post- grazing (kg DM/ha)	900	1200	1500	1800	2100
Cow numbers	51	26	16	11	7
Grazing intensity (cows/ha/d)	300	150	92	64	43

To spread the workload, and because the number of heifers and cows that could be used to graze the plots were limited, one block (paddock) was grazed each successive day. Cows and heifers were randomly allocated to each treatment in the higher post-grazing treatments (Treatments 3, 4 and 5). A greater number of dry cows in the two lower grazing residual plots were used as it was expected that heifers were less likely to graze to very low sward levels. The stock were put into the plots in the afternoon, herbage mass was measured regularly the following day and when the herbage mass was close to the target level the stock were removed. The experiment was of a randomised complete block design, replicated three times, with paddocks as blocks.

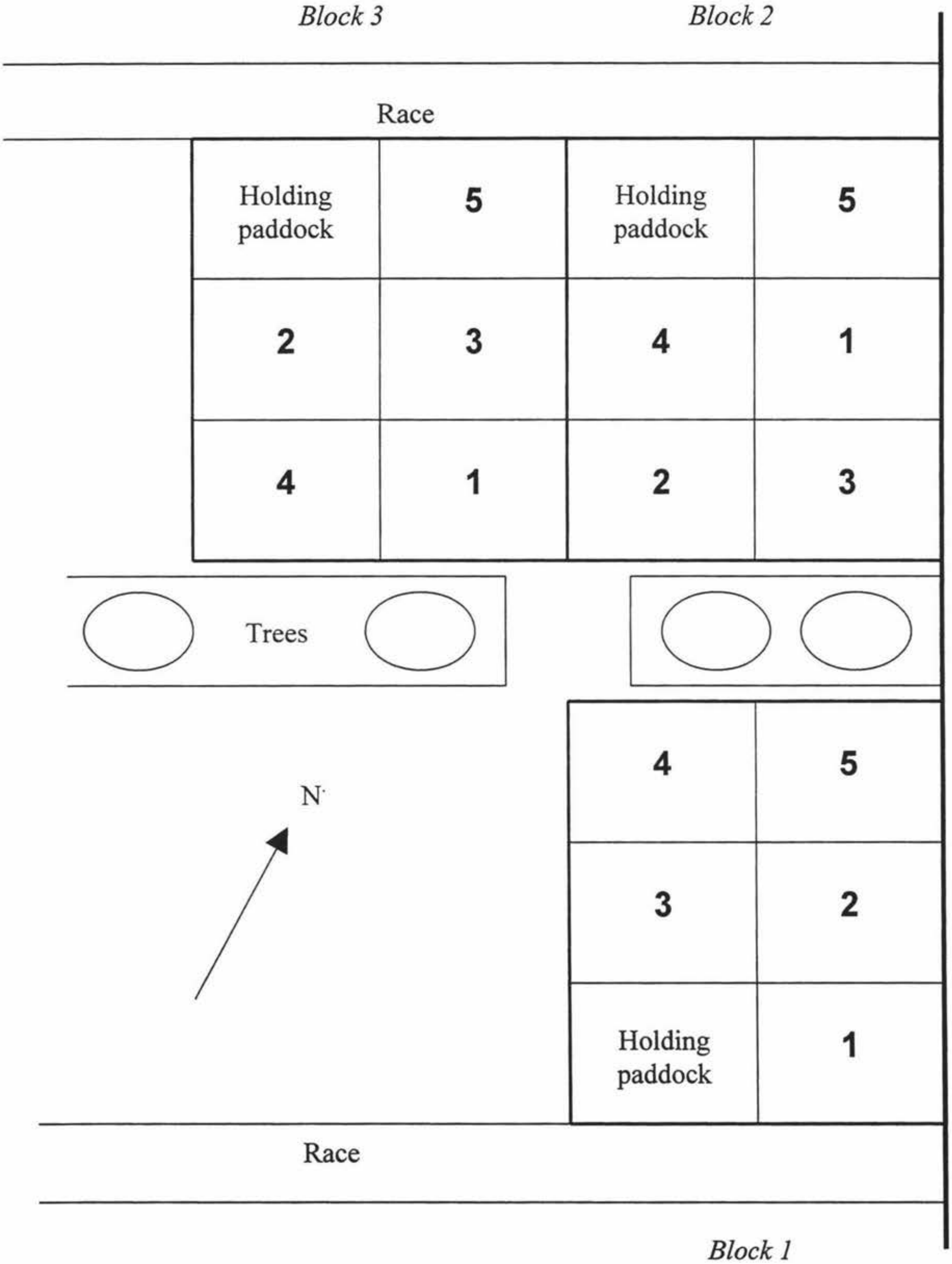


Figure 3.2 Layout of Experiment I.

· Diagram not to scale

3.4 Experiment II: Experimental Design.

3.4.1 Treatments

As with Experiment I a series of post-grazing residuals were implemented. Four treatments were assigned to each paddock (block). The treatments were 1200, 1500, 1800 and 2100 kg DM/ha, and again represented well fed to underfed cows. Again the main aim was to achieve a range of grazing residuals. A new site on the farm was selected for this second experiment (Figure 3.1)

Three different rates of nitrogen fertiliser were also incorporated into Experiment II. This was done as it is common management practice on most dairy farms for an application of nitrogen fertiliser to be applied. The three nitrogen rates were 0, 25 and 50 kg N/ha.

All treatment combinations were replicated three times, with each replicate being encompassed within one paddock. Paddocks were again selected with favourable sward characteristics and appropriate pre-grazing herbage mass in the range between 2600-2800 kg DM/ha.

3.4.2 Treatment layout

Experiment II was designed as a randomised split block design. Grazing treatments were allocated as whole plots and nitrogen treatments as split plots. Although both the grazing and nitrogen treatments were candidates for being whole plots, it was considered that there would be less error in having the grazing treatments as the main plots. The grazing treatments were of greater importance in terms of the aims of the experiment and thus it was more important that a range of post-grazing levels were achieved. It was envisaged that the desired grazing level would be easier to achieve in a larger plot with a greater number of cows.

Each replicate was divided into four equal plots (0.25 ha) again using electric fences. Each 0.25 ha plot was divided into 3 equal subplots using pegs (Figure 3.3). Treatments were randomly allocated to plots within each block.

Cow numbers (Table 3.2) were calculated (Appendix 2b) to achieve the desired post-grazing level so that each treatment level was achieved over an 8 hour grazing period between morning and afternoon milkings. Lactating cows were randomly allocated to graze plots between milkings. Heifers were used on two of the paddocks (for approximately one hour) to achieve set targets, as the cows were not able to reach the set sward targets, during the 7-8 hour period between the morning and afternoon milkings.

Table 3.2 Cow numbers and grazing intensities for Experiment II

Post-grazing (kg DM/ha)	1200	1500	1800	2100
Cow numbers	? 21	38	60	94 ?
Grazing intensity (cows/ha/d)	188	120	64	43

Blocks were grazed over a three-day period, with one block being grazed each day. The size of the subplots was 0.083 ha. Nitrogen as urea (46% nitrogen) was applied following grazing. A total of 4.51 kg urea was applied to plots requiring 25 kg N/ha, and 9.02 kg urea applied to plots requiring 50 kg N/ha.

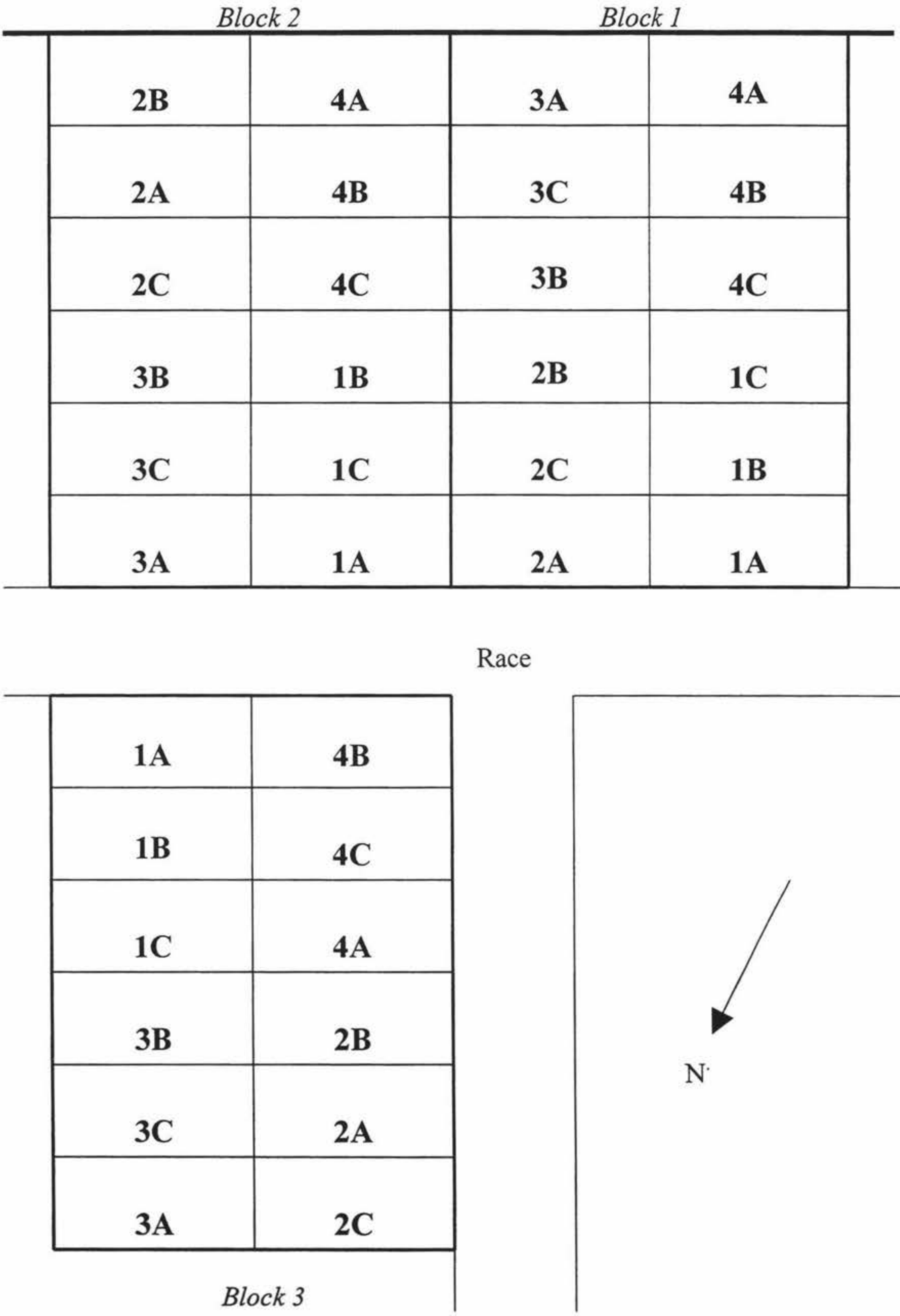


Figure 3.3 Layout of Experiment II

· Diagram not to scale

3.5 Measurements

3.5.1 Introduction

Measurements were chosen so that, within the constraints of available labour, as complete picture as possible of sward changes could be constructed and the importance of different sward characteristics in those changes established.

Measurements made included:

- Herbage mass/herbage mass profile
- Net herbage accumulation
- Botanical composition
- Nutritive value
- Tiller density
- Tiller weight
- Leaf appearance rate/tiller appearance rate
- Leaf extension rate

The main measurements were that of herbage mass and net herbage accumulation (NHA). The more detailed sward measurements were included, essentially to explain the changes that occurred, or did not occur in NHA and herbage mass.

Herbage mass and NHA measurements were taken at 10 days intervals in both experiments. In Experiment I, leaf extension, botanical composition and pasture quality was taken at 20 day intervals. Herbage mass, botanical composition and tiller density measurements were taken on all plots prior to grazing in both experiments. Nutritive value measurements were not taken until the July 20 in Experiment I. In Experiment II all measurements were taken at 10 day intervals due to faster growth rates. A herbage profile of each plot was taken after grazing in each experiment. Leaf extension rate was measured only in Experiment I due to labour constraints.

In Experiment II, labour and time constraints meant that sward component measurements which included leaf appearance rate, botanical composition, herbage quality, tiller density and tiller weight were only measured on plots which received 25 kg N/ha within each grazing treatment. Herbage mass and net herbage accumulation was measured on all sub plots.

3.5.2 Herbage mass

Herbage mass was measured using a calibrated Ashgrove rising plate meter. Due to the variability in sward height in some plots, especially those at the higher residuals (where there was much variability due to the low grazing intensity and the patch grazing which resulted) it was considered that if quadrat cuts were to be taken a large number would be required, and given the number of plots, that this was not practical. A total of 50 readings were taken from each plot, 25 across each diagonal.

The rising plate meter was calibrated using a standard calibration procedure as described by Matthews & Matthew (1997). A total of 70 ($0.10m^2$) quadrat cuts were taken across a range of high, medium and low herbage mass paddocks using a portable battery operated shearing handpiece. Quadrats were cut to ground level (Plate 3.1), following cutting, herbage was washed to remove soil and dung, and then dried at 80 °C for 12 hours before samples were weighed to 0.01g.

A herbage mass profile was taken across all plots on June 29 and September 27 in Experiment I and Experiment II respectively. A total of 40 plate meter readings were taken from one corner to another within each plot and each separate reading recorded. This measurement was aimed at showing the variation and distribution of patches within each plot.

3.5.3 Net herbage accumulation (NHA).

Herbage accumulation (kg DM/ha/day) was determined using the following formula which was adapted from a similar equation by Campbell (1966), and is defined algebraically as:

$$NHA = \frac{(B_i - A_i)}{n}$$

Where: A_i = herbage mass after grazing (or from previous measurement period).

B_i = herbage mass at present period.

n = number of days between measurement periods.

3.5.4 Botanical composition

A total of 15 random samples each of approximately 0.5 x 0.2 m were taken from each plot. Samples were cut to ground level using a battery operated shearing handpiece, bulked, and then three subsamples from each plot dissected to determine the relative proportions of grass leaf, grass stem, clover, weeds and dead material. Herbage that was no longer green was classed as dead. Partly dead leaves were classified dead when more than 50% of the leaf was dead. Dissected samples were oven dried at 80°C for 12 hours before samples were weighed to 0.01g.

3.5.5 Nutritive value

In order to determine the pasture quality of the regrowth, representative samples of the grazed herbage were taken. A total of 15 random samples (approximate sample size 0.1 x 0.5m) were cut to the approximate initial grazing height at each harvest using a battery operated shearing handpiece. In Experiment II a sample of the pre-grazing sward in each plot was also taken. These samples were cut to ground level. Samples were bulked and a subsample dried at 60°C for 12 hours or until dry, they were then ground through a 1 mm sieve and analysed by Near-Infra Red Reflectance Spectrometry (NIR) prediction using calibrations based on wet chemistry method. Variables analysed included crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF), organic matter digestibility (OMD) and metabolisable energy content (ME).

3.5.6 Tiller density

A total of 15 tiller cores (52mm diameter) were taken from each plot (225 and 180 in total for Experiment I and Experiment II respectively) before and after grazing. To give an indication of the trend in tiller density further samples were taken midway through and at the end of both experiments. Cores were taken in a diagonal from one corner to the other within each plot.

3.5.7 Tiller weight

Tiller weight was determined indirectly through pasture botanical composition, herbage mass and tiller density. This was done to save time and labour. The calculation was made by multiplying the herbage mass of each plot by the proportion of grass leaf and grass stem (i.e. tillers) derived from the measurement of botanical composition at the same measurement period. This gave an indication of the weight of tillers/plot. This figure was then converted to grams. The tiller density of each plot at the corresponding time that the herbage mass and botanical composition measurements were taken was then converted to a per hectare basis. The weight of tillers per hectare was then dived by the number of tillers per hectare to give the average weight per tiller (expressed in mg DM/tiller) as is shown below.

A = Herbage mass (kg DM/ha) of each plot at date W

B = Proportion of grass leaf and grass stem (tillers) of each plot at date W

C = Tiller density (tillers/m^2) of each plot at date W

A x B = kg DM(of tillers)/ha

Kg DM(tillers)/ha x 1000 = g DM(tillers)/ha

C x 10000 = tillers/ha

$$\frac{\text{g DM(tillers)/ha}}{\text{tillers/ha}} = \text{g DM/tiller}$$

g DM/tiller x 1000 = **mg DM/tiller**

3.5.8 Leaf appearance rate

Demographic analysis was used to study tiller turnover/survival. A transect technique (Hodgson & Ollerenhaw 1960) was used to mark and locate individual tillers throughout the experiment. A total of 20 tillers per plot were marked with coloured wire twists at 10 cm spacings along each transect (Plate 3.2). A small touch of white paint was applied to the tip of the youngest ryegrass leaf. When the marked leaf senesced and died the next youngest leaf at this stage was again marked. Leaf appearance rate was determined by recording the number of new leaves that emerged between measurement dates and then dividing the number of days between each measurement date by the number of leaves which had emerged, over that measurement period. This then gave a measurement of leaf appearance rate with the units being days/leaf.

3.5.9 Leaf extension rate

In conjunction with the transect technique, leaf extension rate was also measured. The 20 marked tillers in each plot allowed an estimate of leaf elongation. Using a ruler leaf length was measured to the nearest cm at each measurement date. The average increase in leaf length (mm/day) between each measurement period was determined from these recordings. Initially only one leaf was measured from each tiller, however subsequently all leaves on each tiller were measured and the average increase in leaf length determined as above.

Plate 3.1 Sampling of herbage for calibration of the rising plate meter.

Plate 3.2 Setup of tiller appearance measurements using a transect.

3.6 Statistical Analysis

All data was analysed using the ANOVA analysis (SAS 1988) in the SAS statistical package. Both experiments were such that a time sequence of measurements of the same dependent variable was made on each of a number of experimental units, thus the data was analysed using the repeated measures analysis and meant that all data was analysed using time as replication. Means in Experiment I were compared in accordance with the randomised complete block design. In Experiment II herbage mass and pasture accumulation was analysed in accordance with the randomised split plot design. All other measurements were analysed as with Experiment I, as only measurements from one of the three sub-plots was made from each whole plot.

Correlation analysis between measured variables was performed using the Pearson product moment correlation using the proc CORR command in SAS.

Principal component analysis using SAS was used to determine the relative association between pasture accumulation rate and other sward component measurements in an attempt to decrease the dimensionality of the data and add to the understanding of the relationship between these sward components.

Regression analysis was also preformed on growth rate data to determine the trend of regrowth over various measurement periods.

4.0 RESULTS

Experiment I

4.1 Plate Meter Calibration

The calibration equation derived for Experiment I from 70 samples was Y = 123x + 115 (Figure 4.1). The r^2 of 72% illustrated a relatively good fit of the trend line to the data points, allowing some confidence in the estimates of herbage mass taken over the experimental period. Another calibration equation was derived approximately one month after the start of the experiment. This equation showed little difference from the original equation and due to the lower r^2 of the new equation, the use of the original equation was used throughout the experiment.

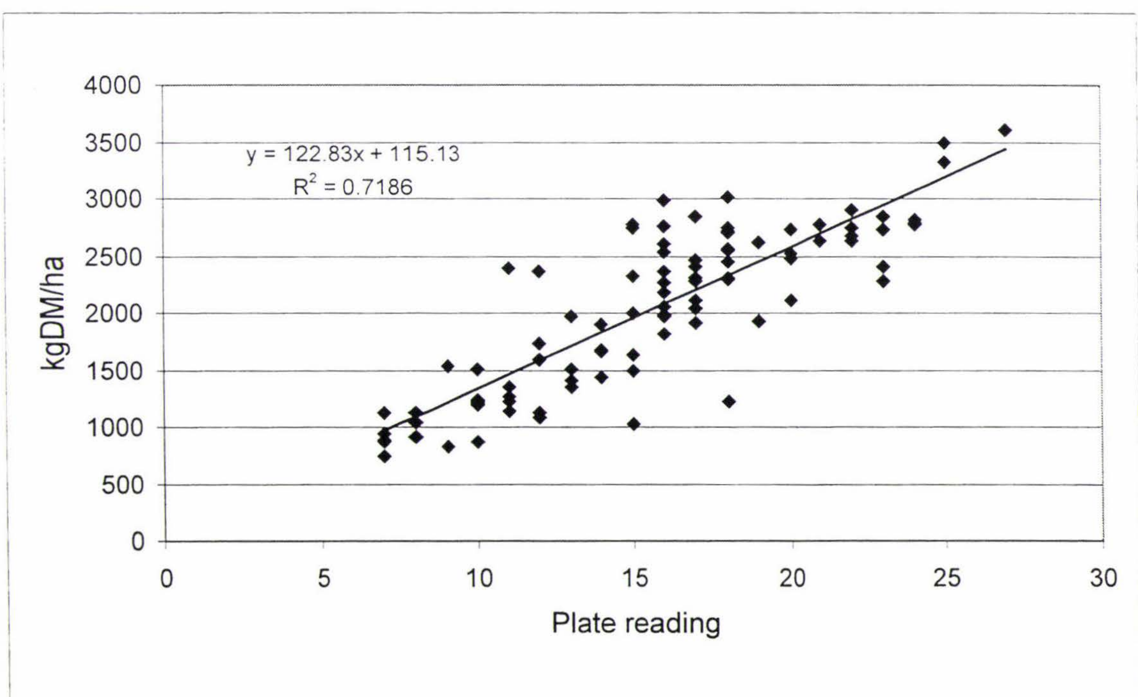


Figure 4.1 Experiment I – Calibration equation of rising plate meter.

4.2 Post Grazing Herbage Mass

The target post-grazing level and actual levels achieved for all treatments are shown in Table 4.1. The actual post-grazing residuals were all slightly lower (109 kg DM/ha on average) than the targets set. Herbage mass targets were more difficult to obtain in treatments with the higher post grazing residual targets. Plates 4.1 – 4.5 illustrate the post-grazing levels achieved. The average pre-grazing level of all treatment plots was 2846 ± 59 kg DM/ha, slightly higher than the desired level of 2700 kg DM/ha. There were no significant differences between pre-grazing herbage mass levels.

Table 4.1 Experiment I – Pre-grazing yields and target vs actual post grazing residuals (kg DM/ha).

Treatment	Pre-grazing Yields	Target post-grazing residuals	Actual post-grazing Residuals	SD
1	2864	900	870[a]	72.1
2	2881	1200	1140[b]	10.0
3	2793	1500	1394[c]	110.1
4	2915	1800	1635[d]	78.0
5	2778	2100	1917[e]	28.0
Average	2846	-	1391	59.6

Note: Treatments with different letters in the same column are significantly different (P<0.01)

Plate 4.1 Experiment I – Treatment 1 (870 kg DM/ha).

Plate 4.2 Experiment I – Treatment 2 (1140 kg DM/ha).

Plate 4.3 Experiment I – Treatment 3 (1394 kg DM/ha).

Plate 4.4 Experiment I – Treatment 4 (1635 kg DM/ha).

Plate 4.5 Experiment I – Treatment 5 (1917 kg DM/ha).

4.3 Herbage Mass

Throughout the experiment the difference in herbage mass between treatments was similar (Figure 4.2), reflecting the initial post-grazing residual herbage mass. The difference between herbage mass at each measurement date and average herbage mass over the entire experimental period was significant ($P<0.01$) between all treatments. Treatment 3 had the greatest increase in herbage accumulation over the experimental period (Table 4.2). Although the results of Table 4.2 indicate a trend in herbage mass accumulation there was no significant difference between treatments. Herbage mass accumulation was highest at the moderate post-grazing residual of Treatment 3 (1394 kg DM/ha), with accumulation decreasing as the grazing residuals both increased and decreased, with the two extreme grazing residuals (Treatments 1 and 5) having the lowest accumulation rates.

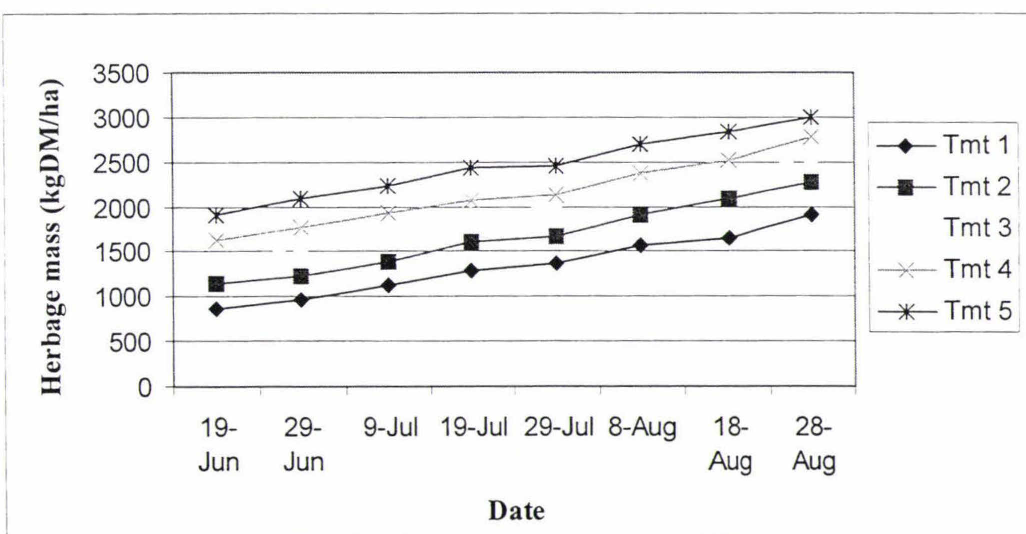


Figure 4.2 Experiment I – Change in herbage mass over time.

Table 4.2 Experiment I - Total Herbage accumulation over experimental period.

Treatment	1	2	3	4	5	SEM
Herbage mass (kg DM/ha)	1049	1124	1142	1134	1075	86 NS

Note: NS= non-significant

4.4 Herbage Mass Profile

The results of the herbage mass profile for one replicate is shown in Figure 4.3 (Profiles for Blocks 2 and 3 can be seen in Appendix 3a). These graphs help illustrate the absolute variation or the 'clumpiness' of plots through selective patch grazing of the cows and heifers. It is clearly shown that at the lower grazing residuals, the sward was more uniform as the higher grazing intensity meant lower cow intakes and increased grazing pressure.

Although Figure 4.3 shows the absolute variation, it does not reflect the variation as a proportion of the mean for each treatment, which gives a better indication of the within plot variation. Table 4.3 gives the means, standard deviation, and the coefficient of variation (CV) for each treatment. The CV gives the variation of each treatment mean as a proportion of that mean, and thus is comparable between treatments.

Table 4.3 Experiment I - Treatment means and coefficient of variation from herbage mass profiles - average of all blocks.

Treatment	1	2	3	4	5
Mean (kg DM/ha)	1210[a]	1355[b]	1838[c]	2056[d]	2373[e]
Min (RPM iterations)	4	4	6	7	9
Max (RPM iterations)	18	19	25	30	29
SD	460	510	579	569	667
CV (%)	38	38	32	19	28

Note: Treatments with different letters in the same row are significantly different ($P<0.05$)

Treatment 1 and 2 had the highest and Treatments 4 and 5 the lowest CV. Although Treatment 1 had the lowest absolute variation, even at high grazing intensities variations in micro-sward exist and will have an influence on the subsequent regrowth and botanical composition. . Figure 4.4 shows the frequency and cumulative distributions for each treatment averaged over all blocks. Figure 4.5 clearly shows that as the post-grazing residual increases, there are a greater proportion of clumps that have a higher herbage mass, meaning that while the shape of the distribution is essentially the same, it is located further up the range in herbage mass. This results in the cumulative curve of the laxer grazed treatments increasing at a higher herbage mass due to the majority of clumps having a greater herbage mass than more intensely grazed treatments which have a greater proportion of lower herbage mass clumps.

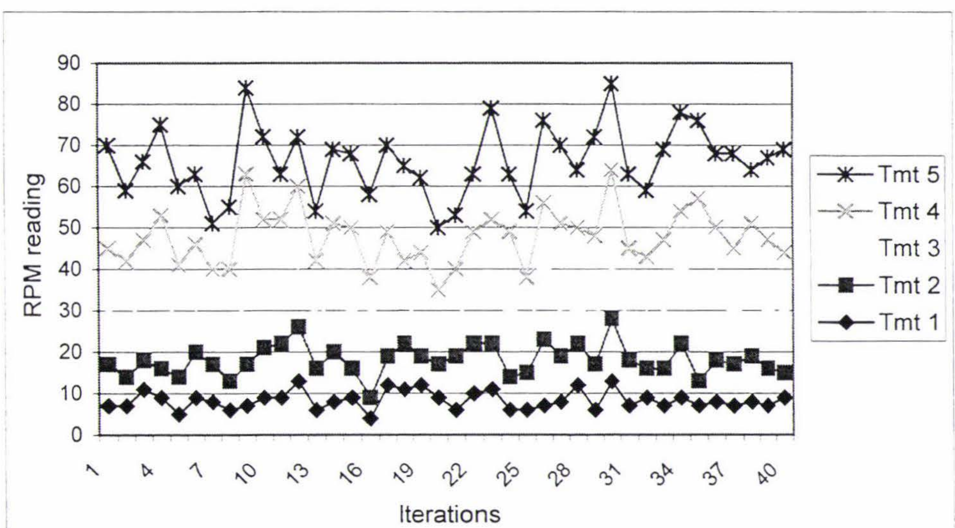


Figure 4.3 Experiment I - Variability in RPM reading within treatments (block 1)

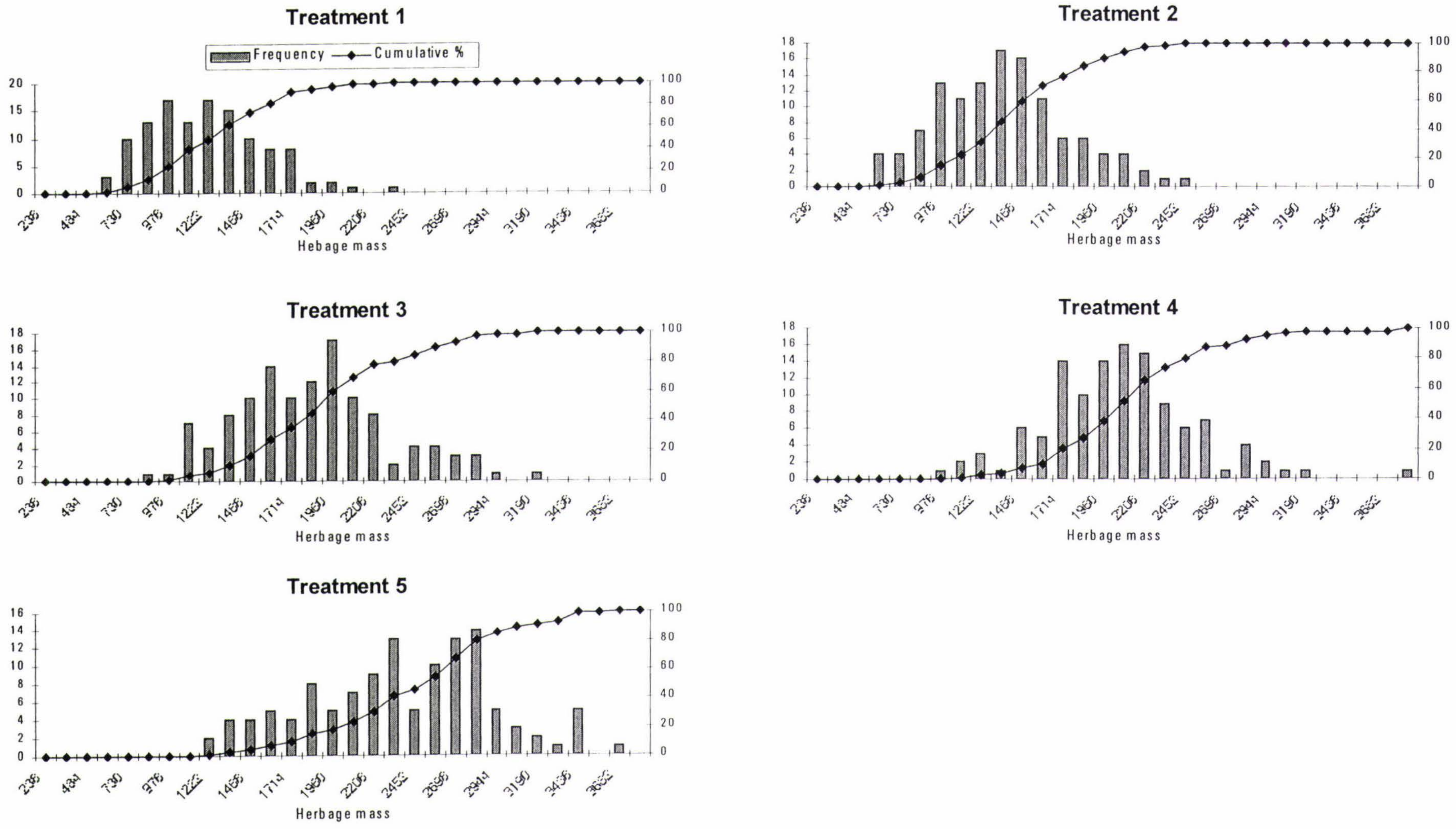


Figure 4.4 Experiment I – Herbage mass frequency and cumulative distribution of treatments averaged over all blocks.

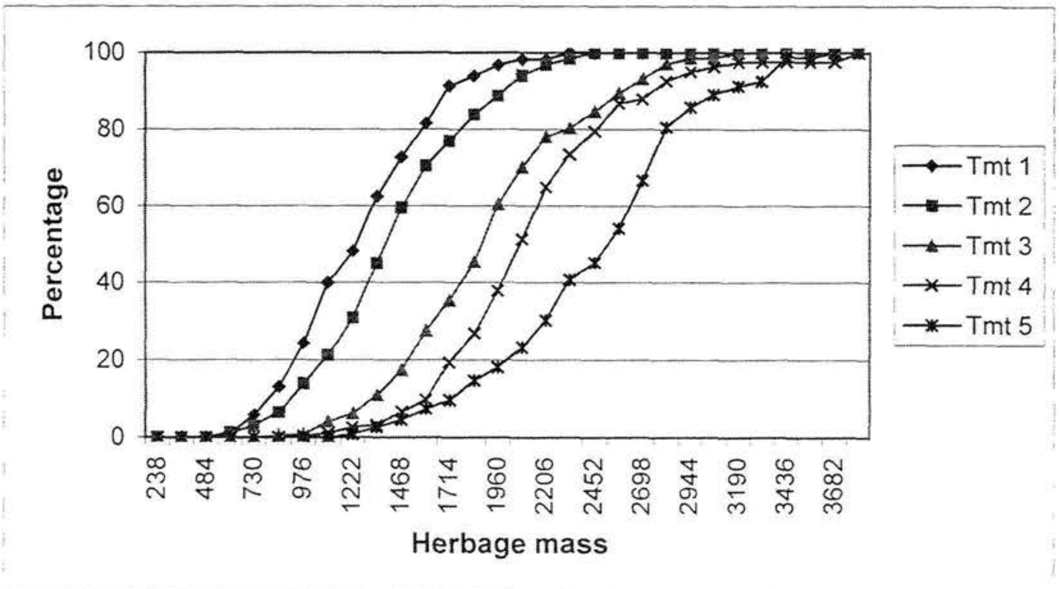


Figure 4.5 Experiment I – Cumulative distribution of herbage mass frequency between treatments.

4.5 Net Herbage Accumulation (NHA).

There were no significant differences in the average NHA rates over the experimental period (Table 4.4). The trend was for Treatment 3 having the greatest NHA with a decline at higher and lower grazing residuals. Assuming a common winter period being 100 days, Treatment 3 would grow 140, 30, 10, and 90 kg DM/ha more than Treatments 1, 2 3 and 5 respectively.

Table 4.4 Experiment I - Average NHA rates for treatments over experimental period.

Treatment	1	2	3	4	5	SEM
NHA (kg DM/ha/d)	14.9	16.0	16.3	16.2	15.4	1.96 NS

Note: NS = Not significant

The results of Table 4.4 show that Treatments 2, 3 and 4 are all very similar with any noticeable drop in NHA occurring in the two extreme grazing treatments. Treatment 3 seemed to maintain a more constant accumulation rate throughout the experiment (Figure 4.6) compared to other treatments. This is also reflected in the lowest CV (32%) compared to the other treatments (Table 4.5). Results were variable and only reached significance at August 18 some 40 days after the treatments were grazed.

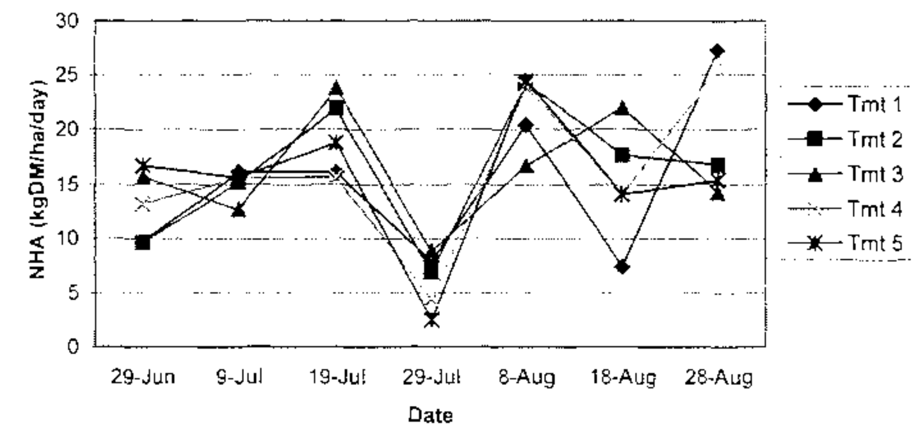


Figure 4.6 Experiment I – Change in NHA rate over experimental period.

No significant difference between the NHA rates of the five treatments at each separate measurement period occurred until August 18. At this measurement date NHA of Treatment 1 was significantly ($P<0.05$) less than Treatment 2 and Treatment 3 (7.4 < 29.6 & 22.0 respectively, SEM = 5.19), with Treatment 2 also being significantly higher ($P<0.05$) than Treatments 4 and 5 (29.6 > 14.1 & 14.1, SEM = 5.19).

Table 4.5 Experiment I - Coefficient of variation between treatments for mean NHA rate over experimental period.

Treatment	1	2	3	4	5
CV (%)	49	39	32	44	43

4.6 Tiller Density

Pre grazing tiller density between treatments was similar (4245 ± 365 tillers/m^2) with no statistical differences present between treatments (Table 4.6). Tiller density in all treatments, except Treatment 3, declined after grazing (Table 4.5). Pasture damage during grazing resulted in Treatment 1 having the greatest reduction in tiller density, where it was reduced by 48% from 4494 tillers/m^2 to 2331 tillers/m^2. Treatment 3 and Treatment 5 were both significantly greater ($P<0.05$) than Treatment 1 at this time.

After the initial reduction in tiller numbers at the lower grazing residuals (Treatment 1 and Treatment 2), the subsequent measurements on 30 July and 28 August showed that these treatments had the highest tiller densities. Treatment 1 and Treatment 2 reached densities of 12413 and 9064 tillers/m^2 respectively by 28 August. By the end of the experiment there was a marked trend in tiller density with Treatment 1 having the highest to Treatment 5 having the lowest. With the exception of Treatment 4 and Treatment 5 the tiller density between all treatments was significantly different ($P<0.05$) by the end of the experiment (Table 4.6).

Table 4.6 Experiment I – Tiller density at each measurement period.

Treatment	1	2	3	4	5	SEM
Pre-grazing	4494	4286	3530	4450	4468	451 NS
Post-grazing	2331[a]	2906[ab]	3629[b]	3301[ab]	3695[b]	423
30 July	8736[a]	7652[ab]	6552[b]	7537[ab]	5714[c]	562
28 August	12413[a]	9064[b]	7487[c]	5994[d]	5484[d]	582

Note: Treatments with different letters are significantly different ($P<0.05$)

All treatments increased in net tiller density over the experimental period. The average net increase in tiller density was greatest in Treatment 1 (Table 4.7), having a 176% increase in density as compared to Treatment 5 with an 22% increase in density. Table 4.7 clearly indicates that a lax grazing in winter resulted in reduced tiller density over the subsequent regrowth period.

Table 4.7 Experiment I – Net gain in tiller density from grazing until 28 August.

Treatment	1	2	3	4	5	SEM
Increase in tiller density (tillers/m^2)	7919[a]	4778[b]	3940[c]	1780[d]	984[e]	255

Note: Treatments with different letters are significantly different ($P<0.05$)

4.7 Tiller Weight

Despite no significant differences in tiller density in pre-grazing swards, this was not the case for tiller weight. Treatment 3 started with a significantly higher ($P<0.05$) tiller weight than Treatments 1, 2 and 5. After grazing tiller weight declined in all treatments. The reduced grazing intensity in Treatments 4 and 5 resulted in these two treatments having the smallest reduction in tiller weight (27% and 12% decrease respectively), and had a significantly greater tiller weight ($P<0.05$) than Treatment 1. Treatment 3 suffered the greatest decline in tiller weight (51%) a result of the high pre-grazing tiller weight. Tiller weight continued to decline in all treatments up until 30 July, with Treatment 5 having a significantly greater average tiller weight than Treatment 1 and Treatment 2 over this 40 day period. Between 30 July and 28 August, with the exception of Treatment 1, all treatments increased in tiller weight, with Treatment 4 having the greatest increase (36%), and Treatment 2 the lowest (6%). At the conclusion of the experiment a trend in tiller weight was obvious, with Treatment 5 having the highest and Treatment 1 the smallest. Results showed a range of statistical differences between treatments, most noticeably Treatment 1 being significantly different (P<0.05) to Treatments 3, 4 and 5, with Treatments 4 and 5 also being significantly different from each other (P<0.05).

Treatment 5 had the highest average tiller weight over the experimental period and Treatment 1 the lowest, reflecting the trend in tiller weight over the experimental period. Treatments 1 and 2 had a significantly lower (P<0.05) average tiller weight than the other treatments (Table 4.8).

Table 4.8 Experiment I – Tiller weight (mg DM/tiller) at each measurement period.

Treatment	1	2	3	4	5	SEM
Pre-grazing	48.7^{ac}	50.4^{ac}	66.2^{b}	$56.2b^{c}$	48.1^{c}	5.9
Post-grazing	28.1^{a}	32.2^{ab}	32.2^{ab}	41.0^{b}	42.5^{b}	5.4
30 July	12.2^{a}	17.5^{a}	23.3^{ab}	22.1^{ab}	31.1^{b}	2.3
28 August	11.6^{a}	18.9^{ab}	25.6^{bc}	34.5^{c}	40.6^{d}	2.3
Average	25.2^{a}	29.8^{a}	36.8^{b}	38.5^{b}	40.6^{b}	2.2

Note: mean values in the same row followed by different letters are significantly different (P<0.05).

4.8 Leaf Extension Rate

Over the experimental period Treatment 3 had the highest average leaf elongation rate with Treatment 1 and 2 being significantly lower ($P<0.01$) than Treatments 3, 4 and 5 (Table 4.9).

Table 4.9 Experiment I – Average rates of leaf elongation rate.

Treatment	1	2	3	4	5	SEM
Leaf elongation (mm/day)	3.26^{a}	3.35^{a}	4.34^{b}	4.17^{b}	4.12^{b}	0.21

Note: mean values followed by different letters are significantly different ($P<0.01$).

The trend in leaf elongation rate over time shows that the harder grazed treatments (Treatments 1 and 2) had lower elongation rates compared to the laxer grazed treatments over the entire experiment (Figure 4.7). Initially Extension rates were spread with Treatment 1 being significantly lower ($P<0.01$) than Treatments 3 and 4, with Treatment 2 also being significantly lower than Treatment 3 ($P<0.05$). Leaf extension rates for all treatments peaked on August 9, at which stage a clear separation between the hard/moderate and lax grazing treatments occurred. At this point Treatment 1 had a significantly slower leaf extension rate than Treatments 3, 4 and 5 ($P<0.05$). However by the end of the experiment there were no differences between treatments.

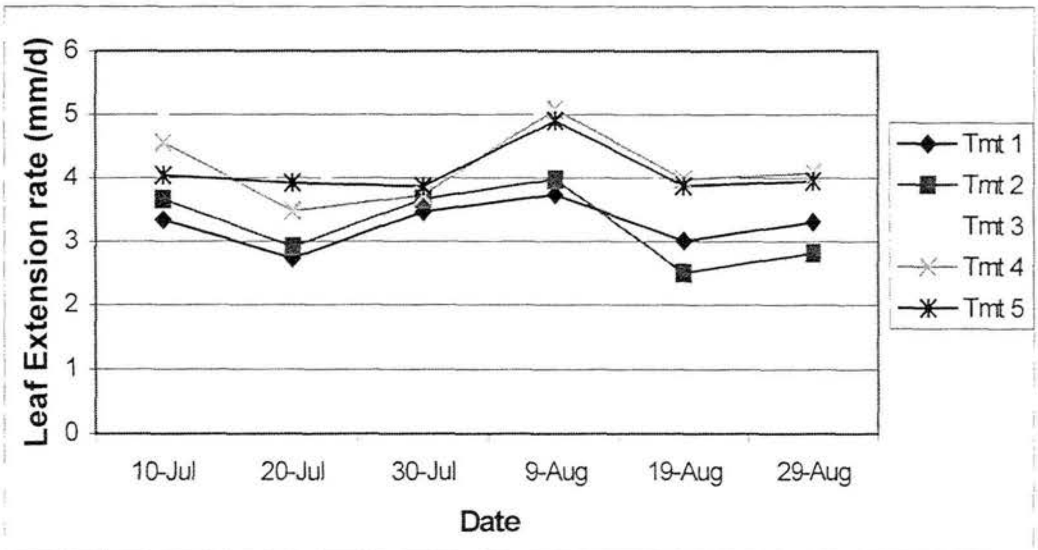


Figure 4.7 Experiment I – Trend in leaf elongation rate.

4.9 Leaf Appearance Rate

Leaf appearance rate was measured over three 20 day periods beginning on July 20. Leaf appearance rates shown in days for one fully established leaf to appear. (e.g. days/leaf). Average leaf appearance rates showed that Treatment 5 was significantly longer ($P<0.05$) than Treatment 1 and Treatment 3 (Table 4.10). As with leaf extension rate a similar trend is shown, as the moderate grazing residual (Treatment 3) had the fastest leaf appearance rate, with leaf appearance rate declining as post-grazing residual both increased and decreased. Leaf appearance rate over the first 20 day period averaged 17.2 days/leaf, however over the next 20 days this slowed markedly to 23.2 days/leaf over the second measurement period.

Table 4.10 Experiment I – Average leaf appearance rates (days/leaf) over experimental period.

Treatment	1	2	3	4	5	SEM
20 July	14.0^{a}	17.8^{ab}	16.3^{ab}	18.4^{ab}	19.4^{b}	0.9
9 August	22.7	20.6	22.5	24.3	25.9	2.9 NS
29 August	15.8	16.2	12.5	16.1	16.8	1.2 NS
Average	17.5^{a}	18.2^{ab}	17.1^{a}	19.6^{ab}	20.7^{b}	1.1

Note: mean values in the same row followed by different letters are significantly different ($P<0.05$).

Trends in leaf appearance show that as with other sward measurements environmental conditions largely dictated changes in appearance rate with small differences between treatments at each measurement period (Figure 4.8). Treatment 1 was significantly different ($P<0.05$) to Treatment 5 on July 20. No statistical differences were present at the subsequent measurement periods.

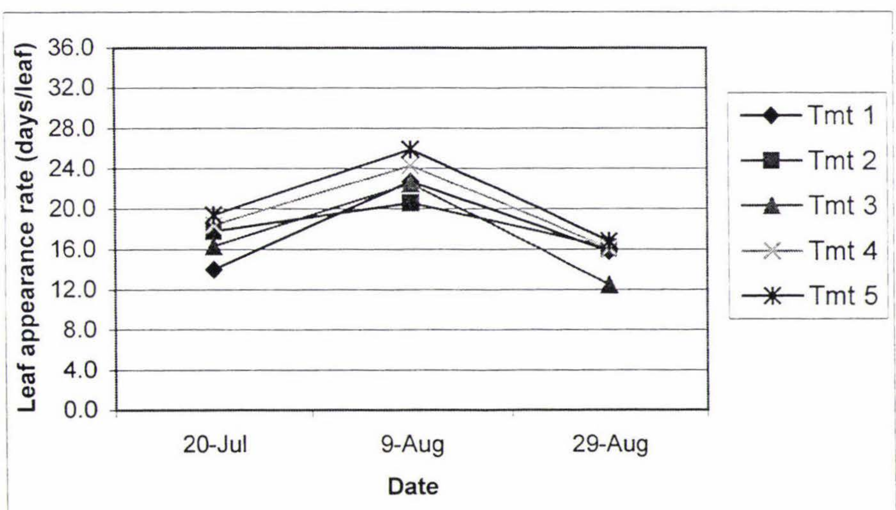


Figure 4.8 Experiment I – Trend in Leaf appearance rate.

4.9.1 Tiller appearance rate

The number of daughter tillers that emerged from the marked tillers within each treatment were also measured. Table 4.11 shows that Treatment 4 had the greatest number of new daughter tillers per tagged tiller with Treatment 5 having the least daughter tiller growth.

Table 4.11 Experiment I – Average number of daughter tillers and their leaves that emerged from marked tillers over experimental period.

Treatment	1	2	3	4	5	SD
Tiller appearance rate (daughter tillers/tiller/10 days)	0.23	0.35	0.23	0.46	0.20	0.21
Leaves per daughter tiller (leaves/tiller)	1.46	2.50	1.60	1.45	1.20	0.50

The number of leaves per daughter tiller also varied between treatments and no apparent trend was evident. Treatment 2 had the greatest number of leaves per daughter tiller with Treatment 5 having the least number.

4.10 Botanical Composition

Figures 4.9 to 4.13 show the change in grass leaf, grass stem, weeds, clover and dead material over the experimental period for Treatments 1 – 5 respectively. A feature on all treatments is the low dead matter (13%) and relatively high proportion of grass leaf (70%) to grass stem in the hard grazed treatment (Table 4.12). The lax grazed plots of Treatments 4 and 5 seem to have suppressed clover whereas the harder treatments show evidence of the amount of clover in the swards increasing.

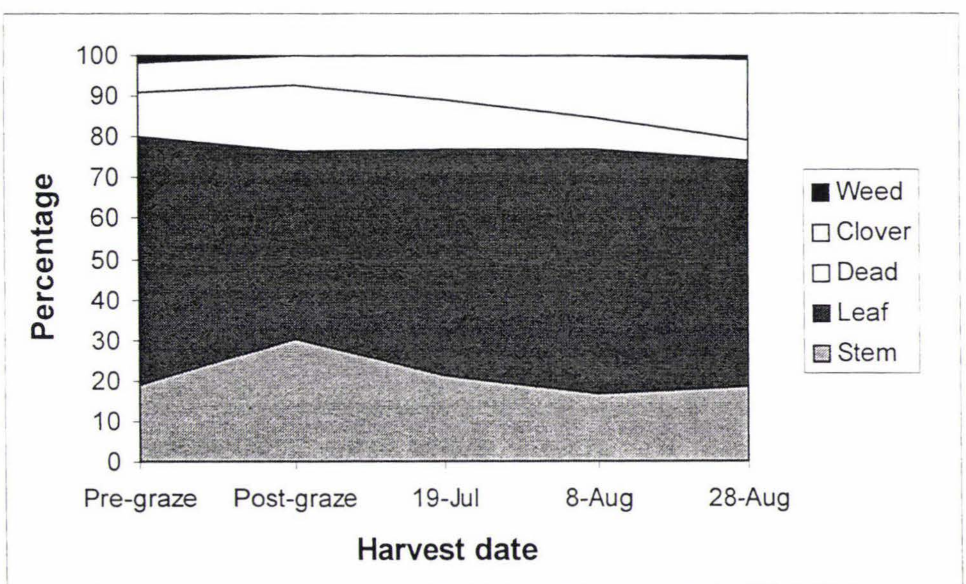


Figure 4.9 Experiment I – Change in sward composition: Treatment 1

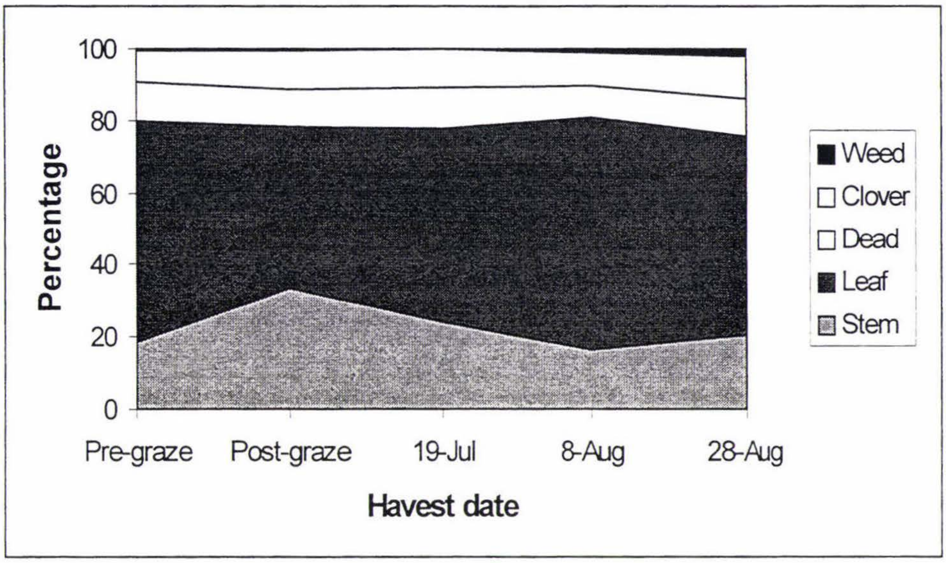


Figure 4.10 Experiment I – Change in sward composition: Treatment 2.

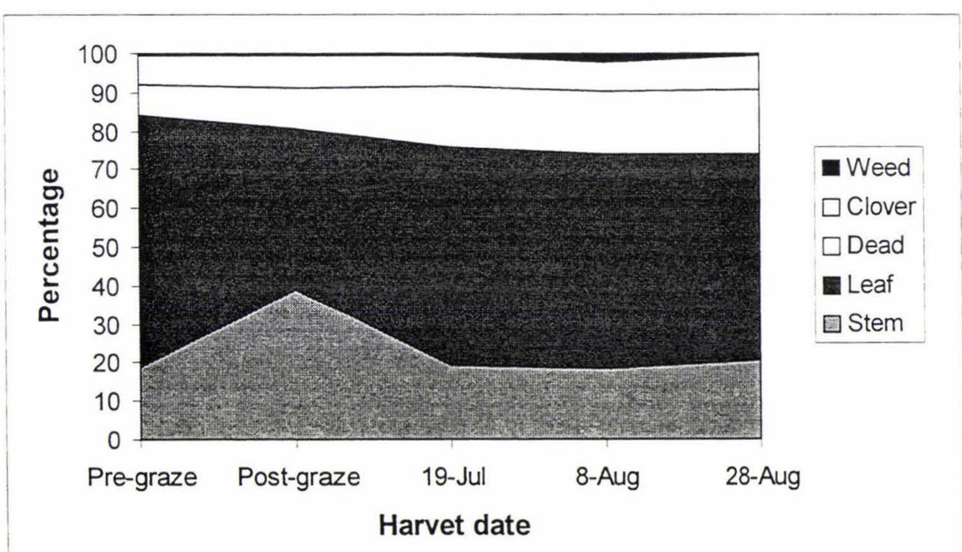


Figure 4.11 Experiment I – Change in sward composition: Treatment 3.

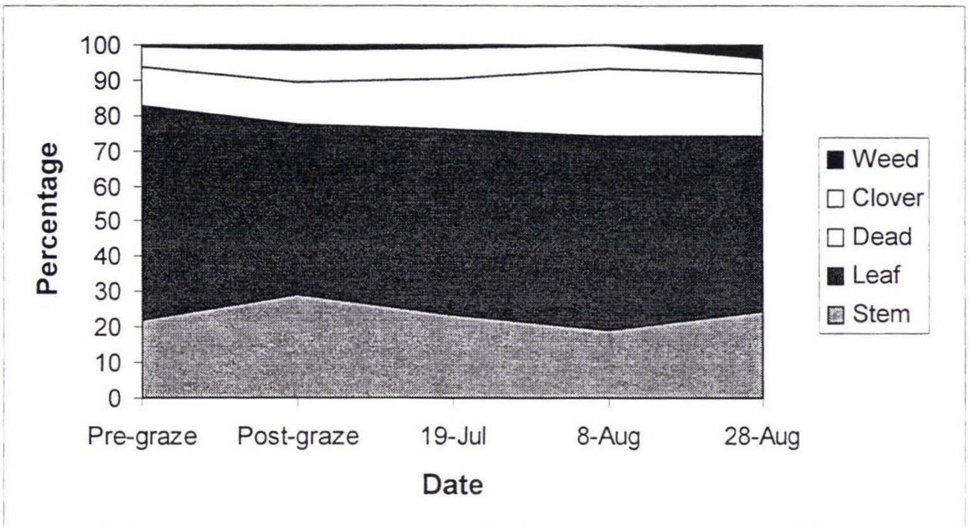


Figure 4.12 Experiment I – Change in sward composition: Treatment 4.

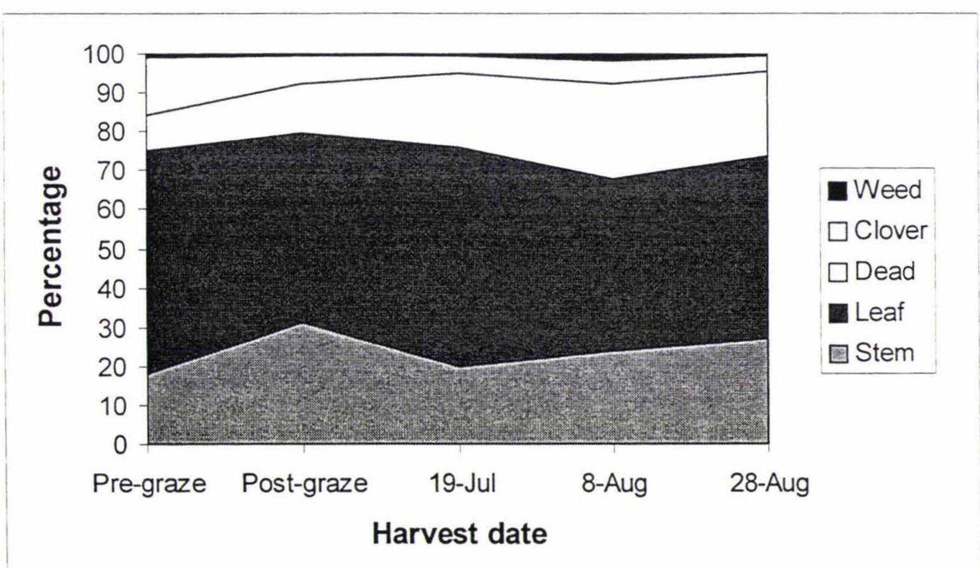


Figure 4.13 Experiment I – Change in sward composition: Treatment 5.

The results in Table 4.12 show that the more intensely grazed treatments in general had a greater leaf to stem ratio, a smaller proportion of the total herbage being dead and a greater clover content.

Grass leaf was greatest in Treatments 1 and 2, both being significantly higher ($P<0.05$) than Treatments 3 and 5. The total proportion of the sward classed as green followed the trend of grass leaf and grass stem. Treatments 1 and 2 had a significantly higher proportion of green material than Treatments 4 and 5, with Treatment 3 also being significantly higher than Treatment 5 ($P<0.05$). The proportion of clover to grass was greatest in the harder grazed treatments. The proportion of clover in Treatment 1 was significantly higher than in Treatments 3, 4 and 5, with Treatment 2 also having a higher proportion of clover than Treatments 4 and 5 ($P<0.05$).

Table 4.12 Experiment I - Comparison of ratios of grass stem vs grass leaf, green vs dead material, and grass vs clover averaged over the experimental period.

Treatment	1	2	3	4	5	SEM
Grass stem (%)	28^{a}	28^{a}	32^{b}	31^{ab}	33^{b}	1.4
Grass leaf (%)	72^{a}	72^{a}	68^{b}	69^{ab}	67^{b}	1.4
Green (%)	90^{a}	90^{a}	87^{ab}	85^{bc}	83^{c}	1.4
Dead (%)	10^{a}	10^{a}	13^{ab}	15^{bc}	17^{c}	1.4
Grass (%)	87^{a}	88^{ab}	91^{bc}	92^{c}	91^{c}	1.4
Clover (%)	13^{a}	12^{ab}	9^{bc}	8^{c}	9^{c}	1.4

Note: mean values with different letters are significantly different ($P<0.05$).

Table 4.13 shows mean values of sward components over the trial period. Comparing the two extreme treatments (Treatments 1 and 5), it can be seen that the hard grazed treatment had a lower proportion of grass stem and dead matter and higher proportion of grass leaf and clover as reflected in Table 4.12. Although pasture production between all treatments was similar, using sward composition as an indicator, the quality of the herbage produced in Treatments 1 and 2 was of a higher quality.

Table 4.13 Experiment I - Average percentage of grass stem, grass leaf, dead matter, clover and weeds of swards over the experimental period.

Treatment	1	2	3	4	5	SEM
Grass stem	21.1	22.6	23.3	23.9	24.1	0.8
Grass leaf	55.5	55.9	54.4	53.6	50.6	1.3
Dead matter	10.9	10.3	13.5	14.6	17.3	1.0
Clover	12.0	10.3	7.9	6.4	7.4	0.8
Weeds	0.5	0.9	0.9	1.5	0.6	0.3

4.11 Near Infrared Reflectance (NIR)

NIR analysis was conducted on three occasions. As few differences occurred between treatments only mean values for the three sample periods is presented. There were no statistical differences between treatments for metabolisable energy content, digestibility and NDF for the average value of each variable over the entire measurement period (Table 4.14). The average ADF percentage showed that Treatment 1 was significantly higher than Treatment 3 and 4, and Treatment 2 was significantly higher than Treatment 4 ($P<0.05$). Analysis of the proportion of protein shows that Treatment 1 was significantly lower than Treatment 2 and Treatment 3, 4 and 5 ($P<0.05$). This is the opposite to what the results of the botanical composition suggested, as it showed clover levels in the hard grazed treatments to be greater than in lax grazed swards.

Table 4.14 Experiment I - Average values measured by NIR for each treatment over experimental period (mg/g).

Treatment	1	2	3	4	5	SEM
ME	11.5	11.6	11.7	11.7	11.8	0.16 NS
Digestibility	77.4	76.7	78.8	78.5	77.5	1.07 NS
ADF	21.4^{a}	21.1^{ab}	$19.5b^{c}$	19.1^{c}	20.2^{bc}	0.68
NDF	38.4	38.6	38.6	37.4	39.5	1.19 NS
Protein	26.2^{a}	27.9^{b}	28.5^{b}	29.0^{b}	28.7^{b}	0.55

Note: mean values with different letters are significantly different ($P<0.05$).

5.0 RESULTS

Experiment II

5.1 Plate Meter Calibration

A total of 70 quadrat samples were again taken to determine an equation to be used over the spring experiment. Figure 5.1 shows that the derived equation was Y = 140x – 89, and the r^2 was 79%. Despite the majority of data points having a relatively good fit to the trendline, a wide variation of herbage mass recordings at plate meter readings above 25 reduced the r^2 value.

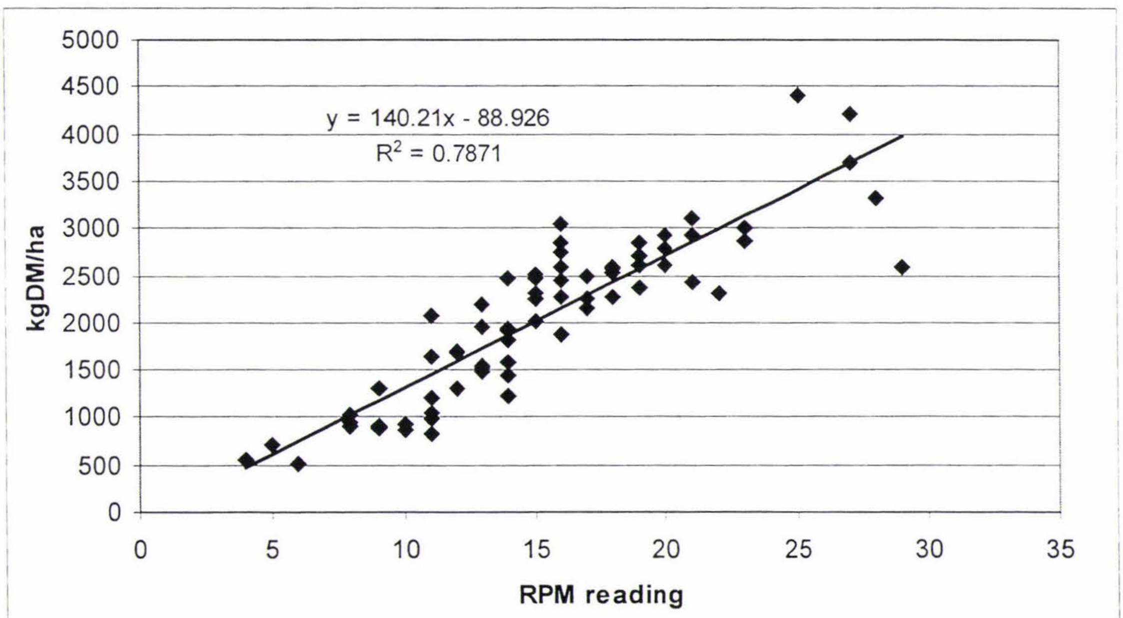


Figure 5.1 Experiment II – Calibration equation of rising plate meter.

5.2 Post Grazing Herbage Mass

Pre-grazing herbage mass averaged 2722 ± 104 kg DM/ha, being close to the desired pre-grazing herbage mass target of 2700 kg DM/ha. The pre-grazing herbage mass of Treatment 1 was significantly lower ($P<0.05$) than the other treatments. Post-grazing levels achieved were lower than the target levels by an average of 114 kg DM/ha (Table 5.1). The highest grazing residual (with the lowest grazing intensity) treatment (Treatment 4) was again the most difficult to achieve, being 187 kg DM/ha below the target herbage mass.

After grazing, all post grazing residuals between treatments were significantly different ($P<0.05$) to each other (with the exception of Treatments 3 and 4, Table 5.1).

Table 5.1 Experiment II – Pre-grazing yields and target vs actual post grazing residuals (kg DM/ha).

Treatment	Pre-grazing yields	Target post-grazing residuals	Actual post-grazing residuals	SD
1	2534^{a}	1200	1098a	118
2	2769^{b}	1500	1424b	142
3	2889^{b}	1800	1704c	183
4	2695^{b}	2100	1913c	189
Average	2722	-	1535	104

Note: Treatments with different letters in the same column are significantly different ($P<0.05$)

Plates 5.1-5.4 illustrate the range in post-grazing levels achieved. From the plates it can be seen that a range of grazing residuals were successfully achieved, with approximately 250-300 kg DM/ha difference between treatments.

Plate 5.1 Experiment II – Treatment 1 (1098).

Plate 5.2 Experiment II – Treatment 2 (1424).

Plate 5.3 Experiment II – Treatment 3 (1704).

Plate 5.4 Experiment II – Treatment 4 (1913).

5.3 Herbage Mass

As with Experiment I the general trend in herbage mass over the experiment reflected the differences in post-grazing values and was similar (Figure 5.2).

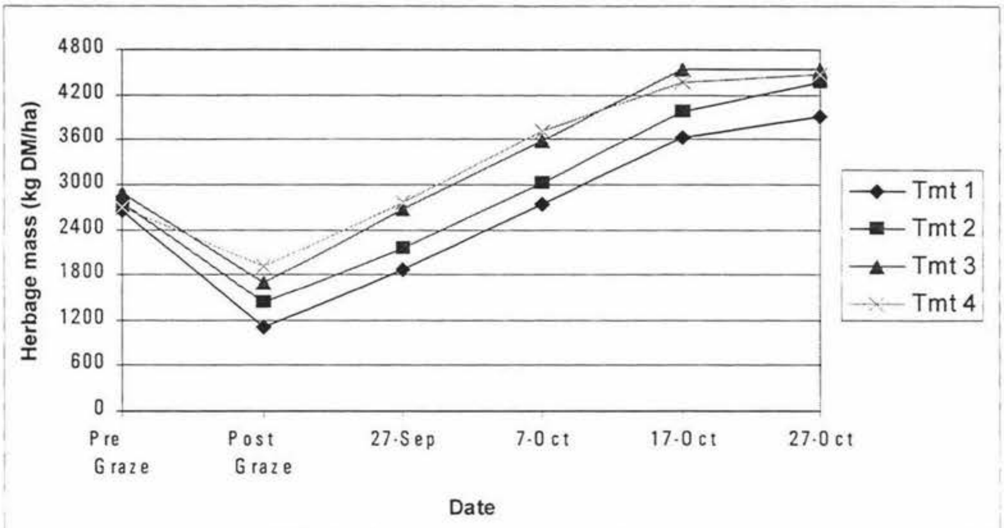


Figure 5.2 Experiment II – Change in herbage mass over time.

However over the experimental period total net accumulation was significantly lower (P<0.1) for Treatment 4 (Table 5.2), being some 244 kg DM/ha on average less than the other treatments.

Treatment 1 had a significantly lower (P<0.01) average herbage mass over the experimental period than Treatment 2 (2638 vs 2949 kg DM/ha respectively) with Treatment 2 being significantly lower (P<0.01) than Treatment 3 (3302 kg DM/ha). Treatment 3 had a slightly greater average herbage mass than Treatment 4, being (3310 kg DM/ha), but was not statistically different.

Table 5.2 Experiment II - Total Herbage accumulation and average herbage mass over experimental period.

Treatment	1	2	3	4	SEM
Herbage accumulation (kg DM/ha)	2802[a]	2819[a]	2781[a]	2557[b]	123
Average herbage mass	2638[a]	2949[b]	3310[c]	3302[bc]	43.6

Note: mean values followed by different letters are significantly different ($P<0.1$).

5.4 Herbage Mass Profile

Figure 5.3 illustrates the within plot distribution of herbage mass between treatments for Block 1 (see Appendix 3b for blocks 2 and 3). In two of the three replicates large clumps of cocksfoot (*Dactylsis glomerata*) were present at one end of the paddock. These were of concern due to their quantity, the cows avoided grazing these large clumps even in the high grazing intensity treatments. Topping of these clumps with a mower was considered, but it was decided to leave the clumps as in most cases topping of pastures occurs late in the spring. The trend as with the first experiment, was that the more intensely grazed swards were more uniform as a result of increased grazing pressure and reduced per cow intakes.

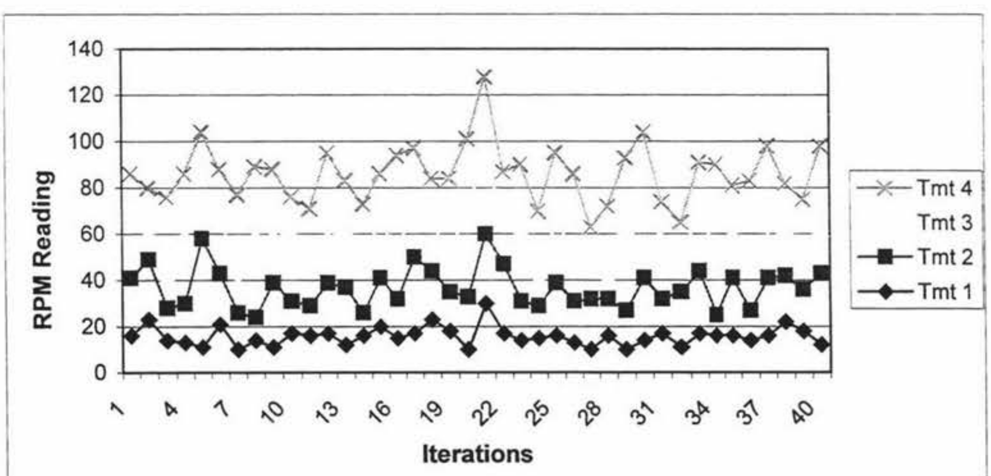


Figure 5.3 Experiment II – Variability in RPM reading within treatments (Block 1).

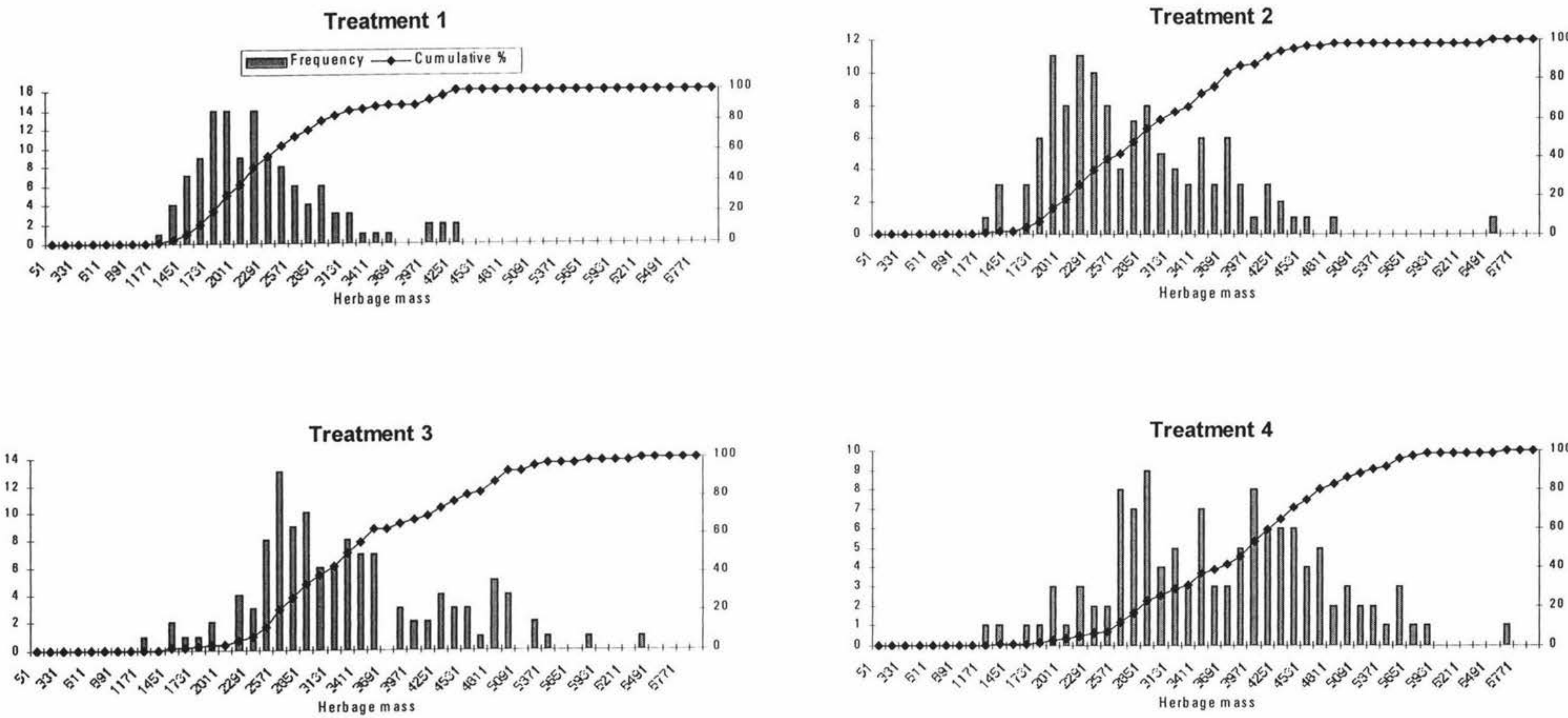


Figure 5.4 Experiment II – Herbage mass frequency and cumulative distribution of treatments averaged over all blocks.

Figure 5.4 shows the frequency and cumulative distributions for each treatment averaged over all blocks. As in Experiment laxer grazed plots had a higher proportion of higher herbage mass clumps (Figure 5.5). Table 5.3 reflects the trend shown in all treatments in Figure 5.4 with the standard deviation of Treatment 1 (± 573 kg DM/ha) being much lower than Treatment 4 (± 971 kg DM/ha). However the variation within treatments as a proportion of the treatment mean reflects a similar degree of variation. The within plot variation between treatments is similar, with the CV ranging between 26 – 29% (Table 5.3).

Table 5.3 Experiment II - Treatment means and coefficient of variation from herbage mass profiles - average of all blocks.

Treatment	1	2	3	4
Mean (kg DMha)	2218[a]	2684[b]	3267[c]	3597[d]
Min (RPM iterations)	9	9	9	9
Max (PRM iterations)	31	47	46	48
SD	573	776	892	971
CV (%)	26	29	27	27

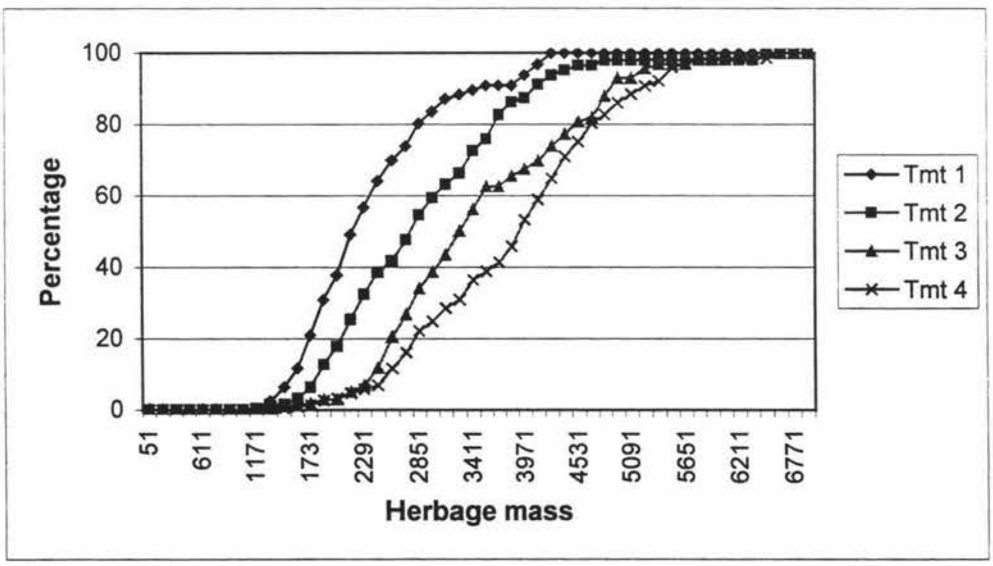


Figure 5.5 Experiment II – Cumulative distribution of herbage mass frequency between treatments.

5.5 Net Herbage Accumulation (NHA)

Table 5.4 shows that over the 40 day spring experiment NHA rates were high (63.8 kg DM/ha/day) with only relatively small non-significant differences between treatments. Treatment 2 had the highest average accumulation rate, and Treatment 4 the lowest.

Table 5.4 Experiment II - Average NHA rates for grazing treatments over experimental period.

Grazing treatment	1	2	3	4	SEM
NHA (kg DM/ha/day)	64.1	67.7	63.8	59.5	4.92 NS

NS = non significant

The trend in accumulation rate between treatments was quite similar (Figure 5.6), with all treatments reaching a maximum herbage accumulation rate on the second measurement period (October 7), 20 days after the treatments were grazed.

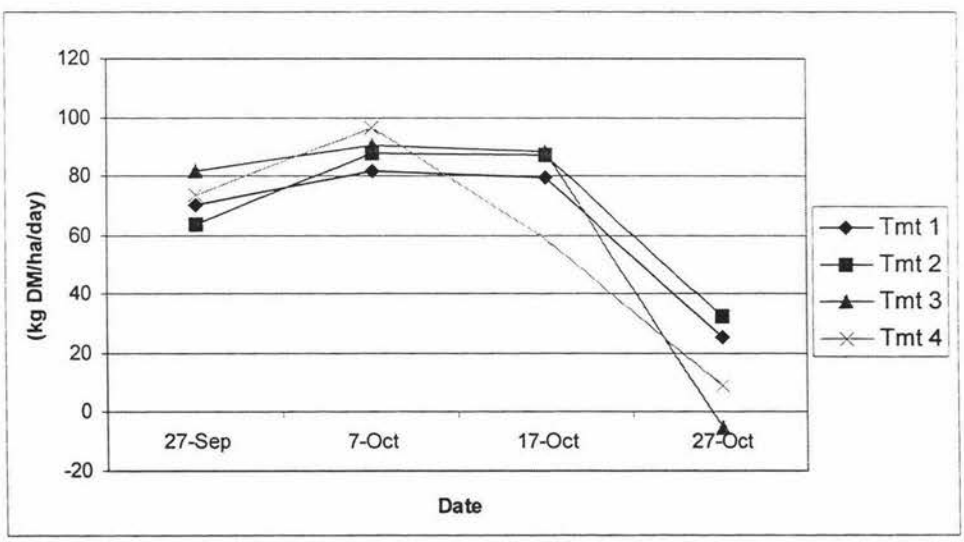


Figure 5.6 Experiment II – Change in NHA rate over experimental period for grazing treatments.

Differences between treatments at different measurement periods occurred at the final two measurement dates (October 17 and 27 respectively). On October 17

Treatments 2 and 3 were significantly higher (P<0.05) than Treatment 4 (87.2, 88.1 and 59.0 kg DM/ha/day respectively). Over the final 10 day period NHA rates for Treatments 1 and 2 were significantly higher (P<0.05) than Treatment 3 (25.5, 32.6 and –5.1 respectively), with Treatment 2 also being statistically higher (P<0.1) than Treatment 4 (9.2 kg DM/ha/day).

The effect of nitrogen sub-treatments on NHA rates is shown in Figure 5.7. There was no interaction present between nitrogen and grazing treatments. However as with the significant interactions between grazing treatments and measurement date (period), there was also a statistical interaction between nitrogen treatments and measurement date. No consistent trend between average herbage accumulation rates and nitrogen treatments were present. Initially growth rates were similar, then nitrogen Treatment C (50 kg N/ha) increased sharply, and had a significantly greater (P<0.05) NHA rate than Treatments A and B between September 27 and October 7 (107.4, 80.1 and 80.0 kg DM/ha/day). Growth rates over the next period were similar with no statistical differences occurring as a result of Treatment C declining by over 40 kg DM/ha/day while Treatments A and B increased slightly. Over the last 10 day period accumulation rate declined sharply (Figure 5.6), with Treatment A being significantly higher (P<0.1) than Treatment B.

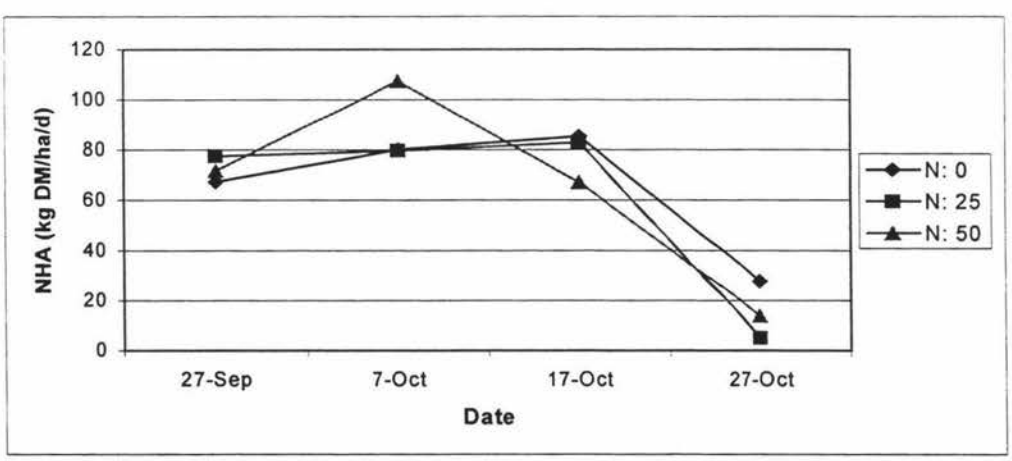


Figure 5.7 Experiment II – Change in NHA rate over experimental period for nitrogen treatments.

Average herbage accumulation rates over the experimental period between the three nitrogen treatments also show no significant response to nitrogen treatments over the experimental period (Table 5.5).

Table 5.5 Experiment II - Average NHA rates for nitrogen treatments over experimental period.

Nitrogen treatment	A	B	C	SEM
NHA (kg DM/ha/day)	65.1	61.3	65.0	4.26 NS

NS = non significant

5.6 Tiller Density

The average pre grazing tiller density was 5673 ± 307 tillers/m^2 and was similar between treatments. As with Experiment I, tiller density in all treatments declined slightly, following grazing. However and trend over the experiment was quite different from that of Experiment I. Tiller density declined over the experimental period (Table 5.6) with the average tiller density at each subsequent measurement date and in most cases being significantly ($P<0.05$) lower than at the previous date. The only difference between treatments was recorded on the third measurement date (October 7) where Treatment 1 was significantly greater than Treatment 4 ($P<0.05$). By the end tiller density between the four treatments was again similar (Table 5.6).

Table 5.6 Experiment II - Tiller density at each measurement period.

Treatment	1	2	3	4	SEM
Pre-grazing	5961	5353	5928	5452	725 NS
Post-grazing	5517	4499	5419	4778	751 NS
7 October	5862^{a}	5140^{ab}	4417^{ab}	3892^{b}	467
29 October	4154	3530	3793	3842	423 NS
Average	5374^{a}	4631^{ab}	4889^{ab}	4491^{b}	308

Note: Treatments with different letters in the same row are significantly different ($P<0.05$)

Despite the difference in trend between the two experiments, a similar pattern was recorded in the average tiller density over the experimental period. Treatment 1 had the highest average tiller density (Table 5.6), and was significantly higher than Treatment 4 ($P<0.05$).

The net increase in tiller density over the experimental period was negative in all treatments (Table 5.7) with Treatment 3 having a significantly ($P<0.01$) greater decline than the other treatments unlike Treatment 4 which had the smallest decline in tiller density.

Table 5.7 Experiment II - Net gain in tiller density from grazing until 29 October.

Treatment	1	2	3	4	SEM
Increase in tiller density (tilles/m^2)	- 1807^a	- 1823^a	- 2145^b	-1610^a	331

Note: mean values followed by different letters are significantly different ($P<0.01$).

5.7 Tiller Weight

Analysis of tiller weight shows a similar trend to that in Experiment I, with the harder grazing treatments having the lowest mean tiller weight over the experiment (Table 5.8). Pre-grazing tiller mass between treatments was non-significant and averaged 35.5 ± 4.8 mg DM/tiller. Following grazing Treatment 1 had the lowest tiller weight followed by Treatments 2, 3 with Treatment 4 having the greatest tiller weight, yet differences were not significant. Tiller weight in all treatments increased markedly from grazing until October 7 (19 day period) by an average of 61% (reflecting the high NHA rates) with Treatments 3 and 4 having a significantly higher tiller weight than Treatments 1 and 2. Between October 7and October 29 (22 day period) the average increase in tiller weight was 38%. At the conclusion of the experiment average tiller weight for Treatment 1 was significantly lower ($P<0.05$) to the other treatments.

Table 5.8 Experiment II - Tiller weight (mg DM/tiller)) at each measurement period.

Treatment	1	2	3	4	SEM
Pre-grazing	34.0	38.2	28.5	41.4	5.9 NS
Post-grazing	13.7	20.1	21.4	29.0	4.2 NS
7 October	37.5^{a}	46.2^{a}	62.1^{b}	71.0^{b}	4.6
29 October	69.8^{a}	94.2^{b}	93.2^{b}	92.3^{b}	11.1
Average	38.7^{a}	49.7^{b}	51.3^{b}	58.5^{b}	3.5

Note: Mean values with different letters are significantly different (P<0.05)

5.8 Leaf Appearance Rate

Leaf appearance rate was measured over the length of the experiment giving a better picture of the trend of this variable compared to Experiment I. No trend is shown in leaf appearance rate (Table 5.9) with Treatment 2 and Treatment 4 having the fastest appearance rate and were both significantly different to Treatment 3 (P<0.05) with the slowest leaf appearance rate.

Table 5.9 Experiment II – Average leaf appearance rates over experimental period.

Treatment	1	2	3	4	SEM
Leaf appearance rate (Days/leaf)	14.7^{ac}	13.2^{a}	16.9^{c}	13.0^{a}	1.3

Note: Mean values in the same row with different letters are significantly different (P<0.05).

Following grazing all treatments had a similar leaf appearance rate, with no statistical differences present (Figure 5.8). Initially (7 October) Treatment 1 had a significantly slower leaf appearance rate than Treatments 2, 3 and 4 (P<0.05). Over the next two measurement periods the intense grazing of Treatment 1 seemed to have a detrimental effect on its leaf appearance rate, as it was clearly much slower than the other treatments (Figure 5.8), however it was not statistically different. Over the last 10 day period the leaf appearance rate of Treatment 3 slowed dramatically to (22.3 days/leaf), and was significantly slower than all other treatments (P<0.05).

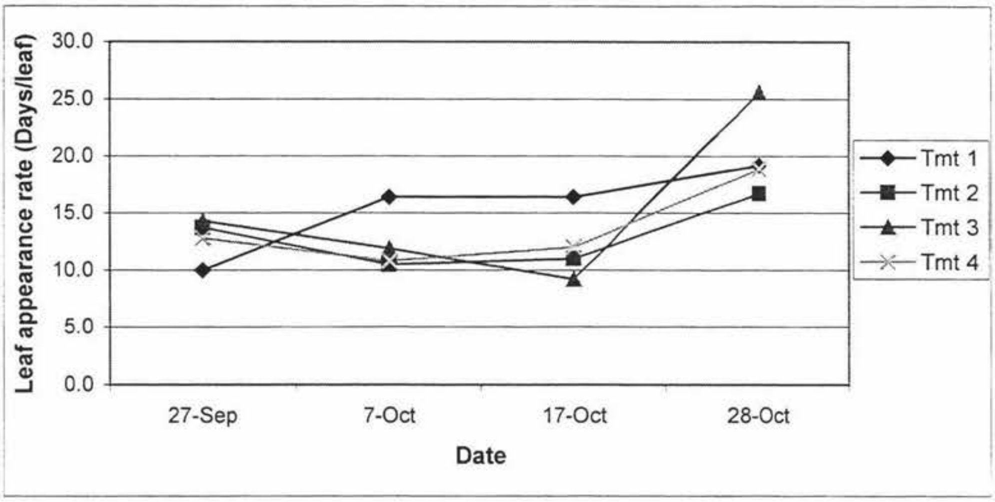


Figure 5.8 Experiment II – Trend in leaf appearance rates.

5.8.1 Tiller appearance rate

The average number of daughter tillers that emerged from primary tillers was again measured. Results (Table 5.10) indicated a trend with more intensive grazing resulting in a greater number of emerged daughter tillers per primary tiller, as Treatment 1 had the greatest number of daughter tillers per primary tiller and Treatment 4 the lowest. The differences were not significant.

The numbers of leaves per daughter tiller was almost opposite to the number of daughter tillers produced. Treatment 3 had the greatest number of leaves per daughter tiller followed by Treatment 4.

Table 5.10 Experiment II – Average number of daughter tillers and their leaves that emerged from marked tillers over experimental period.

Treatment	1	2	3	4	SD
Tiller appearance rate (daughter tillers/tiller/10 days)	0.23	0.20	0.18	0.15	0.11
Leaves per daughter tiller (leaves/tiller)	2.02	1.97	2.24	2.13	0.13

5.9 Botanical Composition

The proportion of stem in all swards was considerably higher than in the first experiment, even when herbage mass was at a similar level. Towards the end of the experiment the proportion of stem in the swards was beginning to increase rapidly as herbage mass started approaching 4000-5000 kg DM/ha and above (Figures 5.9 – 5.12).

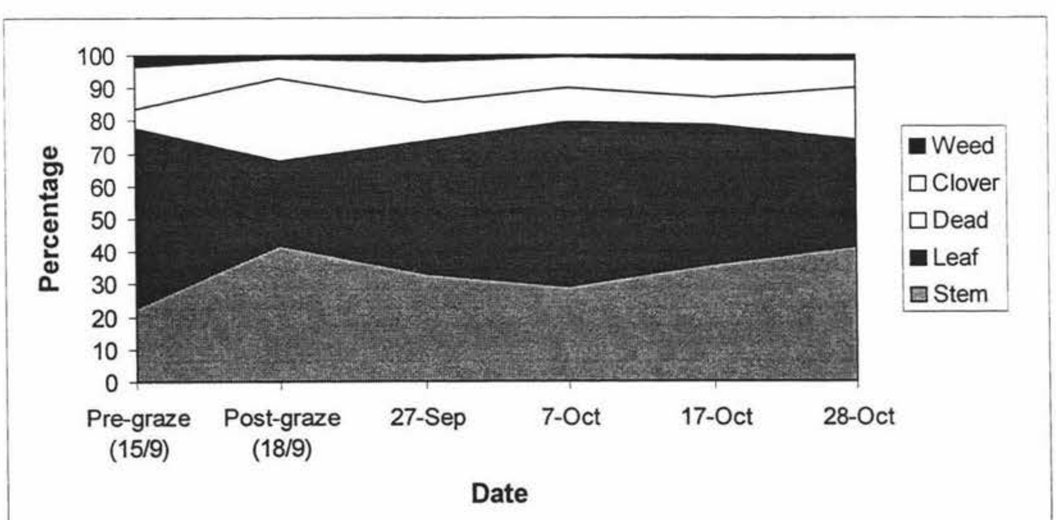


Figure 5.9 Experiment II – Change in sward composition: Treatment 1.

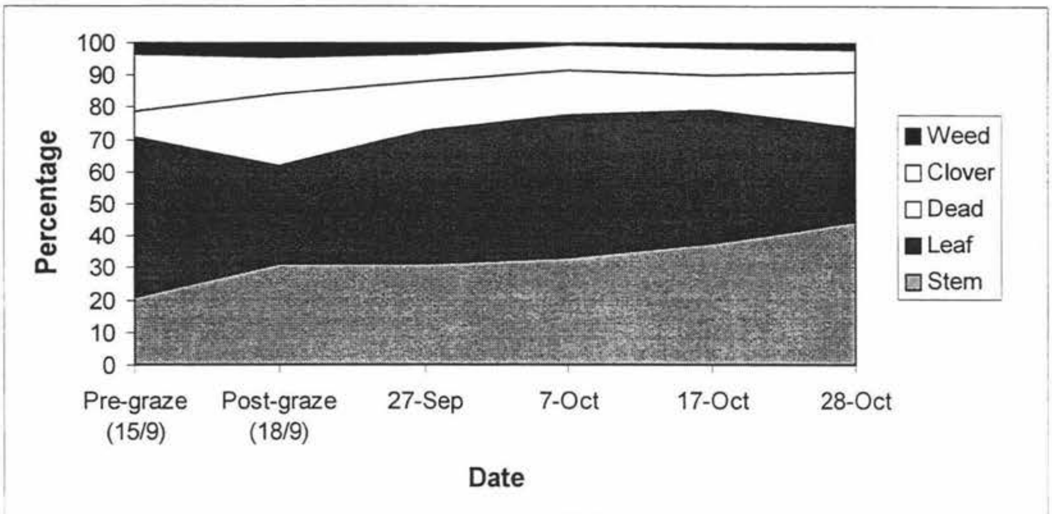


Figure 5.10 Experiment II – Change in sward composition: Treatment 2.

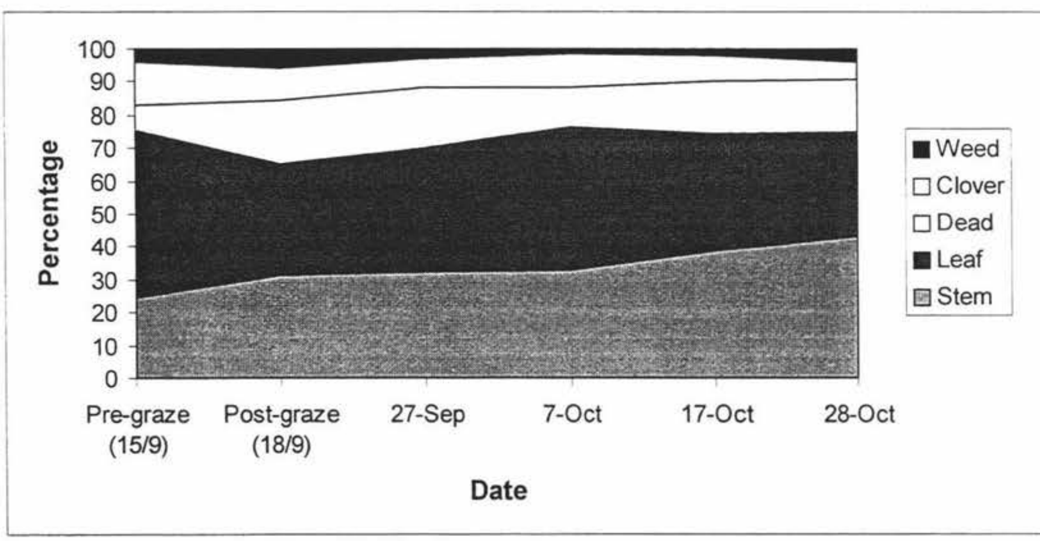


Figure 5.11 Experiment II – Change in sward composition: Treatment 3.

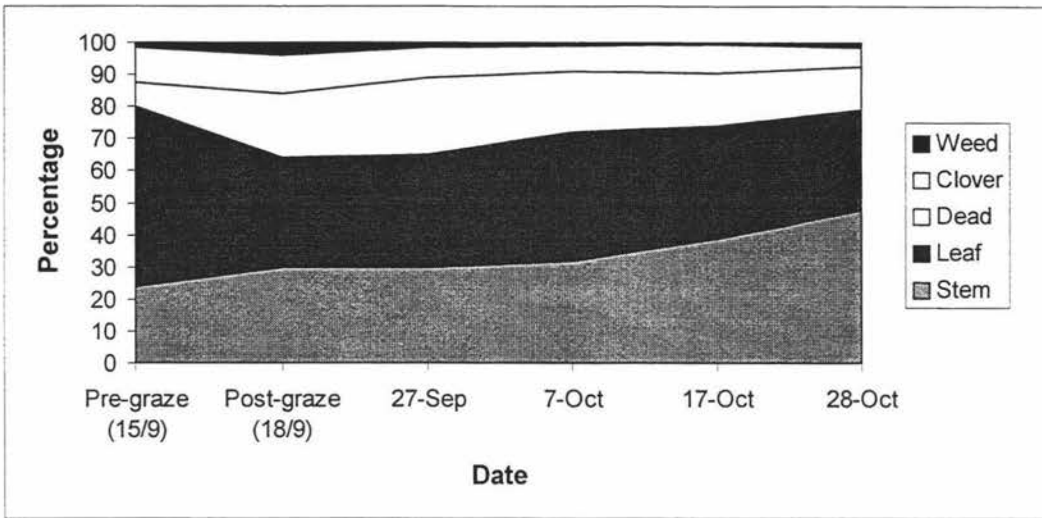


Figure 5.12 Experiment II – Change in sward composition: Treatment 4.

The proportion of grass stem to grass leaf was higher in this experiment compared to Experiment I. Dead matter was similar with clover and weed proportions being slightly higher (Table 5.11). For all variables indicating pasture quality (Table 5.12) there were no statistical differences between treatments.

In summary, using botanical composition as an indicator, treatment swards in Experiment II were of similar quality.

Table 5.11 Experiment II – Average percentage of grass stem, grass leaf, dead matter, clover and weeds of treatment swards over the experimental period

Treatment	1	2	3	4	SEM
Grass stem	34.2	33.1	33.9	33.8	1.2
Grass leaf	41.2	39.6	39.0	38.9	1.2
Dead matter	13.1	14.8	14.7	16.8	0.9
Clover	10.0	10.7	9.3	9.1	0.9
Weeds	1.7	2.6	2.9	1.7	0.6

Table 5.12 Experiment II – Comparison of ratios of grass stem vs grass leaf, green vs dead material, and grass vs clover averaged over the experimental period.

Treatment	1	2	3	4	SEM
Grass stem (%)	46	46	47	46	2.6 NS
Grass leaf (%)	54	54	53	54	2.6 NS
Green (%)	87	85	85	83	2.6 NS
Dead (%)	13	15	15	17	2.6 NS
Grass (%)	88	88	89	89	2.6 NS
Clover (%)	12	12	11	11	2.6 NS

NS = non significant.

5.10 Near Infrared Reflectance (NIR)

The trend of each of the variables measured using NIR analysis over the experiment is shown in Figure 5.13. Digestibility and ME declined slightly over time, although not as much as expected, given the herbage mass levels obtained towards the end of the experiment in all treatments. ADF level increased sharply towards to end of the experiment, while NDF levels maintained a gradual rise throughout the experiment. The protein levels in all treatments declined sharply from grazing until the first measurement date. After increasing again they gradually declined as the experiment progressed. Although not shown by botanical composition analysis, by the end of the experiment, there was evidence that the laxer treatments which allowed slightly increased levels of clover production (although not significant) significantly increased protein content, as Treatment 4 had a significantly higher ($P<0.05$) protein level than Treatment 1.

Table 5.13 shows the average of NIR analysis for each treatment. The non-significant results in the botanical composition analysis (Table 5.12) are largely reflected in the NIR analysis. The reason for non-significant results for ME, digestibility and protein are probably similar to those given for non-significant results in the botanical composition. However it can be seen that Treatment 1 had a significantly higher (P<0.05) ADF level than Treatments 3 and 4, with Treatment 2 also being significantly higher than Treatment 4. NDF levels showed a similar trend, as Treatment 1 and was again significantly higher than Treatments 3 and 4 (P<0.05). Of note was that with all quality indicators all treatments generally showed the same trend, either increasing or decreasing over time, reflecting the lack of statistical differences between treatments.

Table 5.13 Experiment II - Average values measured by NIR for each treatment over experimental period (mg/g)

Treatment	1	2	3	4	SEM
ME	11.1	11.2	11.2	11.1	0.1 NS
Digestibility	75.1	70.2	75.1	74.3	2.4 NS
ADF	26.5a	25.8ab	24.8bc	24.4c	0.4
NDF	44.7a	44.3ab	43.0b	43.3b	0.5
Protein	21.7	21.9	22.7	22.8	0.6 NS

Note: Mean values in the same row with different letters are significantly different (P<0.05).

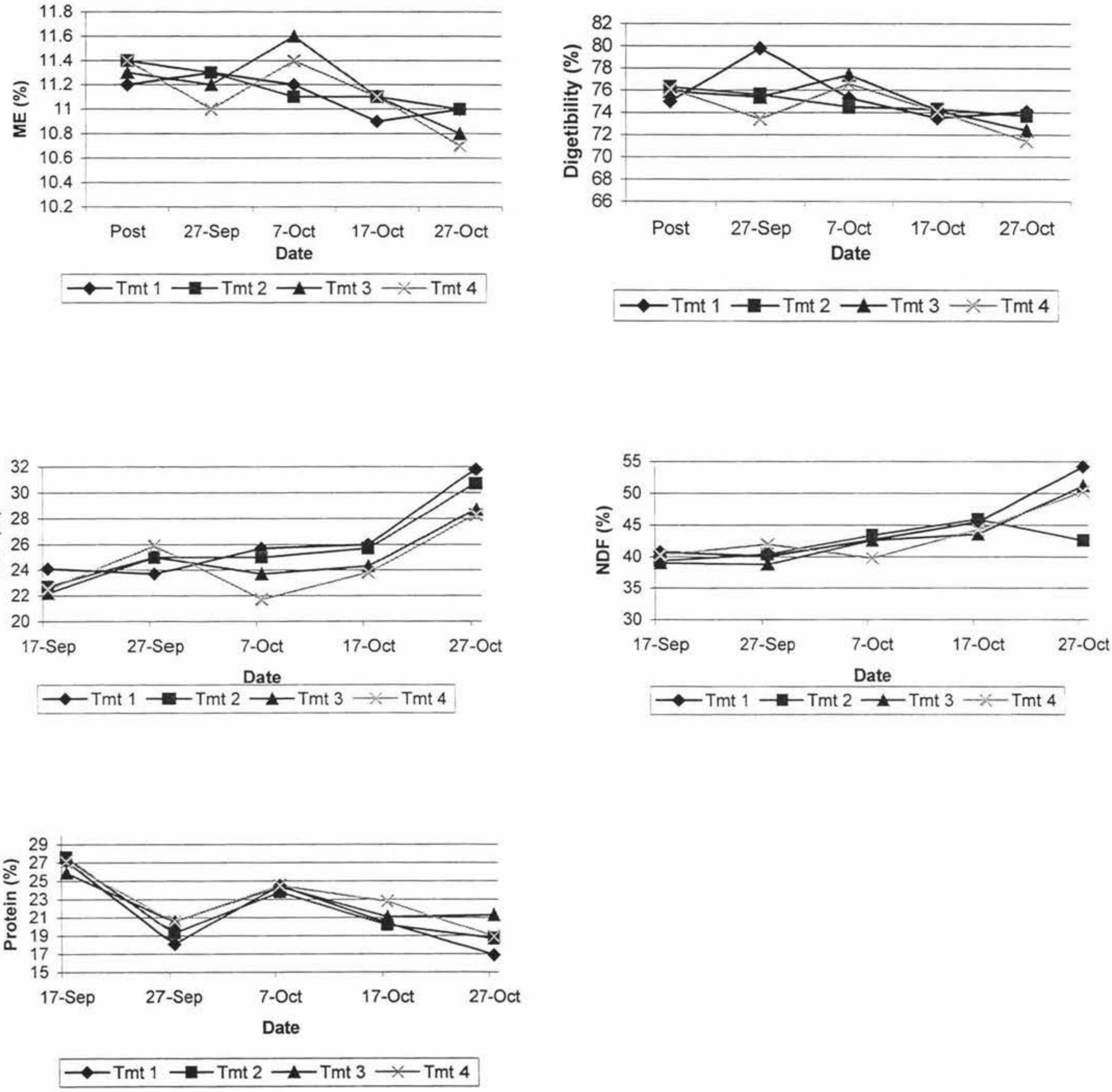


Figure 5.13 Experiment II – Change in ME, digestibility, ADF, NDF and protein over the experimental period for all treatments.

6.0 DISCUSSION

6.1 Introduction

In this chapter the main experimental results, and detailed sward component measurements are explained and their effect and relationship to herbage accumulation discussed. Practical implications of these results to dairy farming systems are also discussed.

6.2 Net Herbage Accumulation

In both experiments herbage accumulation showed evidence of reacting to changes in the environment. In Experiment II the trend in net herbage accumulation was similar to that shown by Bircham & Hodgson (1983), with net accumulation increasing and reaching a maximum as herbage mass increased and then declining slowly as herbage mass increased. This pattern in herbage accumulation can be explained by Bircham & Hodgson (1983) as be due to increasing levels of senescence and decay. In Experiment I this trend was less apparent, partly due to the fact that in some treatment's herbage mass levels did not reach ceiling levels, and did not reach maximum net herbage accumulation levels.

The average NHA in Experiment II was much greater than in Experiment I (63.8 vs 15.8 kg DM/ha/day respectively). Conditions in spring were exceptional for pasture growth (particularly in October) with the combination of sunny weather with warm, moist soil conditions, contributing to the high rates of NHA (Appendix 4). Conditions in winter were very mild with less frosts and less rainfall (in June and August) than usual (Appendix 4).

In Experiment II the response of the nitrogen treatments over the experimental period was varied and unexpected (Table 6.1). The reason for the varied nitrogen responses are unclear, it is likely a combination of the error associated with the measurements of herbage mass (along with the small experimental plots), the hand application of the nitrogen onto the grazed plots, along with the very high growth rates due to the favourable climatic conditions throughout the experiment. However, dry matter responses over the practical range in herbage mass for high producing cows showed a more realistic result (Table 6.1). The lower application rate of Treatment B had a slightly higher response rate, and was hence more efficient and cost effective than Treatment C (10.9 cents/kg DM vs 11.4 cents/kg DM respectively).[1] The relatively low responses to nitrogen, and high NHA rates would suggest that nitrogen was not limiting pasture growth over this period.

Table 6.1 Pasture responses to applied nitrogen plots (kg DM/ha/kg N).

	A (0 kg N/ha)	B (25 kg N/ha)	C (50 kg N/ha)
Entire experiment	-	-6.1	0
Until pre-grazing of 2700 kg DM/ha	-	5.5	5.3

Figure 6.1 and 6.2 show the relationship between herbage mass and NHA of Experiment I and II respectively. A polynomial line of best fit was placed through the data points. The curves produced are similar to those produced from weekly pasture cover readings from a Manawatu dairy farm (Bluett et al 1998). The difference between the two curves is largely due to the range in herbage mass they cover. In Experiment II the range in herbage mass was between 2000 – 4500 kg DM/ha compared to Experiment I where the range was much lower (1000 – 3000 kg DM/ha) and within targets likely to be experienced in practice. For Experiment I the optimum herbage mass is almost identical to that suggested by Bluett et al (1998) of 2500 kg DM/ha, although the lower r^2 value of 5% reduces the confidence that can be placed in the data. In Experiment II the optimum herbage mass was approximately 2900 kg DM/ha. As would be expected the herbage mass level at which growth was maximised was lower in winter than spring (Hay 1987). In the experiment the difference was kg DM/ha.

[1] Assumes $600/t of N applied.

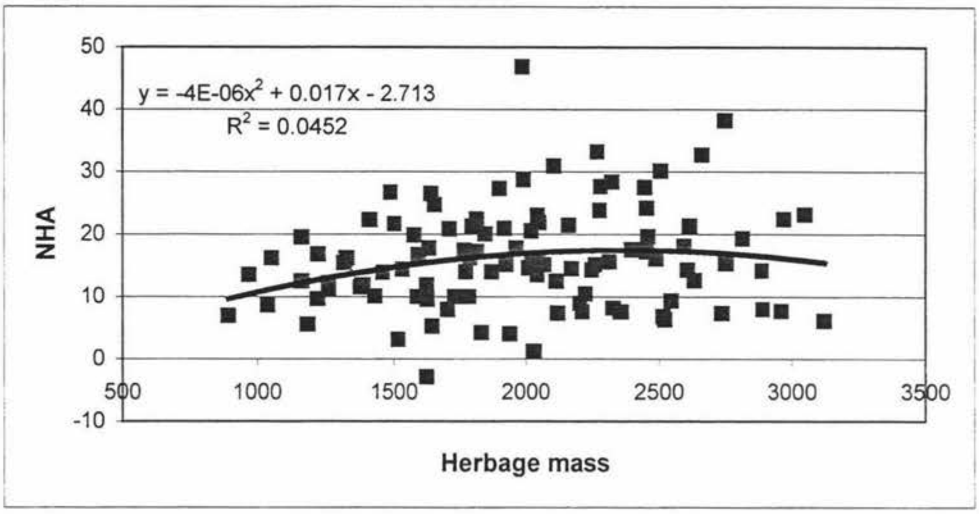


Figure 6.1 Experiment I - The relationship between herbage mass and net herbage accumulation.

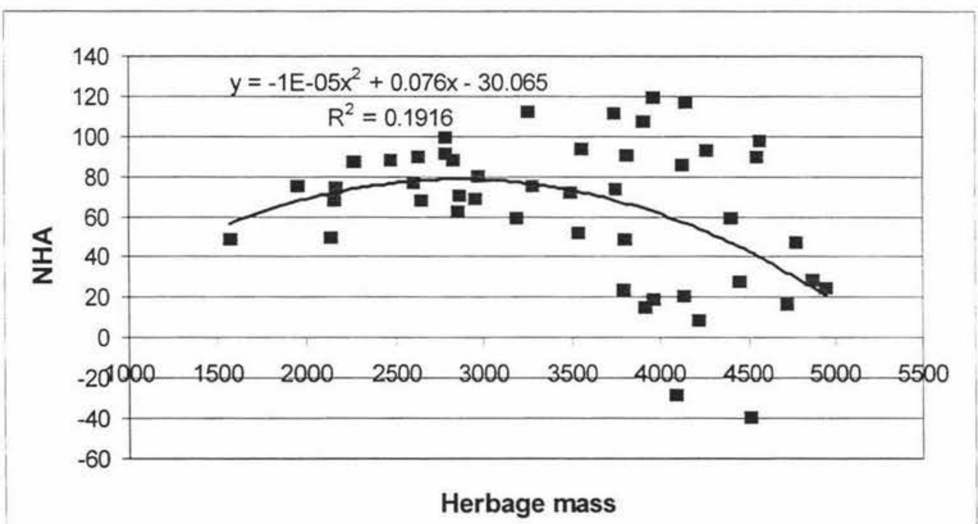


Figure 6.2 Experiment II - The relationship between herbage mass and net herbage accumulation.

When breaking down the regrowth into individual sample periods we can more clearly see the phases of regrowth as described by Brougham (1956) (Appendix 5). In both experiments the first 20 days of regrowth saw pastures in a phase where pasture growth was increasing. In the subsequent periods pasture growth was either constant or declining, particularly in Experiment II where herbage mass levels quickly reached 3000 kg DM/ha.

With much of the herbage mass data in Experiment II being greater than 3000 kg DM/ha it is realistically outside the range which most dairy farmers would endeavour to operate between. We are more interested in the range of herbage mass below 3000 kg DM/ha and the subsequent growth rates associated with these herbage mass levels. This is because it will influence management decisions made, such as the rotation length of the farm, affecting the area grazed each day, with the associated effects on herbage mass levels, intake from pasture, and any need for supplementary feeds.

The length of time that treatments took to regrow back to the desired pre-grazing herbage mass of 2700 kg DM/ha was also examined, as this has implications on the average rate of growth over this regrowth period (Parsons et al 1988).

In Experiment I, Treatments 1, 2 and 3 did not achieve pre-grazing levels by the end of the experiment (Table 6.2). The predicted time (in days) that these three treatments would have taken to reach the desired pre-grazing level, assuming that the average pasture growth for each treatment over the experiment has been calculated, is shown. The growth rate of Treatment 5 was only slightly higher than its previous growth rate, despite the 20 day difference. In Experiment II where growth rates were much higher all treatment swards reached their pre-grazing targets much quicker than the swards in Experiment I. Over the regrowth period from grazing until 2700 kg DM/ha was reached, average herbage accumulation rates for all treatments were greater than for the entire experimental period for Experiment II, which given the herbage mass levels reached by all the treatments was not unexpected. The greatest improvement in NHA was from Treatment 3 (Table 5.4 compared to Table 6.2) which increased in growth rate by 17.9 kg DM/ha/day, with the next biggest increase from Treatment 4 (14.0 kg DM/ha). Treatments 1 and 2 had increases in growth rate by 11.7 and 10.0 kg DM/ha respectively. So over the regrowth period of actual significance, Treatment 3 had the highest accumulation rate being 7.7 kg DM/ha/day more than the average of the other three treatments, which had similar accumulation rates.

Table 6.2 Rotation length and average NHA for treatments until a pre-grazing level of 2700 kg DM/ha was reached.

Treatment	1	2	3	4	5
Experiment I					
Rotation length (days)	122	94	80	70	50
Avg NHA (kg DM/ha/d)	15.0	16.0	16.3	16.2	15.6
Experiment II					
Rotation length (days)	20	16	10	10	-
Avg NHA (kg DM/ha/d)	75.8	72.6	81.7	73.5	-

The experimental results suggest that maximum NHA rates will be achieved at a residual herbage mass in the region of 1400 kg DM/ha in the winter and 1700 kg DM/ha in early spring.

Net herbage accumulation in Table 6.2 was determined by the difference between post-grazing residual and the time required to reach 2700 kg DM/ha. While this provides adequate information, it excludes the trend in herbage accumulation throughout each experiment. Regression analysis was used to determine the growth rate of each replicate for each treatment. The axis of herbage mass and time meant that the slope of the regression line would in fact be the average growth rate over time. Table 6.3 shows the results of this analysis.

Table 6.3 Rates of NHA (kg DM/ha/day) over different periods of regrowth for both experiments.

Treatment	1	2	3	4	5	SEM
Experiment I						
0-30 days	14.17	16.08	16.46	14.87	16.90	3.67 NS
31-70 days	17.26	19.37	17.78	20.80	17.59	1.99 NS
0-70 days	14.47	16.44	16.40	15.56	15.11	1.59 NS
Experiment II						
0-20 days	82.36	80.13	93.30	90.35	-	9.72 NS
21-40 days	48.35[a]	35.83[ab]	-5.63[b]	10.13[ab]	-	18.84
0-40 days	78.15	76.76	74.36	67.28	-	5.55 NS

Note: mean values in the same row followed by different letters are significantly different ($P<0.1$).

Herbage accumulation rate increases in all treatments in Experiment I from the first period (0-30 days) to the second period (31-70 days). This reflects the fact that none of the treatments, even the high post-grazing treatments had reached their ceiling yield. As would be expected however the increase in accumulation rate between the two periods was lower in the high post-grazing treatment (Treatment 5) compared to the low post-grazing treatment (Treatment 1). Although the greatest increase in herbage accumulation rate between the two periods was recorded in Treatment 4.

In Experiment II all treatments had a much lower growth rate over the second period, with all treatments (except for Treatment 1) declining by over half. These figures reflect that some of the treatment swards had reached their ceiling yield within the first 20 days of being grazed. Grazing these swards at the high herbage masses allowed would therefore result in low intakes of low quality pasture and would be likely to also result in low pasture regrowth (Matthews 1994; 1995). At this point control is lost. This point is supported by NIR and botanical analysis results. NIR results reflected the decline in pasture quality, with Figure 5.14 showing ME, digestibility and protein all declining and fibre content increasing with the decline being more noticeable towards the end of the experiment. The

NIR results are further reinforced by Figures 5.9 - 5.12, showing the increase in grass stem, and subsequent decrease in grass leaf.

A management change towards greater herbage mass would necessitate reduced grazing pressure with lower utilisation of pasture, and is likely to result in increased rates of senescence and decay. Figures 6.1 and 6.2 indicate that net pasture production begins to decline at approximately 2500 and 2900 kg DM/ha respectively, similar to the results of Bluett et al (1998). It is probable that cow production (on seasonal supply farms) will decline before this stage is reached because of the reduction of herbage quality due to structural changes within the sward as well as increased dead material reducing nutrient intake (Matthews 1995). However Matthews (1995) suggested that holding sward conditions in the optimal growth range would more than compensate for increased sward losses from high post-grazing residuals. Figures 6.3 and 6.4 show evidence which supports this comment. The graph shows that in spring when cows are in lactation (on seasonal supply farms) a 14 kg DM/ha/day increase in NHA rate was associated with only a moderate decline in utilisation of 15% with an increase in grazing residual from approximately 900 kg DM/ha (Treatment 1) to between 1400-1700 kg DM/ha (Treatment 2 and 3). Figures 6.3 and 6.4 highlight that to optimise both herbage utilisation and pasture growth a compromise must be met. This compromise will vary between farms depending on the specific animal production and grazing management goals that have been set. The figures also show that in winter a higher utilisation (and hence more intense grazing) is required to achieve the optimum NHA rate compared to spring. While these results do not highlight the exact optimum post-grazing residual, they again highlight the advantage (and approximate range in post-grazing residual) of increasing grazing residuals, particularly in winter where block grazing, high grazing intensities and low grazing residuals are often common.

The influence of cow excreta should not be totally overlooked as having an influential effect on herbage accumulation. (Sears 1950) demonstrated that under fertile conditions, return of dung and urine enhanced pasture productivity by 32% compared to no return of excreta. Increases in nitrogen content of the soil from cow excreta has been commonly recorded (Herriott & Wells 1963; Watkin 1954). Urine patches can contain nitrogen concentrations of 5000-15000 mg/L, equivalent to 500-1000 kg N/ha (McLaren & Cameron 1990). Besides the direct input of nitrogen into the soil/pasture system, the addition of readily available nitrogen decreases the carbon/nitrogen ratio, and in doing so increases the rate of mineralisation of organic matter and the release of available nitrogen (Wolten 1955). Increases in earthworm populations may also increase the availability of organic nitrogen (Watkin 1954). The differences in grazing intensities used to achieve the range in post-grazing residuals resulted in differences in quantities of dung and urine on plots (Plates 4.1 – 4.5 and 5.1 – 5.4). One additional benefit likely to arise from higher grazing residuals is that increased senescence and decay of pasture from a more lenient grazing regime will result in a greater accumulation of organic carbon in the soil (Parsons 1983a, 1983b) with positive implications for the longer term sustainability of the sward and sward productivity.

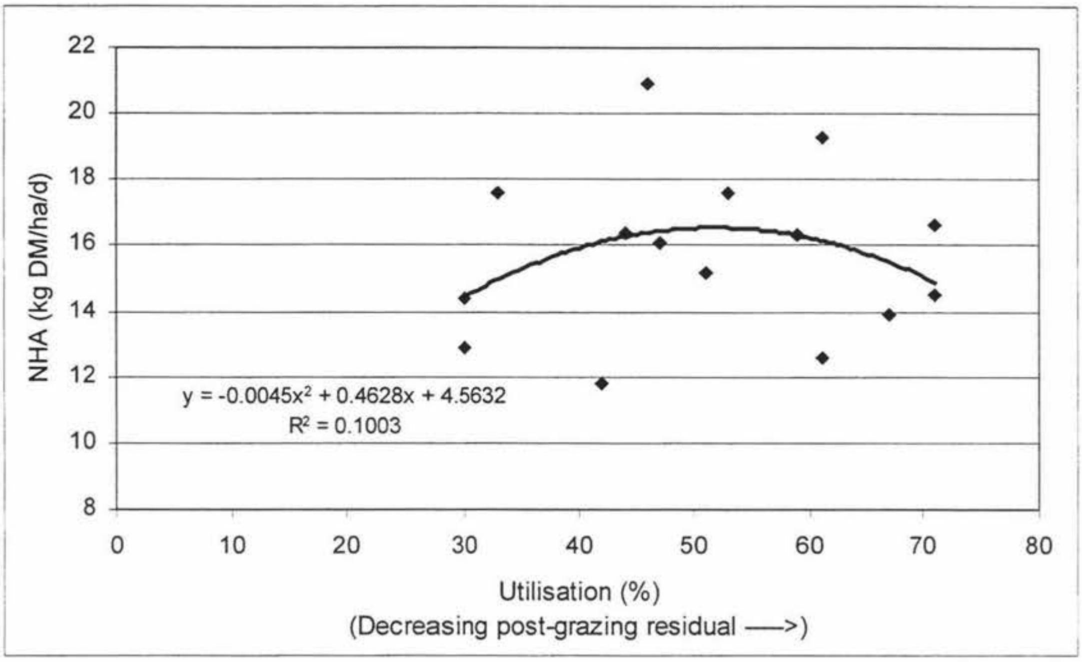


Figure 6.3 Experiment I - The relationship between NHA and estimated pasture utilisation.

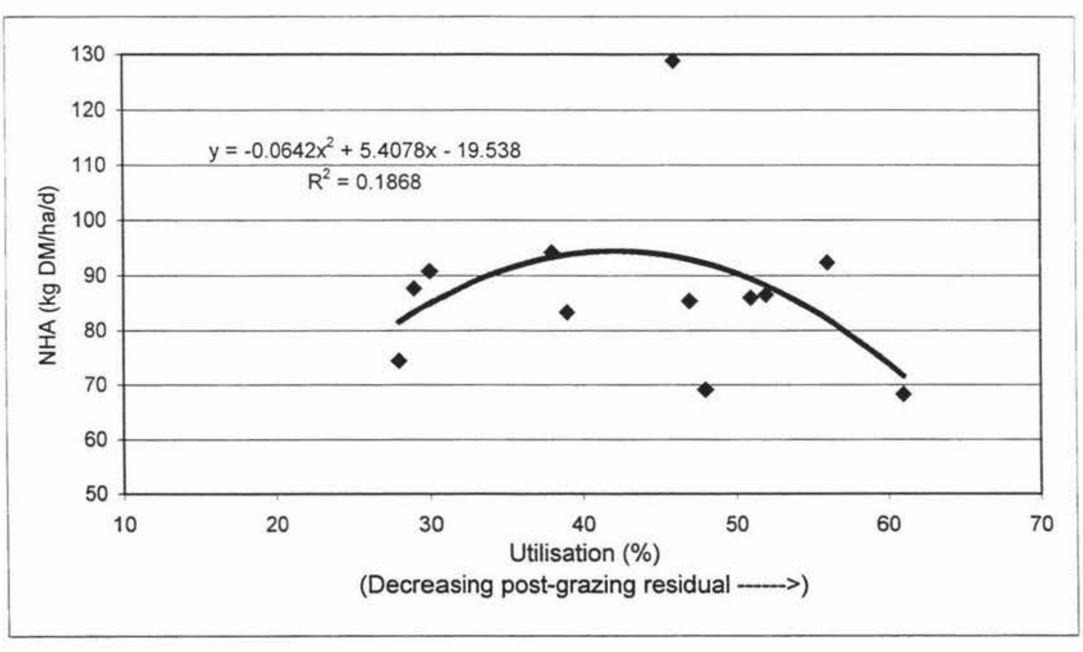


Figure 6.4 Experiment II - The relationship between NHA and estimated pasture utilisation.

Analysis of correlation coefficients showed that tiller mass and leaf extension rate were the main determinants of NHA in Experiment I (Table 6.4). Tiller density and leaf appearance rates were not significantly correlated with NHA. Over winter tiller appearance rates are low compared to the spring (approximately 100 tillers /m^2/day), however when compared to the low tiller death rates at the same time (<50 tillers/m^2/day) tiller density increases rapidly, and in a ryegrass/white clover sward, generally peak in August or September (Korte 1986). Whereas in spring with correspondingly high tiller death rates tiller density is more constant.

In contrast in Experiment II, all sward parameters were significantly correlated to NHA with leaf appearance rate the most highly significant variable, followed by tiller density and tiller mass. In spring new leaves are produced on average every 10 – 20 days compared to 20 – 40 in winter. The average leaf appearance rate in spring was one new leaf every 14.5 days (comparable to results of Hunt & Field 1978 and Vine 1983) compared to every 18.6 days in winter. Average tiller density and tiller mass were lower in Experiment II, this combined with the increase in leaf appearance shifted the relative importance of each variable. The fact that all variables significantly contributed to herbage accumulation in spring reflects the importance of winter management. Management which allows swards to be subjected to pugging, and severe grazing is likely to affect pasture production in early spring, and exacerbate any feed shortage at that time.

Table 6.4 Correlation coefficients between pasture characteristics and net herbage accumulation.

	Winter	Spring
Tiller density	0.32	0.66**
Tiller mass	-0.52*	0.62**
Leaf appearance rate	-0.08	0.84***
Leaf extension rate	-0.48*	-

Note: *= P<0.05, **=P<0.01, ***=P>0.0001

From the results of the correlation analysis, there is evidence to suggest that the dimensionality of the data may be reduced. This was done using Principal Component Analysis (PCA). PCA reduces the dimensionality of a data set with many interrelated variables into principal components (a set of uncorrelated variables) while retaining as much of the variation as possible present in the data set (Jolliffe 1986).

The results of the analysis of Experiment I (Table 6.5) showed that most of the variation within the data (82%) can be explained in the first two principal components (PC's). Hence we can argue that the dimensionality of the given data can be reduced from four dimensions to two.

The positive and negative difference between tiller density and tiller weight would be expected, as they are inversely related (Matthew et al 1996). Thus the most extreme positive value of this PC would be taken by a sward that has a high tiller density and low tiller weight, and on the other hand a large negative value would see a sward with a low tiller density and high tiller weight. Tiller weight and leaf extension rate hold both similar negative values, and thus reflect the results of the correlation analysis.

The coefficients of the first PC seem to reflect that most of the variation in the data (and first PC) is controlled by a contrast between the variables tiller weight and leaf extension rate and the variables tiller density and pasture growth. Hence the first PC can be seen as helping to explain the effect of post-grazing level on sward components, in that a sward that was grazed hard will tend to have a high density, low tiller weight with a correspondingly low leaf extension and low pasture growth compared to a laxly grazed sward which would have a low tiller density with a greater tiller weight and leaf extension rate and high growth rate (this does not take account of the high death rate which would be associated with the high true growth rate). Thus a moderate grazing level will have a moderate tiller density, tiller weight and leaf extension rate, along with a moderate growth rate. In the second

PC tiller density (having a large and positive coefficient) can account for much of the 20% of the variability in the data. However the contribution of leaf extension is considerable, and that of growth, while being negative is not negligible. This PC seems to separate out tiller growth (tiller density and tiller weight) and leaf growth (leaf extension rate).

When analysing the individual component scores a clear pattern emerges in the first PC, which explains most of the variation. It can be seen that from the first measurement made before the swards were grazed until the final measurement at the conclusion of the experiment the component scores increase (Figure 6.5). Hence the conclusion from the data is that they take on the form of a growth cycle, increasing over time. Differences between treatments were non-significant, although the difference between measurement dates were significant ($P<0.05$) emphasising the increase in component scores over time.

Table 6.5 Experiment I - PCA analysis of pre and post-grazings and regrowth measurements made.

	PC 1	PC 2	PC 3	PC 4
Eigenvalue	2.4698	0.57900	0.23953	0.06716
Proportion	0.617	0.202	0.134	0.046
Cumulative	0.617	0.820	0.954	1.000
Tiller density	0.468	0.706	0.084	0.524
Tiller weight	-0.584	-0.202	0.179	0.766
Leaf extension	-0.476	0.517	0.608	-0.369
Pasture growth	0.461	-0.439	0.769	0.056

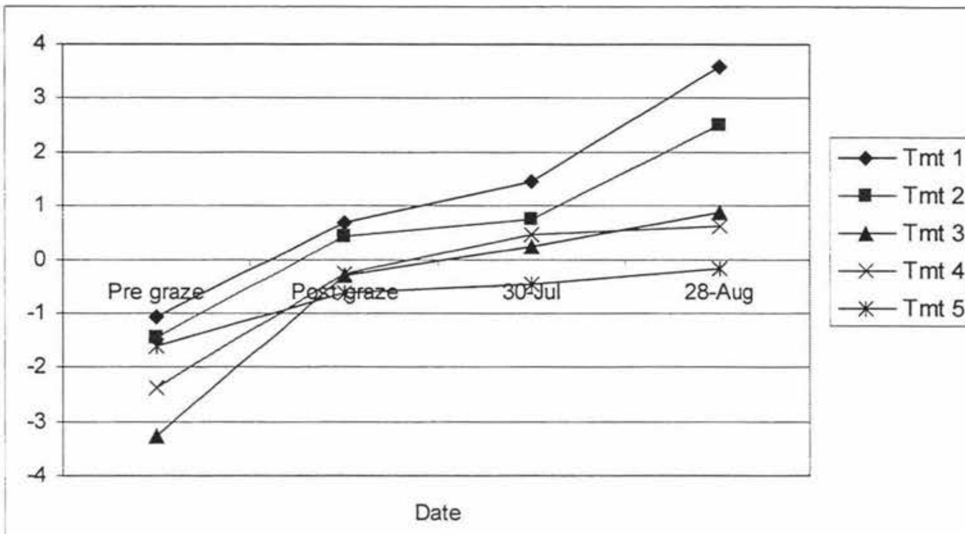


Figure 6.5 Experiment I - Trend of individual component scores for the first principal component.

The conclusion made from the first principal component is also highlighted in the analysis of the component scores from the second third and fourth measurements, i.e. over the actual growth phase. The analysis showed that the first PC explained 78% of the variation with the other three making up the remaining variation. The coefficient for pasture growth was low (0.259) reflecting the low growth rates experienced over the winter period and the small variation in growth rates (despite, as in this study a large range in grazing residuals). The results were interpreted as meaning that over the winter period, when tiller density is low that this has a detrimental effect on pasture growth (although as just mentioned the size of the decline is likely to be small in absolute terms) with tiller weight and leaf extension rate being greater, which the winter experiment showed. When tiller density is high, leaf extension rate tends to be lower, possible due to shading reducing the amount of light that reaches each leaf along with the fact that each leaf is smaller. However leaf extension rates have been shown to both increase and decrease (Grant et al 1981; Thomas & Davis 1978; Grant 1968). Another reason may be as a result of the plant putting a greater proportion of energy into increasing leaf appearance (resulting in a higher tiller density). With pasture cover generally being lower over winter due to low pasture accumulation rates and more intensive grazing levels to restrict cow intakes, the ryegrass plants may be adapting to this. Being aware that a high herbage mass may be unlikely or take a long time to accumulate, it may be less efficient for ryegrass plants to direct limited carbohydrate into increasing leaf area by increasing leaf length which may not be allowed to occur (due to farm management), and prefer instead to increase leaf area through having a high tiller density (Chapman & Lemaire 1993). This is what the intensely grazed treatments showed in Experiment I, as they had the higher tiller density and lower leaf extension rate. In contrast when tiller density is low and tiller size is greater, gross photosynthesis of each leaf is greater and the plant has more available energy for increasing leaf extension rate.

Table 6.6 shows that the mean of the component coefficients of Treatments 1 and 2 was significantly lower than Treatment 5 ($P<0.1$). These differences reflect that there appears to be some benefit in reduced grazing intensities between hard and lax grazing extremes, however with no difference being present between Treatments 2, 3, and 4, it seems that when looking at smaller ranges in post-grazing residuals that it is less clear whether differences exist. This was also found in many of the results of the sward measurements made, with differences often occurring between the extreme post-grazing residuals in many (but not all) of the measurements made.

Table 6.6 Experiment I – Means of individual component coefficients scores from the first PC.

Treatment	1	2	3	4	5	SEM
Component coefficient	-1.467^{a}	-0.747^{ab}	0.327^{ab}	0.588^{bc}	1.299^{c}	0.08

Note: Treatments with different letters are significantly different ($P<0.1$)

Results from Experiment II are similar to that of Experiment I. Leaf extension rate was not measured in this experiment, however leaf appearance rate was. The analysis of all the measurement dates showed that the first PC explained 81% of the variation. The coefficients were all of similar weighting being between -0.47 and 0.52. Tiller density and pasture growth were both negative with tiller weight and leaf appearance rate positive. Again the trend shown by the individual coefficients of each treatments resembled that of a growth cycle, i.e. increasing over time (Figure 6.6), with significant differences between measurement dates but not treatments.

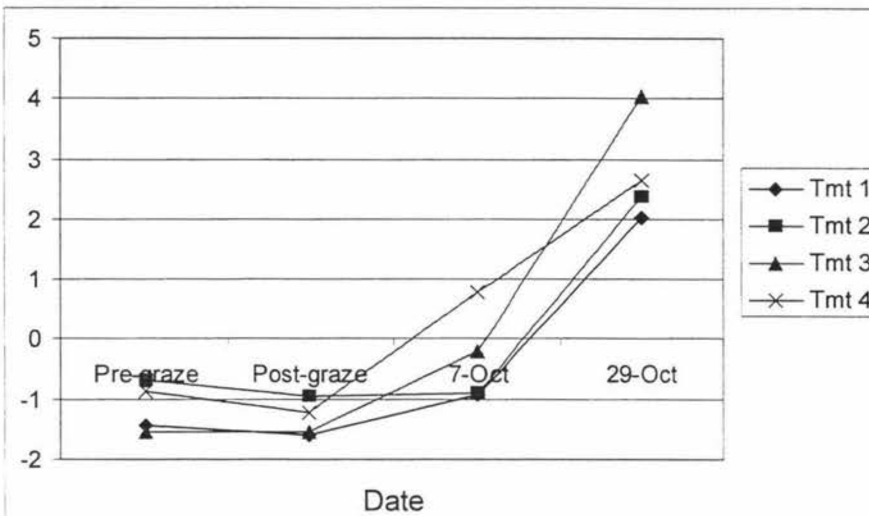


Figure 6.6 Experiment II - Trend of individual component scores for the first principal component.

The measurements were again analysed excluding the pre-grazing measurements to develop a picture of the growing phase of the sward. Results were again similar to those in Experiment I (Table 6.7). All variables are similar in their respective weighting towards the 81% variation that the component explains. Again tiller density is strongly linked with pasture growth as tiller density and pasture growth are positive, with tiller weight and leaf appearance rate being negative. We can interpret the results as the tiller density/tiller weight compensation again being present. Leaf appearance rate is linked with tiller weight, i.e. when tiller density is low and thus tiller weight high, leaf appearance rates can become faster (less days per tiller).

Overall the results have shown the tiller density/weight compensation, and that tiller density is linked with pasture growth. Significant differences between the grazing treatments lend evidence towards the theory that higher grazing residuals may have the effect of improving pasture regrowth.

Table 6.7 Experiment II - PCA analysis of measurements made during sward regrowth.

	PC 1	PC 2	PC 3	PC 4
Eigenvalue	3.22570	0.58463	0.13229	0.05739
Proportion	0.806	0.146	0.033	0.015
Cumulative	0.806	0.952	0.985	1.000
Tiller density	0.470	0.635	0.603	-0.100
Tiller weight	-0.521	-0.276	0.748	0.303
Leaf appearance	-0.467	0.682	-0.272	0.491
Pasture growth	0.537	-0.231	-0.040	0.809

To achieve maximum yield from defoliated swards requires the optimum balance between photosynthesis, gross tissue production, yield (intake), and senescence (Parsons & Chapman 1999). This emphasises the fact that pasture production is a combination of many interrelated factors, and results in this study show that over spring all sward components (measured) were correlated with NHA. While theoretical models such as those by Schwinning & Parson (1999), and Parsons & Penning (1988) may provide guidelines to achieving optimal pasture growth and utilisation within swards, the simple fact that swards are of a dynamic nature affected not only by management but also by an ever-changing environment, it is of no surprise that in a dairy grazing system it seems to still remain an elusive goal for most. However many farmers now have a better understanding and are fine tuning their management systems to achieve the best compromise between pasture production, herbage utilisation, animal production, and farm profitability.

Results from this study have provided information on some of the morphological characteristics determining pasture growth over winter and spring, and have highlighted components that could be used as grazing management criteria over these seasons. The effect of attempting to maximise pasture accumulation through the manipulation of grazing residuals on herbage utilisation has only briefly been covered in this study. The optimum compromise between pasture production and pasture utilisation will result in a balanced, efficient dairy production system. Therefore grazing rotation, that is, the optimum time to re-graze a sward is of importance.

Parsons et al (1988) stated that a residual sward state alone provides a poor indication of average growth rate, as swards may show a wide range of growth rates depending on how long the sward is allowed to grow for. Hence the requirement to not only look at the post-grazing residual but also take account of the duration of regrowth (i.e. pre-grazing sward targets).

It is well known that the regrowth of pasture is a dynamic system of growth, death and decay, leading to net herbage production. The balance of these processes accounts for the sigmoid growth curve commonly observed in herbage dry matter after grazing or cutting. Depending on the goals of the farmer the optimum time for grazing a paddock will change.

The principals for understanding the timing of grazing relate to the foraging theory of ecology called the Marginal Value Theorem (Stephens & Krebs 1986). A diagrammatic form of the processes involved in pasture regrowth is shown in Figure 6.7. If a farmer wanted to achieve the maximum herbage harvested, then they would graze the sward at point 'c' (where $W - W_o$ is greatest). This is the period were gross photosynthesis is at a maximum and all incident light is being intercepted (that is, no light is reaching the ground per unit area - the ceiling yield has been reached). However at point 'c' the net herbage accumulation rate would have been declining for some time. If the sward was grazed at point 'a' then the farmer would be interrupting the NHA rate when it was at its highest although the amount harvested would be small. After this point the rate of leaf death increases rapidly causing the NHA rate to start to decline causing the increase in average pasture growth rate to slow down. When the average pasture growth rate reaches a maximum (point 'b') this is the optimum time to graze the paddock as the utilisation of green leaf is maximised, this is the point where net tissue production (the difference between total growth and death) is at a maximum (Parsons & Penning 1988). It is of note that the maximum average growth rate occurs after the maximum NHA rate but before the ceiling yield is reached.

Parsons and Chapman (1999) looked at deriving a theory for optimising utilisation for all possible initial post-grazing residuals (remembering that optimum utilisation is where average growth rate is maximised). To do this they had to provide a growth curve that took account of the effects of post-grazing residual on net growth, and so takes into account factors affecting regrowth, as different grazing residuals affect all sward components differently.

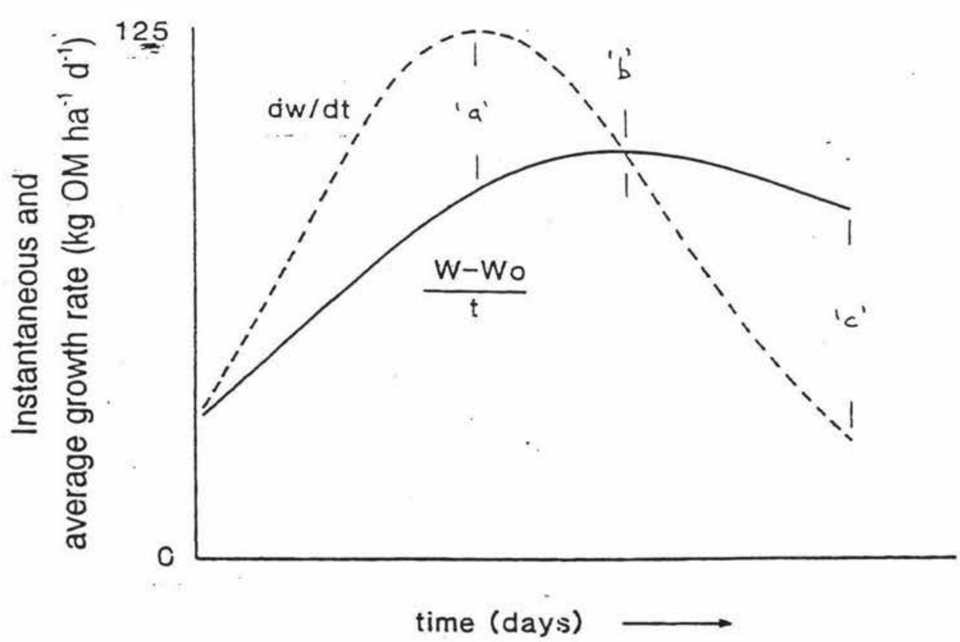


Figure 6.7 Corresponding changes in the weight of the crop (W), the instantaneous growth rate (dW/dt) and the average growth rate ($W - W_0$ /t). See text for explanation of the effects of harvesting at times a, b and c (Parsons & Penning 1988).

Knowing how growth rate changes following a given post-grazing residual Schwinning & Parsons (1999) showed how a certain grazing residual would affect the theoretical maximum average growth rate that would be achieved and the duration of regrowth required to achieve this. Thus while many studies have focused on either grazing severity or frequency or both, virtually none have attempted to combine both in a model to estimate the optimum time for grazing, possible due to the fact that a formal theoretical base for optimum grazing time was not understood.

Figure 6.8 shows that the greatest average growth rate is attained at a post grazing residual of approximately 5cm and is associated with relatively long defoliation intervals. A more lax grazing residual demands more frequent grazing in order to maintain the maximum growth rate (Parsons & Chapman 1999).

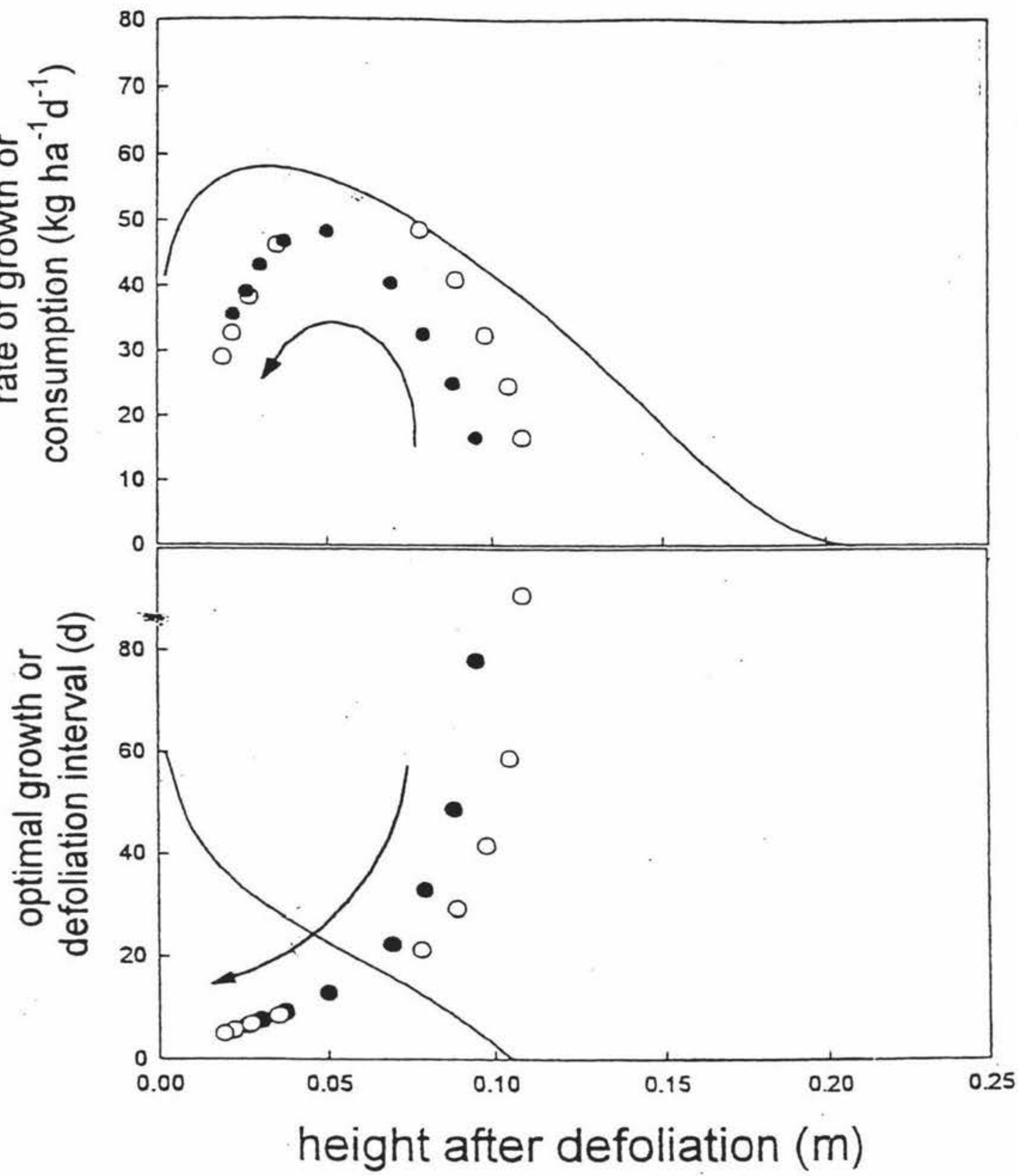


Figure 6.8 **The effect of residual sward state on (a) the maximum average growth rate that may be achieved, and (b) the defoliation interval required to achieve this as predicted by a model that seeks optimal solutions for all combinations of the residual sward state (severity) and the timing of harvest (frequency) in a series of defoliation's in all cases. The solid lines show the optimal solutions. Arrows show the direction of increasing stock density. (Schwinning & Parsons 1999).**

The results from this study support much of the theoretical models made by Parsons & Penning (1988), Parsons et al (1988) and Schwinning & Parsons (1999). The results of the PCA analysis and that of Table 6.4 shows that there is definitely an effect of duration of regrowth on the subsequent effect on yield and of the components that contribute to regrowth.

These results reflected the influence of the duration of regrowth on pasture growth rate, particularly in spring. They support the finding of Parsons & Penning (1988) that although pasture quality is a priority in late spring, intensive grazing is not in itself effective in controlling stem growth and seedhead production, as these will still occur if the duration of regrowth is sufficiently long enough.

6.3 Plate Meter Calibration

The calibration equations derived from the two experiments were significantly different to each other ($P<0.01$), however the r^2 value was similar. Livestock Improvement Advisory (LIA) has recently released a new set of seasonal plate meter equations. These are based on all available calibration data from ryegrass white clover pastures collected from various sites over many years as part of their goal to introduce a new standardised system of pasture assessment. The winter equation that LIA state is PMR (plate meter reading) x 140 +500 (Hainsworth 1999). This equation has both a greater slope and intercept than the equation derived from Experiment I (PMR x 123 + 115). The higher slope of the LIA equation indicates a greater pasture density of average swards compared to the swards of the Dannevirke farm. The intercept value is a measure of the mass of pasture residue present when the rising plate meter is zero. In general over the season this residue amount varies as dry matter accumulates in the base of the pasture from August to December, while decay of the accumulated pasture occurs from March to June (Hainsworth 1999). The low intercept reading of 115 also reflects the low density of the sward. It also indicates that there is little accumulated dead material at the base of the sampled swards, perhaps indicating effective grazing management in late autumn/early winter ensuring effective utilisation.

The spring equation of Experiment II was DM = 140x – 89. Outside of the winter months LIA has different equations for each month. Experiment II was during September and October. The LIA equations for September and October are relatively similar being DM = 115x + 650, and DM = 100x + 850 respectively. In this instance the slope of the recommended equation is lower than the one derived on the Dannevirke farm. This highlights that in early spring pasture density of the sample farm is in general greater than the average New Zealand farm. Results from both experiments showed that a high tiller density results from high grazing intensities, and low post-grazing residuals. In contrast however, the intercept is much lower compared to the LIA equation. The negative figure is difficult to explain, but may be due to an over estimation of the multiplier or slope. The average figure of 750 for the LIA equation is greater than the recommended winter equation and is greater still in late spring (reaching a value of 1100 in December), reflecting the development of reproductive tillers, in both their height and increased dry matter content.

While LIA give equations for each month of the year, with pasture being both dynamic and variable, calibration equations to estimate herbage mass can change on a fortnightly, weekly and at the extreme, on a daily basis, given sudden changes in climatic conditions and grazing management (e.g. topping and conservation). To accommodate these changes Bishop-Hurley (1999) used a fitted Fourier curve to give a dynamic equation over the year (Figure 6.9). This equation also shows that in late spring/early summer herbage mass per unit plate height increases as swards become reproductive. Of interest is the 95% confidence interval. Even though the curves are plotted from three years of data, the wide range of the confidence interval reflects the inherent variability of pasture, and shows that at any period in time herbage mass per unit plate height can vary by over 200 kg DM/ha.

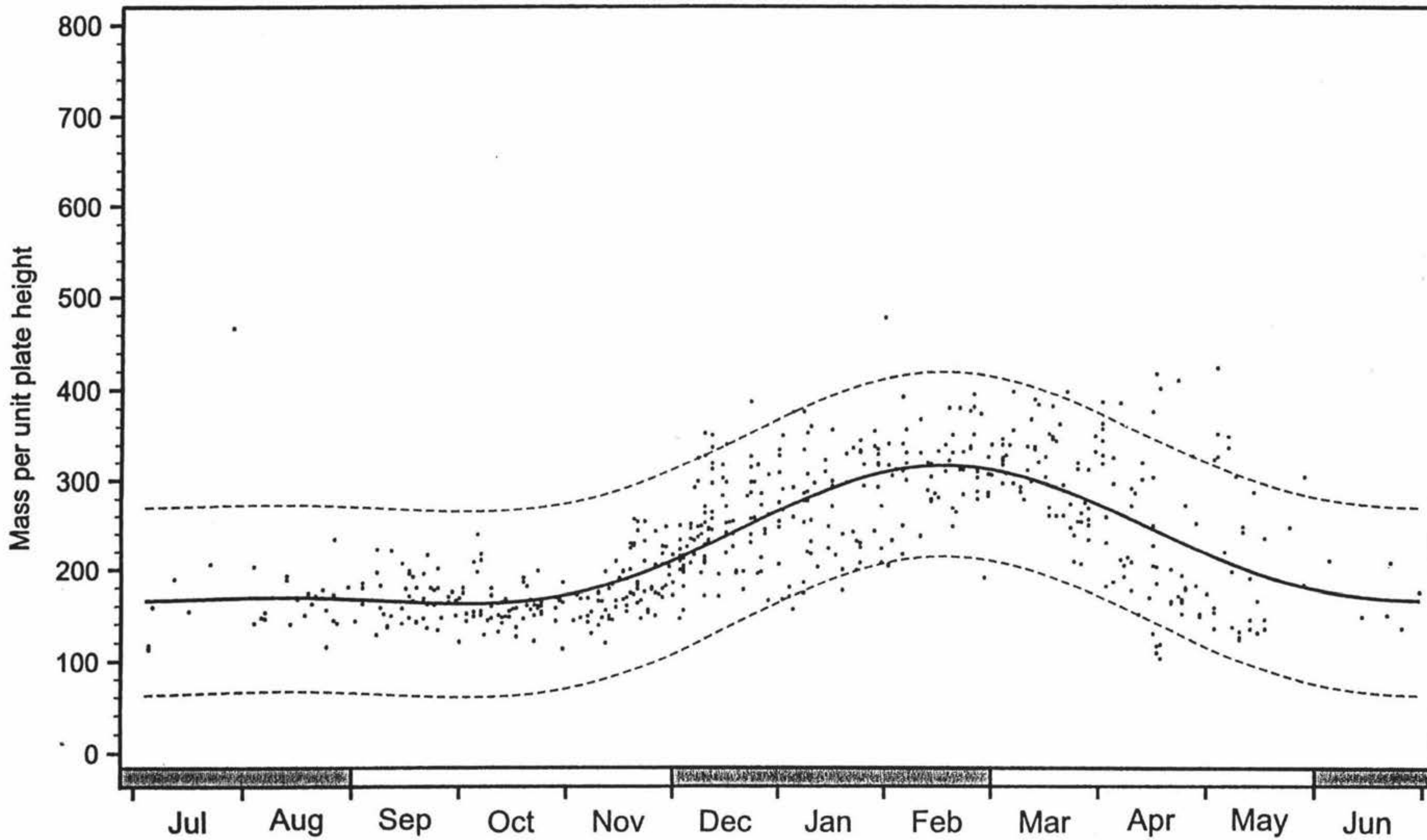


Figure 6.9 **Unit mass per unit height estimates (•), fitted Fourier curve (—) and associated 95% confidence intervals (----) for three years pooled data (Bishop-Hurley 1999).**

6.4 Herbage Mass Profile

In both experiments a clear positive relationship was illustrated between grazing intensity and the 'clumpiness' of the plots after grazing. However the variation in herbage mass of the treatments after grazing, when related to the average herbage mass over the whole experiment was proportionally very similar across all treatments particularly in Experiment II (Tables 4.3 and 5.3).

Low grazing residuals are a common sight on dairy farms over the winter. Block or strip grazing strategies are often used by farmers over the winter period. When combined with high grazing intensities to restrict intake levels to cow maintenance requirements, and when wet conditions prevail, severe soil structure and pasture damage can occur (Matthews 1971). With the high grazing intensity treatment (Treatment 1) the total amount of excreta deposited will be much greater compared to lower grazing intensities. The effect that this will have is unclear as on one hand a greater proportion of pasture spoilage may occur leading to the relatively high within-plot herbage variation. On the other hand, herbage will also be removed quicker which may actually mean less excreta is deposited on ungrazed pasture. The amount of pasture spoilage and hence sward heterogeneity will be determined by the interaction of these two scenarios. Although in both experiments Treatment I had the lowest absolute variation, within plot variation from both experiments averaged 29%, thus even at high grazing intensities variations in micro-sward exist which may possibly influence regrowth and botanical composition (Parsons & Chapman 1999). From the herbage mass profile results, it could be suggested that the patchiness in treatment swards was due to the differences in grazing intensity and excreta distribution.

In practical terms, although the coefficient of variation was similar between treatments, the main difference between high and low grazing intensity treatments is that at the low grazing intensity the clumps are still at a much lower herbage mass than clumps in the high intensity treatments. For example, in Experiment I the average post-grazing residual for Treatment 1 was 870 kg DM/ha, with the top 20% of the readings averaging 1748 kg DM/ha. This can be compared to Treatment 5, which had an average post-grazing residual of 1917 kg DM/ha with the top 20% of reading averaging 3031 kg DM/ha. Padilla (1997) stated that the importance of considering the pattern and intensity of patchiness within the sward is the potential difference in utilisation and possibly pasture regrowth between contrasting herbage mass patches.

The similar degree of variation in herbage mass between lax and hard grazing (low and high grazing intensities) in spring was also shown by Padilla (1997). Despite large differences in pre-grazing herbage mass (3600 vs 5000 kg DM/ha) pre and post-grazing standard deviations between treatments was not significant. Botanical composition was also shown to be similar within paddocks highlighting no effect of patchiness on pasture quality. A significant result of the study showed that when pre-grazing herbage mass is either short or long that short patches within the sward were grazed in less proportion than long patches. As a result low herbage mass and greater proportions of short patches was shown to have a negative effect on total herbage utilisation. This would suggest that the anticipated decline in pasture utilisation by increased sward clumpiness on farms targeting higher per cow and per hectare production, through operating at a reduced stocking rate with higher pasture residuals and cow intake levels, may not eventuate and could in fact increase utilisation.

Practically, patchiness in pasture swards will have no repercussions if it is controlled before pasture quality declines (Padilla 1997). This is of more concern in late spring when reproductive growth occurs, and sward quality can decline quickly. Botanical composition results in Experiment II supported the initial comment with no significant differences between treatments for stem, leaf, dead matter and clover. Experiment I however showed that laxer grazing treatments had significantly more stem and dead matter and significantly less clover (although this did not result in differences in metabolisable energy content or digestibility between treatments). It was suggested that by grazing paddocks according to the tallest patches that quality characteristics and efficient utilisation of pasture can be achieved and will not have negative effects on herbage accumulation provided that short patches are not over grazed (Padilla 1997).

Intake, ingestive behaviour and diet selection are the key variables at the ambit of the plant animal interface, and the heterogeneity of sward state and structure is likely to influence these important variables. Ungar (1996) stated that there are two implications of foraging patchiness. Firstly, a case of diminishing marginal returns occurs after a certain level of depletion at any one patch if grazing continues, and secondly a time cost is incurred in moving to another ungrazed patch. Essentially it is a trade off between net energy ingested through grazing and energy lost through grazing (ie biting, chewing and head movements etc) and searching for patches to graze (Laca & Demment 1996). At a high grazing intensity cow behaviour changes. With reduced pasture allowance, time becomes a limiting factor and less selection occurs resulting in a reduced number of patches (or herbage variability). With cow intake being reduced and assuming that cows attempt to maximise intake, they consequently graze to levels they would otherwise not.

6.4.1 Effect of grazing residuals on animal intake

As expected (Bryant 1983) the high grazing intensity (low pasture allowance) treatment cows achieved the highest pasture utilisation (Table 6.8 and 6.9), and as grazing intensity decreased and pasture allowance increased, utilisation decreased. Measured daily pasture intakes per animal were in general higher than anticipated. The inability to achieve target herbage mass levels in both experiments at the high grazing residual (Treatment 5 in Experiment I and Treatment 4 in Experiment II) may be a result of this under estimation of potential cow intakes (especially on an individual basis). Kolver (pers comm) stated that while maximum intakes for a herd of cows is around 17-18 kg DM/cow/day, on an individual basis some cows are able to ingest 20-22 kg DM/cow/day.

Table 6.8 Experiment I – Dry matter allowance (kg DM/cow), intake levels (kg DM/cow/day) and estimated level of pasture utilisation (%) from treatments.

Treatment	1	2	3	4	5
Pre grazing (kg DM/ha)	2864	2881	2793	2915	2778
Post grazing (kg DM/ha)	870	1140	1394	1635	1917
DM allowance	9.5	19.2	32.5	45.5	64.6
Target intake	6.0	10.0	13.0	14.0	14.0
Actual intake	6.1	11.6	16.3	20.0	20.0
Utilisation	71	60	50	44	31

Table 6.9 Experiment II – Dry matter allowance (kg DM/cow), intake levels (kg DM/cow/day) and estimated level of pasture utilisation (%) from treatments.

Treatment	1	2	3	4
Pre grazing (kg DM/ha)	2534	2769	2889	2695
Post grazing (kg DM/ha)	1098	1424	1704	1913
DM allowance	13.5	23.1	45.1	62.7
Target intake	14.0	10.0	14.0	14.0
Actual intake	7.6	11.2	18.5	18.2
Utilisation	57	49	40	29

Tables 6.8 and 6.9 also highlighted that there was no difference in intake levels in the laxly grazed treatments (Treatments 4 and 5 in Experiment I, and Treatments 3 and 4 in Experiment II). Thus no advantage to animal intake and production would be gained by increasing grazing residuals above 1635 kg DM/ha and 1704 kg DM/ha in winter and spring respectively, or alternatively above a pasture allowance of 45 kg DM/cow. While the results do not accurately determine the herbage mass where intake plateau's they conform closely with the findings of Glassey et al (1980), and Bryant (1980).

Ryan (1986) stated that 90% of a cows intake is achieved by offering a pasture allowance 50% less than that required to achieve maximum intake, reflecting the difficulty farmers face in trying to achieve high cow intakes and production. Bryant (1980) showed that the performance of dairy cows was reduced when daily herbage allowance was decreased. This information was supported by Glassey et al (1980), and shows the overriding influence of pasture allowance on intake.

6.5 Leaf Appearance and Leaf Extension

6.5.1 Leaf appearance rate

The regrowth of a sward can be described in the terms of the appearance of new organs, their rate of expansion and their rate of senescence and decomposition (Chapman & Lemaire 1993). Thus, they stated that the key morphogenic characteristics of a sward regrowing are leaf appearance rate, leaf elongation rate and leaf lifespan.

It is difficult to see any trend established in leaf appearance rate given only three measurement periods in Experiment I. Despite this it is possible to extract useful information from the limited results. In general the results indicated a slight advantage in leaf appearance rate at lower post-grazing residuals reflecting that leaf appearance rate was affected by previous management as shown by Grant et al (1981), although Chapman et al (1983) showed little influence of management, fertility level, slope or aspect on leaf appearance rate. The results of Grant et al (1981) also showed that a moderate grazing intensity (an allowance of 32 kg DM/sheep) gave the fastest leaf appearance rate in both winter and early spring. The results of Experiment I showed that a moderate grazing residual (Treatment 3) resulting from a pasture allowance of 32.5 kg DM/cow also gave the fastest leaf appearance rate. Practically the differences between average leaf appearance rates between treatments are generally small, given the range in post-grazing residuals.

Average leaf appearance rates from Experiment II do not indicate any trend, with Treatments 2 and 4 being significantly faster than Treatment 3 which had the slowest leaf appearance rate. This was largely as a result of the final recording for this treatment over the last 10 day period of the experiment, which was very slow (25.3 days/leaf) and significantly slower than the other treatments at the same time. Peak leaf appearance rates were recorded between 10 and 20 days after grazing. Grant et al (1981) also showed that peak leaf appearance rates in both winter and early spring occurred two weeks after grazing.

More information is given in the change in leaf appearance rates within treatments over time. In both experiments and as with other sward measurements environmental conditions largely dictated changes in leaf appearance rate. And in general differences between treatments at measurements periods were minimal in both experiments, in fact statistical differences between treatments were recorded in only one measurement period in each Experiment.

In Experiment 1 the decline in NHA occurred before the increase in leaf appearance rate and may suggest that leaf appearance rate is not one of the main determinants of NHA over winter and that another sward component has a greater influence. This suggestion is supported by the results of the correlation analysis which showed that leaf appearance rate was not significantly correlated to NHA over winter.

In Experiment II the trend in leaf appearance rate was similar between treatments. The leaf appearance rate of Treatment 1 slowed over the duration of the experiment at a relatively constant rate. All the other treatments remained relatively constant until 17 October, between this date and the end of the experiment leaf appearance dates slowed dramatically in all treatments, the average percentage decline being 44%, largely as a result of a 67% decline in Treatment 3. This large decline in leaf appearance rate mimicked the decline in NHA rate in all treatments, thus compared to Experiment I this result in

Experiment II would suggest that leaf appearance rate has a significant influence on NHA as the results of the correlation analysis reflect. The large slowing in leaf appearance rate (days/tiller) of Treatment 3 is associated with an 89% decline in NHA rate of this treatment. This further highlights the close association between leaf appearance rate and NHA over early spring at higher herbage mass levels.

The constant decline of Treatment 1 especially over the early part of the experimental period (while the other treatments remained constant or even increased slightly in leaf appearance rate) may have been due to the carbohydrate reserves declining and being unable to support the faster appearance rate in Treatment 1. In the other treatments the greater leaf area (and hence greater carbohydrate assimilation) would enable the swards to reach optimum growth rates (and thus leaf appearance rates) much quicker.

Compared to Experiment I, leaf appearance rates in Experiment II were on average faster. Table 6.10 shows the difference in leaf appearance rates between treatments for the two experiments. It can be seen that at the similar target herbage mass targets Experiment II had the faster appearance rate, being on average 3.85 days faster.

Table 6.10 Difference in average leaf appearance rates (days/leaf) between treatments for both experiments.

Treatment		1	2	3	4	5
	Expt I	1	2	3	4	5
	Expt II	-	1	2	3	4
Target herbage mass		900	1200	1500	1800	2100
Leaf appearance rate						
	Expt I	17.5	18.2	17.1	18.7	20.0
	Expt II	-	14.7	13.2	16.9	13.0

6.5.2 Tiller appearance rate

No obvious trend existed in tiller appearance rate in Experiment I, nor was there any apparent association between tiller appearance rate and the number of leaves per daughter tiller. Apart from Treatment 2, which averaged 2.5 leaves/tiller, none of the other treatments came close to having two leaves per daughter tiller. This is difficult to explain and is lower than numbers of leaves recorded by Grant et al (1981), in that case the number of leaves counted for pasture allowances of 16, 32 and 64 kg DM/sheep was 2.22, 2.46 and 2.46 leaves/tiller. These pasture allowances would be similar to Treatments 2, 3 and 5 in Experiment I whose corresponding leaf numbers were 2.50, 1.60, and 1.20 leaves/daughter tiller. However, with recorded leaf appearance rates averaging approximately 19 days/leaf (average of all treatments in Experiment I) then for three fully established leaves to appear it would take approximately 57 days. This may partly explain the low number of leaves/daughter tiller (the average being 1.6 leaves/daughter tiller over all treatments).

In Experiment II the greater number of leaves per daughter tiller seemed to show some compensation for a lower number of daughter tillers per tiller in Treatments 3 and 4. This suggests that there would be little advantage in terms of herbage production through manipulating the growth components of tiller appearance rate and the associated leaf appearance rates of these daughter tillers. The differences in NHA rates seem to be as a result of differences in the leaf appearance rates of the primary tillers. The number of leaves produced per daughter tiller in each treatment were generally higher than in Experiment I, although the stand out was Treatment 2 which was the lowest in Experiment II, but was the highest in Experiment I with 2.50 leaves/daughter tillers. The number of leaves per tiller in Experiment II was similar to those of Grant et al (1981) at the similar pasture allowance.

Grant et al (1981) again showed that a moderate grazing intensity (pasture allowance of 32 kg DM/sheep) resulted in the highest tiller appearance rates in both winter and early spring. While this was not the case in Experiment I or II, the average tiller appearance rate was greater in the winter compared to the spring (0.30 vs 0.19 daughter tillers/tiller/10 days respectively), as was shown by Grant et al (1981) and Chapman et al (1983) for ryegrass white clover swards.

In the spring a more intensive grazing generally resulted in a greater appearance rate of daughter tillers, with a laxer grazing suppressing daughter tiller production. This could be expected to result in leaf appearance rates being slower in more intensely grazed swards as carbohydrate reserves are being utilised to aid in the emergence and establishment of daughter tillers, although this was not necessarily the case, with Treatment 2 having one of the fastest leaf appearance rates. This may have occurred because the decline in leaf area was not substantial enough to require the use of reserve carbohydrates in lax grazed swards. Whereas in intensely grazed swards the requirement to increase leaf area meant the use of plant reserves to increase daughter tiller production. However, the results suggest that to compensate for reduced herbage mass and leaf area in spring, swards increase leaf appearance rate along with tiller appearance rate. In reproductive swards it has been shown that reserve carbohydrates (stored in the stem of the reproductive tiller) are re-distributed to daughter tillers trying to establish when these tillers are grazed or topped (Matthew 1990). The reserves of carbohydrate present after defoliation have been advocated as the main source of carbon for regrowth (Trlica & Sing 1979), however other studies have shown that in some species there is almost no mobilisation of reserves from roots to shoots after defoliation (Davidson & Milthorpe 1966). Also the quantity of stored reserves in grasses is generally very low (Kemp pers comm). Grant et al (1981) recommended that in spring swards be defoliated within one leaf appearance interval so that leaf death is minimised. In Experiment II this would equate to a spring rotation of 14-15 days.

6.5.3 Leaf extension rate.

Lamina growth per hectare is dependent on both the growth of individual tillers and the density of those tillers (Bircham 1981). Grazing management affects the lamina growth of individual tillers mainly through changes in the rate of leaf extension rather than leaf appearance (Butler 1986; Grant et al 1981; Davies 1974; Anslow 1966). Leaf extension rates are more dependent on leaf area of tillers (Grant et al 1981) and are thus generally greater on larger, older tillers (Carton & Brereton 1983). This study was in agreement with this general conclusion. In both experiments the more laxly grazed swards had a greater tiller mass, and leaf extension rates were greatest in these treatments. This trend in leaf extension rate closely follows that shown by (Carton & Brereton 1983), although effect of leaf mass on NHA rate is less clear and depends very much on leaf senescence rate.

The results of Experiment I indicated that as with leaf appearance rate, a moderate grazing residual of 1400 kg DM/ha will optimise leaf extension rate over winter, with leaf extension rate declining as the grazing residual both increased and decreased (although more severely as grazing residual decreased). Davis showed that leaf extension rate was reduced only when two or more whole leaves per tiller were removed. In Treatments 1 and 2 in this study the majority of tillers would have had two or more leaves defoliated (Plates 4.1 and 4.2), which may have been the reason for the significantly lower extension rates in these swards compared to the more laxly grazed swards.

The results of leaf extension rate could suggest a minimum level of herbage mass (of approximately 1400 kg DM/ha) that must be maintained to ensure no detrimental effect on leaf elongation rate. The next logical step would be to determine how much of a contribution leaf extension rate has on NHA rate over the winter, and thus whether management of post-grazing levels in winter should be partly based on optimising leaf extension rate and hence pasture production. Correlation analysis indicated that over winter, leaf extension rate was linked with

NHA (Table 6.4), thus in determining grazing residuals to enhance pasture production over winter this study suggests that management should be partly based around maintaining a high leaf elongation rate resulting in swards with greater tiller mass and hence higher grazing residuals.

Grant et al (1981) showed a similar trend in leaf extension rate with laxer grazing resulting in greater leaf extension rates. However in her study she showed that when leaf extension rates are compared between treatments with the main leaf extension rates of the daughter tillers then any differences between treatments disappeared. This highlights a possible compensation effect between extension rates of daughter tillers and extension rates of leaves on primary tillers. Thus some caution needs to be taken if grazing management decisions were to be based partly on optimising leaf extension rates.

6.6 Tiller Density and Tiller Weight

6.6.1 Tiller density

The difference between tiller appearance rate and tiller death (disappearance) rate determines tiller density at any particular time, with tiller appearance rate controlled by leaf appearance rate (Davies and Thomas 1983). L'Huillier (1987c) showed that stocking rate did not influence tillering as shown in other grazing studies by Chapman et al (1983) and Tallowin (1981). While stocking rate did not affect tillering, stocking rate and grazing management in general has a large influence on tiller death. The accumulation of herbage mass is a major cause of tiller death (Ong et al 1978), and hence tiller death is greater on laxly grazed swards (L'Huillier 1987c), although grazing frequency can also enhance tiller density (Korte 1986). In farming systems where stocking rate has been reduced and a shift towards improving per cow production and efficiency has been set (effectively removing the grazing cow as the buffer against low pasture growth rates), the control and maintenance of tiller density will be less through the control of grazing intensity and more through the control over grazing frequency and/or the conservation of surplus pasture. The control of herbage mass though these management techniques will minimise tiller death and increase pasture production and persistence.

Ryegrass tillering in dairy pastures is greatest over November-January, as is tiller death rate (Korte 1986; L'Huillier 1987c). Autumn and winter are important periods for the replenishment of tiller density (Butler 1986), especially on low stocking rate farms, or where management sees pastures grazed laxly. The net increase in tiller numbers is usually greater in these laxly grazed summer and autumn swards as a compensatory effect occurs (L'Huillier 1987c) see Figure 6.10. Tiller density data from Experiment I supported this finding and showed that the hardest grazed treatments had a greater net increase in tiller density. Figure 6.10 shows the contribution of tillers that emerged in winter that made up part of the total tiller density in spring. It can be seen that tillers that emerged in winter made a significant contribution to spring tiller density, especially in high stocking rate (high grazing intensity) swards. This fact is supported by Butler (1986) and helps explain the reason why tiller density was correlated with NHA in spring. Hence grazing residuals that are too high over winter, and management that results in pasture damage such as pugging will result in low tiller density and is likely to have an adverse effect on pasture accumulation.

At low stocking rates and low grazing intensities that allow herbage mass to increase over spring and summer high rates of tiller death result. Despite relatively high rates of tiller appearance at the same time, a lower tiller density usually results compared to intensively grazed swards. Matthew et al (1995) stated that approximately 75% of all tillers die and are replaced over December/January. In the trial by L'Huillier (1987c) the tiller density in the low stocking rate treatment at the beginning of the trial (which ran for 15 months) was similar to that at the end (5217 vs 5052 tilles/m^2). It was concluded that the sward was adapted to the stocking rate management. Thus there does seem encouragement that at lower stocking rates and with good grazing management, especially at times of pasture surplus stable tiller populations can be maintained, and as a result help to maintain pasture persistence. The low stocking rate used in by L'Huillier (1987c) was 2.77 cows per hectare.

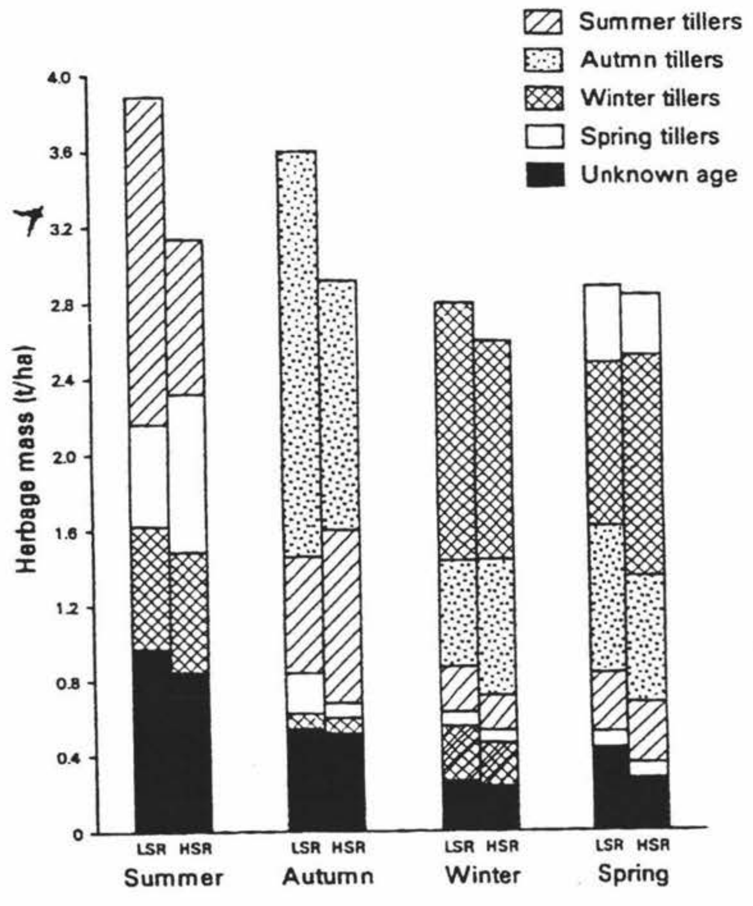


Figure 6.10 Contribution of tillers (t DM/ha) of different seasonal origin to pre-grazing herbage mass in summer, autumn, winter and spring (L'Huillier 1987c).

The average tiller density across all treatments was greater in Experiment I compared to Experiment II (5686 vs 4846 tillers/m^2). The differences in average tiller density between treatments in Experiment I were much greater compared to Experiment II where differences were minimal and no obvious trend was found.

The main contrast between both experiments was the net increase in tiller density from before grazing until the end of the experiment. In Experiment I all treatments had a net incease in tiller density, supporting the comments of Butler (1986) that the winter is an important time for the replenishment of tiller density, and also highlighting the effect of herbage mass on tiller density. While tiller appearance rate is generally low over the winter the increases in tiller density will be due to low tiller death rates (Korte 1986). In Experiment II tiller density in all treatments declined from the pre-grazing density. The effect of the time of year (or more correctly environmental conditions) is very apparent. In Experiment I tiller density increased from grazing right through until the end of the experiment (70 days after grazing). In Experiment II tiller density began to decline 18 days after grazing in the high grazing intensity treatments of Treatments 1 and 2. In Treatments 3 and 4 tiller density began to decline sometime between grazing and the first measurement date 18 days after grazing. This highlights the effect of herbage mass and consequently grazing management on tiller senescence and decay in times when herbage accumulation is high, and should be considered when making grazing management decisions over the spring as this study shows that it may have some effect on NHA rates.

6.6.2 Tiller weight

Individual tiller weight and tiller density are usually highly negatively correlated (Bircham 1981; Langer 1963) as shown in this study. This essentially means that lamina growth per hectare can be similar between swards that have different lamina growth per tiller because lower lamina growth per tiller is compensated for by a greater tiller density.

Instability in the relationship between tiller density and tiller weight, has been found to result in depressed (Davies et al 1981; Bircham & Hodgson 1983) or enhanced herbage growth (Bircham & Hodgson 1983). In Experiment I a clear compensation effect was shown with the harder grazing intensity treatments having the lowest tiller weight. In Experiment II the range in tiller weight between treatments was much smaller but still showed the trend of laxer grazed treatments having a greater tiller weight (Treatment 4 had the highest and Treatment 1 the lowest tiller weight). This is despite tiller density not showing quite the same trend, as Treatment 3 had the second highest average tiller density after Treatment 1.

In Experiment I tiller weight showed a negative trend, decreasing throughout most of the experimental period, increasing only slightly over the final period. In Experiment II the trend in tiller weight was in contrast to that of Experiment I. Tiller weight decreased at grazing as expected (Figure 5.8), however tiller weight quickly increased following grazing matching the large increase in NHA. The rate of increase in tiller weight was maximised over the 20 day period following grazing in Treatments 3 and 4, whereas the rate of increase in tiller weight was maximised in Treatments 1 and 2 between 20 and 40 days after grazing. For Treatments 3 and 4 the range over which tiller weight was maximised was approximately 25 – 60 mg DM/tiller. For Treatments 1 and 2 the range seemed to be slightly higher being approximately 50 - 80 mg DM/tiller. These results occured at a similar time to when tiller density declined. With Treatment 3 (1704 kg DM/ha residual) having a greater NHA rate over the range in herbage mass of practical interest, these results provide evidence that a laxer grazing in spring may result in improved NHA compared to more a intensive grazing when rotation lengths are less than 20 days.

6.7 Interaction of Component Measurements

6.7.1 Winter

It is interesting to note that although the compensation effect between tiller density and tiller weight was clearly evident in Experiment I, with the large increase in tiller density in Treatment 1 coinciding with a large decrease in tiller weight. It was noticed that although tiller weight in Treatment 1 never increased over the experimental period (most likely due to the large increases in tiller density of that treatment), in the other treatments tiller weight began to increase approximately 40 days after swards were grazed. Although tiller weight and hence leaf extension rate were correlated with NHA, the compensation between tiller density and tiller weight is also important to herbage accumulation (Matthew et al 1996), and so NHA is likely to be optimised when management results in more lenient grazing above some threshold level resulting in higher post-grazing residuals. Thus these results may reflect that at an intense grazing residual over winter such as Treatment 1 (870 kg DM/ha), a grazing rotation of 70 days is likely to restrict pasture production as tiller density is not able to fully compensate for the low tiller mass. The relationship between tiller density and weight in a rotation length of less than this minimum period would effectively mean the relationship between the two falling below the theoretical –3/2 compensation line, and resulting in a loss of productivity as has been shown by Matthew et al (1996). The same will apply in spring. With the high NHA rates an intense grazing residual is likely to result in a loss in productivity as a rotation length of greater than 20 days would be required for tiller weight to fully compensate for the decline in tiller density. A rotation of greater than 20 days in spring in this study showed that sward quality is likely to decline with a similar decline in nutrient intakes as the proportion of stem increased, and metabolisable energy and digestibility declined (Figure 5.14).

L'Huillier (1987c) illustrated that green herbage accumulation in high stocking rate swards was greater in summer and autumn, with low stocking rate swards being greater in late spring. He stated that these differences were associated with differences in tiller density between stocking rates. Wade (1979) found a positive relationship between herbage accumulation and tiller density in the range of 5000-15000 tillers/m^2. This study reflected this relationship, although the minimum level seems slightly lower being approximately 3500 tillers/m^2. It seems clear the tiller density has a large effect on pasture productivity, this is again backed up by the comments of L'Huillier (1987c) as he concluded that stocking rate had little influence on herbage accumulation except in swards with associated differences in tiller density. Beneficial effects in terms of NHA from the manipulation of tiller density in swards of high densities (15 000 - 35 000 tillers/m^2) have largely not resulted due to the compensatory effects between tiller density and weight (Bircham 1981). This study showed a relatively clear relationship (especially in winter) between tiller density and weight at densities under 15 000 tillers/m^2, and the non-significant differences in NHA rates in both Experiments suggest that the compensation effect between these two variables also existed at these lower tiller densities.

In summary, grazing residuals between 1400-1500 kg DM/ha over winter generally gave higher leaf appearance rates and leaf extension rates than lower or higher residuals. The small range in NHA rates between treatments in Experiment I reflects the compensation effect between tiller density and tiller mass that occurs within swards. The results of the winter experiment show that there are clear but small gains to be made in pasture production through adjustments in grazing management targeting a grazing residual of 1400-1500 kg DM/ha. The results of the experiment suggest that the management of swards over winter to optimise pasture production should be targeted at varying leaf growth (eg leaf appearance rate and leaf extension rate) rather than tiller numbers, as the greatest NHA rates were achieved at the optimum leaf appearance and leaf extension rates. Therefore we can conclude that the treatment swards attempted to increase leaf area to increase gross photosynthate production. A grazing residual of between 1400-1500 kg DM/ha was the most efficient in terms of increasing leaf area and subsequently had a greater (although not statistical) pasture accumulation rate compared to other post-grazing residuals. Grazing management in winter should focus on optimising leaf extension rate by obtaining an appropriate average tiller mass and tiller density (in this study 37 mg DM/tiller and 5300 tillers/m^2 respectively).

Whether any increase in herbage production can be utilised will depend on the skill of farm managers. At a time of the year where pasture growth is slow, even small increases in NHA can have significant beneficial effects on both pasture and animal targets heading into the spring.

6.7.2 Spring

In spring a grazing residual of 1600-1700 kg DM/ha provided the greatest NHA rate over the range in herbage mass up to an optimum of approximately 2700 kg DM/ha. This was largely a result leaf appearance rate, which in this experiment was highly correlated with NHA. Leaf appearance rates were maximised between 10 and 20 days after grazing which coincided with maximum NHA rates. Although laxer grazed swards had faster daughter tiller appearance rates, there was evidence to show that this was compensated for to some degree by a greater number of leaves per daughter tiller on intensely grazed swards. Thus daughter tiller development seemed of greater importance in winter compared to spring as shown by the average daughter tiller appearance rates over all treatments (being 0.30 and 0.19 daughter tillers/tiller/10 days respectively). All results in Experiment II suggest that a grazing rotation of somewhere between 10 – 20 days would be ideal as leaf appearance rate is at its optimal and starts to decline after this period. Tiller density of laxly grazed swards begins to decline through this period also, however at more intensive grazings (Treatments 1 and 2) a rotation length of 10 – 20 days may not provide sufficient time for tiller density to fully compensate for a low tiller weight and productivity may be lost. By having a grazing rotation of less than 20 days swards will be defoliated within one leaf appearance interval, which will minimise leaf death, and maintain sward quality, as advocated by Grant et al (1981).

In Experiment II at similar herbage mass, tiller density was lower throughout the trial compared to Experiment I, despite the much higher herbage accumulation rates. This suggests that the increased pasture production in Experiment II was through either high leaf appearance or leaf extension rates or by having bigger tillers, or through a combination of all or some of these. In spring the management of leaf growth appears to again be of importance, with leaf appearance rate being highly correlated to NHA, however the management of tiller density and tiller weight is also of importance. While tiller density in winter was not significantly associated with pasture accumulation, its increase over winter is important as it has a large effect on the density of spring swards, and hence herbage accumulation. Tiller weight is again likely to influence leaf extension rate (which was not measured in spring) and with lax grazing it is important that tiller density does not decline to a level where tiller weight is unable to compensate. Leaf extension is also likely to influence herbage accumulation, although it is anticipated that the main mechanism for the increase in leaf area will be through the development of new leaves (from primary tillers) and the interaction of tiller density and tiller weight. Correlation results showed that all variables had an influence on NHA with leaf appearance rate being the most significantly correlated variable, however it is likely that the higher NHA in Treatment 2 is a result of the combination between all of the variables.

6.8 Botanical Composition

Results from the analysis of botanical composition from Experiment I show a high proportion of leaf material and as a result a high leaf:stem ratio. The proportion of stem in the sward was much greater in spring (Experiment II) reducing the proportion of grass by around 14%, and resulting in a lower the leaf:stem ratio. In both experiments the proportion of clover within the sward was low, with the average for all treatments being less than 10% (Table 6.11).

6.8.1 Clover

White clover is an essential component of dairy pastures in New Zealand and is estimated to contribute approximately \$3.1 billion annually (Caradus et al 1996). The two main advantages of clover are through its direct influence on milk production through improved forage quality (Harris 1994; Castle et al 1983;

Rogers et al 1982; Santamaria & Rogers 1980), and as a 'free' source of nitrogen through fixation (Caradus 1996).

The low clover content of all swards over the trial period was a highlight in both experiments. Low clover levels (averaging 8.8%) over winter were difficult to explain. Mild winter conditions would be expected to have resulted in some clover growth; management in autumn may have been part of the reason for low yields. Spring yields were again below 10% for all treatment swards. The results were considerably lower than those observed in a survey of Waikato dairy farms by Harris (1993) where the average annual white clover proportion was 18%, ranging from 13% in mid October to 29% in late January. Harris (1994) stated that over spring there is a large increase in the proportion of first order plants which coincides with a decrease in average plant size, a result of fragmentation of larger plants after decay of older stolon material with increased soil temperature and increased microbial activity. These results were reinforced by Woodfield & Caradus (1996). The fact that white clover plants are susceptible to stress in spring means that they are vulnerable to mismanagement at this time. Heading into late spring and summer where pasture quality is always an issue, high clover levels (along with reducing the content of dead material) provides one of the main avenues for improving pasture quality. Increased levels of clover may have the combined effect of increasing the level of intake and increasing the quality of ingested material resulting in significant gains in milk production. The low level of clover in the pastures on the property used in these experiments should be investigated, and management strategies for increasing the contribution of white clover at this time of the year identified and considered. These low clover levels are likely to have a significant impact on animal performance and nitrogen fixation.

Ettema & Ledgard (1992) stated that in general, frequent intensive grazings in spring favour increased clover growth due to reduced grass competition. There was concern that increases in post grazing levels particularly in spring may have a small adverse effect on clover growth through the effects of shading from more competitive plants such as ryegrass. In this study however, results indicated no apparent effect of post-grazing level on the proportion of clover within the sward.

6.8.2 Dead matter

Dead matter content was surprisingly low in spring swards, being only marginally higher than these in winter swards (Table 6.11). Given the herbage mass levels reached it was expected that dead matter content would be higher and clover levels lower in these spring swards compared to winter swards due to effects of shading and competition. Despite the high growth rates the condition may also have led to the high turnover rate through decomposition of dead material.

Looking at Figures 4.9 - 4.13 there is some evidence that the proportions of dead material in all treatment swards were beginning to increase near the end of the trial period in Experiment I. Over the regrowth period (until desired pre-grazing levels were reached) the proportion of dead material would have been relatively low. This is likely to be a reflection of good autumn/winter management, which saw an appropriate stocking intensity and rotation length lead to swards dominant in green lamina. The mild winter conditions may have also contributed through increased rates of decay of dead material.

Table 6.11 Average proportions of grass stem, grass leaf, dead matter, clover and weeds across all treatments in winter and spring.

	Winter	Spring
Stem	23.0	33.7
Leaf	54.0	39.7
Dead matter	13.3	14.9
Clover	8.8	9.7
Weed	0.9	2.2

In Experiment II there were no significant differences between treatments in any of the variables measured. In Experiment I there were more statistical differences present, however in general Treatments 2, 3 and 4 were similar with only small differences between them. These observations reinforce comments made by C.P.McMeekan some 40 years earlier that even large changes in grazing management can have only small changes on a farming system (McMeekan 1961). However, Holmes pers comm (1997) mentioned that limitations of experimental work through the guidelines of experimental protocol (which usually involves only one variable being changed at a time) may not accurately reflect what occurs in practice. It is often the case that farmers will change more than one variable in making a management change, and so the combination of the small differences that occur from each change may result in a larger more significant change at the system level.

The benefits of higher grazing residuals and pasture cover levels in late spring have been shown to have beneficial effects on pasture production in late spring and summer. Initial work by Colvil & Marshall (1984), and then later by Korte & Harris (1987), and Matthew et al (1989a) illustrated the yearly cycle of perennation of grass tillers and clover stolons. From these, and studies on tiller population turnover by Korte (1986), L'Huillier (1987c) and Chapman et al (1983) the 'late control' grazing management strategy was developed. In short this saw grazing residuals increase by approximately 500 kg DM/ha during early seedhead development, followed by an intensive defoliation of the sward to encourage buds present at the base of tillers which have had their seedheads removed at a time of high tiller turnover.

In Experiment II Treatment 3 provided the greatest net herbage accumulation rate over the regrowth period until a pre-grazing herbage mass of 2600-2700 kg DM/ha was achieved. Botanical composition results showed minimal difference between treatments despite the range in grazing residuals employed. The virtually negligible differences in dead matter between treatments was a surprise given the herbage mass levels reached, yet the values are similar to those recorded by Hoogendoorn et al (1987) at the same time of the year with intensely and laxly grazed swards. The optimum residual of 1700 kg DM/ha is higher than previous recommended levels over spring by other authors (Hoogendoorn 1992b; Sheath & Bryant 1984). Evidence by Hoogendoorn et al (1987) showed that in laxly grazed swards dead matter did not begin to increase significantly (and did not become greater than 20% of the total sward component) until October/November. Therefore concerns over sward quality in late spring are likely to have some effect on the grazing management in early - mid spring. Nevertheless these results support the late control grazing management practice of operating at a higher residual followed by a more intensive grazing in November.

6.8.3 Grass leaf and stem

The proportion of grass leaf and clover compared to the other constituents largely determines pasture quality (Stakelum & Dillon 1990) due to the higher energy content and higher digestibility of these. The leaf component of the swards (grass leaf + clover) differed between experiments. In Experiment I leaf material represented 63% of the total herbage, compared to 50% in Experiment II. This reduction in leaf material was due to the increase in proportion of stem material rather than dead material.

Differences in the response of NHA to management in spring are likely to be as a result of differences in the rates of lamina and stubble accumulation (Butler 1986). Korte (1981) concluded that differences found in NHA rates between lax and hard grazed swards were most likely due to reduced losses through death and decay in the later. In winter this is unlikely to be the case, as senescence and decay rates are usually very low (Clark & Penno 1996). These comments are generally supported by the findings in this study. In winter herbage mass levels were overall much lower than those in spring and NHA was influenced more by environmental conditions. In spring, the initial high rates of NHA led to high levels of herbage mass, as herbage mass increased so to did the rates of death and decomposition as highlighted by Figure 5.6.

Butler (1986) measured changes in NHA rates in terms of lamina growth and death and stubble growth and death recognizing that pasture growth is a combination of two simultaneous but opposing processes. It was concluded that differences in both total and green herbage accumulation in his spring experiment were mostly due to the death and disappearance of reproductive stubble rather than differences in accumulation of new tissue. In Experiment II changes in dead matter were not as large as expected, but was still the only variable to be significantly affected by the grazing treatments involved. The effect on NHA of the death and disappearance of lamina and stubble over the duration of Experiment II is highlighted by the increase in average NHA rates over the time period from grazing until a pre-grazing mass of 2700 kg DM/ha was reached. The fact that death and decay of leaf material increased significantly after this period at higher herbage mass resulted in the decline in NHA rates and supports the data of Bircham & Hodgson (1983). In general NHA results showed that higher grazing residuals have a greater decline in herbage accumulation over the same regrowth period compared to lower post-grazing levels due to greater rates of senescence and decay. This means the system outcome will be affected by the level of pre-grazing herbage mass used.

Using Butler's conclusion, spring management should look at targeting a herbage mass that provides the best compromise between growth and senescence. With grazing management having a smaller effect on NHA (but still an effect), post grazing targets which reduce death and decay of herbage are likely to result in improved pasture production. This study shows that this will be the case if the grazing interval, pre-grazing and post grazing herbage mass are not in balance. Results suggest a 2700-1700 kg DM/ha grazing regime. A finding from the results of Hoogendoorn et al (1987) was that it was not until late November that significant differences in the proportion of dead matter between swards occurred.

Hence there is some leeway in having a high post-grazing residual of 1700 kg DM/ha, as the proportion of dead matter in all treatment swards was similar (supporting the findings of Hoogendorn et al 1987).

The dilemma often faced over early spring is that a compromise has to be made between pasture quality and pasture quantity. With herbage quantity having a dominant effect on milk production in early spring (Bryant & L'Huillier 1986; Bryant & Cook 1980), management over winter that can improve pasture growth rates will only be beneficial. However because the decisions made in one part of the season can affect decisions made later in the season, caution must be taken as to the likely effects in late spring, particularly on herbage composition. Hoogendoorn et al (1992b) emphasised the importance of maintaining green leafy swards into late spring and summer in order to maximise milk yield per cow at this time. Thomson et al (1984) found that over late spring grass stem was not associated with milkfat production. Given the relatively high levels of grass stem in Treatment 3 which had the highest NHA rate (between grazing and a desired pre-grazing level) this would allow some compromise between high intakes and high pasture growth rates in early spring while maintaining sward quality into summer. Hoogendoorn et al (1992b) mentioned a post-grazing herbage mass of no more than 1500 kgDM/ha throughout spring by imposing a sufficiently high stocking rate. Sheath & Bryant (1984) suggested residuals between 1300-1600 kg DM/ha. The level of pre-grazing herbage mass should also be considered as this has a large influence on sward quality (assuming adequate post-grazing levels are applied). In this study herbage mass levels above 2700-2900 kg DM/ha resulted in reduced NHA, through the increase in turnover of herbage material.

The success of achieving high quality swards in late spring is through controlling post-grazing and pre-grazing levels through the early to mid spring. This emphasises the difficulty that farmers face when striving for high per cow production as using the cow to apply grazing pressure to maintain sward quality will mean lower intakes of poorer quality herbage.

6.9 Pasture Quality

From the results in Experiment I it could be suggested that a grazing residual above 1400-1500 kg DM/ha (e.g. Treatments 4 and 5) would lead to a poorer quality sward at the next grazing relative to swards grazed below 1400-1500 kg DM/ha (Table 4.12). The dilemma to the farm manager, and the compromise that must be made is the trade-off between pasture quantity and quality. Of the variables measured it can be argued that the relative proportions of green vs dead material are of most importance over winter. The proportions of clover and dead matter and the leaf to stem ratio in late spring are perhaps more important in spring to late spring when pasture quantity is more important. In winter when pasture supply is restricted due to slow NHA rates, the quantity of herbage present that will contribute towards animal maintenance and/or liveweight gain is of more relevance. This then adds to the support of a grazing residual no greater than 1400-1500 kg DM/ha, as the results showed that the proportion of dead material in Treatments 4 and 5 were significantly greater ($P<0.05$) than Treatments 1 and 2. This is likely to be due to death within the stubble rather than in new growth and therefore may not affect subsequent animal intake and performance.

Analysis of the proportion of protein shows that Treatment 1 was significantly lower than Treatment 2 and Treatment 3, 4 and 5 ($P<0.05$). This is the opposite to what the results of the botanical composition suggested, as it showed clover levels in the hard grazed treatments to be greater than in lax grazed swards. An explanation of this could be that as NIR samples were taken to the estimated grazing height of each treatment then it was new growth rather than the whole sward (e.g. down to ground level) which would have included the residual dry matter left after grazing. This fact may also explain the similar ME and digestibility levels between the treatments, despite the analysis of botanical composition showing some likelihood that there should be differences with the more intensely grazed treatments having higher levels of protein and lower levels of dead material.

The differences (or lack of them) in botanical composition in both experiments were largely reflected in NIR analysis. Table 6.13 shows that in general metabolisable energy content, herbage digestibility, and protein content were higher over all treatments in Experiment I, with ADF and NDF being higher in Experiment II. Apart from herbage digestibility (which is slightly more variable) the higher winter values for metabolisable energy and protein and lower ADF and NDF levels were all expected and are similar to the results of Moller et al (1996). The average values for herbage digestibility are quite low, especially in Experiment II. Values given for herbage digestibility for leafy early spring pasture are approximately 70-90% (Holmes & Wilson 1984), however results from three years of recording by Moller et al (1996) on New Zealand dairy farms showed that herbage digestibility ranged from 65 - 80%. This partly reflects some of the opportunities to increase milk production through improvements in pasture and feed management as advocated by Ulyatt & Waghorn (1993), Muller (1993) and Moller et al (1996). The high proportion of grass stem and low proportion of clover in all swards in Experiment II is likely to be the reason for the low value for herbage digestibility and high values for ADF and NDF.

Table 6.12 NIR results (average of all treatments) compared with recommended values (%).

	Experiment I	Experiment II	Recommended*
ME (%)	11.6	11.2	11-12
Digestibility (%)	77.7	73.7	70-90
ADF (%)	20.3	25.4	20-21
NDF (%)	38.5	43.8	35-40
Protein (%)	28.1	22.3	17-18

* Recommended values sourced from NRC (1989).

The average protein content of the all treatment swards is slightly higher than the requirements of protein (17-18%) for high producing dairy cows. These high protein levels may be limit milk production (Satter et al 1992). The high protein content of the swards in Experiment II is in contrast to the low proportion of clover in treatment swards. Thus the high protein level was not due to the clover component but to the grass component of the sward. The average level of ADF of swards in Experiment II would not be restricting milk production. Minimum levels required are 20 - 21% of total dry matter (NRC 1989). Recommended levels for NDF are 35 - 40% (NRC 1989), spring swards were slightly above this but it is unlikely to limit milk production.

Hoogendoorn et al (1992a) stated that in early spring, herbage from high mass swards was of lower quality than from low mass swards. Despite botanical composition showing no statistical differences between treatments, and NIR results showed only a difference in ADF and NDF levels, Figures 5.9-5.12 show that as time and herbage mass increased, the proportion of grass stem in all treatment swards increased resulting in a decline in sward quality (Figure 5.13).

Hoogendoorn et al (1992a) showed that milk yield per cow will be decreased by an increase in herbage mass in early spring swards. However on the other hand high mass swards will support higher daily stocking rates, resulting in increased per hectare production. The above two statements highlight the requirement to consider milk production per cow and per hectare when assessing the practical implications for grassland farming. With the dairy system, in this study, focused on high per cow production as a way to improving per hectare production, then it would seem more beneficial to maintain lower herbage mass at calving of higher quality, through more intense grazings over winter. Despite the results of Hoogendoorn (1992a) showing that milk yield per cow was decreased at high herbage mass, in similar whole farm experiments, most instances have show that early lactation milk yields both per cow and per hectare were increased by increases in average herbage mass present on the farm in early spring (Bryant & L'Huillier 1986; Bryant & Cook 1980). The reason for this apparent contradiction is due to the fact that the lower quality of the high herbage mass was overcome by the beneficial effects of the increased quantity of herbage eaten per cow. In this study pasture quality at the end of the winter experiment (August 28) was similar between all treatments (with generally the main statistical differences occurring between the two extreme treatments, Treatment 1 and Treatment 2). The fact that pasture quality was similar despite differences in grazing management would mean little variation in milk yield, with the main determinant of milk yield being pasture quantity eaten per cow and per hectare. Hence higher grazing residuals over winter, and thus higher pasture cover in late winter/early spring will allow higher cow intakes and higher per cow production in early spring, resulting in improved total milk production over the early part of the lactation. This must be weighed against reduced herbage use earlier in the winter.

Pasture quality has traditionally been described in terms of organic matter digestibility (OMD) (Holmes & Hoogendoorn 1985). However changes in OMD are largely a response to changes in the proportion of dead herbage. Rattray & Clark (1984) stated that animal performance is less related to the dead content of pastures and much more closely related to green than total herbage mass or allowance. The composition of animal intake is largely green leaf (Butler 1986). The opportunity exists to increase the leaf to stem ratio of spring swards through increases in the proportion of clover, at a time of the year when the leaf to stem ratio is beginning to decrease. Despite high levels of stem, if spring swards contain sufficient levels of ryegrass and clover leaf then it may be possible for the grazing cow to select herbage that will maximise milk production and liveweight gain from the total herbage on offer (Hughes 1998; Gorden & Lascano 1993; Arnold 1987). Thus post-grazing levels which provide the best compromise between allowing high intakes (high pasture allowance) and sufficient levels of green leaf will result in improved milk production from the herd.

Sheath et al (1984) stated that the ideal management should be a compromise between high feed on offer and restricted selective grazing so that control of pasture quantity and quality is not lost. Korte (1984) and Hughes (1983) agreed that a hard grazing in spring is the management required to maintain or regain ideal sward conditions. Butler (1986) stated however that although this management is of benefit to the sward, it would result in large losses in animal production. In a dairy farm system driven towards increasing per cow production the cow cannot act as the buffer in the system against variable pasture growth rates as has been the case in the past (Matthews 1994; 1995). High intakes of high quality pasture throughout lactation are required to produce high production per cow (Matthews 1997). The risk in implementing a hard grazing in spring is that NHA is usually much greater than herbage consumption. A hard grazing by reducing herbage consumption further (besides resulting in an immediate drop in milksolids production) increases this imbalance and leads to greater spells between grazings (Butler 1986). As a result, the quality of pre-gazing herbage deteriorates and this may lead to even lower intakes.

7.0 PRACTICAL IMPLICATIONS

7.1 Implications for Farm Management.

7.11 Winter

The differences in NHA rates over the range of post-grazing levels measured in winter were small. However if we consider the time period of a typical winter (as often assumed by farmers) as being 100 days, then small differences may actually reflect some potential practical benefits. A total difference of 100 kg DM/ha over winter (which represents a difference of 1 kg DM/ha/day) in practical terms could support one dry cow at maintenance of 10 kg DM/cow/day for 10 days, or conversely at a typical winter farm stocking rate of 1.5-2.0 cows/ha, each cow could eat 0.67-0.5 kg DM/cow/day more. Holmes & Brookes (1993) stated that to gain an extra body condition score (approximately 30 kg liveweight) required an extra 150 kg DM eaten above maintenance. Therefore 100 kg DM/ha could effectively increase the condition score of 34% the herd by one at a stocking rate of 2 cows/ha (or 45% of the herd by one at a stocking rate of 1.5 cows/ha). This highlights some of the practical benefits to be gained from enhancing pasture growth through the manipulation of grazing residuals.

It has been shown that pasture intake follows the line of diminishing returns as herbage mass increases (Holmes & Wilson 1984), with increases in herbage mass having marked effects on intake at the lower levels, whereas at higher levels of intake and herbage mass further increases in herbage mass have only a small effect on intake. The benefits from an increase in grazing residual from 900 kg DM/ha to 1400 kg DM/ha (the fastest and slowest accumulation rates) were associated with an increase in intake from 6 to 16 kg DM/cow/day as well as leading to improved sward conditions at calving. The increase in grazing residual from 1400 to 1900 kg DM/ha was only associated with an increase in intake from 16 to 20 kg DM/cow/day. Practically this implies that a compromise between intake and post-grazing level is likely to result at a residual of 1400 kg DM/ha or less, given also the likely cow requirements at the time.

The benefits of improved cow condition at calving through better feeding have been shown in the past. Grainger (1978) showed that an extra condition score at calving could produce an extra 9-18 kg MS/cow, evidence supported by Rogers et al (1979) and Grainger & McGowan (1982). Other advantages are a reduced post-partum anoestrus period (McDougall 1993) and a reduced incidence of retained membranes in induced cows (Grainger et al 1982).

Results from Experiment I suggest that a grazing residual of 1400 kg DM/ha will optimise pasture production. However from the results we can see that residuals between approximately 1200 – 1600 kg DM/ha had little effect on NHA. And thus other decisions such as stock numbers wintered, desired pasture cover levels at calving, and cow intake levels over winter or whatever the farm managers goals and objectives over winter and spring are, are likely to influence the post-grazing residuals chosen.

Despite herbage accumulation being optimised at a grazing residual of 1400 kg DM/ha, the effect of this post-grazing level on pasture utilisation needs to be considered. At this grazing residual a utilisation in the vicinity of 50 - 55% of herbage on offer would be achieved, representing a poor efficiency. The extra growth achieved with higher pasture residuals must be weighted against the lower level of pasture harvested to allow the higher post-grazing levels. A compromise between these two variables must be reached along with obtaining suitable cow intakes. Results suggest that the post-grazing residual which provides the best compromise will lie at the lower range of herbage mass covered in this study. So little is to be gained in increasing residual above 1200 kg/DM/ha other than if higher per cow intakes are required.

The key to winter management, as with at most other times of the year, is obtaining the best compromise between animal requirements and the variables that are most important to pasture productivity at the time. In winter the important variables defined in this study are achieving a high pasture accumulation rate (of which tiller weight and leaf extension rate are the main determinants), a high pasture utilisation rate and increasing tiller density enough so that spring pasture productivity is not unduly compromised. Given these targets, a post-grazing level of between 1200-1300 kg DM/ha is recommended as providing the best compromise between these variables. Above a grazing residual of 1200-1300 kg DM/ha any increase in NHA will be outweighed by the decrease in pasture utilisation. Below this level NHA was reduced due to the decline in leaf extension rate.

7.12 Spring

In spring the difference between the two treatments that had the fastest and slowest NHA rates between grazing and when a pre-grazing mass of 2700 kg DM/ha was achieved (Treatment 3 and Treatment 2 respectively) was 9.1 kg DM/ha. The main difference in spring compared to winter was that this difference in herbage accumulation occurred over 16 days compared to 80 days in winter. This situation highlights the need for constant and regular farm monitoring and good management to maintain sward quality with such high pasture accumulation rates of up to 80-90 kg DM/ha/day .

The composition of spring swards highlighted the low clover content. Results in this study showed that there was little difference in clover proportions over sward levels ranging in post-grazing levels from 1098-1913 kg DM/ha, suggesting it was not a function of the treatments used. This problem has also been observed in the current Agmardt farm-monitoring project (involving 12 southern North Island dairy farms targeting improved per cow production) where clover levels of 5% or less have been recorded (Matthews pers comm), and could be part of the cause for reduced milk production over this October/November period in these farming systems (Hughes 1998). Clearly an opportunity exists to improve pasture intake and milk production levels over this period with an increase in clover content of swards. Therefore the factors that are affecting the clover content of swards need to be identified, and strategies to enhance clover productivity at this time addressed.

Hughes (1998) showed that cows are able to select material that is of higher quality to that which is on offer. Although in this study clover content was low, making the assumption that cows endeavour to maximise energy intake during lactation (as many intake experiments are based on), on lower stocked farms targeting improved per cow performance, grazing intensity is likely to be lower. This lower grazing intensity will allow each cow more opportunity to maximise energy intake even if the sward is lacking in quality. Combellas & Hodgson (1979) showed that the relationship between intake and herbage allowance is not affected by herbage mass provided that pasture composition does not differ too much with herbage mass. Where pasture composition varies, it will be through the control of pre-grazing levels that will control sward quality, thus it is important that an appropriate and sustainable rotation length is instated to maintain appropriate pre-grazing sward conditions. In early spring when a feed deficit is likely to exist, the quantity of supplementary feed used, and the pasture substitution rate resulting will have an effect on this.

While this study has focused on the effect of post-grazing levels on pasture productivity, the effect of pre-grazing herbage mass levels should not be over-looked. In winter it was not possible to gain an indication of the effect of grazing at a level greater than 2700 kg DM/ha as only Treatment 5 reached beyond this level. In spring results suggested that pre-grazing levels greater than 2700 kg DM are likely to result in reduced intakes of lower quality herbage. Figure 6.2 showed that at herbage mass levels greater than approximately 2800-2900 kg DM/ha herbage accumulation starts to decline, indicating that the turnover of dead material is beginning to increase substantially. This is also reflected in tiller density results, with tiller density declining within 18 days after grazing in Treatments 3 and 4, highlighting the increase in tiller death. The fact that these treatments reached 2700 kg DM/ha 10 days after grazing, reflects that a pre-grazing level above 2700 kg DM/ha is very likely to contain a greater proportion of grass stem and dead material (where the rate of decay is slow), with subsequently lower metabolisable energy content and digestibility as Figure 5.14 showed.

The incorporation of a grazing residual of close to 1700 kg DM/ha in early spring seems possible in a dairy system. However in farm systems adopting reduced stocking rates and increased per cow production it is almost certain that the incorporation of supplement into the system would be required to maintain the ideal compromise between grazing residuals, intake levels, and rotation length, as advocated by Matthews (1997) and Brander & Matthews (1997). The amount of supplement required will depend on individual circumstances and supplement quality will have a large effect on this. Simple economics will determine the viability of the use of supplements and the required level of input. However if the advantages in pasture accumulation such as those experienced in Experiment II are achieved (through the manipulation of grazing residuals), then use of supplement will be over a shorter period, as pasture growth will meet herd requirements at a much earlier date, although this may be partly offset by high per animal intake. This in itself highlights that management of surplus pasture will be of even greater importance, as the length of time that the farm is in a surplus situation will be longer. One potential benefit of this however is that a larger amount of supplement can be made, although harvesting costs will be higher, given effective conservation management, a greater quantity of high quality feed will be available to extend lactation in the autumn.

This study showed that in spring management must achieve a balance between a high NHA rate, a medium to high utilisation and the need to maintain sward quality heading into the late spring period. Although a grazing residual of 1700 kg

DM/ha maximised NHA, it was concluded that problems with sward quality in late spring and the low pasture utilisation would outweigh any advantage in herbage accumulation from a grazing residual of 1700 kg DM/ha. From this study a grazing residual of 1500-1600 kg DM/ha would provide the best compromise between all the variables considered important over the early to mid spring period. A residual of 1500-1600 kg DM/ha would provide high leaf appearance rates, which was shown to be highly correlated with pasture growth. Tiller density results indicated that there is a critical post-grazing herbage mass somewhere between 1400 and 1700 kg DM/ha where tiller density begins to decline either in the first 2 ½ weeks of regrowth, or at a point after this period. This reflects the affect of herbage mass and grazing management on tiller death rates. Thus at a residual of 1500-1600 kg DM/ha and at a rotation length of 20 days or less (which is common over the spring period) it is unlikely sward quality at subsequent grazings will be reduced through high levels of dead matter.

With a recommended grazing residual of 1500-1600 kg DM/ha it is very important that effective monitoring of post-grazing residuals and general sward conditions is carried out. With the high growth rates experienced in this study (giving a rotation length of 10-15 days), it would not take long for pre and post-grazing residuals to increase, causing an increase in senescence of stubble leading to reduced cow intakes and production in late spring. At this stage control has been lost. Taking out surplus paddocks over this period would reduce the effective grazing rotation and help maintain control.

One possible beneficial affect that increasing grazing residuals and pasture cover may have, is though improved nitrogen fertiliser responses. Nitrogen is commonly used on New Zealand dairy farms to increase pasture production at various times of the year, as nitrogen is usually the most limiting nutrient in our pastoral swards (Clark & Harris 1996). Roberts et al (1992) stated that nitrogen fertiliser is essentially a growth accelerator, and that responses to nitrogen are greatest when pasture growth rates are fastest. With evidence from this study that (in spring) herbage accumulation rate is increased as post-grazing residuals are increased, then it can be anticipated that the response rate to nitrogen will be higher as herbage mass increases (up to some point), as shown by Roberts et al (1992). The high pasture growth rates achieved in this study however imply that nitrogen was not apparently limiting herbage accumulation, as shown by the small nitrogen responses (Table 6.1). This point highlights that the application of nitrogen should be strategic and planned. If accumulation rates can be improved, then in fact there may be less of a requirement for nitrogen over this time.

7.2 Summary

Matthews (1994) stated that the significant gains in dairy production over the last 40 years has been through improved grazing strategies allowing more of the herbage grown to be harvested. He argued that future gains are likely to be less significant unless we can increase the total amount of pasture produced. This study has explored the relationship between herbage mass and net herbage accumulation. In summary, there seems encouraging results that increases in post-grazing residuals of approximately 1600-1700 kg DM/ha and 1400 kg DM/ha in spring and winter respectively will result in small increases in herbage accumulation (with the response in spring being slightly greater than that in winter). The incorporation of such residuals in a dairy farming system is less clear, particularly in spring. The balance between feeding the herd well in early spring and maintaining control of swards to maintain pasture quality into late spring and summer is delicate. Theoretical evidence suggests that there may be some leeway in maintaining these high intakes and herbage accumulation rates without severely affecting sward quality, and post-grazing levels of 1200-1300 and 1500-1600 kg DM/ha over winter and spring respectively have been proposed. In any sense the timing and control of surplus pasture and the use of supplementary feeds will be critical in achieving a desired balance, along with the duration of regrowth or rotation length employed. Good farm monitoring and decisive decision making will be required. This study adds to the growing evidence to support farming systems more focused on sward targets (Brander & Matthews 1997; Cassells & Matthew 1995; Phillips 1995; Phillips & Matthews 1994) in enhancing both pasture and animal performance. However while it has be argued that the concept of increased NHA from increased grazing residuals is one reason for focusing on sward conditions on farms. From this study we could conclude that the benefit being captured in systems focusing on sward conditions are more likely to be the result of sward quality, animal intakes and animal production advantages, rather than any advantage in pasture production.

Further research is suggested by the author into developing management systems focused on sward conditions on dairy farms. This study has provided some basis for the application of post-grazing residuals that may enhance pasture and animal performance. It is anticipated that to define exact sward conditions, to learn how much of a role supplements will play, and to correctly adjust farm management may take up to five years. Over which time the full effects, both positive and negative, of a farming system adopting higher pasture residuals and pasture covers over winter and spring will be determined.

8.0 CONCLUSION

Currently many farmers are adopting dairy grazing systems using improved per cow productivity to increase total farm output. Such systems aim to increase pasture production through increases in post-grazing (and average farm cover) levels, a direct result of increased pasture intakes from the herd. A key relationship at the centre of such grazing systems is that between herbage mass and pasture growth. Experiments were conducted using a range of grazing residuals to examine and then discuss the effects of these on pasture accumulation, and the components of pasture regrowth, and the practical implications of these.

(1) Sward Characteristics

- A post-grazing residual of 1400 and 1700 kg DM/ha in winter and spring respectively resulted in the greatest NHA rates from grazing until pre-grazing levels of 2600-2700 kg DM/ha were achieved.

- A positive relationship between herbage mass and NHA was shown in both experiments. Pasture accumulation rate was shown to be maximised at a herbage mass of approximately 2500 kg DM/ha in winter, with the optimum being approximately 400kg DM/ha greater in spring at 2900 kg DM/ha.

- In winter NHA was closely related to changes in leaf growth rather than tiller growth, with leaf extension rate and tiller weight being correlated with pasture growth. In spring NHA was significantly related to leaf appearance rate, tiller weight and tiller density, with leaf appearance rate being the most significantly correlated variable. Tiller density and tiller weight were inversely related and showed compensatory effects in both experiments.

- The increase in tiller density over winter is considered an important substrate to pasture growth over spring.

- Swards were able to compensate over a wide range of post-grazing residuals. It is only at the more extreme post-grazing residuals where sward components are unable to fully compensate, and pasture production declines.

- Clover content of all swards in both experiments was low. Reasons for this need to be identified and strategies developed to rectify this. Increases in the proportion of clover in swards will go further in allowing high intakes of high quality pasture.

- Pasture quality largely reflected the small (but significant) changes in botanical composition in winter and spring. Trends in pasture quality indicators in spring showed the decline in sward quality, and highlighted the difficulties likely to be experienced in late spring at herbage mass level greater than 3000 kg DM/ha.

(2) Management Targets

- There does seem some scope for maintaining higher residuals of 1600-1700 kg DM/ha in spring to capture benefits in NHA. However, careful monitoring and manipulation of the system is likely to be required. Initially the use of supplementary feed to maintain post-grazing levels, and then later the control of surplus pasture to maintain pre-grazing levels appear to be critical aspects to achieving and maintaining a higher residual in early spring.

- It was concluded the there is a benefit in the use of sward conditions (targets) in the planning and management of grazing systems. It is recommended that residual herbage mass targets after grazing should be 1200-1300 kg DM/ha and 1500-1600 kg DM/ha in winter and spring respectively. There is no systems advantage in terms of NHA and utilisation of increasing post-grazing levels above those recommended other than for the need to increase animal intake targets.

- Results illustrated no benefit in pre-grazing levels above 3000 kg DM/ha.

(3) Systems Development

- While the results in this study were not always consistent and statistically different, it is considered that there is enough evidence to suggest that there does appear scope to incorporate increased post-grazing levels to enhance pasture production.

- Effective farm monitoring and efficient management will be required in operating farming systems targeted toward improved per cow production and higher sward levels. More so in spring where NHA rates are high and changes within the system are likely to occur quickly.

- Overall the study supports a farming system developed around sward conditions to improve farm productivity.

9.0 REFERENCES

Agyre, J.A. & Watkin B.R. (1967) Some effects of grazing management on the yield and its components of some pasture grasses. *Journal of the British Grassland Society 22:* 182.

Anslow, R.C. (1966) The rate of appearance of leaves on tillers of the gramineae. *Herbage Abstracts 36:* 149.

Arnold, G.W. (1987) Influence of the biomass, botanical composition and sward height of annual pastures on foraging behaviour of sheep. *Journal of applied ecology 24:* 759.

Baker, A.C. & Leaver, J.D. (1986) Effect of stocking ate in early season on dairy cow performance and sward characteristics. *Grass and Forage Science 41:* 333.

Bircham J.S. (1981) Herbage growth and utilisation under continuous stocking management. *Ph.D Thesis, University of Edinburgh.*

Bircham, J.S. & Hodgson, J. (1983) The influence of sward condition on the rates of herbage growth and senescence in mixed swards under continuous stocking management. *Grass and Forage Science 38:* 323.

Bishop-Hurley, G.J. (1999) An evaluation of a dairy systems study of the effects of contrasting spring grazing management on pasture and animal performance. PhD thesis, Massey University New Zealand.

Bluett, S.J.; Matthew, C.; Bishop-Hurley, G. Haslett, S.J. & Hodgson, J. (1998) The relationship between herbage mass and pasture accumulation rate in winter. *Proceedings of the New Zealand Society of Animal Production 41:* 299.

Brander, S. & Matthews, P.N.P. (1997) Feeding practices: recent changes in attitude, their reason and effect – a case study. *Massey Dairyfarming Annual 49:* 72.

Brougham, R.W. (1955) A study in the rate of pasture growth. *Australian Journal of Agricultural Research 6:* 804.

Brougham, R.W. (1956) The rate of growth of short-rotation ryegrass pastures in the late autumn, winter and early spring. *New Zealand Journal of Science and Technology* pp78.

Brougham, R.W. (1957) Pasture growth rate studies in relation to gazing management. *Proceedings of the New Zealand Society of Animal Production 17:* 46.

Brougham, R.W. (1959) The effects of grazing frequency and intensity of grazing on the productivity of a short-rotation ryegrass and red and white clover. *New Zealand Journal of Agricultural Research. 2:* 1232.

Bryant (1983-85) Annual Reports Res. Division Ministry of Agriculture and Fisheries, New Zealand.

Bryant, A. M. & Cook, M.A.S. (1980) A comparison of three systems of wintering dairy cattle. *Proceedings of the Ruakura Farmers Conference, 38:* 181.

Bryant, A.M. & L'Huillier, P.J. (1986) Better use of pastures. *Proceedings of the Ruakura Farmers Conference 38:* 43.

Bryant, A.M. (1980) Effect of herbage allowance on dairy cow performance. *Proceedings of the New Zealand Society of Animal Production 40:* 50.

Butler, B.M. (1986) The effect of grazing intensity and frequency during spring and early summer on the sward characteristics of a ryegrass white clover pasture. M.Agr.Sci. Thesis, Massey University.

Campbell, A.G. (1964) Grazed pasture parameters: dead herbage, net gain and utilisation of pasture. *Proceedings of the New Zealand Society of Animal Production 21:* 17.

Caradus, J.R.; Woodfield, D.R. & Stewart, A.V. (1996) Overview and vision for white clover In: *White Clover, NZ's Competitive advantage*, J.R. Woodfield (Ed), Agronomy Society Special Publication 10: 99.

Carton, O.T. & Brereton, A.J. (1983) The effects of grazing management on dry matter production and sward processes in a rotationally grazed. In*: Efficient Grassland Farming.* A.J. Corrall (Ed). British Grassland Society Occasional symposium. No. 14 p149.

Castle, M.E.; Reid, D. & Watson, J.N. (1983) Silage and milk production: studies with diets containing white clover silage. *Grass and Forage Science 38:* 193.

Cassells, B. & Matthews, P.N.P. (1995) Experiences in improving production by the use of supplements. *Massey Dairyfarming Annual 47:* 40.

Chapman, D.F. & Lemaire, G. (1993) Morphogenetic and structural determinants of plant regrowth after defoliation. *Proceedings of the XVII International Grasslands Congress*. p95.

Chiariello, N.R.; Mooney, H.A. & Williams, K. (1991) Growth, carbon allocation and cost of plant tissues. In *Plant Physiological Ecology*. R.W. Pearcy; J. Ehleringer; H.A. Mooney & R.W. Rundel. (Eds) pp 327.

Clark, D.A.; Carter, W.; Walsh, B.; Clarkson, F.H. & Waugh, C.D. (1994) Effect of winter pasture residual and grazing off on subsequent milk production and pasture performance. *Proceedings of the New Zealand Grassland Association 56:* 55.

Clark, D.A. & Penno, J.W. (1996) The importance of using pasture grown. *Proceedings of the Ruakura Farmers Conference 47: 20.*

Clement, C.R; Hoope, M.J.; Jones, L.H.P. & Leafe, E.L. (1978) The uptake of nitrate by *Lolium perenne* from flowering nutrient solution. II. Effect of light, defoliation and relationship to CO2 flux. Journal of Applied Ecology 20: 225.

Colvill, K.E & Marshall, C. (1984). Tiller dynamics and assimilate partitioning in *Lolium prenne* with particular reference to flowering. *Annals applied Biology 104: 543.*

Combellas, J. & Hodgson, J. (1979) Herbage intake and milk production by grazing dairy cows 1. The effects of variation in herbage mass and daily herbage allowance in a short term trial. *Grass and Forage Science 34:* 209.

Clark, D.A. & Harris, S.L. (1996) White clover or nitrogen for dairying? In: *White clover, NZ's competitive advantage*, J.R. Woodfield (Ed), Agronomy society Special Publication 10: 107.

Coutinho, H.B. (1998) The effects of grazing management on pasture and bull production over the late-autumn to early-spring period. MApplSc Thesis, Massey University.

Culvenor, R.A.; Davidson, I.A. & Simpson, R.J. (1989) Regrowth of swards of subterranean clover after defoliation. 1. Growth non-structural carbohydrate and nitrogen content. *Annal of Botany 64:* 545.

Davidson, J.L. & Milthorpe, F.L. (1966) Effect of defoliation on the carbon balance in *Dactylis glomerata. Annals of Botany* 30: 185.

Davies, A. (1974) Leaf tissue remaining after cutting and regrowth in perennial ryegrass. *Journal of Agricultural Science 82:* 165.

Davies, A.; Evans, M.E. & Sant F.I. (1981) Changes in origin, type and rate of production of ryegrass tillers in the post-flowering period in relation to seasonal growth. In: *Plant Physiology and Herbage Production.* C.E. Wright (Ed). British Grassland Society. Occasional Symposium. No. 13 p193.

Davies A & Thomas, H. (1983) Rates of leaf and tiller production in young paced perennial ryegrass plants in relation to soil temperature and solar radiation. *Annals of Botany 57:* 591.

Dillon, P.; Crosse, G.; Stakelum, G. & Flynn, F. (1995) The effect of calving date and stocking rate on the performance of spring-calving dairy cows. *Grass and Forage Science 50:* 286.

Dijkstra, P. & Lambers, H. (1989) Analysis of specific leaf area and photosynthesis of two inbreed lines of *Plantago major* differing in relative growth rate. *New Phytol. 113:* 283.

Ettema & Ledgard (1992) Getting the best out of white clover. *Proceedings of the Ruakura Farmers Conference 44:* 72-76.

Evans, J.R. (1989) Photosynthesis and nitrogen relationships in leaves of C_3 plants. *Oecologia* 78: 9.

Glassey, C.B.; Davey, W.F. and Holmes, C.W. (1980) The effect of herbage allowance on the dry matter intake and milk production of dairy cows. *Proceedings of the New Zealand Society of Animal Production 40:* 59.

Gold, W.G. & Caldwell, M.M. (1989) The effects of spatial pattern of defoliation on regrowth of a tussock grass. I. Growth responses. *Oecologia 81:* 437.

Gordom, I,J. & Lascano, C. (1993) Foraging strategy of ruminant livestock on intensively managed grasslands: potential and constraints. *Proceedings of the XVII International Grassland Congress* pp 681.

Grant, S.A (1968) Temperature and light as factors limiting the growth of hill pasture species In: *Hill Land Productivity*, Proceedings of Occasional Symposium No. 4, British Grassland Society, pp 30.

Grant, S.A.; Barthram, G.T. & Torvell, L. (1981) Components of regrowth in cut *lolium perenne* swards. Grass and Forage Science 36: 155.

Grant, S.A.; Barthram, G.T. & Torvell, L.; King, J. & Smith, H.K. (1983) Sward management, Lamina turnover and tiller population density in continuously stocked *lolium perenne* dominated swards. *Grass and Forage Science 38:* 333.

Grainger, C. (1978) Effect of body condition at calving on milk yield of the dairy cow. M.Agr.Sci. Thesis, University of Melbourne.

Grainger & McGowan (1982) The significance of pre-calving nutrition of the dairy cow. In: *Dairy Production from Pasture.* K.L. Macmillan & V.K. Taufa (Ed). New Zealand Society of Animal Production. Occasional Publication. pp 134.

Greenhalgh, J.F.D.; Ried, G.W. & Aitken, J.N. (1967) The effect of grazing intensity and herbage consumption and animal production. II. Longer-term effects in striped grazed cows. *Journal of Agricultural Science 69:* 217.

Grime, J.P; Hall, W.; Hunt, T.; Neal, A.M.; Ross-Frases, W. & Sutton, F. (1989) A new development of the temperature-gradient tunnel. *Annals of Botany 64*: 279-287.

Hainsworth, R. (1999) Pasture assessment – talking the same language. Livestock Improvement Corporation, *Farm Advisor*, issue 2: pp 18.

Harris, S.L. (1994) White clover growth and morphology in dairy pasture in the Waikato region of northern New Zealand. *New Zealand Journal of Agricultural Research 37:* 487.

Harris, S.L. (1993), White clover plant morphology in Waikato dairy pastures. *Proceedings of the New Zealand Grasslands Association 55:* 147.

Hay, R.J.M. (1987) Understanding pasture growth. *Massey Dairyfarming Annual 39:* 55.

Heide, O.M.; Bush, M.G. & Evans, L.T. (1985) Interaction of photoperiod and gibberellin. On growth and photosynthesis of high-latitude *Poa pratensis. Physiologia Plantarum 72:* 185.

Hernandez-Garay, A.; Hodgson, J. & Matthew, C. (1993) Spring grazing management and tiller dynamics in a ryegrass/white clover pasture. *Proceedings of the New Zealand Grassland Association 55:* 133.

Herriott, J.B.D. & Wells, D.A. (1963) The gazing animal and sward productivity. *New Zealand Journal of Agricultural Science 61:* 89.

Hodgson, J. & Ollerenhaw (1960) The frequency and severity of defoliation of individual tillers in set-stocked swards. *Journal of the British Grassland Society 24:* 226.

Hodgson, J. (1989) Increases in milk production per cow and per hectare: pasture production. *Massey Dairyfarming Annual 41:* 76-82.

Hodgson, J. (1975) The influence of grazing pressure and stocking rate on herbage intake and animal performance. In: *Pasture Utilisation by the Grazing Animal.* J Hodgson & D.K. Jackson Hurley (Eds). British Grassland Society p 93.

Hodgson, J. & Wade, M. (1978) Grazing Management and herbage production In: *Grazing, Sward Production and Livestock Output.* British Grassland Society, Winter Meeting.

Holmes, C.W. (1987) Pastures for dairy cows. In: *Feeding Livestock on Pasture.* A.M. Nicol (Ed). New Society of Animal Production. Occasional Publication No. 10. pp 65.

Holmes, C.W. & Brookes, I.M. (1993) Planning feed supplied for spring 1993. *Massey Dairy farming Annual. 45:* 71.

Holmes, C.W. & Hoogendoorn (1985) Pature quality and its effects on milk production. *Large Herds Conference*, p 21.

Holmes, C.W. & McLenaghan (1980) The effects of grazing management, including topping on growth of pasture. In: *Some studies in dairy Production*. Department of Animal Science Massey University p2.

Holmes, C.W. & Wilson, G.F (1984) Milk production from pasture. Butterworths, Wellington New Zealand.

Hoogendoorn, C.J.; Holmes, C.W. & Chu, A.C.P. (1987) Grazing management in spring and subsequent dairy cow performance. *Proceedings of the New Zealand Grassland Association. 49:* 7.

Hoogendoorn, C.J.; Holmes, C.W. & Chu, A.C.P. (1992a) Some effects of herbage composition, as influenced by previous grazing management, on milk production by cows grazing on ryegrass/white clover pastures. 1. Milk production in early spring: effects of different regrowth intervals during the preceding winter period. *Grass and Forage Science, 47*: 309.

Hoogendoorn, C.J.; Holmes, C.W. & Chu, A.C.P. (1992b) Some effects of herbage composition, as influenced by previous grazing management, on milk production by cows grazing on ryegrass/white clover pastures. 2. Milk production in late spring/summer: effects of grazing intensity during the preceding spring period. *Grass and Forage Science, 47*: 316.

Hughes, T.P. (1983) Late spring grazing management. *Proceedings of the Lincoln College Farmers Conference 33:* 18.

Hughes, F.P. (1998) A study on the effects of gazing management on animal production in late spring/early summer on seasonal supply dairy farms. BApplSc (Hons) Thesis, Massey University.

Hunt, W.F. & Field, T.R.O. (1978) Growth characteristics of perennial ryegrass. *Proceedings of the New Zealand Grasslands Association 40:* 104.

Jarvis, .C. & Macduff, J.H. (1989) Nitrate nutrition of grasses from steady state supplies in flowering solution culture following nitrate deprivation and/or defoliation. 1. Recovery of uptake and growth and their interactions. *Journal of Experimental Botany 40:* 965.

Judd, T.G.; Thomson, N.A. and Barnes, M.L. (1994) The effect of block and paddock grazing in winter on cow behaviour, cow performance and herbage accumulation. *Proceedings of the New Zealand Society of Animal 54:* 91.

Korner, C.H. (1991) Some often overlooked plant characteristics as determinants of plant growth: a reconsideration. *Functional Ecology* 5: 162.

Korner, C.H.; Pelaez Menendez-Riedli, S. (1989) The significance of developmental aspects in plant growth analysis. In *Causes and Consequences of variation in Growth Rate and Productivity of higher plants.* H. Lambers, M.L. Cambridge, H. Konings & T.L. Pons (Eds). pp141-157. Academic Publishing, The Hauge.

Korte, C.J. (1986). Tillering in 'Grasslands Nui' perennial ryegrass swards 2. Seasonal pattern of tillering and age of flowering tillers with two mowing frequencies. *New Zealand Journal of Agricultural Research 29:* 629.

Korte, C.J. (1981) Studies of late spring Gazing Management in perennial ryegrass dominant pasture. Ph.D Thesis, Massey University.

Korte, C.J.; Chu, A.C.P. & Field, T.R.O. (1987) Pasture production. In*: Feeding Livestock on Pasture.* A.M. Nicol (Ed). New Society of Animal Production. Occasional Publication No. 10. pp 7.

Korte, C.J. & Harris, W. (1987). Stolon development in grazed 'Grasslands Nui' perennial ryegrass. *New Zealand Journal of Agricultural Research 30:* 139.

Korte, C.J. & Parsons, A.J. (1984) Persistence of a large-leaved white clover variety under sheep gazing. *Proceedings of the New Zealand Grassland Association 45:* 118.

Korte, C.J. & Sheath, G.W. (1978) Herbage dry matter production: the balance between growth and death. *Proceedings of the New Zealand Grassland Association 40:*152.

Laca & Demment (1996) Foraging strategies of grazing animals. In*: The Ecology and Management of Grazing Systems.* J. Hodgson and A.W. Illius (Eds). CAB International.

Lambers, H. & Poorter, H. (1992) Inherent variation in growth rate between higher plants: a search for physiological causes and ecological consequences. *Advances in Ecological Research* 23: 187-260.

Langer, R.H.M. (1963) Tillering in Herbage Grasses. *Herbage Abstracts. 33:* 141.

Le Du, Y.L.P.; Baker, R.D. & Newberry, .D. (1981) Herbage intake and milk production by grazing dairy cows. 3 The effect of grazing severity under continuous stocking. *Grass and Forage Science. 36:* 307.

Leafe, E.L., Jones,, M.M. & Stiles, W. (1977). The physiological effects of water stress on perennial ryegrass in the field. *Proceedings of the XIII International Grassland Conges, Leipzig* p253.

LIC (1997) Dairy Statistics 1995/96. Livestock Improvement Corporation.

L'Huillier, P.J. (1987a). Spring grazing management: Effects on pasture composition and density and dairy cow performance. *Massey Dairyfarming Annual 39:* 63.

L'Huillier (1987b) Effect of dairy cattle stocking rate and degree of defoliation on herbage accumulation and quality in ryegrass-white clover pasture. *New Zealand Journal of Agricultural Science 30:* 149.

L'Huillier, P.J. (1987c). Tiller appearance and death of *Lolium perenne* in mixed swards grazed by dairy cows at two stocking rates. *New Zealand Journal of Agricultural Research 30:* 15.

Macdonald, K.A. & Penno, J.W. (1998) Management decision rules to optimise milksolids production on dairy farms. *Proceedings of the New Zealand Society of Animal Production 58:*132.

Matthew, C. (1988). A new perspective on tiller replacement in perennial ryegrass. *Massey Dairyfarming Annual 40: 115.*

Matthew, C. (1990). Translocation from flowering to daughter tillers in perennial ryegrass (Lolium perenne L.*)* Agronomy Department, Massey University Internal Report.

Matthew, C (1991) "Late control" – What is it, and why should it work? *Massey Dairyfarming Annual 43: 37.*

Matthew, C.; Hernandez-Garay, A. & Hodgson, J. (1996) Making sense of the link between tiller density and pasture production. *Proceedings of the New Zealand Grassland Association 57:* 83.

Matthew, C.; Hodgson, J.; Matthews, P.N.P. & Bluett, S.J. (1995). Growth of pasture: Principles and their application. *Massey Dairyfarming Annual 47: 122.*

Matthew, C.; Quilter, S.J.; Korte, C.J.; Chu, A.C.P. & Mackay, A.D. (1989). Stolon formation and significance for sward tiller dynamics in perennial ryegrass. *Proceedings of the New Zealand Grasslands Association 50: 255.*

Matthews, P.N.P. (1971) The effects on pasture of the winter grazing of dairy cows. M.Agr.Sci. Thesis, Massey University.

Matthews, P.N.P (1994) Grazing management strategies for dairy production. *Massey Dairyfarming Annual 46:* 143.

Matthews, P.N.P (1995) Grazing management principles and targets: A case study. *Massey Dairyfarming Annual 47:* 171.

Matthews, P.N.P. (1997) Feeding practices on commercial farms: recent changes in attitudes, their reasons and effects. *Massey Dairyfarming Annual 49:* 67.

Matthews, P.N.P. & Matthew, C. (1997) Trutest Grassmaster Pasture Probe Calibration Protocol pp 11. Plant Science Department, Massey University, Palmerston North.

Mayne, C.S.; Newberry, R.D.; Woodcock, S.C.F. & Wilkins, R.J. (1987) Effect of grazing severity on grass utilisation and milk production of rotationally gazed dairy cows. *Grass and Forage Science 42:* 59.

McLaren & Cameron (1990) Soil science: an introduction to the properties and management of New Zealand soils. *Oxford University Press*.

McMeekan, C. (1961) The pros and cons of a high stocking rate. *Proceedings of the Ruakura Farmers Conference Week 13:* 184-190.

Moller, S.N.; Parker, W.J. & Edwards N.J. (1996) Within-year variation in pasture quality has implications for dairy cow nutrition. *Proceedings of the New Zealand Grassland Association 57:* 173.

Muller, L.D. (1993) Nutritional supplementation and ration balancing for high producing cows. pp 71-80. In: *Improving the Quality and Intake of Pasture Based Diets for Lactating Dairy Cows*. N.J. Edwards and W.J. Parker (Eds). Occasional Publication N. 1. Department of Agricultural and Horticultural Systems Management, Massey University.

McDougall, S. (1993) Stocking rate, breed condition score and anoestrum. *Proceedings of the Ruakura Farmers Conference 45:* 51.

Norris, I.B. (1985) Relationships between growth and measured weather factors among contrasting variables of *Lolium, Dactylis* and *Festuca* species. *Grass and Forage Science 40:* 151.

NRC (1989) Nutrient requirements of dairy cattle (6th edition), Washington, D.C, National Academy Press.

Ong, C.K.; Marshall, C. & Saga, G.R. (1978) The physiology of tiller death in grasses 2. Causes of tiller death in a grass sward. *Journal of British Grassland Society 33:* 205.

Padilla, M.J. (1997) A study of patchiness in mid-season dairy pastures: consequences and control. Masterate of Applied Science, Massey University Palmerston North.

Parsons, A.J. & Chapman (1999) Unpublished book chapter.

Parsons, A.J.; Leafe, E.L.; Collett, B. & Stiles, W. (1983a) The physiology of grass production under grazing. I. Characteristics of leaf and canopy photosynthesis of continuously grazed swards. *Journal of Applied Ecology 20:* 117.

Parsons, A.J.; Leafe, E.L.; Collett, B.; Penning, P.D. & Lewis J. (1983b) The physiology of grass production under grazing. II. Photosynthesis, crop growth and animal intake of continuously grazed swards. *Journal of Applied Ecology 20:* 127.

Parsons, A.J.; Johnson, I.R. & Harvey, A. (1988) Use of a model to optimize the interaction between frequency and severity of intermittent defoliation and to provide a fundamental comparison of the continuous and intermittent defoliation of grass. *Grass & Forage Science 43:* 49.

Parsons, A.J. & Penning, P.D. (1988) The effect of the duration of regrowth on photosynthesis, leaf death and the average rate of growth in a rotationally grazed sward. *Grass & Forage Science 43:* 15.

Penno, J.W.; Bryant, A.M.; Macdonald, K.A. & Carter, W.A. (1996). Enhancing pasture-based dairying with supplementary feeds. *Proceedings of the New Zealand Grasslands Association 58:* 113.

Phillips, R.M.C & Matthews P.N.P (1994) Pasture Targets: Their practical application. *Massey Dairyfarmers Conference 47:* 153.

Poorter, H.; Remkes, C. & Lambers, H. (1990) Carbon and nitrogen economy of 24 wild species differing in relative growth rate. *Plant Physiology*. 94: 621.

Rattary, P.V. & Clark, D.A. (1984) Factors affecting intake in pasture. *New Zealand Journal of Agricultural Science 18(3):* 141.

Richards, J.H. (1993) Physiology of plants recovering from defoliation. *Proceedings of the XVII International Grassland Congress.* pp 85.

Richards, J.H. & Caldwell, M.M. (1985) Soluble carbohydrates, concurrent photosynthesis and efficiency in regrowth following defoliation: A field study with *Agropyron* species. *Journal of Applied Ecology*. 22: 907.

Roberts, A.H.C.; Ledgard, S.F.; O'Conner, M.B. & Thomson, N.A. (1992) Effective use of N fertiliser – Research and practice. *Proceedings of the Ruakura Farmers Conference 44:* 77.

Robson, M.J.; Parsons, A.J. & Williams, T.E. (1989) Herbage production: grasses and legumes. In: *Grass: Its Production and Utilisation.* The British Grassland Society, pp 81.

Robson,, M.J. & Sheehy, J.E. (1981) leaf area and light interception. In: *The Sward Measurement handbook*. J.Hodgson, B.G.S. (Hurley (Eds) p115.

Rogers, G.L.; Grainge, C. & Earle, D.F. (1979) Effect of nutrition of dairy cows in late pregnancy on milk production. *Australian Journal of Experimental Agriculture and Animal Husbandry 19:* 7.

Rogers, G.L.; Porter, R.H.D & Robinson, I. (1982) Comparison of perennial ryegrass and white clover for milk production. *Dairy Production Research Report*. Department of Agriculture and Rural Affairs, Australia pp56.

Rood, S.B.; Buzzell, R.I.; Major, D.J.; & Pharis, R.P. (1990) Gibberellins & heterosis in maize. I Endogenous gibberellin-like substances. *Plant Physiology*. 71: 639.

Ryan, P.M. (1986) A study of the effects of grazing management during winter on pasture quality in spring and milk production. DipAgSci Thesis Massey University.

Ryle, G.J.A. & Powell, C.E. (1975) Defoliation and regrowth in the graminaceous plan: the role of current assimilate. *Annals of Botany*. 39: 297.

Saab, I.N.; Sharp, R.E.; Pritchard, J. & Voetberg, G.S. (1990) Increased endogenous abscisic acid maintains primary root growth and inhibits shoot growth of maize seedlings at low water potential's. *Plant Physiology*. 93: 1329-1336.

Santamaria, A.; McGowan, A.A. (1982) The effect of contrasting winter grazing on current and subsequent pasture production and quality. In: Dairy Production from Pasture. K.L. Macmillan & V.K. Taufa (Eds). *New Zealand Society of Animal Production Occasional Publication 8:* 359.

Santamaria, A. & Rogers, G.L. (1980) Competitive effects of white clover and perennial ryegrass on milk yield and composition of the grazing cow. *Dairy Production Research Report*, Dairy Research Institute, Ellinbank, Victoria, pp 56.

SAS (1988) *User's guide to statistics*. Statistical Analysis Institute. Cary, NC, USA.

Satter, L.D.; Dhiman, T.R. & Cadorniga, C. (1992) Supplementation of forage and pastures for cows. *Proceedings of Australian Dairy Corporation Dairy Foods Country Tour, Sydney University (July):* 1.

Schwinning, S. & Parson, A.J. (1999) The stability of grazing systems revisited: spatial models and the role of heterogeneity. *Functional Ecology* (in press).

Sears (1950) Soil fertility and pasture growth. *Journal of the British Grassland Society 5:* 2367.

Sheath, G.W. & Bryant, A.M. (1984) Integrating the components of pastoral production: What have we learnt from grazing management experiments? *New Zealand Journal of Agricultural Science 18(3):* 147.

Stakelum, G. & Dillon, P. (1990) Influence of sward structure and digestibility on the intake and performance of lactating and growing cattle. In*: Management Issues for the Grassland Farmer in the 1990's.* C.S. Mayne (Ed) pp 30.

Stephens, D.W. & Krebs, J.R. (1986) Foraging theory. Princetown, New Jersey, *Princetown University Press.*

Tallowin, J.R.B. (1981) An interpretation of tiller number changes under grazing. In: *Plant Physiology and herbage production.* C.E. Wright (Ed). British Grassland Society. Occasional Symposium. No. 13 p77.

Thomas, H & Davis, A, (1978) Effect of shading on the regrowth of *Lolium perenne* swards in the field. Annals of Botany 42: 705.

Thomas, H. & Norris, I.B. (1981) The influence of light and temperature during winter on growth and death in simulated swards of *lolium perenne. Grass and Forage Science 36:* 107.

Thompson, N.A. & Holmes, C.W. (1995) Supplementary feeding for increased milk production. *Massey Dairyfarming Annual 47:* 20.

Thompson, N.A.; Lagan, J.F. & McCallum, D.A. (1984). Herbage allowance, pasture quality and milkfat production as affected by stocking rate and conservation policy. *Proceedings of the New Zealand Society of Animal Production, 44:* 67.

Trlica, M.J. & Singh, J.S. (1979) Translocation of assimilate and creation, distribution and utilisation of reserves. Arid-land ecosystems: structure, functioning and management. 1: 537.

Ulyatt, M.J & Waghorn, G.C. (1993) Limitations to high levels of dairy production from New Zealand pastures. pp 11-32. In : *Improving the quality and intake of pasture-based diets for lactating dairy cows.* Eds N.J. Edwards, W.J Parker, Occasional Publication No 1, Department of Agricultural and Horticultural Systems Management, Massey University.

Ungar, E.D. (1996) Ingestive Behaviour. In: *The Ecology and Management of Grazing Systems*. J. Hodgson & A.W. Illius (Eds).

Vine, M.H. (1983) Sward structure changes within a perennial ryegrass sward: leaf appearance and death. *Grass and Forage Science 38:* 231.

Wade, M.H. (1975) The growth and losses of herbage in gazed swards. In*: Pasture Utilisation by the Grazing Animal.* J.Hodgson & D.K. Jackson. (Eds) British Grassland Society Occasional Publication Symposium number 8 p 61.

Wade, M.H. (1979) Leaf and tiller dynamics in grazed swards. M.Phil thesis, University of Reading, United Kingdon.

Watkin, B.R. (1954) The animal factor and levels of nitrogen. *Journal of British Grassland Society 9:* 35.

Waugh, J. (1998) programme to assess lower SR performance. *New Zealand Dairy Exporter. 74:3* p38.

Wilman, D. & Shresta, S.K. (1985) Some effects of canopy height on perennial ryegrass and white clover in a field sward. *Journal Agricultural Science. 105:* 79.

Wilson, G.L. (1992) Crop physiology: some recollections and current perception. *Proceedings of the 6th Australian Society of Agronomy*, Armidale. pp2-10.

Woledge, J. (1979) Effect of flowering on the photosynthetic capacity of ryegrass leaves grown with and without natural shading. *Annals of Botany 44:* 197.

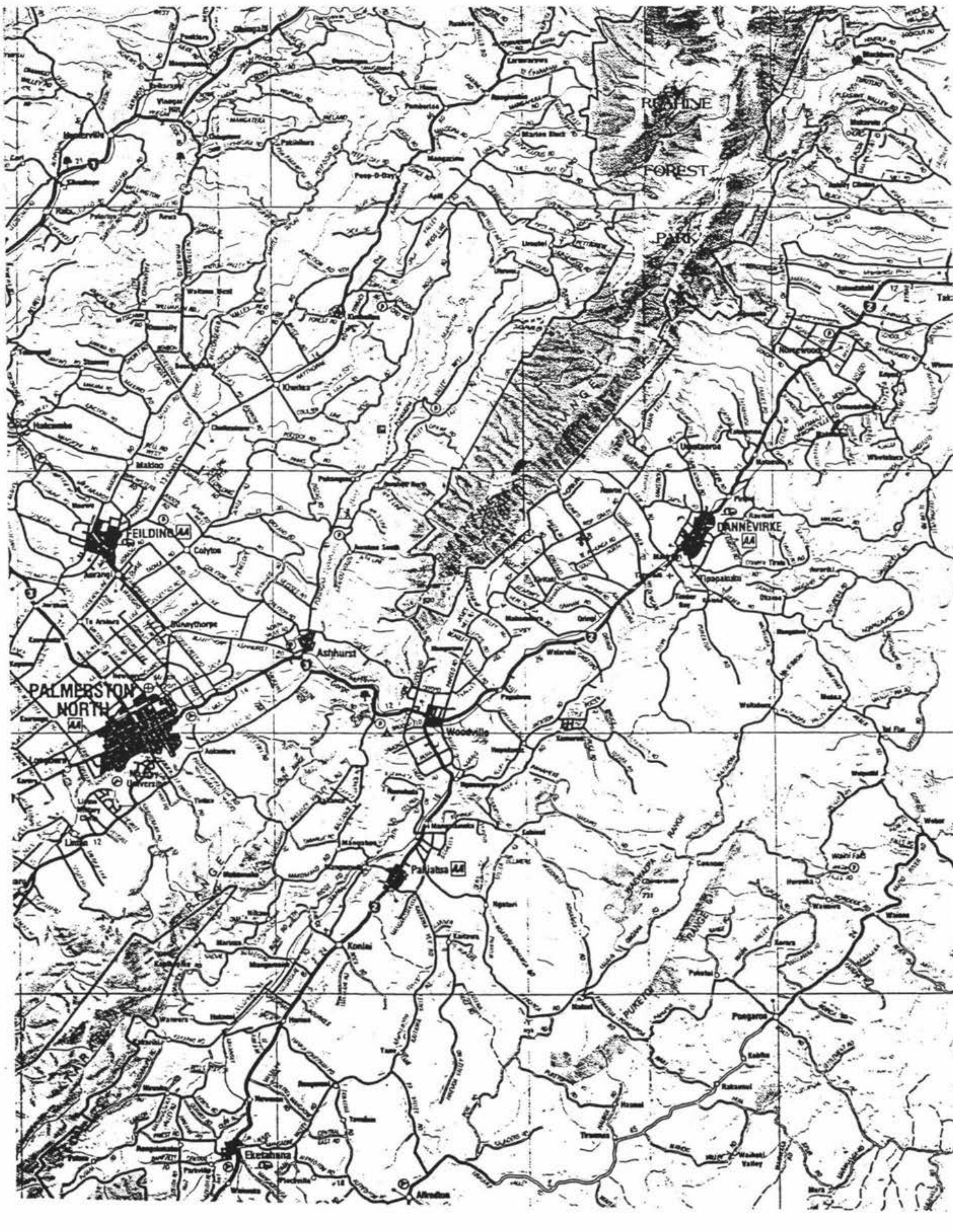
Wolten, M.K. (1955) The effect of sheep excreta and fertiliser treatments on the nutrient status of pasture soil. *Journal of British Grassland Society 10:* 240.

Woodfiled, D.R. & Caradus, J.R. (1996). Factors affecting white clover persistence in New Zealand pastures. *Proceedings of the New Zealand Grassland Association 58:* 229.

10.0 APPENDICES

Appendix 1

<u>Location of study.</u>



Appendix 2a

<u>Cow Numbers for Experiment I</u> (Heifers and dry cow)

Treatment 1 (900 kg DM/ha)

$$\begin{array}{r} 2700 \\ \underline{-\ 900} \\ 1800 \end{array}$$

(Assuming cows are ingesting 6 kg DM each)

$$\frac{1800 \text{ kg DM/ha}}{6 \text{ kg DM/cow}} = 300 \text{ cows/ha}$$

300 cows/ha x 0.17 ha = 51

Treatment 2 (1200 kg DM/ha)

$$\begin{array}{r} 2700 \\ \underline{-1200} \\ 1500 \end{array}$$

(Assuming cows are ingesting 10 kg DM each)

$$\frac{1500 \text{ kg DM/ha}}{10 \text{ kg DM/cow}} = 150 \text{ cows/ha}$$

150 cows/ha x 0.17 ha = 26

Treatment 3 (1500 kg DM/ha)

$$\begin{array}{r} 2700 \\ \underline{-1500} \\ 1200 \end{array}$$

(Assuming cows are ingesting 13 kg DM each)

$$\frac{1200 \text{ kg DM/ha}}{13 \text{ kg DM/cow}} = 86 \text{ cows/ha}$$

92 cows/ha x 0.17 ha = 16

Appendix 2a continued....

Treatment 4 (1800 kg DM/ha)

$$\begin{array}{r} 2700 \\ \underline{-1800} \\ 900 \end{array} \qquad \text{(Assuming cows are ingesting 14[1] kg DM each)}$$

$$\frac{900 \text{ kg DM/ha}}{14 \text{ kg DM/cow}} = 64 \text{ cows/ha}$$

64 cows/ha x 0.17 ha = 11

Treatment 5 (2100 kg DM/ha)

$$\begin{array}{r} 2700 \\ \underline{-2100} \\ 600 \end{array} \qquad \text{(Assuming cows are ingesting 14 kg DM each)}$$

$$\frac{600 \text{ kg DM/ha}}{14 \text{ kg DM/cow}} = 43 \text{ cows/ha}$$

43 cows/ha x 0.17 ha = 7

[1] Assumption made that heifers are only able to consume a maximum of 14 kg DM/ha.

Appendix 2b

Cow Numbers for Experiment II (Milking cows and dry cows)

Treatment 1 (1200 kg DM/ha)

2700 (Assuming cows are ingesting 8 kg DM each)
-1200
1500

$$\frac{1500 \text{ kg DM/ha}}{8 \text{ kg DM/cow}} = 188 \text{ cows/ha}$$

188 cows/ha x 2[2] = 376 cows/ha

376 cows/ha x 0.25 ha = 94

Treatment 2 (1500 kg DM/ha)

2700 (Assuming cows are ingesting 13 kg DM each)
-1500
1200

$$\frac{1200 \text{ kg DM/ha}}{10 \text{ kg DM/cow}} = 120 \text{ cows/ha}$$

120 cows/ha x 2 = 240 cows/ha

240 cows/ha x 0.25 ha = 60

Treatment 3 (1800 kg DM/ha)

2700 (Assuming cows are ingesting 12 kg DM each)
-1800
900

$$\frac{900 \text{ kg DM/ha}}{14 \text{ kg DM/cow}} = 64 \text{ cows/ha}$$

64 cows/ha x 2 = 128 cows/ha

128 cows/ha x 0.25 ha = 38

grazing intensity doubled as cows are only grazing for approximately half the time

[2] Grazing intensity doubled as cows are only grazing for approximately half the day.

Appendix 2b continued.....

Treatment 4 (2100 kg DM/ha)

$$\begin{array}{r} 2700 \\ \underline{-2100} \\ 600 \end{array}$$

(Assuming cows are ingesting 14 kg DM each)

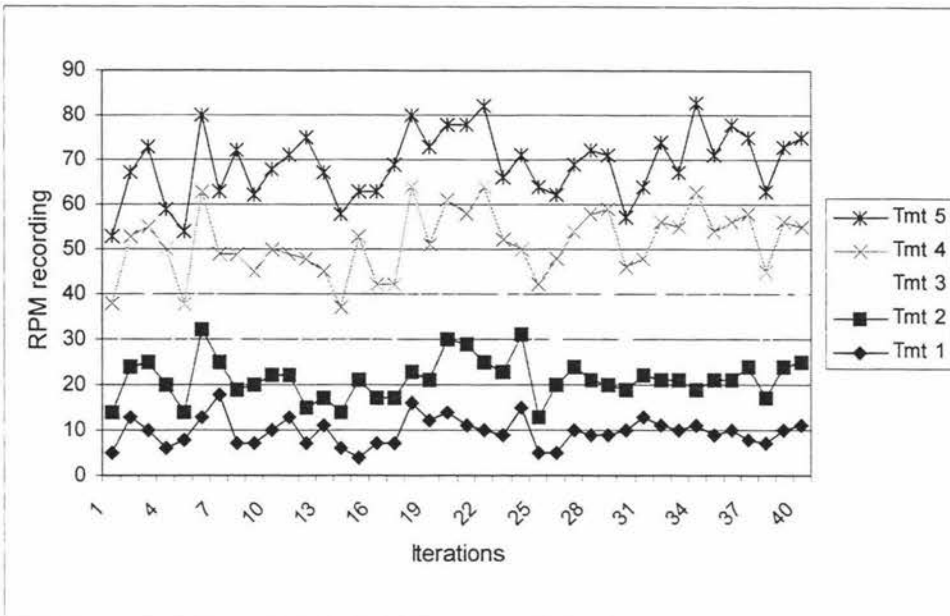
$$\frac{600 \text{ kg DM/ha}}{14 \text{ kg DM/cow}} = 43 \text{ cows/ha}$$

43 cows/ha x 2 = 86 cows/ha

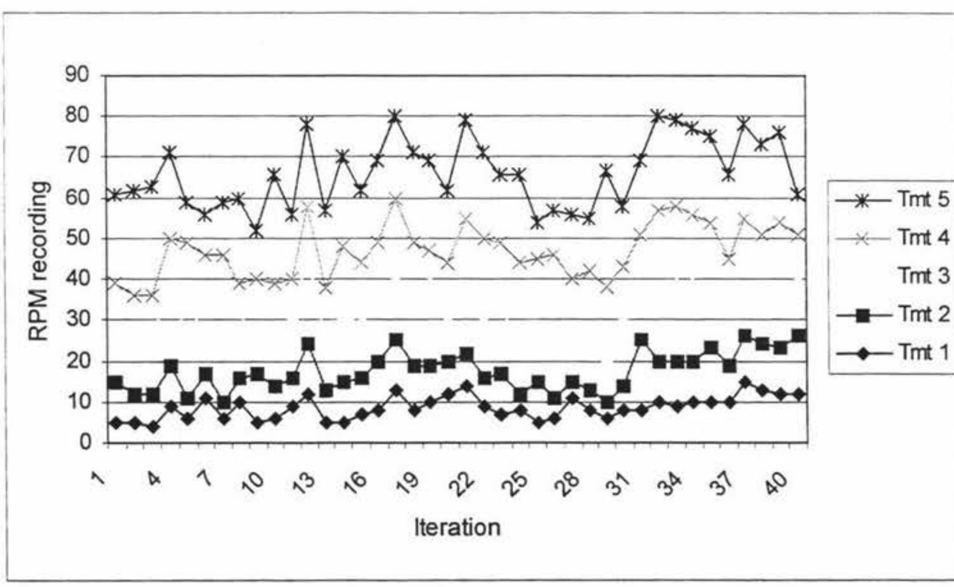
128 cows/ha x 0.25 ha = 21

Appendix 3a

Herbage Mass Profiles, Experiment I



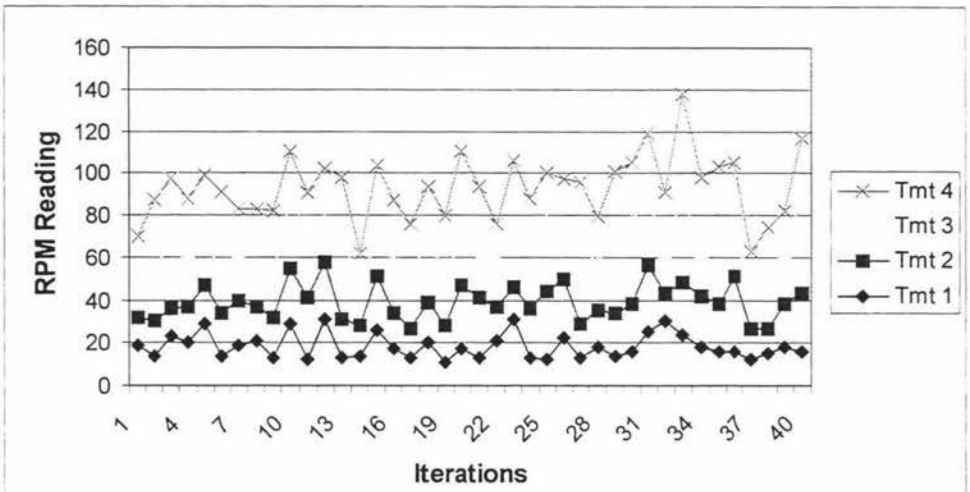
Variability in RPM reading within treatments (block 2)



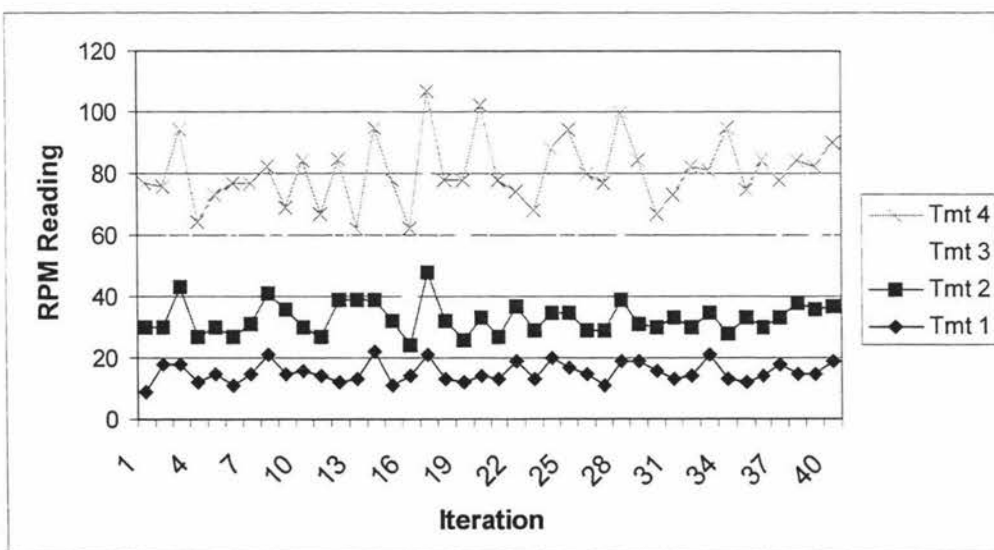
Variability in RPM reading within treatments (block 3)

Appendix 3b

<u>Herbage Mass Profiles, Experiment II.</u>



Variability in RPM reading within treatments (block 2).



Variability in RPM reading within treatments (block 3).

Appendix 4

Climatic Data

Climatic data sourced from National Institute of Water and Atmospheric Research (January 1998 - December 1998) from Dannevirke.

Rainfall Data (mm)

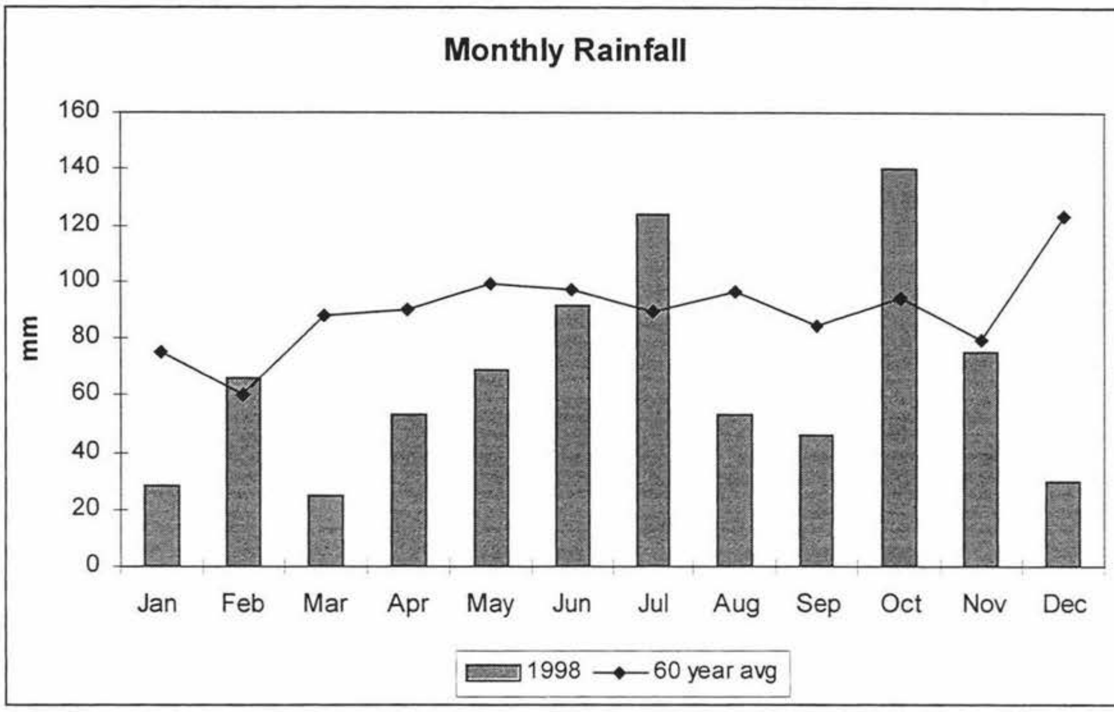
Month	1998	60 year avg
Jan	28	75
Feb	66	60
Mar	25	88
Apr	53	90
May	69	99
Jun	91	97
Jul	124	89
Aug	53	96
Sep	46	84
Oct	140	94
Nov	75	79
Dec	30	123

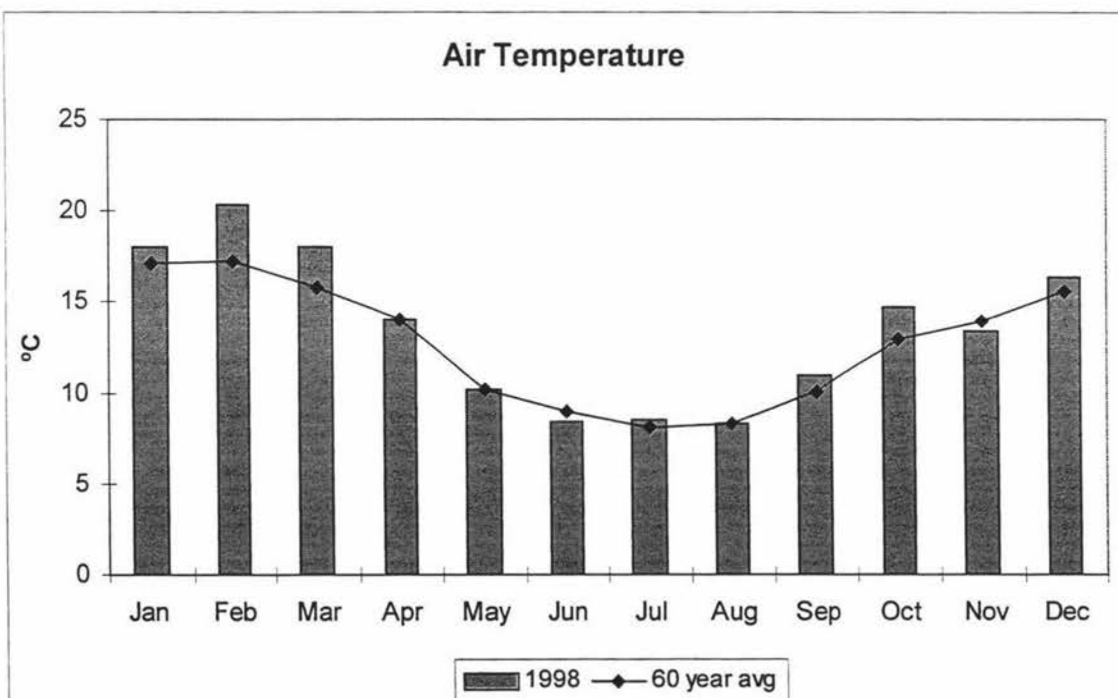
Air Temperature Data (°C)

Month	1998[3]	60 year avg
Jan	18.0	17.1
Feb	20.4	17.3
Mar	18.0	15.8
Apr	14.1	14.0
May	10.2	10.2
Jun	8.4	9.0
Jul	8.5	8.1
Aug	8.3	8.3
Sep	10.9	10.1
Oct	14.7	12.9
Nov	13.4	13.9
Dec	16.5	15.6

[3] Average of minimum and maximum figures for month.

Appendix 4 continued....

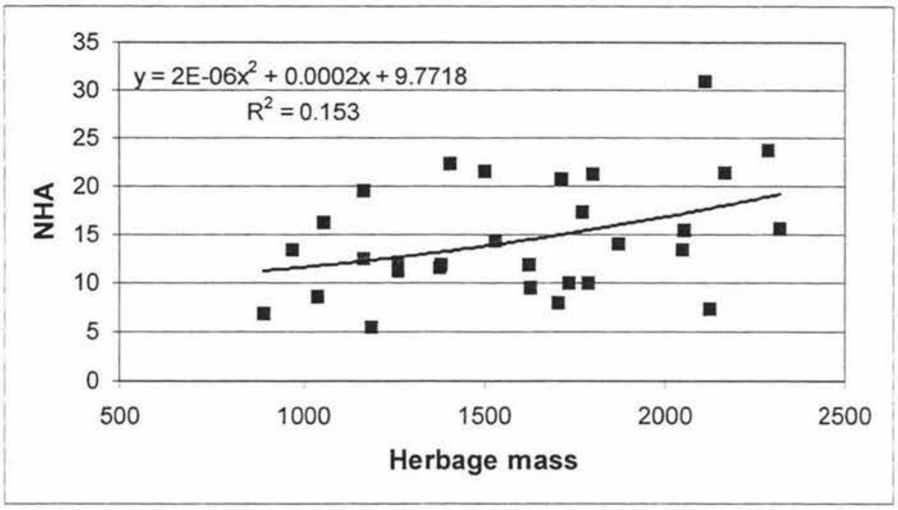




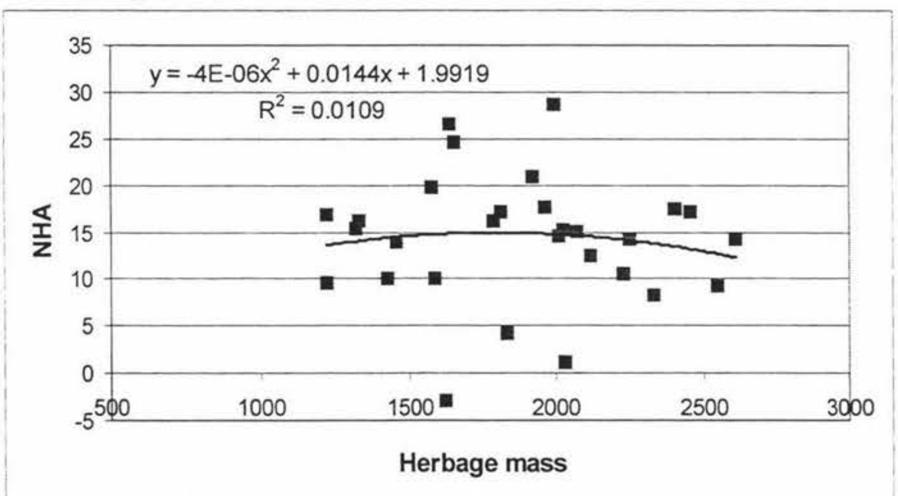
Appendix 5

Pasture regrowth trends

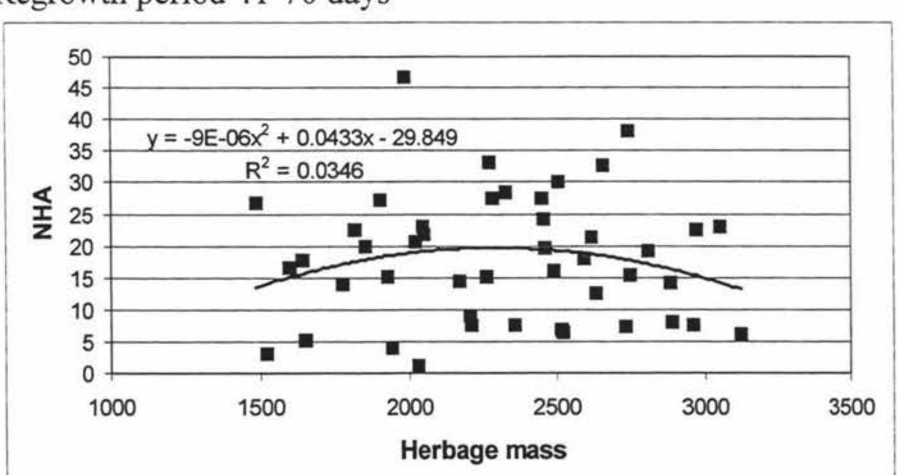
Experiment I.
Regrowth period 0-20 days



Regrowth period 21-40 days



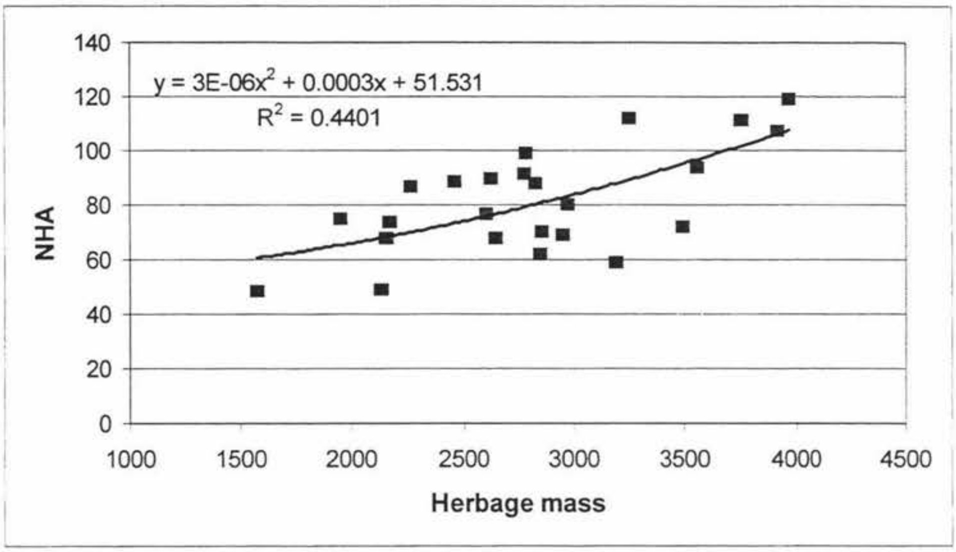
Regrowth period 41-70 days



Appendix 5 continued....

Experiment II

Regrowth period 0-20 days



Regrowth period 21-40 days