THE EFFECT OF HERBAGE ALLOWANCE
ON THE PERFORMANCE OF
LACTATING DAIRY COWS

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

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1980

ABSTRACT

Three groups of six cows were offered daily herbage allowances of 53, 33, and 13.5 kg DM cow^{-1} for a 5 week period in early lactation. These allowances resulted in apparent dry matter intakes of 15.8, 14.3 and 9.6 kg DM cow^{-1} and residual dry matter yields after grazing of 1850, 1550 and 750 kg DM ha.$^{-1}$.

There were no significant differences in milk, milkfat or protein yield between the cows offered 53 kg DM cow^{-1} and 33 kg DM cow^{-1}, but the cows offered the higher allowance had greater liveweight gains, ($P < 0.1$). The group of cows offered 13.5 kg DM cow^{-1} produced significantly less milk, milkfat and protein than the other groups, and lost liveweight and body condition. There were no significant differences in milkfat production amongst the three groups during the 29 week period from the end of the experiment until the end of the lactation.

Measurements of the Nitrogen content of the herbage present before, and the herbage remaining after grazing showed that as herbage allowance increased the N content of the herbage dry matter selected by the cows also increased.

Each group of six cows consisted of three cows with a high lifetime production index (LPI) and three cows with a low LPI. Some data on the responses of cows of different LPI, to variation in herbage allowance are presented.

The results are discussed in relation to the effects of each herbage allowance on milk, milkfat and protein yields per cow and per unit area. The data shows that the achievement of high levels of production per cow as a result of offering high herbage allowances may be in conflict with the need to consider production per unit area and the agronomic needs of the pastures. Alternatively restriction of herbage allowance may limit production per cow and result in losses of cow liveweight and body condition, with possible long-term effects on lactation performance. A discussion of factors

that may affect the carry-over or residual effects from variation of herbage allowance in early lactation is included. Additionally some problems with respect to the estimation of herbage intake by the 'difference' method, and the measurement of liveweight of lactating cows are discussed.

ACKNOWLEDGEMENTS

I am grateful to many people who have contributed to the work and to the ideas during the preparation of this thesis.

To my supervisor, Dr. A.W.F. Davey, who was always willing to discuss ideas and problems with me and waited patiently for the final result.

Dr. C.W. Holmes contributed many thoughts and ideas to the experiment and to its analysis.

Advice on statistical analysis was received from Dr. I.M. Brookes and Professor D.S. Flux.

To members of the Dairy Husbandry Department, Massey University, and all others who also contributed to the discussion and the running of the experiment.

Thanks must go to the following for their assistance during the experiment: Messrs B. Parlane, R.J. McLenaghan and Nguyen Minh Long for the handling of stock and collection of data. Mr. J.A. Raven for the analysis of milk and pasture samples.

Mr. A. Lowe, (Manager, No.3 Research and Development Unit), and his assistant Mr. G. Fowlds for milking and management of the cows during the 1978-79 dairy season.

Finally my thanks to Mrs. V. McKeay-Christie for her assistance with proof reading, and to Mrs. D. Syers for typing the final copy of this thesis.

Financial assistance was received through the D.J. McGowan Scholarship during 1978.

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CHAPTER ONE

REVIEW OF LITERATURE

1.1 The Response of the Dairy Cow to its Level of Feeding

1.1.1 Introduction

Optimum feeding of the dairy cow involves a study of feed inputs and milk outputs and an economic evaluation of this relationship. This is particularly important where the costs of feeding a cow are high, or where alternative feeds are available. The traditional approach to feeding was based on meeting the current energy and protein needs of the cow, which were calculated from the maintenance requirement and the current milk yield. It became evident that meeting the cow's current requirements was not necessarily the optimum means of achieving high outputs while minimising inputs. This led to the idea that the response of the cow to its level of feeding was related to its past and future nutrition as well as to its current level of feeding (Blaxter, 1950; 1956). Blaxter suggested that the emphasis be placed on the need for a more dynamic approach in which food is allocated to secure the greatest advantage for milk production in the long term. Hence the need to view the response of the dairy cow to its level of feeding over the whole lactation cycle.

Emphasis in research has now been placed on the distribution of feed within a lactation cycle for optimum use of feed inputs. As well as analysis of immediate responses to intake at the different stages of the lactation cycle, the cumulative effects of level of intake over time have to be studied.

In New Zealand research has been focussed on the importance of feeding level both before and after calving, on milk production in early lactation. Under New Zealand conditions, where calving generally occurs after a time of minimum pasture growth, the adverse effects of underfeeding a cow prior to and immediately after calving have been studied. The level of feeding both before and after calving has been shown to influence the peak milk yield and susbsequent milk production over the whole lactation (see reviews by Broster, 1971; Broster, 1972; Broster and Strickland, 1977).

1.1.2 The Influence of Pre-Partum Levels of Feeding on Milk Production

In New Zealand, Lees et al. (1948), Campbell and Flux (1948), and Patchell (1957) have all investigated two levels of feeding in the last three months of pregnancy and the effect of that feeding in the subsequent lactation. In all the above experiments the higher level of feeding consisted of autumn saved pasture with hay and silage supplements, fed ad lib., while the poorly fed groups received restricted amounts of hay and silage with limited pasture. Post-partum all cows were grazed in one group. Details of the experiment are set out in Table 1.1.

The results of these experiments agree in that underfeeding in late pregnancy resulted in a reduction of milk production post-partum.

The average rate of weight gain of the uterus and its contents from ten weeks before calving is approximately 0.4 kg day^{-1} (Bryant, 1976). If pregnant cows gain less than this amount then their own body weight is likely to be declining. These experiments compared levels of feeding that either induced large losses in maternal liveweight or kept maternal liveweight almost constant.

In a later experiment, Hutton and Parker (1973) obtained consistently higher milk yields in two consecutive years from cows that were maintaining liveweight before calving, compared with cows that were loosing maternal liveweight.

Broster (1971) reviewed many experiments carried out in countries other than New Zealand that have studied the responses by dairy cows to a wide range of pre-partum levels of feeding. Cows fed at moderate and high levels of feeding pre-partum generally

Table 1.1 A summary of some experiments on the effects of underfeeding in the final three months of pregnancy on milk and milkfat yield post-partum

Source	Level of Feeding	Liveweight Change Pre-Partum	Difference in Liveweight at Calving	Effect on Milk and Milkfat Yields Post-Partum
Lees et al. (1948)	High	increase in maternal body weight*	60 kg	22 kg extra milkfat produced by better fed cows. 50% of differences in the 1st 3 weeks
	Low	loss in maternal body weight*		
Flux and Campbell (1948)	High	maintained total liveweight (yr I) increased total liveweight (yrs II and III)*	Not given	11 kg of extra milkfat produced by better fed cows. Most of difference in the 1st 3 months
	Low	lost 40 kg cow^{-1}*		
Flux (1950)	High	+ 0.57 kg $cow^{-1} day^{-1}$	40 kg	477 kg of extra milk and 25 kg of extra milkfat produced by better fed heifers
	Low	- 0.09 kg $cow^{-1} day^{-1}$		
Patchell (1957)	High	+ 8.4 kg cow^{-1}, year I *	Not given	1.5 kg extra milk $cow^{-1} day^{-1}$ in weeks 0-6 of lactation produced by better fed group. 260 kg milk over the whole lactation
		- 7.7 kg cow^{-1}, year II*		
	Low	- 35.4 kg cow^{-1}, year I*		
		- 52.2 kg cow^{-1}, year II*		

*Weights corrected for gain in uterus and contents.

yield more milk post-partum than those fed at low levels. There is however an apparent diminishing returns effect in the milk yield response to increases in the level of feeding pre-partum. Broster concluded that daily liveweight gains of cows in late pregnancy up to but not exceeding 0.5 kg day^{-1} for cows in moderate condition, increased milk yield in the first ten weeks of lactation. This was thought to be sufficient liveweight gain to account for the growth of concepta.

Despite the realization that a beneficial effect on milk production arose from increasing the level of feeding prior to calving, the physiological mechanism by which this was achieved was not apparent. Blaxter (1956) suggested that nutrition exerted its influence on lactation by controlling the activity and the number of secretory cells in the udder. There is however little experimental evidence for this. Hutton and Parker (1973) found evidence suggesting that a high level of pre-calving feeding increased the amounts of pasture dry matter consumed after calving. This is not supported by the experiments of Grainger, Wilhelms and M^C^Gowan (1978) who found that cows that calved in good body condition consumed less dry matter than those calving in poor body condition, when the pasture offered was equal.

Broster (1971) speculated that as a higher level of feeding in late pregnancy leads to a greater liveweight gain in the cow (or less liveweight loss), it will also help arrest the potential loss of milk yield in early lactation due to underfeeding as there is now increased potential for mobilization of that liveweight to support milk yield post-partum. He added that if the objective of increased feeding pre-partum was to build up body energy reserves, then the nutrition of the cow over the preceding lactation also had to be taken into account. Liveweight changes immediately pre-partum did not indicate directly what changes may have occurred in body tissues.

Rogers, Grainger and Earle (1979) took up this point and questioned whether rate of liveweight gain during pregnancy *per se* or the availability of energy reserves in early lactation was the key factor in determining increases in milk yield obtained from increases in pre-partum feeding. They carried out three experiments to examine this question. In all experiments two groups of identical twin cows were fed so that by six weeks before calving there was a difference of about 50 kg liveweight between the animals in the two groups. The pattern of liveweight change up to calving in the experiments is shown in Fig. 1.1. In experiments one and two, cows were fed so as to gain weight at different rates but calve in similar body condition. In experiment three, cows gained weight before calving at similar rates, but calved at different body conditions and with a difference of 51 kg liveweight.

In experiments one and two, there were no significant differences due to pre-calving liveweight gain on milk, fat or protein production in the first 100 days of lactation. In experiment three, cows in heavier condition had a 7% greater milk yield and a higher milkfat concentration in the first 100 days of lactation, and these differences were significant.

The results demonstrate that levels of body condition of cows at calving are the important factor affecting milk production and that liveweight changes per se prior to calving were unimportant in influencing subsequent milk production.

Means of assesment of cow body condition, that are independent of liveweight and concepta gain have now been devised. Body condition is assessed by visual inspection and handling of cows, to assess the flesh covering mainly on the base of the tail and over the hips, back and pinbones. The degree of cover is given a value on a scale of 1-10 (1 very thin, 10 very fat).

Grainger, Wilhelms and McGowan (1978) obtained a mean response of 8.0 kg of extra milkfat produced in the first 20 weeks of lactation, per unit increase of condition score at calving. The response of milkfat production over weeks 1-5 of lactation to condition score at calving was for practical purposes linear, in the range of condition scores three to six. This confirmed the earlier work by Rogers, Grainger and Earle (1979), that cow body condition at calving has an important effect on milk production.

There is evidence from earlier experiments that the level of

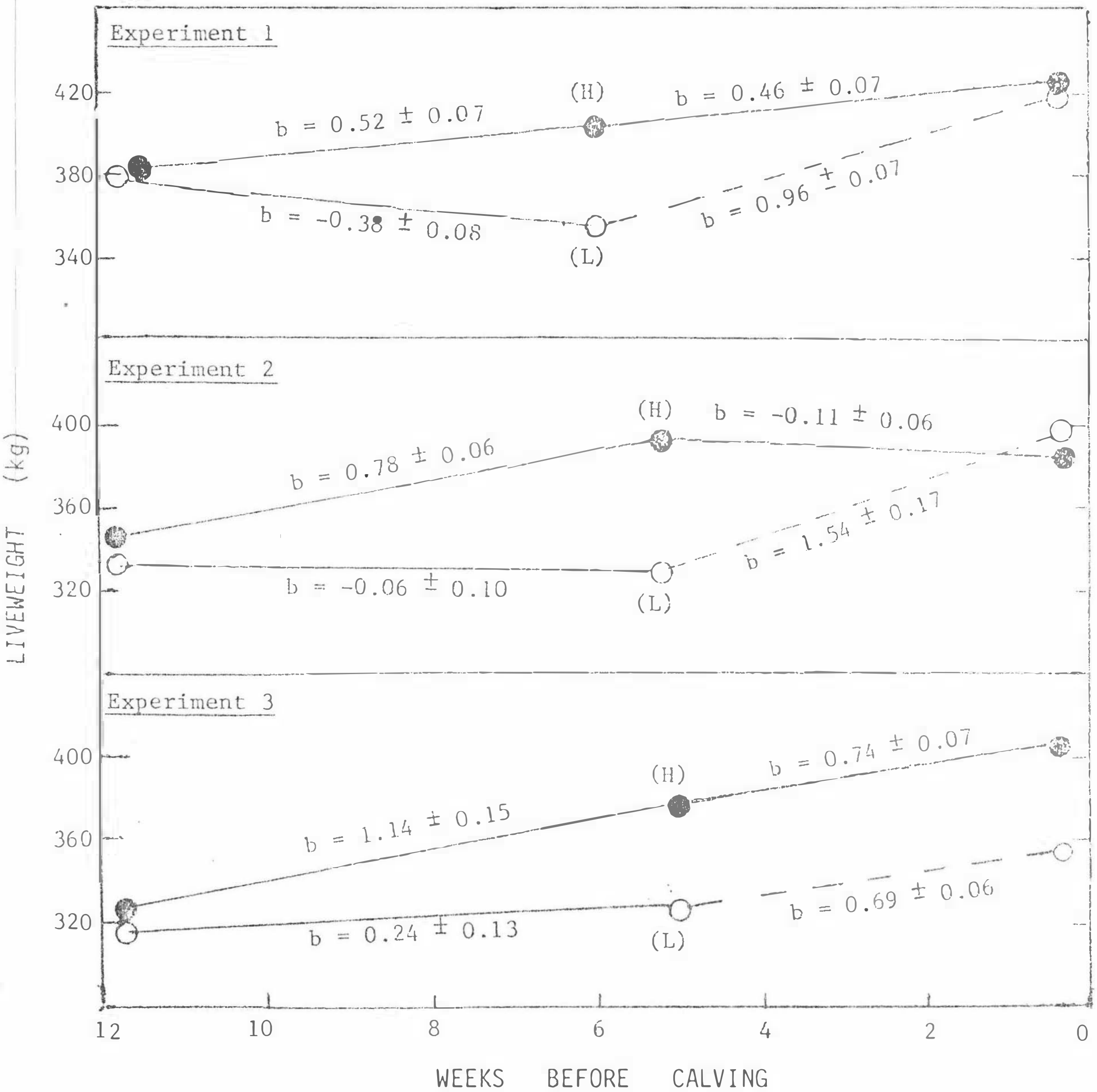


Fig. 1.1 Liveweights and rate of liveweight change (b $\pm$ SE) before calving for three experiments by Rogers et al.(1979)

feeding pre-partum, reflected as cow body condition, may alter the pattern of liveweight change post-partum. Flux (1950) noted that heifers fed prior to calving so that they lost on average 0.09 kg liveweight day^{-1}, did not lose as much liveweight in the first eight weeks of lactation as their well fed twin sisters. The poorly fed heifers also had a higher rate of liveweight gain from the end of the eighth week after calving, until the end of lactation. Flux suggested that lower milk production in the lactation by the poorly fed heifers could be accounted for by increased use of nutrients for liveweight gain or growth. Similar trends were reported by Patchell (1957), and Broster (1971) reviews experiments that show low levels of feeding pre-partum resulted in less liveweight loss or greater liveweight gain post-partum compared with animals better fed pre-partum.

The results of Grainger, Wilhelms and McGowan (1978) suggested that increased body condition at calving caused more energy to be partitioned into milk production and less into liveweight gain. Cows that calved at lower condition scores (< score 5) put on more condition post calving, than cows that calved at higher condition scores (> score 5).

Conclusion

It is apparent that the body condition of the dairy cow at calving will affect its response in terms of milk production to the level of feeding over the following lactation. This is due to:

1. the cow in heavier condition at calving having increased energy reserves available in the form of body tissue in order to support milk production

2. the cow in poorer condition at calving appearing to partition more of its dietary energy towards liveweight gain and less towards milk production.

1.1.3 The Response of the Dairy Cow to its Level of Feeding in Early Lactation

Experimental evidence discussed in the preceeding section showed that the response of the dairy cow to its level of feeding in early lactation is modified by its condition at calving (Grainger et al. 1978). Nevertheless important effects of level of feeding in early lactation per se have been determined in relation to peak milk yield and the whole lactation yield. Under the New Zealand seasonal dairying system, calving is arranged to coincide as far as possible with the onset of more rapid pasture growth in spring. Because of the variability in pasture growth rates from year to year, pasture availability at calving varies each year. Several New Zealand research workers have examined the consequences of underfeeding in early lactation (Flux and Patchell, 1954; Patchell, 1957; Wallace, 1957), because of its frequency under pastoral conditions.

These experiments generally studied the effects of different levels of feeding in the early part of lactation on milk production and liveweight change. Subsequently cows then received the same grazing treatment for the remainder of the lactation. Some results from these experiments are summarised in Table 1.2. The table refers to the immediate losses of milk production obtained in these experiments as well as the losses in production over the whole lactation. The residual effect has been calculated as a ratio of the milk production lost subsequent to the cessation of underfeeding, to the direct loss in milk production during the underfeeding (see Gordon, 1976). (i.e. residual effect equals x times the direct effect from underfeeding). While the absolute levels of feeding and thus the exact extent of underfeeding were not always well defined in these experiments, the effects of low levels of feeding are clear. Underfeeding in early lactation resulted in lower milk and milkfat yields. Peak milk yields were lower and reached earlier in lactation than when cows were well fed.

A consistent effect of underfeeding in early lactation, apart from year one of the experiment by Patchell (1957), was the apparent residual or carry-over effect of a restriction in milk production early in lactation on subsequent production. The extent of this residual effect varied between experiments (see Table 1.2).

Table 1.2 A summary of New Zealand experiments which investigated the consequences of underfeeding in early lactation

Experiment	Number and Age of Cows	Feeding Treatments	Stage of Lactation	Immediate Milk Yield Response	Whole Lactation Response	Residual Effect	Change in Liveweight	Post-Experimental Change in Liveweight
Flux and Patchell (1954)	14 Sets of Monozygous Twins Less than 4 years old	(1) 'Normal' (2) 40% of pasture and silage that 'normal' plane group received	Weeks 3-8 after calving inclusive	Loss of: 93 kg milk cow^{-1} ($P < 0.01$) 3.6 kg milkfat cow^{-1} ($P < 0.01$)	Loss of: 288 kg milk cow^{-1} 14 kg milkfat cow^{-1} (NS)	2.1 times the immediate effect 2.9	(1) + 5.9 kg cow^{-1} (2) - 15.5 kg cow^{-1}	Not Given
Patchell (1957)	12 Sets of Monozygous Twins Year I. 15 Sets of Twins Year II. Mixed ages	(1) Ample pasture from calving onward (2) 40% of pasture offered to group (1) Underfeeding more severe in Year II than Year I.	Weeks 1-6 after calving	Year I. Loss of: 59.5 kg milk cow^{-1} (NS) Year II. 82.9 kg milk cow^{-1} ($P < 0.05$)	25 kg milk cow^{-1} (NS) 226 kg milk cow^{-1} ($P < 0.05$)	Nil 1.72	Cows in treatment (2) lost no more liveweight than (1)	Cows in treatment (2) regained bodyweight more rapidly than (1).
Wallace (1957)	22 Sets of Twins in both Year I and Year II Mixed ages	2.7 kg concentrates cow^{-1}day^{-1} plus grazing versus grazing alone Year I Hard Grazing Year II Lax Grazing	Weeks 1-8 after calving	Year I. Supplemented cows produced 180 kg more milk cow^{-1} 8.2 kg more milkfat cow^{-1} Year II. Supplemented cows produced 67.5 kg more milk cow^{-1} 3.6 kg more milkfat cow^{-1}	Year I. 666 kg more milk cow^{-1} 35.9 kg more milkfat cow^{-1} Year II. 189 kg more milk cow^{-1} 10.9 kg more milkfat cow^{-1}	2.7 3.4 1.8 2.0	Not Given	Unsupplemented cows when fed well, used much of feed to replenish body reserves

(NS) = not significant.

A comparison of the results between years in the studies by Wallace (1957), and Patchell (1957) suggests that the greater the underfeeding in early lactation, the greater the residual effect on the rest of the lactation. It was also noticeable that cows underfed in early lactation partitioned a greater part of their feed energy to liveweight gain after the period of underfeeding.

These experiments have previously been reviewed by Gerring and Young (1961), who concluded that 'errors in management shortly after calving, which may cause only a slight, and at times almost an unnoticed drop in production are likely to affect the level of production throughout the whole of the remainder of lactation'.

W.H. Broster and his colleagues were able to extend the experimental evidence for the presence of the residual or 'carry-over' effect from early lactation feeding on production over the whole of the lactation. An extensive series of studies with first calving heifers has been carried out over a number of years. The experiments have included studies of the allocation of extra concentrates to groups of heifers in early lactation, compared with lower rates of concentrate feeding. In all experiments extra concentrate feeding in early lactation has had beneficial effects on peak milk yield, as well as on milk yield for the remainder of the lactation. Some results of these experiments are summarised in Table 1.3.

Two experiments in particular were designed to study specifically the nature of this residual effect. Broster et al. (1969) used 80 Friesian heifers to study the effect on milk production of two fixed levels of intake at two stages of lactation. Two levels of intake were used for weeks 1-9 of lactation, and the heifers were re-allocated at random to these two levels for weeks 10-18.

Generous feeding in weeks 1-9 increased the current milk yield and had a residual effect on the whole lactation yield. Generous feeding in weeks 10-18 resulted in a smaller response in current milk yield and had no residual effect in the remainder of the lactation.

Table 1.3 Results from experiments by Broster, showing the losses in total lactation milk yield following a reduction in early lactation yield due to inadequate feeding (From Broster, 1972).

Experiment	Period of Underfeeding (Weeks from Calving)	Production Losses (kg milk)		
		Early Lactation	Full Lactation	Residual Effect
Broster, Ridler and Foot (1958)	12	136	590	3.3
Broster, Tuck and Balch (1964)	8	45	181	3.0
Broster and Tuck (1967)	8	177	884	4.0
Broster, Broster and Smith (1969)	9	161	533	2.3
Broster, Broster, Smith and Siviter (1975)	8	190	680	2.6

In weeks 10-18, those animals which had enjoyed the more generous level of feeding in weeks 1-9 gained less liveweight than those cows that had the poor feeding in weeks 1-9. This suggests that the cows which had been better fed in early lactation continued to partition more nutrients to milk at the expense of body gains, than those that had previously been poorly fed. It also provides a possible explanation for the residual effects on milk production obtained from early lactation feeding.

Broster et al. (1975) experimented with six early lactation feeding treatments. Five groups of cows received the high level of feeding from 0, 4, 8, 12 and 16 weeks after calving. From the end of the period on the high level (H) each group changed to the low level (L) until week 24 of lactation. Thus one group started on the L level and others joined it at that level at intervals of 4 weeks. The immediate effects of the H minus L levels of intake on milk yield indicated a fall in the immediate response of milk production to feeding as the time from calving was extended. The H levels of feeding induced a beneficial residual effect on milk production later in lactation, together with a reduced liveweight gain in mid lactation. Extension of the H treatment period beyond week four after calving did not much increase the residual effect, confirming the earlier observation by Broster et al. (1969) that the level of feeding in the first few weeks after calving influences performance of the cow for the remainder of the lactation.

Johnson (1977) was able to obtain an advantage in total lactation yield as a result of higher milk production in early lactation. Cows that received higher allocations of concentrates in early lactation yielded on average about 500 kg more milk over the whole lactation than cows which were allocated fixed amounts of concentrates per day. All cows received the same total amounts of concentrate.

Gleeson (1970) also obtained a residual effect from feeding additional concentrates in weeks 0-6 of lactation but not from additional feeding in weeks 7-12.

Other experiments dealing with the effects of early lactation feeding on total lactation yield are reviewed by Broster and Strickland (1977). Not all experiments were able to show a residual effect from extra feeding in early lactation. Broster and Strickland (1977) speculated that an 'upper limit of nutrition' in the early post-partum period, above which residual and cumulative effects do not result from variation in intake, may exist. They proposed that this might explain the apparent dichotomy of results obtained.

The rations fed in many of the above experiments generally comprised of a basal ration of hay and/or silage supplemented with concentrates. Recently it has been questioned how well the results of these experiments can be extrapolated to situations where the dairy cow is fed on pasture for most if not all of the lactation.

Gleeson (1970) noted that carry-over effects of feeding in early lactation with spring calving cows were less than for autumn calving cows. In his experiments cows were fed indoors on silage alone or silage plus concentrates immediately after calving. He found that on going to pasture the animals fed silage alone recovered rapidly in both milk production and body weight. Because the spring calving cows went to pasture earlier in their lactations than the autumn calving cows, Gleeson felt that this might explain the reduced carry-over effect.

In further experiments, Gleeson (1973) fed three levels of concentrates plus silage in the first eight weeks of lactation over 2 years. At the end of the eighth week cows were grazed on pasture as one herd. Feeding higher levels of concentrates was found to be advantageous in early lactation. However, analysis of milk yields for the remainder of the lactation showed no advantage to the cows that had been fed high levels of concentrate in the first year of the experiment, and only a slight advantage in the second year.

Gordon (1976) fed different total amounts of concentrate to groups of cows during the three month indoor feeding period immediately after calving. All cows received the same rate of concentrate feeding in the first four weeks of lactation and were then allocated to the different levels of feeding. Grazing commenced approximately three months after calving, and there were no supplements offered during the grazing period. The mean milk outputs during the indoor feeding period were 2064 and 1971 kg cow^{-1}, and over the total lactation 4991 and 4984 kg cow^{-1} for the high and low concentrate groups respectively. There were no significant differences between the two groups of cows in milk yield during the period at pasture. Gordon suggested that a possible reason for the absence of a residual effect in these trials was that cows received the same level of feeding in the first four weeks of lactation. The other reason put forward was that residual effects are reduced when animals are grazed at pasture after a period of underfeeding.

Recent experiments in New Zealand and Australia have also failed to find a large residual effect on milk yield from extra feeding in early lactation, (Bluett, 1977; Grainger and Wilhelms, 1979; Bryant and Trigg, 1979). All cows in these experiments were fed on pasture. Bluett (1977), evaluated a leader-follower grazing system where cows in the leader group, which had been offered fresh pasture _ad libitum_, produced more than cows (of a similar stage of lactation) in the follower group which had to graze the residue left behind by the leaders. Bluett found no residual or carry-over effect in the post-experimental period.

Bryant and Trigg (1979), found only small and transient losses in subsequent production from dairy cows offered restricted amounts of pasture after calving. One of each set of 9 sets of identical twins was restricted in intake for six weeks after calving sufficient to lose 62 kg of liveweight while her mate gained a small amount of liveweight. Dry matter intake and milk production were 48% and 40% less respectively for the restricted cows. From the sixth week after calving cows were returned to the same level of feeding. By the eighteenth week of lactation differences in fat and protein yield between the two groups of cows had disappeared. Energy balance studies on these cows in weeks 8-18 of lactation indicated that partitioning of metabolizable energy (ME) to milk production was altered by under nutrition in early lactation. The cows which had been better fed in early lactation later converted more digestible energy to ME, due to smaller losses of energy as urine and methane than cows which had been on the lower levels of feeding in early lactation. However the energy gained amounted only to the equivalent of 57g of milkfat day^{-1}. Differences between treatments in cow liveweight had also disappeared by week 12.

In a second experiment, (Bryant and Trigg, 1979) five groups of 12 cows that, on average, had calved 30 days earlier were given the following grazing treatments over a period of 26 weeks. A control group was well fed throughout (a daily herbage allowance of 44-55 kg DM cow^{-1}), while other groups were offered restricted grazing during weeks 1-3, 1-6, 7-9 or 7-12 so as to reduce daily dry matter intake by about 20%. Week 1 was the first week of the experiment, not the first week of lactation. The reduction in yield of milk and its constituents within times of restriction was consistently highly significant, but residual effects on milk production, from when restricted feeding ceased until the end of the trial, were small and not significant.

Grainger and Wilhelms (1979), offered cows different amounts of pasture over the first 10 weeks of lactation. The two levels of feeding were:

(1) _ad libitum_ pasture intake (High) (H)

and (2) 7 kg DM intake cow^{-1}day^{-1} (Low) (L)

These treatments were used factorially for weeks 1-5 and 5-10 of lactation. The effects of five week periods of underfeeding on milk, milkfat and milk protein yields were equal and additive over the first 10 weeks of lactation. The HL and LH groups of cows produced 11 kg less and the LL group 22 kg less milkfat than the HH group. Full lactation milkfat yields were 133, 113, 123 and 90 kg milkfat cow^{-1} for HH, HL, LH and LL respectively. (LSD = 11.2). Residual effects of only 0.7 and 1.0 times the immediate effect on milkfat yield occurred as a result of underfeeding in the first five or ten weeks of lactation respectively. Despite the statistically significant effects of under-feeding in early lactation on the whole lactation milk yields, the experiment failed to find residual effects on milk yield as large as those found in other experiments, (Broster, 1972; Flux and Patchell, 1954; Wallace, 1957), (see Tables 1.2 and 1.3).

Summary

The milk yield of the dairy cow is most responsive to changes of intake in early lactation (Broster et al., 1969; Broster et al., 1975). As well as the immediate effect on milk yield caused by changes in intake, there are many experiments which have found a 'residual effect' from early lactation feeding on the whole lactation yield. (Flux and Patchell, 1954; Wallace, 1957; Broster et al., 1958; 1969; 1975).

Recent experiments involving cows fed on pasture, suggest that the residual effect from severe restriction of pasture intake in early lactation may be small (Bluett, 1977; Grainger and Wilhelms, 1979; Bryant and Trigg, 1979). Research in Ireland has suggested that the ability of cows to recover from poor early lactation feeding is enhanced when they are grazed on pasture after the period of underfeeding (Gleeson, 1973; Gordon, 1976; 1977). This is in contrast to earlier grazing experiments by Flux and Patchell (1954) and Wallace (1957).

The reasons for the contrasting results between the earlier and later experiments are not apparent. Some possible factors could be due to differences in calving condition, the potential milk yield of cows in early lactation, and the level of feeding in the post-experimental period. Bryant and Trigg (1979) suggest that if residual effects from underfeeding in early lactation are small, then considerable flexibility in the management of feed supply in early lactation may be possible.

1.1.4 The Effect of Level of Feeding of the Dairy Cow on Milk Composition

1.1.4.1 Pre-Partum Level of Feeding and Milk Composition.

Lees et al. (1948) and Campbell and Flux (1948) both found that the fat percentage of milk produced in early lactation was depressed by very low pre-partum planes of nutrition. Flux (1950), and Hutton and Parker (1973) showed that the solids-not-fat percentage was depressed as well as milkfat percentage by low levels of feeding prior to calving. Blaxter (1944) observed that milkfat percentage was increased by more generous feeding before calving. Broster (1971), in a review of the subject, concludes that under-feeding before calving reduced both the milkfat and solids-not-fat percentages of milk produced in early lactation.

As discussed previously, it is apparent that a pre-partum level of feeding is most likely to exert its influence on milk production and composition through its effect on body condition at calving. Davenport and Rakes (1969), Rogers, Grainger and Earle (1979), Grainger, Wilhelms and M^{c}Gowan (1978), all consistently showed that milk from cows that calved in heavier condition had a significantly higher fat concentration, and a slightly lower protein concentration, throughout lactation than milk from cows that calved in lighter condition.

1.1.4.2 Feeding in Early Lactation and Milk Composition.

It is widely recognised that the energy and protein intake of the dairy cow during lactation has a marked effect upon milk composition. In the short-term a sudden reduction in intake will lead to a decrease in milk yield, an increase in milkfat percentage and a decrease in solids-not-fat percentage. This has been shown to occur in response to underfeeding for one day (Munford et al., 1964), for 5-10 days (Flux and Patchell, 1957) or for up to ten weeks, (Flux and Patchell, 1954; Grainger and Wilhelms, 1979; Bryant and Trigg, 1979). Bryant (1979), summarises the effects of varying the level of feeding of dairy cows on their milk composition from 14 experiments involving some 300 cows. The results suggested that a 50% reduction in intake increases the fat content by about 0.4 units, and decreases the contents of protein by 0.3 units and of lactose by 0.1 units.

Some researchers have noted that raised milkfat percentages due to underfeeding are normally associated with periods when milk yields are also depressed, and there is little residual effect once normal feeding resumes (Flux and Patchell, 1954). However other experiments (Grainger and Wilhelms, 1979; Bryant and Trigg, 1979), have found that milkfat percentage while significantly increased in the short-term because of underfeeding, may be significantly depressed once normal feeding resumes. It appears that prolonged underfeeding will eventually result in a fall in milkfat percentage. (see also review by Kirchgnesser et al., 1967).

Stobbs and Brett (1974) examined the effect of three levels of intake on milk yield and milk composition. A reduction in energy intake caused milk yield to decline, and as milk yield fell milkfat percentage increased.

Other researchers have found that the protein concentration of milk is raised by increased levels of dietary energy (Gordon and Forbes, 1970) and decreased by reduced levels of dietary energy (Flux and Patchell, 1954; Bryant and Trigg, 1979; Grainger and Wilhelms, 1979). Milk protein content appears to be very sensitive to variations in energy intake, but not so sensitive to variations in protein intake (Greenhalgh, 1969). Paquay et al. (1973) found that increases in protein intake did not necessarily increase milk or milk protein yields, and that high levels of dietary N intake enhanced urinary N losses. Recent evidence has suggested that there is an important interaction between both dietary energy and protein, and the milk yield and milk composition of the cow (Broster and Oldham, 1977). Utilization of high levels of dietary N for milk production will be dependent upon the availability of dietary energy. It appears that the decrease in protein content of milk produced by cows restricted in pasture intake is likely to be a function of both dietary energy and protein restriction.

As well as the quantity of herbage eaten and its effect on milk composition there are probably effects on milk composition caused by the quality of the herbage consumed. The effects of different pasture species on milk composition (e.g. lower milkfat contents caused by grazing Manawa c.f. Ruanui, Bryant 1979), would suggest that minor changes in the chemical composition of the herbage selected by the cow may have some effect on the milk composition. However there are difficulties in separating the effects of quality and quantity of feed consumed because a cow may have a low intake anyway, if presented with food of low quality. Herbage selected by grazing animals has been shown to have a consistently higher digestibility and crude protein content and a lower crude fibre content than animals offered the same herbage without the opportunity to select (Combellas and Hodgson, 1979; Greehalgh et al., 1966; Stobbs, 1977). There may be some alteration to milk composition caused by the fibre or crude protein composition of the diet, which is independent of the quantity of herbage consumed.

A summary of the effects of restricting herbage allowance on milk composition would suggest that high grazing intensities would be expected to depress milk yield, lower the milk protein and lactose concentrations and increase the fat concentration of milk (Stobbs, 1977; Bryant and Cook, 1977; Greenhalgh et al., 1966).

1.2 Factors Affecting the Herbage Intake of Grazing Ruminants

1.2.1 Animal Factors Affecting Pasture Intake

This review is concerned with some of the factors affecting voluntary intake of grazing animals such as the effects of lactation, milk yield, body condition, size and breed.

Conventional theories of appetite control in housed animals postulate that food intake may be limited either by the concentration of metabolites in the bloodstream, or by the volume of digesta in the alimentary tract, Balch and Campling (1969). The upper limit of nutrient intake is set by the rate at which metabolites can be removed from circulation and/or the distention of the alimentary tract. The rate at which metabolites will be removed from the circulation will be related to the energy demand of the animal, in the case of the dairy cow its requirements for lactation, tissue deposition and maintenance. Under grazing conditions a further potential limitation to intake related to the ability of the animal to sustain grazing activity under difficult sward conditions must be considered.

In general, the physiological state of an animal will influence its demand for energy (Bines, 1976). For any animal at any one time its energy demand depends upon the interactions among genotype, body size, fatness, the potential energy loss due to lactation, energy expenditure in exercise and grazing, and expenditure in countering climatic effects. Some data used by Hodgson (1977) to illustrate the effects of age, pregnancy and lactation on the intakes of dairy stock relative to their live-weights are given in Table 1.4.

Table 1.4 The herbage intakes (g organic matter kg LW^{-1}) of lactating cows (LC), pregnant heifers (H) and calves (C) grazing perennial ryegrass swards varying in weight and maturity. (From Hodgson, 1977)

Period	I			II			III			SE of difference between Animal Classes
Animal Class	LC	H	C	LC	H	C	LC	H	C	
Weight of Herbage (kg OM ha^{-1})		2880			6340			8240		
Digestibility of Herbage (OMD%)		78.1			71.8			64.6		
Herbage Intake (g OM kg LW^{-1})	30.2	15.6	24.9	36.2	20.4	27.8	24.8	16.0	25.9	1.13 ($P < 0.001$)

The lactating cow, with its high energy loss through milk production, might be expected to have a higher food intake than a similar non-lactating cow under similar feeding conditions. Hutton (1963) was able to show this in an indoor feeding experiment using thirteen sets of identical twins, each pair comprising one lactating and one dry animal. The lactating twin steadily increased intake from calving so that it was consuming 50% more than its non-lactating twin sister by the fifth month of lactation. The study showed a lag in the response of food intake to the increased energy demand of lactation. Peak milk yield was reached in the sixth week of lactation, while peak intake was obtained 15 weeks later. It is not clear why food intake in early lactation cannot provide for the energy output in milk. Tulloh (1966) showed that a gradual enlargement of the alimentary tract occurs after parturition, and this might explain the delay in the increase in intake from calving. Another possibility is that the rate of metabolism in both the rumen and body tissues takes time to adapt after calving to the increased demand for nutrients, although there is no experimental evidence for this (Bines, 1976).

Hancock (1954) associated differences in grazing time between sets of identical twins, with their differences in size and fat corrected milk production. He suggested the following relationship:

$$\left.\begin{array}{l}\text{productive capacity}\\ \text{growth capacity}\\ \text{maintenance requirement}\end{array}\right\} \longrightarrow \text{grazing time} \longrightarrow \text{feed intake}$$

Later studies which have measured pasture intake of grazing and stall-fed cows, have used multiple regression analysis to partition the variance in energy intake between liveweight (maintenance requirements), and the various forms of production (Wallace, 1956; Wallace, 1961; Hutton, 1962; Curran and Holmes, 1970; Broster and Alderman, 1977). Fat corrected milk production and cow liveweight have both been found to be significant variables for use in predicting dry matter intake of grazing cows. However there are problems associated with predicting intake by using this approach. Bines (1976) suggests that prediction equations for food intake are, at best, only generalizations. One problem is that intake lags behind production (Hutton, 1963). Additionally changes in liveweight have to be taken into account in a prediction model and there are inherent errors in the measurement of both liveweight and intake. The prediction models also assume intake to be the dependent variable, but milk yield might be considered to be the more appropriate dependent variable. Milk yields are dependent on energy supply, and in some feeding situations (i.e. low energy density rations) bulk may limit the intake of energy and therefore milk production will be limited. Intake will be altered by numerous characteristics of the feed offered (e.g. herbage allowance, % green material in a sward, digestibility) and milk yield is a more easily measured variable than intake.

Monteiro (1972) has developed a model which takes account of weight changes, stage of lactation and delays in response of food intake to previous changes in both milk yield and liveweight. There is also some account of the ration composition. These prediction equations, despite their inadequacies, have suggested that the larger and the higher yielding cow might be expected to eat more than the lower yielding and smaller cow.

There is some suggestion that cow appetite may be an inherited characteristic (Bines, 1976). A cow with a low appetite relative to her liveweight cannot produce a high yield of milk unless she is an efficient converter of food into milk. Likewise a cow that has a large appetite may use the energy it consumes either to produce milk or to produce body tissues. It may not necessarily be a high milk producer if it uses consumed energy for the latter. It is likely that the control mechanisms for the partitioning of energy are inherited, as is appetite, and investigations are underway in Britain and at Massey University looking at these aspects of dairy cow productivity.

There is a limited amount of evidence to suggest that the higher the yield potential of the cow the greater is the output of milk from a given amount of food (Broster and Alderman, 1977; Hind, 1979). At Massey University, in a small pilot study, the pasture intakes of stall fed high and low producing cows were measured (Davey and Holmes, 1978). High producing cows ate more than low producers when given unrestricted access to pasture, but at the same time they required less dry matter to produce a litre of milk. This suggests that the cows selected as low producers directed more of their feed energy to body tissue, or had higher maintenance requirements than the high producers. Experiments in the U.K. have shown that selection of cows for increased milk yield appears to have led to increases in food consumption, and the efficiency of conversion of that food to milk (Hind, 1979).

The attempts to predict pasture intake from the energy demand of the animal, have indicated that the two are generally related. However, there are problems associated with such relationships, due to the inaccuracies of measuring the intake of the grazing animal and because milk production may be supported by tissue energy reserves. Differences in the efficiency of conversion of food to milk between cows may complicate the relationship. The implications of the selection of cows which are high milk producers on their efficiency of conversion of pasture to milk, and their appetites, is a subject in which more information is required. Studies at Massey University and Ruakura Agricultural Research Centre investigating these factors are underway.

Another important factor in determining the energy demands of an animal appears to be its body condition. Bines et al. (1969) found that thin cows will consume about 20% more of a high concentrate diet during 5 hours access to food, than the same cows when fat. Grainger, Wilhelms and McGowan (1978) found that cows which calved in poor condition, ate more pasture in the first five weeks of lactation than cows that had calved in good condition. At the same time the thin cows produced less milk, and lost less liveweight, indicating that the partition of energy towards body reserves was favoured.

Arnold (1970) noted that there appeared to be a strong negative relationship between body condition and pasture intake in sheep. He suggested that body condition is probably a better indicator of energy demand than liveweight in the mature animal, as differences in liveweight amongst mature animals may reflect differences in skeletal body size. Thin sheep grazing with fat sheep make compensatory gain by increasing intake by up to 20% or more on a per unit liveweight basis (Allden, 1968). As thin grazing animals become fat, intake decreases (Arnold, 1970; Bines, 1976).

1.2.2 Pasture Factors Affecting the Voluntary Herbage Intake of Grazing Ruminants

1.2.2.1 Introduction

In general many of the pasture factors that affect pasture intake by the grazing animal are not well understood, for two principal reasons as suggested by Hodgson (1977):

(1) The difficulties associated in measuring pasture intake by the grazing animal,

(2) difficulties in describing the pasture characteristics to which animal intake is sensitive.

Herbage intake by the grazing ruminant will not only be a response to appetite, but will be also modified by the intrinsic and extrinsic factors of the herbage on offer (Raymond, 1969). Intrinsic factors of herbage are defined as features in the herbage that will affect intake once the food is consumed, while extrinsic factors are involved in the actual consumption of the herbage and are concerned with the method of presentation of the food and the effects of the environment on food intake.

A lack of precise knowledge about the composition of the herbage which the grazing animal selects has been a major obstacle in studying the nutrition of the grazing ruminant (Ulyatt, 1973). A grazing ruminant commonly has available a wide range of potential food in the form of different plant species, each with its young and old leaves, stems, seeds and other components. A high degree of diet selection occurs from the total amount available. Cattle and sheep generally select leaf in preference to stem, young leaf in preference to old leaf, and green leaf in preference to dead leaf, (Hodgson and Ollerenshaw, 1969; Dudzinski and Arnold, 1973; Stobbs and Hutton, 1974). Considerable research effort has been directed towards defining in quantitative terms the influence of some of the major sward variables which influence selective grazing and herbage intake.

1.2.2.2 The Effect of Herbage Digestibility on Herbage Intake

The digestibility of a forage diet is conventially accepted as a measure of nutrient concentration and a factor which influences the voluntary intake of grazing animals (Hodgson, 1977). Earlier experiments with housed animals (Hutton, 1962b; Blaxter and Wilson, 1962), provided evidence that a positive linear relationship between the digestibility of the diet and its voluntary intake by cattle exists up to levels of 70-75% digestibility. Above this level of digestibility the relationship was not so clear and was thought to be curvilinear (Baker, 1976). More recent experiments with grazing animals demonstrate a linear increase in pasture intake with increasing digestibility, to over 80% digestibility (Hodgson, 1968; Hodgson et al., 1977). Stehr and Kirchgnesser (1976) found a positive linear relationship between pasture intake and organic matter digestibility over the range 64-82% digestibility with lactating dairy cows. In the earlier experiments relating forage digestibility and intake, mature animals with low energy demands were used, whereas the more recent experiments involved lactating or growing animals. The suggestion that the metabolic control of intake dominants the physical control of intake at high levels of digestibility, does not appear to be appropriate for animals of high nutrient demand on a forage diet (Baker, 1976). The digestibility of the plant components selected from the sward will therefore exert a dominant influence on animal intake and performance over a wide range of digestibilities.

Digestibility appears to influence the voluntary intake of ruminants largely through the rate of disappearance of digesta from the reticulo-rumen (Campling, 1970). Rumen retention time depends on the rate of physical and chemical breakdown of the diet, and voluntary intake is a reflection of these factors. A high proportion of soluble components in the herbage usually results in a quicker breakdown than a high proportion of insoluble structural components (Ulyatt, 1973).

The structural components of herbage fluctuate with the seasonal conditions and the stage of growth of the herbage. This causes seasonal changes in digestibility with an expected influence on voluntary intake throughout the year (Hutton, 1962b). Corbett et al. (1963), found that as pasture digestibility fell during the spring from 80-68%, it was accompanied by a fall of about 20% in digestible organic matter intake by lactating cows. Seventy-five percent of the decline in intake was due to the decline in digestibility.

A measure of digestibility does not necessarily provide a reliable indicator of dry matter (DM) intake. For instance, Ulyatt (1971) found that sheep consumed more white clover than perennial ryegrass when the digestibility of the herbage offered was the same, apparently because of differences in the rate of breakdown of the two forages in the rumen. Laredo and Minson (1975) fed separate leaf and stem fractions of the temperate grass Lolium perenne. The voluntary intake of leaf was 20% higher than that of stem despite similar digestibilities of the components. This would suggest that there are intrinsic factors of herbage other than digestibility per se, which are involved in determining the voluntary intake of herbage by ruminants.

It appears that any physical and/or chemical characteristic of ingested herbage that has the effect of decreasing the retention time of the digesta in the rumen will contribute to an increase in intake of that herbage. Rumen retention time is thought to be influenced by how quickly the digesta is broken down to a particle size that is able to pass on down the digestive tract. For example Reid et al. (1977) found that particles passing from the rumen to the abomasum of sheep fed chaffed or ground lucerne hay appear to be of a size that will allow them to pass through a 1.0 mm sieve.

Soluble CHO and protein are rapidly digested by rumen micro-organisms compared with the less soluble structural components, therefore the higher the soluble fraction of the forage, the shorter the rumen retention time. Chemical analyses of forages of similar digestibility has shown that some species have a higher proportion of soluble cell contents and a lower proportion of insoluble cell constituents in the digestible fraction (Raymond, 1969). Thornton and Minson (1973) suggested that the higher intakes they obtained from feeding legumes compared with grasses at the same digestibility was due to the more soluble nature of the legume cell wall components. Associated with the higher intake of the legumes was a significantly lower apparent retention time of organic matter (OM) in the rumen, suggesting that the chemical composition of the legume material favoured a rapid rate of disappearance from the rumen.

Other plant factors have been reported to influence the rate of cellulolytic activity in the rumen and hence the retention time of digesta in the rumen. Laredo and Minson (1973) observed that the leaf fractions of five tropical grasses passed through the rumen at a greater rate than the stem fraction of the same digestibility. They suggested that the increased surface area of the leaf fraction available for initial bacterial degradation contributed to its faster rate of passage through the rumen. It is also noted that the observed effect may have been confounded by the increased Nitrogen (N) content of the leaves causing an increase in the cellulolytic activity of the rumen microflora. There is evidence to suggest that an increased supply of N in the rumen will reduce the retention time of digesta in the rumen, especially when feeds have a low protein content (Campling et al. 1962, cited by Campling 1970). As well as N, the addition of certain minerals (e.g. Co) or specific long chain fatty acids have been shown to increase the intake of low nutritive value roughages, presumably by enhancing microbial digestion of the herbage in the rumen (Ulyatt, 1973).

1.2.2.3 Sward Characteristics that Influence the Herbage Intake of Grazing Animals

The intake of herbage by a grazing animal is partly a function of its grazing behaviour (Arnold, 1964; Stobbs, 1974). Arnold (1964) describes the grazing pattern of sheep and cattle as movement in a horizontal plane and selection in a vertical plane. Any physical characteristic of the sward that interferes with 'normal' selective grazing will therefore influence pasture intake. Stobbs (1974) suggested that intake of herbage (I) by a grazing animal is a function of both the time spent grazing (T), the rate of biting (B) and the size of bite (S). ($I = T \times B \times S$). A reduction in any of the components, (e.g. average bite size), requires an increase in the other components if intake is to be maintained. Intake will therefore be related to the 'ease of prehension' of the sward components that the animal wishes to select. There is considerable interest in defining the sward characteristics to which grazing behaviour and hence pasture intake responds.

A definition of terms is required before a discussion of sward characteristics affecting pasture intake by grazing animals can commence. Hodgson (1979), defines the sward canopy 'as the above ground parts of a population of herbaceous plants, including connotations of the distribution and arrangement of constituent plants and their parts'. The distribution and arrangement of constituent plants and their parts (structure) will affect the 'ease of prehension' which is defined by Hodgson (1979) as the 'ease with which sward components can be approached and grasped in the mouth of an animal during grazing'. The terms 'sward canopy structure', and 'ease of prehension' are qualitative terms and can only be quantified in terms of their effects upon the grazing behaviour and rate of herbage consumption by the grazing animal.

A number of sward characteristics and their effects on herbage intake have been studied.

Weight of Sward Canopy per unit area

The weight of herbage present per unit area has been shown to have a relationship with herbage intake which is generally curvilinear (Baker 1976). Below some critical weight of herbage (measured to ground level) the rate of intake declines at an increasing rate, and eventually a point is reached where the animal cannot utilize any of the herbage DM in the sward. The rate of decline is usually associated with the inability of the animal to increase grazing time to compensate for decreasing bite size (Allden and Whittaker, 1970). However the critical point at which herbage intake starts to decline has varied greatly between experiments, being found as 1100 kg DM ha^{-1} through to 2800 kg DM ha^{-1} for cattle grazing temperate swards, and 1100 - 4000 kg DM ha^{-1} for sheep grazing mainly on sub-tropical swards (review by Hodgson, 1977, see also Johnstone-Wallace and Kennedy, 1944; Van der Kley, 1956; Arnold and Dudzinski, 1967a and b; Allden and Whittaker, 1970).

Some of the reasons for this variation could be attributed to: (1) differences in techniques used to measure sward characteristics

(2) differences in the definitions of sward characteristics, and differences in the sward characteristics themselves between experimental pastures

(3) the age, breed and physiological status of the stock used.

However it is unlikely that all the variation can be accounted for by these factors. It appears that measurements of weight of herbage per unit area are inadequate within themselves to describe a relationship with an animals herbage intake. Hodgson (1976) suggests that the above wide range of herbage yields may reflect differences in the availability of herbage to the animal between pastures, at the same weight of herbage DM. Some swards may facilitate larger bite sizes by animals, to lower levels of DM per ha. than others. This will be related to what is broadly termed the sward canopy structure.

Sward Canopy Structure

There is increasing evidence that the spatial distribution of the most palatable or preferred parts of the sward canopy will be more important in some circumstances, than the weight of herbage present per unit area in affecting the rate of herbage intake.

The work of the late T.H. Stobbs and his colleagues with dairy cows grazing tropical pastures, has highlighted some important aspects of sward canopy structure and its effect on the rate of herbage intake by the grazing animal. These may prove to be of importance in relation to temperate pastures. In a series of grazing behaviour studies, dairy cattle were shown to select leaf rather than stem, and the horizontal and vertical distribution of leaf and stem in the sward greatly influenced the ease with which herbage was removed from the sward (Stobbs and Hutton, 1974). The size of bite was related to the leaf yield, the accessibility of leaf and the leaf length. As the pastures matured, leaf yields, canopy density and bite size increased. However if tropical pasture regrowth is too long (grazing interval of 6-8 weeks), an increased stem content results and this prevents animals harvesting a high proportion of leaf. Bite size will then decline. Dairy cows grazing mature tropical pastures can be underfed even though 'adequate' DM is on offer, because they are unable to increase their grazing time sufficiently to compensate for the low bite size caused by selective grazing for leaf. Cow bite size was measured using cows with an oesophageal fistula, Stobbs (1973), and a theoretical minimum bite size of 0.3g OM ingested per bite was calculated for a 400 kg cow to achieve adequate organic matter intake at a mean rate of biting. Bite size on mature tropical swards often fell below this critical figure because of a high stem/leaf ratio and resulting low leaf availability. If the animal is forced to eat an increasing proportion of stem rather than leaf in its diet, then intake may be restricted by the slower rate of passage of stem digesta through the rumen (Laredo and Minson, 1973), as well as reduced bite size.

Sward, and in particular leaf density was also shown by

Stobbs (1973) to be an important factor which affected the availability of leaf and hence the rate of herbage intake. The mean bite size of cows grazing a dense leafy sward induced with a plant growth regulator, was higher then from the more erect open swards resulting from treatment with Giberellic Acid. Application of inorganic nitrogen to tropical pasture swards also increased sward and leaf density and the size of bite taken. Chacon and Stobbs (1976) found that the intake of grazing cattle at a particular time is largely determined by the amount of leaf offered per unit area. They concluded that leaf yield, leaf percentage and the bulk density of green material, are the major sward factors influencing the intake of tropical pastures by grazing cattle.

While the sward characteristics affecting the rate of pasture intake have been well defined for tropical pastures by Stobbs, there is as yet little quantitative information, particularly in relation to dairy cattle, on the importance of these characteristics in temperate pastures. This is probably because fewer difficulties have been experienced with temperate pastures in achieving high pasture intakes. For example, measurements of grazing time and the rate of grazing of cows offered the temperate species Avena sativa by Stobbs and Hutton (1974), show that cows had the shortest grazing time and the largest bite size when grazing this species, when compared with measurements recorded with cows grazing tropical pasture species.

The research of Arnold and Dudzinski 1967 (a and b), and Allden and Whittaker (1970), suggests that the sward characteristics of temperate pastures which affect the herbage intake of sheep are of some importance. Arnold and Dudzinski (1967b) set out to determine some of the physical characteristics of several temperate pastures that influence digestible organic matter intake (DOMI) of grazing sheep. They showed that sheep selected the more digestible green material from a sward even when up to 50% of the total DM on offer was dead material. The ability of the sheep to select a diet of higher digestibility was important as the overall digestibility of the sward was low. Over a wide range of total pasture DM yields on offer, leaf length and the proportion of green dry matter became the two most important factors influencing DOMI. Where the green dry matter (GDM):total dry matter (TDM) ratio is high, even at low levels of TDM, leaf length became the dominant factor influencing pasture intake. Leaf length was also found to be more important than either GDM or TDM in accounting for variation in intake in a further experiment, (Arnold and Dudzinski, 1967b).

Allden and Whittaker (1970) established that there was a relationship between the rate of intake and the length of tiller for sheep grazing Wimmera ryegrass (Lolium rigidum) in South Australia. The rate of ingestion increased with tiller length up to a height of 7.7cm. Above this height a constant rate of intake was maintained by a lowering of the rate of biting. The authors reasoned that the rate of intake of herbage by the grazing animal is largely a function of the ease with which plants can be prehended and the evidence suggests that tiller length is a good measure of this characteristic. Additionally in swards where different plant densities had been induced by the removal of plants by cultivation, it was evident that the rate of intake was affected by the plant density. At yields of 1000 kg DM ha^{-1}, distributed at two plant densities, two different rates of herbage intake resulted.

Arnold (1963), noted that when two pastures both yielding 1600 kg DM ha^{-1} were grazed, sheep had a higher rate of intake from a pasture which was long and sparse compared with a shorter denser sward. Arnold and Dudzinski (1969) presented evidence to suggest that quite different rates of intake, at the same leaf length, result because of different pasture species and the different densities of herbage. In contrast to the above, the denser pasture resulted in a larger bite size and a higher rate of intake.

Hodgson et al. (1977) conducted experiments with six-month old steer calves on two swards, one being S.24 perennial ryegrass (Expt. 1), and the other being Pangola grass in Venezuela (Expt. 2). Multiple regression analysis was carried out to determine the relative importance of sward variables and their affect on animal intake. On this basis organic matter digestibility of the diet was the most important variable related to intake in both experiments. Variations in the weight, the green to dead ratio of the herbage and in sward structure also had significant effects on herbage intake in Experiment 2 but not in Experiment 1. More sophisticated descriptions of the vertical distribution of herbage within the sward were no more effective than sward height in explaining variations in herbage intake.

1.2.2.4 Summary and Conclusions

Although it has been demonstrated that sward weight and height per unit area is of some significance in determining the intake of temperate grasses, wide variations in the ease of prehension of temperate pastures varying in height or weight have not been demonstrated, Baker (1976). However, as discussed, sheep and cattle are capable of being highly selective in their diet, selecting for leaf versus stem, green versus dead material and young leaves versus old leaves. The physical canopy structure of the pasture might therefore be expected to play an important role in selective grazing of the preferred plant parts and the plant species in temperate pastures.

As yet there is no agreement on how to describe the spatial distribution of herbage in a sward and how it might be related to intake, Baker (1976). Hodgson (1977) points to the likely inadequacy of measurements of total herbage weight and overall sward height to explain variation in herbage intake.

The components of sward canopy structure that have been shown to influence the rate of herbage intake apart from total weight per unit area or height of pasture are:

(1) the leaf:stem ratio
(2) the ratio green material:dead material
(3) leaf density or leaf offered per unit area.

All these factors will affect the availability and accessibility of the preferred plant parts and species, and therefore influence grazing behaviour.

1.3 Herbage Allowance and its Relationship with Herbage Intake and Animal Performance

1.3.1 Introduction

If a major objective of grassland farming is to maintain a high level of animal performance, and at the same time a high efficiency of herbage utilization, more quantitative information is required on the ways in which animals and swards respond to various grazing intensities. Some research would suggest that improvements in the productivity of grazing systems may come as much from improvements in the utilization of herbage grown as from further increases in herbage production (Baker et al., 1975). Improvements in the utilization of pasture grown will require more information for use in the objective management of grazing systems.

Grazing pressure and stocking rate are parameters which provide some indication of the quantitative relationship between the herbage requirements of animals and the feed supply. Grazing pressure is defined by Hodgson (1979), as the number of animals of a specified class, per unit weight of herbage at a point in time. As grazing pressure is increased, in an effort to increase the percentage of herbage harvested, the amount of herbage available becomes the major factor which limits intake by the individual animal. As a result animal performance may suffer.

This is illustrated by the experiment of Marsh and Murdock (1974), who measured a significant decrease in herbage DM availability, and a corresponding decrease in mean daily digestible organic matter intake as stocking rate increased from 5.0 to 7.5 steers $ha.^{-1}$ As a consequence mean daily liveweight gain per animal decreased at the high stocking rate, however there was an increase in output per ha. (LWG $ha.^{-1}$) at this high stocking rate. Gordon (1973) also demonstrated that as stocking rate increases herbage availability per cow is reduced, resulting in reduced intake and performance per cow, but an increase in milk production per ha.

Grazing pressure is an instantaneous expression of the relationship between grazing animals and their feed, and describes the proportionality between animals and food in a way not commonly used by the nutritionist who thinks in terms of unit of food per animal (Greehalgh et al., 1966). The preferred parameter for use in determining quantitative relationships is the inverse of grazing pressure, the herbage allowance.

1.3.2 Definition of Herbage Allowance

Herbage allowance has been defined as the total weight of herbage DM or OM (measured to ground level) per unit of animal liveweight per day (Hodgson, 1976). The term has its limitations in that it is best applied to rotational grazing systems where animals move to new areas of pasture each day. It also involves a subjective assessment of the 'availability' of the herbage to the animal. Two equal herbage allowances, but on different pasture types, may not offer the animals the same opportunity to eat similiar amounts of herbage due to differences in the accessibility of the preferred herbage (refer to Chapter 1.2.2.3). For example Hodgson and Wilkinson (1968), demonstrated differences in organic matter intake by dry cows at similar herbage allowances, because the allowances were offered on two swards different in their stage of maturity. Provided herbage allowance is used with the influence of sward characteristics in mind (e.g. Stobbs, 1977) it will be a useful expression in determining some quantitative relationships between animals and the pasture sward. Rattray and Jagusch (1978) suggest that 'pasture allowance is probably the most important single factor that is responsible for differences in production per animal between farms, between years, and between stocking rates, under New Zealand pastoral farming conditions'.

1.3.3 Experimental Studies of the Relationship between Herbage Allowance, Milk Production and Herbage Intake with Dairy Cows

The extent to which grazed herbage can meet the requirements of dairy cows remains largely undefined in precise terms, largely because of the lack of quantitative information on the extent to which plant and animal factors govern herbage intake.

Several earlier experiments noted a positive association between the quantities of DM offered and the quantity consumed, but the results of these studies were confounded by the fact that higher offerings of pasture were associated with more mature herbage. Waite, Holmes and Boyd (1952), in a comparison between two grazing systems, measured the herbage consumption of dairy cows as the difference in weight of herbage present before and after grazing (weight determined by cutting herbage to a sampling height of 13 mm). They noted the decrease in the proportion of herbage consumed as the area grazed was enlarged.

Van der Kley (1955, cited by Greenhalgh et al., 1966) found that intake increased from 8 - 17 kg DM $cow^{-1}day^{-1}$ as the amount of herbage offered daily rose from 11 to 40 kg DM cow^{-1}.

Greenhalgh et al. (1966) first introduced the concept of herbage allowance as a means of describing the grazing intensity of dairy cows. Their objectives were to investigate the effects of the herbage allowance on the quantity and quality of the herbage consumed and the milk produced by strip grazed cows. Twenty Ayrshire cows in their second or subsequent lactation were used in four groups of five cows at different allowances. They varied in stage of lactation from three to twelve weeks after calving at the start of the experiment. The pastures used were predominantly ryegrass/timothy species and had an average yield of 3300 kg DM ha^{-1} before grazing. Intake of herbage was measured by the use of the chromic oxide-faecal N technique. Pasture yield was determined by cutting to a height of 2.5 - 5cm from ground level because it was felt that this height gave a more realistic estimate of the herbage available to the cows. This assumption was subsequently found to be unsatisfactory. Herbage allowances were offered for three periods of 3 to 4 weeks, interspersed between four standard periods of 2 - 3 weeks in which all the cows were strip grazed on 23 - 27 kg DM cow^{-1} day^{-1}. Some results from this experiment are in Table 1.5.

Table 1.5 Herbage allowance, herbage intake and their effects on milk production and liveweight change of dairy cows. (Greenhalgh et al. 1966)

Treatment	A	B	C	D	Sig.
Herbage Allowance ($kg\ DM\ cow^{-1}day^{-1}$)	11.4	15.9	20.5	25.0	-
Herbage Intake ($kg\ DM\ cow^{-1}day^{-1}$)	11.7	12.9	13.6	13.6	***
Digestibility of OM %	75.0	75.2	75.7	75.6	***
Milk Yield ($kg\ cow^{-1}day^{-1}$)	14.9	14.8	15.8	15.5	**
Yield of FCM (4%) ($kg\ cow^{-1}day^{-1}$)	15.2	15.0	15.9	15.6	NS
Liveweight change ($kg\ cow^{-1}day^{-1}$)	- 0.73	+ 0.32	+ 0.23	+ 0.27	*
Fat Percentage	4.25	4.04	4.02	4.12	*
Protein Percentage	2.98	3.19	3.24	3.20	NS

*** ($P < 0.001$)

** ($P < 0.01$)

* ($P < 0.05$)

NS = non-significant.

There are a number of important points arising from this comprehensive study in relation to the grazing intensity of dairy cows, and these are summarised below.

1. The relationship found between herbage allowance and herbage intake was curvilinear.

2. The differences between treatments in milk production were smaller and less consistently related to herbage allowance than were those for intake. The differences were significant however. Increasing the amount of herbage offered to the cows had a marked effect on the solids-not-fat content of milk, with both protein and lactose increasing with increased herbage allowance. When liveweight changes and milk production were considered together there was a more consistent relationship between intake and animal production, than between intake and milk yield alone.

3. Herbage allowance appeared to have the same relative effects when offered under different pasture conditions. Under two extremes of pasture conditions, one being ryegrass in full flower at 5000 kg DM ha^{-1} and the other a leafy regrowth yielding 1800 kg DM ha^{-1}, the same herbage allowances had a similar effect on herbage intake.

4. Increasing herbage allowance provided greater opportunities for selection. The cows on the highest allowance were able to reject nearly half the herbage offered to them. The effect of the selection opportunity on the digestibility of the herbage consumed was statistically significant, but the differences between treatments were small enough to suggest that the effect had little practical significance. Although the top growth consistently had a higher nitrogen content than the bottom, the average organic matter digestibility was virtually the same as that of the bottom growth.

5. The most obvious difference between the allowance areas in their appearance after having been grazed was in the height of the stubble. The lowest allowance cows grazed down to a very low level and they also grazed very close to their own defaecations.

6. It was concluded that the herbage allowances were without significant residual effects on milk production, although SNF and protein percentages appeared to have longer term effects upon them than other milk production characteristics. The differences in milk yield between treatments disappeared in the standard periods.

7. There was a suggestion that the effects of herbage allowance on milk yield would vary according to the general level of production of the cows.

8. Promoting relatively small increases in the intake and production of the animal by relatively large increases in the amount of herbage offered must be considered in its economic context (per animal versus per ha. production).

In a second experiment Greenhalgh et al. (1967) set out to determine the effects of the same herbage allowances when offered over a longer period of time (10 weeks). Fifteen Ayrshire cows in mid-lactation were used on pastures that were predominantly ryegrass/cocksfoot mixtures. The same methods for estimating herbage intake and DM yields were used as those used by Greenhalgh et al. (1966). The results were very similar to those of the previous experiment and are set out in Table 1.6.

Cows offered 11.4 kg DM $cow^{-1}day^{-1}$ appeared to eat more than that available to them. This was put down to the cows grazing below the sampling height of 5cm and also being adept at grazing under fences. Once again there was little evidence that selective grazing leads to differences between treatment groups in herbage digestibility. This was true even over a wide range of digestibilities encountered (68 - 79% DOM).

The overall conclusion made was that the effects on herbage intake and milk production of imposing different herbage allowances for three months, are no different from those caused by imposing them for only 3-4 weeks. It appeared that the effect on liveweight change may be smaller in the long-term than in the short-term.

Table 1.6 The effects of herbage allowance on herbage intake, milk yield and liveweight change of dairy cows. (Greenhalgh et al. 1967).

Herbage Allowance (kg DM $cow^{-1}day^{-1}$)	11.4	15.9	20.5	
Pasture Intake (kg DM $cow^{-1}day^{-1}$)	11.7	12.5	12.9	NS
Digestibility of OM %	74.9	74.8	75.3	NS
Milk Yield (kg $cow^{-1}day^{-1}$)	13.82	14.0	14.9	*
Liveweight Change (kg $cow^{-1}day^{-1}$)	+ 0.23	+ 0.5	+ 0.55	NS

Another important point to come out of these experiments is the height at which the herbage sample is taken. The inability of cutting machines to mimic the selectivity of grazing animals is probably related to the influence of sward structure on the selectivity of grazing by an animal. For this reason, Hodgson (1976) specifies the need to measure herbage allowance to ground level in his definition of herbage allowance.

In an extrapolation of his previous experiments, Greenhalgh (1970) extended the use of the three herbage allowances to produce three grazing intensities throughout a grazing season. Each area was rotationally grazed 6 times by groups of cows given herbage allowances of 11.4 (A), 15.9 (B) and 20.4 (C) kg DM $cow^{-1}day^{-1}$. These grazing intensities resulted in an average consumption of 92, 75 and 58% of the herbage available at any one grazing for treatments A, B and C respectively (5cm sampling height). In effect the group C cows removed mainly the new growth that had accumulated since the previous defoliation and left material that had previously been ungrazed.

Net herbage growth for each treatment was calculated as the mean yield before grazing, less the yield after grazing in the previous cycle. The results are summarised in Table 1.7.

Table 1.7 Some effects of herbage allowance applied over a grazing season on dairy cow performance (Greenhalgh, 1970).

Herbage Allowance ($kg\ DM\ cow^{-1}day^{-1}$)	11.4	15.9	20.4
Herbage Grown ($kg\ DM\ ha.^{-1}$)	11,350	11,110	10,680
Herbage Intake ($kg\ DM\ cow^{-1}day^{-1}$)	10.7	12.0	11.7
Herbage Consumed ($kg\ DM\ ha.^{-1}$)	11,000	10,550	9,600
Digestibility of herbage OM %	77.9	78.1	76.4
Milk Yield ($kg\ cow^{-1}day^{-1}$)	16.2	16.6	16.8
Liveweight Change ($kg\ cow^{-1}day^{-1}$)	- 0.07	- 0.04	+ 0.11
Production ($kg\ milk\ ha.^{-1}$)	16,250	14,950	13,260

Treatment A gave the highest production per ha. without significantly reducing production per animal. At the other extreme, treatment C allowed the greatest flexibility of management but caused some deterioration in the nutritive value of the herbage. The later point illustrates the longer term effects of different grazing intensities on the subsequent pasture growth, and the quality of DM that is available for consumption later. These must be considered when looking for any herbage allowance which seeks to maximise animal production in the short term.

Combellas and Hodgson (1975) examined the suggestion from the data of Greenhalgh et al. (1966) that the effects of herbage allowance on milk yield varied according to the level of production of the cows being used. Two groups of eighteen cows were placed on two levels of feeding from before calving (January 7th) until the start of the grazing season (April 22nd). At the start of the grazing season each group of eighteen cows was divided into three sets of six cows which grazed at daily herbage allowances of 25g, 50g or 75g herbage DM kg LW^{-1}. Measurement was to ground level. This was equivalent to 12.8, 25.6 and 38.4 kg DM offered $cow^{-1}day^{-1}$ for cows averaging 512 kg at the start of the experiment. Some results are presented in Table 1.8.

Table 1.8 The effects of three herbage allowances on herbage intake and milk production (Combellas and Hodgson, 1975).

Treatment	A	B	C	SE diff.
Herbage Allowance (g DM kg LW^{-1})	25	50	75	
Herbage Intake (kg DM $cow^{-1}day^{-1}$)	11.7	14.6	15.4	
Milk Yield (kg $cow^{-1}day^{-1}$)	14.0	17.1	17.7	$\pm$ 0.26***
Fat %	3.74	3.56	3.48	$\pm$ 0.07 *
Protein %	3.22	3.31	3.34	$\pm$ 0.02 **
Daily Fat Yield (kg cow^{-1})	0.52	0.61	0.62	
Daily Protein Yield (kg cow-1)	0.45	0.57	0.59	

Intake was depressed by only 4% as the allowance was reduced from 75g - 50g kg LW^{-1}, but there was a 17% depression in intake between 50g and 25g kg LW^{-1}. The authors concluded that whilst cows differing in milk yield and body condition respond in much the same way in terms of herbage intake to variations in herbage allowance, the milk yields of the cows used in this experiment were more sensitive to a given reduction in herbage intake than those used by Greenhalgh et al. (1966).

In an experiment designed primarily to examine the relationship between the intake of herbage by the dairy cow and pasture digestibility, Stehr and Kirchgnesser (1976) measured the daily herbage allowance and herbage intake of 60 lactating dairy cows. Intake was measured by difference between samples of the sward cut before and after grazing, (cutting height 2 cm above ground level).

The DM intake of herbage was significantly and positively correlated with both herbage supply and the digestibility of the organic matter. Daily herbage intake increased by 0.3 kg DM cow^{-1} for each additional kg DM offered. In this and previous studies by the authors a strict linear relationship was found between herbage supply and intake up to an allowance of 35 kg DM $cow^{-1}day^{-1}$. However in this experiment, different herbage allowances were not offered with herbage of the same maturity and length and the effect of the allowances could have been confounded with variations in sward quality

In the study by Stehr and Kirchgnesser (1976) multiple regression analysis determined that herbage allowance and organic matter digestibility accounted for 66% of the variation of the DM intake by the dairy cows over this particular range of allowances. The relative importance of the effect of these two variables upon pasture intake may well vary over a range of herbage allowances. Gordon (1973) suggests that at low grazing intensities (i.e. high herbage allowances) intake will be related more to the animal's physiological condition and the quality of herbage on offer than at high grazing intensities (low herbage allowances), where the amount of herbage available becomes the major factor limiting the intake of the individual animal.

Under New Zealand and Australian farming conditions, grazing systems are based on all year round pasture feeding. Grazing systems by necessity must endeavour to match the pasture supply to animal requirements throughout the year, despite the fluctuations in pasture growth rates and animal requirements. One of the most critical times in terms of matching feed supply to demand is the winter-early spring period, (i.e. calving). While the implications of the level of feeding of dairy cows before and after calving have been examined (see Chapter 1.1), quantitative information to enable objective planning of feed supply and feed demand at this time of the year is lacking. The limited number of herbage allowance experiments with the dairy cow under New Zealand and Australian conditions have been concerned with the winter-early spring period. The importance of studying the effects of herbage allowance during this period appears to have been for the following reasons:

1. Determining what grazing intensities are required in order to achieve the necessary changes in cow condition before calving.

2. Determining what grazing intensities are required following calving to meet the cow's requirements for milk production. Production in early lactation may have an effect on the production over the remainder of the lactation, although there is considerable doubt as to the extent or importance of this effect (see Chapter 1.1.3).

3. Estimating the feed requirements of the dairy cow and how the intake of the dairy cow responds to different pasture conditions.

Bryant and Cook (1977) compared the effects of four herbage allowances on the intake and milk production of dairy cows in early lactation. Thirty sets of identical twins that had calved on average 25 days prior to the start of the experiment were divided between the four herbage allowances. Pasture yields were measured to ground level before and after grazing and from these pasture measurements intakes were estimated. Results are summarised in Table 1.9.

Table 1.9 The effect of herbage allowance on cow performance and the severity of grazing (from Bryant and Cook, 1977).

Treatment	1	2	3	4
Herbage Allowance (kg DM $cow^{-1} day^{-1}$)	52	40	26	13
Area ($m^2 cow^{-1} day^{-1}$)	167	125	83	42
Grazing Intensity (cows $ha^{-1} day^{-1}$)	60	80	120	238
Milkfat (kg $cow^{-1} day^{-1}$)	0.81	0.76	0.69	0.64
Fat %	4.51	4.33	4.31	4.33
Protein %	3.43	3.41	3.31	3.20
Lactose %	5.03	5.05	4.99	4.98
Weight change (kg $cow^{-1} day^{-1}$)	+ 0.30	+ 0.70	+ 0.25	- 0.14
Pasture Intake (kg DM $cow^{-1} day^{-1}$)	12.3	11.8	9.3	8.9
Pasture Yield (kg DM ha^{-1})				
Before Grazing	3133	3194	3124	3057
After Grazing	2394	2252	2008	919
% Utilized	24	29	36	70

Points of particular interest from this experiment are listed below.

1. The severity of grazing increased as herbage allowance decreased but cows were not prepared to increase the severity of grazing sufficiently to maintain intake, fat yield and liveweight gains.
2. It is noticeable, that the relationship between herbage allowance and fat yield appears to be linear rather than curvilinear.

3. The twins in this experiment were of relatively low genetic merit.

4. It was considered that neither the amount of DM remaining after grazing nor the percentage utilization of the DM offered adequately reflected the intensity of grazing, and herbage allowance was the preferred term.

5. The effects of the treatments persisted after the experiment had ceased. After four weeks of common grazing, production was 0.73, 0.69, 0.65 and 0.63 kg fat cow^{-1}day^{-1} for cows previously grazed in groups 1-4 respectively.

Bryant (1977a) also examined the effects of herbage allowance on milkfat yield and liveweight change at two other stages during lactation. The same herbage allowances as reported by Bryant and Cook (1977) were used for four weeks in November - December and for three weeks in March. The results are shown in Table 1.10.

Table 1.10 Milkfat yield and liveweight change for herbage allowances offered at two stages of lactation (Bryant, 1977a).

	Herbage Allowance (kg DM cow^{-1}day^{-1})			
	53	40	26	13
Trial 1 (Nov-Dec)				
Milkfat Yield (kg cow^{-1}day^{-1})	0.68	0.66	0.59	0.49
Liveweight Change (kg cow^{-1}day^{-1})	0.35	0.35	0.09	- 0.15
Trial 2 (March)				
Milkfat Yield (kg cow^{-1}day^{-1})	0.46	0.44	0.41	0.30
Liveweight Change (kg cow^{-1}day^{-1})	0.67	0.90	0.63	- 0.12

The results in Table 1.10 show that smaller increases in milkfat yield are obtained from offering increased herbage allowances to cows at these later stages of lactation. The relationship between herbage allowance and milkfat yield in mid to late lactation appears to be more curvilinear than the relationship in early lactation.

In an experiment, more specifically designed to determine the effects of condition score at calving on milk production, the herbage allowances, herbage intakes and the residual herbage yields were measured by the Ellinbank rising plate grass meter for several groups of cows in early lactation (Grainger, Wilhelms and McGowan, 1978). Some data are shown in Table 1.11.

Table 1.11 Herbage offered, herbage intake and residual herbage yield for two levels of feeding in weeks 1-5 of lactation in two years (Grainger, Wilhelms and McGowan, 1978).

Herbage Offered (kg DM $cow^{-1} day^{-1}$) $\pm$ SD	Herbage Intake (kg DM $cow^{-1} day^{-1}$) $\pm$ SD	Residual Herbage kg DM ha^{-1} $\pm$ SD
33.0 $\pm$ 4.4	13.0 $\pm$ 1.9	1400 $\pm$ 158
45.3 $\pm$ 7.7	15.0 $\pm$ 2.2	1870 $\pm$ 145
8.6 $\pm$ 0.7	7.0 $\pm$ 0.4	500 $\pm$ 150
9.9 $\pm$ 0.8	8.5 $\pm$ 0.3	400 $\pm$ 149

Milk production figures are not given and in any case are confounded by different levels of cow condition at calving. The results are consistent with previous herbage allowance studies in that as pasture offered per cow increases, herbage intake increases, but there is also a higher residual herbage yield remaining after grazing.

Examination of the effects of herbage allowance on the liveweight and condition score changes in pregnant, non-lactating dairy cows has been carried out in two recent winters at Massey University (Nottingham 1978, Holmes 1980). The experimental technique of offering different herbage allowances by adjusting the areas of pasture offered has proved very useful in determining the pasture requirements of the dry dairy cow. For example the conclusions reached were that for cows to maintain their body condition at a constant level over a period of about 40 days they need to consume 7 - 8 kg pasture DM cow^{-1} day^{-1}. In order to consume this amount the cows needed to be offered an allowance of about 10 kg DM cow^{-1} daily. Herbage intake also increased with residual herbage yield so that intake could be predicted from observations of the intensity of grazing each day (see Figure 1.3). Nottingham (1978) suggested that the estimation of yield of pasture remaining after grazing could be a useful one-step method to give farmers a guide to expected liveweight and condition score change. In Figures 1.2 and 1.3 (from Holmes, 1980), the relationships between herbage allowance and herbage intake, and residual yield and herbage intake are shown. The pasture yields before grazing were 4020, 3320 and 2850 kg DM ha.$^{-1}$ for Group A 1978, Group B 1978 and 1979 respectively. All three groups of cows had very similar intakes at the same herbage allowances despite the different herbage masses before grazing, (Figure 1.2). In Figure 1.3 we can see that for a particular residual yield, herbage intake was highest for the 1979 experiment (lowest DM yield before grazing), and lowest for Group A, 1978, (the highest DM yield before grazing). It is apparent from these results that the yield of herbage offered before grazing will influence the yield of pasture remaining after grazing, with higher post-grazing residual yields required for a given intake when longer pastures are offered.

A recent comprehensive experiment investigating the effects of daily herbage allowance on the herbage intake and milk production of dairy cows was conducted by Combellas and Hodgson (1979) at the Grasslands Research Institute, England. Twenty-four British Friesian cows were allocated between six grazing treatments (two levels of herbage mass x three levels of daily herbage allowance) in a balanced change-over design with four periods of 12 days each at monthly intervals. Herbage organic matter mass ranged from 3790 to 5770 kg ha.$^{-1}$ measured to ground level, and daily herbage DM allowances were 30, 60 and 90g kg^{-1} animal liveweight. Estimates of herbage intake were made by measuring faecal output using Cr_2O_3 as a marker, and measuring the '_in vitro_' digestibility of extrusa samples from six cows fistulated at the oesaphagus. The cows were

Fig. 1.2 The relation between pasture allowance and the intake of pasture by dry cows (From Holmes, 1980)

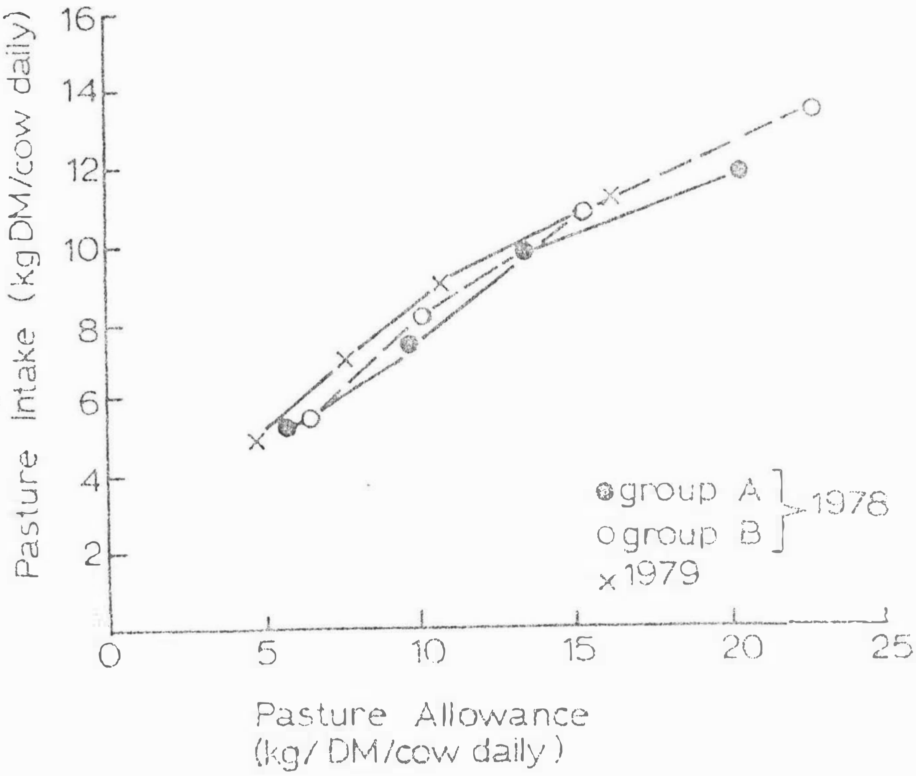
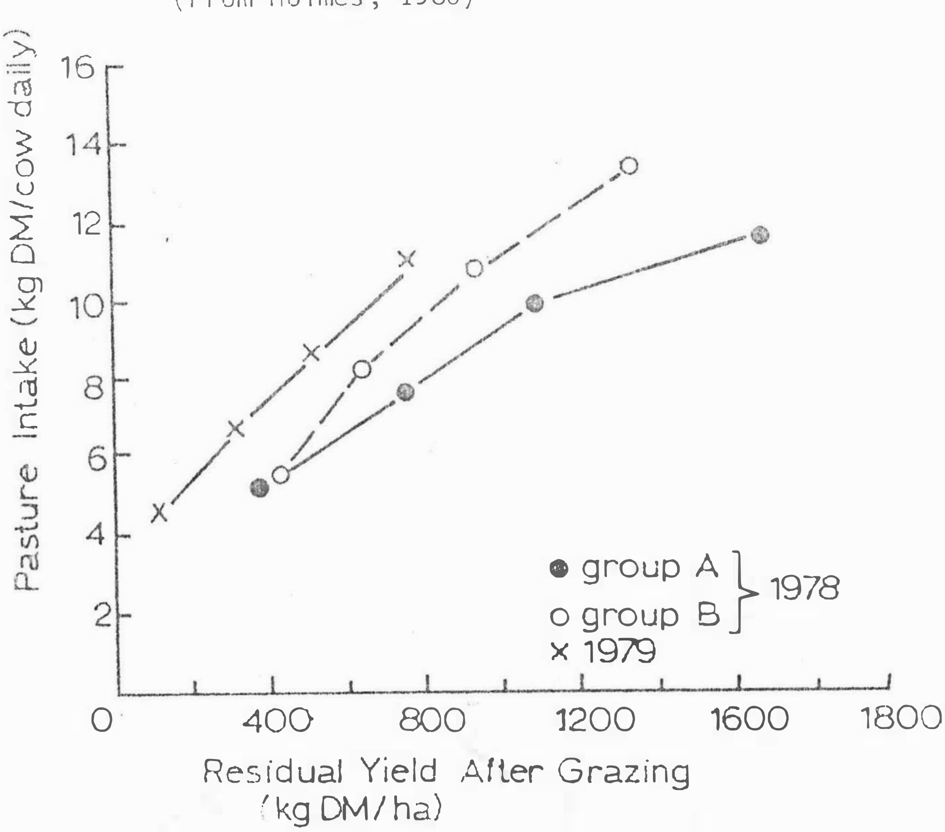


Fig. 1.3 The relation between post-grazing residual yield of pasture and the intake of pasture by dry cows (From Holmes, 1980)



in mid lactation and grazed perennial ryegrass pastures. Some data from this experiment are presented in Table 1.12.

Table 1.12 The effects of three herbage allowances on the herbage intake, milk production and digestibility of the diet selected by grazing dairy cows (Combellas and Hodgson, 1979).

	Herbage Mass	Daily Herbage Allowance (kg DM 100kg LW^{-1}) 3	6	9	SE mean
OM Intake (kg $cow^{-1} day^{-1}$)	L	11.4	13.5	12.8	0.23*
	H	10.6	12.2	12.9	
	Mean	11.0	12.8	12.8	0.29***
Milk Yield (kg $cow^{-1} day^{-1}$)	Mean	15.5	17.0	17.1	0.29***
Fat %	Mean	3.49	3.34	3.43	0.062 NS
Protein %	Mean	3.70	3.65	3.70	0.052 NS
Digestibility of Diet Selected	Mean	0.792	0.802	0.803	0.0028**

Herbage organic matter intake was higher on the lighter than on the heavier herbage mass, although the digestibility of the diet selected was not affected by herbage mass. Milk yield was not affected by herbage mass but was depressed at the low herbage allowance. The efficiency of grazing, defined as herbage intake expressed as a proportion of the herbage allowance, was 0.85, 0.49 and 0.33 for allowances of 3, 6 and 9 kg DM 100 kg LW^{-1} respectively. Because differences in intake at the same allowance occurred when allowances were offered on different herbage masses, the efficiencies were approximately 5% lower on treatment H than on treatment L. Thus herbage intake was near maximal when grazing efficiency was about 0.50, i.e. when the allowance was equivalent to twice intake.

1.3.4 The Nature of the Relationship between Herbage Allowance, Herbage Intake and Animal Performance. A Summary.

In this section an attempt will be made to review some of the major points to emerge from the experiments described in the previous section. The following points will be discussed;

1. The asymptotic nature of the relationship between herbage allowance and herbage intake.
2. The influence of sward characteristics on the relationship.
3. The influence of herbage allowance on selective grazing.
4. The influence of herbage allowance on milk production.

Greenhalgh et al. (1966, 1967) demonstrated that the relationship between herbage allowance and herbage intake for grazing dairy cows was asymptotic, intake declining at a progressively faster rate as herbage allowances decreased. However herbage sampling was not made to ground level in these experiments and it was apparent that cows were able to graze herbage from below this height of sampling. More recently Gibb and Treacher (1976) demonstrated an asymptotic relationship between herbage allowance and herbage intake for lambs and they re-defined herbage allowance in terms of weight of herbage per unit of animal liveweight with herbage measurements being made to ground level. Herbage intake and lamb growth declined quickly once the daily herbage allowance fell below 60g DM kg LW^{-1}. Because of the confusion over the height of sampling of herbage it was unclear as to whether a similar asymptotic relationship existed for lactating dairy cows. Stehr and Kirchgessner (1976) found that intake increased progressively up to daily herbage DM allowances of 35 kg cow^{-1} (approximately 50g kg LW^{-1}), but again they sampled herbage above ground level.

The two experiments by Combellas and Hodgson (1975, 1979), have established an asymptotic relationship between herbage allowance and herbage intake with a herbage sampling height to ground level. The results are similar to those of Gibb and Treacher (1976) in that once the daily DM allowance fell below 60g DM kg LW^{-1}, a decline in herbage intake at an ever increasing rate occurred. Greenhalgh et al. (1966) suggest an asymptotic relationship between herbage allowance and herbage intake implies that there will be an optimum minimal allowance which allows near maximal herbage intake. Above this so called optimum allowance there is considerable flexibility in the amount of feed that can be offered without seriously reducing intake per cow. Because animal intake and performance respond to sward variables other than the weight of herbage offered alone, it is probably unwise to try and define an 'optimum herbage allowance' without recognising the influence of the other sward variables on herbage intake.

The relationship between herbage allowance and herbage intake is a function of the rate at which animals graze down to some limiting weight or height below which the prehension of herbage becomes progressively more difficult. This is due to the weight of herbage harvested per bite falling as animals graze down through a sward (Jamieson, cited by Hodgson, 1976). As has already been discussed, the sward canopy structure will influence the weight or height of herbage below which bite size falls. Therefore variations in the botanical composition, length, density and herbage yields between pastures might be expected to alter the relationship between herbage allowance and herbage intake.

In the experiment of Greenhalgh et al. (1966), two extremes of pasture conditions under which herbage allowances were offered did not appear to influence herbage intake. However when similar herbage allowances were offered on pastures of two different herbage yields by Combellas and Hodgson (1979) there were significant reductions in herbage intake caused by offering an allowance at a higher herbage yield before grazing. Holmes (1980) was unable to show an effect of differences in herbage yield before grazing on the relationship between herbage allowance and herbage intake with dry cows. Where experiments have been designed to look at the effects of different pasture conditions on herbage intake, the range of pasture conditions has not been as large as intended, (Combellas and Hodgson, 1979; Holmes, 1980).

The relationship between herbage allowance and herbage intake (and animal performance) is also a function of the quality of the diet selected. As herbage allowance increases the animal is confronted with greater opportunity to select preferred herbage and therefore consumes herbage of a higher digestibility (Greenhalgh et al. 1966; Combellas and Hodgson, 1979). Stobbs (1977) found that as herbage allowance increased on a tropical pasture sward, lactating dairy cows selected a higher % of leaf in preference to stem, and consequently herbage with a significantly higher organic matter digestibility, nitrogen and calcium content. Cows that grazed the lowest allowance were forced to eat more stem than leaf in their diets, and had to graze leaves from lower in the sward than the cows offered the highest allowance. Consequently the quality of the herbage eaten declined as well as the quantity.

The relationship between herbage allowance and the yield of milk and its constituents appears to have a similar asymptotic nature as the relationship with herbage intake, (Greenhalgh et al. 1966; Combellas and Hodgson, 1979; Stobbs, 1977). However, the experiments of Bryant (1977a) suggest that the nature of the response of the dairy cow to herbage allowance will be altered by the cow's stage of lactation. Cows in early lactation appear to respond in larger increments of milkfat yield to extra herbage allowance than do cows in mid and late lactation. The milk yield response of the dairy cow to extra herbage offered will be affected by the partition of dietary energy between body tissue gain and milk production. Therefore liveweight change as well as milk production will be a reflection of any response to extra herbage offered. Greenhalgh et al. (1966) noted that the milk production differences between cows offered different herbage allowances were small, and not consistent with intake differences. However when liveweight data was added there was a more consistent response of animal production to differences in herbage allowance and intake.

There is some evidence to suggest that the effects of herbage allowance on milk yield would vary according to the general level of production of the cows (Greenhalgh et al., 1966; Combellas and

Hodgson, 1975). Cows of higher milk yield may be more sensitive to restrictions in herbage allowance than lower yielding cows (Combellas and Hodgson, 1975). Evidence of the effects of herbage allowance on cows of different potential for milk production is limited.

The effects of herbage allowance on milk composition are generally consistent with the previously reviewed effects of level of nutrition on milk composition (see Chapter 1.1.4), although the trends are not quite so marked as they were in some of the experiments more specifically designed to study milk composition. Fat percentages decreased as herbage allowance increased in the experiments of Greenhalgh et al. (1966), and Combellas and Hodgson (1975). In the experiments by Bryant and Cook (1977) and Combellas and Hodgson (1979) the effects of increasing herbage allowance on milkfat percentage were not consistent. The highest allowance offered in Bryant and Cook's experiment resulted in the highest milkfat percentage and this was also the case in the experiment by Stobbs (1977).

Milk protein percentages increased as herbage allowance increased in the experiments of Greenhalgh et al. (1966), Combellas and Hodgson (1975), Bryant and Cook (1977) and Stobbs (1977), but there was no consistent effect of herbage allowance on milk protein percentage in the experiment by Combellas and Hodgson (1979).

Total solids-not-fat content increases with increasing herbage allowance. Lactose percentages were increased by increased feed offered in the experiments of Greenhalgh et al. (1966), Bryant and Cook (1977) and Combellas and Hodgson (1979).

Stobbs (1977) found that the molar percentages of the short chain fatty acids of milkfat (C_6, C_8, C_{10}, $C_{10:1}$, C_{12} and C_{14}) increased ($P < 0.001$) as cows were offered more herbage. Conversely the oleic acid ($C_{18:1}$) content of milkfat decreased ($P < 0.001$) with increased herbage allowance. The relative contributions therefore of nutrients derived from feed and metabolism of body reserves could therefore be assessed. The fatty acid analysis suggests that animals offered low herbage allowances were drawing upon body reserves to a greater extent than cows offered high herbage allowances. This technique proved useful in assessing changes in a cow's body reserves as liveweight measurements of cows were insensitive due to varying amounts of gut fill. While several researchers have measured higher liveweight gains or lower liveweight losses as herbage allowance increases, (Greenhalgh et al. 1966, 1967; Bryant and Cook, 1977; Bryant, 1977a; Holmes, 1980), the extent to which increases in herbage intake and therefore gut fill have contributed to this trend is unclear. Methods such as milkfat fatty acid analysis used by Stobbs (1977), and observing condition score changes (Nottingham, 1978; Holmes, 1980) have overcome this problem to some extent.

1.3.5 Conclusions

Herbage allowance has become a preferred term for use by dairy cow nutritionists in expressing the unit of herbage offered per cow in a grazing system, and in determining the likely intake and production responses to that particular unit of herbage. The relationship between herbage allowance and herbage intake is asymptotic in nature, and this suggests considerable flexibility in the grazing management practices that may be used in order to supply sufficient quantities of herbage to grazing dairy cows.

Because of the considerable number of sward variables to which the grazing animal has been shown to respond, it has become clear that the relationship between herbage allowance and herbage intake needs to be defined specifically for particular pasture types, and different pasture characteristics within that type.

There seems to be little quantitative information as to the specific pasture requirements of the dairy cow in relation to milk production in early lactation. A definition of herbage allowance requirements for a dairy cow in early lactation, under specific pasture conditions, would enable seasonal dairy farmers to plan herd and pasture management in the winter and spring period on a more objective basis. No herbage allowance studies with lactating dairy cows had previously been attempted on predominantly ryegrass-white clover pastures typical of the Manawatu and many other New Zealand dairying districts. The only previous New Zealand study of herbage allowances with dairy cows had been at Ruakura by Bryant and Cook (1977) on pastures that have a different botanical composition.

In several earlier experiments concerned with the level of feeding of the grazing dairy cow, quantitative information on the levels of feeding was not available (e.g. Flux and Patchell, 1954). Therefore an objective of this experiment was to obtain estimates of herbage intake as well as herbage allowance measurements. The experiment also provided an opportunity to examine some of the longer term responses of dairy cows to early lactation level of feeding under conditions where the levels of feeding had been quantified.

In earlier herbage allowance experiments the mean effects of herbage allowance offered, on a group of cows had been reported. Greenhalgh et al. (1966) had noted a possible variation in the response of cows at different levels of production to herbage allowance. Combellas and Hodgson (1975) investigated this point further and suggested that higher yielding cows may be more sensitive to changes in herbage intake brought about by changes in herbage allowance, than lower yielding cows. A long term objective of the Dairy Husbandry Department is the investigation of differences between cows of high and low genetic merit, particularly with respect to the interaction of differences in grazing pressure and genetic merit. Interest in this facet of dairy production meant that the opportunity was taken to investigate differences between high and low producing cows within the limits of the small number of animals available for selection in the Massey University herds.

CHAPTER TWO

EXPERIMENTAL METHODS

2.1 Experimental Design

The Experiment consisted of three periods;

Period I A covariance period (22/8/78 - 11/9/78).

Measurements of milk yield and composition were made for three days per week for three weeks, and the mean daily yields for each cow were used as covariates in the analysis of the effects of herbage allowance on milk production. During this period the experimental cows were managed as part of the main No.3 herd.

Period II An experimental period (five weeks from 12/9/78 - 13/10/78).

Three groups of six cows (low, moderate and high treatments) were each offered a new area of pasture daily which was intended to provide a daily herbage allowance of 15, 35 and 55 kg DM cow^{-1} day^{-1} for each group respectively. Measurements of herbage intake, milk yield, milkfat and milk protein yields were made during this period as were liveweight and condition score changes (see Table 2.1). Weekly treatment means for daily milk, milkfat and milk protein yields were adjusted by covariance analysis using the mean daily yields for each cow measured during period I as covariates.

The experimental design also allowed for the factorial analysis of the effects of the three herbage allowances on the milk production and liveweight change of cows of two phenotypes, (high and low milkfat production).

Period III The post-experimental period (13/10/78 - 1/5/79).

At the end of period II all experimental cows were grazed with the No.3 dairy herd and were not required for any further experiments during the dairy season. All animals received similar grazing and milking management during this period.

Table 2.1 The Experimental Design and Procedure

Period I	Period II	Period III
Preliminary Period 22/8/78 - 11/9/78	Treatment Period 12/9/78 - 12/10/78	Post-Treatment Period 13/10/78 - 1/5/79
<u>Objective</u>: To measure between-cow variation in milk production under common management	<u>Objective</u>: To examine the effects of three herbage allowances on the pasture intake, milk production and liveweight changes of dairy cows	<u>Objective</u>: To examine the 'carry-over' effects of three levels of feeding in early lactation on subsequent milkfat production
<u>Management</u>: Experimental cows managed as part of the No.3 dairy herd	<u>Management</u>: Herbage allowances of 15, 35 and 55 kg DM $cow^{-1}day^{-1}$ offered daily	<u>Management</u>: Experimental cows managed as part of the No.3 dairy herd
<u>Measurements</u>: <u>For Each Cow</u> Milk Yield, Milkfat Yield, Milk Protein Yield } measured on three consecutive days per week Cell Counts - one per week Initial Liveweight Initial Condition Score	<u>Measurements</u>: <u>For Each Herbage Allowance</u> Pasture Offered, Pasture Remaining, Apparent Pasture Intake } Daily Quality of Pasture DM selected 1. Protein % 2. ADF % 3. DM digestibility % <u>For Each Cow</u> Milk Yield, Milkfat Yield, Milk Protein Yield } measured on four consecutive days per week Cell Counts, Liveweight, Condition Score } Weekly	<u>Measurements</u>: <u>For Each Cow</u> Milk Yield, Milkfat Yield: Weekly until 21/12/78; Fortnightly from 21/12/78 to 1/5/79

Milk and milkfat yields were recorded weekly until 21/12/78, and then fortnightly until 28/4/79. The herd was dried off on the 1st of May 1979. The total milkfat production (kg cow^{-1}) for each cow from the end of period II until drying off was adjusted by the use of the total fat yields obtained for each cow in period I as covariates.

2.2 The Experimental Area

The experiment was carried out during the 1978-1979 dairy season at the No.3 Dairy Research and Development Unit, Massey University. The farm area is 45 ha. and approximately 100 cows are milked plus their replacements. The majority of stock carried are monozygotic twins used for experimental purposes.

The soil type is Tokomaru silt loam, a soil which consists of a 15-30 cm layer of heavy silt above a mottled clay loam. This soil type requires drainage during the winter and the farm is tile and mole drained.

The unit was developed for dairying by Massey University approximately twenty years ago. Because much of the experimental work involves the evaluation of new pasture species, pastures are resown fequently. Pastures are topdressed with 375 kg $ha.^{-1}$ of 15% potassic superphosphate annually.

2.3 The Experimental Pastures

The pastures at No.3 Research and Development Unit are made up principally of a mixture of ryegrass varieties (*Lolium spp.*) and white clover, (*Trifolium repens*). The ryegrasses found include Manawa, Ariki and Ruanui, while small proportions of cocksfoot (*Dactylis glomerata*) and prairie grass (*Bromus uniloides*) are also found in the pastures.

The pastures used in the experiment were selected so that;

(1) pasture composition was representative of the above description, and (2) pastures were in their second or subsequent year after resowing. There was also some selection because of the shape of paddocks, a rectangular paddock being easier to subdivide into the areas required for offering daily herbage allowances.

Selected paddocks were progressively removed from the grazing rotation of the main herd from mid-July onward so that the pastures grazed in the first three weeks of the experiment, (paddocks 27, 18, 19, 11) had not been grazed for 9-12 weeks since a previous grazing with dry cows. The pastures used in the final two weeks of the treatment period had not been grazed for 3-5 weeks and had previously been grazed by lactating cows as part of the normal grazing rotation. Details of the experimental pastures are given in Table 2.2. The mean DM yield before grazing of 2610 kg DM ha^{-1} in fact differs from the mean DM yield of the herbage offered to the cows because of the variation in the number of days in which cows grazed each paddock.

Table 2.2 The experimental pastures

Paddock No.	Date Grazed	kg DM ha^{-1} before grazing
27	12/9 - 15/9	2727
19	16/9 - 18/9	2968
18	19/9 - 22/9	3018
11	23/9 - 27/9	3413
41	28/9 - 30/9	2242
40	1/10 - 3/10	2475
1	4/10 - 5/10	2707
8	6/10 - 7/10	2043
5	8/10	2283
17	9/10 - 12/10	2225
		Mean DMY 2610 kg DM ha^{-1}

2.4 The Experimental Animals

Eighteen cows, of mixed breed were used in the experiment. These cows consisted of nine 'high' and nine 'low' milkfat producers which had been selected in order to examine the responses of cows of different phenotypic merit, to the three herbage allowances offered. The criteria used for selection of 'high' and 'low' producers was based on the Lifetime Production Index (Livestock Improvement Association, Herd Test Data). All cows were in their third or subsequent lactation.

At the end of the preliminary period, (Period I), the cows were placed in groups of three, the three cows having similar characteristics according to

1. their current milkfat production measured in period I.
2. lifetime production index
3. breed
4. age.

The three cows in each group were then allocated randomly to the three herbage allowances. This resulted in three groups of six cows. Each group consisted of three 'high' and three 'low' producing cows. Details of the experimental cows and their treatment groups are shown in Table 2.3.

All cows calved within a period of 26 days (21/7 - 16/8) with the mean calving date 29th July. This meant that the cows had calved on average 46 days prior to the commencement of the experimental period (Period II).

2.5 Pasture Measurements

Measurements of the required pasture parameters were made during period II of the experiment, when the cows were offered different herbage allowances.

The measurements were:

(1) the DM yield of the pasture on offer (kg DM $ha.^{-1}$)

(2) the DM yield of the pasture remaining after grazing (kg DM $ha.^{-1}$)

(3) the areas of pasture grazed each day.

Samples of herbage offered and herbage remaining after grazing were collected for chemical analysis.

2.5.1 The Daily Herbage Allowance Offered

The three herbage allowances offered were to be approximately 55, 35 and 15 kg DM $cow^{-1}day^{-1}$, and designated the high, moderate and low treatments. At the commencement of grazing for each new paddock, the pasture DM yield was estimated by the use of an Ellinbank rising plate grass meter (Earle and McGowan, 1979) calibrated with previous cutting measurements from No.3 dairy (I.M. Brookes, unpublished data). The length, width and area of the paddock were measured by tape measure and the paddock divided longitudinally into three areas by electric fences. Each paddock was divided longitudinally in the ratio of 0.54; 0.32; 0.14 of the total width. A transverse electric fence across the width of the paddock completed the area for the daily herbage allowance. The herbage allowances were therefore offered on adjacent areas in the same paddock. The initial estimate of DM yield was used to calculate the areas to be grazed on the first day in each paddock. The transverse fence was moved daily after the morning milking and a back fence was used to prevent further grazing of the previous days allowance. An example of the subdivision of a paddock and the calculation of the estimated herbage allowances is shown in Appendix I.

Table 2.3 The experimental cows and their treatment groups

Pasture Allowance	Milkfat Production	Cow No.	Breed	Age	Calving Date	LPI	Fat Yield 1977/1978 Kg cow^{-1}	Average Daily Fat Yield 22/8/78 - 12/9/78 Kg $cow^{-1} day^{-1}$
High	High Producers	23	F	4	7/8	107	128	0.71
		42	J	6	22/7	111	169	0.83
		157	FJ	5	22/7	135	147	0.67
	Low Producers	38	JA	4	27/7	91	125	0.59
		53	JF	4	27/7	93	93	0.66
		118	JF	8	29/7	99	140	0.60
Mean				5	27/7	106	134	0.68
Moderate	High Producers	51	J	7	22/7	121	149	0.82
		138	FJ	5	24/7	128	169	0.72
		144	F	5	16/8	144	177	1.06
	Low Producers	56	FX	6	29/7	110	139	0.54
		114*	JF	9	30/7	112	130	0.57
		127	J	5	27/7	77	104	0.54
Mean				6	30/7	115	145	0.71
Low	High Producers	141	J	5	3/8	127	139	0.77
		199	F	4	21/7	136	149	0.82
		216	F	7	3/8	129	244	0.76
	Low Producers	57	J	5	4/8	91	132	0.45
		113*	JF	9	28/7	101	153	0.56
		153	FJ	5	30/7	109	123	0.55
Mean				6	30/7	117	156	0.65

J = Jersey F = Friesian A = Ayrshire X = Crossbred

* Identical twin sisters.

2.5.2 Measurement of Dry Matter Yield (DMY) of the Herbage on Offer and the Herbage Remaining After Grazing

Once the pasture had been subdivided into areas for each herbage allowance, daily measurements of yield of DM before and after grazing for each herbage allowance area were made.

This was done using two methods:

1. The Ellinbank rising plate grass meter (Earle and McGowan, 1979).
2. Cutting random quadrats to ground level with a portable shearing hand piece, washing the herbage and measuring the weight of material after oven drying at 85°C for 36 hours.

For each day in period II, a minimum of twenty readings with the rising plate grass meter, were made for each allowance, both before and after grazing. A mean reading for each allowance area was found. For three days per week (Tuesday, Wednesday, Thursday), a pre-determined number of 30cm x 60cm quadrats were cut on each allowance area (both before and after grazing). Material from quadrats cut on a particular area was bulked, washed to remove soil contamination and oven dried. Regression equations were calculated using the DM yield estimates made from cutting herbage, against the meter readings made on the same areas on the same day. The calibration of the meter to the measurements of DM yield made by cutting enabled estimates of DMY both before and after grazing to be made for each day of the experiment.

The number of quadrats cut for each allowance area varied according to the size of that area, and the uniformity of grazing height achieved. The number of 0.18 m^2 quadrats cut per allowance are shown in Table 2.4.

Table 2.4 The number of quadrats (0.18 m^2 each) cut per treatment to measure pasture DM yield

Herbage Allowance	High	Moderate	Low
Before grazing	10	10	8
After grazing	10	10	6

On two occasions during the treatment period (Period II), the variation between individual quadrats in estimated DM yield was examined. Twenty quadrats per allowance area were cut, washed and oven dried individually and the dry weight of herbage per quadrat obtained. These data enabled a coefficient of variation and a standard error for the estimate of DM yield to be calculated. The number of quadrats to be cut for each allowance area was determined after the first of these repeatibility studies. The number of quadrats chosen to estimate the DM yield of an area was limited by the time available to cut these quadrats.

2.5.3 Estimation of the Herbage Dry Matter Intake

Pasture intake was estimated as the difference between the herbage offered per cow (measured to ground level), and the herbage remaining per cow (also measured to ground level). It was assumed that the pasture DM which disappeared during grazing had been consumed by the cows. No correction was made for growth of pasture during the grazing period (one day), or for material that may have disappeared through other means such as by trampling or decomposition.

This method of estimating intake has been described by Van der Kley (1956) and evaluated by Walters and Evans (1979). The method was such that a group mean intake only could be measured.

2.5.4 Estimation of the Quality of Herbage Consumed

To examine the effects of herbage allowance on the quality of the diet selected by the cows, the cut, oven dried herbage was sub-sampled, ground to pass through a 1 mm sieve and analysed for:

1. Acid Detergent Fibre (van Soest, 1963)
2. *In vitro* organic matter digestibility (Tilley and Terry,1963)
3. Nitrogen content (Kjeldahl Method).

This enabled a comparison to be made of the quality of the herbage offered with the quality of the herbage remaining after the three grazing intensities had been applied. An equation which enabled estimates to be made of the quality of herbage selected was developed by Van der Kley (1956). The equation is as follows:

$$\left.\begin{array}{l}\text{ADF\%}\\ \text{Crude Protein \%}\end{array}\right\}\text{ in the dry matter consumed} = \frac{\text{An.Cn} - \text{An + 1.Cn + 1}}{\text{An} - \text{An + 1}}$$

When Cn = % crude protein (% ADF) of the DM before grazing
Cn + 1 = % crude protein (% ADF) of the DM after grazing
An = quantity of DM before grazing (per cow)
An + 1 = quantity of DM after grazing (per cow).

Estimates of the N content and ADF content of the herbage consumed were obtained for each day that cows were grazing in pastures from which herbage was sampled. Differences in the quality of the diet between treatments were tested by analysis of variance (n = 15).

2.6 Measurement of the Responses of Cows to Daily Herbage Allowance Offered

2.6.1 Milk Production

Milk yield was measured by the use of milk sampling meters (Tru-test Distributors Ltd.), which sampled a proportion of the milk flow of each cow. Daily milk yield was recorded as the yield of milk at the evening milking plus the yield at the next morning's milking. The milk samples from the two milkings were combined and tested for fat concentration, using a Milko-tester, Mark III F 3140 (A/s N Foss Electric, Denmark), and protein concentration, using a Pro-milk tester, Mark II 12500 (A/s N Foss Electric, Denmark). Milkfat and milk protein yields were then calculated for each cow. A weekly mean figure for daily milk, milkfat and milk protein yield was obtained during periods I and II. During period III only milk and milkfat yields were obtained. The recording of milk yield and composition was carried out at the following frequencies:

Period I	Three consecutive days per week (Monday evening to Thursday morning)
Period II	Four consecutive days per week (Monday evening to Friday morning)
Period III	Weekly until 21/12/78 Fortnightly from 21/12/78 to 1/5/79.

A 10 ml sample of milk was taken weekly from each cow, treated with 0.1 ml of formalin and left overnight at room temperature. Somatic cell counts were made the following day with this milk, using a Coulter somatic cell counter, (Coulter Electronics Inc., Florida).

2.6.2 Liveweight Change

All cows were weighed unfasted each Friday between 0800 - 0900 hours. Weighing commenced on 7/9/78 (the end of Period I) and ceased on 13/10/78 (end of Period II). Two fasted liveweights for each cow were taken, before (8/9/78) and after (16/10/78) period II. Cows were fasted overnight without food or water for 17 hours and were weighed the following morning. The fasted weights (16/10/78) were obtained after the cows had been removed from their respective herbage allowances for three days and had been returned to graze with the main herd. This was done so that the three groups of cows were given time to equalize their gut contents before fasting and weighing.

Two methods of estimating liveweight change over period II were available. Unfasted liveweights were plotted against time for each cow using all recorded weights between 7/9/78 and 13/9/78. The slope of the regression line through these points was taken as the rate of liveweight change per day for each cow. The difference between the two fasted liveweights, divided by the number of days between fasts was the second method of estimating liveweight change.

2.6.3 Cow Body Condition

Condition scores were awarded to each cow fortnightly by three independent scorers. Each person scored the cows and recorded their scores separately. The condition score for that cow on a particular day was taken as the average of the three scores.

Condition scores were awarded on a scale of one (thinnest) to ten (fattest) based on a subjective assessment of the level of subcutaneous fat cover over five areas of the cow's body.

1. The spinous processes of the lumbar vertebrae
2. Over the lower rib cage
3. Over the hip bones
4. Around the tail head
5. At the thighs.

The scale allowed provision for half-scores to be awarded. The methods used to condition score cows and photographs of cows at different condition scores have been published by Earle (1976).

The change in condition score over period II was taken as the difference between the scores estimated on 7/9/78 and 13/10/78 (i.e. the beginning and the end of period II).

The average condition score of the experimental cows at the start of the experiment was 3.9.

2.7 Experimental Management

2.7.1 Milking Management

The cows were milked each day at 0530 hrs and 1530 hrs throughout the lactation. While the cows were being offered their different herbage allowances, they were milked in their groups before the main No.3 herd was milked. The cows were then returned to their herbage allowance areas in their treatment groups.

The milking routine consisted of:

1. a short 10-20 second wash with warm water
2. cups on
3. cups off (automatic cup removers)
4. teat spraying with Hibitane (a glycerine based spray)
5. drenching as a protection against bloat.

2.7.2 Water Supply

All cows were given access to water at each milking since water was not supplied to cows on the areas allocated to them. Care was taken to ensure that cows had sufficient time to drink at troughs as they went to and from milking. On some occasions free access to a water trough coincided with a particular herbage allowance area. The allocation of herbage allowance areas in each paddock was designed so that no particular group of cows was favoured by having access to water on more occasions than any other group.

2.7.3 Grazing Management (Pre and Post-Experimental)

The quantities of herbage offered during the treatment period, (Period II), have already been described. During periods I and III cows were managed as part of the No.3 dairy herd. The management of this herd during these periods is described below.

From calving until the time that cows were allocated to their treatments the herd spent 24 hours in each paddock, the rotation length being 21 days. Hay was fed at one bale per 10 cows during this period as the pasture available was inadequate for the herd. From the end of period II (mid-October), to the end of January the herd received an all pasture diet, being offered a new paddock every 12 hours. During February a crop of choumoellier was grazed by the herd for 12 hours daily, with the remaining 12 hours spent on pasture. Good pasture growth in March and April ensured an adequate supply of pasture from February until May. Fresh pasture was offered every 12 hours during this period.

No objective measurements of herbage availability and herbage consumption were made outside the treatment period (Period II).

2.7.4 Animal Health

During the first week of period II, a case of grass staggers was diagnosed in one cow. As a result all cows were blood sampled and tested for blood magnesium levels on 21/9/78. Because blood magnesium levels were found to be low amongst the experimental cows, all cows were drenched with Magnesite powder (MgO) suspended in water at the rate of 56g MgO $cow^{-1} day^{-1}$ for a two week period. The blood Mg status of the experimental cows on 21/9/78 is shown in Appendix II.

2.8 Statistical Analysis

2.8.1 Milk Yield, Milk Composition, Liveweight Change, Dry Matter Intake

Data for milk production (i.e. milk yield, FCM yield, Milkfat and milk protein yields) in periods II and III, were subjected to analyses of covariance using the means obtained for each cow during the preliminary period as covariates. This method of analysis meant that between cow variation in milk production during the treatment period, that was asssociated with between cow variation existing before the treatments were applied, was removed. A similar design was used by Greenhalgh et al. (1966). Differences between the treatment groups were tested by least significant difference (LSD).

The data for pasture dry matter intake, liveweight change and cow condition change were subjected to analysis of variance. Differences between treatment means were tested by LSD.

2.8.2 Evaluation of the Responses of Cows of Two Phenotypes to Herbage Allowance

To evaluate the response of cows of differing phenotypes to herbage allowance, two means of analysis were available. The first was a multiple regression analysis (Snedecor and Cochran, 1967) in which lifetime production index and herbage allowance were used as independent variables and related to measurements of FCM yield, liveweight change and condition score (dependent variables).

The following equation was used:

$$y = a + b_1x_1 + b_2x_2$$

Where y = FCM yield, liveweight change, condition score change

x_1 = Lifetime production index

x_2 = feed offered (kg DM $cow^{-1} day^{-1}$)

b_1, b_2 = regression coefficients for x_1 and x_2 respectively.

The second means was a 3 x 2 factorial analysis evaluating the effects of the three levels of feed offered and the two levels of cow 'phenotypic merit' on the mean FCM yields, liveweight change and cow condition changes.

2.8.3 Calculation of the Standard Error of Estimates of Dry Matter Intake

On two occasions where the variation amongst quadrat samples was measured, the standard errors of the estimates of DM intake were calculated. This was done by calculating the standard error of the difference between the mean estimate of DM yield before grazing and the mean estimate of the DM yield after grazing.

The following equation was used (Cox et al., 1956):

$$\text{Standard Error of DM intake per cow} = \frac{\text{Area Grazed}}{\text{No. of cows}} \times \sqrt{\frac{Sp^2}{Np} + \frac{Sr^2}{Nr}}$$

Where Sp and Sr = The standard deviations of the estimates of DMY for the pre-grazing and post-grazing (residual) samples respectively (kg DM ha^{-1}).

Np and Nr = The number of sample quadrats taken on each occasion.

Sp^2 and Sr^2 are in fact the variances of the estimates of DM yield pre-grazing and post-grazing.

CHAPTER THREE

RESULTS

3.1 Pasture Measurements

3.1.1 Daily Herbage Allowance

The average daily herbage allowances offered to each group of cows over the 32 day treatment period are shown in Table 3.1. The average weight of herbage DM on the areas on which the allowances were offered, and the stocking intensities at each herbage allowance are also shown. Measurements of pasture DM yield made by both cutting herbage samples and by using the Ellinbank pasture meter are included. Details of the calibration of the pasture meter to the cutting measurements are given in Appendix III.

Measurements of the herbage allowances offered daily were made by cutting herbage on 15 of the 32 days, and by pasture meter readings on 27 of the 32 days. From Table 3.1 it can be seen that the intended daily herbage allowances of 55, 35 and 15 kg DM cow^{-1} were achieved approximately. Both methods used for estimation of herbage yields before grazing were in reasonable agreement with each other ($r = 0.82$, $P < 0.01$).

3.1.2 Herbage Dry Matter Remaining After Grazing (Residual Herbage Yield)

The yields of pasture DM remaining after grazing, (residual herbage yields), were expressed as kg DM remaining per ha. and kg DM remaining per cow. Mean residual herbage yields for each herbage allowance, measured by both methods of DM yield determination are shown in Table 3.2.

As the amount of pasture offered per cow increased so did the amount of pasture remaining after grazing increase. This is illustrated by the photographs in Chapter 4.1.4.

Table 3.1 Herbage allowances (kg DM $cow^{-1} day^{-1}$ ± SD) for the 32 day period for each group of cows

	Treatment					
	High		Moderate		Low	
Method	cutting	meter	cutting	meter	cutting	meter
Herbage Allowance (kg DM $cow^{-1} day^{-1}$)	52.7 ± 8.1	55.6 ± 5.5	33.2 ± 6.5	32.2 ± 3.1	13.5 ± 2.2	14.1 ± 2.2
Weight of Herbage Offered (kg DM $ha.^{-1}$)	2672 ± 465	2734 ± 460	2785 ± 664	2689 ± 473	2729 ± 495	2730 ± 484
Area (m^2 cow^{-1})	205 ± 42		123 ± 23		52 ± 12	
Mean Stock Density (cows $ha.^{-1} day^{-1}$)	49		81		192	

Table 3.2 Herbage dry matter remaining after grazing (kg DM ha^{-1} $\pm$ SD, kg DM cow^{-1} $\pm$ SD) for each herbage allowance treatment

	Herbage Allowance					
	High		Moderate		Low	
Pasture DM remaining	cutting	meter	cutting	meter	cutting	meter
Kg DM ha^{-1}	1842 $\pm$ 266	1663 $\pm$ 342	1546 $\pm$ 249	1367 $\pm$ 282	765 $\pm$ 159	972 $\pm$ 130
Kg DM cow^{-1}	36.7 $\pm$ 6.4	33.7 $\pm$ 4.3	18.9 $\pm$ 4.5	16.7 $\pm$ 2.3	3.9 $\pm$ 1.1	5.1 $\pm$ 0.9

Table 3.3 The mean dry matter intakes of cows offered three herbage allowances ($kg\ DM\ cow^{-1}day^{-1} \pm$ SE of mean; kg DM per 100 kg LW)

	Herbage Allowance				
	High	Moderate	Low	SE diff.	Sig.
DM Intake ($kg\ DM\ cow^{-1}day^{-1}$) (cutting data)	15.8 $\pm$ 2.1	14.3 $\pm$ 1.4	9.6 $\pm$ 0.6	$\pm$ 1.5	H > L ** M > L *
DMI ($kg\ DM\ cow^{-1}day^{-1}$) (meter data)	21.8 $\pm$ 0.9	15.9 $\pm$ 0.4	9.0 $\pm$ 0.3	$\pm$ 0.6	H > L ** M > L ** H > M **
DMI (kg DM per 100 kg LW) (cutting data)	4.5	3.9	2.8	-	-

** $P < 0.01$ * $P < 0.05$ + $P < 0.1$ NS = Non-significant.

There was poor agreement between the two methods used to determine the DM yield of pasture remaining after grazing. The relationship between the estimates of residual herbage yields made by the grass meter and by cutting was significant only when the measurements from all the allowance areas were pooled ($r = 0.81$, $P < 0.01$). The regression coefficients relating the two methods for estimating residual herbage yields within each treatment were not significant. The Ellinbank meter appeared to underestimate the residual herbage yield for the high and moderate allowances and overestimate it for the low allowance.

3.1.3 Dry Matter Intake

Mean DM intakes measured for each herbage allowance are shown in Table 3.3.

Daily DM intakes measured by cutting, and the corresponding daily herbage allowances are plotted in Figure 3.1. Higher DM intakes were measured at the higher herbage allowances. Table 3.3 and Figure 3.1 both show that there was greater variation about the treatment means (i.e. greater day to day variation in intake), as herbage allowance increased. This may partly be explained by the greater variability of the daily herbage allowances offered at the higher allowance treatment (see Table 3.1), but is more likely associated with the technique used for intake estimation.

The Ellinbank meter measured considerably greater rates of pasture DM disappearance during grazing on the high and moderate allowances than the cutting and drying technique (see Chapter 4). It was less variable between days in estimating herbage allowance (see Table 3.1) and DM disappearance (see Table 3.3), than the cutting technique.

3.1.4 The Variation amongst the Estimates of Dry Matter Yield and Herbage Intake

The variation between individual quadrats in estimating DM yield was examined using the method described in section 2.5.2.

Fig. 3.1 The measured relation between daily herbage allowance and herbage intake

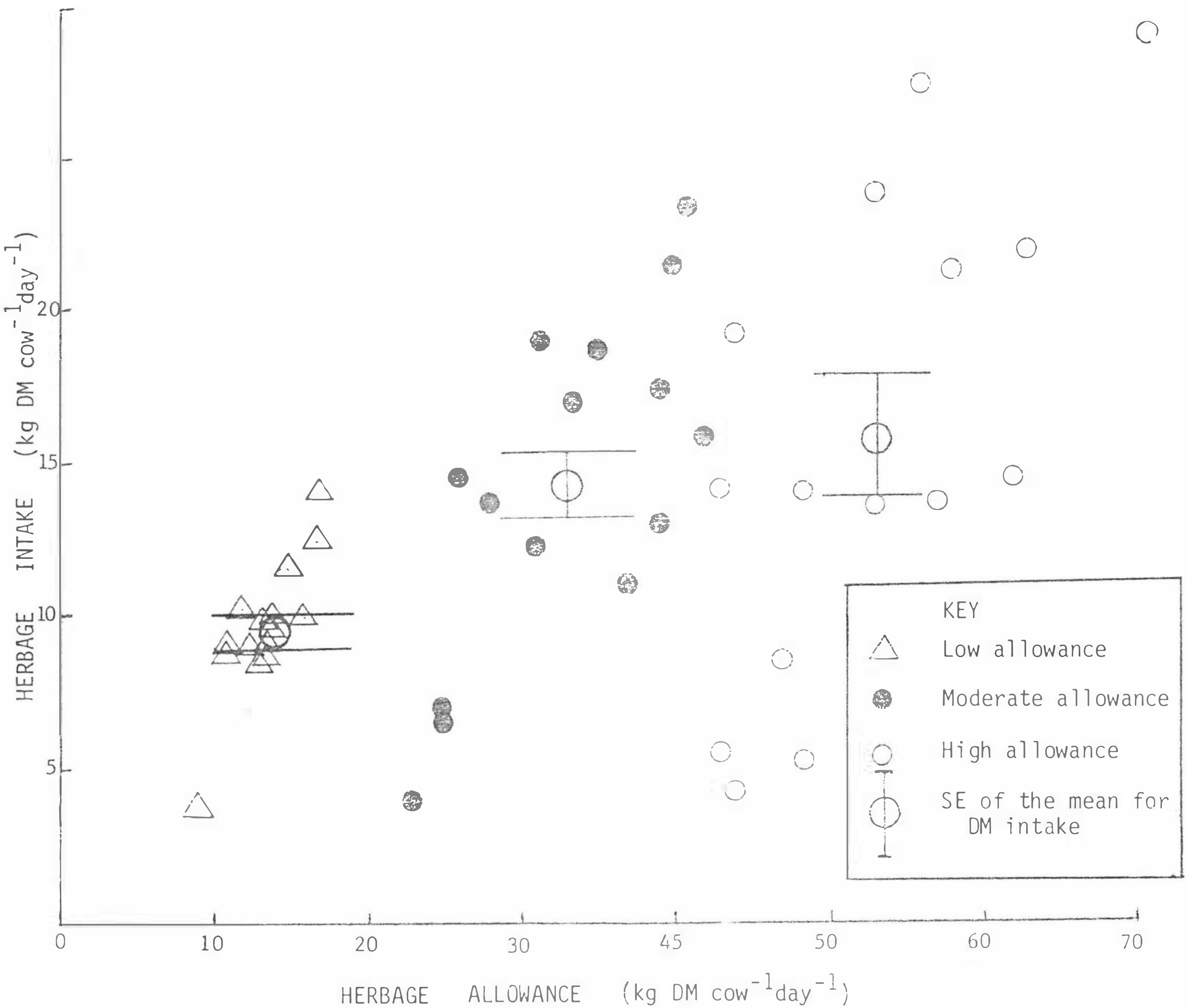


Table 3.4 The variability of estimates of dry matter yield before and after grazing, measured for allowance areas on two occasions

		Mean DMY Estimate (kg DM ha^{-1})	Std. Deviation	SE of Mean	CV%
High Allowance					
Before Grazing					
Pad 18	10 quadrats	3239	970	307	29.94
	20 quadrats	3266	1305	292	39.96
Pad 17	10 quadrats	1922	236	75	12.29
	20 quadrats	1858	431	96	23.20
After Grazing					
Pad 18	10 quadrats	1868	488	154	26.10
	20 quadrats	1893	537	120	28.37
Moderate Allowance					
Before Grazing					
Pad 18	10 quadrats	3076	319	101	10.37
	15 quadrats	3095	427	110	13.80
Pad 17	10 quadrats	2281	436	138	19.12
	15 quadrats	2470	678	175	27.45
After Grazing					
Pad 18	10 quadrats	1670	355	112	21.25
	20 quadrats	1628	341	76	20.95
Low Allowance					
Before Grazing					
Pad 18	8 quadrats	3018	568	201	18.82
	10 quadrats	3190	648	205	20.31
Pad 17	8 quadrats	2449	287	102	11.73
	10 quadrats	2399	409	129	17.05
After Grazing					
Pad 18	6 quadrats	839	298	122	35.58
	15 quadrats	792	279	72	35.22

Table 3.5 The standard errors, coefficients of variation and confidence intervals of the estimates of dry matter intake made on a single day

	kg DM ha^{-1}	± SE	CV	kg DM cow^{-1}	± SE	95% Confidence Interval (kg DM cow^{-1})
<u>High Allowance</u>						
DM offered (10)	3239	307	29.9	55.2	5.20	43.4 - 66.9
DM remaining (10)	1868	154	26.1	31.8	2.62	25.9 - 37.8
Difference (Intake)	1371	343	79.2	23.4	5.85	11.1 - 35.6
<u>Moderate Allowance</u>						
DM offered (10)	3076	101	10.4	31.6	1.04	29.7 - 34.3
DM remaining (10)	1670	112	21.3	17.1	1.15	14.6 - 19.7
Difference (Intake)	1406	151	34.0	14.4	1.55	11.2 - 17.7
<u>Low Allowance</u>						
DM offered (8)	3018	201	18.8	12.3	0.82	10.4 - 14.3
DM remaining (6)	839	122	35.6	3.4	0.50	2.1 - 4.7
Difference (Intake)	2179	234	34.0	8.9	0.96	6.8 - 11.0

N.B. Numbers in brackets are the number of quadrats cut for each allowance area.

Table 3.4 shows the mean estimates of DM yield for allowance areas before and after grazing and statistics showing the variation amongst quadrat samples about the estimated means. The table includes estimates of DM yield made from the standard number of quadrats used throughout the experiment, (see Table 2.4) and estimates made from an increased number of quadrats.

It is evident in Table 3.4 that increasing the number of quadrats cut per allowance area reduced the standard errors of the mean estimate for the herbage DM remaining after grazing. High C.V. values for the measurement of residual herbage yield at the moderate and low allowances are evident and may suggest that more samples were required to estimate residual herbage yield than for pre-grazing herbage yield. Increasing the number of quadrats above the number used for measuring pre-grazing herbage yields did not reduce the standard errors of the mean estimate to any extent, for all three allowances.

The standard errors for the estimates of DM intake can be calculated for the days on which the variation amongst quadrat herbage samples were measured. This was done using the method outlined in Chapter 2.8.3 and the data are tabulated in Table 3.5.

The standard errors, when expressed as a percentage of the mean DM intake per cow, were 25.05%, 10.74%, and 10.8% for the high, moderate and low allowances respectively.

3.1.5 The Nature of the Relationship Between Herbage Allowance and Herbage Dry Matter Intake

For each treatment there were fifteen occasions when daily herbage allowance was measured by cutting herbage samples and fifteen corresponding estimates of DM intake made for each herbage allowance. In order to examine the nature of the relationship between herbage allowance and DM intake by regression analysis, transformation of the y data (pasture DM intake) was necessary. This was because the variation in the measured DM intakes increased consistently as herbage allowance increased, (see Figure 3.1), to the extent that the variations about the treatment means were not homogenous (Bartlett's test of homogeneity of variance, Snedecor and Cochran, 1967).

The y data were transformed to $^{y}/x$ (i.e. $\frac{\text{food consumed}}{\text{feed offered}}$, or the utilization of feed offered at a single grazing). Table 3.6 shows the means $\pm$ standard deviations of the dry matter intake data (y) and the transformed data ($^{y}/x$). The standard deviations of the means resulting from the transformation were tested for homogeneity of variance using Bartlett's test and the variances were found not to differ significantly between treatments.

Table 3.6 Means $\pm$ standard deviations of the dry matter intakes (y) for each treatment, and the transformed means (y/x) $\pm$ standard deviations

Allowance	Intake data (y) (means $\pm$ SD)	Transformed data ($^{y}/x$) $\pm$ SD
High	15.8 $\pm$ 7.9	0.29 $\pm$ 0.09
Moderate	14.3 $\pm$ 5.6	0.42 $\pm$ 0.13
Low	9.6 $\pm$ 2.1	0.71 $\pm$ 0.13

The means of the transformed data ($^{y}/x$) are in fact the mean utilizations of the herbage offered at a single grazing (kg DM eaten/kg DM offered per cow).

Linear regression analysis relating $^{y}/x$ to x resulted in the following equation:

$$^{y}/x = 0.7515 - 0.00837x \qquad r = -0.6864 \qquad (P < 0.001)$$

By multiplying through the equation by x, the equation relating pasture DM intake (y) to herbage allowance (x) can be found

$$y = 0.7515x - 0.00837x^2$$

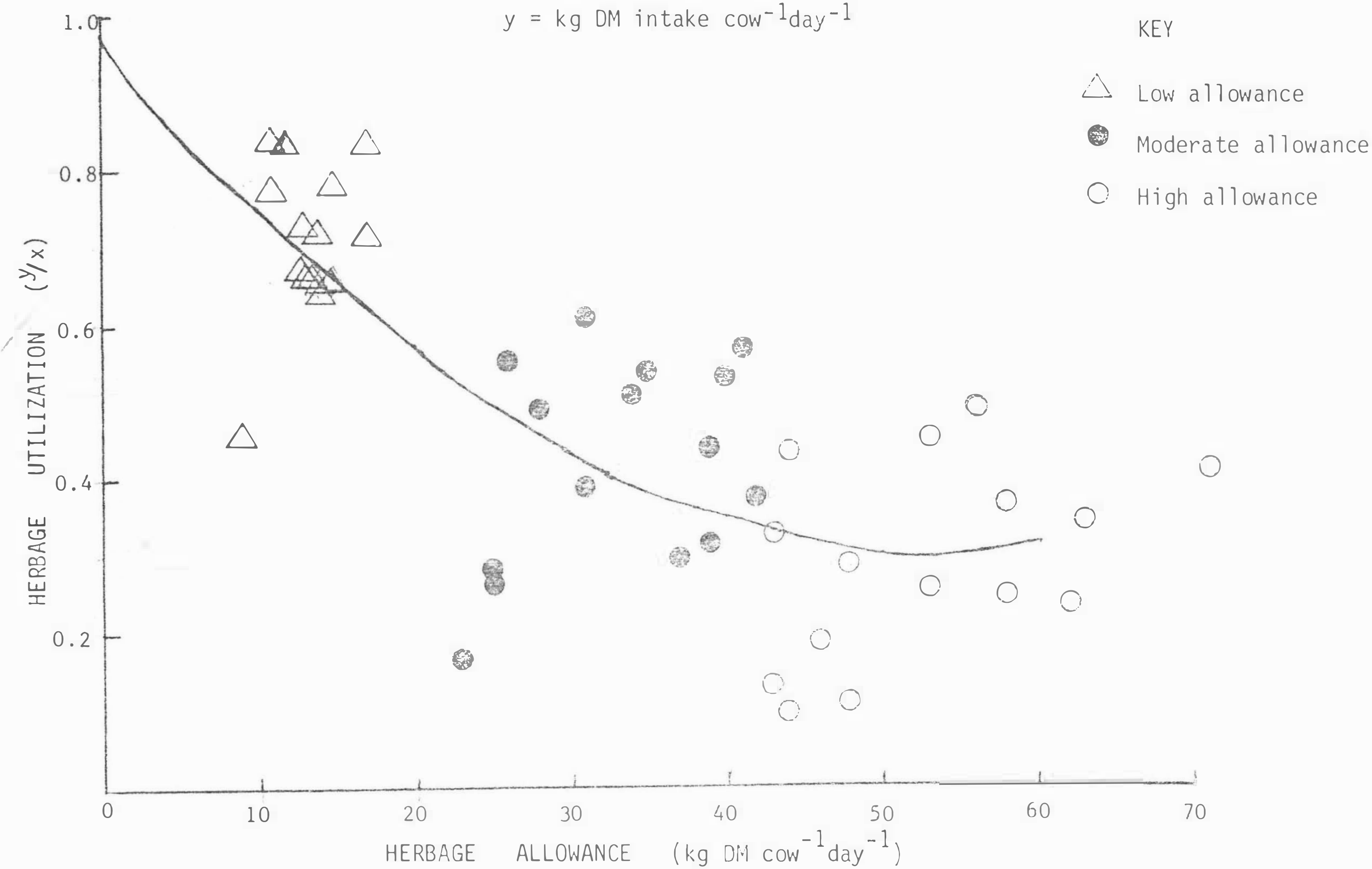
Curvilinear regression analysis (to the 2nd degree polynomial)

Fig. 3.2 The relation between herbage utilization at a single grazing (y/x) and daily herbage allowance (x)

$$y/x = 0.977 - 0.0252(\pm 0.0057)x + 0.00024(\pm 0.000078)x^2 \quad RSD = 0.14 \quad r = -0.68$$

where x = kg DM offered $cow^{-1}day^{-1}$

y = kg DM intake $cow^{-1}day^{-1}$



relating $^y/x$ to herbage allowance (x) gave the following equation:

$$^y/x = 0.977 - 0.0252x + 0.00024x^2 \quad (P < 0.001) \quad RSD = \pm 0.14$$

The extra precision which results from the curvilinear regression was statistically significant ($P < 0.01$).

The relationship between herbage utilization at a single grazing and daily herbage allowance is plotted in Figure 3.2.

Over the range of herbage allowances studied the relationship between herbage allowance and herbage intake is curvilinear. As herbage allowance increases, progressively smaller increases in herbage intake are obtained. At the same time lower levels of utilization of the herbage offered occurs.

3.1.6 The Effect of Herbage Allowance on the Quality of Diet Selected

The quality of the herbage selected by each group of cows was estimated using the methods described in Chapter 2.5.5. The effects of herbage allowance on the protein and acid detergent fibre contents of the herbage consumed by the cows is shown in Table 3.7.

As herbage allowance increased there was greater opportunity for the cows to select herbage of a higher crude protein content, to the extent that the cows offered the high allowance had a significantly higher protein content in their diet than those offered the low allowance. The difference in the crude protein contents of the residual herbage between the high and the low allowance treatments was significant at the 10% level.

There were no significant differences in the acid detergent fibre concentrations of the herbage consumed,or the herbage remaining after grazing,amongst the three allowances. All cows apparently consumed herbage with a lower ADF content than the total herbage on offer, irrespective of the herbage allowance.

The *in vitro* organic matter digestibility measurements were carried out on the herbage sampled from two out of the five pastures. Results are shown in Table 3.8.

Table 3.7 The crude protein and acid detergent fibre concentrations of the herbage offered, the herbage remaining, and the herbage apparently ingested

Allowance	Crude Protein (% of DM)			Acid Detergent Fibre (% of DM)		
	Herbage on Offer	Herbage Remaining	Herbage Consumed	Herbage on Offer	Herbage Remaining	Herbage Consumed
High	↑	16.9	26.8	↑	24.5	23.8
Moderate	19.5	16.3	24.2	24.5	26.0	21.8
Low	↓	13.8	21.8	↓	25.8	23.8
SE		± 0.9	± 1.3		± 1.0	± 1.0
		H > L ($P < 0.1$)	H > L ($P < 0.01$)		NS	NS

Table 3.8 *In vitro* DOMD% of herbage offered and herbage remaining after grazing from two pastures

Allowance	Herbage Offered	Herbage Remaining		
		High	Moderate	Low
Pad 40	70.8	69.6	57.1	55.8
Pad 1	69.9	64.0	58.5	61.4

Assuming that the trends shown in Table 3.8, from two of the pastures, are representative of all the pastures used in the experiment then it is apparent that as herbage allowance decreased so did the organic matter digestibility of the herbage remaining after grazing. Cows offered the low allowance may have been forced to eat herbage of lower digestibility as they grazed to lower levels of residual DM yield. Attempts to calculate the organic matter digestibility of the herbage consumed from an equation used by Walters and Evans (1979), produced unrealistic estimates of organic matter digestibility.

The metabolizable energy content of the herbage offered can be estimated from the following equation:

Metabolizable Energy Value of Herbage = 0.15 DOMD% (MAFF,1975).
(MJME Kg DM^{-1})

Assuming that the mean of the two DOMD% figures shown in Table 3.8 is representative of all the herbage offered in the experiment then the ME value of the herbage offered equalled 10.6 MJME kg DM^{-1}.

3.2 Herbage Allowance and Milk Production

Unless otherwise stated, the milk production data presented in the tables are the adjusted treatment means as a result of analysis of covariance. The milk production data for the first seven days of the treatment period are not included in the overall mean in order to exclude the influence of the level of feeding immediately prior to the differential feeding, on the mean values.

Full details of milk production for each cow are given in Appendix IV.

3.2.1 Milk Yield

Mean milk yields for the cows offered each allowance are presented for each week in Table 3.9.

Table 3.9 Milk yields (litres $cow^{-1} day^{-1}$) for cows offered one of three herbage allowances for a 5 week period

	Herbage Allowance			LSD	Sig.	
	High	Moderate	Low	(P = 0.05)		
Pre-treatment	15.1	14.2	14.1	4.0	NS	
Weeks 1	15.1	14.4	13.7	1.1	H > L*	
2	17.4	16.6	14.0	2.8	H > L*	
3	16.3	16.3	13.3	2.0	H > L**	M > L**
4	16.7	16.0	12.6	2.1	H > L**	M > L**
5	16.6	15.8	11.7	2.2	H > L**	M > L**
Mean (2 - 5)	16.7	16.2	12.8	2.0	H > L**	M > L**
Post-treatment 6	14.6	15.0	13.6	2.4	NS	
7	14.2	13.5	13.5	2.1	NS	

**(P< 0.01) *(P < 0.05) †(P < 0.1) NS = Not significant

A decrease in herbage allowance from 53 to 33 kg DM $cow^{-1}day^{-1}$ had no significant effect on milk yield at any stage. However a further decrease to an allowance of 13 kg DM $cow^{-1}day^{-1}$ resulted in significant reductions in milk yield per cow (a mean decrease of 3.4 litres $cow^{-1}day^{-1}$). The three herbage allowances resulted in only slight changes in milk yield in the first week that they were offered. However as the period of differential feeding continued, the cows offered the lowest allowance reduced their milk yields progressively. After week 2, the milk yields of cows offered the high and moderate allowances were fairly stable at levels above those recorded before or after the treatment period. The significant advantages in daily milk yield obtained by offering the high and moderate allowances were not sustained when the three groups of cows were returned to graze with the No. 3 dairy herd, (weeks 6 and 7).

3.2.2 Fat Corrected Milk Yield (FCM)

Milk yields corrected to a 4% fat content, (FCM, Gaines, 1928) are presented in Table 3.10. There were no significant differences in FCM yield between the cows offered the high and moderate allowances at any stage. The FCM yields of the cows offered the low allowance were significantly depressed from week 2 onwards. As with milk yields, the cows offered the high and moderate allowances did not maintain their significantly higher yields of FCM when the cows were returned to graze with the No. 3 dairy herd.

There was no effect of herbage allowance on FCM yield in the first week in which the different herbage allowances were offered, and cows offered the high and moderate allowances reduced FCM yields during this week.

3.2.3 Milkfat Percentage

Mean milkfat percentages for each group of cows are presented week by week in Table 3.11.

Table 3.10 Fat corrected milk yields (kg $cow^{-1}day^{-1}$) of cows offered different herbage allowances for a 5 week period

	Herbage Allowance					
	High	Moderate	Low	LSD	Sig.	
Pre-treatment	16.2	16.3	15.4	4.3	NS	
Week 1	15.7	15.4	15.4	1.0	NS	
2	18.1	16.5	14.7	2.1	H > L**	
3	17.5	17.4	15.0	1.7	H > L**	M > L**
4	17.6	17.1	12.9	2.1	H > L**	M > L**
5	17.3	16.4	12.7	2.4	H > L**	M > L**
Mean Weeks 2-5	17.7	16.8	13.8	1.9	H > L**	M > L**
6	16.8	16.5	15.2	2.4	NS	
7	15.2	15.9	15.2	2.3	NS	

Table 3.11 Milkfat percentages for cows offered different herbage allowances for a 5 week period

	Herbage Allowance				
	High	Moderate	Low	LSD	Sig.
Pre-treatment	4.53	5.00	4.75	0.70	NS
Week 1	4.28	4.74	4.91	0.59	L > H*
2	4.26	4.00	4.36	0.45	NS
3	4.50	4.65	5.02	0.69	NS
4	4.29	4.63	4.48	0.68	NS
5	4.32	4.26	4.74	0.46	L > M*
Mean Weeks 2-5	4.35	4.38	4.65	0.44	NS
Post-treatment 6	5.01	4.95	4.92	0.81	NS

The mean milkfat percentages for weeks 2-5 of the treatment period were not significantly different amongst the three groups of cows. Cows offered the lowest allowance had significantly higher milkfat percentages than one of the other treatment groups in weeks 1 and 5, suggesting a slight increase in milkfat percentage as herbage allowance decreased.

3.2.4 Milkfat Yield

The mean daily milkfat yields for the cows in each treatment are shown week by week in table 3.12, along with the total milkfat production (kg cow^{-1}) for weeks 2-5 of the treatment period.

Table 3.12 Milkfat yields (kg MF $cow^{-1} day^{-1}$) for cows offered different herbage allowances for a 5 week period

	Herbage Allowance					
	High	Moderate	Low	LSD	Sig.	
Pre-treatment	0.68	0.71	0.65	0.19	NS	
Week 1	0.65	0.69	0.68	0.09	NS	
2	0.74	0.66	0.61	0.09	H > L**	
3	0.73	0.73	0.64	0.07	H > L*	M > L*
4	0.73	0.71	0.54	0.09	H > L**	M > L**
5	0.71	0.68	0.54	0.10	H > L**	M > L**
Mean Weeks 2-5	0.73	0.70	0.58	0.08	H > L**	M > L**
Post-treatment 6	0.73	0.71	0.65	0.11	NS	
7	0.65	0.71	0.66	0.10	NS	
Total Milkfat (kg cow^{-1})						
Weeks 2-5	17.5	16.7	14.0	1.72	H > L**	M > L**

Decreasing the amount of herbage offered daily from 53 kg DM cow^{-1} to 33 kg DM cow^{-1} had no significant effect on milkfat yield at any stage. Reducing the herbage offered further, to 13 kg DM $cow^{-1}day^{-1}$ resulted in a reduction in yield of up to 0.19 kg milkfat $cow^{-1}day^{-1}$. This meant significant ($P < 0.01$) losses of milkfat, when compared to the cows offered the high and moderate allowances (3.54 and 2.76 kg milkfat cow^{-1}). Significant differences in the daily yield of milkfat amongst the three groups of cows were not sustained in the two weeks immediately after the cows were returned to the No.3 dairy herd.

The effects of offering the different herbage allowances on the milkfat production over the remainder of the lactation are summarised in Table 3.13.

Table 3.13 Milkfat yields (kg cow^{-1} $\pm$ SE) for cows offered three different herbage allowances in early lactation

1. Treatment yield
2. Post-treatment yield
3. Total yield

	Herbage Allowance			LSD	
	High	Moderate	Low	(P=0.05)	Sig.
Weeks 2-5	17.5 $\pm$ 0.9	16.7 $\pm$ 1.6	13.9 $\pm$ 1.2	1.7	H, M > L**
5-34	104.5 $\pm$ 6.5	109.6 $\pm$ 17.3	104.0 $\pm$ 9.7	28.3	NS
2-34	122.0	126.3	118.0	-	NS

Note: The milk production data for week 1, (the first week of differential feeding), were excluded.

Differences in milkfat yield established through offering different herbage allowances during weeks 2-5 did not persist throughout the remainder of the lactation (weeks 5-34). Of the total milkfat yield difference for the whole lactation of 4.0 kg, between cows offered the high and low allowances, 3.5 kg cow^{-1} of this difference occured during the time that cows were offered the different herbage allowances. The cows offered the moderate allowance produced at a considerably higher level during weeks 5-34 than the other two groups of cows, and their advantage in milkfat yield over the cows offered the low allowance had increased from 2.76 kg MF cow^{-1} to 8.3 kg MF cow^{-1} by the end of lactation. The later difference was not statistically significant.

3.2.5 Milk Protein Percentage

Mean protein contents (%) of the milk produced are summarised on a week by week basis in Table 3.14.

Table 3.14 Milk protein percentages for cows offered one of three herbage allowances

	Herbage Allowance			LSD	Sig.	
	High	Moderate	Low	(P=0.05)		
Pre-treatment	3.21	3.37	3.48	0.40	NS	
Week 1	3.34	3.32	3.21	0.19	NS	
2	3.73	3.70	3.35	0.20	H > L**	M > L**
3	3.66	3.64	3.44	0.21	H > L*	
4	3.52	3.55	3.25	0.25	H > L*	M > L*
5	3.77	3.78	3.46	0.24	H > L*	M > L*
Mean Weeks 2-5	3.68	3.66	3.36	0.19	H > L**	M > L**

Milk protein percentage proved to be more sensitive to the herbage allowance offered than did milkfat percentage. Differences in milk protein percentage between the cows offered the high and moderate allowances were small and non-significant. There was a significant fall in the milk protein percentage of the milk produced by the cows offered the low allowance.

3.2.6 Milk Protein Yield

The influence of offering different herbage allowances to cows on their milk protein yields is shown in Table 3.15.

Table 3.15 The milk protein yields (kg $cow^{-1} day^{-1}$) of cows offered one of three herbage allowances

	Herbage Allowance			LSD	Sig.
	High	Moderate	Low	(P=0.05)	
Pre-treatment	0.48	0.48	0.49	-	NS
Week 1	0.51	0.47	0.43	0.16	NS
2	0.65	0.61	0.47	0.17	$H > L^{*}$
3	0.60	0.58	0.45	0.15	$H > L^{*}$
4	0.60	0.56	0.37	0.13	$H > L^{**}$ $M > L^{**}$
5	0.63	0.59	0.43	0.14	$H > L^{**}$ $M > L^{**}$
Mean Weeks 2-5	0.62	0.59	0.43	0.14	$H > L^{**}$ $M > L^{*}$
Total Yield (kg cow^{-1})					
Weeks 2-5	14.8	14.1	10.1	3.3	$H > L^{**}$ $M > L^{*}$

The effects of the three herbage allowances on milk protein yield were similiar to the effects on milk and milkfat yields. There were no significant differences in the milk protein yields between the cows offered the high and moderate allowances. The milk protein yields of the cows offered the lowest allowance were significantly depressed from week two onwards. Cows offered the high and moderate allowances produced 4.7 kg cow^{-1} ($P < 0.01$) and 4.00 kg cow^{-1} ($P < 0.05$)

more milk protein during weeks 2-5 than cows offered the low allowance. Protein yields were not measured following the removal of cows from their herbage allowance treatments.

3.2.7 Somatic Cell Counts

The mean somatic cell counts for the 32 day treatment period were 4.58×10^5, 8.28×10^5 and 5.19×10^5 cells ml^{-1} for the cows offered the high, moderate and low allowances respectively. The means were not significantly different (LSD P=0.05, 7.71×10^5). These cell counts, if used as an indicator of sub-clinical mastitis, would suggest that the occurence of sub-clinical mastitis in the experimental cows may have been relatively high, and may have placed a limitation on milk yield. However the results indicate no treatment effect. The incidence of sub-clinical mastitis as measured by the somatic cell count, could not be considered as a contributor to differences in milk production between treatments.

3.3 Liveweight and Cow Body Condition Change

3.3.1 Liveweight Change

Both unfasted and fasted liveweights were available for estimating the rate of liveweight change during the treatment period (see Chapter 2.6.2). The mean liveweight changes (kg $cow^{-1} day^{-1}$) calculated by using each of the methods described above are shown in Table 3.16. Full details of liveweight and condition score for each cow are shown in Appendix V.

The mean initial liveweights (unfasted) of the three groups of cows were 337, 356 and 369 kg for the high, moderate and low allowances respectively. At the end of the treatment period the mean liveweights (unfasted) were 365, 371 and 358 kg for the three groups of cows.

Table 3.16 The mean rate of liveweight change (kg $cow^{-1} day^{-1}$) of cows offered three different herbage allowances

	Herbage Allowance			LSD	
	High	Moderate	Low	(P=0.05)	Sig.
Method 1:					
Unfasted Weights	+0.70	+0.34	-0.30	0.42	$H > M^{\dagger}$ $H, M > L^{**}$
Method 2:					
Fasted Weights	+0.63	+0.42	+0.22	0.33	$H > L^{*}$

The two methods of estimating liveweight change were in reasonable agreement for the cows offered the high and moderate allowances, but not for the cows offered the low allowance.

Cows offered the high allowance increased their liveweight at a faster rate ($P < 0.1$) than cows offered the moderate allowance if the unfasted weights are used. Five of the six cows offered the low allowance lost weight if the unfasted weights are used, and their rates of liveweight change differed significantly ($P < 0.01$) from the other groups of cows.

If the fasted weights are used (Method 2), only the rates of liveweight change between the cows offered the high and low allowances were statistically significant ($P < 0.05$). Reasons for the apparent differences between the two methods in estimating liveweight change will be discussed in Chapter 4.

3.3.2 Cow Body Condition Change

The mean condition scores for the cows in each group, before and after the period in which the different allowances were offered, plus the mean change in condition score over this time are in Table 3.17.

Table 3.17 Initial and final condition scores for the cows offered each herbage allowance

	Herbage Allowance			LSD	Sig.
	High	Moderate	Low		
Mean C.S. at start	4.08	3.83	3.75	0.84	NS
Mean C.S at finish	4.82	4.25	3.37	1.03	H > L**
Mean Changes in C.S	+0.73	+0.42	-0.38	0.80	H > L** M > L*
Mean C.S. Last month of Lactation	4.46	4.36	4.29	0.52	NS

There was very little difference in the mean condition scores of the three groups of cows at the start of the experiment, but the cows offered the lowest allowance lost condition, and the cows offered the moderate and high allowances gained condition in the following five week period. The mean condition score changes would support the liveweight change measurements made by using the unfasted liveweights.

3.4 Evaluation of the Responses of Cows of 'High' and 'Low' Merit for Milkfat Production to Herbage Allowance

3.4.1 Fat Corrected Milk Production

The mean 4% fat-corrected milk yields for each cow were related to lifetime production index (LPI) and herbage allowance by the following equation:

$$FCM\ (kg\ cow^{-1}day^{-1}) = -4.22 + 0.1385\ (^{**})\ X_1 + 0.1427\ (^{**})\ X_2$$

$(P < 0.01,\ SE \pm 2.1459)$

X_1 = LPI. X_2 = Herbage Allowance (kg DM $cow^{-1}day^{-1}$).

$^{**}(P < 0.01)$.

Lifetime production index and feed offered accounted for 66% of the variation in fat corrected milk yield during the 32 day period in which different herbage allowances were offered.

3.4.2 Liveweight Change

The rate of liveweight change was related to LPI and herbage allowance by the following equation;

$$\Delta LW\ (kg\ cow^{-1}day^{-1}) = 0.3301 - 0.0072\ (NS) X_1 + 0.022\ (^{**})\ X_2$$

$(P < 0.01,\ SE \pm 0.3445)$

X_1 = LPI. X_2 = Herbage Allowance (kg DM $cow^{-1}day^{-1}$).

NS = Not significant. ** $(P < 0.01)$.

Lifetime production index and herbage offered accounted for 58% of the variation in liveweight change during the 32 day period.

3.4.3 Cow Condition Score Change

Changes in cow condition score were related to LPI and herbage allowance by the following equation;

$$\Delta CS = 1.7001 - 0.0188\ (^{\dagger})\ X_1 + 0.0203\ (^{*})\ X_2$$

$(P < 0.01,\ SE = 0.5809)$

X_1 = LPI. X_2 = Herbage Allowance (kg DM $cow^{-1}day^{-1}$).

† $(P < 0.1)$. * $(P < 0.05)$.

Lifetime production index and feed offered accounted for 44% of the variation in the condition score changes during the 32 day treatment period.

3.4.4 Analysis of Variance

The effects of three levels of herbage offered and two levels of cow 'phenotypic merit' on FCM yield, liveweight change and condition score change were examined by 3 x 2 factorial analysis of variance. Table 3.18 shows the mean values for FCM yield, liveweight change and condition score change for the 'high' and 'low' producers offered each herbage allowance.

Herbage allowance had significant effects ($P < 0.05$) on FCM yield, liveweight change and condition score change. High producing cows produced significantly more ($P < 0.01$) fat corrected milk on the moderate and low allowances than the 'low' producing cows. Differences in the rates of liveweight gain between 'high' and 'low' producing cows approached significance ($P < 0.05$) on two of the three allowances, suggesting that the 'low' producing cows may have gained more or lost less liveweight when offered the same herbage allowances as 'high' producers. There were no significant interactions between herbage allowance and cow phenotypic merit. Full analysis of variance tables for this analysis are shown in Appendix VI.

Table 3.18 Mean FCM yields, liveweight changes and cow condition score changes of cows with 'high' and 'low' lifetime production indices, offered three different herbage allowances

	Herbage Allowance						LSD (P=0.05)	
	High		Moderate		Low		H.A.	LPI
Mean LPI	118	96	131	100	131	100	-	-
FCM yield (litres $cow^{-1} day^{-1}$)	18.46	17.20	19.43	14.76	15.66	11.12	3.57	2.91
Liveweight Change (kg $cow^{-1} day^{-1}$)	+0.53	+0.87	+0.24	+0.44	-0.46	-0.13	0.43	0.35
Condition Score Change (per cow)	+0.80	+0.67	+0.43	+0.40	-1.00	+0.23	0.72	0.59

CHAPTER FOUR

DISCUSSION

4.1 Herbage Allowance and Herbage Intake

4.1.1 Daily Herbage Allowance Offered

The mean daily herbage allowances offered of 52.7, 33.2 and 13.5 kg DM cow^{-1} approximated the intended herbage allowances of 55, 35 and 15 kg DM cow^{-1}. I have preferred to express herbage allowance as kg DM cow^{-1} in contrast to the definition by Hodgson (1976), which expresses herbage allowance as kg DM per unit liveweight. The expression of herbage allowance as defined by Hodgson has not been widely applied in New Zealand except in relation to young beef cattle, (e.g. Trigg and Marsh, 1979). This may be a reflection of the need to express herbage allowances in terms that are recognisable to farmers and since few New Zealand farmers have scales available to weigh their stock, few would find expressions relating to liveweight meaningful. For comparative purposes the daily herbage allowances offered in this experiment can be expressed as 16, 10 and 4 kg DM per 100 kg liveweight or 160, 100 and 40g DM per kg liveweight for the high, moderate and low allowances respectively.

The daily herbage allowances offered in this experiment are similar to the range of allowances offered by Bryant and Cook (1977). This was intended as a means to examine some of the differences that might arise as a result of offering herbage allowances on pastures of differing characteristics. The herbage allowances offered to cows in New Zealand experiments were high in comparison to those offered in the experiments by Combellas and Hodgson (1975, 1979), (i.e. 25 - 90g DM $kgLW^{-1}$). Some implications of the differences in the range of herbage allowances offered will be discussed later.

The measurements of daily herbage allowance made by cutting herbage to ground level and those made by the Ellinbank pasture meter were significantly correlated (r = 0.82). The use of herbage allowances in the planning of grazing management requires a knowledge of the yield of DM per unit area. The comparison made in this experiment suggests that the Ellinbank meter is an alternative to cutting and drying herbage in order to provide estimates of the yield of ungrazed herbage. Quicker and easier, but less objective methods may be more useful to the dairy farmer in assessing daily herbage allowances. The comparison between the two methods of herbage DM yield estimation in this experiment suggested that there may be considerably more problems in estimating yields of herbage after it has been grazed (see Chapter 3.1.2 and following discussion).

4.1.2 Estimation of Dry Matter Intake

Mean DM intakes of 15.8, 14.3 and 9.6 kg DM $cow^{-1}day^{-1}$ were measured for the high, moderate and low allowances respectively over the five week period. Estimates of herbage intake for grazing animals are often regarded with considerable suspicion due to the lack of precision of current methods of measuring grazing intake (Pigden and Minson, 1969; Clark and Brougham, 1979). A plot of the daily herbage allowances offered versus the daily herbage intake in Figure 3.1, shows that there was considerable day to day variation in measured herbage intake per cow despite similar herbage allowances being offered each day. This immediately casts some doubt on the reliability of the 'difference' method for estimating DM intake.

The estimates of intake were apparent rather than true intake in that some DM may have disappeared from the pasture during grazing by means other than ingestion by the cow, e.g. trampling below the height of sampling. Clark and Brougham (1979) noted that the 'difference' method became increasingly more inaccurate when soil moisture levels were high as the disappearance of DM by trampling below the height of sampling was more likely to occur under wet conditions. The present experiment took place during a period of comparatively low rainfall and soil moisture levels did not appear to reach the point that there was noticeable pasture damage.

Another factor affecting the estimates of intake which was not accounted for in this experiment was the growth of pasture occuring between the two estimates of herbage yield (before and after grazing). The period between the sampling before grazing, and when grazing commenced was almost 24 hours. The maximum growth rate during September and October at No.3 dairy is approximately 60 kg DM ha^{-1} day^{-1} (C.W. Holmes and R.J. McLenaghan, unpublished data). If this growth rate occured between the estimation of herbage yield and the commencement of grazing then the actual herbage allowances offered may have been up to 1.1 kg DM, 0.6 kg DM and 0.3 kg DM higher per cow than those measured the day before for the high, moderate and low allowances respectively. Due to the variability in pasture growth rates each day, and the variation in estimates of herbage allowance independent of the growth of herbage, these 'plant growth errors' were not considered important enough to enter into the calculation of apparent herbage intake.

The errors for estimating herbage intake on a single day have been calculated for this experiment and are presented in Chapter 3.1.4. A standard error of 25% was associated with measuring DM intake at the high allowance and there was an exceedingly high coefficient of variation. (C.V. = 74% c.f. 34% for the moderate allowance). Clark and Brougham (1979) noted that the 'difference' method became increasingly inaccurate as herbage allowance increased.

The magnitude of the error associated with estimating herbage intake on any one day will be determined by the variability of the weight of herbage in the sward and losses of DM not recovered by clipping. Sward variability can be compensated for by increasing sample numbers,(Pigden and Minson, 1969). In this experiment there appeared to be inadequate intensity of sampling to cover the variation in sward weight over the large area of herbage offered at the high allowance. However the lower standard errors associated with the estimates of herbage intake made for the moderate and low allowances increases confidence in the technique as a means of determining DM intake on smaller areas of pasture. Values of C.V. for intake of 34% for each of the lower allowances appear to be at the lower end of the range of reported C.V. values for estimating intake by the 'difference' method. Walters and Evans (1979) report that C.V.

values for estimates of intake made by the 'difference' method range from 7 - 250% depending on the level and variability of pasture yield, the length and intensity of the grazing period, and the number and size of sample units. Green et al., (1952) noted that the error variability of estimating intake by the 'difference' method may be minimised if sample units take the form of long narrow strips cut to ground level. The quadrats in this experiment were 60 cm x 30 cm rectangles, and possibly the error could have been further reduced by using a different shaped quadrat covering the equivalent area.

A further factor that could have influenced the estimates of intake could be through the incomplete recovery of sampled herbage from quadrat areas. This can be attributed to three factors:

1. Wind
2. The action of the shearing handpiece
3. The botanical composition of the sampled herbage.

The first needs little explanation. On several occasions it was noted that material was blown from the quadrat area and not recovered due to high winds. The shearing handpiece caused some problems when sampling the residual herbage at the low allowance. This herbage was mostly short, stemmy material and tended to be flicked outside the quadrat area by the shearing handpiece. Longer pasture because of its increased weight sat inside the quadrat when cut.

The prostrate growing habit of the white clover plants appeared to cause a further sampling problem. The white clover stolons proved hard to cut both before and after grazing and once cut tended to be flicked outside the quadrat. Walters and Evans (1979) noted that larger errors occured when using the 'difference' method to estimate intake on prostrate growing cocksfoot sward (Dactylis glomerata var. Cambria) when compared to a more erect growing pasture species.

There are some differences in the estimates of DM intake made by using the two means of measurement outlined, (i.e. the Ellinbank meter and the cutting and drying technique). There was poor agreement between the two methods in determining the DM yield of pasture remaining after grazing (see Table 3.2). The regression coefficients relating the two methods for estimating DM yields after grazing within each allowance were not significant. There is evidence in the results of Nottingham (1978) that the Ellinbank meter overestimated DM disappearance at the higher allowances. There are several reasons why this problem might occur.

The pasture meter does not take into account the distribution of DM in the sward, as it only measures the height of pasture. While this is adequate when the sward has not been grazed, the herbage that is left after grazing is uneven in height and is in various stages of defoliation depending on the intensity of grazing. This may contribute to the lack of agreement between the meter and cutting techniques in estimating post-grazing DM yields. Some of the ungrazed herbage will also have been trampled and while its DM yield will not have changed, its height may have changed sufficiently to alter the meter reading. It was evident that the meter produced unrealistic estimates of DM intake at the higher allowances and for this reason the cutting data was preferred in the analysis of the experiment.

While there was considerable variability in the day to day estimates of intake, particularly at the high allowance, acceptable estimates of herbage intake would seem to be the mean estimates taken over a number of grazing periods, (Davison, 1959). The mean estimates of herbage intake (kg DM cow^{-1}day^{-1}) were used as there was no attempt to relate herbage consumed to any particular sward condition on a single day. The variability about these estimates makes it impossible to conclude from the means that the cows offered the high allowance consumed on average 1.5 kg DM cow^{-1} more than those offered the moderate allowance. In addition, the inherent variability between cows of their intakes under the same conditions probably meant there was a considerable overlap in intakes between the cows offered the high and moderate allowances. But the increased liveweight and body condition gain by the cows offered the high allowance at similar levels of milk production suggests that the intakes were on average greater at the higher allowance.

Vernon (1979) examined the plasma concentrations of non-esterified fatty acids (NEFA) and glucose for cows involved in this experiment on the last two days of the treatment. Cows offered the high allowance had significantly lower levels of plasma NEFA than those offered the moderate allowance ($P < 0.01$) and the low allowance ($P < 0.001$). They also had significantly higher levels of plasma glucose ($P < 0.05$) than either of the other two groups of cows. If the plasma concentrations of these metabolites reflect DM intake then these data suggest that the cows offered the high allowance were consuming more herbage than the cows offered the moderate allowance.

It is clear from both the intake data (and the animal production data) that the cows offered the low allowance had their intakes significantly reduced ($P < 0.01$). These cows were unable to compensate for the reduced herbage allowance by increasing the utilization of herbage offered to an extent where intake was maintained.

Could better estimates of DM intake have been obtained using other methods of estimating grazing intake? Both Walters and Evans (1979), and Clark and Brougham (1979) found little difference between the chromic oxide dilution techniques, and the pre and post-grazing 'difference' technique, although the latter technique became increasingly inaccurate as herbage allowance increased. The drawback with using the 'difference' method in this experiment was that individual cow intakes could not be obtained. This would have been useful for the purposes of examining possible differences in intake and efficiency between cows of different merit for milkfat production under similar grazing conditions.

A further means of examining the reliability of the estimates of intake is to examine the metabolizable energy intakes against the calculated energy requirements of the cows.

A number of assumptions are required:

1. That the ME value of the herbage on offer was 10.6 MJ ME kg DM^{-1} (see Chapter 3.1.6).

Table 4.1 Estimates of metabolizable energy input and expenditure of cows offered three different herbage allowances

Energy Intake MJME $cow^{-1} day^{-1}$		Energy Expenditure MJME day^{-1}			
		Milk Production	Maintenance	LW Change	Total
Herbage Allowance					
High	166.7	84.7	48.2	28.0	160.9
Moderate	150.9	80.8	50.1	13.6	144.5
Low	101.3	66.4	50.8	- 5.3*	111.9

*Assume 1. NE value of 1 kg Liveweight = 22 MJME.
2. K (tissue loss) = 0.80 (Van Es, 1976).

2. Cow Maintenance Requirement = 0.62 MJME/kg$^{0.75}$ (Flatt et al., 1969).

3. Energy Required to Produce 1 kg FCM = 3.14 MJME (MAFF, 1975). x $^{1}/.65$ (Kl) = 4.8 MJME kgFCM^{-1}

4. Requirement for Liveweight Gain = 40 MJME kgLWG^{-1} (A.W.F. Davey, pers. comm.).
   K gain = 0.55, k (tissue loss) = 0.80 (van Es, 1976).

Mean estimates of the energy balances for cows in each allowance are in Table 4.1.

While recognising some deficiences in the estimates in Table 4.1, it appears that the energy intake and energy expenditure estimates correspond reasonably well. The difference between energy input and output estimates is at a maximum at the low allowance (10.6 MJME) and this is approximately equivalent to 1 kg DM intake. While the lack of precision of the method for estimating herbage intake in this experiment is recognised, the mean estimates of herbage intake from the 5 week period were considered satisfactory estimates of apparent herbage intake for the purposes of this experiment.

4.1.3 The Nature of the Relationship between Herbage Allowance and Herbage Intake

As expected it was found that as daily herbage allowance increased so did the intake of DM per cow. The data suggest that as herbage allowance increased the gains in DM intake became progressively smaller. The analysis of the pooled herbage allowance versus herbage intake data, (Chapter 3.1.5) shows that the relationship between herbage allowance and herbage intake was asymptotic in nature. Asymptotic relationships between daily DM intake and daily herbage allowance have been reported by Greenhalgh et al. (1966, 1967) and Combellas and Hodgson (1979) for grazing dairy cows, Trigg and Marsh (1979) for young beef cattle and Rattray and Jagusch (1978) for sheep.

An asymptotic relationship between intake and herbage allowance suggests that there may be considerable flexibility in the level of feed offered to the grazing cow. In some situations there may be scope for reducing the amount of herbage offered without significantly reducing herbage intake or milk production and this is certainly shown by the results of this experiment.

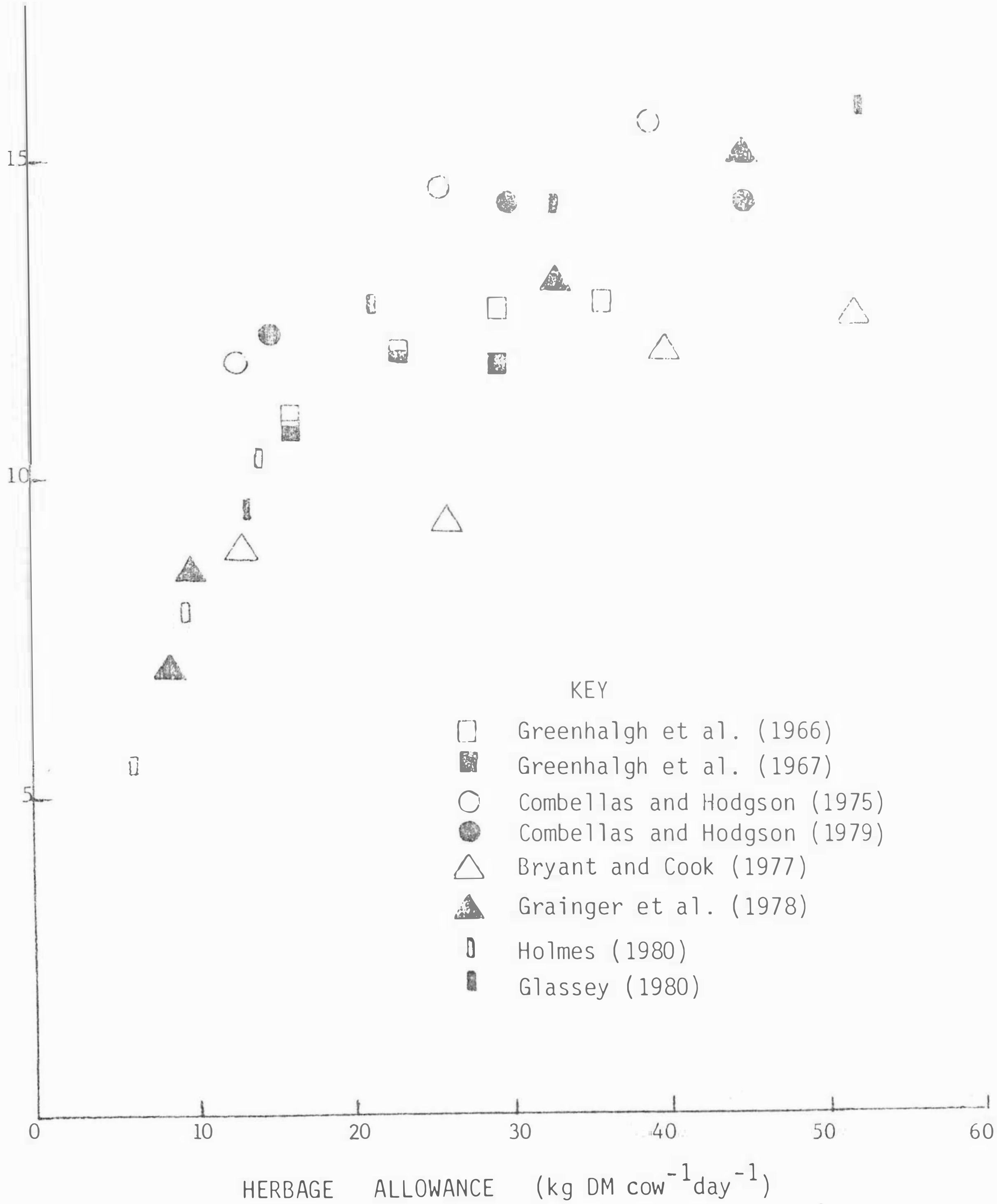
An asymptotic relationship between allowance and intake also implies that there may be an optimum herbage allowance (kg DM cow^{-1} or g DM $kgLW^{-1}$) for a particular class of stock, above which little is gained in terms of DM intake from offering increased amounts of herbage (Greenhalgh et al., 1966). Combellas and Hodgson (1979) tentatively suggest that a daily herbage allowance of 60g DM per kg LW appeared to be a critical allowance below which substantial declines in herbage intake occur for dairy cows, and they compare this figure with similar results published for lambs and calves.

It may not be wise to assume that daily herbage allowance alone will be the only factor affecting the voluntary intake of grazing animals. Other sward characteristics of tropical and temperate pastures have been shown to influence herbage intake apart from herbage allowance. These are the leaf:stem ratio and the horizontal and vertical distribution of leaf and stem (Stobbs and Hutton, 1974), leaf length and the proportion of green material to dead material (Arnold and Dudzinski, 1967a, 1967b; Allden and Whitaker, 1970; Hodgson et al., 1977), plant density (Allden and Whitaker, 1970; Arnold, 1963; Arnold and Dudzinski, 1969), and herbage mass (Combellas and Hodgson, 1979), (see section 1.2.2.3).

There seems to be increasing evidence to support the contention that pasture characteristics other than herbage allowance *per se* influence herbage intake and animal performance (e.g. Combellas and Hodgson, 1979; Stobbs, 1977). This may detract from the usefulness of defining the relationship between herbage allowance and animal performance under particular conditions, in order to apply them across a range of pasture types.

Some of the reported experimental relationships between herbage allowance and herbage DM intake of dairy cows are graphed in Figure 4.1 along with the results from this experiment. Some assumptions

Fig. 4.1 Some relations between herbage allowance and herbage intake with dairy cows



were required in order to plot these relationships with the same units, (kg DM $cow^{-1}day^{-1}$). These assumption were:

1. That 1500 kg DM ha^{-1} was present below the height of sampling (5 cm) in the experiments by Greenhalgh et al. (1966) and Greenhalgh (1970).

2. That all herbage had an ash content of 10% for converting figures expressed as organic matter to DM.

3. That the cows used in the experiment by Combellas and Hodgson (1979) weighed 500 kg.

The relationship appears to be curvilinear, with very little increase in herbage intake per cow as herbage allowance was increased from 30 kg DM cow^{-1}. The use of non-lactating pregnant cows by Holmes (1980) does not appear to affect the relationship at the lower herbage allowances. Lactating cows offered low herbage allowances appear to consume similar quantities of herbage as dry cows offered the same herbage allowances.

The data in Figure 4.1 show that herbage intake is not always similar when the same herbage allowance is offered because the experimental pastures had differing characteristics. The herbage intakes reported by Bryant and Cook (1977) are noticeably lower than other estimates of herbage intake. Despite such variation existing between experiments these data reinforce some of the conclusions made from individual experiments, namely that little extra intake is achieved from offering dairy cows herbage in excess of approximately twice their intake requirement (Combellas and Hodgson, 1979), and that there is a steady increase in intake of approximately 0.3 kg DM per extra kg DM offered up to a herbage allowance of 35kg DM cow^{-1} (Stehr and Kirchgnesser, 1976).

Defining the quantitative relationship between herbage offered and herbage intake is important in examining the pasture requirements of dairy cows. The results of this experiment are consistent with those of other similar experiments and provide some information towards defining the pasture requirements of dairy cows in early lactation (Figure 4.1). However a greater understanding of the characteristics of herbage that influence herbage intake other than the quantity offered will be required to make information obtained from herbage allowance studies more meaningful. To extrapolate the present results to pastures that were not of similar botanical composition or had extremely different herbage yields would be unwise unless there was a greater understanding of the likely influence of the different pasture characteristics (extrinsic or intrinsic) on pasture DM intake and animal performance.

4.1.4 The Residual Herbage Yields

As herbage allowance increased, the proportion of the herbage offered utilized at each grazing decreased (Figure 3.2 and Chapter 3.1.2). Cows offered herbage allowances of greater than 33 kg DM cow^{-1} were consuming on average less than 40% of the herbage on offer to them. The effects of the three herbage allowances on the yield of residual herbage are illustrated in the photographs on page 113. Cows offered the lowest allowance grazed very close to the ground (mean residual yield 750 kg DM $ha.^{-1}$) (Plate A). The residual herbage remaining after grazing at the moderate allowance (1550 kg DM $ha.^{-1}$) contained a far greater amount of leaf and larger areas of pasture left ungrazed around dung patches (Plate B). This effect was extended further when cows were offered the highest allowance, with the photo showing longer clumps of ungrazed pasture (mean residual yield = 1850 kg DM $ha.^{-1}$). (Plate C).

Other researchers have noted similar effects from increasing herbage allowance on residual herbage yields. Greenhalgh et al. (1966) noted that the most obvious difference in pastures that had been grazed by cows offered different herbage allowances was in the height of the post-grazing stubble. Few researchers have considered the longer term effects of the levels of residual herbage achieved after one grazing on the utilization of herbage at the following grazing. Gibb and Treacher (1976) felt that herbage allowances which resulted in less than 40% of the herbage offered being consumed might be impractical from a pasture management point of view.

Plate A. Residual herbage yield, Low allowance, 860 kg DM ha^{-1} (Mean 750 kg DM ha^{-1})

Plate B. Residual herbage yield, Moderate allowance, 1350 kg DM ha^{-1} (Mean 1550 kg DM ha^{-1})

Plate C. Residual herbage yield, High allowance, 1670 kg DM ha^{-1} (Mean 1850 kg DM ha^{-1})

Greenhalgh (1970) conducted the only experiment in which different herbage allowances have been applied in the long term and measurements of herbage consumed and herbage grown were made. Three herbage allowances were offered to dairy cows throughout an entire grazing season. The lowest herbage allowance offered throughout the grazing season resulted in the highest milk production per ha. and did not significantly reduce intake per cow. At the highest herbage allowance there was slightly increased production per cow, but Greenhalgh measured a deterioration in the nutritive value of the sward as the grazing season progressed and a decline in the amount of herbage grown. Higher yields of residual herbage remaining after grazing at the highest allowance did not provide an advantage in pasture growth rate or in the maintenance of sward nutritive value.

It is beyond the scope of this discussion to comment on the effects of intensity of defoliation on sward characteristics. Lenient defoliation has been shown to lead to faster regrowth of pasture, than more severe defoliation (Brougham, 1956, 1960), but Campbell (1966) showed there was increased loss of herbage DM in the sward through senescence and decay as a result of lenient grazing Tainton (1974) measured losses due to decay amounting to 25% of the gross production in pastures laxly grazed in the spring and early summer by sheep. Matthews (1979) suggests that lenient grazing, the nature of which was illustrated by the residual yields left behind when cows were offered the highest allowance in this experiment, may in fact provide no added growth advantage over more intensively grazed pastures. Additionally he felt that lenient grazing is likely to cause a pasture quality deterioration at future spring grazings. Lenient grazing to meet cow requirements in early spring may not enable farmers to efficiently utilize the pasture DM that is grown, and may not enable the growth of high quality pasture throughout the spring and early summer. Hockings (1979) points out that a great danger in ensuring unrestricted feeding in early lactation, (high herbage allowances), is that the overall stocking rate will be too low to take advantage of the feed available later in the spring. These claims have yet to be backed up by grazing experiments.

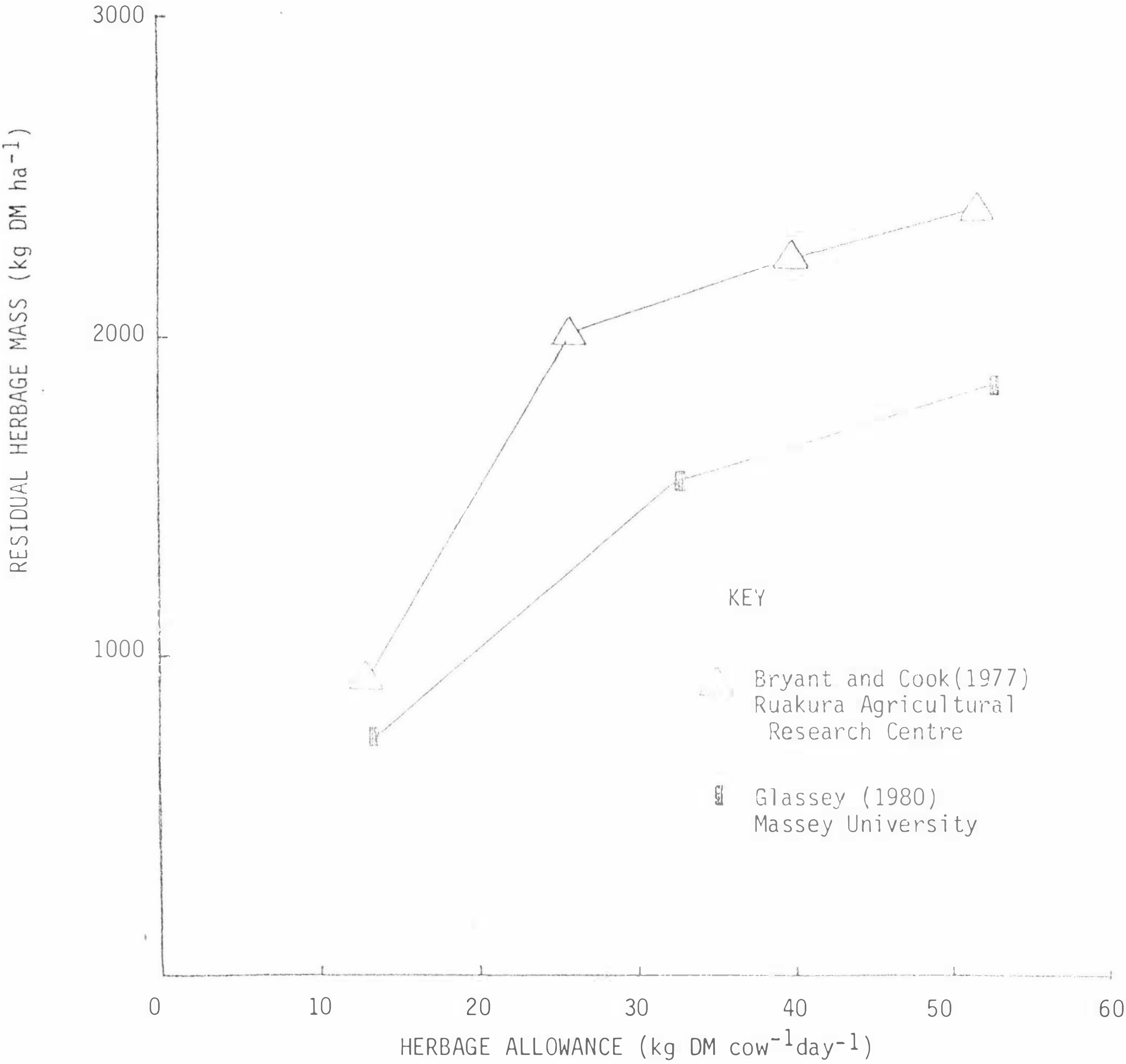
While experimental evidence on the losses in pasture dry matter due to decay, and losses in pasture quality as a result of lenient grazing of dairy cows in early spring is lacking, it is apparent that such processes are likely to occur in spring pastures. The question remains as to what happens to the milk yield of cows when they are restricted in early lactation in order to improve pasture management, and can this pasture management be achieved without reducing intake per cow and milk production?

There has been some interest in the yield of residual herbage remaining after grazing as a means of determining the level of intake of grazing livestock. Tayler (1966) showed that the herbage intake of cattle declined when the height of stubble remaining on grazed areas fell below 9.7 cm, and there have been a number of estimates made to determine the critical yield of residual herbage below which herbage intake or animal performance will decline (Baker, 1976). Nottingham (1978) found that intake, condition score and liveweight changes were significantly correlated to the level of residual herbage and suggested that residual herbage might be a more useful means of assessing dairy cow requirements than herbage allowance because it did not require the area being grazed to be known. Holmes (1980), evaluating data from three experiments, (including the data analysed by Nottingham (1978)), also noted that intake increased with residual herbage yield so that intake could be predicted from observations of the intensity of grazing each day. But the intakes obtained at a particular residual herbage yield were different in each experiment (see Figures 1.2 and 1.3). Levels of residual herbage yield were altered according to the pre-grazing herbage yields, and while herbage intake was not altered by offering the same herbage allowance on pastures of differing yield, post-grazing residual yield changed. The same doubt that herbage allowance expressed as kg DM cow^{-1} adequately describe all the characteristics of a pasture that influence herbage intake, must apply also to residual herbage yield expressed as kg DM ha^{-1}. There is increasing evidence that the spatial distribution of tillers within a sward in terms of density, length and height can, in some circumstances, be a more important influence on intake than the amount of herbage present per unit area (Baker, 1976; Le Du et al., 1976).

The residual yields of herbage obtained from this experiment were not analysed for any possible relationship with herbage intake because of the large amount of variation in the relationship. This variation was particularly evident at the high levels of residual herbage yield. Undoubtedly some of this variation could be attributed to the variation in the herbage yields of the pastures used in the experiment, before they were grazed (see Table 2.2). Holmes (1978) speculated that attempting to determine the critical weight or height of pasture below which intake declines will depend upon whether or not the pasture remaining at any particular stage of grazing contains a lot of leaf left ungrazed or material that is largely stem. He contends it is probable that the animal would be prepared to graze lower on material that is leafier close to the ground than stemmy close to the ground. On the same basis Matthews (1979) contends that cows offered shorter leafier pastures may be able to maintain intake while grazing to low yields of herbage dry matter. However there is little experimental evidence to support this contention.

There is a noticeable difference in the yields of residual herbage reported by Bryant and Cook (1977) and those found in this experiment despite similar herbage allowances. The data from the two experiments are compared in Figure 4.2. At any herbage allowance there were considerably greater quantities of residual herbage measured to ground level on the pastures at Ruakura compared with the pastures at Massey University. This seems to reflect the difference in pasture compostion between the two research centres. Ruakura pastures contain paspalum species in addition to ryegrass and white clover, and this is a possible factor causing differences in the levels of residual herbage after the same grazing intensity has been applied. The Ruakura pastures also had a higher DM yield before grazing (3100 c.f. 2700 kg DM ha^{-1}) which may account for some of the difference between the residual herbage yields. The comparison appears to support the contention that an estimate of DM yield per ha. is inadequate in itself as a description of the 'availability' of

Fig.4.2 A comparison of residual herbage yields obtained at various herbage allowances by Bryant and Cook (1977) and from the present experiment.



herbage to the grazing animal. At Ruakura it seems that cows were unable to graze to levels of DM yield as low as the cows at Massey University and this may explain the lower intake figures obtained at Ruakura for a given herbage allowance.

4.1.5 Herbage Allowance and the Quality of Selected Herbage

The relationship between herbage allowance and animal performance may be a function of the quality of the herbage selected by the animal as well as the quantity on offer (Hodgson, 1977). The estimated crude protein content of the diet selected by cows was significantly greater for the cows offered the high allowance than for the cows offered the low allowance, ($P < 0.01$) (Table 3.7). This suggests that as herbage allowance increased there was greater opportunity for the cows to select herbage of a higher crude protein content. Additionally the crude protein content of the residual herbage decreased as the herbage allowance decreased. As herbage allowance decreased cows were forced to graze material of a lower crude protein content, as they grazed closer to the ground.

The mean estimate of the N% of the total DM offered was 3.12% and this appears to be a typical value for temperate pasture species in the spring (Lyttleton, 1973). The estimates of the N% of the DM consumed at each allowance were 3.5, 3.9 and 4.3% for the low, moderate and high allowances respectively. These values are higher than the N% of the total DM offered, and may reflect the cow's preference for material of high N content. Pasture leaf blade generally contains more protein than the leaf sheath or stem (Laredo and Minson, 1973) and the trend towards higher N contents of the herbage consumed is perhaps a result of more leaf than stem being consumed as herbage allowance increased (Stobbs, 1977).

There were no significant differences in the acid detergent fibre concentrations of the herbage consumed or the herbage remaining after grazing amongst the three allowances. The estimates of the ADF content of the herbage consumed indicated that cows grazed herbage of a lower fibre content than the total herbage on offer, irrespective of the allowance offered.

Van der Kley (1956) measured a decrease in the crude protein content of the diet of cows as they were required to graze from DM yields of 2880 kg ha^{-1} to 670 kg ha^{-1} over a period of several days. In the same experiment he measured an increase in the fibre content of the herbage consumed as cows grazed lower into the sward. Eldridge (1973) noted a decline in the protein content of the herbage selected by lactating dairy cows for each day they spent grazing a particular pasture. The decline in protein content of the diet was associated with a drop in all components of milk production over the same period. Stobbs (1977) also measured a higher N content ($P < 0.01$) of the herbage selected by cows grazing at high rather than low herbage allowances on tropical pastures. This was a result of increased selection for leaf rather than stem as allowance increased.

While the data from this present experiment confirm that the relationship between herbage allowance and animal performance includes a quality factor as well as a quantity factor, the significance of the ability of cows to select diets higher in crude protein percentage as herbage allowance increases is unclear. We do not know whether the cows are in fact selecting for herbage with higher levels of N, or whether this is just coincidental with selection for other characteristics. It is also unclear whether selection of herbage of a higher N content provides cows with any great advantage over eating the same amount of herbage of a lower N content. M^ac^Rae (1976) suggests for ruminants consuming large quantities of fresh pasture in which the protein is highly soluble, that the extent of degradation of soluble protein to amino acids and ammonia in the rumen is likely to exceed the capacity of rumen microbles to utilise these metabolites for microbial protein production. As a result large amounts of excess ammonia will then be absorbed and excreted as urea in the urine. This could well be the fate of the extra N consumed by the cows offered the highest allowance.

Several researchers have examined the effects of herbage allowance on the organic matter digestibility of the herbage selected by grazing dairy cows. Greenhalgh et al. (1966) estimated the digestibility of organic matter selected at different herbage allowances from the concentration of N in the faeces of each cow. Increases in herbage allowance resulted in an increase in the digestibility of organic matter from 75.0 to 75.7%. While this was statistically significant the authors felt this had little nutritional significance. Stobbs (1977) measured the digestibility of the herbage selected at different allowances of tropical pasture using cows fistulated at the oesophagus. Organic matter digestibility of herbage increased from 63.5% at a daily allowance of 15 kg DM cow^{-1} to 66.8% at a daily allowance of 55 kg DM cow^{-1}. Combellas and Hodgson (1979) also measured a significant increase in the organic matter digestibility of the herbage selected by cows as daily allowance increased from 30 to 90g DM kg LW^{-1}. The extent of this change was small, the change being from 79.2% to 80.3% as allowance increased.

The in vitro estimates of organic matter digestibility of the herbage in this experiment, (see Table 3.8), were applied to an equation designed to calculate the OM digestibility of herbage consumed from estimates of DOM before and after grazing (Walters and Evans, 1979). Realistic estimates of the organic matter digestibility of the diet selected by cows were not obtained, casting some doubt on the realiability of the in vitro estimates of digestibility. However, if the trends in organic matter digestibility reflected in Table 3.8 are correct they suggest that as herbage allowance decreased, cows were forced to consume herbage of lower digestibility as they grazed to lower levels of residual herbage yield but there are insufficient data to be able to draw firm conclusions.

4.2 Herbage Allowance and Milk Production

4.2.1 Short-term Effects on Milk, Fat and Protein Yields

The discussion in the previous section (Chapter 4.1), raised the question as to whether maximising herbage intake of the grazing dairy cow in early lactation is desirable from the point of view of the amount of herbage that has to be offered per cow, the herbage mass remaining after grazing and the resulting decreases in stocking rate required to achieve these allowances. The answers to these questions will depend upon the magnitude of the gain in milk production per cow as a result of increasing herbage intake, assessed in the short-term, and in the longer-term because of possible carry-over effects of feeding level on subsequent milk production (Broster, 1972).

The experimental cows had calved on average 42 days before the experiment commenced and calved with a mean body condition score of 4.9, (I.M. Brookes, pers. comm.). It was apparent that the experimental cows were underfed in the 42 days following calving. Mean daily fat yields dropped from 0.78 kg milkfat per cow to 0.68 kg milkfat per cow in the four weeks immediately prior to the experiment. During this period body condition was lost so that cows entered the experiment with a mean body condition of 3.9. The period of underfeeding between calving and the start of the experiment may have affected the milk production responses of the cows during the experimental period (Patchell, 1957; Broster, 1972; Bryant and Trigg, 1979).

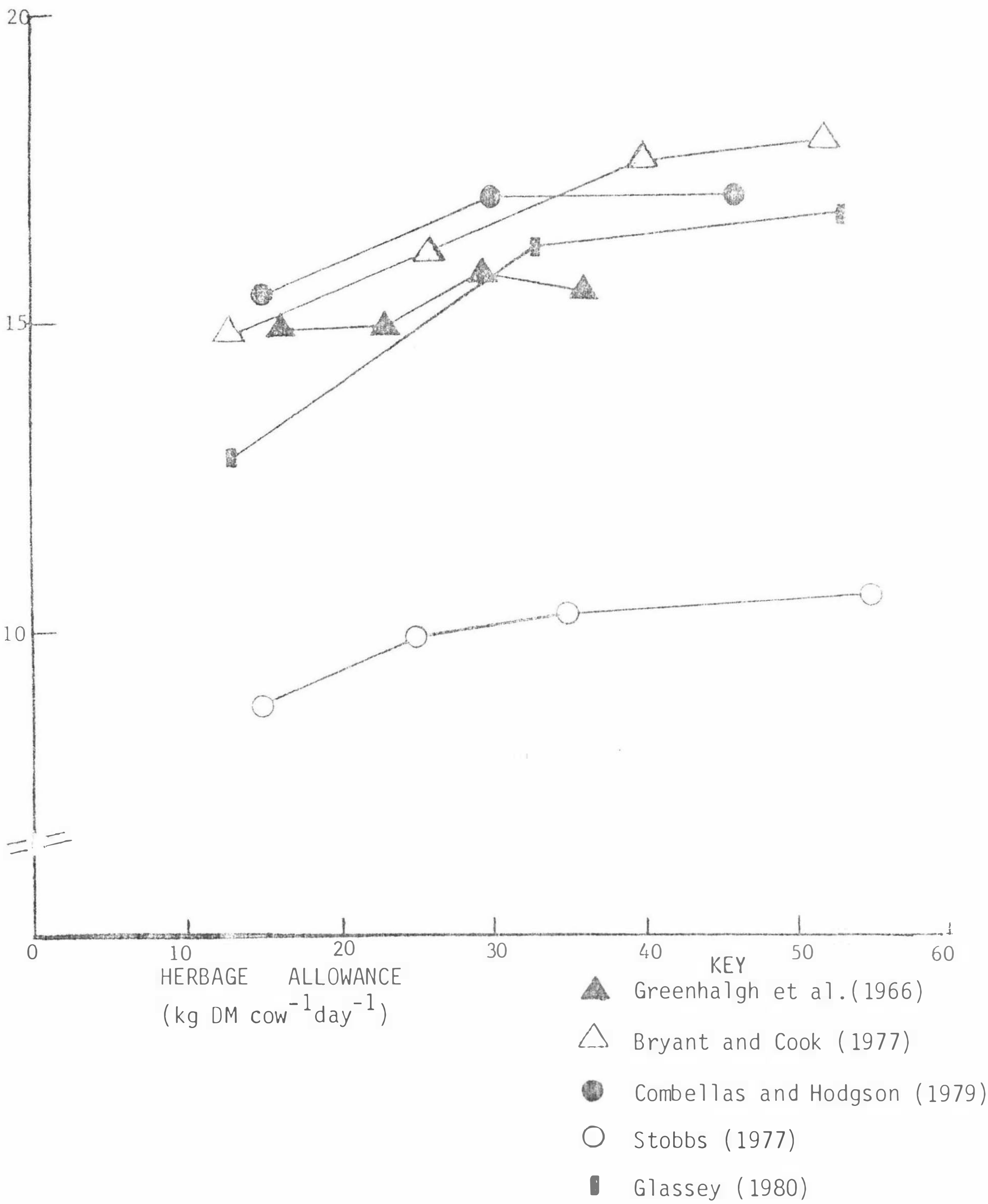
The experimental period consisted of 32 days of differential feeding through offering the three different daily herbage allowances. No significant differences in milk, fat and protein yield between the cows offered the high and moderate allowances occurred during this 32 day period. An increase in mean daily herbage allowance from 33.2 to 52.7 kg DM cow^{-1} yielded only an extra 0.5 litres of milk and an extra 0.03 kg MF cow^{-1}day^{-1}. This suggests that the experimental cows were not responsive to the extra herbage offered above 33 kg DM $cow^{-1}day^{-1}$.

In Figure 4.3 some of the experimental relationships between herbage allowance and milk yield are plotted. While there are limitations to the data with respect to the differing stages of lactation of the cows and differences in their genetic merit for milk production, it appears that there is very little return in terms of milk yield per cow for each extra kg of feed offered above a daily herbage allowance of approximately 30 kg DM cow^{-1} day^{-1}, for any of the experiments described. The cows that were most responsive to the extra herbage offered were those at the earliest stage of lactation, (Bryant and Cook, 1977), and there seemed to be no response in terms of milk yield from cows in mid-lactation (Combellas and Hodgson, 1979). This corresponds to the experimental evidence that the responsiveness of milk yield to variation in intake decreases as the cows move further through lactation (Broster et al. 1969).

A means of assessing the responsiveness of the cow to the extra feeding is to examine the input-output relationship in terms of kg DM intake per kg milkfat produced. The cows offered the highest allowance consumed 22.6 kg DM per kg milkfat produced, compared with 21.4 kg DM and 17.2 kg DM per kg milkfat for the cows offered the moderate and low allowances respectively.

The extra DM consumed by the cows offered the moderate allowance to produce 1 kg extra milkfat over that produced by the cows offered the low allowance was 42.6 kg DM per kg milkfat. (i.e. $\frac{25 \text{ days @ } 4.7 \text{ kg DM cow}^{-1}}{2.76 \text{ kg MF cow}^{-1}}$). The equivalent figure for the extra milkfat produced by cows offered the high allowance over that produced at the moderate allowance was 48.1 kg DM per kg extra milkfat. C. Grainger (pers. comm.) has measured the short-term marginal response to extra feed offered to cows in early lactation. An extra 35.6 kg DM was consumed per kg extra milkfat produced, for a cow at condition score 5 at calving. This suggests that the cows used in the present experiment were less responsive than those

Fig. 4.3 Some experimental relations between herbage allowance and milk yield



used by Grainger, either for genetic reasons or because of their previous nutritional history.

The data show that as herbage allowance increased the cows became less efficient in terms of the DM consumed per kg milkfat produced. In addition it required increasing quantities of DM to produce an extra kg milkfat as herbage allowance was increased, (i.e. a diminishing returns response). The decrease in efficiency occurred despite the measured and presumed increase in the quality of the DM consumed as herbage allowance was increased.

An explanation of the apparent lack of responsiveness in terms of milk production to the increased feed offered may be in the underfeeding of the experimental cows immediately after calving. The partitioning of dietary energy between milk production and liveweight change may be altered by a previous period of underfeeding (Flux and Patchell, 1954; Wallace, 1957; Patchell, 1957; Broster et al., 1969; Bryant and Trigg, 1979). The previous underfeeding may have contributed to a loss of potential milkfat yield of the experimental cows and increased liveweight gain at the expense of milk production. The liveweight and condition score data for the cows offered the high and moderate allowances would support the contention that they were partitioning energy into liveweight gain. The decreasing efficiency of the utilization of the DM consumed for milk production as allowance was increased is probably related to the increased amount of dietary energy being used for liveweight gain.

Another factor that could influence the responsiveness of dairy cows to variation in herbage allowance is the genetic potential of the cows. It has been claimed that a potentially higher yielding cow will produce more milk from a given amount of feed (Broster, 1976) than a lower yielding cow, and this suggests that a different relationship between herbage allowance and milk yield may exist than that shown in Fig. 4.3, where cows were producing in the range of 15 - 18 litres of milk per cow. Broster (1972) concluded that the response of milk yield to the level of feed intake is directly related to the cows initial milk yield. While Combellas and Hodgson (1975) were unable to show that two groups of cows with different milk yields as a result of previous nutrition, responded differently to variation in herbage allowance, they did show that the cows they used were more sensitive to reductions in herbage intake than the lower yielding cows used by Greenhalgh et al. (1966). There is little experimental evidence as yet to support the hypothesis that high yielding cows will be more responsive to high herbage allowances and the limited evidence available from the present experiment does not add any weight to the hypothesis.

By offering the high allowance rather than the moderate allowance, then on a per ha. basis we are grazing 32 fewer cows each day (Table 3.1). The amount of production lost per ha. each day, even taking into account the slight but non-significant lift in production per cow at the high allowance, would be 493 kg milk, 20.9 kg milkfat and 17.4 kg milk protein per ha.. Production per unit area was declining at a faster rate than production per cow was increasing. A recognition of the longer-term benefits of increased production per cow at this stage of lactation (Broster, 1972) cannot be excluded and this will be discussed in the following section. In the short-term however there was a substantial loss of production per unit area through the decrease in grazing intensity required to achieve the high herbage allowances. The data emphasises the importance of achieving a compromise between stocking rate and production per cow. As Hockings (1979) suggests, a danger in trying to achieve a high peak milk production was that stocking rate might become too low in order to utilize the pasture grown in the remainder of the dairy season. Some possible effects of the lax grazing intensity resulting from offering high herbage allowances have already been discussed (Chapter 4.1.4).

Further increases in daily milk production per unit area were obtained by restricting herbage allowance to a mean of 13.5 kg DM $cow^{-1} day^{-1}$. In this instance production per cow was significantly reduced in the short term. The effects of the reduction in herbage allowance appeared to progressively reduce milk, fat and protein yields over the experimental period. Additionally some of the milk production was achieved at the expense of cow liveweight and body condition. What effect would feeding cows at this grazing intensity have on production per cow and per ha. if it were to be sustained?

The only available data where herbage allowances have been offered over a sustained period of time comes from Greenhalgh (1970). A daily allowance of approximately 15 kg DM $cow^{-1}day^{-1}$, offered throughout a grazing season, resulted in the highest production per ha. without significantly reducing production per cow, when compared with daily allowances of 23 and 30 kg DM cow^{-1}. The cows used were in mid-lactation prior to being allocated to their herbage allowances, with the possibility that the restriction had less effect on milk production at this stage of lactation. Additionally this milk production was sustained at the expense of liveweight and this might necessitate additional inputs of feed later in lactation or during the dry period in order to recover body condition, although the data of Greenhalgh et al. (1967) suggests that the effects of herbage allowance on liveweight may be more severe in the short-term than the longer term.

4.2.2 Long Term Effects on Milkfat Yield

The long term effects of variation of herbage allowances offered in early lactation need to be considered because of the importance of early lactation milk production on production in the remainder of the lactation (Broster, 1972). In Table 3.13 the effects of the three herbage allowances offered on milkfat yield throughout the lactation are summarised. Despite the significant effect caused by the variation in herbage allowance in the short-term, there was only a very slight and non-significant effect in the long term. It should be noted that a very large difference in milkfat yield during the post-experimental period would have been required for significant residual effects on milkfat yield to be found (LSD ($P = 0.05$) = 28.3 kg milkfat). This is probably related to the small number of cows used in the experiment and the variation in the persistence of their lactations. Even so, the actual losses of milkfat production in the post-experimental period were small and not consistent with the levels of feeding imposed earlier. This agrees with the conclusion of Bryant and Trigg (1979) that the losses in production subsequent to underfeeding in early lactation are small and do not persist throughout the remainder of the lactation.

Earlier experiments had found larger residual effects from the underfeeding of dairy cows in early lactation. Flux and Patchell (1954) and Wallace (1957) found residual effects on milkfat yield of up to 3.0 - 3.4 times the immediate effects of underfeeding in early lactation (see Table 1.2). As a result of these experiments the New Zealand dairy farmer has been advised to have as his objective high levels of feeding for dairy cows early in lactation because of the penalties of underfeeding at this time (Gernig and Young, 1961). There is a good deal of other experimental evidence to support these experiments, (Broster 1972, Broster and Strickland 1977). However other experiments have failed to show residual effects of the same magnitude as those produced in the above mentioned experiments (Gleeson, 1973; Gordon, 1976; Bluett 1977; Grainger and Wilhelms, 1979; Bryant and Trigg, 1979).

In this experiment the small number of cows apparently placed a limitation on the likelihood of finding a residual effect from underfeeding. Despite this, there may be biological reasons as to why differences in the size of the residual effect occur between experiments. Differences between experiments exist in, (1) the magnitude and duration of the underfeeding in early lactation, (2) the timing of the underfeeding in relation to calving, and (3) the feedstuffs used. Overall there appears to be a poor understanding of factors affecting residual effects from underfeeding in early lactation.

The experiments of Flux and Patchell (1954) and Wallace (1957) did not define in exact terms the two levels of feeding imposed in early lactation. The depression in milkfat yield in these experiments was comparable to the depression caused by offering the low rather than the moderate allowance in the present experiment, (0.06 - 0.14 kg MF $cow^{-1} day^{-1}$). More severe restrictions on pasture intake and milkfat yield were placed on cows in the experiments of Grainger and Wilhelms (1979) and Bryant and Trigg (1979). Grainger and Wilhelms (1979) restricted cows to an intake of 7 kg DM $cow^{-1} day^{-1}$

for periods of up to 10 weeks of lactation. This resulted in twice the depression in milkfat yield caused by restricting pasture intake to 9.6 kg DM $cow^{-1} day^{-1}$ in the present experiment. Despite the more severe intensity and duration of the underfeeding in the experiment of Grainger and Wilhelms (1979) they were unable to find the residual effects of the same magnitude as those reported by Flux and Patchell(1954) and Wallace (1957). From the evidence available, the magnitude of the immediate loss of milkfat yield due to underfeeding does not appear to be a factor that influences the size of the residual effect.

The cows in this present experiment were on average in their sixth week of lactation at the start of the differential feeding. The experiment by Broster et al. (1975) would suggest that the level of feeding in the first four weeks after calving was the most important period in determining the whole lactation yield. It is possible that the different herbage allowances were offered to the cows in this experiment at a stage in their lactations which would have a smaller effect on their subsequent yields than an earlier restriction. But the data of Grainger and Wilhelms (1979) suggest that the timing of underfeeding in the first ten weeks of lactation had little effect on lactation performance, (i.e. little difference between underfeeding in weeks 1 - 5 or weeks 5 - 10). Bryant and Trigg (1979), severely underfed cows in the first six weeks after calving but were unable to find residual effects on milkfat yield 12 weeks after underfeeding ceased. There does not appear to be enough consistent evidence to suggest that differences in the magnitude of residual effects found between experiments could be attributed to differences in the timing of underfeeding during the first ten weeks of lactation.

The diet of the cows used in the experiments by Broster consisted of a basal ration of hay and/or silage supplemented with concentrates until the cows were put out to graze in mid to late lactation. In experiments conducted in Ireland (Gleeson, 1970, 1973; Gordon, 1976, 1977), the underfeeding of cows occurred on similar diets immediately after calving, but cows were turned out to graze at a much earlier stage of lactation. These experiments did not find large residual effects from the early lactation underfeeding.

Gleeson (1970) noted reduced residual effects from underfeeding spring calving cows compared with autumn calving cows. This was attributed to the spring calving cows being turned out to graze sooner than the autumn calving cows. Gordon (1977) also felt that residual effects were reduced when cows were grazed soon after a period of underfeeding. While the experiment of Grainger and Wilhelms (1979) would add further evidence to support this contention, the experiments by Flux and Patchell (1954) and Wallace (1957) do not. There is no evidence to suggest why the pasture feeding of dairy cows, that were previously underfed should enhance their ability to recover from underfeeding.

Clearly there is a poor understanding of factors affecting residual effects from underfeeding in early lactation, despite the amount of experimentation conducted on the topic. There are several possible reasons which may explain some of the different results found between experiments. Flux and Patchell (1954) found a large residual effect overall, but this was not statistically significant which suggests that a repetition of the experiment with a different group of cows may have found no residual effect at all. There was a considerable amount of variation between sets of twins in their ability to recover from underfeeding. Some cows were able to recover all the production lost while they were underfed and produce as much in the lactation as their twin sisters which had not been underfed. This variation in the dairy cow population twenty-five years ago may not be evident in the dairy cow population today because of selection over this time for cows with more persistent lactations. Survey figures (N.Z. Dairy Board, 1977) show that the mean lactation length of all cows herd tested, has stayed the same in the last 20 years but there has been an increase in milkfat production of 10 kg milkfat cow^{-1}.

Many experiments that have examined early lactation nutrition have been carried out with a high proportion of first calving heifers (Broster, 1972; Flux and Patchell, 1954; Wallace, 1957). First calving heifers may respond differently to early lactation underfeeding than mature cows, and this might explain some of the difference between experiments.

It is apparent that there is a change in the partitioning of dietary energy by dairy cows as a result of underfeeding in early lactation (Bryant and Trigg, 1979). Whether this is important in terms of a residual effect on milk and milkfat production over the whole lactation is still not clear. Differences in the genotype of cows, the body condition of cows at calving, the age of cows, and the levels of feeding imposed later in lactation may have contributed to differences between experiments in the size of the residual effects found. More investigations are probably required to further define possible contributing factors to residual effects. If residual effects from underfeeding in early lactation are small then there may be considerable flexibility for variation of herbage allowance in early lactation.

4.2.3 Summary: Herbage Allowance and Milk Production

The data from this experiment suggest that a compromise is necessary amongst the need for high levels of milk production per cow in early lactation, high yields of milk solids per ha., and the agronomic requirements for pasture production. The increase in yield per cow of milk and milk solids as herbage allowance increased was much smaller than the corresponding decrease in the yield of these per hectare. The reduction in yield per ha. may have resulted from a decrease in the percentage of DM harvested, and from the large increase in pasture intake necessary to induce an increase in the yield of milk, milkfat and milk protein per cow.

The experimental data are consistent with other herbage allowance experiments in that little extra milk yield per cow was obtained when cows were offered herbage allowances in excess of 30 kg DM cow^{-1} (Fig. 4.3). Combellas and Hodgson (1979), were unable to obtain any increase in milk yield from cows in mid-lactation when herbage allowance offered was greater than 60 kg DM kg LW^{-1}. Therefore the offering of 160g DM kg LW^{-1} as opposed to 100g DM kg LW^{-1} in this experiment, while, offered to cows much earlier in their lactation, would not be expected to result in large gains in milk yield.

While these data, and the data of Greenhalgh (1970) suggest that production per unit area is maximised by restricting cows to daily allowances of 13 - 15 kg DM cow^{-1}, this should not be interpreted as a desirable grazing intensity unless the longer term effects of this level of feeding are considered. The drop in milk production per cow in this experiment was severe (17 - 20%), and milk production was at the expense of liveweight and body condition. McMeekan and Walshe (1963) calculated that maximum production per ha. could be sustained when production per cow was depressed by 10 - 12% of what could be achieved by lenient grazing.

The present experiment did not attempt to examine whether the low allowance, if offered over a sustained period, would maximise production per ha.. But an examination of any residual effect of this level of feeding on production per cow was conducted. Residual effects on milkfat production did not occur because of the variation of herbage allowance, but a lack of understanding of the factors affecting residual effects from underfeeding in early lactation is apparent. The longer term effects of variation of herbage allowance on liveweight and condition score change were not intensively measured. The possible effects of a restriction of herbage allowance in order to increase production per unit area at any stage of lactation, may be a requirement for extra inputs of feed at another stage of lactation in order to maintain animal health and efficient animal production.

The data suggest that there may be considerable flexibility in the feeding of the dairy cow in early lactation. The higher the herbage allowance the farmer is able to offer a herd of cows the more production per cow he will obtain. But an objective of early lactation management should not be the achievement of such high herbage allowances that stocking rate is decreased to a point that production per ha.is sacrificed, and the utilization of pasture DM falls. If the farmer were to find himself in a position to offer herbage allowances in spring that meant that there was a low level of herbage utilization he might have to consider how to utilize the considerable amounts of residual herbage remaining after grazing.

On the other hand for the farmer facing a feed shortage, the data would suggest that herbage allowances as low as 13 kg DM cow^{-1} offered over short periods, while reducing production per cow in the short-term, may not have serious detrimental effects on the whole lactation milkfat production provided adequate high quality feed is available subsequently. Milk production at these low allowances will be at the expense of body condition, and extra inputs of feed may be required at other times to compensate for this loss in condition. The effect of underfeeding at this stage of lactation on fertility, while not examined in this experiment must also be considered (Grainger and Wilhelms, 1979).

4.2.4 Herbage Allowance and Milk Composition

The mean effect of variation in herbage allowance on the milkfat content of milk was not significant, although in two of the five weeks the cows offered the low allowance did have significantly higher ($P < 0.05$) milkfat contents than one of the other groups of cows. It is possible that there was too much within treatment variation in milkfat content caused by the mixture of breeds used, to be able to find significant effects due to a variation in herbage allowance. The experimental design did not allow for the breed effects to be isolated.

Significant changes in the milkfat content caused by variations of herbage allowance have been found in other experiments. There was a significant rise in the milkfat content of milk produced by the cows offered the lowest allowance in the experiment by Greenhalgh et al. (1966). Restriction of herbage allowance also resulted in increased milkfat contents in the experiments by Flux and Patchell (1954), Grainger and Wilhelms (1979), and Bryant and Trigg (1979). There were no significant effects of variation of herbage allowance on the milkfat content in the experiments by Stobbs (1977), or Combellas and Hodgson (1979), although Stobbs measured significant increases in the proportions of long chain fatty acids in milkfat as herbage allowance decreased. Bryant and Cook (1977) found that the milkfat content increased slightly when herbage allowance offered was greater than 40 kg DM cow^{-1}. Bryant's data suggest that there may be effects of stage of lactation on the response of milk composition to herbage allowance variation (Bryant, 1979). In early lactation both the milkfat and milk protein concentrations decreased as herbage allowance decreased, whereas later in their lactation both of these increased as herbage allowance was decreased.

There appeared to be little or no longer-term effect of the restriction of intake on the milkfat content during the remainder of the lactation. In the week immediately after the variation of herbage allowance ceased the milkfat concentrations of those cows that were previously restricted were slightly but not significantly lower than those cows that were offered the high and moderate allowances. This trend did not continue however. Some other researchers have noted a significant depression in milkfat content following a restriction of herbage intake in early lactation (Grainger and Wilhelms, 1979; Bryant and Trigg, 1979).

It is apparent that the effect of variation of herbage allowance on the fat concentration in milk is not large, but may be significant in some instances depending upon such factors as the stage of lactation, the body condition of the cows, and the mixture of breeds used in the experiment. Bryant (1979), calculated that a 50% reduction of intake increases on average the fat content of milk by 0.4 units. Restriction of herbage allowance would have to be very severe before a 50% reduction in herbage intake could be achieved.

The effect of the variation of herbage allowance on the milk protein content was more pronounced than the effect on milkfat content. While there was no significant difference in the protein content of the milk produced by the cows offered the high and moderate allowances, the restriction of herbage allowance to 13.5 kg DM cow^{-1} resulted in a significant reduction of milk protein content, (0.3 units, $P < 0.01$), and milk protein yield. Similar responses to the variation of herbage allowance on milk protein content were obtained by Stobbs (1977), Bryant and Cook (1977), Grainger and Wilhelms (1979) and Bryant and Trigg (1979). There were no significant effects of variation of herbage allowance on milk protein content in the experiments by Greenhalgh et al. (1966) and Combellas and Hodgson (1979).

The lack of response of milk protein content and yield to an increase in daily herbage allowance above 33 kg DM cow^{-1} occurred despite the increase in the energy and crude protein intake. As herbage allowance increased smaller proportions of the dietary N were recovered as N in milk protein suggesting that there was increased use of dietary N for functions other than milk production, or increased wastage of dietary N. Paquay et al. (1973) noted that in some instances the increased N consumption of dairy cows only served to enhance the urinary N output, and did not alter milk or milk protein yields.

The examination of any possible carry-over effect of underfeeding on milk protein yield was not possible, as the milk protein content of the milk produced in the post-experimental period was not measured.

4.2.5 Liveweight and Body Condition Changes

The two methods used to examine liveweight change during the experimental period provided some conflicting trends in liveweight change during the experiment. The use of unfasted weights showed that the cows offered the low allowance lost liveweight at the rate of 0.3 kg cow^{-1}day^{-1}. While this could be attributed to the effects of gut-fill, the measured loss of body condition would support the unfasted liveweight data.

In contrast, the use of fasted liveweights suggested that the cows offered the low allowance had gained weight slightly. The method of fasting and weighing used was similar to that reported by Bryant (1977b). The problem with using this method came at the end of the treatment period when there were three groups of cows with three different levels of gut-fill. It was felt that fasting the cows immediately would bias the weights in favour of the cows previously offered the high allowance, as they had the larger gut-fill and 18 hours would not be sufficient for them to loose it all. It was decided to allow the cows to equalize their gut-fill by having them graze together for three days. The result of this was that the cows previously offered the low allowance restored their gut-fill to levels where after fasting the cows weighed more than they had three days previously without fasting. Because the unfasted liveweight data corresponded more closely to the condition score data, it was felt that it would be used as the estimate of liveweight change given the limitations caused by differing gut-fill.

The difference in the rate of liveweight change between the cows offered the high and moderate allowances was signficant at the 10% level, and was the only significant difference between the two groups of cows caused by the variation of herbage allowance. This difference supports the estimates of herbage intake made for these groups of cows which suggest that the cows offered the high allowance consumed approximately 1.5 kg DM $cow^{-1}day^{-1}$ more than those offered the moderate allowance. The advantages from offering the high herbage allowance in terms of the better cow condition at the end of the treatment period have to be considered. There may be some longer term benefits from the higher herbage allowance if this difference in condition score (0.6 of one condition score) were to be maintained.

The monitoring of cow body condition and liveweight did not continue throughout lactation. An estimate of condition score was available for the cows one month before the end of lactation (3/4/79), this estimate being the mean of 33 scorers (I.M. Brookes, pers.comm.). At this stage of lactation there was very little difference amongst the three groups of cows in their mean body condition although the cows previously offered the high allowance were in slightly better condition overall (Table 3.17). During the lactation there had been a considerable improvement in the body condition of the cows previously offered the low allowance but there was no change and some loss of body condition for the cows offered the high and moderate allowances. This supports the data of Flux and Patchell (1954), Wallace (1957), Patchell (1957), Grainger and Wilhelms (1979), and Bryant and Trigg (1979), who all noted that cows that had previously been underfed and had lost liveweight appeared to compensate for this when returned to normal feeding, by having higher rates of liveweight gain.

There appeared to be no significant benefit from the extra cow condition obtained by offering the high and moderate allowances during the five week experimental period. The extra condition did not result in significantly higher body conditions towards the end of lactation, nor did it significantly increase milk production during the lactation, over those cows that had lost significant amounts of body condition during the experimental period.

4.3 The Response of Cows of Different Phenotypes to Variation in Herbage Allowance

The interest in the evaluation of the response of 'high' and 'low' producing cows has arisen because of the strong emphasis placed on the genetic improvement of the New Zealand dairy herd, through the N.Z. Dairy Board's artificial breeding service. Until recent studies at Massey University little information has been available about the production characteristics of cows of a high breeding index and cows of a low breeding index under the Dairy Board scheme.

In the United Kingdom it seems to be accepted that the cow of greater dairy merit produces more milk from a given amount of food and that there is greater milk response obtained per unit of extra food from such an animal (Broster, 1976; Broster and Alderman, 1979). In New Zealand there is no such evidence for cows of higher dairy merit (i.e. high breeding index), although there is already some evidence which showed that cows of high production index produce more than cows of low production index (Davey and Holmes, 1978). While cows of a known genotype were not available for this experiment, it was felt that an evaluation of the responses of cows of high and low production index to different herbage allowances could be made.

In the experiment cows that had been selected as 'high' producers based on their production index produced significantly more fat-corrected milk than those that had been selected as 'low' producers (see Table 3.18). Additionally the 'high' producers had significantly ($P < 0.1$) lower rates of liveweight gain than the low producers, suggesting that the partition of dietary energy in favour of milk production rather than liveweight change occured with the 'high' producing cows. The multiple regression equations supported this analysis with increases in lifetime production index having a negative but non-significant effect on liveweight gain and a negative effect ($P < 0.1$) on condition score change.

Broster and Alderman (1979) in a discussion of the nutrient requirements of the high yielding cow suggest that the higher the yield potential of a cow the greater is the output of milk from a given amount of food. That the higher yielding cows respond better to extra feeding is not supported by the evidence of this experiment. The fat-corrected milk production of the cows selected as 'high' producers did not differ significantly when these cows were offered the different herbage allowances. The 'low' producers increased their milk production by 0.155 kg FCM for each kg DM offered per cow ($P < 0.05$). The ability of high producing cows to maintain their milk production when offered the lowest allowance appears to be due to the greater loss of liveweight and condition score by these cows compared with those offered the higher allowances. It appears that body condition was lost in order to maintain milk production at a level which was not significantly different from the high producing cows offered the other allowances.

The information that could be obtained from this experiment was limited by the inability to measure individual DM intakes and by the limited number of cows used. Selecting 'high' and 'low' producing cows on the basis of lifetime production index, especially from an experimental herd, was not a wholly satisfactory way of determining cow merit. Some cows selected as 'low' producers had comparable levels of production with cows selected as 'high' producers when they were offered high pasture allowances, suggesting that production had previously been limited by previous experimental treatments.

The information obtained on the differing responses of cows of high and low phenotype from this experiment raises more questions than it answers due to the limited number of cows used, and the means by which cows were selected. The data does highlight some possible differences in the characteristics of milk production by cows of 'high' and 'low' merit for milk production.

CHAPTER FIVE

CONCLUSIONS

Mean daily herbage allowances of 53, 33 and 13.5 kg DM cow^{-1} resulted in mean herbage intakes of 15.8, 14.3 and 9.6 kg DM cow^{-1}. As herbage allowance increased the measurement of herbage intake became increasingly inaccurate, but the mean estimates of intake were considered satisfactory for the purposes of the experiment and were supported by data obtained by Vernon (1979) and estimates of energy balance. The relationship between herbage allowance and herbage intake was asymptotic with very little extra herbage intake obtained when cows were offered a daily herbage allowance greater than 33 kg DM cow^{-1}. A daily allowance of more than 33 kg DM cow^{-1} meant that the cows were consuming less than 40% of the herbage offered to them each day (Fig. 3.2). This meant high levels of residual herbage remained after grazing. Low grazing intensities brought about by offering high herbage allowances may present pasture management problems, and a subsequent deterioration of pasture quality, with little benefit to the cow in terms of extra herbage intake.

The data obtained in this experiment are consistent with other experiments relating herbage intake to herbage allowance (Fig. 4.1), although it is apparent that herbage allowance, expressed as kg DM cow^{-1} does not necessarily reflect the likely herbage intake from that allowance because of other pasture characteristics that influence herbage intake. Relating residual herbage yields to herbage intake also has limitations upon it caused by the characteristics of the herbage being grazed (Fig. 4.2).

Increasing daily herbage allowance resulted in an increase in the N content of the herbage that was selected by the cows. However the nutritional significance of this was not clear. As herbage allowance increased, the percentage of the N consumed by the cows that was recovered in milk protein fell. The data suggest that as herbage allowance increases, cows have a greater opportunity to select preferred herbage.

Increasing daily herbage allowance from 33 to 53 kg DM cow^{-1} did not result in any significant increase in milk, milkfat or milk protein yield per cow. On a per ha. basis, 32 less cows were grazing the high allowance each day, and the slight increase in production per cow was not sufficient to offset the loss in production per ha.. Production per unit area was further increased by restricting herbage allowance to 13.5 kg DM cow^{-1}, but this meant a significant loss in milk, fat and protein production per cow, as well as significant losses in cow liveweight and body condition. There was no effect of this restriction on milkfat production for the remainder of the lactation, although the limited number of cows used meant that finding a significant residual effect was unlikely. A poor understanding of the factors affecting residual effects caused by early lactation underfeeding is evident in the literature, although Bryant and Trigg (1979) have measured a change of energy partitioning in cows subsequent to underfeeding.

The response in milk production to herbage allowance was consistent with other experiments in that there was very little extra milk yield obtained by offering herbage allowances greater than 30 kg DM cow^{-1} for cows producing 15 - 18 kg milk day^{-1} (Fig. 4.3). Previous underfeeding may have limited the response of the cows to extra herbage offered in this experiment.

As herbage allowance increased the cows became less efficient in terms of the dry matter consumed per kg milkfat produced. This was probably related to the increased amount of dietary energy being used for liveweight gain as allowance increased.

Cows with a high lifetime production index produced more fat-corrected milk than cows with a low lifetime production index, at each herbage allowance. There were no significant differences in the FCM yield amongst the 'high' producers as a result of variation of herbage allowance, although the 'high' producers offered the low allowance lost considerable amounts of body condition to maintain their milk yields. The 'low' producers gained more liveweight, (or lost less liveweight) than 'high' producers at each allowance, and significantly reduced FCM yields as herbage allowance was decreased.

The data suggest that a compromise is necessary with respect to the need for high levels of milk production per cow in early lactation, high yields of milk solids per ha. and the agronomic requirements for pasture production. An objective of early lactation management should not be the achievement of high peak production per cow if this means that stocking rate is decreased to a point that production per ha. is sacrificed, and the utilization of pasture DM falls.

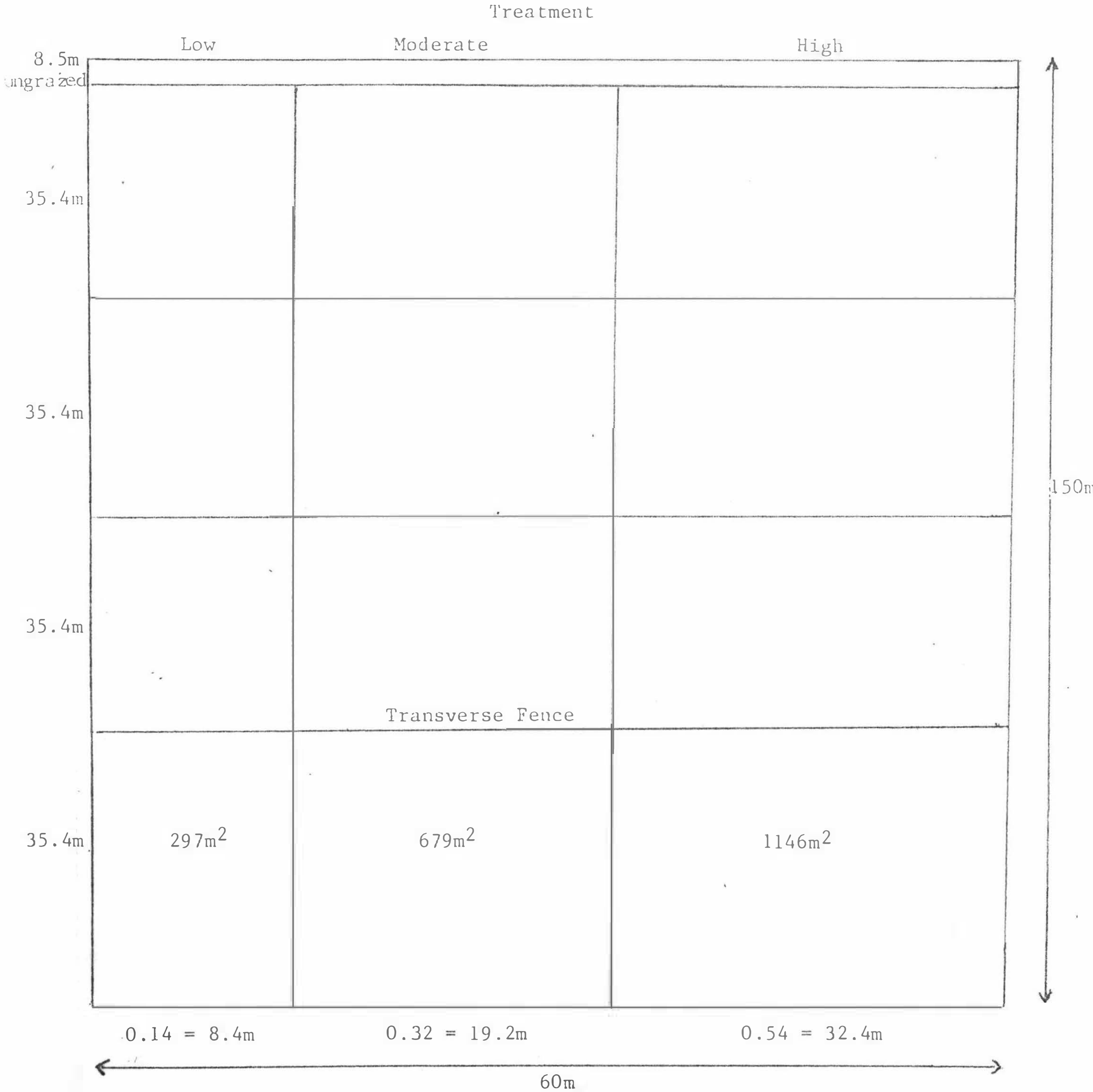
APPENDICES

Appendix I

An example of the subdivision of an area of pasture in order to offer the three daily herbage allowances

Example Pasture: 60m wide, 150m long = $7800m^2$

Estimated DM yield = 3000 kg DM ha^{-1}



Appendix I contd.

60 x 0.54 = 32.4m width of high allowance area

60 x 0.32 = 19.2m width of moderate allowance area

60 x 0.14 = 8.4m width of low allowance area

Area Required in order to offer 55 kg DM $cow^{-1}day^{-1}$

$$\text{DM to be offered} = 6 \times 55 = \frac{330 \text{ kg DM}}{3000 \text{ kg DM ha}^{-1}} = 0.11 \text{ ha. or } 1100m^2$$

Area Required in order to offer 35 kg DM $cow^{-1}day^{-1}$

$$\text{DM to be offered} = 6 \times 35 = \frac{210 \text{ kg DM}}{3000 \text{ kg DM ha}^{-1}} = 0.07 \text{ ha. or } 700m^2$$

Area Required in order to offer 15 kg DM $cow^{-1}day^{-1}$

$$\text{DM to be offered} = 6 \times 15 = \frac{90 \text{ kg DM}}{3000 \text{ kg DM ha}^{-1}} = 0.03 \text{ ha. or } 300m^2$$

To determine the Position of the Transverse Fence (x)

High Allowance $x = \frac{1100}{32.4} = 33.95m$

Moderate Allowance $x = \frac{700}{19.2} = 36.46m$

Low Allowance $x = \frac{300}{8.4} = 35.71m$

Mean of three treatments = 35.4m

Therefore the transverse fence was placed across the width of the paddock at 35.4m from the boundary fence and moved up 35.4m each day.

Therefore the Actual areas offered were:

High Allowance 35.4 x 32.4 = $1146m^2$

Moderate Allowance 35.4 x 19.2 = $679m^2$

Low Allowance 35.4 x 8.4 = $297m^2$

Appendix I contd.

The herbage yields were then measured before grazing so that the actual herbage allowances were then known. This system meant that there was some variation in the actual herbage allowances offered for each treatment between days.

Appendix II

The blood Mg status of the experimental cows on 21/9/78

Treatment	Cow Number	Mg (mg 100ml^{-1})
High Allowance	23	2.40
	38	2.65
	42	1.65
	53	2.20
	118	1.10
	157	2.48
Moderate Allowance	51	1.80
	56	1.35
	114	1.85
	127	2.00
	138	2.55
	144	1.00
Low Allowance	57	1.85
	113	1.75
	141	2.05
	153	2.55
	199	2.45
	216	2.55

Appendix III

The calibration of the Ellinbank Pasture meter

Before Grazing. ($n = 44$)

$$y = 1120.06 + 85.91X \quad (r = 0.82)\ (P < 0.01)$$

where y = estimated herbage yield (kg DM $ha.^{-1}$)
X = meter reading.

After Grazing. ($n = 39$)

$$y = 287.63 + 108.72X \quad (r = 0.81)\ (P < 0.01)$$

where y = estimated herbage yield (kg DM $ha.^{-1}$)
X = meter reading.

Appendix IV The mean daily milk, milkfat and milk protein yields (unadjusted) for each experimental cow over the 32 day treatment period (Period II) and their total lactation MF yields

Treatment	Cow No.	Milk Yield litres day^{-1}	Fat Yield kg day^{-1}	Protein Yield kg day^{-1}	Lactation Fat Yield kg cow^{-1}
High Allowance	23	14.8	0.65	0.53	142
	38	14.8	0.59	0.52	140
	42	19.8	0.85	0.70	154
	53	15.4	0.70	0.56	173
	118	19.2	0.74	0.66	173
	157	18.4	0.73	0.61	161
Moderate Allowance	51	15.5	0.74	0.60	189
	56	13.0	0.58	0.46	159
	114	16.3	0.66	0.58	153
	127	10.9	0.54	0.41	80
	138	14.1	0.71	0.51	182
	144	23.4	1.02	0.82	222
Low Allowance	57	7.5	0.38	0.27	89
	113	12.0	0.54	0.44	133
	141	10.5	0.60	0.35	155
	153	10.7	0.53	0.41	140
	199	17.9	0.74	0.57	191
	216	17.4	0.67	0.57	171

Appendix V Cow liveweights and body condition scores before and after treatment and body condition at the end of the lactation

Treatment	Cow No.	Liveweight (kg) 7/9/78	Liveweight (kg) 13/10/78	Condition Score 7/9/78	Condition Score 13/10/78	Condition Score 3/4/79
High Allowance	23	347	363	4.0	5.2	4.3
	38	289	319	3.5	4.5	4.4
	42	369	393	5.5	6.2	5.2
	53	323	364	4.5	5.0	4.3
	118	334	358	3.5	4.0	4.2
	157	361	390	3.5	4.0	4.4
Moderate Allowance	51	361	396	3.5	4.5	4.5
	56	307	323	4.0	3.7	3.9
	114	361	393	4.0	4.2	4.6
	127	315	323	3.5	4.8	5.0
	138	340	354	3.5	4.0	4.2
	144	450	437	4.5	4.3	4.1
Low Allowance	57	294	289	3.0	3.5	4.8
	113	405	412	4.0	4.8	4.9
	141	278	264	3.5	2.0	3.6
	153	343	323	4.0	3.4	4.2
	199	482	450	5.0	4.3	4.3
	216	414	411	3.0	2.2	4.0

Appendix VI — Evaluation of the responses of cows of two phenotypes for milkfat production to variation of herbage allowance

(3 x 2 factorial analysis of variance)

Analysis of variance tables.

(a) Fat Corrected Milk Yield

Source	d.f	SS	MS	F
Total	17	230.71		
A (feed offered)	2	67.84	33.92	4.22*
B (cow phenotype)	1	54.88	54.88	6.83*
A x B Interaction	2	11.55	5.78	0.72 NS.
Error	12	96.44	8.04	

* ($P < 0.05$) NS = not significant

(b) Liveweight Change

Source	d.f	SS	MS	F
Total	17	4.84		
A (feed offered)	2	3.06	1.53	13.34**
B (cow phenotype)	1	0.38	0.38	3.34 †
A x B Interaction	2	0.02	0.0098	0.085 NS
Error	12	1.38	0.1146	

** ($P < 0.01$) † ($P < 0.1$) NS = not significant

Appendix VI contd.

(c) Cow Condition Change

Source	d.f	SS	MS	F
Total	17	10.30		
A (feed offered)	2	4.08	2.04	6.28*
B (cow phenotype)	1	0.68	0.68	2.09 NS
A x B Interaction	2	1.63	0.82	2.51 NS
Error	12	3.90	0.33	

* ($P < 0.05$)   NS = not significant

Plate D. The area of pasture offered at the High allowance, with a comparison of the severity of grazing with the Low allowance.

Plate E. The area of pasture offered at the Low allowance, with a comparison of the severity of grazing with the Moderate allowance.

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