ANALYSIS OF THE CHARACTERISTICS OF THE LACTATION CURVES IN A GROUP OF HIGH PRODUCING DAIRY FARMS IN NEW ZEALAND

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This project focused on the analysis of the characteristics of the lactation curves in a group of commercial dairy farms in New Zealand which use supplementary feed strategically in order to increase overall production through increases in production per animal and per hectare (*AGMARDT-Dairy Farm Monitoring Programme*). The relationship between levels and quality of feeding, sward characteristics, sward management and levels of milk production were analysed in different phases of the lactation. In all lactation phases studied milksolids yield was more closely related to intakes from supplements than to intakes from pasture, reflecting the relatively high levels of supplements used, especially in late lactation. Average peak yield was 2.04 (1.88-2.26) kg MS/cow/day and significantly associated with total intake, enhanced by strategic use of supplements, but not significantly associated with pasture consumption, even though this provided 88% of the total intake at peak. Peak yield increased by 3.8 g MS with an increase of 1 MJME of supplements eaten, which on average is higher than the responses found experimentally. Quality of pasture and of the total diet was also moderately correlated to peak yield. A temporary decline and recovery in MS yield of on average 3.02 (0.89-4.56) kg of MS "loss" over 40 days, was observed immediately after the peak period. This appeared to be associated with a period of adverse climatic conditions in mid October, which resulted in decreases in nutrient intake as reflected in marked changes in milk protein content and protein:fat ratio that were not adequately compensated by changes in supplement feeding. Close monitoring of the concentrations of protein and fat in milk at this time would help in the assessment of the herd's nutritional status, and of the need to modify feeding strategies although, on average, this "loss" represented less than 1% of the total lactation yield. Long term rate of post peak decline in MS yield (from peak to late lactation) was 4.00 (2.57-4.72) g

MS/cow/day. Peak yield was the only factor associated significantly with post peak decline, and this correlation was positive as expected. The absence of significant correlations between rate of decline and feeding level over the same period, appeared to be a consequence of the low variability in the data. However, in general, the farms with higher rates of post peak decline apparently consumed slightly more supplements during peak period and also over the post peak decline period. Average MS yield in late lactation was 1.16 (1.01-1.24) kg MS/cow/day. Although not significant, there was a negative association between milk yield in late lactation and pasture quality. This appeared to be an effect of the relatively high level of supplementary feed input, which improved the diet consumed, but also caused some substitution for pasture eaten, resulting in some decrease in utilisation efficiency and pasture quality. Total lactation yield was 417 (374-438) kg MS/cow and the most important component affecting it was lactation length which was on average 243 (208-272) days. Between farm differences in peak yield and late lactation yield were not strongly related to total lactation yield, indicating the flexibility of lactation response to the relatively high levels of supplementation in mid to late lactation. However, these two components when combined with lactation length, made significant contributions to the model. It is concluded that the *AGMARDT-Dairy Farm Monitoring Programme* demonstrates that a management strategy based on close monitoring of pasture conditions and the flexible use of supplementary feeds, can achieve high milk production per cow and also per hectare. The results also suggest the need for development of more effective methods for pasture measurements. The use of milk composition as a short-term indication of nutrient status may also be useful as a tool to provide a qualitative basis for feed management decisions.

Keywords: pasture based systems, supplementary feed, lactation curves, peak yield, post peak decline, level of feeding, quality of feeding, sward conditions.

*To my Mum **Giselda,***

who has taught me the meaning of

Courage

*To my Dad **Tadeu,***

who has taught me the meaning of

Happiness

*To my Uncle **Francisco Lombardi Neto,***

who has taught me that the love by the

Science is a life-long journey

*To my beloved aunt **"Tuta"** (in memoriam),*

who taught me the importance of

Education in our lives

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CHAPTER 1

General Introduction

1.1. LACTATION CURVES IN THE NEW ZEALAND DAIRY SYSTEM

The New Zealand dairy industry is recognised worldwide for its ability to efficiently produce low cost milk. This low cost of production is possible because dairy production is based primarily on grazed pasture (Wilson *et al.*, 1995) and because production systems have been developed relying on high stocking rates and high levels of pasture utilisation with minimal use of supplementary feeds. In contrast, systems based on high stocking rates aiming at high pasture utilization, can lead to low animal performance because intake levels are restricted and the efficiency with which food is converted to milk also decreases as the cost of maintenance becomes a higher proportion of the cow's annual feed intake. (Holmes & Parker, 1992). Furthermore, lactations tend to be shorter (Edwards & Parker, 1994) and reproductive performance unsatisfactory (McDougall *et al.*, 1995) as the animals often face periods of severely limited forage intake.

The effects of low nutrient intakes can be seen in the lactation curves that characterise New Zealand herds. These lactation curves are below the biological maximum, reflecting lower levels of peak production and persistency compared to the TMR (total mixed ration) systems (Bryant & Mac Donald, 1983; McFadden, 1997; Kolver *et al.*, 2000; Davis *et al.*, 2000). It has been argued that high rates of post peak decline are related to particular factors in the pasture based system, but can be minimized if forage intake level and quality are kept high and constant (Penno *et al.*, 1995; Exton *et al.*, 1996; Shaw *et al.*, 1997).

Concerns about the limitations of high stocking rate systems led in 1998 to the establishment of the *AGMARDT-Dairy Farm Monitoring Programme* (AGMARDT, 2000; AGMARDT, 2001) by a group of twelve high production farms in the Southern North Island. These farms have adopted a common approach towards increasing production per hectare through increasing production per cow emphasising the importance of high levels of peak yield per animal and high levels of lactation persistency. Feeding levels are high and supplementary feed is used whenever pasture intake does not match the targets. Levels of peak milk yield and also overall production have been well above the national average (LIC, 2001) but as peak milk yield increased there appeared to be an associated increase in the rate of post peak decline in milk yield, especially for the two months after peak (October and November).

The objective of this study was to utilise the data from the *AGMARDT-Dairy Farm Monitoring Programme* for the 2000/2001 season to

- Define the influence of pasture and supplement management on levels of milksolids production and on the pattern of lactation, with particular reference to cow nutrition and herd management, comparing the findings, where possible, with industry standards and research information;
- Define the relationships between the components of the lactation curve and their effect on total lactation yield and;
- Use this information as basis for recommendations for modifications to herd management in order to improve animal performance and the efficiency of utilization of pasture and supplementary feeds.

CHAPTER 2

Literature Review

2.1. INTRODUCTION

The main objective of this research is to understand the seasonal pattern of lactation and the factors affecting it, in selected seasonal supply dairy farms in New Zealand. However, this review initially focuses (Section 2.2) on the general definitions of the lactation curve components (peak yield, rate of decline and persistency), on the methods employed to estimate or calculate them, and on the particular behaviour of lactation curves for the New Zealand pastoral dairy system. The general factors affecting the characteristics of the lactation curve are also considered. As it has been argued that lactation curves for the New Zealand pastoral dairy system differ dramatically from the lactation curves for total mixed ration systems, Section 2.3 of this review compares the pattern of the lactation curve and the levels of milk yield between the two systems, in order to identify which are the main points of difference. Finally, the last section (2.4) focuses on specific components of the grazing system, with particular reference to the New Zealand dairy system, which may influence the shape of the lactation curve and overall milk production.

2.2. LACTATION CURVES

Milk production starts at the day of calving, rises for a time, reaches a maximum, and then gradually declines until the animal goes dry (Turner, 1925; Keown & Van Vleck, 1973). This pattern of milk production throughout the lactation period is called as "lactation curve", which is generally expressed by qualitative descriptions or by mathematical functions.

Numerous mathematical functions have been used to describe the lactation pattern. One of the earliest and best know is the gamma type function (Wood, 1967) which describes the lactation period based on the relationships between the components of the lactation curve; rate of increase to peak, peak yield and rate of decline after peak. However, over time, the gamma type function has been improved and nowadays there are several other models (Beever *et al.*, 1991) to describe the lactation curve considering some additional parameters (environment, management, nutrition and genetic).

The components of the lactation curve and some models utilised to describe it are discussed briefly in the next section with emphasis on peak yield, rate of decline and the overall persistency of lactation.

2.2.1. Peak yield

Most definitions of peak yield are based on observational concepts. The simplest one considers peak as the highest yield of the lactation, expressed weekly (Wood, 1967) or daily (Broster & Broster, 1984), however these definitions do not consider a time frame in which peak yield should occur. Keown *et al.* (1986), utilizing observational parameters and including a time frame, estimated peak yield and peak date by considering Day 7 to Day 100 of the lactation as individual groups (Group 1 to 94) and taking the group which presented the highest yield measurement as the peak and that respective day as date of peak. For this estimation, it was assumed all cows would peak by day 100 of the lactation. The same approach was utilised by Bar-Anan *et al.* (1985), who calculated peak as the mean of the two highest sample-day ECM (economically corrected milk for economic value of fat), within 95 days post-partum. Keown & Van Vleck (1973), also described peak yield and peak date within a time frame as the maximum level of production achieved around six weeks post calving.

Assuming the mathematical approach based on the gamma function; $yn = an^b \exp(-cn)$ (Wood, 1967), peak milk yield at week n (kg/week) and time to peak are the derived functions $y_{max}=a\,(b/c)^b e^{-b}$ and $N = b/c$ respectively, where a, b and c are constants. At week N, b is a parameter representing the rate of increase to peak production, c

represents rate of decline after peak and *a* represents the scale of the production of the cow, increasing the initial yield and peak yield, but also increasing rate of post peak decline. The typical values of the parameters *b* and *c* are 0.20 and 0.04 respectively, which gives a predicted peak yield at the 5th week of lactation (Beever *et al.*, 1991) (Figure 2.1). Those relationships are useful to obtain lactation curves resulting from manipulation of the parameters involved (Bryant & Mac Donald, 1983).

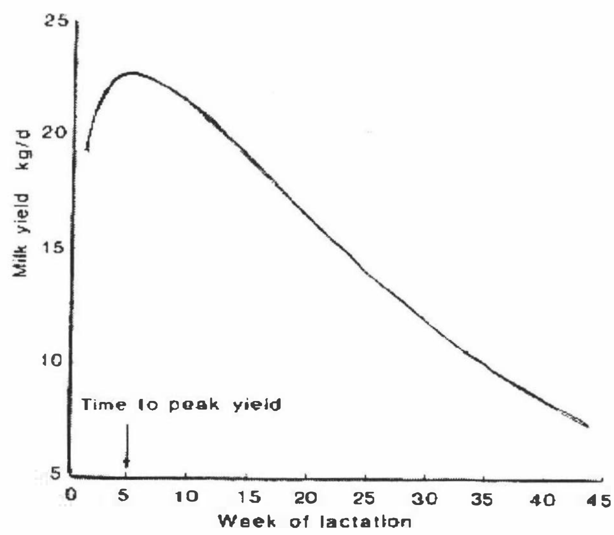


Figure 2.1 The shape of a typical lactation curve generated using the model of Wood (1967), $yn = an^b \exp(-cn)$, with parameters a = 20, b = 0.2 and c = 0.04. Extracted from Beever *et al.* (1991).

The descriptions and the model presented above assume no variation in the nutritional status of the animal, but peak yield and peak date pattern may differ under different nutritional levels.

2.2.2. Rate of decline

"The curve of lactation increases rapidly from calving to peak, which is followed by a more or less gradual decline until the lactation is terminated" (Wood, 1967). This gradual decline after peak, which can be natural or selective, is defined as rate of post

peak decline. Persistency is defined as the extent to which peak production is maintained (Wood, 1967) and is the inverse of rate of decline.

The rate of decline and lactation persistency can be measured in several ways. In the lactation model; $yn=an^b \exp(-cn)$ proposed by (Wood, 1967) (Section 2.2.1), the parameter c is a constant which represents the weekly rate of decline, so rate of decline in a time scale base, assuming no external effects, should not vary over time.

The monthly/weekly sustainability of milk or fat production after peak has also been established as a constant percentage of the preceding month/week which generally presents a linear fit with time (Turner, 1925; Keown & Van Vleck, 1973; Dhanoa & Le Du, 1982; Broster & Broster, 1984). This decrease per month or week can also be stated as percentage of peak yield (Broster & Broster, 1984). After day 260, the lactation curve tends to changes its linear fit, starting to decrease at an increasing rate (Keown & Van Vleck, 1973; Dhanoa & Le Du, 1982). Therefore it is recommended the exclusion of the last months of the lactation, when calculating rate of decline utilising linear methods because production decreases at increased rates. This seems to be associated with the change in the fat concentration towards the end of the lactation (Turner, 1925; Keown *et al.*, 1986) and also with foetal development (Keown & Van Vleck, 1973).

Assuming uniform conditions of nutrition and management, the rate of post peak decline calculated as the proportion of milk yield decline from the previous month, generally varies from 4 to 9% (Sturtevant, 1886 cited in Turner, 1925; Shanks *et al.*, 1981; Chase, 1993; Knight & Wilde, 1993).

The rate of decline of fat yield during the lactation period can be calculated in the same way as for milk. Due to the fact that the percentage of fat increases during the lactation as the milk yield declines, the persistency of fat yield is greater than the persistency of milk yield. In comparing individual animals or groups of animals it is important that comparisons be made only of either one or the other in order to avoid confusion between persistency of fat yield and persistency of milk yield (Turner, 1925).

2.2.3. Persistency

There are also a vast number of definitions for lactation persistency. Basically it is the opposite of rate of decline and it can be derived from Wood (1967) as; $S = c^{-(b+1)}$ where, S is persistency and b is rate to peak and c is rate of decline. By definition, for lactations starting at the same level which is defined by the constant a, total lactation yield $ln\ (y) = ln\ (a) + ln\ (S) + ln\ (b+1)$, is a function of persistency therefore, total lactation yield will depend almost entirely on variations in a and S (Wood, 1967).

Persistency can also be estimated as the proportion of the total yield achieved in given periods of the lactation, eg. 100 or 300 days (Broster & Broster, 1984), as the proportion of average daily yield to day 300 of the lactation in relation to peak yield (Bar-Anan *et al.*, 1985) or as a proportion of average daily yield to day 300 in relation to production at day 300 (Keown *et al.*, 1986).

The persistency index (Turner, 1925) is another way to estimate milk yield sustainability and it is obtained by calculating an average value for the monthly rate of decline from peak to the end of lactation, calculated as the proportion of production fall from the previous month/week (see Section 2.2.2).

2.2.4. Description of the lactation curve for the New Zealand dairy system

Figure 2.2 and Figure 2.3 describe the lactation curves and the rates of post peak decline for the New Zealand herds utilising data from the dairy industry (LIC) over the last seven milk seasons.

Generally, peak production (defined as the highest yield after start of calving) occurred either in September or in October, which resulted in an interval from calving to peak interval ranging from 30 to 60 days (considering starting of calving on 1st of August). Peak yield ranged from 1.50 kg to 1.65 MS/cow/day over the seven seasons.

Peak duration is observed more precisely when the lactation curve is expressed in shorter intervals of time such as weekly, however there is no specific manner or function to determine peak duration. Although the data show monthly milk yield values for the lactation curve, which does not allow peak duration to be well defined, the duration of the period in which peak production is maintained seems to vary between seasons. Sometimes, peak yield shows sharp shoulders as for season 1998/1999 and 1999/2000 whereas, for season 1994/1995, peak shoulders are flatter. Wood (1968) observed that for lactations in which milk yield was expressed weekly and that started in March (North Hemisphere), there were extended peaks due to the stimulus of spring grazing 6 to 8 week after calving.

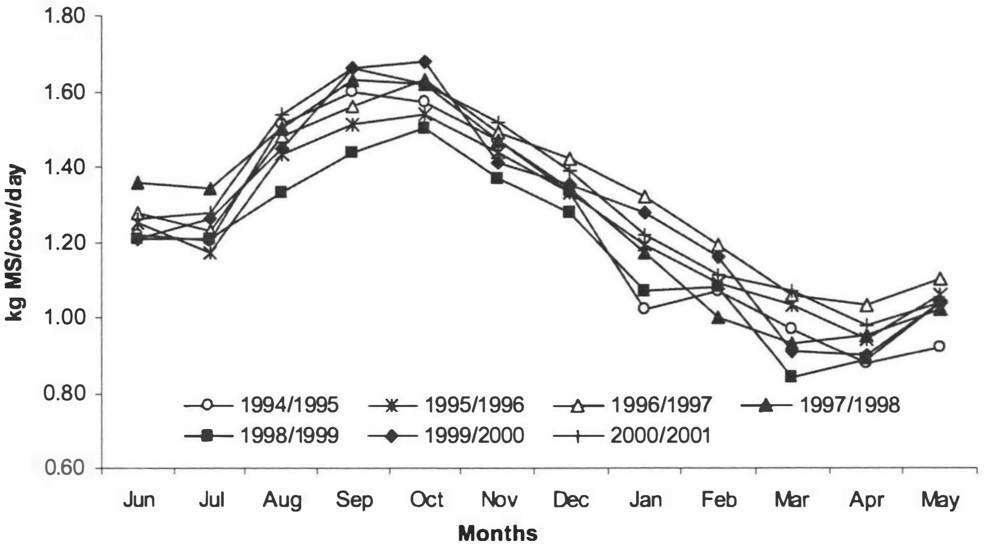


Figure 2.2 Average monthly milksolids yield per cow for the last seven milk seasons in New Zealand. Adapted from LIC (1995 to 2001).

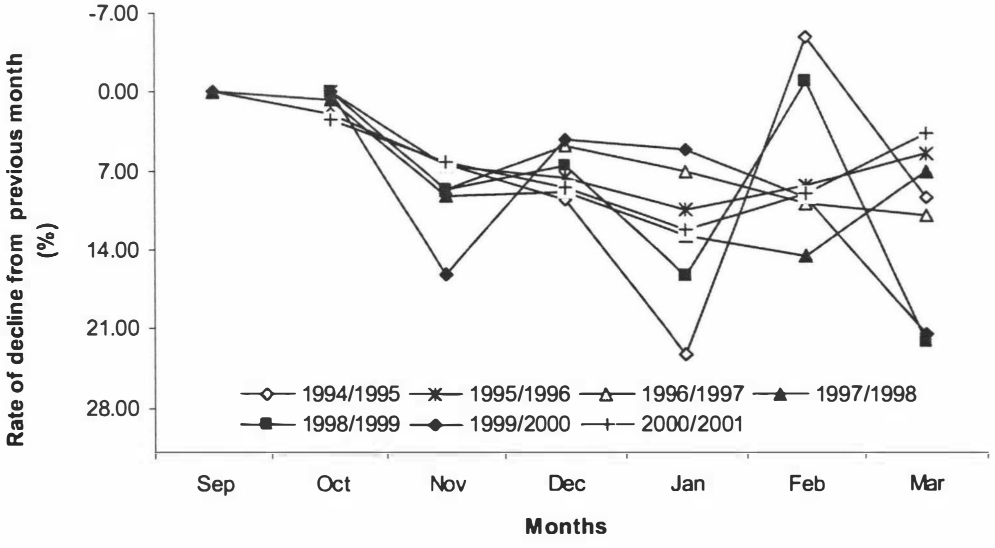


Figure 2.3 Post peak milksolids decline pattern for the last seven milk seasons in New Zealand. Adapted from LIC (1995 to 2001).

As for peak yield, the rate of decline and persistency can vary markedly for the New Zealand seasonal milk production system. According to the data from Figure 2.3, rate of post peak decline, which was calculated as follows;

$$\text{Monthly decline (\%)} = 1 - \frac{\text{Daily MS yield per cow at month } n}{\text{Daily MS yield per cow at month } n-1} \times 100,$$

varies considerably between and within seasons. It ranges from less than 1% to more than 14% in the first month after peak production. McFadden (1997), Kolver *et al.* (2000) and Davis *et al.* (2000) have also reported rates of decline ranging from 10 to 20% per month for the New Zealand seasonal pasture based system. It has been suggested that these high values of post peak decline are related to particular factors in the pasture based system, and that there is potential to keep this rate around 7% if feeding level and quality are kept high and constant (Penno *et al.*, 1995; Exton *et al.*, 1996; Shaw *et al.*, 1997).

2.2.5. General factors affecting the lactation curve characteristics

The shape of the lactation curve is mainly modified by the relationship between peak yield and rate of decline and persistency. Peak yield is positively correlated with rate of decline and therefore negatively correlated with persistency (Wood, 1967; Shanks *et al.*, 1981; Broster & Broster, 1984; Chase, 1993)

High production and high genetic merit animals/herds, tend to present higher levels of peak production but also faster rates of decline post peak and lower persistency (Chase, 1993). In contrast, Keown *et al.* (1986) showed that cows in high production herds started their lactations at higher production levels, had higher peak yields and maintained yield better throughout the season, thereby being more persistent than the low production animals. The low persistency shown by the low production herds seemed to be more associated with the levels of feeding, than the lactation curve relationships. According to the author, the high production herds might have had a higher percentage of confinement and might have been fed more uniformly through the year, resulting in the high persistency levels.

The shape of the lactation curve varies more between cows than between lactations of the same cow (Grossman *et al.*, 1986), therefore suggesting that genetic characteristics do alter the shape of the lactation. However, the evidence of genetic variation in the lactation curve traits is still unclear. Bar-Anan *et al* .(1985) found positive pleiotropic effects for yield, persistency and conception rate which might encourage selection for persistency. In addition, Shanks *et al.* (1981) found genetic correlations indicating that selection for increased peak would not change persistency or week of peak. On the other hand, Grossman *et al.* (1986) studying first lactation curves, concluded that the shape of the curve would not be successfully changed by genetic selection, with the possible exception of initial scaling of the curve.

Keown *et al.* (1986), working in North America, reported that production at peak was depressed, and the period from calving to peak was longer, when calving occurred in the hottest and wettest months. The highest peak production and the least persistency occurred for the January to March calving period (corresponding to the late winter period in the North Hemisphere). For pastoral systems, the effects of season of calving on peak yield and persistency have been primarily attributed to seasonal differences in pasture availability and pasture quality. Wood (1968) reported that persistency varied considerably with calving month due to changes in patterns of pasture production.

First lactation cows tend to take longer to reach peak yield, have lower peak productions and higher persistency than cows in subsequent lactations (Shanks *et al.*, 1981; Keown *et al.*, 1986; Chase, 1993). Peak yield increases as number of lactation increases (Killen and Keane, 1978 cited in Broster & Broster, 1984; Keown *et al.*, 1986;

Dekkers *et al.*, 1998). This seems to be associated with the low peak yield of the first lactation, because the correlation between peak yield and persistency is generally negative (Keown *et al.*, 1986). The time taken to reach peak production for animals in their first, second or third lactations seems not to vary significantly (Keown *et al.*, 1986).

Up to the fifth month, pregnancy has little effect on milk yield, but from this point to the end of lactation, pregnancy can substantially affect persistency rate and also milk composition (Turner, 1925; Keown & Van Vleck, 1973; McFadden, 1997).

Bar-Anan *et al.* (1985) found that changes in milk yield immediately preceding and following insemination, are associated with an unfavourable environment within a cow for reproduction, with decreased conception rates. This evidence suggests that reproductive performance and maintenance of higher yields and persistency are negatively associated. This trend is well illustrated in MacMillan *et al.* (1996) that found lactation negatively associated with fertility because pregnancy rates in maiden heifers exceed those obtained after first or subsequent calving.

2.3. PATTERN OF THE LACTATION CURVE FOR DIFFERENT PRODUCTION SYSTEMS

The pattern of the lactation curve differs between systems of production. Results from Kolver *et al.* (2000) (Table 2.1) show that cows fed total mixed ration (TMR) produced more milk and milksolids, were more efficient, had a greater persistency of lactation and ended lactation with a greater body weight than cows grazed on quality pasture.

The TMR systems are able to maintain high levels and quality of feeding throughout the season, therefore nutritional variations are not likely to affect the pattern of the lactation curve (Clark *et al.*, 1997). On the other hand, for grazing systems, although pasture can potentially provide a high quality feed for the dairy cow, it is not possible to offer constant levels of quantity and quality from pasture all around the year (Clark *et al.*, 1997).

Table 2.1 Mean annual milk production, lactation persistency, efficiency of milksolids production, body condition score and DM intake of New Zealand genetics first lactation cows grazing pasture or fed total mixed ration (TMR) during season 1998/1999. Extracted from Kolver *et al.* (2000)

Measurements	Grass	TMR
Milk yield (kg/cow)	3317	5036
Milksolids (kg/cow)	281	380
Decline in milksolids (% per month)	9.8	3.8
Efficiency (kg MS/LW $^{0.75}$)	3.1	4.0
Season end condition score	4.6	6.2
DM intake (kg/cow)	3254	4661

In pasture based systems there are more variables involved with milk production than in the TMR systems (Figure 2.4). While for the TMR systems the main concerns are the nutritional balance and the digestive process, in the pasture systems it is also necessary to account for pasture growth, pasture structure and ingestive processes. The large number of variables and the complex relationships between them make the control of milk production a harder task in grazing systems. The establishment of an optimal milk production system based on pasture is therefore not easy (Clark *et al.*, 1997).

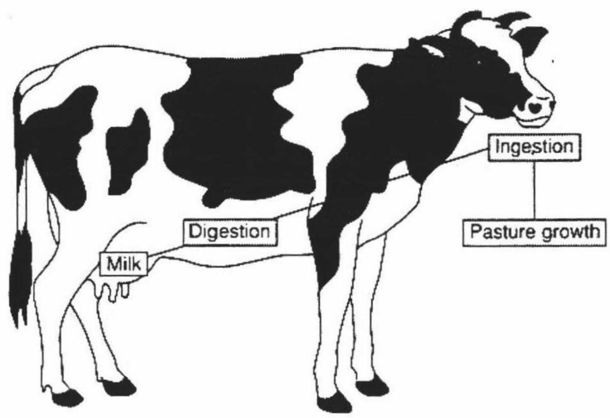


Figure 2.4 Linked factors related to milk production from grazed pasture. Extracted from Clark *et al.* (1997)

The relationship between milk flow to the dairy factories and pasture production data for the South Island in New Zealand, demonstrated that the overall shape of the lactation curves does reflect the seasonal pasture production (Thomson, 1999). The main factor is represented by the choice of calving date which allows better balance between demand and supply, with the calving event generally concentrated during early spring so that the lactation peak coincides with the peak of pasture production (Holmes *et al.*, 1987). However, the overall shape of the lactation curve for the New Zealand system is strongly dependent on climatic variation because this dictates the pattern of pasture production (Thomson, 1999). For TMR systems, season of calving does not affect lactation curves, apart from the effects of changes in the environmental parameters which can affect animal behaviour, animal comfort and animal welfare (Keown *et al.*, 1986).

The ingestive component of milk production in grazing systems is primarily represented by the factors that drive levels of pasture intake. Lower dry matter intake has been recognised as the most important aspect restricting milk production on pasture based systems when compared to TMR systems (Kolver, 1997; Kolver & Muller, 1998; Kolver *et al.*, 2000). With high quality forage it has been suggested that low intake could be the consequence of slow rates of intake and insufficient grazing time (Kolver, 1997).

The digestive aspect of the grazing system relies on the wide variation in nutritional characteristics of the grazed forage caused by season, maturity and management (Beever *et al.*, 2000). The resultant variations in nutritional composition therefore affects the pattern of the lactation curve and milk production, whereas in TMR systems the daily feed offered to the cows is constant in its chemical composition (Clark *et al.*, 1997). Pasture may also present some nutritional problems, such as high concentration of protein and low concentration of dry matter and digestible energy, which may limit milk production (Kolver, 1997).

2.4. FACTORS RELATED TO GRAZING SYSTEMS THAT MAY INFLUENCE THE SHAPE OF THE LACTATION CURVE AND OVERALL MILK PRODUCTION

2.4.1. Seasonality of herbage production

Due to economic reasons the New Zealand dairy system strongly depends on the use of grazed pasture as the main source of feed for the dairy herd (Holmes *et al.*, 1987). However, pasture based systems are characterised by the seasonal pattern of production dictated by climate variations (Holmes *et al.*, 1987; Korte *et al*, 1987) which does not allow maintenance of constant levels and quality of feed over the year. "*As a result, the pattern and variability of milk production has reflected the seasonal pattern and variability of pasture growth characterised by high peaks and a decline from peak greater than twice the 7% per month considered reasonable for a well fed high BI herd*" (Thomson & Holmes, 1995).

Feed supply varies during the year especially because of changes in the pasture growth rates (Figure 2.5). During spring, rapid pasture growth rates are observed, while during the summer/winter there is a frequent deficit of pasture available (Holmes *et al.*, 1987). Consequently, the lactation curve for New Zealand's herds can be largely determined by the pasture growth curve patterns.

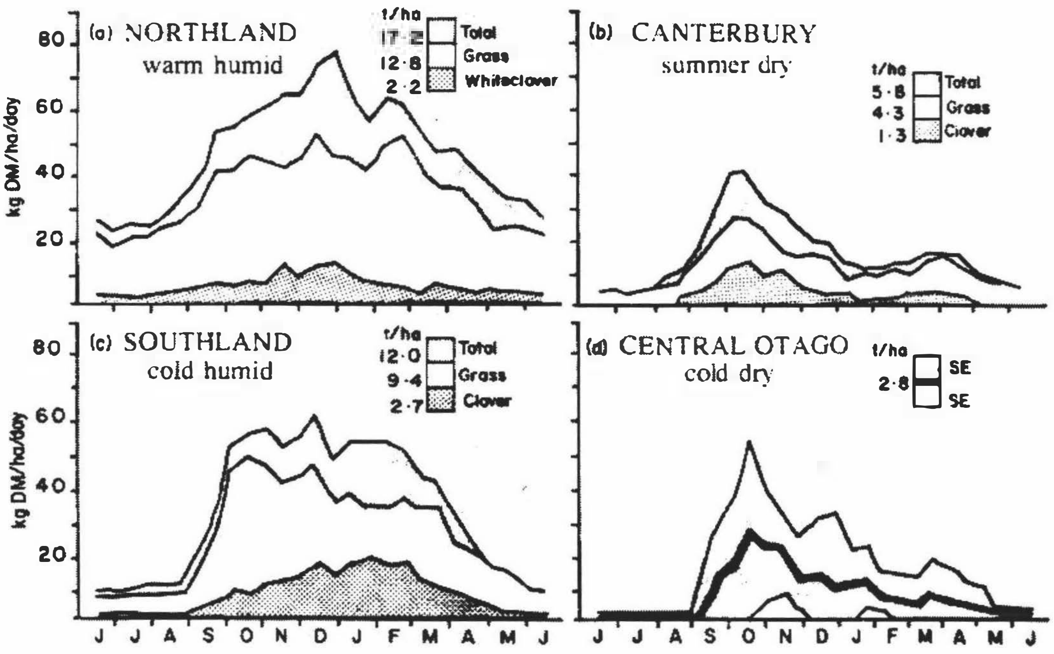


Figure 2.5 Typical seasonal rates of pasture production in New Zealand, showing the daily accumulation rates (kg DM/ha/day) for clover grass and the total pasture. Mean annual production is also given (t DM/ha). Extracted from Korte *et al.* (1987)

Increases in milk production in New Zealand have been primarily attributed to increases in peak production due to genetic improvement exploited during the spring, but not at other times of the year when seasonal factors have greater impact (MacMillan and Henderson, 1987 cited in Edwards & Parker, 1994).

Generally, from calving to October/November, milk production seems to be strongly associated with feed allowance, and, to feed on farm during spring, whereas the same trend does not apply for production during summer (Bryant & Mac Donald, 1983; Thomson *et al.*, 1984; Clark *et al.*, 1994). High stocking rate systems and early forage conservation policies are associated with decreases in milk production during early spring due to decreases in herbage allowance, whereas for low stocking rates, early conservation of pasture surplus increases total fat production due to increases in pasture quality over summer and autumn (Thomson *et al.*, 1984).

In order to fully utilize the seasonal availability of herbage, the feed demand is manipulated in order to match the period of maximum herd requirement and the period of maximum pasture growth rates. Consequently, the lactation curves for New Zealand's herds are largely determined by the adjustment of feed demand and feed supply (Holmes *et al.*, 1987). This adjustment is obtained by the manipulation of calving dates, drying-off dates, stocking rates, conservation of pasture surplus and utilization of conserved herbage and/or introduction of supplementary feed in the system.

2.4.2. Calving season, calving date and drying-off dates

On the seasonal supply dairy farms in New Zealand, calving generally starts in the early spring in order to synchronise the increase in feed requirements observed in the early lactation with high pasture growth rates observed during spring. In contrast animals are dried-off after relatively short lactations (220-240 days) (LIC 2000) as it is not possible to maintain the balance between feed demand and feed supply throughout the summer/winter, unless extra feed is inserted in the system (Holmes *et al.*, 1987). However, alterations in the calving season or in the dry off dates do affect the feed demand and feed supply balance, which consequently affects the shape of the lactation curve by modifying the level of yield at peak, the rate of decline after peak and total days in milk (Garcia & Holmes, 1999).

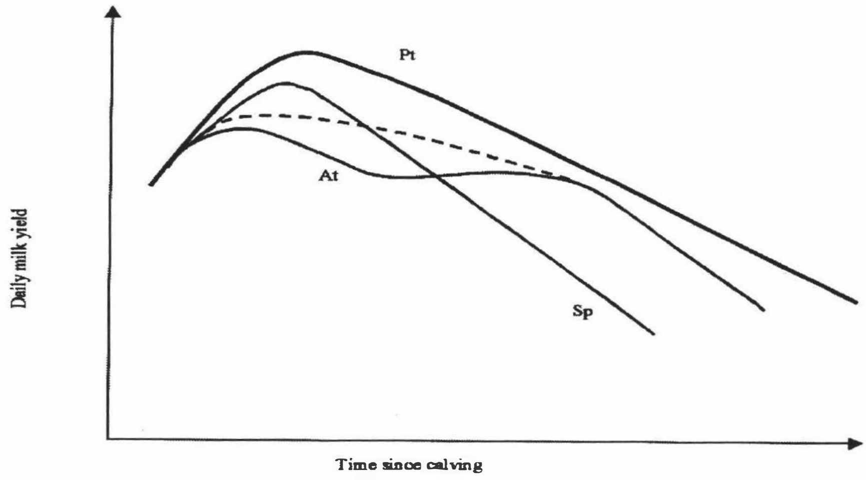


Figure 2.6 A hypothetical explanation of the difference between lactation curves of cows calving in autumn (At), or spring (Sp) in pasture-based systems, in which both groups of cows are prevented from achieving the potential yield (Pt). The broken line represents the theoretical lactation curve of well-fed autumn-calved cows. Extracted from Garcia & Holmes (2001)

Spring calved herds tend to present higher peak production as the result of the spring pasture flush coinciding with early lactation, however followed by a sharp post peak decline during summer. In contrast autumn calved herds present lower level of peak production as this occurs during winter and before the spring flush, however they present higher persistency rates, as during spring and summer, milk production remains levelled off, resulting in a total lactation production similar to that of spring calved herds (Garcia & Holmes, 2001). The autumn calved cows also tend to present two peaks during lactation (Figure 2.6). The first one is the result of the physiological peak that occurs around 60 days after calving and the second one seems to be the result of the higher availability and quality of pasture during the spring (Garcia & Holmes, 2001). Recent studies have shown that there are some small yield advantages in autumn calving over spring calving due to more days in lactation and higher milk production during late lactation, however the amount of supplements necessary in early lactation for the autumn calved cows may not be economically worthwhile (Garcia & Holmes, 2001).

Date of calving also affects the levels and pattern of milk production. Total milk fat yield per cow is higher for the early calving spring herds than for late calving herds due to more days accumulated from calving to 31st December. In contrast average daily milk fat per cow tends to be higher for late calving herds than for early calving herds, as consequence of the positive relationship between feed on farm during spring and milk production response (Bryant & Mac Donald, 1983).

2.4.3. Stocking rate

Stocking rate dictates levels of peak production as well as persistency rates (Clark *et al.*, 1997; Roche, 2001). As stocking rate increases, feed allowance decreases and consequently peak production and total milksolids production per cow also decrease which is a result of shorter peak extension and decreased lactation length. It has been also observed that peak tends to occur later in higher stocked herds (Roche, 2001).

2.4.4. Dry matter intake

Restriction in DM intake has been considered as the most important factor affecting milk production and its pattern in pasture based systems (Kolver, 1997; Kolver & Muller, 1998). Low DM intake levels lead to low ME intake levels, therefore milk production is restricted by the supply of metabolizable energy (Kolver & Muller, 1998).

The relatively low intake levels observed in grazing systems can be associated with ingestive and digestive constraints. Assuming high quality pasture, the main restriction to upper limits of intake seems to be related less to effects of rumen fill (digestive aspects) and more to the restriction imposed by grazing time, bite rate and bite weight (ingestive aspects) to consume high amounts of pasture per day (Kolver, 1997).

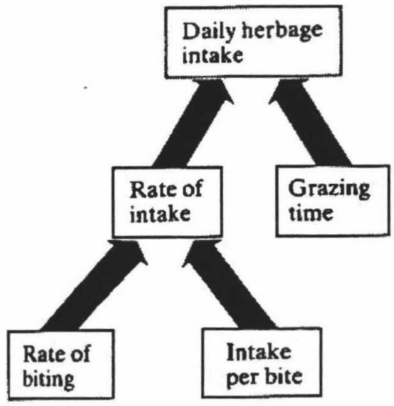


Figure 2.7 The components of ingestive behaviour. Extracted from Hodgson (1990).

The ingestive components of the daily herbage intake are shown in Figure 2.7. To some extent, they are determined by the sward conditions which, in their turn, are mainly defined by grazing management. Herbage height, herbage density and herbage allowance are the main sward features affecting daily herbage intake (Hodgson, 1990; Woodward, 1998).

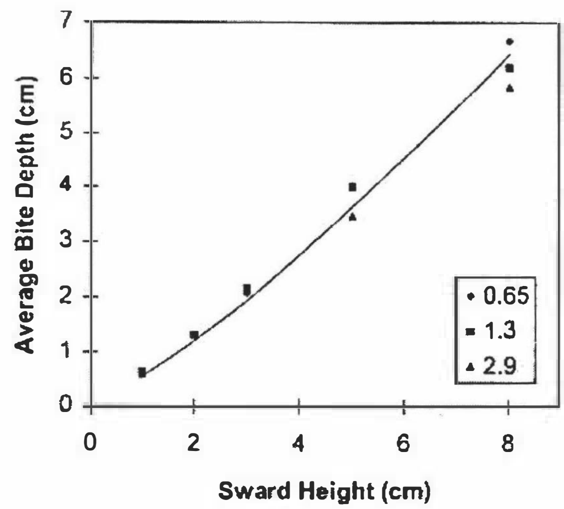


Figure 2.8 Prediction of average bite depth according to sward for three bulk densities (0.65, 1.3 and 2.9 mg cm^{-3}) and five swards height (1, 2, 3, 5 and 8 cm). Extracted from (Woodward, 1998).

Generally, the correlation between herbage intake and sward height is positive. Increases in sward height are related to increases in the bite depth, as illustrated in Figure 2.8, which will result in increases in the bite weight, therefore in the total herbage intake (Woodward, 1998).

However, when the animal grazes down through the canopy, the amount of leaves decreases and the amount of dead material and stem increases, (Figure 2.9), decreasing bite weight and consequently daily herbage intake. The decrease in bite weight seems to happen because animals avoid those components of the sward due to low quality and difficulties in fracturing and apprehending herbage (Hodgson, 1985) Therefore when referring to sward height affecting herbage intake it is necessary to consider the distribution of the botanical components through the sward profile and the proportion of green material.

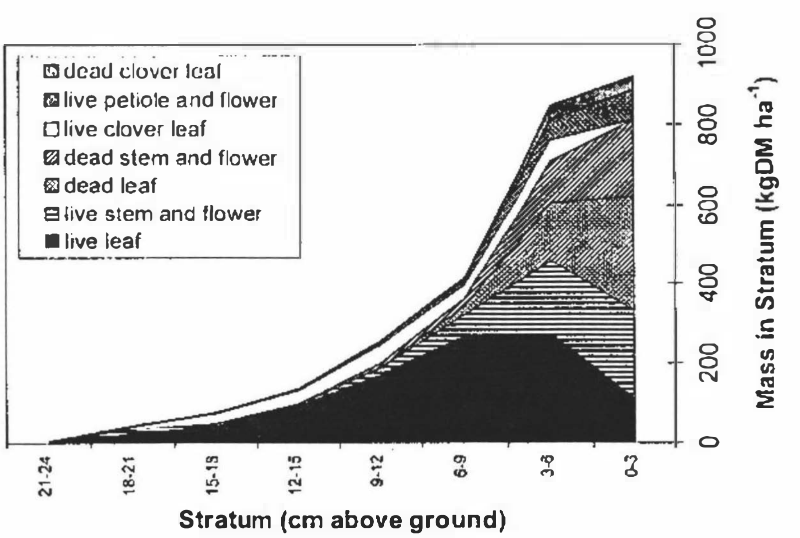


Figure 2.9 Distribution of the different botanical components of the sward through different heights. Extracted from Woodward (1998).

Daily herbage intake for cattle decreases as herbage becomes more defoliated or less dense. Penning *et al.* (1991) observed that as leaf area index falls, mass per bite decreases linearly and the time per day spent grazing increases greatly. On the other hand, Forbes (1995) stated that there is a reduction in number of bites and bite mass and also in grazing time. Grazing time, indeed increases to compensate for the lower bite weight. However the degree of compensation is limited, so decreases in bite weight will cause decreases in daily herbage intake. Grazing time can decrease in particularly short swards (Hodgson, 1985; Woodward, 1998).

Increases in total herbage allowance and in green leaf allowance are associated with increases in the daily herbage intake (Holmes, 1989; Hoogendoorn *et al.*, 1992; Wales *et al.*, 1999) (Figure 2.10). Bryant (1980), working with cows in several stages of lactation found that, for all animals, the yield of milk, fat, protein and lactose, liveweight change, herbage intake and herbage mass following grazing decreased as allowance was reduced.

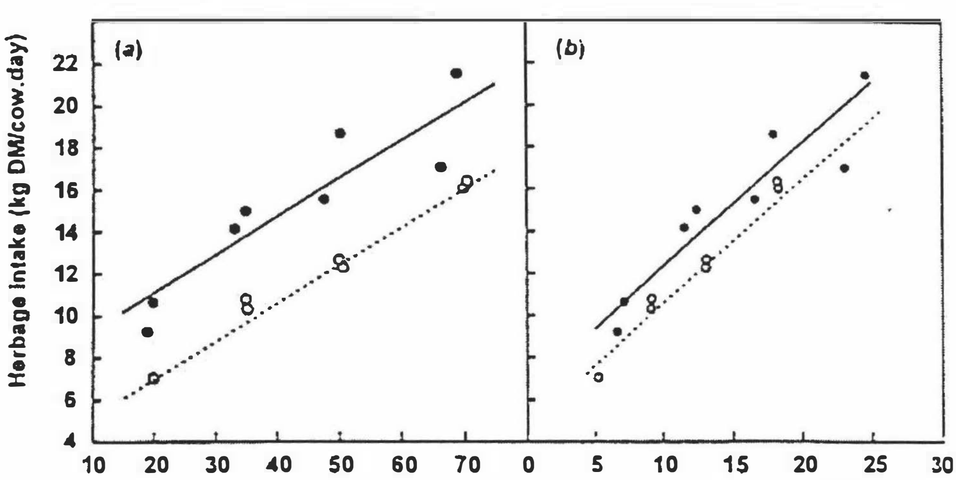


Figure 2.10 Relationships between herbage allowance (total and green leaf) and herbage intake for cows grazing irrigated perennial rye-grass-white clover low mass (**O**) and medium mass (●) Adapted from Wales *et al.* (1999).

In a experiment carried out by Wales *et al.*(1999) during summer and spring, herbage mass and allowance had a greater effect on intake in spring than during the summer due to the decline in nutritive characteristics that occurs in the summer. The average daily intake increased by 0.23 and 0.13 kg DM in the spring and summer respectively for every 1 kg DM increased in herbage allowance during those experiments.

The digestive aspects influencing intake are related to the quality of the grazed herbage grazed. Low quality swards (increased maturity), were associated with decreasing wet feed intake (John & Ulyatt, 1987). This is a consequence of increased rumen fill that is associated with the extension of digestion, the rate at which products of digestion are absorbed and the rate at which indigestible elements pass through the digestive tract. The qualitative effects of the grazed herbage on milk production are discussed in the next section.

However, although the evidence suggests that there are ingestive and digestive constraints for higher levels of herbage intake in grazing systems, some models to predict intake in grazing systems, already adjusted to account for grazing activity, have described high levels of pasture intake, similar to these for TMR systems (Kolver *et al.*, 1996; Clark *et al.*, 1997).

Table 2.2 A comparison of nutritional parameters of a small (450 kg) Friesian dairy cow offered spring pasture or a maize silage/alfafa hay based plus concentrates Total Mixed Ration (TMR), as predicted by the Cornell Net Carbohydrate Protein System Kolver *et al*. (1996) at Day 60 of lactation. Extracted from Clark *et al.* (1997).

Parameter	**Pasture**	**TMR**
Dry matter intake (kg DM day^{-1})	17.4	17.4
Crude protein (%)	19.5	21.2
ME (MJ kg^{-1}DM)	11.3	10.7

According to the data shown in Table 2.2, despite the relatively high values for DM intake predicted for both systems, it is still theoretically possible to achieve high intakes of DM in pasture-based systems. Clark *et al.* (1997) argues that in fact, feed allowances and the absolute expression of DM intake, irrespective of liveweight are the factors responsible for the lower DM intakes presented by grazing animals if compared to animals fed TMR, and not inherent problems in pasture such as high moisture content which would restrict rumen capacity. These authors also refute the idea that the balance of metabolizable protein or the quantity of amino acids arriving at the small intestine would be responsible for lower production in pasture based systems.

2.4.5. Herbage quality

As discussed in the previous section, DM intake is an important determinant of milk production as nutrient intake is clearly related to DM intake. However, pasture quality also plays a very important role in the amount of ME eaten by the animal because the total daily nutrient intake is also a function of the concentration of nutrients in the feed eaten. The concentration of nutrients present in the pasture has a double effect, as the amount of pasture eaten (dry matter intake), in most circumstances, is closely related to the nutrient concentration in the pasture (digestive aspects).

Factors that influence forage growth (species, water, light and nutrient availability) are dynamic processes, which change significantly with time. Consequently, the chemical and physiological characteristics of the herbage are influenced by stage and rate of growth, as well as by previous management. As maturity approaches, the proportion of stem increase and the proportion of leaves decrease, therefore the ratio cell content/cell walls changes very dramatically (Figure 2.11).

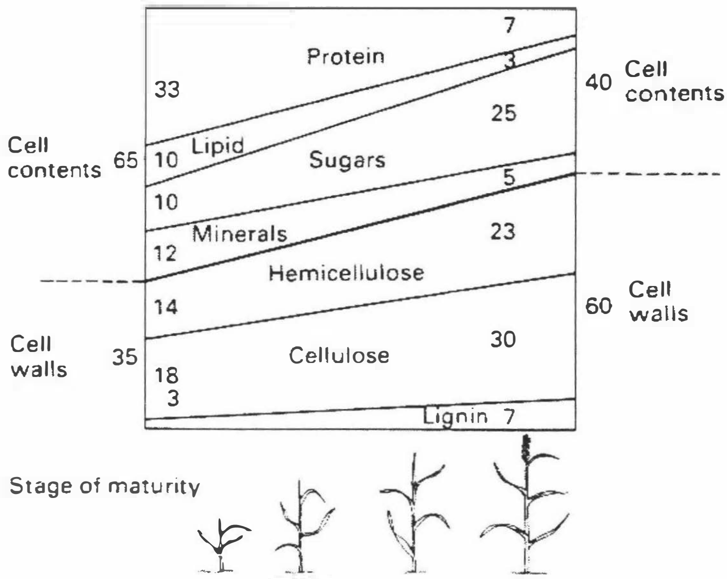


Figure 2.11 Schematic representation of the effect of maturity on the chemical composition of grasses. Adapted from Beever *et al.* (2000).

Herbage mass may affect milk production by affecting the sward composition and therefore herbage nutritional value as illustrated in Table 2.3. Comparing swards managed through winter to result in low or high masses swards during spring, the authors found that the low mass swards resulted in higher yields of milk, milk fat and milk protein, when grazed by the cows, due to lower concentrations of grass stem and senescent material and higher concentrations of clover, which increased digestibility. Low mass swards had higher feeding value for lactating cows in early lactation, although the high mass swards resulted in higher production per ha due to larger amount of herbage accumulated per hectare.

Table 2.3 Pre grazing mass, composition for herbage and daily yields of milk and milksolids measured over the experimental period. Adapted from Holmes *et al.* (1992)

	Experiment and treatment					
	1984			*1985*		
Composition of herbage (g kg^{-1})	**High mass**	**Low mass**		**High mass**	**Low mass**	
Grass leaf	506	538	NS	550	562	NS
Grass stem	222	171	**	221	114	**
Clover leaf	40	132	**			**
Clover stem[1]	37	73	**	115	247	**
Senescent material[1]	183	83	**	107	50	**
Daily yield (kg cow^{-1})	**High mass**	**Low mass**		**High mass**	**Low mass**	
Milk	17.0	17.8	**	19.9	22.3	**
Milk fat	0.81	0.87	**	0.80	0.92	**
Milk protein	0.57	0.62	**	0.67	0.75	**

[1] Values for 1985 assume leaves plus stem.

(**) Significant at 1%; (NS) Not significant.

Changes in herbage composition, are also attributed to alterations in the climate pattern over the season (Wilson *et al.*, 1995; Moller, 1997). Due to the increases in day length and especially in temperature, the first marked change in pasture quality during the season occurs in late spring when grasses reach their reproductive stage (Wilson *et al.*, 1995). This seeding process can lead to very large differences in chemical composition as the proportion of cell wall to cell contents starts to increase (Wilson *et al.*, 1995; Beever *et al.*, 2000). The likely effect on milk production for the New Zealand dairy herds is considerable, because the cows are normally on a pasture ration in October/November with little or no supplementation. During summer the decreased levels of rainfall bring the major effect of climate on grass quality. The lack of water decreases the leaf to stem ratio, and also decreases clover growth. As the feeding value of the leaf is higher than the stem, the overall quality of the herbage starts to decrease (Wilson *et al.*, 1995).

Over the second half of the season (Dec-March), high proportions of stem and dead material are often observed, resulting in decreases in milk production from October onwards as a result of the lower digestibility of pasture over summer (Thomson *et al.*, 1984; Hoogendoorn *et al.*, 1992; Clark *et al.*, 1994). According to Butler *et al.* (1987) and Hoogendoorn *et al.* (1992), as the season advances, the allowance of green herbage, the proportion of dead material, green material, and clover are significantly correlated to animal performance, although the content of stem does not have any influence on animal productivity in any stage of the season. In addition, there are indications that leaf mass allowance is the most important factor determining intake levels and performance of dairy cows during late spring and summer, more important than green or total DM allowance, or any negative effect of grass stem

Short-term variations in pasture nutritive value and also variations between paddocks on the same property can be associated with different plant species and differences in management including intensity/frequency of grazing or fertility/fertilizer effects. Although managers seem to be aware of such effects, it is still difficult to have all paddocks at the ideal composition all of the time. However, dairy cows face significant day by day variations in their diet, which could account for daily fluctuations in milksolids output (Wilson *et al.*, 1995).

2.4.5.1. Digestibility, ADF and NDF

As the maturity of the sward increases, digestibility decreases due to increases in the ratio of cell wall to cell content (Beever *et al.*, 2000). The reproductive stage of ryegrass is likely to be one of the causes of the decrease in digestibility during late spring (Moller, 1997).

Table 2.4 shows that concentration of ME present in the herbage is closely related to the digestibility of organic matter (Hodgson, 1990; Beever *et al.*, 2000). Dry matter intakes on pasture have also been positively linked to *in vitro* DM digestibility and negatively correlated with lignin content (Horn *et al.*, 1979; Hodgson, 1990). In addition, decreases in organic matter digestibility are likely to result in decreases in milksolids production.

Table 2.4 Organic matter digestibility (OMD) and metabolizable energy (ME) concentration for herbage, at normal levels of N concentration. Extracted from Hodgson (1990).

OMD (%)	ME (MJ/kg DM)
50	6.5
60	9.0
70	10.5
80	12.0

Moller (2001) found pasture digestibility high in spring and low in mid summer. ADF and NDF levels, which are related to the digestibility of organic matter, start to rise in late spring, reaching a peak in January/February (Figure 2.12). Although the highest levels of ADF and NDF occur just in January/February, there is a linear rate of increase until this maximum level, which may be one factor driving the post peak declines in milk yields.

The gradual decrease in digestibility is also detrimental for spring calving cows that reach their peaks between mid September and mid October, and need to maintain high DM intakes to maintain production after peak. Moller (1997), suggests that the improvement of diet quality (ME concentration) around October/November may help reduce the monthly milk production decline from peak lactation. Also, the concentration of some nutrients over the year, can be either inadequate or in excess of the recommended feeding level for a dairy cow, particularly if more than 25 kg milk/cow/day is to be produced (Moller, 1997). Kolver & Muller (1998) also concluded that for grazing systems aiming at more than 30kg/milk/day, some supplemental energy would be necessary because even at high daily intakes of pasture (19 kg DM/day), there is still significant mobilization of energy as body reserves.

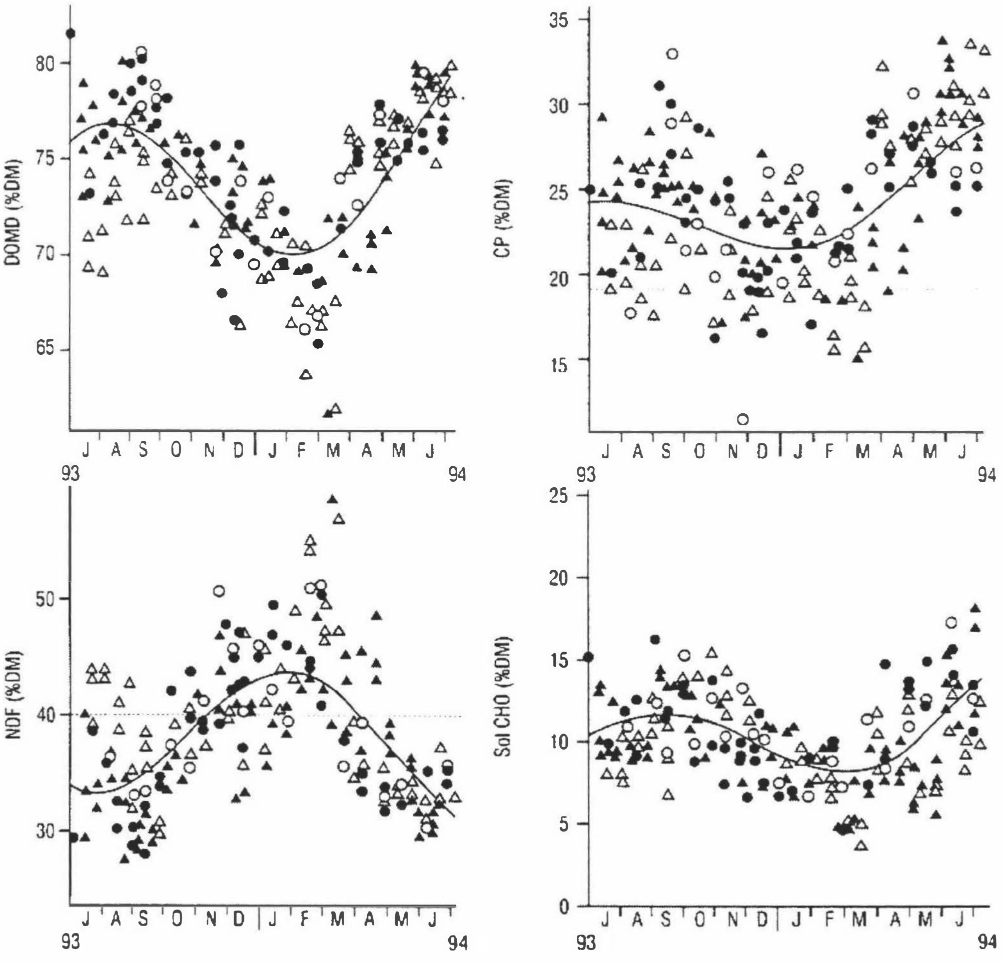


Figure 2.12 Seasonal changes in the composition of pasture sampled from four dairy farms (different symbols for each farm). Adapted from Wilson *et al.* (1995).

2.4.5.2. *Crude protein and soluble carbohydrates levels*

In New Zealand, during autumn and spring, crude protein (CP) concentration in pasture often exceed 25% (Figure 2.12). Nitrogen applications are the main external factor affecting pasture protein levels and, levels higher than 18% can penalize milk production because there is a strong negative relationship between urea levels in blood and milk production (Moller, 1997). Also, the soluble CHO, despite the slightly higher levels observed during spring than during summer, are not enough to create a satisfactorily balance between degraded protein and fermentable CHO inside the rumen (Moller, 1997). Therefore, the rumen unbalance may be another factor causing relatively low peak yield and high rates of decline after peak in New Zealand herds.

2.4.6. Effects of supplementation

The addition (or reallocation) of extra feed through the season, can potentially modify lactation curve patterns in pasture based systems. Higher responses to supplements are generally observed when animals have not been fed to their potential, such as under high stocking rates or during summer and autumn when shortages of feed are often observed (IVABS, 1999).

Stockdale & Trigg (1989) found that responses in early lactation were better at lower levels of pasture fed, even better than the responses in late lactation. However, responses in early lactation, at higher levels of feeding, were less than the ones obtained during late lactation at any level of feeding. This suggests that there is a more constant response to supplements when they are feed in late lactation.

Recent researches have indeed suggested that the highest production response to supplementary feeding comes from the extended lactation lengths (Penno *et al.*, 1996; Deane, 1999). In New Zealand, cows achieve only around 240 days in lactation whereas the potential length is 305 days, but the maintenance cost is still the same irrespective of being in milk or dry. However, when supplements are utilised to extend lactation length, responses are more reliable because of the extra milk which would not otherwise be produced (Penno *et al.*, 1996).

Table 2.5 shows that at moderate stocking rates, the response to supplementary feeding increases dramatically as lactation progresses whereas, at high stocking rates, the response seems to be lower as lactation progresses (Penno *et al.*, 1996). This is associated with the restricted pasture allowance observed towards the end of lactation. For high stocking rates, despite differences in the need for extra feed over the lactation period, there will be an overall need for extra feed, whereas for low stocking rates, the need for extra feed occurs gradually as pasture feeding levels start to decrease in summer and autumn.

Table 2.5 Response to supplementary feed over the season for low and high stocking rates. Adapted from Penno *et al.* (1996)

	Response (g MS/kg DM)	
Period	*Moderate SR (3.24/cows/ha)*	*High SR (4.48 cows/ha)*
1st June – 1st October	11	63
1st October – 31st January	53	81
1st February – end of season	134	91

More evidence for better responses when supplements are used to extend lactation, relies on the difficulty to increase the daily energy intake of animals which are already fully fed on pasture during the first 6-8 weeks of lactation (Stockdale *et al.*, 1997). Feeding supplements at this stage will cause substitution and wastage of pasture. However this situation may be different for high stocking rates as the "need" for extra feed is high in early lactation.

In summary, within the farm system, interactions between the use of supplements, cow condition, stocking rates and average herbage mass may be of greater importance than the changes that occur in the partitioning of nutrients due to stage of lactation (Penno *et al.*, 1996).

2.4.7. Genetic merit of the herds

New Zealand cows have been selected to produce milksolids under grazing conditions. Despite the desirable attributes of selection for the specific system, they have been considered to have low milk yields when compared to the overseas genetics (Roche, 2001). A recent study with Holstein Friesian cows (Kolver *et al.*, 2000) has compared animals of New Zealand and overseas genetics with the same breeding worth under a grazed pasture regime. Despite the higher milk yield presented by the overseas animals, milksolids production, efficiency of milk production and persistency of lactation were comparable between the two groups. However the milksolids production of overseas cows was achieved partly at the expense of the liveweight gain as it was lower than for New Zealand cows (22 kg versus 55 kg liveweight gain after calving over the lactation period).

It also appears that the influence of peak milksolids production on total yield is greater for overseas genetics, but this difference disappears when animals are fed on pasture suggesting the effect of the system on the persistency of the animal (McFadden, 1997).

2.4.8. Physiology of the animal

After calving, dairy cattle have to eat from 50 to 100% more than during the dry period in order to have a positive energy balance in early lactation (Faverdin, 1995). In early lactation rumen volume seems to be the greatest factor that limits intake because the highest distension capacity of the rumen does not coincide with the highest early lactation demand. This situation results in body tissue mobilization in early lactation, especially in the case of high production animals (Faverdin, 1995).

This tendency is illustrated in Figure 2.13. Feed intake increases gradually following calving, reaching maximum levels in the second or third month of the lactation. In contrast, peak milk yield occurs slightly before peak intake, while the dairy cow mobilises body tissues in order to satisfy its demand. However, there is a short phase of around 2 months (from month 3 to 5 in Figure 2.13) in which the animal may stop using body cover reserves while it has not reached the upper level of DM intake yet. The negative energy balance observed during this phase, may also increase the rates of post peak decline in milksolids.

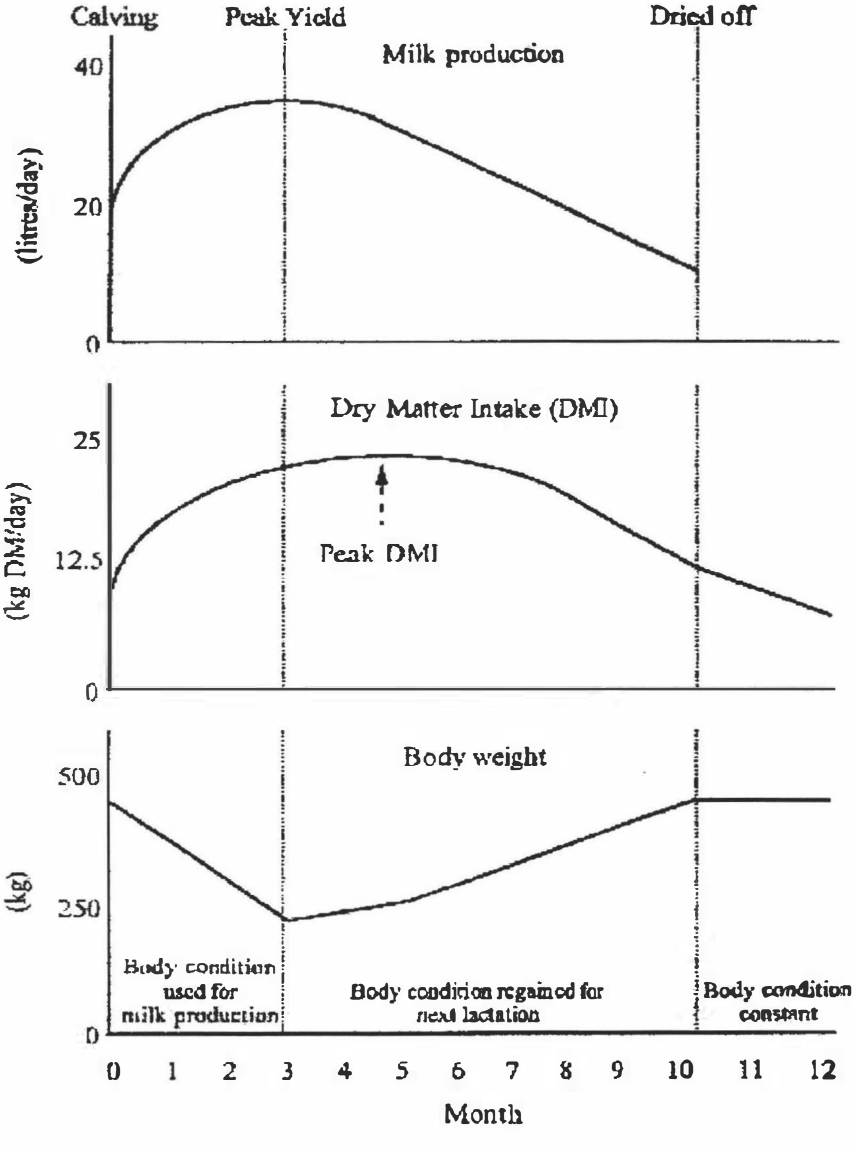


Figure 2.13 Typical changes in feed intake, milk yield and liveweight during lactation for a mature cow. Extracted from Chamberlain & Wilkinson (1996)

2.4.9. Liveweight and condition score

The research data shown in Table 2.6 suggest that cows underfed in early lactation tend to gain more liveweight and more condition score, in late lactation, at expense of milk yield.

Table 2.6 Effect of levels of feeding in early lactation on fat and protein yield and on liveweight change from Week 12 to the end of the lactation. Adapted from Grainger & Wilhelms (1979).

	Level of feeding in early[1] lactation	
Measurements taken from Week 12	*High*[2]	*Low*[2]
Fat (kg)	133.4_a	90.4_c
Protein (kg)	111.0_a	75.7_c
Liveweight change (kg day^{-1})	0.36_a	0.62_c

[1] Over the first ten weeks after calving

[2] High = *ad libitum*; Low = 7 kg of pasture DM/day.

Grainger *et al.* (1982) also found that improved body condition at calving results in increases in milk production over the lactation period. Cows which calved in poor body condition partitioned a higher proportion of feed energy to liveweight at the expense of milk yield. However the input-output relationships showed that the benefits of extra feed to improve body condition before calving were less than that of additional feed after calving.

2.4.10. Milk composition

Milk composition varies through the lactation period. This factor may be an important determinant of the shape of the lactation curves in New Zealand as milk production is commonly expressed as yield of MS.

Changes in milk composition over the lactation period, occur mainly due to seasonal differences (within year and between years) in the chemical composition of the pasture (Figure 2.14) and stage of lactation and nutritional levels (Figure 2.15).

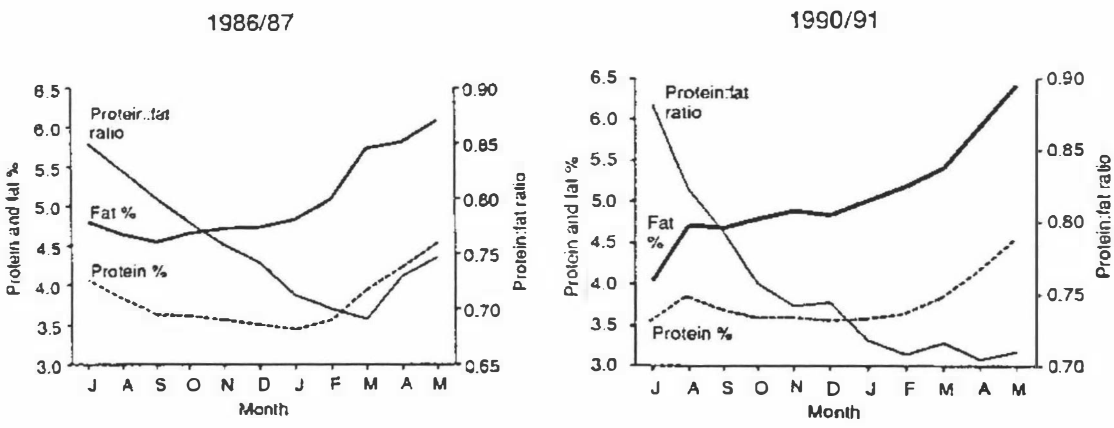


Figure 2.14 Changes in protein and fat contents during the 1986/87 and 1990/91 seasons in the Waitoa area – New Zealand. Extracted from Kolver & Bryant (1992).

The data presented in Figure 2.15 is based on results of trials conducted in New Zealand. The information was stratified for stage of lactation in order to avoid its effects on milk composition. Underfeeding in early lactation reduces fat and protein content. In mid lactation restricted feeding results in no change in fat content but a fall in protein content. In late lactation both fat and protein content increase under feed restriction (Kolver & Bryant, 1992). The same trend was observed by Grainger (1990) who found that reduced levels of feeding in late lactation appeared to accelerate the changes in milk composition which occur normally in late lactation; increases in the concentration of milk fat and protein and decrease in lactose concentration.

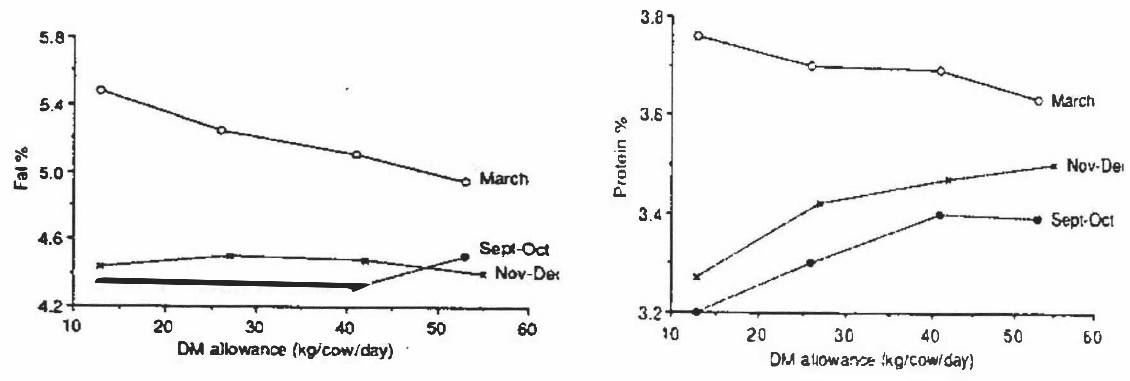


Figure 2.15 Effect of stage of lactation on milk composition response to a changing in feeding level. Extracted from Kolver & Bryant (1992).

In contrast, Auldist *et al.* (2000), comparing milk composition of animals fed total mixed ration or grazed pasture which were fed generously throughout the lactation, found that diet had no effect on the variation in milk composition throughout the season. Generally, the magnitude of the reduction in variation between diets, if any, was minimal and the changes in milk composition were fairly similar between diets as lactation progressed. Based on that, the author suggested that factors other than alterations to the quality and availability of pasture are primarily responsible for variation in milk composition which are typical of seasonal calving, pasture based systems. Improvements in nutrition may partly obviate seasonal variation in composition, but nutrition alone is not the primary cause of variation in milk composition. On the other hand, milk yield of cows grazing pasture were lower than that for cows fed total mixed ration, and also declined to much lower levels in late lactation as a result of limitation in quality and availability of pasture during summer and autumn.

CHAPTER 3

The AGMARDT Dairy-Farm Monitoring Programme

3.1. INTRODUCTION

This current study was developed utilising information gathered from nine commercial dairy farms as part of a three-year monitoring project which was partially funded by the Agricultural Marketing and Research and Development Trust (*AGMARDT*) and known as the *AGMARDT Dairy Farm Monitoring Programme*. The basic aim of the farmers involved is *to efficiently use pasture to feed dairy cows, as this is and will remain, New Zealand's competitive advantage* (AGMARDT, 2000). On the other hand, they have also identified that high pasture utilisation leads to a certain degree of underfeeding and therefore low milk yield per cow, short lactations and pasture degradation, as a consequence of excessive grazing pressure dictated by high stocking rates. While agreeing that pasture has to be well utilised, farmers felt that it is also necessary to focus on a better balance between pasture production, pasture use and per cow production which are achieved by manipulation of the stocking rate, sward characteristics and strategic use of supplements to increase levels of feeding and lactation lengths (Matthews & Phillips, 1998). This chapter briefly discusses some concepts involved in the *AGMARDT-Dairy Farm Monitoring Programme*, as well its background, objectives, design, outcomes and previous results.

3.2. PROJECT BACKGROUND

In the late 1980's, a group of farmers from the Southern North Island in New Zealand plus their consultant, started to question the underlying concepts and philosophies of dairy production in New Zealand. At that stage, aiming at the maximum utilisation of pasture by the herd, they reached a plateau of around 4 cows and 600 kg milkfat/1050 kg milksolids per hectare and further progress seemed to be unachievable (Cassells & Matthews, 1995). They identified that the main barrier to increased production was associated with high stocking rates leading to low production per cow, short lactations and the inability to maintain desirable pasture targets, as the high feed demand per hectare did not allow efficient control over pasture management.

High stocking rates required a late calving date followed by a premature drying off, as the diminished feed supply over the summer limited production with such high numbers of cows. Over the summer and autumn, declines in daily milk yield per herd of around 14% per month were observed, which under utilized the cows productive potential. Furthermore, the feeding of a high number of cows was achieved at the expense of the cow's requirements in early lactation. High feed demand per hectare depressed reproductive performance and liveweight/condition score remained under target during the whole season. There was also a high expenditure on supplementary feed plus grazing off in order to maintain the high number of cows over the dry period (Cassells & Matthews, 1995). Facing this situation, they concluded that they might be able to increase overall productivity and profitability by decreasing stock numbers and exploring the opportunity for increasing production per animal.

Over the years, the philosophy of increasing production per cow was gradually put into practice as illustrated by the example provided by Cassells & Matthews (1995). The first step taken was a reduction in stocking rates to increase the individual cow nutrition and the quantity of supplements produced that, combined, would increase overall production per cow, lactation length and feed supply over autumn (Table 3.1). The animal was no longer treated as a buffer for the system and supplementary feed started to be used in response to pasture growth variations. The role of the supplements was more linked to overcoming periods of limited pasture supply rather than supporting higher stocking rates or balancing diets. The outputs of this first step indeed showed that production could be raised through improvement of cow performance. From 1993, stocking rate was reduced even more and also calving date was advanced even more. There were increases in the purchases of supplements to feed lactating cows over summer, which increased lactation length. Nitrogen use also increased. The evolution of the system resulted in an increase in productivity of 55% per cow and 20% per hectare despite a 23% reduction in the stocking rate.

Table 3.1 The effect of chances in stocking rate and supplement use on per cow production. Adapted from Cassells & Matthews (1995).

Year	Stocking rate	Milksolids Production		Feed inputs	
	(cows/ha)	*kg fat/cow*	*kg fat/ha*	*(kg DM/ha)*	
				Grazing	*Supplements*
1980-1988	3.93	152	595	1060	1433
1989-1993	3.47	183	636	605	551
1994-1995	3.03	235	712	924	2455

The key factors to the satisfactory operation of this system are those related to grazing management (Matthews, 1994; Matthews, 1995). The control of pre and post grazing sward conditions and stocking rate policies to allow high intake of high quality feed are paramount. Pre grazing herbage mass levels determine pasture quality and set the potential post grazing levels, whereas post grazing herbage mass levels determine herbage intake and pasture growth rates. In order to achieve such herbage mass targets, pre grazing levels tend to be reduced while post grazing residuals increased. Supplements are fed whenever intake and/or pasture targets are not achieved. While using supplements, stocking rates should not be too high otherwise the supplements will be used to maintain the increased number of animals, a situation that is less likely to show an economic return to the farmer.

However, over this period new limitations were identified. As peak production per cow increased due to better levels of nutrition over spring, the October/November post peak milk drop became more accentuated and the reasons for or the effects of a such a sharp decline on overall production have not been established. Furthermore, it was necessary to identify the best autumn feeding strategies to extend lactation and improve production per cow and per hectare. The group then felt a need for a monitoring programme in which information collected on the respective farms could be analysed in order to explain such limitations, hastening the evolution of the system (AGMARDT, 2000).

In 1997, a formal discussion group was established among the participants in order to share experiences and concepts. These experiences and concepts included the improvement of production and profitability through high per cow production levels, monitoring of pasture production/quality and use of supplements strategically. Also in 1997, an application to the Agricultural and Marketing Research and Development Trust (*AGMARDT*) for a Progressive Farming Grant was made and successfully approved. This established the intensive monitoring involving both the evaluation of management strategies used and the identification of the limitations to be overcome.

A final group of farmers was identified by March 1998. They had actively supported the project and were prepared to put time and effort into monitoring, as they were extremely positive about the benefits they would obtain over the monitoring period. The group became known as *AGMARDT-Discussion Group* and the new monitoring programme as *AGMARDT - Dairy Farm Monitoring Programme* (AGMARDT, 2000). They were about to start an intensive three years on-farm monitoring project involving 12 farms, around 2000 ha and 5000 animals. The scientific management of the project was undertaken by Mr. Parry Matthews, former lecturer of the Institute of Veterinary, Animal and Biomedical Sciences, Massey University.

3.3. PROJECT OBJECTIVES

The group identified, as the main objectives of the project, the establishment of pasture and animal performance indicators associated with high per hectare production achieved through improved per cow performance while maintaining an efficient utilization of pasture grown. The farmers also agreed with the necessity of an evaluation of the effects of strategic supplementation on farm production and profitability and the investigation of the reasons for and evaluation of management strategies to overcome two other major limitations to productivity which came along with the changes in the system;

- The rapid decline in per cow performance and total milk production during the post peak period
- How to successfully and economically extend lactation in the autumn to improve both per cow and per hectare performance.

3.4. THE PROGRESS OF THE *AGMARDT-DAIRY FARM MONITORING PROGRAMME*

The three year AGMARDT – *Dairy Farm Monitoring Programme* commenced in June 1998. By 1st May 1998, the programme was implemented on four farms in order to evaluate the measurement techniques, which were to be used in all farms. The full technical and financial recording programme started on all farms on 1st June 1998. The first year of the programme (1998/1999) allowed measurement techniques, recording and reporting procedures to be developed and the first season's data to be collected. Because of the identification of discrepancies in the herbage assessments carried out by different managers, a calibration was developed for each farmer's assessment of herbage mass(AGMARDT, 2000). The activities of the first year included discussion groups, dairy cow nutrition workshops held at Massey University and funded by the project, research activities being established on the case farms, teaching activities, and hosting national and international visiting groups. Over the three years of monitoring, some farms have been added to the programme as some others have been withdrawn due to changes in the land holding and adverse climate conditions (such as severe flooding), making monitoring difficult and generating unrealistic results.

Twelve farms participated in the second season of the project (1999/2000). The activities continued with discussion groups and field days, including one of the farmers being awarded the Manawatu sharemilker of the year. Teaching and research activities also continued to be expanded. The results for season 1999/2000 were published in a formal report, which contains information about climate, milksolids production, nitrogen use, feed consumption and sward conditions as well as an evaluation of the post peak decline in milk yield based on the data generated by the programme for the previous season. Two papers were presented at the XIX International Grasslands Congress based on post graduate studies carried out within the project.

A similar report for the third year (2000/2001) of the monitoring programme is already published (AGMARDT, 2001). The final year of the project also included the outcomes of this current study plus the outcomes of another MApplSci project, which evaluated the effect of supplements usage on the productivity and profitability of dairy farms.

In the third year, the No. 4 Dairy Unit - Massey University was also added as a project participant. In its last year the project included 12 farms, which together represent around 3700 cows grazing 1400 effective hectares (Table 3.2). Over the three years of the programme, there were 10 farms which consistently remained in the project.

Table 3.2 Some details of the *AGMARDT Dairy Farm Monitoring Programme* over its three years of monitoring.

	Year 1	Year 2	Year 3
Number of farms	12	12	12
Total effective area (ha)	1638	1628	1430
Total cows wintered	4420	4430	3850
Average effective area per farm (ha)	136	135	119
Average cows wintered per farm	368	369	320
Average stocking rate per farm (cows/ha)	2.70	2.73	2.68

3.5. DESIGN OF THE PROJECT

To achieve the objectives, the project was committed to monitor pasture and feed targets and animal performance. Monitoring such targets involves daily recording of pre and post grazing herbage mass levels, daily milk production and weekly measurements of average pasture cover as well as supplements conserved and fed. This level of recording enables farmers to calculate total pasture harvested annually and the contribution from supplementary feeding, and together with accounts analysis, to calculate EFS (economic farm surplus) each year, allowing the fine tuning of pasture targets, supplementary feeding levels and stocking rates to improve both production and financial efficiency. Data collection was done by the farmers plus a technician contracted by the programme, who also processed the information.

3.6. GENERAL OUTCOMES OF THE PROJECT

The Project brings several benefits to the dairy industry due to:

- The range of soils and climate that the project covers. The farms are spread over four different regions of the south North Island (Rangitikei, Manawatu, Northern Wairarapa and Southern Hawkes Bay), which makes the outcomes more representative.
- The detailed analysis that the farmers have about their farming systems which will enable them to better understand the system, its limitations and opportunities for improvement.
- The discussions that the project held within the group to enhance communication as well as providing an opportunity for the exchange of information and ideas.
- Most areas covered by the project have not been well covered by current formal research programmes in New Zealand.
- The postgraduate students' trials on the farms as well as more detailed analysis of the information collected by the project.
- A unique three year detailed on-farm data set of value to the New Zealand dairy industry.

3.7. PRODUCTION AND PERFORMANCE FIGURES FOR THE *AGMARDT* GROUP FOR SEASON 1999/2000

3.7.1. Milksolids production

Favourable climate conditions and pasture growth rates allowed good levels of milksolids production with some farms achieving record production. In comparison to the previous season (1998/1999), production increased around 12% for both per cow and per hectare. Table 3.3 shows the average production figures for the *AGMARDT* farms and their relative performance compared to district production figures.

Table 3.3 Production statistics for all farms involved in the project and the comparison with district averages (season 1999/2000)

MS production	AGMARDT group	District	
	Average and range	*Average*	*Top 10%*
Per cow (kg MS/cow)	405 (332 - 465)	338	394
Per ha (kg MS/ha)	1061 (839 - 1291)	913	1281

3.7.2. Lactation length, peak yield and the average milksolids yield

The favourable climate conditions allowed the farmers to milk into June, therefore increasing the lactation length and total milksolids production for the season. The averages milksolids production per cow across all farms was 1.54 kg MS/cow (ranging from 1.22 to 1.81 kg MS/cow/day), average peak yield based on monthly average across all farms was 2.05 kg MS/cow/day and lactation length across all farms was 263 days.

3.7.3. Feed consumption

Total feed consumption per cow averaged 5840 kg DM with 80% of this from pasture grazed in *situ* and 20% from supplementary feed. The 80% of total intake coming from pasture highlights the farmer's emphasis on efficient pasture utilisation. It is also important to mention that part of the supplement consumed consisted of herbage conserved on farm.

Supplements were fed all around the year, but the greatest proportion was fed over summer and autumn. From September to December, supplementary feed was utilised just to cover shortfalls of pasture growth (12% of the total feed eaten), whereas from January to May the proportion of supplement fed increased (27% of the total feed eaten). During summer/autumn the main sources of supplementary feed were turnips and pasture silage, with some by-products also being fed while during winter the main source was grazing off (Figure 3.1). Over the whole season, pasture silage was the most commonly fed source of supplementary feed the (conserved on farm or brought in).

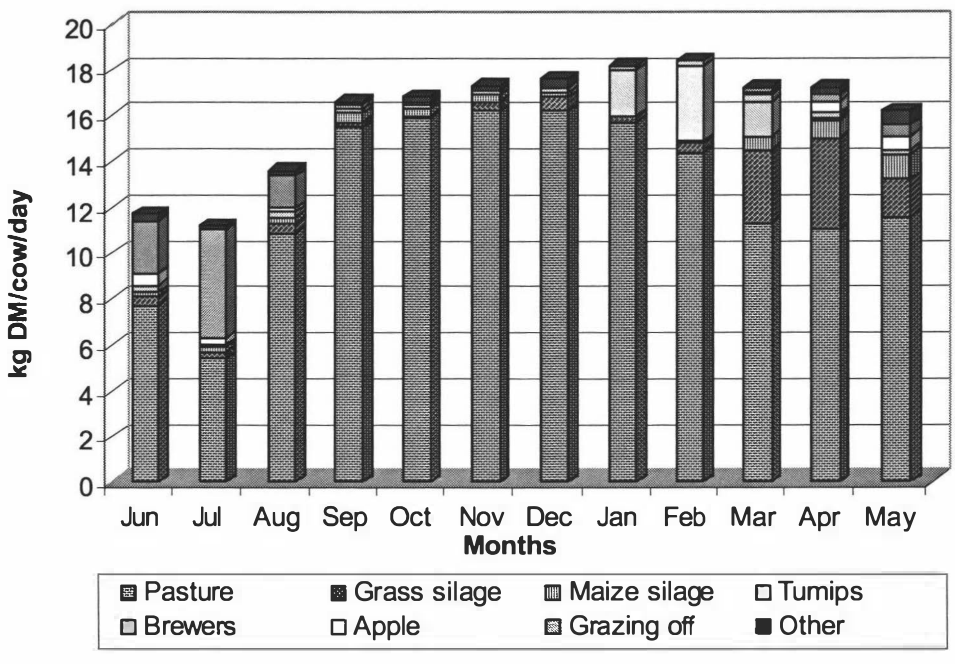


Figure 3.1 Monthly composition of cow's intake for the *AGMARDT* group. Adapted from (AGMARDT, 2000)

CHAPTER 4

Materials and Methods

4.1. INTRODUCTION

The main objectives of this study are to define and better understand the characteristics of the lactation curve, factors affecting its shape and the implications of the lactation pattern on the overall farm productivity for nine dairy farms involved in the *AGMARDT–Dairy-Farm Monitoring Programme*.

To achieve these objectives, data were collected in order to obtain a quantitative and qualitative picture of the components likely to affect the performance of the dairy systems, as shown in Figure 4.1. Most of the data originated from the *AGMARDT–Dairy Farm Monitoring Programme* (see Chapter 3) with additional information collected exclusively for this research project. Although the *AGMARDT-Dairy Farm Monitoring Programme* involved twelve dairy farms, only nine were considered in this current study, as there was not enough information available for the other three farms.

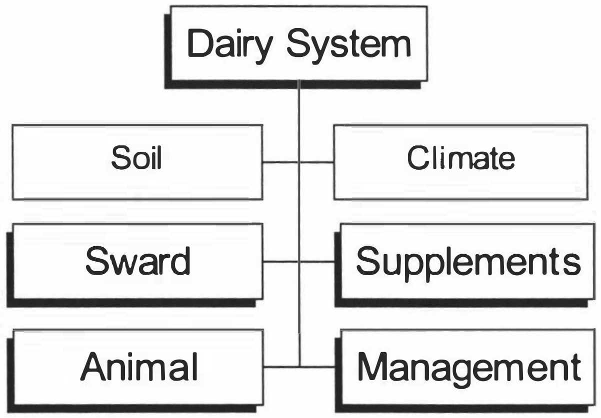


Figure 4.1 Factors that influence the dairy systems studied. Less emphasis was given to soil and climate data components in the current analyses.

In this Chapter, Section 4.2 provides general information on each of the farms. Section 4.3 to 4.7 describe the routine measurements and monitoring of pasture (Section 4.3), supplementary feeds (Section 4.4), animal and milk measurements (Section 4.6) and additional management factors (Section 4.7). Section 4.8 outlines procedures for data processing and statistical analysis.

4.2. FARM DESCRIPTION

The farms are located in three regions in the southern North Island; Rangitikei, Manawatu and Northern Wairarapa. These regions cover a range of soil types, soil fertility and climate. The data in Table 4.1 were obtained from soil and climate maps from Massey University and from the latest soil analyses carried out on individual farms. Further information on soil characteristics is in Appendix 1.

Table 4.1 Characteristics of the farms. Season 2000/2001.

Farm	Location	Area (ha)		Soil P status[3]	Rainfall[4]
		Total[1]	*Effective*[2]	(ug/ml)	(mm/year)
1	Pahiatua	231	213	35	1200
2	Woodville	141	125	31	1180
3	Bulls	133	122	32	840
4	Bulls	197	155	29	840
5	Feilding	55	52	36	940
6	Pahiatua	73	69	35	1600
7	Shannon	102	81	31	1000
8	Pahiatua	74	70	36	1300
9	Palmerston North	92	87	35	1020

[1], [2] Total area includes woodland, drainage channels, building and wasted areas. Effective area includes just the grazable pastures.

[3] Olsen P.

[4] Average of 30 years (from 1941 to 1970). Source: NZMS (1979).

The herds consisted of Jersey and Holstein-Friesian crossbred animals. They varied in size, productivity, breeding worth (BW) and production worth (PW) (Table 4.2).

Table 4.2 Characteristics of the herds. Season 2000/2001.

Farms	Peak number of milking cows	BW[1]	PW[1]
1	570	62	71
2	295	76	96
3	326	66	78
4	405	61	72
5	148	50	56
6	164	80	101
7	215	56	55
8	210	91	112
9	253	52	72

1 BW (breeding worth); PW (production worth) (LIC, 2000)

The predominant pasture species on the properties were perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*). Some farms also allocated some areas to turnips (*Brassica campestris*) as a summer crop. Even though grown on the farm, turnips were considered as a supplementary feed in this study. All farms utilised grazing-off areas to provide a proportion of the grazing requirement during the dry period.

4.3. SWARD MEASUREMENTS

Pasture samples and data were collected in order to measure sward productivity, sward characteristics and sward management. Measurement of pasture quantity consisted of pre grazing herbage mass, post grazing herbage mass. Measurements of sward quality were obtained from pasture samples cut before grazing at grazing. Grazing level herbage samples were collected in order to determine the pasture quality of herbage consumed by the cows.

4.3.1. Herbage mass

Pre and post grazing herbage mass (kg DM/ha) were estimated daily for all paddocks currently being grazed. They were estimated by the farmers, through visual assessment (L'Huillier & Thomson, 1988; Hodgson *et al.*, 1999) and, once a month, pre and post grazing herbage mass for 15 to 20 paddocks selected randomly for each farm were also estimated by the technical staff utilising an Ashgrove Rising Plate Meter (RPM) (Hodgson *et al.*, 1999) with the standardised monthly calibration equations developed by Livestock Improvement and the Dairying Research Corporation (Hainsworth, 1999). The paddocks for which the pre and post herbage mass were estimated through the RPM technique, were the same ones assessed visually by the farmers. Regression analysis was then used to derive a monthly regression between RPM and visual sward assessment, in order to standardise pasture measurements between farms (AGMARDT, 2000) (Appendix 2). The adjusted herbage data were then used as the values for pre and post grazing herbage mass which were also utilised to calculate the pasture intake figures utilised in this study.

Pre and post grazing herbage mass along with grazing intensity (cows/ha/day) were used to estimate the apparent herbage intakes (Matthews *et al.*, 1999) as the difference between the pre grazing and post grazing herbage masses (kg DM/ha/day) divided by grazing intensity which is expressed in cows/ha/day, or the number of cows in a given day divided by the area grazed on the same given day.

4.3.2. Grazing level herbage samples

From 23rd August 2000 to 31st January 2001, samples of pre grazing herbage mass were hand plucked (Cosgrove *et al.*, 1998) by the farmers at the estimated grazing height, along a diagonal line crossing the paddock from corner to corner. Samples from three different paddocks were collected within each 10 day period, and thoroughly mixed to obtain a single sample, which was frozen at the farm for further analyses. From 1st

February to 31st May 2001, samples were collected at monthly intervals and within each month, samples from three different paddocks were taken and processed as described above.

At Massey University, the samples were thawed (Plate 4.2), thoroughly mixed and sub-sampled to obtain two sub samples of approximately 300g fresh weight, which were used for the chemical analysis and botanical composition.

The first pasture sub sample was dried at 60°C to constant weight and then ground through a 1 mm sieve for subsequent analysis by Near-Infra Red Reflectance Spectroscopy (NIRS) (Plate 4.1 (left) page 62) prediction using calibrations based on wet chemistry methods (Ulyatt *et al.*, 1995; Corson *et al.*, 1999). Variables analysed included metabolizable energy (expressed as MJME/kg DM), crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF) and organic matter digestibility (OMD) (expressed as percentage of DM). Pasture samples were not collected from 1st June to 23rd August 2000, so the values for these months were estimated from September 2000 values and from May 2001 results respectively.

The second sub sample was further mixed and reduced to 80g for botanical classification (Plate 4.1 (right) page 62). This sample was separated into grass leaf, grass vegetative stem, grass reproductive stem, clover, weeds and dead material, to determine their relative proportions. Herbage which was no longer green was classified as dead material. Partly green leaves were classified as green leaf when more than 50% of the leaf was green, otherwise, it was classified as dead material. Once separated, the constituents were dried at 80°C to constant weight and a 0.01g precision scale was used for weighing. Each component was expressed as a percentage of the total dry matter.

4.3.2.1. *Dietary variables obtained from sward measurements*

Figure 4.2 shows how the sward data were transformed in order to obtain the final outputs; ME intakes and protein intakes from grazed pasture.

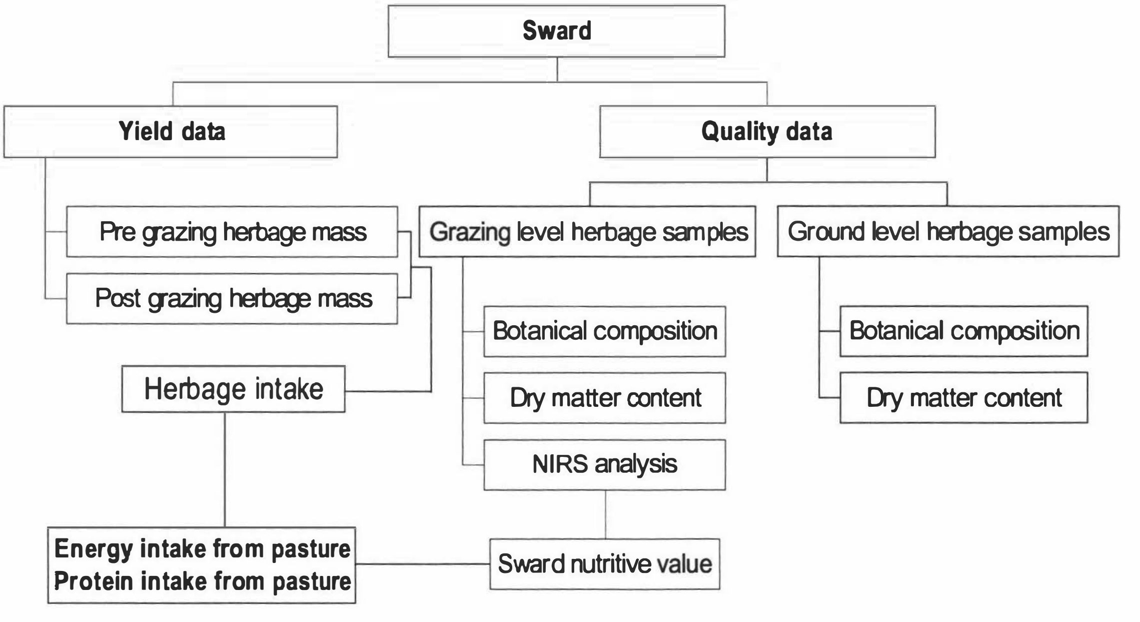


Figure 4.2 Outline of sward data collection and measurements.

Initially, daily pasture DM intake per cow (apparent intake) was calculated as explained in Section 4.3.1. and then daily pasture ME and protein intake per cow were obtained by multiplying pasture DM intake per cow by the respective contents of ME (MJME/kg DM) and protein (g crude protein/kg DM) in the pasture samples.

4.4. SUPPLEMENTARY FEED MEASUREMENTS

The quantity and the quality of the supplements fed were measured on each one of the case study farms. Those supplements consisted of apple pomace, baleage, barley grain, barley silage, brewers grain, carrot pomace, corn waste, grazing off, hay, maize grain, maize silage, molasses, oat silage, palm kernel, pasture silage, squash and turnips. However none of the farms used all those types of supplements during the season.

4.4.1. Quantity of Supplement Fed

The farmers recorded the quantities of all supplementary feeds (fresh weight) every time they were offered to the cows. For most supplements, the quantities were determined utilising load cells fitted on the feeding wagons or with the use of bucket on front-end loaders of the tractors. Also, the weights of bales or supplement bags were used to determine the quantity of some supplementary feeds.

For turnips, five small areas defined by a rectangular quadrat (0.5m x 0.5m) (Hodgson *et al.*, 1999) were cut by the researchers and technical staff to estimate the yields of the whole plant (bulb and leaf) per hectare. The final fresh weight was represented by an average value including the five samples. One of the five samples (0.5m x 0.5m) was dried at 80°C to constant weight to determine the dry matter percentage. Once the dry matter percentage was estimated, the yield per hectare (kg DM/ha) was obtained by multiplying the weight of the material which was collected within the quadrat area by 10,000 m^2 (1 ha) and then dividing by the area of the quadrat (0.25 m^2). This procedure was carried out twice for each farm on which turnips were grown and the average of these two estimations was used to determine the final yield per hectare (kg DM/ha). In addition, the area fed each day was recorded by the farmers and the estimation of daily turnips consumption per herd was calculated as the product between crop yield (kg DM/ha) and area fed each day (ha).

A wastage of 5% from the quantity of all supplements offered to the cows in feed pads was assumed to determine the apparent dry matter intake of those supplements. For turnips and supplements fed on the paddocks a wastage of 10% was assumed.

4.4.2. Type and composition of the supplement

Samples of each type of supplement were collected by the farmers for NIRS analyses and estimation of dry matter content. One sample of each type of supplement used was collected every ten days, from 23rd August to 31st January. From 1st February to 31st May 2001, the samples were collected monthly. Each sample consisted of several handfuls from different points in the feeding line on the paddock or on the feeding pad. The samples were frozen at the farms for further chemical analysis. Samples of supplements were not collected from 1st June to 23rd August 2000. Therefore, the respective NIRS values for the supplements used in this period were assumed to be the same as the average values of the same supplements fed after 23rd August 2000. For all supplements for which the dry matter content was unknown by the farmers, a fresh sample was taken by the researchers and technical staff in order to determine its dry matter content (DM%).

The preparation of supplement samples and their chemical analysis followed the same procedures utilised for pasture samples (see Section 4.3.2). However, it was not possible to determine the ME values in apple pomace, barley grain, brewers grain, maize grain and squash through the NIRS methodology because no equation was available for predicting ME from proximate analyses for these feeds. Therefore, their ME values were estimated from the values of protein, lipid, ash, ADF, NDF and CHO (soluble carbohydrates) measured by NIRS, and standard values of those components and associated ME values found in the literature (NRC, 1988; MAFF, 1990).

For carrot pomace, palm kernel and turnips, ME values were derived directly from the literature (NRC, 1988; MAFF, 1990) due to lack of information about the relationship between nutritional components and NIRS analysis for these feeds. For grazing-off, 10.5 MJME/kg DM was assumed and the crude protein, ADF and NDF were estimated as the average concentration of those components in the grazing height pasture samples which presented 10.5 MJME/kg DM. The same values were utilised for all farms.

4.4.3. Dietary variables obtained from supplements measurement

Figure 4.3 shows how the supplementary feed data were transformed in order to obtain the final outputs ME intake and protein intake from supplements.

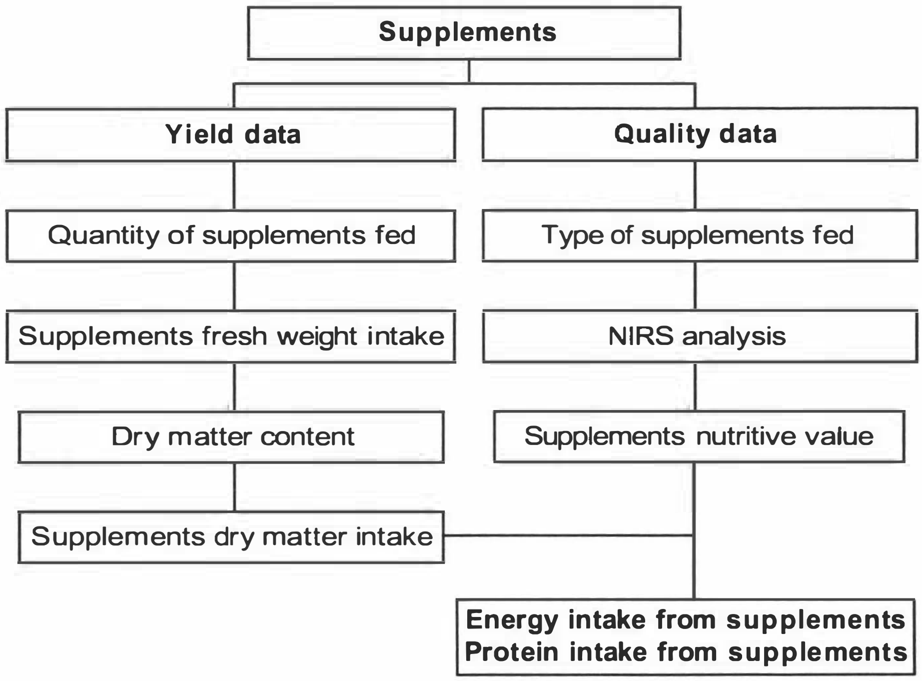


Figure 4.3 Outline of supplement data collection and measurements.

Initially, the daily DM intake per herd for each supplement fed was obtained from the records of the *AGMARDT–Dairy Farm Monitoring Programme* as descried in Section 4.4.1. Then, daily ME and protein intake per herd were calculated for each supplement by multiplying the amount of DM supplement eaten by the respective contents of ME (MJME/kg DM) or crude protein (g crude protein/kg DM) in the supplement.

Finally, the daily ME and protein intake per cow for each supplement was obtained by dividing the daily herd intake by the daily number of cows. ME and protein intake per cow for each supplement were then summed in order to obtain the daily total intake of ME and protein, from supplements, per cow.

4.5. OTHER DIETARY VARIABLES

4.5.1. Concentration of metabolizable energy and protein in the total diet

The concentration of metabolizable energy and protein in the total diet (pasture plus supplements), expressed as MJME/ kg DM and kg protein/kg DM was calculated from intakes per cow by dividing total ME intake or total protein intake by total DM intake.

4.6. ANIMAL MEASUREMENTS

The current study focused on the dairy herd itself. Therefore, performance measurements for any other class of animal which not lactating or pre calving dry animals was not considered.

4.6.1. Numbers (Stock Reconciliation)

Number of animals in each stock class (dries, milkers and dries grazing off farm) as well as transfers between classes, stock sales, stock purchases and stock deaths, were recorded daily by the farmers.

4.6.2. Liveweight and condition score

A random sample of lactating cows representing approximately 25% of each herd was weighed and condition scored by the researchers and technical staff in late September, late November, mid March and late May/early June (Plate 4.2 page 62). The condition score system utilised was based on the Livestock Improvement Corporation model (LIC, 2000), scale (1 – 10) (Plate 4.4 page 63). Due to time and labour constraints, it was not possible for the same person to carry out the condition scoring on all occasions. However procedures were standardised between the three people involved.

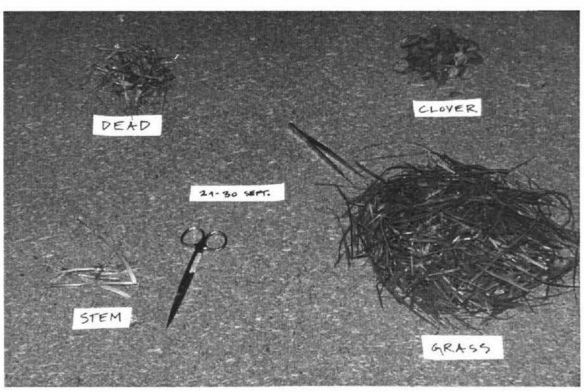
4.6.3. Milk yield and composition

Daily data for milk yield and composition (fat % and protein %) per herd from each farm was obtained from the milk statement provided monthly by the former Kiwi Co-operative Dairies. The milk used for feeding calves was not measured by the farmers, consequently the milk production for all the farms was underestimated slightly.

4.6.3.1. Milk yield derived variables

Utilising information described in the previous section, daily fat and protein yield per herd (kg/day) were calculated by multiplying daily yield per herd (litres) by daily concentration of fat or protein in the milk (g/l). Then, daily MS yield per herd (kg) was obtained by summing daily fat and protein yield per herd (kg). Finally, daily MS yield per cow (kg/cow/day) was obtained by dividing daily MS yield per herd by the daily number of cows.


Plate 4.1 Equipment utilised for the NIRS analyses (left) and botanical composition classification procedure (right).



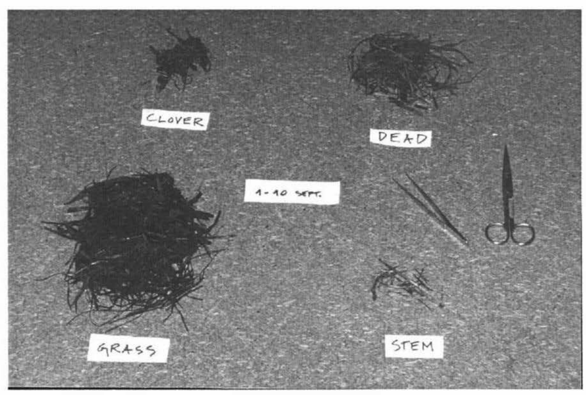


Plate 4.2 Botanical composition of a fresh sample (left) and of a thawed sample (right).

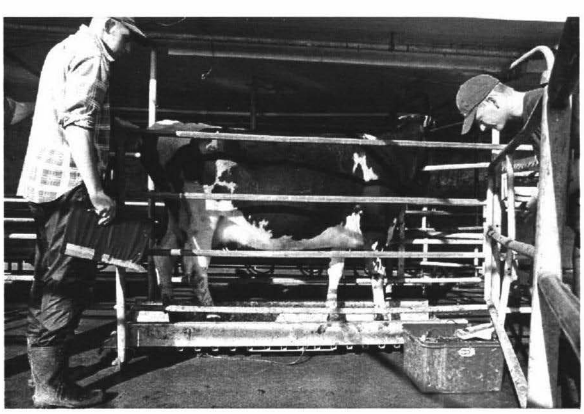
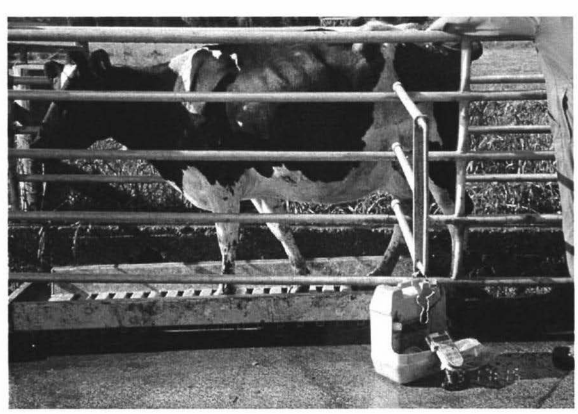



Plate 4.3 Weighing and condition scoring procedures.

Score 3 **Score 4** **Score 5**

Plate 4.4 Condition scoring system for Friesian cows (LIC, 2000).

4.7. MANAGEMENT FACTORS

Information on general management is listed below. The information was gathered on a routine basis throughout the season.

- Decisions regarding supplementary feed;
- Changes in stock numbers;

- Dates when stock were removed to grazing off areas and returned to the home farm.
- Calving and drying off dates, calving pattern;
- Mating dates and submission rates;
- Decisions regarding disposal of stock;

4.8. DATA PROCESSING AND STATISTICAL ANALYSIS

4.8.1. Data processing

Procedures for evaluating and the statistical analysis of the current data were strongly influenced by the following factors:

1. The main focus was on the short term (peak period) and long term (post peak period) changes in daily milk yield per cow and associated changes in feeding levels to the dairy herd. The other feature of interest was the short period of markedly reduced milk production from late September to early November, which may have been associated with a short term weather event that may have adversely affected feed supply and utilisation. This scenario, therefore, imposed restrictions on conventional methods for analysis of the lactation curve (see Section 5.3) as a means of defining the pattern of milk production, particularly in early lactation. Instead, attention was concentrated on measuring changes in milk yield over sections of the lactation curve defined after appraisal of individual farm lactation data by observational analysis, and then relating them to feeding information (pasture and supplements intake) measured during associated periods of time.

2. Measurements of pasture and supplement intake and milk yield and composition were available on a daily basis but the determination of feed composition was available only at intervals of 10 days for the first part of the season (August to February) and monthly for the second part of the season (February to May). As a result, the lactation period was also divided into sub periods of 10 days (in some cases 11 days as there are months of 31 days), and consequently milk yield and composition as well as feed intake and its composition were expressed as mean values over the respective 10 day periods.

4.8.2. Statistical analyses

All the statistical analyses were performed using the MINITAB ™ Statistical Software version 13.1. The initial assessment of the correlations between the response (y) and explanatory ($x_1, x_2, \ldots, x_n$) variables and between the explanatory variables themselves were based on a simple Pearson correlation matrix which provided values for r (correlation coefficient) and P (probability estimation) for all the combinations of variables presented in the matrix.

The explanatory variables which presented the best correlation to the response variables in the correlation matrix were then selected for a simple regression analysis in order to measure the quantitative relation between the two variables. The regression coefficient is a measure of the change in the y variable which occurs in association with a unit change in the x variable; $y = a + bx$.

Some X variables which did not present strong correlation to the Y variables, were considered for the simple regression analysis because of their expected biological importance.

Then, those variables were combined in stepwise regression analyses (2 or 3 factors), in order to measure the variation in Y explained by two or more X variables combined, as show the MINITAB ™ output below:

Regression equation:

$$y = 36.8 + 73.6\ x_1 + 0.999\ x_2$$

Predictor	Coefficient	Standard Error	T	P
Constant	36.84	96.15	0.38	0.715
x_1	73.60	37.66	1.95	0.098
x_2	0.9994	0.2326	4.30	0.005

S = 12.95 R2 = 78.7%

Source	Degrees of freedom	Sum of squares	Mean square	F	P
Regression	2	3706.6	1853.3	11.06	0.010
Residual error	6	1005.6	167.6		
Total	8	4712.2			

The significance of each additional variable included in the model was determined by F-test as follows:

$$F = \frac{\text{Additional sum of squares for the regression} / \text{Additional degrees of freedom}}{\text{Mean square error}}$$

This test indicates if the additional sum of square which is explained by X_2 given that X_1 is already in the model is significant at 5% level based on F table values. The additional sum of squares is obtained by subtracting the sum of squares value for the simple regression analysis, including just x_1, from the sum of square value for the multiple regression including x_1 and x_2 (IIST, 2000).

In order to test if the mean value for the proportion of fat and protein in the milk, for the ratio fat to protein and also for the levels of ME intake per cow, over specified section of the lactation, differed from zero, a t-test was employed. The t-test outputs were obtained from the MINITAB™ Statistical Software version 13.1.

The descriptive statistics were also obtained through the MINITAB™ Statistical Software version 13.1.

CHAPTER 5

Results

5.1. INTRODUCTION

This chapter reports the results for the analyses of the characteristics of the lactation curves and evaluation of the nutritional factors influencing them. The components utilised for these analyses were:

- The peak milk yield (Section 5.2).
- The temporary decline and a subsequent recovery in milk yield immediately after the peak period, observed in all farms, which seemed to be associated with a short period of adverse climatic conditions at that time (Section 5.3).
- The long-term decline in milk yield over the post-peak period and the milk yield in late lactation (Section 5.4).

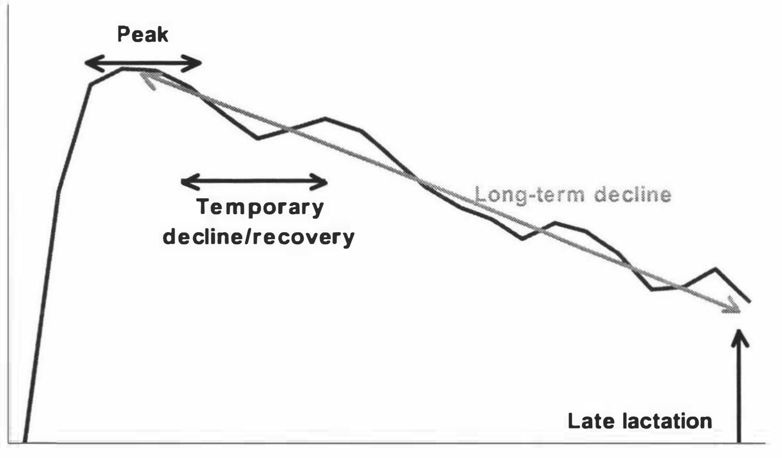


Figure 5.1 Illustration of the lactation components and periods for the farms involved in this study.

The components described above are illustrated in Figure 5.1 and specific details are given in the appropriate sections. The analyses made in these sections are based on mean values for MS yield and nutrient intakes per cow for each farm, calculated over 10 days periods (as explained in Section 4.8.1).

The relationships between some of the components of the lactation curve and their overall influence on lactation yield are described in Section 5.5 and finally, Section 5.6 involves a comparison of the feeding levels associated with the contrasting patterns of lactation defined within the set of the farms studied.

5.2. ANALYSES RELATED TO THE PEAK YIELD PERIOD

5.2.1. Definition of peak duration

Peak yield, in kg MS per cow, was defined as the highest value observed after the date when 50% of the herd had calved, to avoid risks of distortion before a substantial proportion of the herd had calved. The lactation curves and cow numbers are shown, for individual farms, in Appendix 3. However, in some farms, there was an extended peak, with little change in MS yield per cow over periods of 20 to 70 days. For these farms, if the variations in MS yield between the periods before and/or after peak were less than +/-2.33%, then this (these) period(s) were also included in the peak period (see example in Table 5.1). The variation in MS yield between periods was calculated as follows:

$$\text{Variation in MS yield (\%)} = 1 - \frac{\text{Daily MS yield at period } n}{\text{MS yield at period } n-1} \times 100$$

The value of 2.33% was derived from published data (see Section 2.2.2 and 2.2.4) which suggested, under constant conditions, a post peak rate of decline in milk yield of around 7% per month from the previous month yield, which is equivalent to 2.33% decline per each 10 days period.

In the example presented in Table 5.1, for Farm A, peak yield occurred in the second period of September (2/Sep) and the variation in milksolids yield between this period and the previous and successive periods was greater than +/-2.33% (+6.60% and -10.61% respectively). Peak yield was therefore the value of 2.26 kg MS/cow/day and its duration was of 10 days, or just one period. For farm B, the peak yield occurred in the third period of September (3/Sep), but the yields in adjacent periods (from 2/Sep to 1/Nov) were within 2.33% of the peak yield, therefore, peak yield was calculated as the average of the yield values from period 1/Sep to 1/Nov which was 1.90 kg MS/cow/day and its duration was 70 days.

Table 5.1 Data from a long peak farm and a short peak farm to show how peak yield and peak duration were defined.

	Farm A		Farm B	
Period*	**Yield**	**Variation (%)**	**Yield**	**Variation (%)**
3/Aug	2.07	-	1.84	-
1/Sep	2.12	+2.41	**1.89**	+ 2.71
2/Sep†	**2.26†**	+6.60	**1.89**	0.00
3/Sep	2.02	-10.61	**1.91**	+1.05
1/Oct†	1.88	-6.93	**1.88†**	-1.57
2/Oct	1.87	-0.53	**1.88**	0.00
3/Oct	1.89	+1.06	**1.90**	+1.06
1/Nov	1.80	-4.76	**1.92**	+1.05
2/Nov	1.71	-5.00	1.83	-4.68

Bold figures represent the values utilised for peak yield and for peak duration determination (long peak herds).

(†) Mid peak – period and yield values (see section 5.2.2).

(*) 1, 2 and 3 indicate successive 10 days periods for each month.

5.2.2. Description of the peak characteristics

Information on peak characteristics for the nine farms is shown in Table 5.2. Peak MS yield (mean values for the herds with prolonged peak) ranged from 1.90 to 2.26 kg

MS/cow/day, and duration of the peak ranged from 10 to 20 days for six of the farms, but 30 to 70 days for the other three farms. The period between start of calving to peak varied from 20 to 50 days. The peak occurred during late August/September for eight of the farms, but extended through October for one of the farms.

To make comparisons between the herds with long or short peak periods in further analyses, peak yield was also represented by the 10 days interval in the middle of the peak period of the extended peak herds, and this period was defined as the "mid peak period" (Figure 5.2. See also Table 5.1 for example). For the short peak herds (just one 10 days period interval) peak and mid peak yield are represented by the same values and by the same period (see Table 5.1 for example).

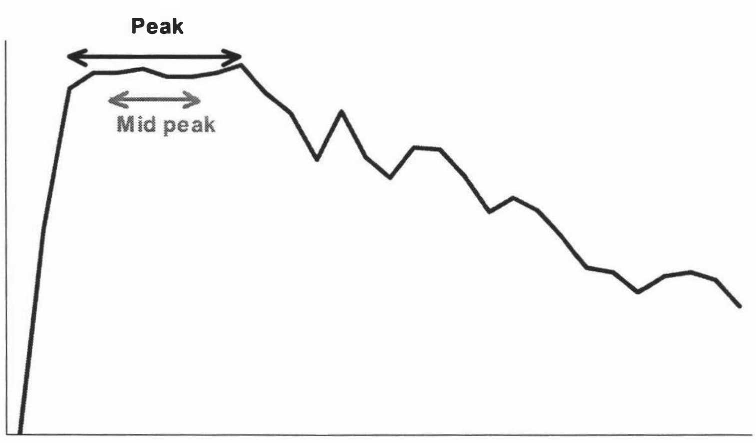


Figure 5.2 Representation of the peak period and mid peak period.

The mid peak yield values differed little from the averaged peak yield values. The period between calving and mid peak ranged from 20 to 60 days and the mid peak dates occurred between the last period of August and the first period of October. Details of peak yield characteristics are shown in Table 5.2.

Table 5.2 Values for peak daily yield, peak dates and interval from calving to peak, in relation to the whole peak period and to the mid peak period.

Farm	Peak yield (Kg MS/cow/day)	Mid peak yield (kg MS/cow/day)	Peak period dates	Peak duration (Days)	Mid peak date	Calving to start of peak (Days)	Calving to mid peak (Days)
1	2.02	2.04	1/Sep to 3/Sep	30	2/Sep	30	40
2	2.02	2.02	1/Sep to 2/Sep	20	1/Sep	30	30
3	2.26	2.26	3/Sep	10	3/Sep	50	50
4	2.18	2.18	3/Sep	10	3/Sep	50	50
5	1.90	1.88	1/Sep to 1/Nov	70	1/Oct	30	60
6	1.93	1.94	2/Sep to 3/Sep	20	2/Sep	30	30
7	1.97	1.97	3/Aug to 1/Sep	20	3/Aug	20	20
8	2.16	2.13	3/Aug to 3/sep	40	1/Sep	20	30
9	2.01	2.00	3/Aug to 1/Sep	20	3/Aug	20	20

5.2.3. Factors related to peak yield

For these analyses, the response variables (y) were peak MS yield or mid peak MS yield and the predictor variables (x) were represented by the intakes of ME, protein and DM, by the sward characteristics and by some general variables represented by condition score at peak, peak date, peak duration and time from calving to peak.

5.2.3.1. ME intake and general variables

In preliminary analyses of the association between ME intake and peak MS yield, correlations were established between the peak MS yield or the mid peak MS yield and the variables total ME intake, pasture ME intake, supplements ME intake and ME concentration in the total diet, expressed as daily averages over the following periods of time;

- Over the full period of peak yield – 10 days for the short peak yield and up to 70 days for extend peak herds (see Table 5.2).
- Over the 10 days period of peak yield (short peak herds) or the middle 10 days in the extended peak farms (mid peak period).
- Over the mid peak period plus the preceding 10 days.
- Over the mid peak period plus the preceding 20 days.
- From starting of calving to peak or mid peak.
- From the time when 50% of the herd had calved to peak or mid peak.
- From early June to starting of calving (to test the association between level of pre calving intake and peak yield).

The 10 days estimation of ME intakes coinciding with mid peak period presented a slightly better correlation to peak MS yield than the longer combinations of preceding periods, therefore it was chosen to continue the regression analyses. From this point forward, the other estimations were no longer considered and values for MS yield and ME intakes always represent the 10 days period coinciding with the mid peak period. However, the correlation matrix showing the relationships between all variables described above is given in Appendix 4.

Generally, the correlations between mid peak yield and the ME variables measured at mid peak were not strong ($P>0.05$) (Table 5.3). However, all the ME variables were still considered for the regression analysis, either because of their expected biological importance, as in the case of pasture ME intake, or in order to test the possibilities that when combined in a multiple regression analyses, they could explain significant variation in mid peak yield.

Table 5.3 Values for the correlation coefficients (r) and *P* for the relationships between the response variable mid peak MS yield and the predictor variables; ME intakes measured at mid peak period and the general variables related to mid peak period.

Response variable (y): *mid peak MS yield (kg MS/cow/day)*

Predictor variables (x)	r[1]	*P*
Total ME intake (MJME/cow/day)	**0.760**	**0.018**
Pasture ME intake (MJME/cow/day)	0.266	0.489
Supplements ME intake (MJME/cow/day)	**0.633**	**0.067**
ME concentration in the diet (MJME/kg DM)	0.561	0.116
Calving to mid peak interval (days)	0.225	0.560
Date of mid peak	-0.220	0.569
Duration of peak (days)	-0.561	0.116
Condition score [2] (units/cow)	0.038	0.923

1 The squared value of r, expressed in percentage, corresponds to the R^2 % value. The same applies for the next Tables.

2 The condition score was not necessarily estimated at the mid peak period, but around peak period (late September).

The x variable(s) best correlated to the y variable is shown in bold. The same applies for the next Tables of this Chapter..

The initial assessment of the correlations between mid peak yield and the general variables was made independently (Table 5.3) and then some of these variables were combined in the ME intake analyses. From the set of general variables represented by duration of peak (days), date of mid peak, interval from calving to mid peak and condition score measured in late September, peak duration was the only variable which was even moderately correlated to MS yield at peak, so it was considered further in the regression analysis. Although condition score at peak was correlated poorly to MS yield at mid peak, it was also considered in the regression analyses in order to test if this variable, in combination with others, could become significant. The full correlation matrix for the mid peak period analysis is shown in Appendix 5 and the plots presenting the pattern of cow's condition score over the lactation period are shown in Appendix 6.

In the simple regression analyses, none of the predictor variables explained more than 57.7% of the variation in mid peak MS yield. Total ME intake at mid peak explained most variation in mid peak yield and was the only significant variable. The regression plots of mid peak yield on total ME intake, pasture ME intake and supplements ME intake are shown in Figure 5.3 and the regression equations for the other variables are shown in Table 5.4.

The regression coefficient of the regression equations (slopes b), represent responses in mid peak yield of 3.8, 1.3 and 3.9 g MS per cow day per extra unit of MJME per cow day of total, pasture and supplements ME respectively. The plots showing the levels and pattern of ME intake, for each individual farm over the lactation period, are given in Appendix 7.

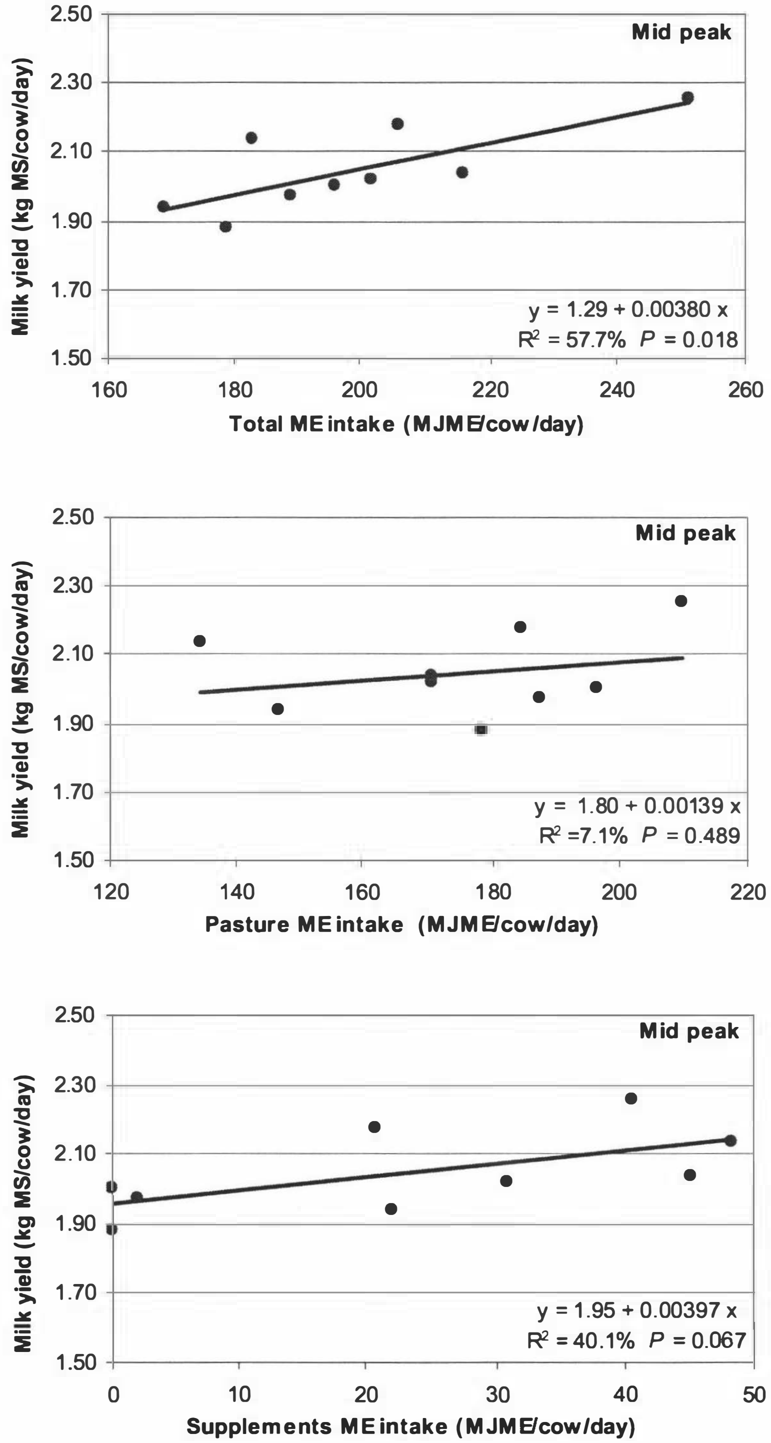


Figure 5.3 Regression plots of mid peak MS yield on total, pasture and supplements ME intake at mid peak period, the respective regression equations, R^2 and *P* values. Note the different scales for X axis.

The predictor variables utilised in the simple regression, with the exception of total ME intake at mid peak, were also combined in a multiple regression analysis (Table 5.4). The sequence in which the variables were added to the model took more account of their biological importance than their statistical significance in the simple regression analysis. Because on average, 88% of the total ME intake at mid peak was supplied by pasture (Figure 5.4), pasture ME intake at mid peak was considered as the first variable to be included to the model, although, on its own it had only explained 7% of the variation in mid peak milk yield (Table 5.4).

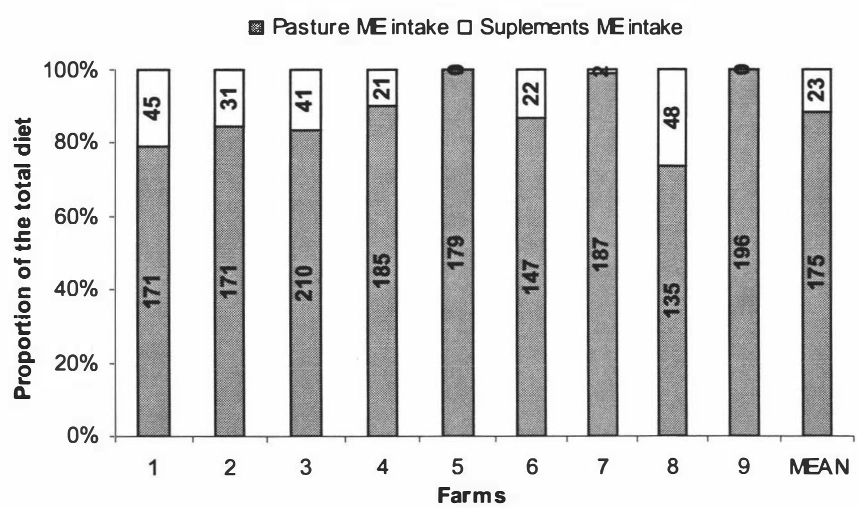


Figure 5.4 Proportions of the ME intake from pasture and from supplements, in the total diet, at the mid peak period. The numbers within the bars represent the daily average ME intake of pasture and supplements per cow at the mid peak period.

Following the simple regression equation of mid peak yield on pasture ME intake at mid peak, the variable supplement ME intake at mid peak was added (Table 5.4) and the additional amount of variation explained by the second variable was significant ($P<0.05$) according to the F-test (see section 4.8.2). The combined analysis also increased the significance of the variable pasture ME intake (from $P=0.489$ to $P=0.059$).

The slopes, b_1 and b_2, of the multiple stepwise regression equation (Table 5.4) represent responses in mid peak yield of 2.9 and 5.2 g MS per cow day per extra unit of MJME per cow day of pasture and supplement respectively, which were higher than the slopes of the simple regression equations for pastures and supplements individually (Figure 5.3 and Table 5.4).

After the addition of the variable supplement intake in the model, all the other variables considered in the individual regression analysis were also added, however the additional amount of R^2 explained by them was not significant, therefore the regression equations are not presented.

Table 5.4 Regression equations of mid peak MS yield (y) on individual x variables and on a combination of individual x variables, all measured at mid peak period, and the respective R^2 and *P* values.

Individual x variables	Regression equation	R^2%	*P*
Total ME intake	*y = 1.29 + 0.00380 x*	57.7	0.018
Pasture ME intake	*y = 1.80 + 0.00139 x*	7.1	0.489
Supplements ME intake	*y = 1.95 + 0.00397 x*	40.1.	0.067
ME concentration in the total diet	*y = 0.434 + 0.139 x*	31.5	0.116
Peak duration	*y = 2.14 – 0.00364 x*	31.4	0.116
Condition score around peak time[1]	*y = 1.97 +0.020 x*	0.1	0.923

Combination of x variables	Regression equation	R^2%	*P*
	$y = 1.40 + 0.00298\,x_1 + 0.00528\,x_2$	68.4	
Pasture ME intake (x_1)			0.059 (x_1)
Supplements ME intake (x_2)			0.014 (x_2)

In order to investigate the influence of ME intake during specified periods **before** the peak period on the peak yield, the mean value of total ME intake over the pre calving period (x_1) and the period from 50% of the herd calved to mid peak (x_2) were also combined in two independent multiple regression analyses, where total ME intake at mid peak was already present as the first variable (x_1). The period from when 50% of the herd had calved to mid peak (P=0.214), was used in preference to the period from starting of calving to the mid peak period (P=0.163) because the correlation between ME intake and mid peak yield was better if intake was estimated for the former period. The addition of either total ME intake pre calving or from 50% calving to mid peak in the model, increased the R^2 value slightly compared with the initial model, but this improvement was not significant, so the combination of the three periods was not analysed further.

The correlation between pasture ME intake and supplements ME intake (r=-0.363; P=0.336, Appendix 5), although not significant, was negative suggesting that, when supplements were added in the system at the mid peak period, the amount of ME intake from pasture was reduced.

5.2.3.2. Protein intake

The best correlations between peak yield and the ME variables were identified during the mid peak period, therefore this period was also taken as the basis for analysis of the protein variables. The variables utilised in this analysis were all measured in the mid peak period and are described in Table 5.5. The plots showing the levels and patterns of protein intake, for each individual farm over the lactation period, are given in Appendix 8.

Individually, none of the protein variables was strongly correlated to mid peak yield (P>0.05) (Table 5.5). The protein intake variable which best correlated to the mid peak yield was concentration of protein in the diet and this relationship was negative. In view of the poor correlations, regressions and multiple regression analyses were not considered to be justified. The full set of correlations for the protein variables is given in Appendix 5.

Table 5.5 Values for the correlation coefficients (r) and *P* for the relationships between the response variable mid peak MS yield and the protein intake predictor variables measured at mid peak period.

Response variable (y): *mid peak MS yield (kg MS/cow/day)*		
Predictor variables (x)	**r**	***P***
Total protein intake (g/cow/day)	-0.026	0.948
Pasture protein intake (g/cow/day)	-0.241	0.532
Supplements protein intake (g/cow/day)	0.322	0.398
Protein concentration in the diet (g/kg DM)	**-0.422**	**0.258**

In order to test if there was significant association between total ME and total protein intake explaining variation in mid peak yield, these two variables were tested in a multiple stepwise regression analysis on mid peak yield where total ME intake at mid peak was added as the first variable (x_1), and the total protein intake was added as the second variable(x_2), however the addition of total protein intake as the second variable increased the R^2 value only slightly, and this increment was not significant, so the regression equation is not presented.

5.2.3.3. Dry matter intake and sward characteristics

As mentioned before, the best correlations between peak yield and the ME variables were identified during the mid peak period, therefore this period was also taken as the basis for analyses of the DM and sward variables. The DM intake and sward variables were all measured at mid peak period and are described in Table 5.6.

Among the DM intake variables, total DM intake was the only variable which was correlated significantly to mid peak yield, in agreement with the results found for total ME intake (Table 5.6).

Table 5.6 Values for the correlation coefficient (r) and *P* for the relationships between the response variable mid peak MS yield and the predictor variables; DM intakes and sward characteristics measured at mid peak period.

Response variable (y): *mid peak MS yield (kg MS/cow/day)*

Predictor variables (x)	r	*P*
Total DM intake (kg DM/cow/day)	**0.717**	**0.030**
Pasture DM intake (kg DM/cow/day)	0.060	0.878
Supplements DM intake (kg DM/cow/day)	**0.597**	**0.089**
Pre grazing herbage mass (kg DM/ha)	-0.241	0.532
Post grazing herbage mass (kg DM/ha)	0.228	0.556
ME concentration in the pasture (MJME/kg DM)	0.499	0.171
Protein concentration in the pasture (g/kg DM)	-0.251	0.515
ADF concentration in the pasture (g/kg DM)	-0.288	0.453
Proportion of leaf in the sward (g/kg DM)	**0.637**	**0.065**
Proportion of clover in the sward (g/kg DM)	-0.481	0.190
Proportion of stem in the sward (g/kg DM)	-0.271	0.481
Proportion of dead material in the sward (g/kg DM)	-0.369	0.329
Proportion of weed in the sward (g/kg DM)	-0.078	0.843
Proportion of seedhead in the sward (g/kg DM)	0.265	0.491

None of the sward variables was strongly correlated to mid peak yield, with the exception of proportion of leaf in the sward which, though, not significant, was moderately and positively correlated to mid peak yield as shown in Figure 5.5. The regression coefficient of the regression equation (slope b), represents a response in mid peak yield of around 10 g MS per cow day per extra g of leaf DM present in the sward.

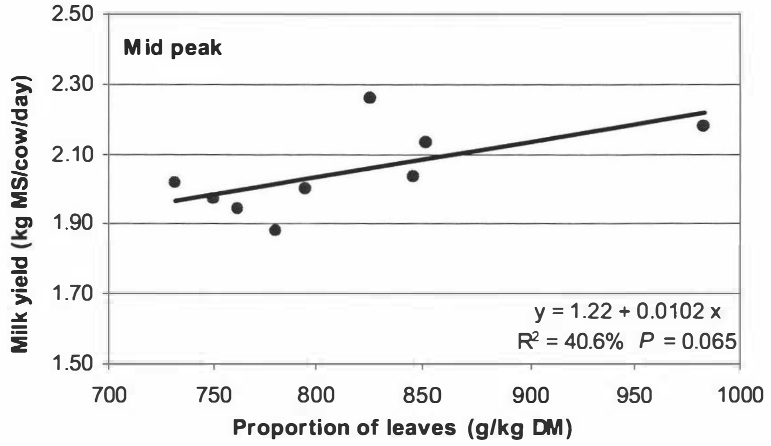


Figure 5.5 Regression plot of mid peak MS yield on proportion of leaf in the sward at mid peak period, the respective regression equation, R^2 and *P* values.

The sward variables were also not strongly correlated to pasture DM intake at mid peak (Appendix 5), with the exception of seedhead proportion which was negatively correlated to pasture DM intake at mid peak (P=0.040).

The full set of correlations for the DM intake variables and for sward variables at mid peak period is given in Appendix 5. The plots showing the levels and pattern of DM intake, pre and post grazing herbages masses and the sward characteristics, for each individual farm over the lactation period, are given from Appendix 9 to Appendix 13.

5.3. ANALYSES RELATED TO THE TEMPORARY DECLINE AND RECOVERY PERIOD

All the herds involved in this study experienced a relatively short period of decline in MS yield, from late September to early November (after peak yield), followed by a rapid recovery. This decline in milk yield seemed to be attributable to adverse climatic conditions observed over October. According to the climate data from NIWA (2000);

"...heavy rainfall and high winds battered the central North Island at the start of the month, with widespread surface flooding from Taranaki to Wellington ... westerlies were stronger than the normal over the lower North Island...and rainfall was well above 125 percent of normal in many southwestern North Island regions".

The main interest in this analysis was to quantify this short decline/recovery in MS yield, relating it to level of peak yield and levels of intake and sward characteristics which might be modified due to adverse weather conditions over that period.

For seven farms this period of decline corresponded to the end of the peak period, however there were two exceptions, Farm 5 and Farm 7 (Appendix 14). For Farm 5 the period of decline occurred within the peak period, and the MS loss was smaller than for the other farms, as MS yield variation within peak period should not be higher than +/- 2.33% from peak yield (see Section 5.2). Farm 7, in fact, showed two "peak" yields and according to the assumption of peak yield which considers peak as the first highest measurement of MS yield after 50% of the herd calved, the peak was considered to be the first one. After the first peak there was a temporary decline which did not coincide with the period of interest. After this decline there was a second peak followed by another decline which exactly coincided with the period of interest. Therefore, for Farm 7 this second temporary decline after the second peak was taken as the period for the analyses.

The MS variation over the temporary decline and recovery period was expressed as the "loss" in MS which might otherwise have been produced, if the decline had not been observed. The MS loss over the decline period was estimated by calculating the area formed by the depression in the lactation curve during that period and a straight line drawn from the yield before the decline to the peak yield after the decline (see Appendix 14 for illustration). The magnitude of the temporary decline and recovery in

MS yield varied between farms, but the period in which the decline and recovering occurred was consistent between the farms as already discussed (Table 5.7).

Table 5.7 The quantity of milksolids "lost" and the interval in which the short decline/recovering was observed, for each farm.

Farms	MS loss (kg/cow)	Period of decline/recovery	Duration of decline/recovery (Days)
1	2.23	3/Sep to 1/Nov	40
2	1.86	2/Sep to 1/Nov	30
3	4.56	3/Sep to 1/Nov	40
4	4.22	3/Sep to 1/Nov	40
5	0.89	3/Sep to 1/Nov	40
6	4.43	3/Sep to 1/Nov	40
7	2.15	3/Sep to 1 Nov	40
8	2.44	3/Sep to 1/Nov	40
9	4.35	1/Sep to 1/Nov	60
Mean	*3.02*	-	*41*

5.3.1. Factors related to the temporary decline and recovery

For these analyses, the response variable (y) was the loss of MS during the temporary decline and recovery period (see Table 5.7) and the predictor variables (x) were represented by the intake of ME, protein and DM and by the sward characteristics, calculated as mean values over the short period of temporary decline and recovery period (Table 5.7). Mid peak milk yield was also added as a predictor variable.

5.3.1.1. ME intake and mid peak yield

This analysis tested the association between the loss of MS during the temporary decline and recovery period and the ME intake variables described in Table 5.8, all measured over the decline and recovery period. Mid peak yield was also included in this analysis.

Table 5.8 Values for the correlation coefficient (r) and *P* for the relationships between the response variable MS loss, and the predictor variables; ME intakes measured over the temporary decline and recovery period and mid peak yield.

Response variable (y): *MS loss (kg MS/cow)*

Predictor variables (x)	r	*P*
Total ME intake (MJME/cow/day)	0.013	0.973
Pasture ME intake (MJME/cow/day)	0.060	0.879
Supplements ME intake (MJME/cow/day)	-0.060	0.878
ME concentration in the diet (MJME/kg DM)	**0.561**	**0.116**
Mid peak yield (kg MS/cow/day)	0.514	0.157

The correlation analysis (Table 5.8) showed that neither the ME intake predictor variables nor mid peak yield were significantly correlated to the response variable MS loss (P>0.050). The predictor variable which was best correlated to the response variable was ME concentration in the diet. The regression plots for MS loss on total ME intake, pasture ME intake and supplements ME intake over the temporary decline and recovery period are shown in Figure 5.7. Due to the poor correlations between the variables, multiple regression analyses were not considered in this analysis however, the full set of correlations for the ME variables is given in Appendix 15.

The correlation between pasture ME intake and supplements ME intake (r=-0.890; P=0.001, Appendix 15), although not significant, was significant and negative suggesting that, when supplements were added in the system during the temporary decline and recovery period, the amount of ME intake from pasture was reduced.

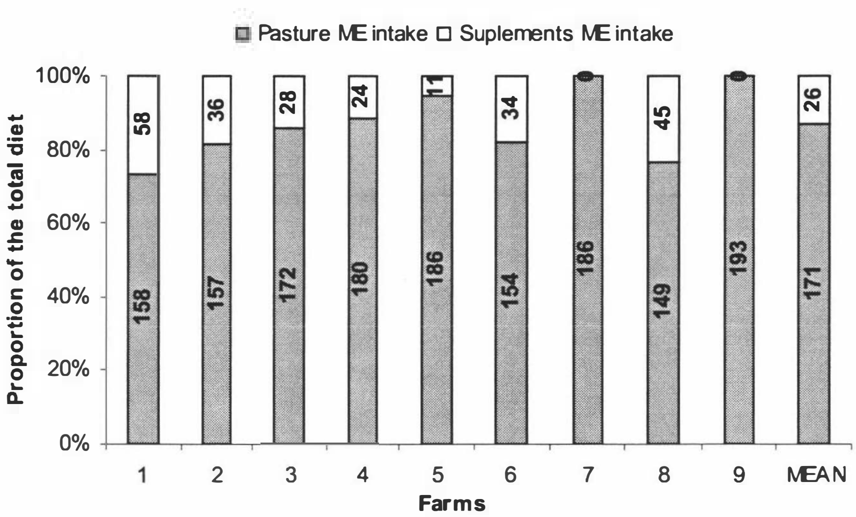


Figure 5.6 Proportions of the ME intake from pasture and from supplements, in the total diet, during the temporary decline and recovery period. The numbers within the bars represent the daily average ME intake of pasture and supplements per cow over the temporary decline and recovery period.

The average proportion of ME intake as supplements was relatively low and represented only 13,1% of the total diet, although the amount of supplements offered varied considerably between farms as shown in Figure 5.6.

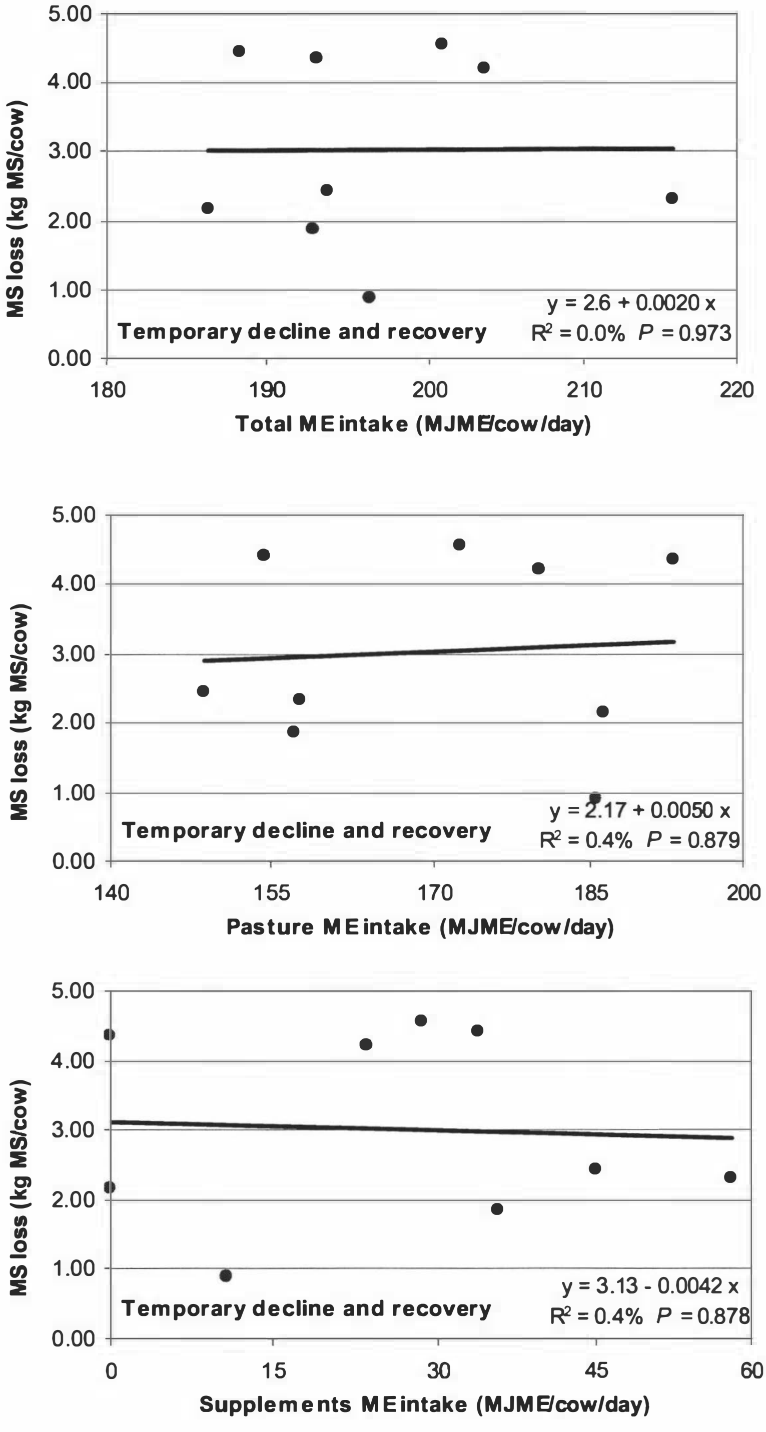


Figure 5.7 Regression plots of MS loss on total, pasture and supplements ME intake over the temporary decline and recovery, the respective regression equations, R^2 and *P* values. Note the different scales for X axis.

5.3.1.2. *Protein intake*

This analysis tested the association between MS loss over the temporary decline and recovery period and the protein variables described in Table 5.9, all measured over the decline recovery period.

The correlation analysis (Table 5.9) showed that none of the protein intake predictor variables was significantly correlated to the response variable MS loss (P>0.05). The full set of correlations for the protein variables is given in Appendix 15. Due to the poor correlations between the variables, multiple regression analyses were not considered in this analysis.

Table 5.9 Values for the correlation coefficients (r) and P for the relationships between the response variable MS loss and the protein intake predictor variables measured over the temporary decline and recovery period.

Response variable (y): *MS loss (kg MS/cow)*

Predictor variables (x)	**r**	***P***
Total protein intake (g/cow/day)	-0.061	0.876
Pasture protein intake (g/cow/day)	0.104	0.790
Supplements protein intake (g/cow/day)	**-0.177**	**0.649**
Protein concentration in the diet (g/kg DM)	0.098	0.802

5.3.1.3. *Dry matter intake and sward characteristics*

This analysis tested the association between MS loss over the temporary decline and recovery period, intake of DM and sward characteristics. The DM intake variables and sward variables are described in Table 5.10, and all of them were measured over the temporary decline and recovery period. However, only eight farms were included in the analysis involving the botanical composition variables because there was one farm which did not have the complete set of data on botanical composition for the temporary decline and recovery period.

Table 5.10 Values for the correlation coefficients (r) and *P* for the relationships between the response variable MS loss and the predictor variables; DM intakes and sward characteristics measured over the temporary decline and recovery period.

Response variable (Y): *MS loss (kg MS/cow/day)*		
Predictor variables (X)	**r**	***P***
Total DM intake (kg DM/cow/day)	**-0.277**	**0.471**
Pasture DM intake (kg DM/cow/day)	-0.038	0.922
Supplements DM intake (kg DM/cow/day)	-0.097	0.803
Pre grazing herbage mass (kg DM/ha)	0.398	0.289
Post grazing herbage mass (kg DM/ha)	0.381	0.312
ME concentration in the pasture (MJME/kg DM)	0.298	0.437
Protein concentration in the pasture (g/kg DM)	0.149	0.702
ADF concentration in the pasture (g/kg DM)	-0.268	0.485
Proportion of leaf in the sward (g/kg DM)	0.284	0.495
Proportion of clover in the sward (g/kg DM)	-0.287	0.490
Proportion of stem in the sward (g/kg DM)	-0.492	0.216
Proportion of dead material in the sward (g/kg DM)	0.138	0.744
Proportion of weed in the sward (g/kg DM)	-0.063	0.883
Proportion of seedhead in the sward (g/kg DM)	**0.542**	**0.165**

The correlation analysis (Table 5.10) showed that none of the DM intake or sward variables was significantly correlated to the response variable MS loss ($P>0.050$). The DM predictor variable which was best correlated to the response variable was total DM intake and the sward predictor variable which was best correlated to the response variable was proportion of seedhead in the sward. The sward variables were also not strongly correlated to pasture DM intake over the temporary decline and recovery period (Appendix 15), with the exception of pre and post grazing level which were significantly and positively correlated to pasture DM intake ($P=0.036$ and $P=0.054$ respectively). Due to the poor correlations between the variables, multiple regression analyses were not considered in this analysis.

5.3.1.4. Extra analyses related to the temporary decline and recovery period

In order to investigate if the animals did face nutritional deficiencies over the decline/recovery period, a t-test (see section 4.8.2) was employed to verify if the mean value for the change in fat and protein concentration in the milk, for the ratio protein to fat in the milk and for total ME intake over the temporary decline and recovery period, differed from zero. The replications utilised in these analyses were each one of the farms and the values for those changes are given in Table 5.11. An example showing how the change in the fat and protein concentrations and in the ratio, protein to fat, was calculated is shown in Appendix 16.

Table 5.11 Change in fat and protein concentrations (%) and in the ratio protein to fat in the milk and change in total, pasture and supplements ME intake (MJME/cow/day) over the temporary decline and recovery period and the significance of t-test for the variables tested

Change over the temporary decline recovery period[1]						
Farm	**Fat** (%)	**Protein** (%)	**Ratio Protein to fat**	**ME intake** (MJME/cow/day)		
				Total	*Pasture*	*Suppl.*
1	-0.040	-0.065	-0.0075	-24.5	9.5	-35.0
2	-0.060	-0.015	0.0060	9.5	17.5	-8.0
3	-0.145	-0.110	-0.0060	3.5	8.5	-5.0
4	0.020	-0.140	-0.0320	3.5	5.5	-2.0
5	-0.010	-0.040	-0.0070	14.0	-2.5	16.5
6	-0.035	-0.145	-0.0245	-22.5	-14.5	-8.0
7	0.010	-0.010	-0.0045	14.0	14.0	0.0
8	0.000	-0.085	-0.0175	-5.0	19.5	-24.0
9	0.045	-0.095	-0.0275	8.5	8.5	0.0
Mean	-0.023	-0.078	-0.0133	0.06	7.33	-7.28
Significance of the t-test[2]	*NS*	**	*	*NS*	*NS*	*NS*

[1]An example showing how these values were obtained is shown in Appendix 16.

[2]*(*) Significant at 5%; (**) Significant at 1%; (***) Significant at 0.1%; (NS) Not significant*

The t-test procedure showed that the mean values for the change in the protein concentration and in the ratio protein to fat, over the temporary decline and recovery period, were significantly different from zero ($P<0.05$), whereas the changes in fat concentration and in total, pasture, and supplements ME intake were not significantly different from zero ($P>0.05$). Note that positive values represent increases in the values over the temporary decline and recovery period, whereas negative values represent decreases over the same period. The decrease in protein % and in the ratio protein to fat during the temporary decline and recovery period suggest that animals did face nutritional deficiencies over that period, but that could not be detected in the intake data available, although the decrease in pasture intake was nearly significant.

5.4. ANALYSES RELATED TO THE LONG TERM DECLINE IN MS YIELD AND LATE LACTATION YIELD

This analysis aims at the measurement of the rate of post peak decline in MS yield, and the effects of the factors affecting this decline. These factors were levels of peak yield, levels of intake (ME, protein and DM), sward characteristics and condition score change over the post peak decline period. This analysis also aims at the establishment of the factors driving MS yield in late lactation by relating it to the same factors used for the analysis of the post peak decline.

5.4.1. Definition of post peak decline, persistency and MS yield in late lactation

The post peak decline measurement was obtained, for each farm, through regression equations of milk yield over time as illustrated in Figure 5.8. The regression analyses were carried out from the mid peak period (Period 0) to the last period in which at least 80% of the herd was still being milked, to avoid effects of strategic drying-off of cows with low yields and also, to avoid the non linear behaviour of the lactation curve at the end of the lactation period. The fit of the regression was tested in linear and quadratic models, but there were minimal differences in R^2 values between them, so the linear model was adopted. The period in which at least 80% of the herd was still being milked will be termed as *80% H in milk.*

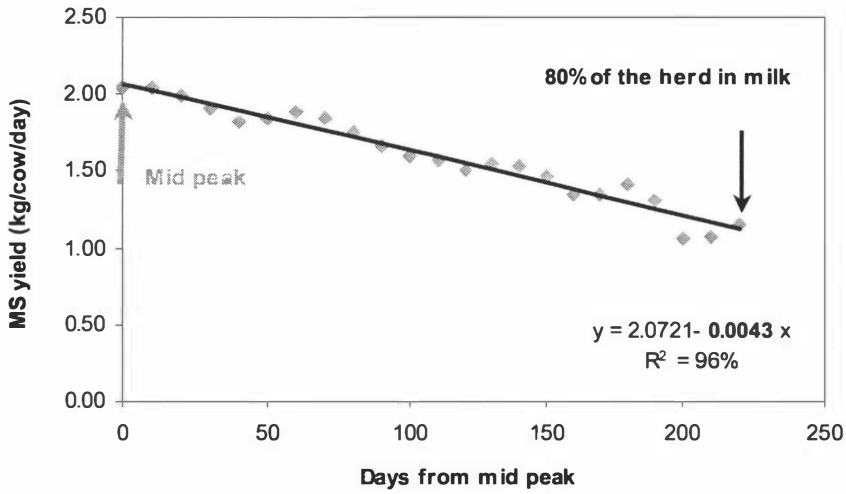


Figure 5.8 Regression plot of MS yield on time from mid peak to the date in which at least 80% of the herd was in milk. Milksolids values are expressed as 10 days average values as well as the period of time.

The post peak decline in MS yield was then considered as the coefficient b of the linear regression equation that represents the daily decline in MS yield per cow from mid peak period to 80% H in milk period. In the example from Figure 5.8, this value is 0.0043 kg MS/cow/day or 4.3g MS/cow/day.

Persistency was calculated as the proportion of average daily yield to the period 80% H in milk in relation to mid peak yield, and as the proportion of average daily yield to the period 80% H in milk in relation to yield at the 80% H in milk period (late lactation yield). These definitions of persistency were adapted from Keown *et al.* (1986) and Bar-Anan *et al.* (1985). However persistency was not utilised as a response variable.

The measurement of MS yield in late lactation was the MS yield at the 80% H on milk period. Details of the post peak decline in MS and MS yield for the nine farms are shown in Table 5.12.

Table 5.12 Late lactation period, lactation persistency, rate of post peak decline in MS yield and MS yield in late lactation

Farm	Late lactation period[1]	Persistency		Rate of post peak decline[4]	MS late lactation[5]
		Peak[2]	*Late lactation*[3]	(g/cow/day)	(kg/cow/day)
1	2/Apr	0.78	1.37	4.31	1.16
2	2/May	0.74	1.47	4.39	1.01
3	3/Apr	0.74	1.46	4.58	1.14
4	1/Apr	0.78	1.47	4.72	1.19
5	2/Apr	0.85	1.37	3.78	1.17
6	3/May	0.82	1.37	2.57	1.16
7	1/Apr	0.83	1.34	3.56	1.22
8	1/Apr	0.82	1.41	4.57	1.24
9	2/Mar	0.83	1.35	3.50	1.23
Mean	-	*0.79*	*1.40*	*4.00*	*1.16*

[1] 80% H in milk period.

[2] Average daily yield per cow from starting of calving to 80% H in milk period divided by mid peak yield.

[3] Average daily yield per cow from starting of calving to 80% H in milk period divided by late lactation yield (80% H in milk period).

[4] Measured from mid peak period to 80% H in milk period.

[5] Measured at the 80% H in milk period.

5.4.2. Analyses related to the post peak decline in MS yield

For these analyses, the response variable (y) was the post peak decline in MS yield and the predictor variables (x) were represented by mid peak yield, by the intakes of ME, protein and DM, by the sward characteristics and by the change in condition score from peak calculated as mean values over the post peak decline period (from mid peak to 80% H in milk). The condition score for the 80% H in milk period was estimated from the average values for the measurement in March and in May, for the herds which presented this date in April. For the herds which presented 80% of the cows still in milk in March or May, these respective month's measurements were utilised.

5.4.2.1. ME intake, mid peak yield and change in condition score

This analysis tested the association between post peak decline in MS yield and the intake variables described in Table 5.13, all measured over the post peak decline period, with the exception, of course, of mid peak yield. However, only eight farms were included in the analysis involving the variable change in condition score over the post peak decline period because there was one farm in which this measurement was not taken.

Table 5.13 Values for the correlation coefficient (r) and *P* for the relationships between the response variable post peak decline in MS yield and the predictor variables; ME intakes measured over the post peak decline period, mid peak yield and change in condition score over the post peak decline period.

Response variable (y): *post peak decline in MS yield (g MS/cow/day)*

Predictor variables (x)	r	*P*
Total ME intake (MJME/cow/day)	0.052	0.895
Pasture ME intake (MJME/cow/day)	-0.205	0.598
Supplements ME intake (MJME/cow/day)	0.286	0.456
ME concentration in the diet (MJME/kg DM)	**-0.516**	**0.155**
Mid peak yield (kg MS/cow/day)	**0.731**	**0.025**
Change in condition score (units/cow)	-0.161	0.678

As expected, the correlation between post peak decline and mid peak yield was significant and positive (Table 5.13). The regression coefficient of the regression equation (slope b), represents a post peak decline of 4.24 g/cow/day for each kg of MS produced at peak (Figure 5.9). None of the ME intake predictor variables was significantly correlated to post peak decline in MS yield ($P>0.050$). The predictor variable which was best correlated to response variable was ME concentration in the diet, and as expected, the correlation was negative.

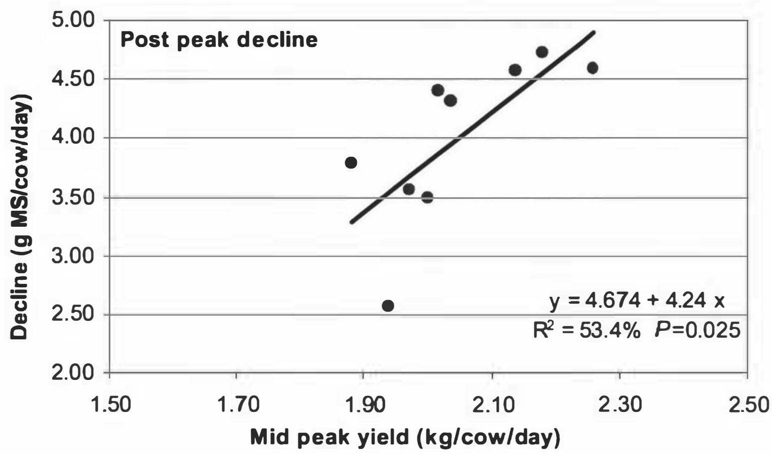


Figure 5.9 Regression plot of post peak decline in MS yield on mid peak MS yield, the respective regression equation, R^2 and *P* values.

The correlation between pasture ME intake and supplements ME intake (r=-0.241; *P*=0.533, Appendix 17), although not significant was negative, suggesting that when supplements were added in the system over the post peak decline period, the amount of ME intake from pasture was reduced.

The full set of correlations for the ME variables is given in Appendix 17. The regression plots for post peak decline in MS yield on total ME intake, pasture ME intake and supplements ME intake are shown in Figure 5.10.

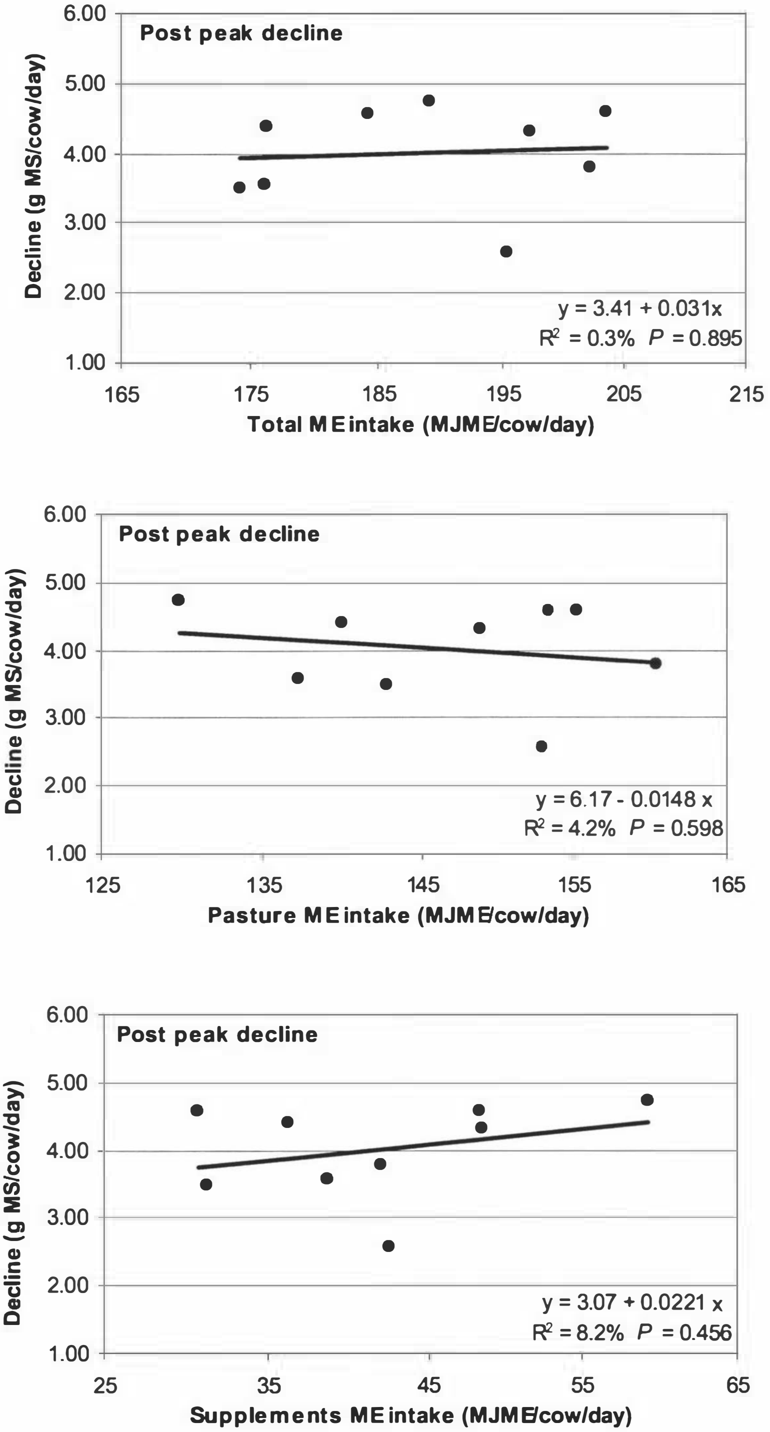


Figure 5.10 Regression plots of post peak decline in MS yield on total, pasture and supplements ME intake over the post peak decline, the respective regression equations, R^2 and *P* values. Note the different scales for X axis.

After December supplements started to contribute more to the proportion of ME in the diet than during early lactation (peak period) (see Appendix 7). According to Figure 5.11, on average, the contribution of supplements ME intake over the whole post peak period was 22.2%. This proportion is even higher, if measured towards the end of the lactation period. Therefore, although the relationships between the ME intake variables and post peak decline were not significant, the ME predictor variables were combined in multiple regression analyses to test if, together, they could explain significant variation in post peak decline in MS yield. Pasture ME intake over the post peak period, was used as the first predictor variable (x_1), followed by supplements ME intake over the post peak period (x_2). The addition of the second predictor variable did not increase the R^2% value significantly, therefore stepwise regression analyses were not taken further.

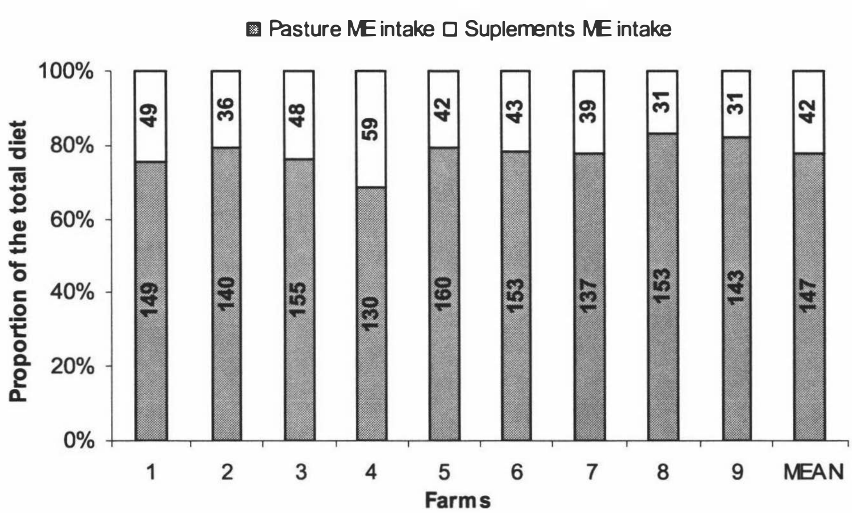


Figure 5.11 Proportions of the ME intake from pasture and from supplements, in the total diet, during the post peak period (from mid peak to 80% H in milk). The numbers within the bars represent the average daily ME intake of pasture and supplements per cow over the post peak period (from mid peak to 80% H in milk).

5.4.2.2. *Protein intake*

This analysis tested the association between the post peak decline in MS yield and the protein variables described in Table 5.14, all measured over the post peak decline period.

The correlation analysis (Table 5.14) showed that none of the protein intake predictor variables was significantly correlated to the response variable post peak decline (P>0.050). The predictor variable which was best correlated to response variable, was supplements protein intake. The full set of correlations for the protein variables is given in Appendix 17.

Table 5.14 Values for the correlation coefficient (r) and *P* for the relationships between the predictor variable post peak decline in MS yield and the protein intake predictor variables measured over the post peak decline period.

Response variable (y): *post peak decline in MS yield (g MS/cow/day)*

Predictor variables (x)	r	*P*
Total protein intake (g/cow/day)	0.049	0.900
Pasture protein intake (g/cow/day)	-0.211	0.586
Supplements protein intake (g/cow/day)	**0.564**	**0.114**
Protein concentration in the diet (g/kg DM)	-0.044	0.910

5.4.2.3. *Dry matter intake and sward characteristics*

This analysis tested the association between post peak decline in MS yield, intake of DM and sward characteristics. The DM intake and sward variables are described in Table 5.15 and all were measured over the post peak period. However, only eight farms were include in the analysis involving the botanical composition variables because there was one farm which did not have the complete set of data on botanical composition for the post peak decline period.

Table 5.15 Values for the correlation coefficient (r) and *P* for the relationships between the response variable post peak decline in MS yield and the predictor variables; DM intakes and sward characteristics measured over the post peak decline period.

Response variable (y): *post peak decline in MS yield (g MS/cow/day)*

Predictor variables (x)	**r**	***P***
Total DM intake (kg DM/cow/day)	0.232	0.549
Pasture DM intake (kg DM/cow/day)	-0.134	0.732
Supplements DM intake (kg DM/cow/day)	**0.393**	**0.296**
Pre-grazing herbage mass (kg DM/ha)	0.266	0.489
Post grazing herbage mass (kg DM/ha)	0.341	0.370
ME concentration in the pasture (MJME/kg DM)	-0.121	0.757
Protein concentration in the pasture (g/kg DM)	-0.156	0.689
ADF concentration in the pasture (g/kg DM)	-0.031	0.937
Proportion of leaf in the sward (g/kg DM)	0.353	0.391
Proportion of clover in the sward (g/kg DM)	-0.111	0.794
Proportion of stem in the sward (g/kg DM)	**-0.504**	**0.203**
Proportion of dead material in the sward (g/kg DM)	-0.331	0.423
Proportion of weed in the sward (g/kg DM)	-0.332	0.422
Proportion of seedhead in the sward (g/kg DM)	-0.493	0.215

The correlation analysis (Table 5.15) showed that neither DM intakes nor the sward variables was significantly correlated to the response variable post peak decline (P>0.050). The DM variable which was best correlated to the response variable was supplements DM intake and, surprisingly, this relationship was positive. The sward variable which was best correlated to the response variable was proportion of stem in the sward, however, against the expected, the correlation was negative. Not just proportion of stem was negatively correlated to post peak decline but also all the other attributes of the sward (proportion of stem, dead material, weed, and seedhead), adverse to milk production, were negatively correlated to post peak decline.

Also, none of the sward variables was significantly correlated to pasture DM intake over the post peak decline period. The full set of correlations for the DM intake and sward variables is given in Appendix 17.

5.4.3. Analyses related to the MS yield in late lactation

For this analysis, the response variable (y) was the MS yield in the period in which at least 80% of the herd was in milk. This period is denominated as MS yield in late lactation. The predictor variables (x) were represented by the mid peak yield, by the intakes of ME, protein and DM, by the sward variables and by condition score in the period in which at least 80% of the herd was in milk. The measurement of condition score utilised for this analysis were the same as for Section 5.4.2.

5.4.3.1. ME intake, mid peak yield and condition score

This analysis tested the association between the late lactation yield and the variables described in Table 5.16, all measured at the 80% H in milk period, with the exception, of course, of mid peak yield. However, only eight farms were included in the analysis involving the variable condition score in late lactation period (80% H in milk) because there was one farm in which this measurement was not taken.

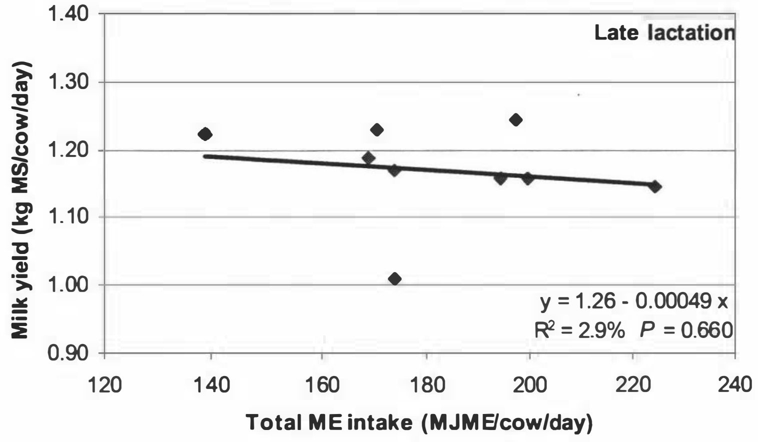
The correlation analysis (Table 5.16) showed that none of the ME intake predictor variables was significantly correlated to the response variable MS yield in late lactation (P>0.050). The predictor variable which was best correlated to the response variable was ME concentration in the diet, however, against the expected, the correlation was negative.

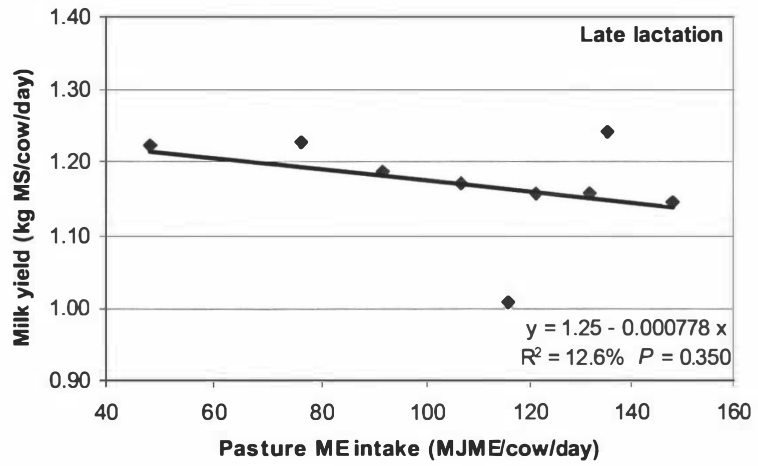
Table 5.16 Values for the correlation coefficient (r) and P for the relationships between the response variable MS yield in late lactation (at the 80%H in milk period) and the predictor variables; ME intakes and condition score measured in late lactation (at the 80%H in milk period) and mid peak yield.

Response variable (y): *MS yield in late lactation (kg MS/cow/day)*

Predictor variables (x)	**r**	***P***
Total ME intake (MJME/cow/day)	-0.171	0.660
Pasture ME intake (MJME/cow/day)	-0.354	0.350
Supplements ME intake (MJME/cow/day)	0.544	0.130
ME concentration in the diet (MJME/kg DM)	**-0.626**	**0.071**
Mid peak yield (kg/cow/day)	0.013	0.974
Condition score (units/cow)	**-0.086**	**0.840**

The full set of correlations for the ME variables is given in Appendix 18. The regression plots for late lactation MS yield on total ME intake, pasture ME intake and supplements ME intake are shown in Figure 5.12. The regression coefficient of the regression equations (slopes b), represent responses in late lactation yield of 0.49, 0.77 and 2.9 g MS per cow day per extra unit of MJME per cow day of total, pasture and supplements ME respectively.





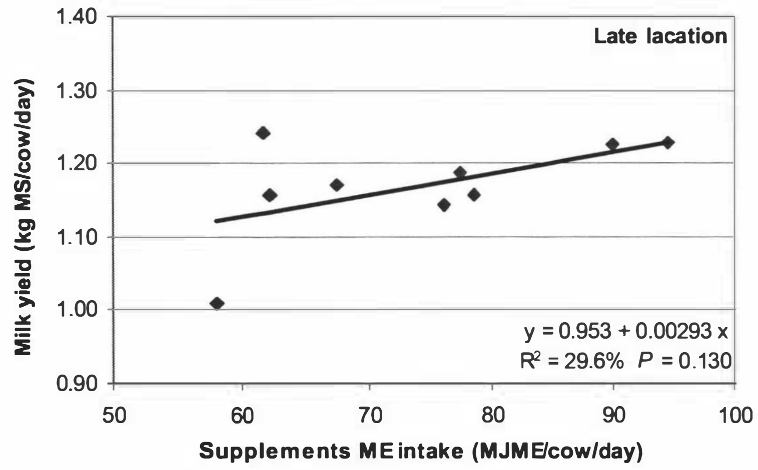


Figure 5.12 Regression plots of MS yield in late lactation on total, pasture and supplements ME intake in late lactation, the respective regression equations, R^2 and *P* values. Note the different values for the X axis.

Condition score was also moderately correlated to the response variable, showing negative value (Figure 5.13). The regression coefficient of the regression equation (slope b), represents a decrease in late lactation yield of around 1 10g MS per cow day per extra unit of condition score.

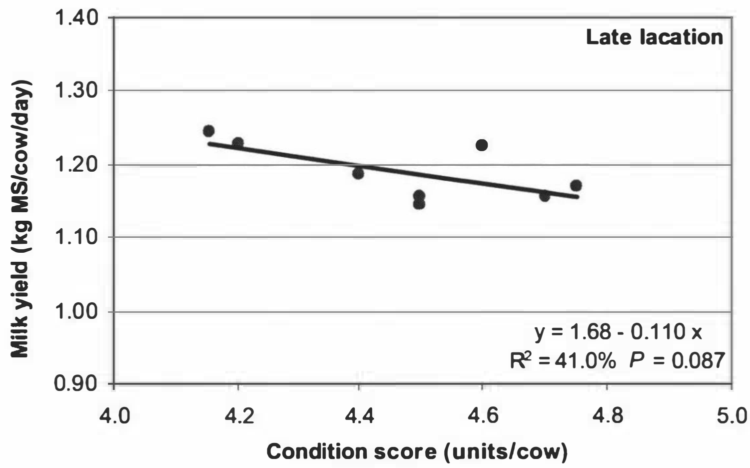


Figure 5.13 Regression plot of MS yield in late lactation on condition score at late lactation period (80% H in milk period), the respective regression equation, R^2 and *P* values.

Although the relationships between the ME intake variables and late lactation MS yield were not significant, the ME predictor variables were combined in a multiple regression analysis to test if when together, they could explain significant variation in late lactation MS yield, as supplements contributed to a reasonable amount of ME in the total diet (40.6%) (Figure 5.14).

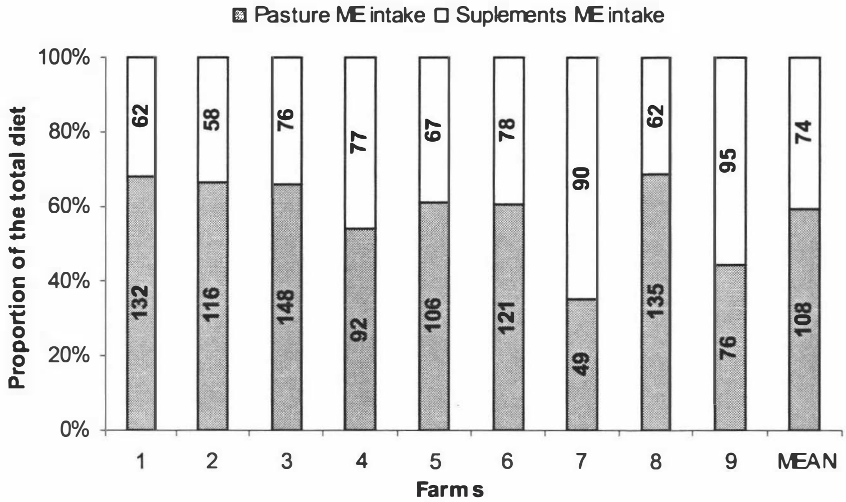


Figure 5.14 Proportions of the ME intake from pasture and from supplements, in the total diet, in late lactation (at the 80% H in milk period). The numbers within the bars represent the average daily ME intake of pasture and supplements per cow in late lactation (at the 80% H in milk period).

Pasture ME intake in late lactation, was added as the first predictor variable (x_1), followed by supplements ME in late lactation (x_2). The addition of the second predictor variable did not increase the R^2% value significantly, therefore stepwise regression analyses were not taken further.

The correlation between pasture ME intake and supplements ME intake (r=-0.699; *P*=0.036, Appendix 18), was significantly negative, suggesting that when supplements were added in the system at the late lactation period (80% H in milk period), the amount of ME intake from pasture was effectively reduced.

5.4.3.2. Protein intake

This analysis tested the association between late lactation MS yield and the protein variables described in Table 5.17, all measured at the 80% H in milk period.

The correlation analysis (Table 5.17) showed that none of the protein intake predictor variables was significantly correlated to the response MS yield in late lactation ($P>0.050$). The predictor variable which was best correlated to the response variable was supplements protein intake. The full set of correlations for the protein variables is given in Appendix 18.

Table 5.17 Values for the correlation coefficients (r) and *P* values for the relationships between the response variable MS yield in late lactation (at the 80% H in milk period) and the protein intakes predictor variables measured in late lactation (at the 80% H in milk period).

Response variable (y): *MS yield in late lactation (kg MS/cow/day)*

Predictor variables (x)	**r**	***P***
Total protein intake (g/cow/day)	-0.056	0.885
Pasture protein intake (g/cow/day)	-0.129	0.741
Supplements protein intake (g/cow/day)	**0.327**	**0.390**
Protein concentration in the diet (g/kg DM)	-0.179	0.645

5.4.3.3. Dry matter intake and sward characteristics

This analysis tested the association between late lactation MS yield, intake of DM and sward characteristics. The DM intake and sward variables are described in Table 5.18 and all of them were measured at the 80% H in milk period. However, only eight farms were include in the analysis involving the botanical composition variables because there was one farm which did not have the complete set of data on botanical composition for the late lactation period (80% H in milk period).

Table 5.18 Values for the correlation coefficients (r) and *P* for the relationships between the response variable MS yield in late lactation (at the 80% H in milk period) and the predictor variables; DM intakes and sward characteristics measured in late lactation (at the 80% H in milk period).

Response variable (y): *MS yield in late lactation (kg MS/cow/day)*

Predictor variables (x)	**r**	***P***
Total DM intake (kg DM/cow/day)	0.175	0.653
Pasture DM intake (kg DM/cow/day)	-0.215	0.579
Supplements DM intake (kg DM/cow/day)	**0.535**	**0.138**
Pre grazing herbage mass (kg DM/ha)	-0.111	0.776
Post grazing herbage mass (kg DM/ha)	0.281	0.463
ME concentration in the pasture (MJME/kg DM)	**-0.644**	**0.061**
Protein concentration in the pasture (g/kg DM)	0.049	0.900
ADF concentration in the pasture (g/kg DM)	0.599	0.088
Proportion of leaf in the sward (g/kg DM)	-0.344	0.405
Proportion of clover in the sward (g/kg DM)	-0.033	0.937
Proportion of stem in the sward (g/kg DM)	0.395	0.332
Proportion of dead material in the sward (g/kg DM)	0.525	0.182
Proportion of weed in the sward (g/kg DM)	0.213	0.612
Proportion of seedhead in the sward (g/kg DM)	0.440	0.276

The correlation analysis (Table 5.18) showed that none of the sward predictor variables was significantly correlated to the response variable MS yield in late lactation ($P>0.050$). The DM intake variable which was best correlated to the response variable was supplements DM intake, and this correlation was positive as expected. The sward variable which was best correlated to response variable, was ME concentration in the pasture however, against expectations, the correlation was negative. In addition all the other attributes of the sward, adverse to milk production (proportion of stem, dead material, weed, and seedhead) were positively correlated with milk yield in late lactation, against logical expectations.

Also, none of the sward variables, measured in late lactation, was significantly correlated to pasture DM intake over in late lactation period. The full set of correlations for the DM intake and sward variables is given in Appendix 18.

5.5. ANALYSES OF THE RELATIONSHIPS BETWEEN PARTIAL LACTATION YIELD AND LACATION CURVE COMPONENTS

5.5.1. Description of the lactation curve components

The purpose of this analysis was to measure the influence of the components of the lactation curve; mid peak yield, peak duration, calving to mid peak period, post peak MS decline, late lactation MS yield and lactation days, on partial lactation yield per cow. The denomination *"partial"* is used here because this estimation of lactation yield per cow does not include the whole lactation period, but the interval between the 10 days period in which calving started to the 10 days period in which at least 80% of the herd was in milk. This time frame was taken to be in accordance with the calculations of post peak decline and late lactation yield which also did not include the final phase of the lactation as explained in Section 5.4.1. However, in order to make comparisons with the industry data, MS yield per cow was also calculated over the entire lactation period.

The partial lactation yield, expressed in kg MS/cow, was calculated through two different methods. Firstly, by summing daily MS yield from the farm (expressed as averages of 10 days), from the 10 days period in which calving started to the 80% H in milk 10 days period, and then, dividing this value by the peak number of cows. The second method consisted of the sum of daily MS yield per cow from the 10 days period in which calving started to the 80% H in milk 10 days period. Table 5.19 shows partial lactation yield values calculated through the two different methods, as well as the absolute values for all the other lactation curve components analysed.

Table 5.19 Values for partial lactation yield calculated through the peak number of cows method (PLY peak), partial lactation yield calculated through the daily MS yield method (Σ PLY), mid peak yield (MPY), peak duration (PDu), calving to mid peak interval (CTMPI) rate of post peak decline (PPD), late lactation yield (80%MSY) and lactation days (PLD).

Farm	PLY peak *(kg/cow)*	Σ PLY *(kg/cow)*	MPY *(kg/cow/day)*	PDu *(Days)*	CTMPI *(Days)*	PPD *(g/cow/day)*	80%MSY *(kg/cow/day)*	PLD
1	389	418	2.04	30	40	4.31	1.16	243
2	393	435	2.02	20	30	4.39	1.01	265
3	419	458	2.26	10	50	4.58	1.14	257
4	397	433	2.18	10	50	4.72	1.19	237
5	400	421	1.88	70	60	3.78	1.17	245
6	435	465	1.94	20	30	2.57	1.16	272
7	377	415	1.97	20	20	3.56	1.22	230
8	401	444	2.13	40	30	4.57	1.24	231
9	341	385	2.00	20	20	3.50	1.23	208
Mean	*394*	*430*	*2.04*	*26*	*36*	*4.00*	*1.16*	*243*

Legend

PLY peak = partial lactation yield calculated through the peak number of cows method (kg MS/cow).

PLY Σ = partial lactation yield calculated through the daily MS yield method (kg MS/cow).

MPY = mid peak yield (kg MS/cow/day).

P Du = peak duration (days).

CTMPI = interval from calving to peak (days).

PPD = post peak decline (g MS/cow/day).

80%MSY = late lactation yield (80% H in milk) (kg MS/cow/day).

PLD = partial lactation days.

Total lactation yield (from calving to drying off) was also calculated through both methods, for the entire lactation period and these values are shown in Table 5.20.

Table 5.20 Values for total lactation yield calculated through the peak number of cows method (TLY peak) and total lactation yield calculated through the daily MS yield method (Σ TLY).

Farms	**TLY peak**	**Σ TLY**
	(kg/cow/day)	
1	421	468
2	398	445
3	438	491
4	413	468
5	433	469
6	435	465
7	409	476
8	438	502
9	374	463
Mean	*417*	*471*

In the correlation analysis (Table 5.21), the two measurements of partial lactation yield were highly correlated with each other. However, for most x variables, the correlations with the total lactation yield values estimated by the daily MS yield method, were slightly higher than with the total lactation yield estimated by the peak number of cows method. As there was little difference in the correlation between the two methods, the values calculated through the daily MS yield method were used for the correlation comparisons and regression analyses because of the interest in cow performance, which is the main focus of this research, and to minimize the influence of fluctuations in cow numbers which is not accounted for in the peak number of cows calculation.

Partial lactation days were estimated by dividing the sum of the daily number of milking cows from the 10 day period in which calving started to the to the 80% H in milk 10 days period, by the maximum daily number of milking cows over the lactation. A concern about the lactation days variable was wether this measurement could be compared to the total lactation yield calculated by average daily MS yield over the lactation period. However the correlation coefficients between lactation days and both measurements of total lactation yield were similar (Table 5.21).

5.5.2. Associations between partial lactation yield and the lactation curve components

For this analysis the response variable (y) was partial lactation yield and the predictor variables (x) were all the other lactation curve components. The initial assessment (Table 5.21) of the correlations between partial lactation yield and the lactation curve components showed that only lactation days was significantly correlated to partial MS yield per cow (*P*<0.01).

Table 5.21 Correlation matrix showing the correlation coefficients (r) between the lactation curve components, with their statistical significance.

	PLY peak	PLY Σ	MPY	PDu	CTMPI	PPD	80%MY
PLY Σ	0.957***						
MPY	0.187	0.360					
P Du	0.018	-0.173	-0.561				
CTMPI	0.454	0.293	0.225	0.378			
PPD	-0.048	0.042	0.731*	-0.087	0.403		
80%MSY	-0.305	-0.319	0.013	0.142	-0.171	-0.171	
PLD	0.847**	0.807**	-0.010	-0.077	0.311	-0.118	-0.731*

Legend

PLY peak = partial lactation yield calculated through the peak number of cows method (kg MS/cow).

PLY Σ = partial lactation yield calculated through the daily MS yield method (kg MS/cow).

MPY = mid peak yield (kg MS/cow/day).

PDu = peak duration (days).

CTMPI = interval from calving to peak (days).

PPD = post peak decline (g MS/cow/day).

80%MSY = late lactation yield (80% H in milk) (kg MS/cow/day).

PLD = partial lactation days.

(*) Significant at 5%; (**) Significant at 1%; (***) Significant at 0.1%

Surprisingly, late lactation yield, though the correlation was not significant, was negatively correlated with partial lactation yield per cow. Among the x variables, there were significant correlations between mid peak yield and post peak decline, which was positive as expected, and between MS yield in late lactation and lactation days which was negative also as expected.

Lactation days explained 65% of the variation in total lactation yield (Figure 5.15). The regression coefficient (slope b) of the regression equation, represents a response in total lactation yield which is close to 1kg MS/cow for each extra lactation day.

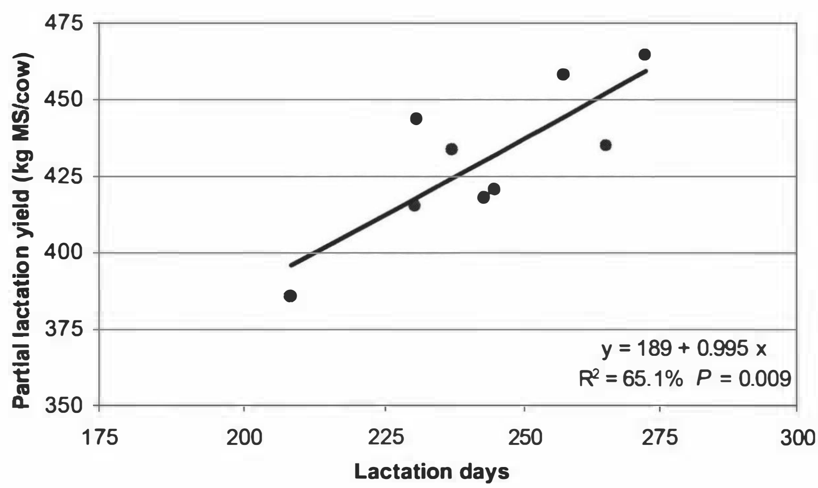


Figure 5.15 Regression plot of total lactation yield on lactation days.

Stepwise analyses were also carried out through the MINITAB™ statistical program. This program was used in preference to the manual stepwise procedure (which had been used in previous analyses) because, in this analysis, the variables had the same degree of importance. Forward selection and backward elimination stepwise procedures were carried out and both indicated that the best set of predictor variables was represented by lactation days, late lactation yield and mid peak yield, organised in the order presented in the model shown in Table 5.22.

Table 5.22 Regression equations of total lactation yield per cow yield (y) on individual components of the lactation curve (x) and on a combination of individual variables, and R^2 and *P* values.

Individual x variables	Regression equation	R^2%	*P*
Lactation days	$y = 189 + 0.995x$	60.1	0.009
Late lactation yield (80%H in milk)	$y = 562 - 112x$	10.2	0.403
Mid peak yield	$y = 283 + 71.9x$	13.0	0.341

Combination of x variables	Regression equation	R^2%	*P*
	$y = -325 + 1.52x_1 + 203x_2 + 73x_3$	94.1	
Lactation days (x_1)			0.001 (x_1)
Late lactation yield (x_2)			0.015 (x_2)
Mid peak yield (x_3)			0.020 (x_3)

When combined in the multivariate model, the regression coefficients of the variables were larger than the regression coefficient of each variable in the simple regression equations. The biggest change was for the variable late lactation yield (from -112 to +203). Also, all the variables became significant ($P< 0.05$) when combined in the model.

5.6. COMPARISON BETWEEN HERDS WITH SHARP, MODERATE OR FLAT PEAK YIELDS

Table 5.23 shows a comparison between some production and feeding variables, stratified for different "shapes" of peak yield; sharp (short duration – Farms 2 and 3), intermediate (moderate duration – Farms 1, 4, 6, 7, 8 and 9) and flat (long duration – Farm 5).

Table 5.23 Mean, maximum and minimum values for some variables analysed in the study stratified according to duration of peak period.

	Sharp peak[1] N=2			**Intermediate peak**[2] N=6			**Flat peak**[3] N=1
	Mean	*Min*	*Max*	***Mean***	*Min*	*Max*	
Mid peak period							
Peak yield (kg MS/cow/day)	**2.22**	2.18	2.26	**2.01**	1.94	2.13	**1.88**
Peak duration (days)	**10**	10	10	**25**	20	40	**70**
Total ME intake (MJME/cow/day)	**228**	206	251	**192**	169	216	**179**
Pasture ME intake (MJME/cow/day)	**197**	185	210	**167**	135	196	**179**
Supplements ME intake (MJME/cow/day)	**31**	21	41	**24**	0	48	**0**
Condition score at peak (units per cow)	**4.3**	4.2	4.4	4.1	3.8	4.6	**4.2**
Temporary decline and recovery period							
Loss of milksolids (g/cow/day)	**4.39**	4.22	4.56	**2.92**	1.86	4.43	**0.89**
Total ME intake (MJME/cow/day)	**202**	201	204	**195**	186	216	**197**
Pasture ME intake (MJME/cow/day)	**176**	172	180	**166**	146	193	**186**
Supplements ME intake (MJME/cow/day)	**26**	24	28	**28**	0	58	**11**
Post peak decline period[4]							
Post peak decline in MS (g/cow/day)	**4.65**	4.58	4.72	**3.82**	2.57	4.57	**3.78**
Total ME intake (MJME/cow/day)	**196**	189	203	**184**	174	198	**202**
Pasture ME intake (MJME/cow/day)	**142**	130	155	**145**	137	153	**160**
Supplements ME intake (MJME/cow/day)	**53**	48	59	**38**	31	49	**42**
Change in condition (units/cow)	**0.15**	0.10	0.20	**0.34**	0.00	0.70	**0.60**
Late lactation period[5]							
MS yield at late lactation (kg/cow/day)	**1.16**	1.14	1.19	**1.17**	1.01	1.24	**1.17**
Total ME intake (MJME/cow/day)	**196**	169	224	**179**	139	199	**173**
Pasture ME intake (MJME/cow/day)	**120**	92	148	**104**	49	135	**106**
Supplements ME intake (MJME/cow/day)	**76.5**	76	77	**74**	58	95	**67**
Condition score (units/cow)	**4.45**	4.40	4.50	**4.44**	4.20	4.70	**4.80**
Lactation yield measurements[6]							
Partial (kg/cow)	**408**	397	419	**389**	341	435	**400**
Total (kg/cow)	**425**	413	438	**412**	374	438	**433**

[1,2, 3] Based on duration of peak period. Sharp peak = 10 days; Moderate peak = from 20 to 40 days; Sharp peak = more than 40 days.

[4, 5] To the 80% H in milk period.

[6] The values for partial and total lactation yield were obtained through the peak number of cows method.

Although the statistical analyses showed no strong correlation between peak duration and levels of peak yield, the descriptive comparisons showed that shorter peak durations seemed to be associated with high levels of peak yield, higher MS loses over the temporary decline and recovery period and also higher rates of post peak decline in MS yield.

Short peak durations and, consequently, higher levels of peak yield, were related to higher ME intakes at all the lactation phases analysed in this study. During the mid peak period, higher levels of ME intake, mainly achieved through increased feeding of supplements, were associated with high levels of MS yield as expected. In contrast, there was a negative association between levels of ME intake, the temporary decline in MS yield and the long term decline in MS, as the farms which fed more ME during such phases of the lactation also presented the highest values for MS loss over the temporary decline and for long term rate of post peak decline. Milksolids yield in late lactation presented similar values, independently of the shape of peak stratification. However, the farms which had sharp peaks fed more ME during late lactation than did the moderate or flat peak farms, agreeing with the trend found in the statistical analyses.

Levels of peak yield seemed to have no clear effect on total and partial lactation yield per cow. The three different "shapes" of peak yield presented similar values for total and partial lactation yield per cow. However, a point of interest was that the flat peak farm which, presented the lowest peak yield, also presented relatively high total and partial lactation yield, even higher than the intermediate peak farms.

CHAPTER 6

Discussion

6.1. INTRODUCTION

This Chapter includes the discussion of the data reported in Chapter 5, relating the present findings to some industry and research data. The sections of this Chapter are organised as follows:

- General comments on data sampling, data processing and statistical analyses (Section 6.2.1);
- Discussion of the analyses for the peak period (Section 6.2.2);
- Discussion of the analyses for the temporary decline and recovery period (Section 6.2.3);
- Discussion of the analyses for long term decline period including both response variables; rate of post peak decline in MS yield and late lactation MS yield (Section 6.2.4);
- Discussion of the analyses for the relationships between lactation curve characteristics and lactation yield (Section 6.2.6);
- Overview of the most relevant aspects addressed in the above discussions (Section 6.2.7)

6.2. DISCUSSION

6.2.1. General comments

Firstly, it is necessary to emphasise that the present study was not set up as an experimental design, but it involves observations collected routinely on a small number of commercial dairy properties without control measurements. Therefore, this study does not intend to create new theories about lactation curves, but it attempts to show some lactation performance trends and their relationship with feed management strategies, for a specific group of high producing farms which have the same overall management philosophy, namely to achieve, profitable high yield per hectare by high yields per cow and moderate stocking rates.

Although there are several methods for lactation curve modelling (see Section 2.2), none was utilised in this study because the main interest was in the short term pattern of the lactation curve behaviour. Also, due to the small sample size and data variability, the analyses of the lactation period were limited to correlation and linear regression procedures. Visual appreciation showed little indication of curvilinearity in relationships after the period of peak yield therefore, not justifying quadratic analysis.

The primary focus of the analyses was on the relationships between MS yield, MS persistency and ME intakes, over the lactation period. The analyses involving the additional variables (protein and DM intakes and the characteristics of the sward), were used as explanatory analyses where appropriate.

6.2.1.1. Sample size and range of values

For all the lactation periods analysed, most of the predictor variables which had been expected to be biologically important, were not strongly correlated to the response variables. The low correlation values could be due to the small sample size (N=9) available for the analyses and to the small range of values within the samples. The farms involved in the project had similar philosophies regarding levels of animal feeding with high levels of pasture and supplements intake (ME and DM) . Also, the ranges of variation were not wide, which resulted in a set of data with very low variability. The small sample size does not invalidate the results, but it does reduce the likehood of obtaining significant results from correlation and regression analysis (IIST, 2000).

6.2.1.2. Monitoring

Pasture DM intake per cow was calculated from estimations of pre and post herbage masses plus grazing intensity (see Section 4.3.1). This is the simplest method to estimate intake, which is widely utilised at the farm level, but does not necessarily represent either the precise amount of the herbage eaten by animals, or describe the diet selected. However, due to the scale of the project (10 commercial farms involving around 1160 effective hectares and 3059 cows) this technique was considered the most appropriate, but the relative inaccuracy of the method may have contributed to the low significance of the correlations which involved the pasture intake variables.

Another aspect which could have caused inaccuracy in the pasture intake estimations might be related to the visual assessment of herbage mass. As part of the *AGMARDT-Dairy Farm Monitoring Programme*, the technician in charge of the data collection visited the farms monthly and the measurements of pre, post and average pasture cover were taken using the rising plate meter (RPM) (see Section 4.3.1). When the plate measurement was compared to the farmer's visual assessment, it seemed that the farmers underestimated pasture measurements over late spring but overestimated during summer. Both of these are the periods when farmers usually comment that the visual scoring is most difficult. As they assess pasture mainly based on height, they do not account for changes in dry matter percentage, accumulation of dead material, stem to leaf ratio or pasture density, which are events that show most variations around late spring and summer (AGMARDT, 2000). This lack of accuracy should not have been reflected in the pasture DM intake estimations because these values were calculated based on the adjusted values (see Section 4.3.1), though the possibility that the adjusted values could in fact be creating such inaccuracy should be considered.

The difficulties in the determination of ME content of some supplements (carrot pomace, palm kernel, turnips and grazing-off) might also have caused bias in the estimates of supplements and total ME intake. Due to limited information for the calibration of the equipment, the ME content for some supplements was not measured by the NIRS technique, but was estimated through published data which do not necessarily represent the most accurate information for the particular feeds used on these farms.

For the peak period, there was a reasonable correlation between supplements ME intake and MS yield, but the amount of supplements fed over that period was not as high as during other periods of the lactation, where the correlations between supplements ME intake and MS yield presented the lowest values (See Figure 5.4, Figure 5.6, Figure 5.11 and Figure 5.14).

Data on total farm milk production and composition were very consistent as they came from daily dairy company statements. However, especially in early and late lactation, bias might have occurred in the assumptions of production per cow because number of cows fluctuated daily during those periods of the season due to pattern of calving and strategic drying-off. Also, it was not possible to measure the amount of milk which was fed to the calves in early lactation, therefore, in order to avoid bias, the milk consumption by calves was not estimated for any of the farms.

6.2.2. Peak milk yield

The peak duration was defined based on the 7% monthly milk yield decline from the previous month which is a measurement of persistency and rate of decline (Section 5.2). The figure of 7% is a general parameter, found in published data and used to express a standard persistency or rate of decline (Section 2.2.2 and Section 2.2.4). However, this assumption will only be valid if the MS persistency over early lactation period is constant. The evidence suggests that in late lactation (the last month of lactation) due to increases in fat % and foetal development (Turner, 1925; Keown & Van Vleck, 1973)

(Keown *et al.*, 1986), the decline in milk yield starts to show exponential behaviour but, in early lactation (from peak) under uniform conditions, the decline in milk yield shows linear and constant behaviour. Therefore there is no strong evidence against the concept utilised to determine peak duration in the present study.

Levels of peak yield (mid peak measurement) ranged from 1.88 to 2.26 kg MS/cow/day (10 days period average). Peak yield duration varied from 10 days to 70 days and peak yields occurred between the last 10 days of August and the last 10 days of September with the exception of Farm 5, which had an extremely long peak duration of 70 days, from 1/Sep to 1/Nov (see Table 5.2 for more details).

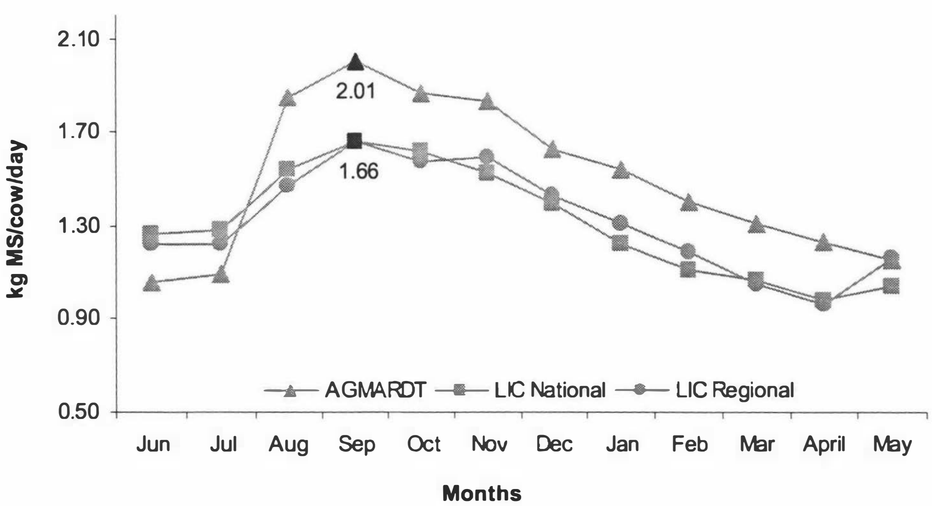


Figure 6.1 Monthly milk production pattern for the *AGMARDT* group (mean across farms) and for the national and regional industries (Palmerston North, Wellington regions). Season 2000/2001.

Milksolids yield (mean value across farms) was also calculated on a monthly basis, in order to make comparisons with the industry data (Figure 6.1). While both the national and regional industry reached a peak yield of 1.66 kg MS/cow/day, the set of farms involved in the present study reached a peak yield of 2.01 kg MS/cow/day, which represents an increase of 17.4% above the industry figures. A similar value of peak MS yield (2.05 kg MS/cow/day) was also observed for the *AGMARDT* group for the previous season (1999/2000) (AGMARDT, 2000).

Research results have suggested that underfeeding before calving and in early lactation and, consequently, poor body condition during the peak yield period, resulted in more liveweight gain and condition score in late lactation at the expense of milk yield (Grainger & Wilhelms, 1979). In addition, improved body condition at calving resulted in increases in milk yield over the subsequent periods of the lactation (Grainger *et al.*, 1982).

The farmers involved in this study have also commented that a higher level of feeding during the dry period appears to be an important factor influencing peak yield. However, the present analyses showed no significant effect of either level of feeding (ME intakes) during the pre calving and post calving to peak periods (Appendix 4) or body condition score at peak (Table 5.3) on peak MS yield. Broster & Broster (1998) stated that there is little or no effect of body condition score on milk yield for body condition score values higher than 3.3 units in early lactation, which seems to be the current case as the condition score at peak averaged 4.1 units across the *AGMARDT* farms (Table 6.1). The lack of correlation between pre calving feeding levels, condition score at peak and peak yield levels might also be attributed to the small sample size and the low variability in the data.

The positive and significant correlation between MS yield and total ME intake at the peak period agrees with expectation, and with published data for the whole lactation period (Kolver, 1997; Kolver & Muller, 1998). Table 6.1 shows that the feeding systems which were able to provide the highest amount of DM and energy during the peak period were the ones which also achieved the highest levels of peak yield. The pasture systems (Table 6.1), even though utilising supplements and presenting good levels of ME in the overall diet (as in the present study) were not able to achieve levels of peak yield similar to the TMR system presented in the same Table, agreeing with previous doubt about the ability of grazed pasture to support high levels of DM and ME intakes and therefore MS yield (Clark *et al.*, 1997; Kolver, 1997; Kolver & Muller, 1998; Kolver *et al.*, 2000).

The present results compare favourably with research data from pasture based trials (Table 6.1). Kolver & Muller (1998) also showed high levels of pasture DM intake for grazing cows but, in this experiment, the animals were pure American genotype and, therefore, higher intakes may simply reflect higher body weight of this genotype. For the present data and also for the research data presented in Table 6.1, the main aspect of the grazing system which appeared to affect the level of peak MS yield was the amount of DM consumed rather than concentration of nutrients in the diet. This is well illustrated in the present data, as the correlation between MS yield and total DM intake was higher than the correlation between MS yield and ME concentration during the peak period (Table 5.3 and Table 5.6). If the estimations of pasture intake for the present data are corrected, then the *AGMARDT* group was able to achieve high peak yields through high intakes of pasture because the levels of supplementation during the peak period were minimal (Figure 5.4).

Table 6.1 Comparisons between the *AGMARDT* data and some published data on levels of milk yield and feeding over the peak period[1]

Studies	**Levels of yield** *(Litres-kg/cow/day)*		**Feeding policy**	**DMI**[5] *(kg/cow/day)*		**ME**[5] *(MJME/kg DM)*		**OMD**[5] *%*		**CS**[5] *(units/cow)*
	MS	*Litres*		*P*[5]	*S*[5]	*P*	*S*	*P*	*S*	
AGMARDT farms[2]	2.04	24.0	Pasture plus strategic use of supplements	15	2.0	11.5	11.2	NA	NA	4.1
LIC (2001) National average[3]	1.66	20.8	Mainly pasture	NA	NA	NA	NA	NA	NA	NA
Kolver & Muller (1998)[4]	2.74	44.1	TMR	23.4		NA		92.6		2.5
Kolver & Muller (1998)[4]	1.87	29.6	Only pasture	19.0	-	NA		90.6		2.0
Grainger & Mathews (1989)	1.75	24.0	Pasture plus grain-based pellet	13.7	3.2	NA	NA	77	72	NA
Garcia (2000)[6]	1.78	24.1	Pasture plus restricted maize and grass silage use	14.6	0.0	11.7	10.6	85.0	67.2	NA
Penno (2001)[6]	NA	23.0	Pasture plus maize silage	12.3	4.9	12.2	NA	78.3	NA	4.2

[1] There are minor differences in the period considered as peak / early lactation yield, between the studies.

[2] Mean values across the farms for Mid peak yield.

[3] Monthly average values for the national average in September 2000.

[4] American genetics

[5] *P*=pasture; *S*=supplements; DMI=Dry matter intake; ME=Energy intake; OMD=Organic matter digestibility; CS=Condition score

[6] Mean of three seasons.

NA=Not available.

In the present data, although pasture supplied on average 88% of the total ME intake at peak (Figure 5.4), pasture ME intake itself was not significantly correlated with peak MS yield, whereas the relationship between supplements ME intake and peak MS yield was reasonable high. This trend seems to be an effect of the higher variation of the supplements ME intake data than for pasture ME intake data, with some farms feeding no supplement during the peak period.

Supplements ME intake explained a larger amount of the variation in peak yield (R^2=40%; P=0.067) than pasture ME intake (R^2=7%; P=0.489) (Figure 5.3). Therefore, the variation in peak yield explained by total ME intake is mainly a result of the supplements ME intake rather than pasture ME intake. The higher variation in ME intake from supplements seemed to be an effect of the three farms with zero and 2MJME/cow/day of supplements ME intake in the mid peak period.

When pasture and supplements were combined in a multiple regression analysis, both variables were significant (in the simple regression pasture ME intake was not significant) (P<0.05) and explained 68% of variation in mid peak MS yield. The regression coefficients also increased if compared to the regression coefficients of the simple regression analysis The differences between the simple and combined regression analyses are due to the fact that the combined analysis isolates the specific effect of each x variable. The combined regression equation was (Table 5.4);

MS yield at peak = 1.40 + 0.00298 ME pasture intake + 0.00528 ME supplements intake;

which represents a response of 3.0 and 5.2 g MS per MJME of pasture and supplements respectively. According to the sequential sum of squares, the proportion of the total variation explained by supplements ME intake is 8.5 times higher than the proportion explained by pasture ME intake because, even though pasture ME intake became significant in the combined analysis, its significance is still lower than the supplements ME intake significance.

The DM intake variables showed the same trend as ME intakes. Only total DM intake was significantly correlated to peak yield while supplements DM intake was moderately correlated to MS yield at peak. This again suggests that the proportion of extra feed in the diet during the peak period is the main driver of MS production, although ME concentration in the diet also plays an important role, as it was moderately correlated to peak yield. This latter finding was supported by the sward characteristics analyses which showed that the proportion of leaf in the sward was significantly correlated to MS yield at peak (Figure 5.5). This is in general agreement with earlier work which showed that leaf mass allowance is an important factor in determining intake levels and performance of dairy cows during late spring (Butler *et al.*, 1987; Hoogendoorn *et al.*, 1992).

The fact that the other sward variables, and also pre and post grazing levels, were not significantly correlated to MS yield at peak, is probably a result of the similar management employed on those farms, which aims to control sward conditions and pre and post grazing herbage mass levels, in order to improve intake. The depth to which the animals graze into, the sward does not allow them to reach the relatively poor quality lower strata of the sward and, therefore, the effects of the poor quality components of the sward were probably not fully evident.

The present milk yield response to extra feed during the peak period was 3.9 g MS per per extra unit of MJME, measured as regression coefficient (Figure 5.3). Research evidence has suggested that the milk yield responses to supplementary feed in early lactation increase as pasture intake decreases (Stockdale & Trigg, 1989; Grainger & Mathews, 1989). However, comparing the *AGMARDT* and the research data for the response to extra feeding during peak period/early lactation (Table 6.2), the former value appears to be relatively high considering the high levels of pasture intake achieved. The most important aspects to be considered, in order to add extra feed in the system during peak period under low stocking rates or high levels of pasture intake, would be the price paid for MS and for the supplementary feed over the peak period and also the contribution of peak yield to the total lactation yield. The addition of supplementary feed over a period in which pasture presented high levels of production and quality could be a non profitable way to increase production. The role of peak yield in the total production per cow is discussed further in Section 6.2.6.

Table 6.2 *AGMARDT* and research data on MS response to supplementary feed in early lactation (peak period)

Study	**Pasture intake**	**Response[1]**	
	kg/cow/day	*(g MS/kg DM)*	*(g MS/MJME)[2]*
AGMARDT farms	15.0	44.8	3.9
Stockdale & Trigg (1989)	11.5	44.4	3.9
Grainger & Mathews (1989)	13.7	12.1	1.1
Penno *et al.* (1996)	11.5	19.0	1.7
Penno *et al.* (1998)	11.6	54.0	4.0

[1]The values for response were obtained through different methodologies, however the main objective of this exercise is to compare trends and not absolute values.

[2]A value of 11 MJME/kg DM supplement was assumed to express response in MJME for the research data when the ME value for the supplementary feed was not available.

In summary, total ME intake explained a significant amount of variation in peak MS yield and the main factor contributing to this variation was the proportion of ME intake which came from supplementary feed. Amount eaten was of higher importance than quality eaten, however quality must also be considered seriously since, for example, the proportion of leaf in the sward was significantly related to peak milk yield. Therefore the identification of the factors affecting total ME intake have to be enhanced.

Penalties to milk production have been observed when dietary protein levels exceed 18% (NRC, 1988). Since crude protein levels in spring pasture in New Zealand often exceed 30% (Moller, 1997), it has been argued that this might contribute to the low levels of peak yield observed in New Zealand (Moller, 1997; Kolver, 1997; Clark *et al.*, 1997). The results indicated that the correlations between MS yield at peak and protein intakes and protein concentration in the diet over the peak period were not significant (Table 5.5) but, all the protein intake variables were correlated negatively to MS yield at peak. Concentrations of crude protein in the pasture and in the total diet, were all above 18%.

Table 6.3 Levels of crude protein in the pasture and in the total diet during the mid peak period.

Farms	Protein concentration during mid peak period *g/kg DM*		
	Pasture	**Supplements**	**Total diet**
1	271	157	245
2	262	102	238
3	207	52	182
4	283	68	258
5	285	-	285
6	235	79	212
7	261	180	260
8	300	233	284
9	275	-	275

6.2.3. Temporary decline and recovery in milk yield

The temporary decline and recovery in MS yield after peak has occurred within the *AGMARDT* farms group in each of the last two seasons, although its magnitude and time of occurrence have varied between years as illustrated from monthly information in Figure 6.2. For season 1999/2000 the decline was more marked and it occurred later than in 2000/2001.

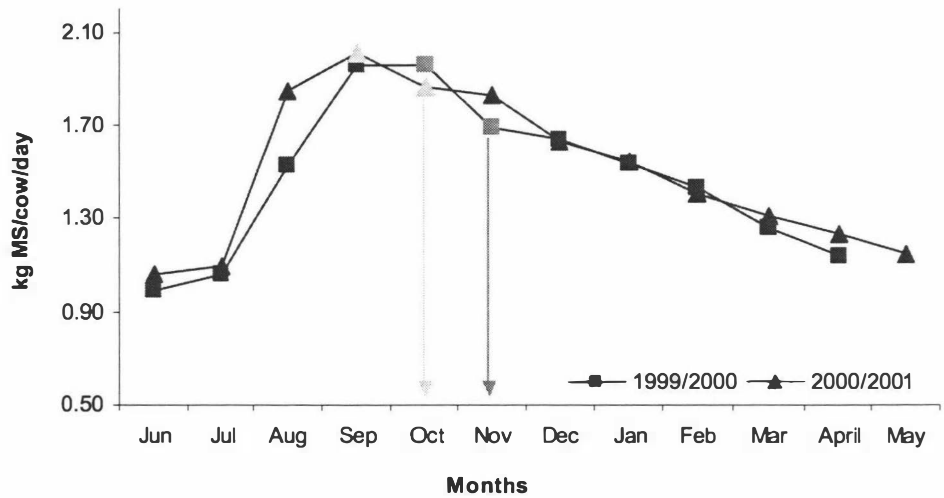


Figure 6.2 Monthly average milk production pattern for the farms involved in this current study. Seasons 1999/2000 and 2000/2001 (In season 1999/2000 Farm 1 is not include in the average). The vertical arrows show the period of highest decline in MS yield after peak yield.

Similar trends can also be observed for the regional milk flow patterns to the processing plants, as illustrated in Figure 6.3, but there are also some regional and seasonal variations.

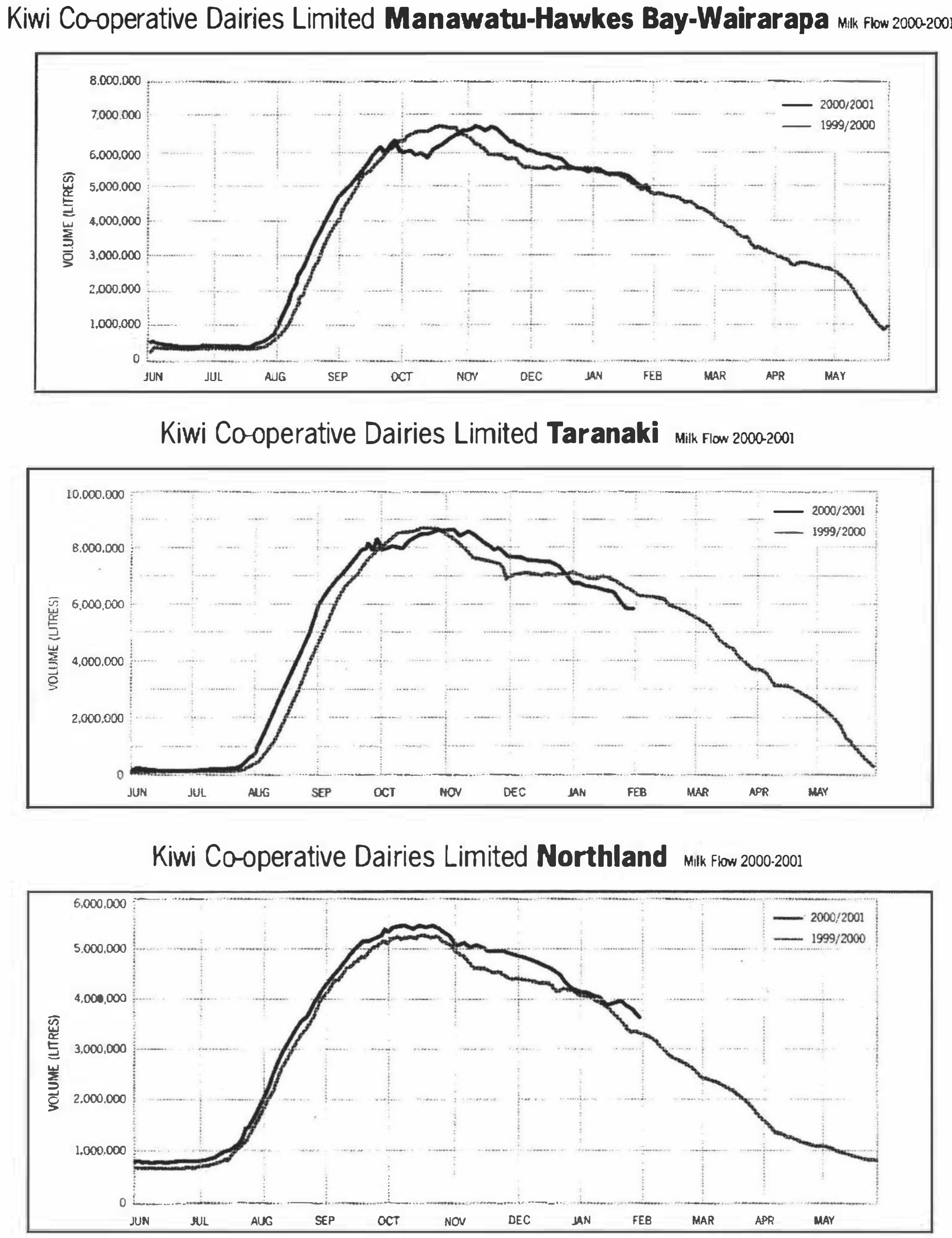


Figure 6.3 Information on total milk volume received by the former Kiwi Co-operatives Dairies Limited, in three different regions in the North Island. Note that the complete curve refers to season 1999/2000 and the incomplete curve refers to season 2000/2001. Source Kiwi Co-operative (2001)

For season 2000/2001, Manawatu, Hawkes Bay and Wairarapa regions showed the most evident decline and recovery pattern, whereas in Taranaki the event was of lower magnitude, and in Northland the fluctuation was not observed. However, this could be associated with the lower peak yield per cow achieved in Northland and to the greater incidence of split calving in that region. The temporary decline occurred early in season 2000/2001 in all regions. The differences observed between regions and seasons suggest that the temporary decline and recovery, especially in 2000, was probably associated with a short period of adverse climatic conditions, as discussed in Section 5.3, which seems to occur every year around the same period of time and in different intensities depending on the region. As already mentioned during October 2000 the following weather scenario was occurring;

"...heavy rainfall and high winds battered the central North Island at the start of the month, with widespread surface flooding from Taranaki to Wellington ... westerlies were stronger than the normal over the lower North Island...and rainfall was well above 125 percent of normal in many southwestern North Island regions" (NIWA, 2000).

There have also been previous speculations as to the influence of the breeding period on the temporary decline and recovery in MS yield, as both events appear to coincide. Therefore the mating periods for the sample farms were examined (Figure 6.4). The dates of breeding were available for only five farms, but in all these farms the start of breeding coincided with the start of the temporary recovery period in MS yield (the 3rd period of October), suggesting that mating would not have contributed to decreases in MS yield. It is also very likely that the other four remaining farms presented similar mating period as they all had similar calving dates. The differences between years in the time of occurrence of the temporary decline and recovery do not support the hypothesis that the breeding period causes such fluctuations in MS yield, as the breeding period remains fairly constant between years.

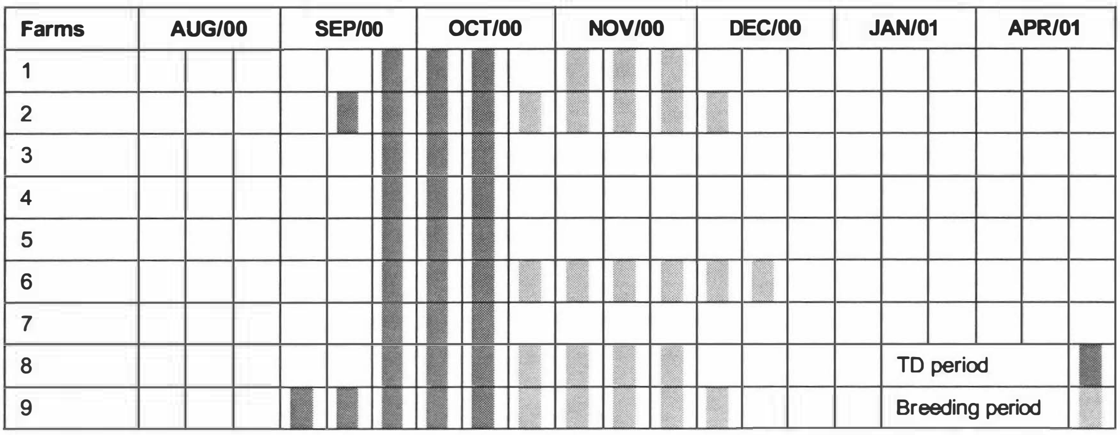


Figure 6.4 Diagram showing the period in which the temporary decline period (TD) was observed in each farm and the breeding period for 5 of those farms.

Therefore, the main interest in the results was to know if this short period of adverse climate conditions affected milk yield by affecting intakes and/or sward conditions over that period of time. The effects of level of peak MS yield on the temporary decline and recovery were was also analysed.

The levels of MS "loss" ranged from 0.89 to 4.56 kg MS/cow over the temporary decline and recovery period (Table 6.4). In spite of the visual impact of such a trough in the lactation curve, the magnitude of the decline and recovery event represents less than 1% of the total lactation yield (Table 6.4). There was no clear evidence of prolonged influence on MS yield following this temporary decline, but in the absence of a control it was not possible to quantify this effect categorically. The temporary "peak" following the recovery period occurred in the first 10 days period of November for all farms, whereas the beginning of the temporary decline period varied slightly between farms over the three periods of September.

Table 6.4 Values for mean, minimum and maximum MS loss over the temporary decline and recovery period, for total lactation yield and for the proportion of total lactation yield represented by the MS loss prediction.

Measurements	Mean	Min	Max
MS loss (kg/cow)	3.02	0.89	4.56
		Mean	
Total lactation yield (kg/cow) [1]		417	
% of total lactation yield as MS loss		0.72%	

[1] Mean value across farms obtained through the peak number of cows method.

The *AGMARDT* report (AGMARDT, 2000) has shown a positive relationship between this short-term rate of decline in MS yield from peak to November (the duration of the temporary decline and recovery period) and levels of peak yield. Also, the large amount of published information on lactation curves has suggested that rates of post peak decline are closely associated with levels of peak yield (Shanks *et al.*, 1981; Keown *et al.*, 1986; Chase, 1993). However, the measurement of the loss in MS yield over the temporary decline and recovery period was not significantly related to peak MS yield, although the comparisons shown in (Table 5.23) indicate that there a positive relationship between these two variables

A wide range of factors have been blamed for this temporary decline and recovery in MS yield. The most usual explanation is the low ME concentration in the pasture around October and November which is related to the appearance of the reproductive stage of the ryegrass (Moller, 1997; Barret, 1999; Mirams, 2001). The relatively low levels of protein which may be observed in the pasture around October and November (late spring), have also been considered as a potential factor affecting the sharp period of MS yield decline immediately after peak (Moller, 1997).

The time scale of these effects is greater than the relatively short period of loss in milk yield associated with adverse weather in the current study, where the regression analyses showed that there was no evidence that MS yield was affected by daily intakes, feeding levels or concentrations in the diet (Table 5.8, Table 5.9 and Table 5.10).

The fall in milk protein concentration and in protein to fat ratio over the period of temporary decline and recovery in MS yield (Table 5.11) are strongly indicative of a period of under nutrition (Bryant, 1979; Grainger & Wilhelms, 1979; Mitchell, 1985), coincident with a reduction in feed intake by the cows caused by the short period of wet stormy weather, despite the fact that observed changes in pasture and supplements ME intakes values over this period were not significant. This suggests that the monitoring procedures were not adapted to detect a real fall in nutrient intake over the period, and that managers may not have been sensitive enough to adjust supplementary feed to compensate for a temporary fall in pasture intake. However, small changes in DM intake as in wastage through treading, for example, would be difficult to detect through visual assessment of the herbage masses, although the correlation between pasture and supplements intakes (ME and DM) was negative and highly significant. In fact, this correlation was significant only for the temporary decline and recovery period.

Supporting the above evidence, information presented in the *AGMARDT* report (AGMARDT, 2001) indicated that there was some over estimation of herbage intake during September and October 2000 which might have contributed to the decline in MS yield observed during that period. According to Figure 6.5, the pasture assessments carried out by the managers (unadjusted), resulted in higher estimations of herbage harvested than the rising plate meter estimation (adjusted) indicated over the temporary decline and recovery period. The current analysis was carried out utilising the adjusted values for pasture DM intake, but pasture measurements based on unadjusted values over this period may have under estimated that actual fall in pasture intake.

Considering the difficulties of estimating short and temporary changes in pasture intake, the most sensible alternative for the managers in order to monitor the temporary decline in nutrient intake, would be close monitoring of milk composition straight after peak, particularly protein content and protein:fat ratio, in order to properly and early identify evidence of under feeding to enable strategic input of high energy supplements.

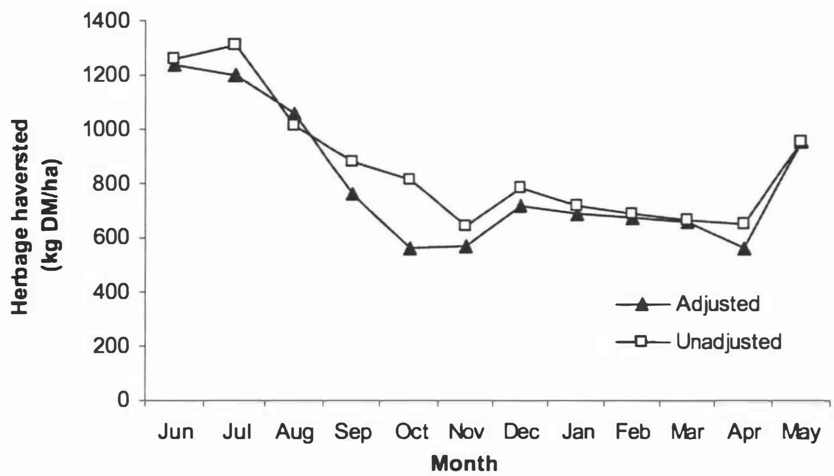


Figure 6.5 Comparison of estimations of dry matter harvested between adjusted and unadjusted values, at individual grazings, for the *AGMARDT* farms group. Season 2000-2001. Extracted from AGMARDT (2001).

6.2.4. Long term decline in milk yield

The long term decline in milk yield was measured as the regression coefficient of daily MS yield (g/cow/day) on time (days) over the period from peak (mid peak period) to late lactation (80% H in milk period). The whole lactation period was not considered for the regression procedure because some low yield cows were dried off in the latter part of the season. The final phase of lactation is usually avoided when fitting linear models for the lactation curve because, due to alterations in milk composition and also due to foetal development (Section 2.2.2), the pattern of milk production is not truly linear in the final month of lactation. Quadratic models were also tested for the whole lactation period (from mid peak to drying off) and also for the partial lactation period (from mid peak to 80% H in milk period) and the differences between the models were minimal. The regression analysis of milk yield on time generated predicted peak yield values which were similar to the observed values (Table 6.5).

Table 6.5 Actual and predicted values for peak yield, the regression coefficient (*b*) which was assumed as the post peak decline measurement and the R values for the regression of MS yield on time (days).

Farms	**Peak actual**[1] *(kg/cow/day)*	**Predicted peak** *Regression constant (kg/cow/day)*	**Rate of post peak decline**[2] *Regression coefficient (g/cow/day)*	**R^2%**
1	2.04	2.07	4.31	96.1
2	2.02	2.02	4.39	98.0
3	2.26	2.03	4.58	94.4
4	2.18	2.04	4.72	95.7
5	1.88	1.95	3.78	92.5
6	1.94	1.91	2.57	91.1
7	1.97	2.03	2.56	94.6
8	2.13	2.21	4.57	96.3
9	2.00	1.98	3.50	93.8
Mean	***2.04***	***2.02***	***4.00***	-

[1] Mid peak measurement.

[2] From peak to 80% H in milk period.

As several methods have been suggested to calculate persistency (Shanks *et al.*, 1981; Broster & Broster, 1984; Bar-Anan *et al.*, 1985; Keown *et al.*, 1986), and persistency is supposed to be the opposite of rate of post peak decline, then some persistency measurements were compared with the method utilised in this study. Persistency measured in relation to MS yield in late lactation (average daily yield from mid peak period to 80% H in milk period divided by yield at the 80% H in milk period) was significantly correlated to the present measurement, whereas persistency measured in relation to peak MS yield (average daily yield from mid peak to 80% H in milk period divided by peak yield), was not, although the correlation was moderate (Table 6.6). It appears that the different methodologies to estimate rate of post peak decline and persistency did not differ dramatically, and the regression methodology was used in preference to the other methods as it gives a direct estimation of decline rather than a ratio value. The values for the different measurements of persistency and rate of decline for all the farms involved in this study are shown in Table 5.12.

Table 6.6 Correlation matrix for rate of decline and persistency of MS yield measurements for the *AGMARDT* farms.

	Rate of post peak decline (g/cow/day)	Persistency in relation to peak yield	Persistency in relation to late lactation yield
Rate of post peak decline (g/cow/day)	**1.000**		
Persistency in relation to peak yield	-0.593	**1.000**	
Persistency in relation to late lactation yield	0.849**	-0.781**	**1.000**

(**) Significant at 1%

The measurement of post peak decline which was compared to the industry data were the daily decline in MS yield per cow obtained through the regression method. Information on MS yield per cow, per 10 days period was not available in either the LIC publications or in the dairy companies records, so the *AGMARDT* data were also calculated over monthly periods for comparison with industry figures. There were small differences between the monthly measurements and the 10 days period measurements, but the main point of interest in this analysis was not to show differences in the calculation methodologies but to compare the *AGMARDT* herds with the industry values using comparable sources of information.

Table 6.7 shows that the values for absolute rate of post peak decline for the *AGMARDT* herds was slightly higher than the industry and research values, whereas the relative rate of post peak decline was slightly lower than the industry and research values, with the exception of the TMR system. The differences observed in the rate of post peak decline between the absolute and the relative values indicate the need for care in interpreting information on decline in yield at different levels of peak yield. The monthly rate of post peak decline in milk yield, under standard conditions, generally ranges between 4 and 9% of the previous month's production or from peak yield (Sturtevant, 1886 cited in Turner, 1925; Shanks *et al.*, 1981; Knight & Wilde, 1993). Therefore, the *AGMARDT* herds, the industry data, and the research date are within the suggested range of values. In contrast, national data presented in Figure 2.3 and also the short term *AGMARDT* data showed that rates of post peak decline in relation to the previous months production can be higher than 9% or even "positive" (short term increases in MS yield) during specific periods after the peak. However, the majority of the published data are derived from systems with higher absolute milk yields which do not rely on grazing, and are probably not directly comparable to the New Zealand dairy system. Therefore, comparisons between the published data and the present data should be treated with caution.

Table 6.7 Information on peak yield and on absolute (g/cow/day) and relative (monthly percentage in relation to peak) for the *AGMARDT* farms (mean value across farms), for the industry data (LIC, 2001) and for research data adapted from Kolver (2001)[1].

	Peak yield	Absolute decline	Relative decline
	(kg/cow/day)	*(g/cow/day)*	*(% of peak)*
AGMARDT farms[1]	2.04	4.00	5.9
LIC (2001)[2]	1.66	3.50	6.3
Kolver TMR[3]	2.11	2.50	3.5
Kolver GRASS[3]	1.64	3.60	6.5

[1] Values extracted from the first year of the trial.

[2] Mean value across farms; 10 days interval measurements.

[3] Monthly measurements.

[4] Weekly measurements. There were only heifers in this experiment, which may present lower rates of post peak decline.

Peak MS yield was correlated positively and significantly with rate of post peak decline in MS yield, in agreement with a wide range of published results (Wood, 1967; Shanks *et al.*, 1981; Broster & Broster, 1984; Chase, 1993). These results agree with the initial speculation that the *AGMARDT* farms would have higher rates of post peak decline than the national industry average or any "grass only system" because higher levels of overall yield and peak milk yield are associated with lower persistency and higher rates of post peak decline (Shanks *et al.*, 1981; Keown *et al.*, 1986; Chase, 1993). On the other, the TMR system presented in Table 6.7, which utilised heifers with New Zealand genetics, was able to maintain relatively low levels of post peak decline following high levels of peak yield, suggesting that rate of post peak decline could be controlled through generous feeding levels and feed quality. However it is important to note that the rate of post peak decline in heifers is usually lower, although the treatment New Zealand genetics heifers on GRASS also show a relatively high rate of post peak decline.

The *AGMARDT* data showed no strong association between rate of post peak decline and level of feeding. Assuming that rates of post peak decline can be controlled through feeding management, it seems that just the strategic use of supplements, as in the *AGMARDT* group, is not sufficient to maintain a level of post peak decline similar to the TMR systems despite the negative correlation between pasture and supplements intake. However, for the present data, the rate of post peak decline was of minor importance for the total lactation yield as discussed further in Section 6.2.6.

Although none of the intake variables was significantly correlated with the rate of post peak decline in MS (Table 5.13), there were some interesting points in these analyses. Total and supplements intakes (ME and DM) were positively correlated with rate of post peak decline, which is the reverse of expectation (Figure 5.10 and Table 5.15). In contrast pasture intakes were negatively correlated with rate of post peak decline. This suggests that higher levels of supplementation and lower levels of pasture feeding are associated with higher peak yield and higher overall milk yield and consequently with higher levels of post peak decline. Indeed, inspection of Table 5.23 shows that the farms which had relatively high pasture and low supplements consumption also showed the lowest rates of decline, although, the differences between groups was minimal and could not be confirmed by statistical analysis due to the small sample size. These trends seems to be in agreement with published data (Broster & Broster, 1984; Keown *et al.*, 1986) which shows that high levels of peak yield and high levels of overall production are the most important factors affecting the rate of post peak decline, and that changes in the levels of feeding will immediately influence milk yield, but thereafter levels of feeding may not influence the rate of decline (Broster, 1972).

Also, although the relationships were not significant, the percentage of leaf in the sward was positively associated to rate of post peak decline, whereas proportion of stem, dead material, weed and seedhead were negatively associated, again contrary to expectations

(Table 5.15). These unexpected trends suggest that, despite the lower pasture consumption, the higher post peak decline farms maintained pasture quality targets better than the lower peak farms but, surprisingly, ME concentration in the pasture and in the total diet were negatively correlated with post peak decline which is not in agreement with initial statement. However, these inconsistent trends may be a result of the low values which those associations presented. In contrast, assuming only the late lactation period these trend takes the opposite direction as, in that period, milk yield is negatively correlated with pasture quality as discussed in the next Section.

Condition score and liveweight measurements, in general, show the opposite trends to those of milk yield over the lactation, falling after calving before increasing from mid to late lactation (Broster & Broster, 1998). In agreement with this evidence, the present data also showed the same trend (Appendix 6). These changes probably reflected the partition of energy into milk production in early lactation and into body reserves in late lactation.

The measurement of change in condition score over the post peak period showed almost no correlation with rate of post peak decline in MS yield. It was expected that rates of post peak decline, which are generally positively associated with levels of MS yield, would also be positively associated with decreases in condition score. However, Broster & Broster (1998) suggested that there is indeed little variation in the change in condition score and when it occurs it is observed in less well fed groups, which was not the case in this data set.

6.2.5. Milk yield in late lactation

One of the objectives of this analysis was to identify the role of the balance between pasture and supplement feeding in late lactation as the amount of supplementary feed consumed increased dramatically in late lactation when compared with the early lactation or peak period. The measurement of late lactation yield utilised in this analysis was the milk yield in the 80% H in milk to avoid effects of change in milk composition and the drying-off of low yield animals as already discussed.

The values for the research data presented in Table 6.8, were extracted from treatments/experiments which were as similar as possible to the management employed in the *AGMARDT* farms. These farms achieved relatively high levels of milk yield in late lactation, through the more liberal use of supplementary feed, maintaining condition score on target, although pasture intake was lower than values for research (Table 6.8). One could argue that the low level of pasture intake, observed within the *AGMARDT* group (Table 6.8), could simply reflect low levels of pasture availability in late lactation and that farmers were able to compensate this with supplements. Appendix 12 shows that, according to the difference between pre and post grazing, on average, pasture intakes appeared to decrease slightly over late lactation period. The lower pasture intake in late lactation could also be related to either, pasture intake measurements which were not very accurate, or with high substitution rates caused by supplementation input as during this period the proportion of ME intake from supplements was 40% (Figure 5.14). However, the most likely explanation seemed to be due to probably higher substitution rate over late lactation period as there was negative correlation between milk yield and pasture quality over the same period.

Table 6.8 Comparisons between the *AGMARDT* data and some published data on levels of milk yield and feeding per cow in late lactation period[1]

Studies[1]	**Levels of yield** *(Litres-kg/cow/day)*		**Feeding policy**	**DMI** *(kg/cow/day)*		**ME** *(MJME/kg DM)*		**OMD** %		**CS** *(units/cow)*
	MS	*Litres*		*P*[4]	*S*[4]	*P*	*S*	*P*	*S*	
AGMARDT farms[2]	1.16	12.1	Pasture plus strategic use of supplements	9.5	7.0	11.1	10.5	NA	NA	4.5
LIC (2001) (National average)[3]	0.98	9.7	NA	NA	NA	NA	NA	NA	NA	NA
Stockdale & Trigg (1989)	1.03	13.3	Pasture plus pellets	11.3	4.4	NA	NA	69	81	5.4
Pinares & Holmes (1996)	0.96	NA	Pasture plus pasture silage	11.6	5.5	9.9	9.0	NA	NA	4.6
Penno (2000)	NA	11.2	Pasture plus maize silage	9.6	6.3	12.0	NA	78.5	NA	4.5
Penno *et al.* (1998)	1.12	NA	Pasture plus rolled maize grain	11.0	3.7	12.6	13.5	79.9	NA	NA

[1] There are minor differences between the studies in the period considered as late lactation.

[2] Mean values across farms.

[3] Monthly average values for the national average in May 2000.

[4] *P*=pasture; *S*=supplements; DMI=Dry matter intake; ME=Energy intake; OMD=Organic matter digestibility; CS=Condition score

NA = Not available.

There was no significant relationship between peak yield and late lactation yield. Although condition score in late lactation was not significantly correlated to MS yield in late lactation, the relationship was almost significant and as expected negative (R^2=41%; P=0.087) because it is supposed that relatively high levels of milk yield in late lactation limit the recovery of body reserves. Remembering that the set of data is small, it seems that variations in condition score in late lactation did explain some of the variation in milk yield in late lactation and vice-versa.

None of the ME and protein intake variables were significantly correlated with late lactation yield. Surprisingly, though the correlations were not significant, total ME intake, pasture ME intake and ME concentration in the total diet, were negatively correlated to MS yield in late lactation (Table 5.17). Also, ME concentration in the pasture was negatively correlated and ADF concentration in pasture was positively correlated with late lactation yield, which seems to be the opposite of expectations.

From inspection of the full correlation matrix (Appendix 18), even though some of these correlations were not significant, pasture intakes (ME and DM) were positively correlated with concentration of ME in the diet and in the pasture, whereas supplement intakes (ME and DM) were negatively correlated to concentration of ME in the diet and in the pasture. This suggests that when pasture intake and pasture quality decreased, they were compensated by an increase in the supplement offered which increased the milk yield. Therefore the negative correlation between MS yield and concentration of ME in the diet and in the pasture was an indirect effect of the manipulation of supplement intakes (ME and DM) which, in their turn, were positively correlated to MS yield. In summary, the relatively high and positive correlation between late lactation yield and the concentration of ADF in the pasture is an indication that MS yield increased when pasture quality decreased because supplements were added to compensate the decrease in quality.

In practical terms, the explanation presented above suggests that the managers, in an attempt to graze only the leafy top of the sward, did not force the animals to graze into the lower strata of the sward which contains higher proportion of lower quality components. Then, in order to replace the deficit in pasture intake, supplementary feed was added in the system. This situation can have cumulative effects on subsequent grazing rotations as the amount of senescent material tends to accumulate, unless some mechanic control is employed (eg. topping). This process can also compromise the pasture utilisation targets if managers are not able to identify the correct balance between pasture utilization and supplements use over time, although in none of the lactation periods analysed did the managers increase the amount of ME fed as supplements at the same time as they increased the amount of ME fed as pasture. However the assessment of pasture intake which was utilised may not be accurate.

The research evidence suggest that for moderate stocking rates, the variations in the response to supplementary feed in late lactation are smaller than in early lactation (Grainger, 1990; Kolver *et al.*, 1996). However, the response to supplementary feed for the *AGMARDT* group did not differ significantly between early and late lactation (Table 6.2 and Table 6.9).

The *AGMARDT* figure for MS response to supplementary feed in late lactation seems to be low even when compared with slightly higher levels of pasture intake. However, the present estimates of "response" were taken as the regression coefficient for the correlation between MS yield and ME intake whereas the experimental values for response were calculated based on the difference between supplemented, unsupplemented groups.

Table 6.9 *AGMARDT* data and research data on MS response to supplementary feed in late lactation.

Study	Pasture intake	Response	
	kg/cow/day	*(g MS/kg DM)*	*(g MS/MJME)*[1]
AGMARDT farms	9.5	31.9	2.9
Stockdale & Trigg (1989)	11.3	43.1	3.9
Penno *et al.* (1996)	NA	132	12.0
Penno *et al.* (1998)	11.0	67.5	5.0
Holmes *et al.* (1994)	7.0	156	14.1

[1]The values for response were obtained through different methodologies. However, the main objective of this exercise is to compare trends and not absolute values.

[2] A value of 11 MJME/kg DM supplement was assumed to express response in MJME for the research data when the ME value for the supplementary feed was not available.

6.2.6. Total/partial lactation periods

Although there is variation in the research data due to differences in the management employed, Table 6.10 shows that the mean value across farms for total MS production per cow per in the *AGMARDT* farms is well above industry and research values. According to the industry data (LIC, 2001) less than 5% of the national herds presented total production per cow higher than 400kg MS/cow. In contrast, levels of feeding were not as high as some research data values. However these data are shown only in order to have an approximate guide to values for total lactation yield per cow and, as already mentioned, these data were obtained under different conditions.

Table 6.10 Comparisons between the *AGMARDT* data and some published data on total levels of yield and feeding per cow per lactation

Studies	Total MS yield (kg MS/cow)	Feeding policy	Levels of feeding (kg DM/cow)		
			Pasture	Suppl.	Total
AGMARDT farms[1]	417	Pasture plus strategically use of supplements	3380	940	4320
LIC (2001)[2]	307	NA	NA	NA	NA
Penno *et al.* (1999)[3]	363	Pasture plus maize silage	3800	1270	5070
Penno *et al.* (1999)	407	Balanced ration (pasture maize grain and maize silage)	3900	1458	5358

[1] Milk yield and feed intakes per cow were calculated through the peak number of cows method. Just the lactation period was included.

[2] National average

[3] Considering 365 days

NA=Not available

Lactation days explained most of the variations in the total MS yield per cow (Table 5.22 and Figure 5.13) which compares well with Penno, (2001), who also found strong correlation between lactation days and total yield per cow. This result again suggests the importance of the extra days in milk for the total lactation yield per cow in the New Zealand dairy system (Edwards & Parker, 1994) because in this system feeding levels are not able to be maintained late in the season due to diminished rates of pasture growth. Recent evidence on the use of supplementary feed has suggested that the highest production response to supplementary feed comes from the extended lactation (Penno *et al.*, 1996) because in New Zealand, cows normally achieve only 240 days in lactation whereas the potential length is 305 days and the energetic cost to maintain the animals is still the same irrespective of being in milk or dry (Penno *et al.*, 1996; Deane, 1999).

Peak yield and peak duration, individually were not significantly correlated with total lactation yield per cow (Table 5.22). However, Broster & Broster (1984) suggest that peak yield is the dominant factor influencing the whole lactation performance, accounting for 60 to 80% of variance in total lactation yield, and that the decrease in persistency, resulting from higher levels of peak, is not enough to reduce the benefit to total yield from increased peak yield. For the *AGMARDT* data, peak yield as an individual component accounted for only 13% (Table 5.22) of the variation in total yield per cow, although the low variability in peak yield values in the *AGMARDT* data might decrease the correlation values.

Rate of post peak decline in MS yield or persistency from peak to late lactation were also not related to the total yield per cow. In general, persistency appears to account for only 8-12% of the variance in the total lactation yield (Broster & Broster, 1984; Keown *et al.*, 1986), but this evidence applies to confined systems thus the same concept may not apply to pasture based systems. For the *AGMARDT* data, persistency or rate of post peak decline accounted for only 1 to 8% of the variation in total yield per cow. The variables calving to peak interval and late lactation MS yield were also unrelated to total yield per cow.

Some relationships between the components of the lactation curves were in agreement with published data. Peak yield was correlated positively to the rate of decline post peak, as already discussed. The correlation between peak yield and peak duration was negative, as previous investigation suggested (AGMARDT, 2000), but was not significant. Also, the negative association between late lactation yield and lactation days was significant, which is logical as yields decline towards the end of the lactation.

On the other hand, when the lactation curve predictor variables were combined in a stepwise regression to test which would be the best set of variables to explain the variation in total lactation yield per cow, peak MS yield and late lactation MS yield, in addition to lactation days, became significant in the model (Table 5.22). Also the regression coefficients for those three variables increased when they were combined in a model. This model is represented by the following equation:

Total yield per cow = - 325 + 1.52 Lactation days + 203.0 Late lactation yield + 73.0 Peak yield

Where, according to the sequential sum of squares, the variations explained by late lactation yield and peak yield are respectively 4 and 4.8 times lower than the variation explained by lactation days.

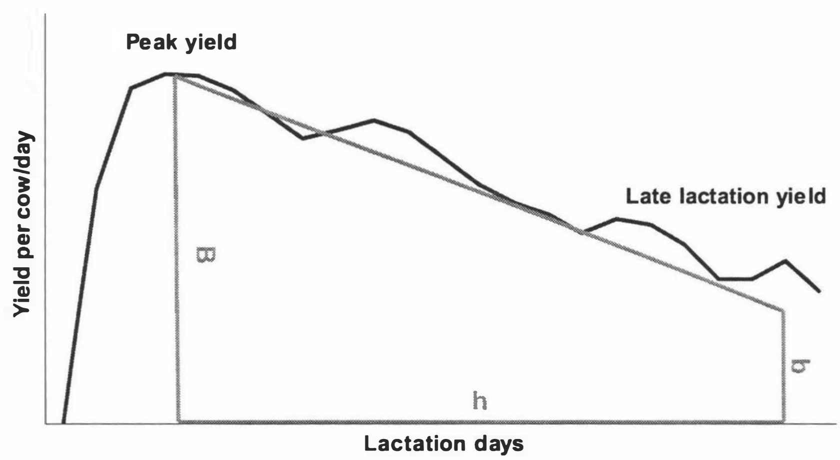


Figure 6.6 Influence of the main components of the lactation curves indicated by the model in total lactation yield per cow.

The relationship expressed by the model is represented by the geometric figure illustrated in Figure 6.6, where the area of the rectangular trapezoid representing the total lactation yield per cow is calculated by the formula;

$$\frac{(B+b)\times h}{2}$$

Mathematically, by increasing any one of the components of the model, total lactation yield should increase. However, because the individual correlations between those components and total lactation yield per cow were poor, the increment of just one component would not necessarily increase total lactation yield per cow significantly.

To illustrate the relationships demonstrated by the model, it can be calculated that an extra 10 kg/cow/lactation could be produced by;

- Either an extra 6.6 days in milk which would require an extra 1200 MJME of total intake, assuming a daily intake of 182 MJME/cow/day (Figure 5.14). The daily intake was used here because the information for the response in lactation days on ME intake was not available in the present study. However, Penno (2001) found a response of 1 extra lactation day for an extra 285 MJME/cow over the lactation, which in the present case would require 1881 MJME/cow to maintain an extra 6.6 days in lactation;

- Or an increase of 0.14 kg MS/cow/day in the peak yield and maintaining this yield over 71.4 days. This would require an extra 2640 MJME/cow assuming the MS response to supplements ME intake shown in Figure 5.3, which is 3.9g MS/MJME;

- Or an increase of 0.5 kg MS/cow/day increase in the late lactation yield and maintaining this yield over 20 days. This would require an extra 3448 MJME/cow assuming the MS response to supplements ME intake shown in Figure 5.12, which is 2.9g MS/MJME.

As discussed before, increases in the total lactation yield per cow can be due to increases in peak daily yield, late lactation daily yield and lactation length, individually or in combination. However, the energetic cost of increasing milk production was smaller if this was achieved through increases in lactation length than through increases in daily yield at peak. The high energy cost of increase milk production through increases in daily yield in late lactation with no increases in days in milk, is associated with the low milk responses to extra feed because, at that stage, the partitioning of nutrients to body condition occurs at the expense of milk yield. Therefore, according to the present model, the most effective way to increase total lactation milk yield per cow would be to increase lactation length, at reasonable levels of production (eg. 1.2 kg MS/cow/day), and to increase peak yield slightly as this energy cost is also relatively low.

6.2.7. Overview of the most relevant aspects discussed

6.2.7.1. Pasture utilization and supplements usage

Most of the total feed consumed came from grazed pasture (Figure 5.4, Figure 5.6 Figure 5.11 and Figure 5.14). In spite of the addition of supplements in the system, the contribution of the pasture was still relatively high, however the data for sward composition and quality in late lactation suggest that pasture could be better utilised at that stage.

Table 6.11 shows that, in all the lactation phases analysed, ME and DM intakes from pasture were negatively correlated with ME and DM intakes from supplements, the expected substitution rate effect, although in some phases these relationships were not significant. The extent to which substitution occurred varied according to the lactation phase. This indicates that a proportion of the pasture, which would have otherwise been eaten, was substituted by the supplementary feed. The negative association between pasture and supplements intake also suggests that managers appear to be sensitive to decreases in pasture intake levels. However, whether the accuracy of judgment of variation in pasture intake levels is still controversial, as the pasture scoring seems to be inaccurate during some periods of the year.

In contrast, unpublished results from another *AGMARDT* project (Salles, 2002), which utilised the data from the same set of farms in the same season, found positive correlations between pasture and supplements intakes over the whole lactation period. Perhaps the difference observed between the two studies is due to the fact that on an annual basis farmers are adding supplementary feed in the system, to some extent independently of decreases in pasture intake levels. This may be a consequence of the difficulties of estimating pasture intakes in short term measurements.

Table 6.11 Correlation coefficients (r) and their significance for the relationships between pasture and supplements ME (MJME/cow/day) and DM (kg DM/cow/day) intakes for the different phases of the lactation period.

Phase of lactation	**Correlation between pasture and supplements intake (r)**	
Present data	*ME*	*DM*
Mid peak	-0.363	-0.569
Temporary decline and recovery	-0.890***	-0.933***
Post peak decline	-0.241	-0.417
Late lactation	-0.699*	-0.790**
Salles (2002)[1]	0.375	NA

[1] Measured as the total eaten in during entire lactation period.

(*) Significant at 5%; (**) Significant at 1%; (***) Significant at 0.1%

NA=Not available.

Most of the supplements fed were forage based. This suggests that the character of the extra feed on these farms is more related to filling gaps in pasture availability, pasture quality and consequently intake targets rather than to nutritionally balancing the diets.

6.2.7.2. *Contrast between early lactation (peak period) and late lactation*

Table 6.12 shows the theoretical requirements and the measured ME intakes for the present data for early and late lactation. During early lactation the measured intakes were in good agreement with the theoretical requirements. However, as expected, the theoretical requirements decreased in late lactation in relation to early lactation, but the total measured ME intake did not decrease to the same extent as the requirements decreased. This trend can be also observed in the graphs in Appendix 7. Note that

Table 6.12 is just an illustrative example and therefore, it was not possible to allow for changes in body reserves.

Table 6.12 Theoretical daily energy requirements (MJME/cow/day) for the measured values of MS yield and liveweight and the measured daily ME intake (MJME/cow/day) for the peak period and for late lactation period.

Theoretical requirements (MJME/cow/day)	Early lactation (peak period)	Late lactation
MS yield	130	65
Maintenance	61	63
Pregnancy	-	14
Total ME required (MJME/cow/day)	*191*	*142*
Measured ME intakes (MJME/cow/day)		
Pasture intake (MJME/cow/day)	172	105
Supplements (MJME/cow/day)	22	73
Total intake (MJME/cow/day)	*194*	*180*
Difference between Theoretical and measured	**2%**	**21%**

The theoretical values for requirement were based on;

Early lactation (peak period)

- MS yield = 2.04 kg MS/cow/day (Table 6.1)
- Liveweight = 481kg (average across the farms) measured in early September 2000

Late lactation

- MS yield = 1.16 kg MS/cow/day (Table 6.8)
- Liveweight = 497 kg (average across the farms) measured in mid April 2001

No allowance was made for change in body reserves. Due to a possible weight gain in early lactation, the requirements may be underestimated, whereas in late lactation due to a weight loss, the requirements may be overestimated.

There are some hypothesis which could explain this discrepancy between theoretical requirement and measured ME intakes in late lactation. First, pasture ME intake estimations could have been overestimated due to the lack of consistency within and between farms, and this inaccuracy is more evident in the late lactation period than in early lactation. Second, the managers could have been too generous in relation to feeding levels towards the end of the lactation, resulting in addition of supplements when it was not strictly needed. This procedure also results in decreases in pasture quality because uneaten herbage remains in the sward to dilute further grazings and, to compensate for this decrease in pasture quality, even more supplementary feed is added generating an dangerous cycle as already discussed.

6.2.7.3. Effects of pasture characteristics on milk production

In general, botanical composition and sward qualitative measurements had little effect on milk yield and also on pasture intake which was not expected (Hoogendoorn *et al.*, 1992; Holmes *et al.*, 1992). These trends appear to be consequence of the low correlations between the variables involving pasture intake pasture and milk yield. This again suggests the high reliance on supplements to buffer the system.

6.2.7.4. The role of supplements

Supplement intakes were consistently more important to milk production and its sustainability than pasture intake, in all the lactation periods analysed, although on average, pasture was still the main source of nutrients. This might be related to the relatively high dependence on supplementary feed in order to meet the cow's requirements and pasture targets. It seems that the managers are utilising pasture as a secondary tool instead of supplements. For instance, there is an unexpected positive correlation between the low quality attributes of the sward and milk production in late lactation. This could arise because as quality falls, the managers feed more supplements which help to maintain milk yield but also cause reduced pasture consumption. The latter causes further decreases in pasture quality. There may be a need to put more emphasis on pasture utilisation towards late lactation while still utilising supplementary feed as a buffering tool.

CHAPTER 7

Conclusions

The present study shows that this group of farms achieved high milk yield per cow, 417 (374-438) kg MS/cow utilising 21% of supplements in the total diet (ranged from 11% in peak lactation to 40% in late lactation), which are high figures by New Zealand standards. In this context, the overall conclusions are:

- Peak yield (1.94-2.26, mean 2.04 kg/cow/day) was significantly influenced by total ME intake (R^2=57.7%; P=0.018), with an increment of 3.8g MS/MJME. Although the average amount of supplementary feed utilised during the peak period was relatively low (23 MJME/cow/day), there was a wide range (from 0 to 48 MJME/cow/day) and the results indicated that supplements intake also influenced peak yield (R^2=40.1%; P=0.067). This suggests that supplements could be used strategically to enhance peak yield values. However, the prices for milk and for supplementary feed also play a role in feeding decisions over the peak period, because pasture is still the cheapest high quality feed available.

- Throughout this study, MS yield was primarily related to ME intake, and other dietary components (for example crude protein and fibre) were of less importance within the ranges recorded (crude protein in the total diet from 120-285 g/kg DM and ADF in the pasture from 175-240 g/kg DM)

- The evidence suggested that the temporary decline and recovery in MS yield (0.89-4.56, mean 3.02 kg/cow/day), observed after the peak yield period, was a consequence of underfeeding over that short period. This nutritional deficiency appeared to be caused by the effect of adverse climatic conditions that influenced pasture consumption, probably resulting in increased pasture wastage over the same period. The data suggest that the management response to increase supplements feeding was neither fast enough nor substantial enough to deal with the short-term problem. However, on average across farms, the decrease in MS production over that period represented only a small proportion (0.72%) of the total lactation yield and there was no clear evidence of a long term effect on lactation.

Although not expressed in the regression analyses, comparison of farms with different peak yield characteristics showed that the high peak farms also presented the highest MS losses over the temporary decline and recovery period. Close monitoring of concentrations of protein and fat in milk at this time would help in the assessment of nutritional status and the need to modify feeding strategies.

- The only variable which was significantly associated with long term rate of post peak decline in MS yield (2.56-4.72, mean 4.00 g MS/cow/day) was peak milk yield as expected (R^2=53%; P=0.025). The absence of significant association between levels of feeding and rate of post peak decline could be associated with the small variability in the data, which was probably a consequence of the similar management employed in these farms although some research results, which were not based on pasture dairy systems, have suggested that the rate of post peak decline in milk yield does not necessarily depend on levels of feeding. In general, the farms with higher peak yields had higher rates of post peak decline and apparently consumed slightly more supplements during peak period and also over the post peak decline period, although there was no clear evidence of differences in pasture consumption between the farms with high and low long term post peak decline. Because the farms with higher long term decline in MS yield utilised more supplements, and probably less pasture, there was no consistent association between rates of post peak decline of either botanical or chemical measurements.

- Although also not significant, the correlations with late lactation yield (1.01-1.24, mean 1.16 kg MS/cow/day) were unusual because of the effects of supplement utilisation. The negative correlation between pasture quality and MS yield appeared to be caused by the apparent low pasture utilisation in late lactation due to increased supplementation input. The low utilisation of pasture, in its turn, may be a consequence of either the possible underestimation of pasture yield over the late lactation period, or the high supplements allowances which have caused further increases in residual pasture mass and decreases in pasture quality. The balance between feeding supplements and pasture quality is a crucial issue over this period.

- Lactation days (208-272, mean 243 days) was the main individual factor affecting total lactation yield (R^2=65.1%; *P*=0.009), however peak yield and late lactation yield were also of importance when combined in a model with lactation days. The independent effect of rate of post peak decline was of less importance to the total lactation yield, but its effect was partly explained by links to both peak yield and late lactation yield. Among the three alternatives to increase total lactation yield (increases in lactation length, in peak yield or in late lactation yield) the most energetically efficient was an increase in lactation length, followed by an increase in peak yield. Increase in milk yield in late lactation was of relatively high energetic cost.

- Differences between farms in peak milk yield were largely balanced by differences in the long-term rate of decline in yield, so that the range of variation in total lactation yield was relatively small. This emphasises the potential flexibility in management of cow nutrition in a system designed to balance pasture and supplements on an objective basis.

- The evidence suggests that there are difficulties in achieving accurate estimations of pasture production and consumption using conventional field based techniques. This is a serious limitation to the interpretation of the results of dairy systems studies, and needs to be addressed particularly in circumstances, like in this study, where questions about pasture utilisation and targets for pasture and supplements management are so important.

- As the estimations of intakes may not be accurate, close monitoring of milk composition could be a more sensitive tool to indicate short term variation in the nutritional status of the animal, as in the case of the temporary decline and recovery in milk yield.

- In general, the use of supplements clearly worked to maintain improved MS yield per cow, but its potentially adverse effects on pasture utilisation and pasture quality need to be carefully managed in order to maintain the components of the system in balance.

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Appendices

Appendix 1 Soil types and characteristics for all case study farms

- Manawatu soils: well drained, Recent Soils from river alluvium, commonly on sand or gravel. They flood approximately every decade (Farms 4 and 6).
- Manawatu silt loam: Manawatu soils with silt loam textured topsoil (Farms 2 and 8).
- Manawatu fine sand loam: Manawatu soils with fine sand loam textured topsoils (Farm 5).
- Manawatu sand loam: Manawatu soils with sand loam shallow topsoil. Drought prone (Farm 5).
- Manawatu sand loam gravely phase: Manawatu soils with gravel in the surface. Drought prone (Farm 5).
- Rangitikei soils: Recent Soils that normally flood every year and are well to excessively drained. Texture and depths vary considerably; tends to be drought prone (Farms 3, 4, 6 and 8).
- Rangitikei sand loam: Rangitikei soils with sand loam topsoils (Farm 5).
- Parewanui soils: Recent Gley Soils that flood frequently and are poorly drained. May have sandy, silty or clayey texture (Farm 3).
- Kairanga soils: Recent Gley Soils that are poorly-imperfectly drained. They flood approximately every decade and are prone to pugging and compaction (Farms 2, 3 and 7).
- Kairanga fine sand loam: Kairanga soils with sand loam topsoils (Farm 5).
- Kairanga silt loam: Kairanga soils with silt loam textured topsoils (Farm 9).
- Kairanga peaty silt loam: Kairanga soils with peaty silt loam textured topsoils (Farm 9).

- Opiki soils: Recent Soils which flood approximately every decade. Imperfectly to moderately well drained. Alluvium interbedded with layers of peat (Farm 7).

- Matamau silt loam: generally imperfectly to poorly drained. Brown Soils that are developed in loess and other silt and clays with silt loam topsoils (Farms 1, 6 and 8).

- Matamau hill soils: generally imperfectly to poorly drained. Brown Soils that are developed in loess and other silt and clays on rolling to hilly slopes (15-25°) (Farms 1 and 8).

- Dannevirke silt loam: well drained Allophanic Brown Soils developed on loess and volcanic ash on terraces and gently rolling slopes. Excellent physical properties (Farm 6).

- Te Arakura soils: Gley Soils that do not normally flood. Poorly to imperfectly drained and found on river terraces that no longer flood (Farm 5).

- Puke puke soils: Gley Soils of the sand plains between dunes. Poorly drained with rising water table. Very sandy (Farm 3).

- Motuiti soils: Recent Soils of the dunes. Weakly developed topsoils and subsoils. Prone to wind erosion when disturbed (Farm 3).

- Foxton soils: Brown Soils of slightly older dunes. Thick topsoils and some B horizon development (Farm 3).

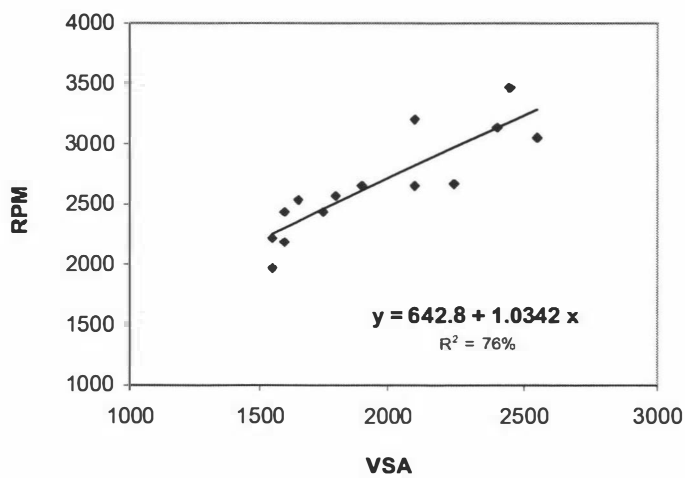
- Raumati soils: Gley Soils with poor drainage usually on colluvium (Farm 2).

- Himitangi soils: Recent Soils of the drier sand plains between dunes. Water table is not so high as in Puke Puke soils; soils are imperfectly drained. Very sandy (Farm 3).

Appendix 2 Example showing how the derived monthly regression between the Rising Plate Meter (RPM) measurement and the visual sward assessment (VSA) was obtained in order to standardise herbage measurements between farmers.

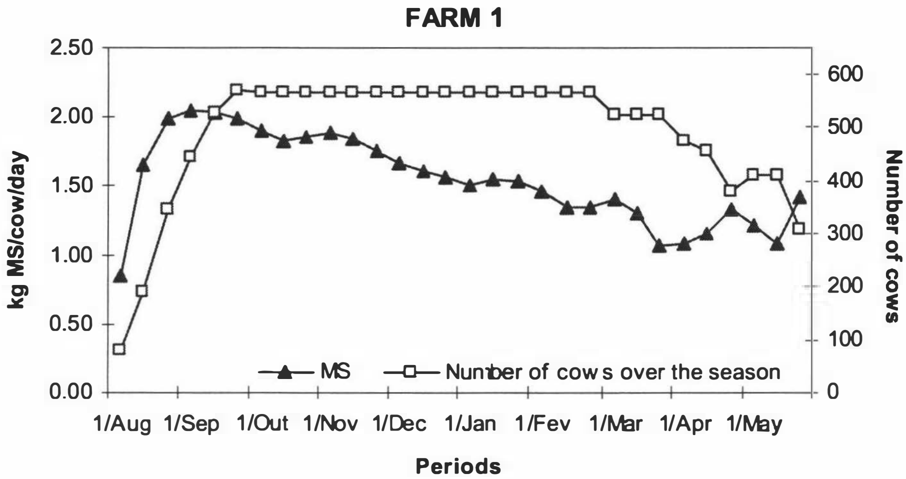
Paddock	Estimations	
	VSA	RPM
	(x)	*(y)*
2	2400	3133
3	1600	2190
4	1900	2650
7	2100	3208
9	1650	2541
12	1750	2441
23	2100	2643
24	1550	2209
27	2550	3046
28	1600	2435
31	2450	3468
33	2250	2674
36	1550	1971

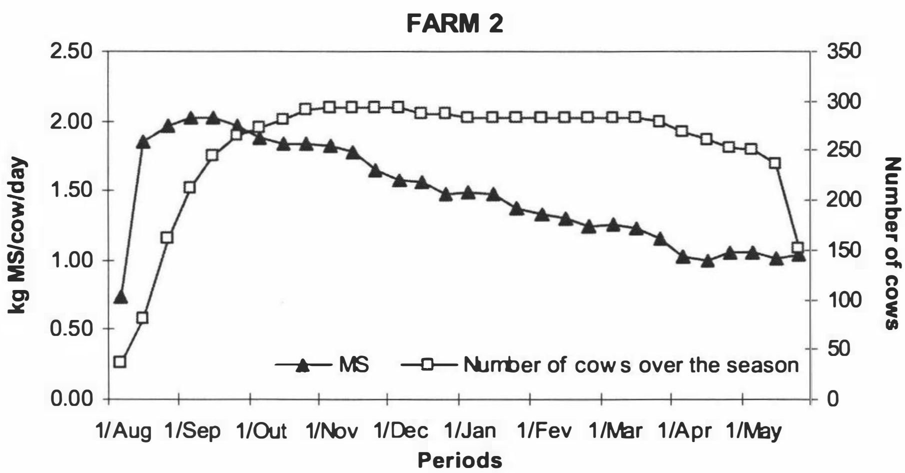
Regression plot and regression equation of RPM x VSA

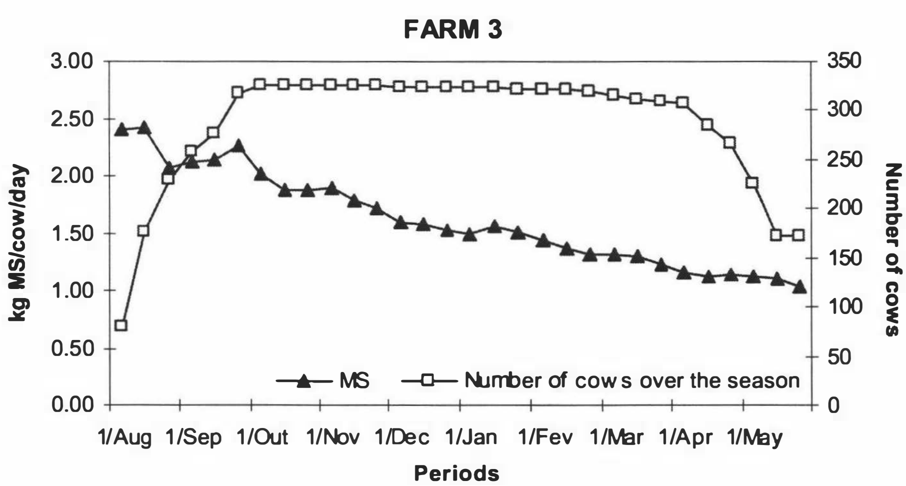


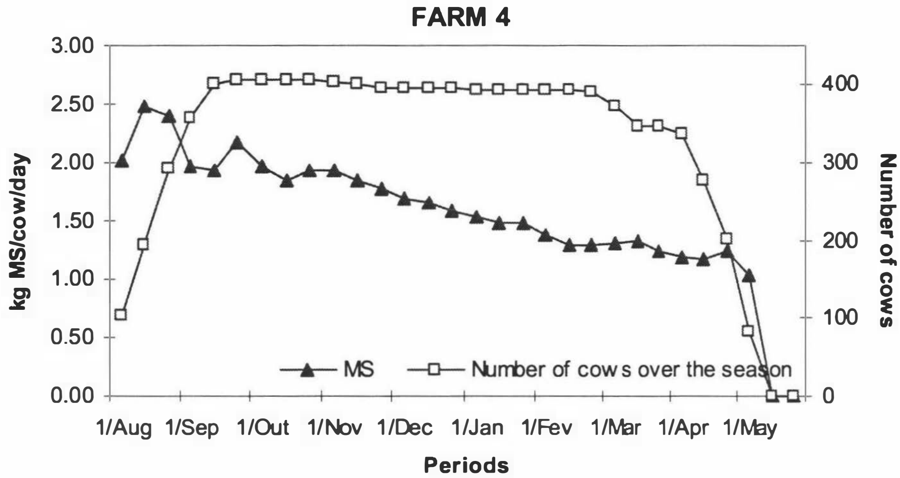
Managers visual assessment is utilized as the x variable in the regression equation above in order to obtain the standardize measurement between farmers. The resulting y values are then utilised for the analyses. This calibration is carried out once each month, for pre and post herbage masses, at each one of the farms involved in the *AGMARDT- Dairy Farm Monitoring Programme.*

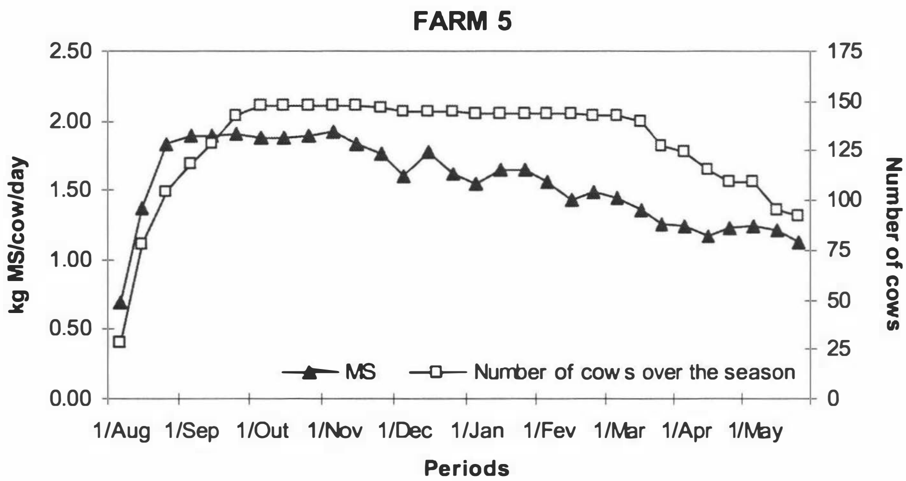
Appendix 3 Lactation curves expressed in MS/cow/day and the daily number of lactating cows over the season, for each individual farm involved in this study.

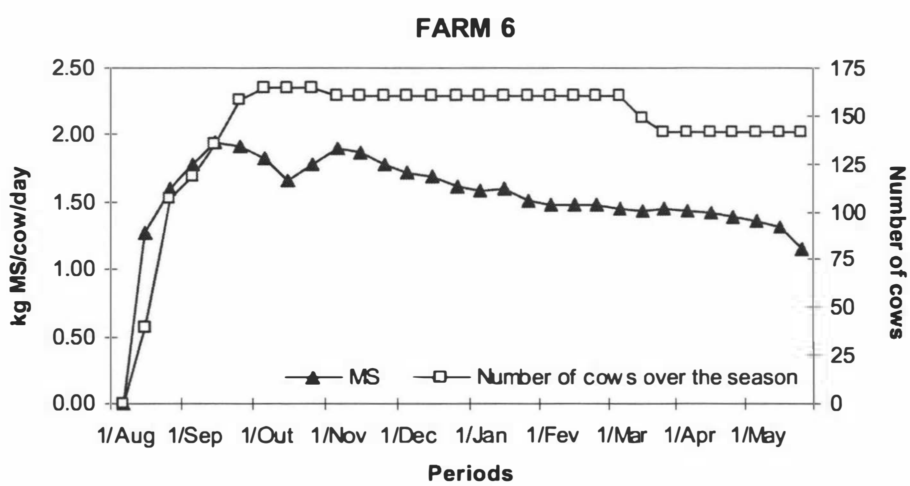


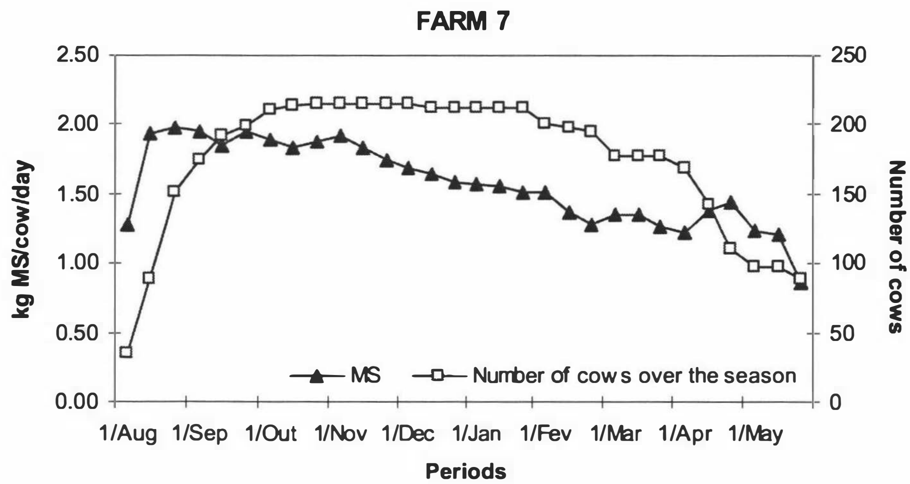


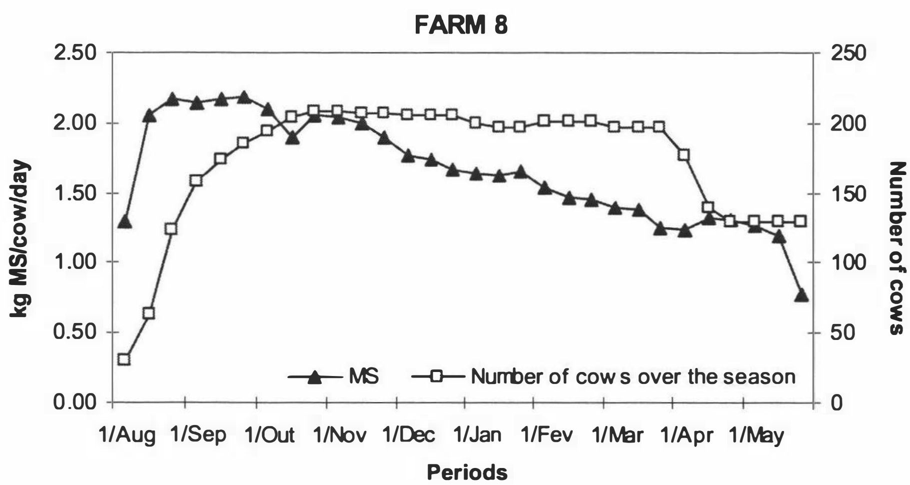


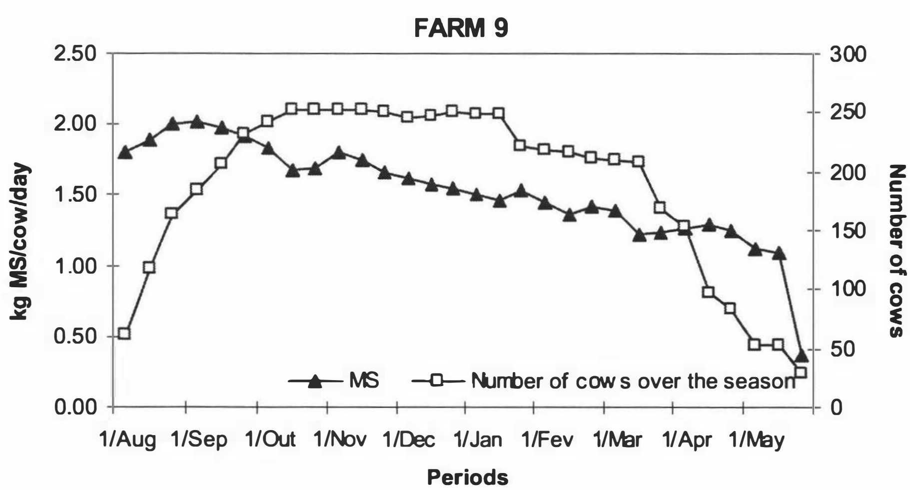

FARM 4
3.00
2.50
2.00
1.50
1.00
0.50
0.00
kg MS/cow/day
400
300
200
100
0
Number of cows
MS
Number of cows over the season
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods


FARM 5
2.50
2.00
1.50
1.00
0.50
0.00
kg MS/cow/day
175
150
125
100
75
50
25
0
Number of cows
MS
Number of cows over the season
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods


FARM 6
2.50
2.00
1.50
1.00
0.50
0.00
kg MS/cow/day
175
150
125
100
75
50
25
0
Number of cows
MS
Number of cows over the season
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods


FARM 7
2.50
2.00
1.50
1.00
0.50
0.00
kg MS/cow/day
250
200
150
100
50
0
Number of cows
MS
Number of cows over the season
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods


FARM 8
2.50
2.00
1.50
1.00
0.50
0.00
kg MS/cow/day
250
200
150
100
50
0
Number of cows
MS
Number of cows over the season
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods


FARM 9
2.50
2.00
1.50
1.00
0.50
0.00
kg MS/cow/day
300
250
200
150
100
50
0
Number of cows
MS
Number of cows over the season
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

Appendix 4 Correlations matrix for the response variables peak MS yield and mid peak MS yield and the several combinations of periods in which the ME predictor variables were tested.

	PY	PTMEI	PPMEI	PSMEI	PME[ ]	MPY	MPTMEI	MPPMEI
PTMEI	0.729 0.026							
PPMEI	0.358 0.345	0.684 0.042						
PSMEI	0.575 0.105	0.572 0.107	-0.207 0.593					
PME[ ]	0.603 0.085	0.831 0.005	0.838 0.005	0.173 0.657				
MPY	0.992 0.000	0.760 0.017	0.384 0.307	0.587 0.096	0.626 0.071			
MPTMEI	0.714 0.031	0.960 0.000	0.752 0.019	0.442 0.233	0.808 0.008	0.760 0.018		
MPPMEI	0.232 0.547	0.546 0.128	0.972 0.000	-0.360 0.342	0.717 0.030	0.266 0.489	0.669 0.049	
MPSMEI	0.616 0.078	0.547 0.127	-0.226 0.559	0.987 0.000	0.151 0.698	0.633 0.067	0.449 0.225	-0.363 0.336
MPME[]	0.520 0.152	0.790 0.011	0.833 0.005	0.124 0.751	0.957 0.000	0.561 0.116	0.778 0.013	0.737 0.023
MP20TMEI	0.688 0.040	0.948 0.000	0.621 0.075	0.574 0.106	0.693 0.038	0.737 0.024	0.949 0.000	0.519 0.152
MP20PMEI	0.229 0.553	0.575 0.106	0.948 0.000	-0.295 0.441	0.788 0.012	0.268 0.486	0.616 0.077	0.913 0.001
MP20SMEI	0.499 0.171	0.432 0.245	-0.281 0.464	0.895 0.001	-0.047 0.904	0.512 0.159	0.393 0.296	-0.353 0.351
MP20ME[]	0.616 0.077	0.875 0.002	0.846 0.004	0.222 0.565	0.969 0.000	0.646 0.060	0.857 0.003	0.734 0.024
MP30TMEI	0.575 0.105	0.843 0.004	0.368 0.330	0.716 0.030	0.508 0.162	0.633 0.067	0.818 0.007	0.282 0.463
MP30PMEI	0.205 0.597	0.623 0.073	0.896 0.001	-0.172 0.658	0.760 0.017	0.238 0.537	0.635 0.066	0.854 0.003
MP30SMEI	0.391 0.298	0.288 0.452	-0.427 0.252	0.866 0.003	-0.167 0.668	0.420 0.261	0.253 0.511	-0.476 0.196
MP30ME[]	0.610 0.081	0.733 0.025	0.519 0.152	0.399 0.287	0.813 0.008	0.615 0.078	0.690 0.040	0.416 0.265
PCTMEI	0.211 0.586	-0.036 0.927	0.162 0.677	-0.230 0.552	-0.146 0.708	0.201 0.605	0.124 0.751	0.291 0.447
PCME[]	-0.116 0.765	-0.164 0.673	-0.041 0.918	-0.174 0.654	-0.138 0.723	-0.093 0.812	-0.068 0.862	0.076 0.846
CTPTMEI	0.513 0.158	0.455 0.219	0.081 0.836	0.519 0.153	0.326 0.392	0.576 0.105	0.390 0.300	-0.037 0.925
CTPPMEI	0.400 0.286	0.531 0.141	0.546 0.128	0.098 0.802	0.610 0.081	0.450 0.224	0.506 0.165	0.435 0.242
CTPSMEI	0.129 0.741	-0.072 0.854	-0.489 0.182	0.453 0.221	-0.293 0.444	0.143 0.714	-0.115 0.768	-0.498 0.173

CTPME[]	0.523	0.630	0.543	0.234	0.788	0.526	0.560	0.418
	0.149	0.069	0.130	0.544	0.012	0.146	0.117	0.262
50CTPTMEI	0.511	0.551	0.244	0.464	0.553	0.570	0.458	0.095
	0.160	0.124	0.526	0.208	0.123	0.109	0.215	0.808
50CTPPMEI	0.279	0.492	0.686	-0.112	0.720	0.341	0.495	0.607
	0.467	0.179	0.041	0.774	0.029	0.369	0.175	0.083
50CTPSMEI	0.283	0.068	-0.552	0.712	-0.214	0.279	-0.051	-0.638
	0.461	0.862	0.123	0.032	0.580	0.467	0.897	0.065
50CTPME[]	0.487	0.643	0.664	0.115	0.804	0.502	0.625	0.579
	0.184	0.062	0.051	0.767	0.009	0.168	0.072	0.102
CTMPTMEI	0.422	0.475	0.113	0.510	0.370	0.482	0.368	-0.023
	0.257	0.196	0.773	0.161	0.328	0.189	0.330	0.953
CTMPPMEI	0.232	0.503	0.655	-0.062	0.645	0.276	0.459	0.555
	0.548	0.167	0.056	0.875	0.061	0.472	0.214	0.121
CTMPSMEI	0.184	-0.033	-0.537	0.560	-0.276	0.198	-0.094	-0.571
	0.635	0.933	0.136	0.117	0.472	0.609	0.809	0.108
CTMPME[]	0.431	0.618	0.571	0.187	0.790	0.440	0.548	0.455
	0.246	0.076	0.108	0.630	0.011	0.235	0.127	0.218
50CTMPTMEI	0.455	0.566	0.276	0.449	0.588	0.508	0.444	0.113
	0.219	0.112	0.473	0.226	0.096	0.163	0.231	0.772
50CTMPPMEI	0.178	0.448	0.720	-0.208	0.717	0.223	0.420	0.637
	0.647	0.226	0.029	0.592	0.030	0.564	0.260	0.065
50CTMPSMEI	0.326	0.137	-0.528	0.777	-0.156	0.335	0.026	-0.622
	0.391	0.725	0.144	0.014	0.688	0.378	0.947	0.074
50CTMPME[]	0.411	0.634	0.640	0.132	0.797	0.428	0.595	0.547
	0.272	0.066	0.064	0.735	0.010	0.250	0.091	0.127

	MPSMEI	MPME[ ]	MP20TMEI	MP20PMEI	MP20SMEI	MP20ME[	MP30TMEI	MP30PMEI
MPME[]	0.090							
	0.819							
MP20TMEI	0.566	0.669						
	0.112	0.049						
MP20PMEI	-0.325	0.829	0.521					
	0.393	0.006	0.150					
MP20SMEI	0.917	-0.112	0.540	-0.437				
	0.000	0.775	0.133	0.240				
MP20ME[]	0.191	0.949	0.798	0.798	0.054			
	0.622	0.000	0.010	0.010	0.890			
MP30TMEI	0.688	0.562	0.910	0.285	0.677	0.643		
	0.041	0.115	0.001	0.457	0.045	0.062		
MP30PMEI	-0.231	0.793	0.618	0.922	-0.257	0.842	0.440	
	0.550	0.011	0.076	0.000	0.504	0.004	0.235	
MP30SMEI	0.890	-0.142	0.359	-0.532	0.903	-0.106	0.606	-0.447
	0.001	0.715	0.343	0.140	0.001	0.787	0.083	0.228
MP30ME[]	0.364	0.786	0.606	0.388	0.257	0.823	0.612	0.508
	0.335	0.012	0.083	0.303	0.505	0.006	0.080	0.163
PCTMEI	-0.195	-0.078	0.140	0.060	0.089	0.007	0.140	0.154
	0.615	0.842	0.719	0.879	0.820	0.986	0.719	0.692

PCME[]	-0.176	-0.032	0.028	-0.045	0.074	0.042	0.180	0.214
	0.650	0.936	0.943	0.908	0.850	0.915	0.644	0.581
CTPTMEI	0.533	0.424	0.454	0.217	0.265	0.332	0.507	0.084
	0.140	0.255	0.219	0.576	0.491	0.382	0.163	0.829
CTPPMEI	0.111	0.572	0.577	0.675	-0.057	0.645	0.337	0.634
	0.775	0.108	0.103	0.046	0.884	0.061	0.375	0.067
CTPSMEI	0.454	-0.147	-0.121	-0.479	0.345	-0.323	0.189	-0.577
	0.219	0.705	0.756	0.192	0.364	0.396	0.626	0.104
CTPME[]	0.199	0.715	0.587	0.522	0.103	0.844	0.466	0.690
	0.607	0.030	0.097	0.149	0.792	0.004	0.207	0.040
50CTPTMEI	0.460	0.622	0.482	0.384	0.130	0.525	0.487	0.258
	0.213	0.073	0.188	0.308	0.739	0.147	0.183	0.503
50CTPPMEEI	-0.109	0.740	0.479	0.834	-0.317	0.718	0.261	0.739
	0.780	0.023	0.192	0.005	0.406	0.029	0.498	0.023
50CTPSMEI	0.703	-0.152	-0.001	-0.563	0.555	-0.246	0.277	-0.602
	0.035	0.696	0.999	0.114	0.121	0.524	0.471	0.086
50CTPME[]	0.086	0.763	0.630	0.632	0.041	0.882	0.500	0.796
	0.825	0.017	0.069	0.068	0.916	0.002	0.171	0.010
CTMPTMEI	0.489	0.487	0.446	0.273	0.201	0.382	0.528	0.177
	0.182	0.183	0.229	0.477	0.605	0.310	0.144	0.649
CTMPPMEI	-0.091	0.648	0.524	0.807	-0.243	0.697	0.305	0.805
	0.815	0.059	0.147	0.009	0.529	0.037	0.425	0.009
CTMPSMEI	0.569	-0.164	-0.082	-0.530	0.436	-0.315	0.215	-0.623
	0.110	0.673	0.834	0.142	0.240	0.409	0.579	0.073
CTMPME[]	0.140	0.738	0.571	0.561	0.049	0.850	0.469	0.740
	0.720	0.023	0.108	0.116	0.900	0.004	0.203	0.023
50CTMPTMEI	0.421	0.662	0.477	0.426	0.082	0.565	0.490	0.330
	0.260	0.052	0.194	0.253	0.833	0.113	0.180	0.386
50CTMPPMEI	-0.239	0.752	0.406	0.882	-0.441	0.721	0.200	0.816
	0.536	0.019	0.278	0.002	0.235	0.028	0.606	0.007
50CTMPSMEI	0.781	-0.111	0.082	-0.542	0.621	-0.188	0.343	-0.579
	0.013	0.777	0.834	0.131	0.074	0.628	0.367	0.102
50CTMPME[]	0.088	0.762	0.610	0.620	0.032	0.873	0.503	0.801
	0.821	0.017	0.081	0.075	0.935	0.002	0.168	0.009

	MP30SMEI	MP30ME[]	PCTMEI	PCME[]	CTPTMEI	CTPPMEI	CTPSMEI	CTPME[]
MP30ME[]	0.160							
	0.680							
PCTMEI	0.003	-0.011						
	0.993	0.977						
PCME[]	-0.010	0.177	0.652					
	0.979	0.649	0.057					
CTPTMEI	0.431	0.154	-0.216	-0.266				
	0.247	0.693	0.576	0.488				
CTPPMEI	-0.225	0.198	-0.158	-0.107	0.558			
	0.560	0.609	0.686	0.783	0.119			
CTPSMEI	0.700	-0.044	-0.066	-0.173	0.485	-0.456		
	0.036	0.910	0.866	0.657	0.186	0.218		

CTPME[]	-0.147	0.798	-0.022	0.281	0.152	0.605	-0.474	
	0.705	0.010	0.955	0.463	0.696	0.084	0.197	
50CTPTMEI	0.257	0.346	-0.390	-0.314	0.944	0.660	0.317	0.370
	0.504	0.362	0.299	0.411	0.000	0.053	0.405	0.327
50CTPPMEI	-0.395	0.294	-0.192	-0.080	0.513	0.925	-0.425	0.600
	0.292	0.443	0.620	0.839	0.158	0.000	0.254	0.088
50CTPSMEI	0.809	0.061	-0.242	-0.288	0.527	-0.337	0.920	-0.290
	0.008	0.876	0.530	0.452	0.145	0.375	0.000	0.450
50CTPME[]	-0.207	0.791	0.134	0.389	0.101	0.598	-0.521	0.973
	0.593	0.011	0.732	0.300	0.796	0.089	0.150	0.000
CTMPTMEI	0.369	0.209	-0.304	-0.258	0.973	0.552	0.462	0.214
	0.329	0.589	0.426	0.502	0.000	0.123	0.211	0.581
CTMPPMEI	-0.409	0.237	-0.135	-0.017	0.424	0.943	-0.539	0.645
	0.274	0.540	0.730	0.965	0.256	0.000	0.134	0.061
CTMPSMEI	0.765	-0.030	-0.164	-0.235	0.533	-0.392	0.985	-0.428
	0.016	0.940	0.673	0.542	0.140	0.296	0.000	0.250
CTMPME[]	-0.188	0.802	-0.046	0.309	0.115	0.580	-0.488	0.991
	0.627	0.009	0.906	0.419	0.769	0.101	0.182	0.000
50CTMPTMEI	0.196	0.388	-0.441	-0.306	0.899	0.658	0.271	0.427
	0.613	0.302	0.235	0.424	0.001	0.054	0.480	0.252
50CTMPPMEI	-0.524	0.303	-0.186	-0.051	0.407	0.862	-0.472	0.618
	0.148	0.428	0.633	0.895	0.278	0.003	0.200	0.076
50CTMPSMEI	0.854	0.100	-0.301	-0.300	0.580	-0.245	0.881	-0.229
	0.003	0.799	0.431	0.432	0.101	0.525	0.002	0.553
50CTMPME[]	-0.209	0.797	0.043	0.372	0.085	0.578	-0.518	0.974
	0.590	0.010	0.913	0.324	0.828	0.103	0.153	0.000

	50CTPTMEI	50CTPPMEI	50CTPSMEI	50CTPME[]	CTMPTMEI	CTMPPMEI	CTMPSMEI	CTMPME[]
50CTPPMEI	0.674							
	0.046							
50CTPSMEI	0.395	-0.412						
	0.293	0.270						
50CTPME[]	0.303	0.630	-0.410					
	0.428	0.069	0.273					
CTMPTMEI	0.958	0.538	0.513	0.155				
	0.000	0.135	0.158	0.690				
CTMPPMEI	0.570	0.941	-0.467	0.665	0.483			
	0.109	0.000	0.205	0.051	0.188			
CTMPSMEI	0.374	-0.404	0.964	-0.505	0.501	-0.516		
	0.321	0.281	0.000	0.165	0.170	0.155		
CTMPME[]	0.347	0.607	-0.327	0.976	0.199	0.657	-0.454	
	0.360	0.083	0.390	0.000	0.607	0.055	0.219	
50CTMPTMEI	0.987	0.688	0.362	0.354	0.949	0.613	0.322	0.418
	0.000	0.041	0.339	0.350	0.000	0.079	0.397	0.263
50CTMPPMEI	0.595	0.969	-0.471	0.651	0.478	0.954	-0.475	0.645
	0.091	0.000	0.201	0.057	0.193	0.000	0.196	0.061
50CTMPSMEI	0.460	-0.337	0.987	-0.355	0.555	-0.407	0.945	-0.271
	0.212	0.376	0.000	0.349	0.121	0.277	0.000	0.481

```
50CTMPME[]0.306   0.621   -0.396   0.991    0.164    0.667   -0.499    0.990
          0.423   0.074    0.292   0.000    0.673    0.050    0.172    0.000


         50CTMPTMEI 50CTMPPMEI 50CTMPSMEI
50CTMPPMEI 0.644
           0.061

50CTMPSMEI 0.419    -0.426
           0.262     0.253

50CTMPME[] 0.373     0.657      -0.339
           0.323     0.054       0.372

Cell Contents: Pearson correlation
               P-Value
```

Legend

Y = MS yield.

P = mean values representing the whole peak period.

MP = values represent the mid peak period.

20 = mean values representing the mid peak period and the previous period of 10 days.

30 = mean values representing the mid peak and the two previous periods of 10 days.

PC = mean values representing the period form 1st June to start of calving.

CTP = mean values representing the period from calving to peak.

CTMP = mean values representing the period from calving to mid peak.

50CTP = mean values representing the period from 50% of the herd calved to peak.

50CTMP = mean values representing the period from 50% of the herd calved to mid peak period.

TMEI = total ME intake.

PMEI = pasture ME intake.

SMEI = supplements ME intake.

ME[ ] = ME concentration in the diet.

Appendix 5 Correlation matrix for the response variable mid peak yield and the associated predictor variables.

	MPY	MPTDMI	MPPDMI	MPSDMI	MPTMEI	MPPMEI	MPSMEI	MPME[]
MPTDMI	0.717							
	0.030							
MPPDMI	0.060	0.437						
	0.878	0.239						
MPSDMI	0.597	0.491	-0.569					
	0.089	0.180	0.110					
MPTMEI	0.760	0.950	0.472	0.412				
	0.018	0.000	0.200	0.271				
MPPMEI	0.266	0.552	0.933	-0.399	0.669			
	0.489	0.123	0.000	0.287	0.049			
MPSMEI	0.633	0.527	-0.531	0.996	0.449	-0.363		
	0.067	0.145	0.141	0.000	0.225	0.336		
MPME[ ]	0.561	0.547	0.447	0.068	0.778	0.737	0.090	
	0.116	0.127	0.228	0.863	0.013	0.023	0.819	
MPTPrI	-0.026	-0.013	0.073	-0.083	-0.070	0.018	-0.110	-0.088
	0.948	0.973	0.852	0.832	0.858	0.962	0.778	0.822
MPPPrI	-0.241	-0.096	0.570	-0.640	-0.080	0.461	-0.654	0.077
	0.532	0.806	0.109	0.063	0.838	0.212	0.056	0.843
MPSPrI	0.322	0.124	-0.745	0.835	0.020	-0.660	0.818	-0.241
	0.398	0.751	0.021	0.005	0.960	0.053	0.007	0.533
MPPr[ ]	-0.422	-0.582	-0.167	-0.371	-0.587	-0.273	-0.407	-0.354
	0.258	0.100	0.667	0.326	0.097	0.477	0.277	0.350
MPMEP	0.499	0.505	0.357	0.116	0.735	0.666	0.121	0.979
	0.171	0.165	0.346	0.766	0.024	0.050	0.756	0.000
MPADFP	-0.288	-0.272	-0.372	0.111	-0.422	-0.538	0.117	-0.637
	0.453	0.479	0.324	0.775	0.257	0.135	0.764	0.065
MPCPP	-0.251	-0.478	-0.346	-0.102	-0.496	-0.392	-0.150	-0.322
	0.515	0.194	0.362	0.794	0.175	0.297	0.699	0.398
MPleaf	0.637	0.118	-0.211	0.312	0.299	0.067	0.295	0.565
	0.065	0.762	0.586	0.413	0.434	0.864	0.441	0.113
MPclover	-0.481	-0.008	0.587	-0.576	-0.072	0.397	-0.568	-0.118
	0.190	0.984	0.096	0.104	0.853	0.290	0.110	0.763
MPstem	-0.271	-0.239	-0.290	0.062	-0.205	-0.288	0.089	-0.160
	0.481	0.535	0.449	0.873	0.596	0.452	0.820	0.680
MPdead	-0.369	0.019	0.049	-0.030	-0.206	-0.189	-0.031	-0.580
	0.329	0.961	0.901	0.940	0.594	0.626	0.937	0.102
MPweed	-0.078	0.120	0.393	-0.271	0.130	0.363	-0.274	0.166
	0.843	0.759	0.295	0.480	0.738	0.337	0.476	0.670
MPseed	0.265	-0.170	-0.690	0.513	-0.250	-0.691	0.518	-0.394
	0.491	0.662	0.040	0.158	0.517	0.039	0.153	0.295
MPpre	-0.241	-0.264	0.399	-0.628	-0.071	0.462	-0.644	0.401
	0.532	0.493	0.288	0.070	0.856	0.211	0.061	0.285

MPpost	0.228	0.123	-0.061	0.172	0.273	0.163	0.147	0.519
	0.556	0.752	0.876	0.658	0.476	0.675	0.706	0.152
CTMPP	0.225	0.123	0.002	0.111	0.320	0.232	0.123	0.594
	0.560	0.753	0.996	0.777	0.401	0.549	0.752	0.092
MPdate	-0.220	-0.043	-0.456	0.403	-0.151	-0.472	0.377	-0.313
	0.569	0.913	0.217	0.283	0.697	0.200	0.317	0.412
ApDu	-0.561	-0.516	-0.278	-0.203	-0.479	-0.324	-0.210	-0.255
	0.116	0.155	0.469	0.601	0.192	0.395	0.587	0.509
CSP	0.038	0.253	0.764	-0.509	0.337	0.748	-0.477	0.421
	0.923	0.511	0.017	0.162	0.375	0.020	0.194	0.259

	MPTPrI	MPPPrI	MPSPrI	MPPr[ ]	MPMEP	MPADFP	MPCPP	MPleaf
MPPPrI	0.766							
	0.016							
MPSPrI	0.285	-0.398						
	0.457	0.288						
MPPr[ ]	0.815	0.685	0.142					
	0.007	0.042	0.716					
MPMEP	-0.065	0.063	-0.187	-0.325				
	0.868	0.872	0.630	0.393				
MPADFP	-0.376	-0.417	0.086	-0.145	-0.658			
	0.319	0.264	0.827	0.710	0.054			
MPCPP	0.839	0.568	0.351	0.946	-0.261	-0.120		
	0.005	0.111	0.355	0.000	0.497	0.758		
MPleaf	0.219	0.048	0.241	0.111	0.598	-0.466	0.301	
	0.571	0.902	0.532	0.776	0.089	0.206	0.431	
MPclover	0.340	0.563	-0.353	0.283	-0.142	-0.342	0.038	-0.605
	0.370	0.115	0.351	0.460	0.715	0.368	0.922	0.084
MPstem	-0.840	-0.759	-0.068	-0.523	-0.187	0.505	-0.606	-0.451
	0.005	0.018	0.863	0.148	0.630	0.166	0.084	0.223
MPdead	-0.240	-0.123	-0.160	-0.226	-0.580	0.784	-0.223	-0.677
	0.534	0.753	0.682	0.558	0.102	0.012	0.564	0.045
MPweed	0.336	0.434	-0.169	0.187	0.171	-0.771	0.092	-0.035
	0.377	0.243	0.665	0.630	0.660	0.015	0.815	0.928
MPseed	0.331	-0.241	0.831	0.373	-0.420	0.162	0.479	0.236
	0.385	0.532	0.006	0.323	0.260	0.677	0.192	0.542
MPpre	0.444	0.696	-0.404	0.535	0.416	-0.591	0.382	0.237
	0.231	0.037	0.281	0.137	0.266	0.094	0.311	0.539
MPpost	0.308	0.240	0.081	0.201	0.571	-0.123	0.361	0.629
	0.420	0.534	0.835	0.604	0.108	0.753	0.340	0.070
CTMPP	-0.132	-0.060	-0.100	-0.125	0.573	0.039	-0.043	0.439
	0.734	0.879	0.798	0.749	0.107	0.921	0.912	0.237
MPdate	0.416	0.008	0.582	0.368	-0.257	0.354	0.494	-0.120
	0.265	0.984	0.100	0.330	0.505	0.349	0.176	0.758
ApDu	0.314	0.208	0.138	0.596	-0.259	0.249	0.518	-0.210
	0.411	0.592	0.724	0.090	0.501	0.518	0.153	0.588
CSP	-0.164	0.299	-0.678	-0.249	0.352	-0.105	-0.425	-0.170
	0.674	0.435	0.045	0.518	0.353	0.789	0.254	0.662

	MPclover	MPstem	MPdead	MPweed	MPseed	MPpre	MPpost	CTMPP
MPstem	-0.163							
	0.674							
MPdead	0.018	0.232						
	0.963	0.549						
MPweed	0.605	-0.370	-0.369					
	0.084	0.326	0.328					
MPseed	-0.312	-0.061	-0.242	-0.188				
	0.414	0.876	0.531	0.629				
MPpre	0.467	-0.377	-0.580	0.292	-0.282			
	0.205	0.317	0.102	0.445	0.463			
MPpost	-0.450	-0.360	-0.214	-0.300	-0.078	0.305		
	0.224	0.341	0.580	0.433	0.841	0.425		
CTMPP	-0.508	0.113	-0.155	-0.373	-0.163	0.126	0.825	
	0.162	0.773	0.690	0.323	0.675	0.746	0.006	
MPdate	-0.127	-0.067	0.299	-0.254	0.387	-0.223	0.430	0.287
	0.745	0.864	0.435	0.509	0.304	0.564	0.248	0.454
ApDu	0.123	0.166	0.028	-0.148	0.252	0.245	0.314	0.378
	0.753	0.669	0.943	0.703	0.513	0.525	0.411	0.316
CSP	0.386	-0.006	0.013	-0.128	-0.608	0.482	-0.011	0.063
	0.305	0.988	0.973	0.743	0.082	0.189	0.977	0.873

	MPdate	ApDu
ApDu	0.695	
	0.038	
CSP	-0.526	-0.265
	0.146	0.490

Cell Contents: Pearson correlation
P-Value

Legend

MP = mid peak period.

Y= MS yield.

TDMI = total dry matter intake.

PDMI = pasture dry matter intake.

SDMI = supplement DM intake.

TMEI = total ME intake.

PMEI = pasture ME intake.

SMEI = supplements ME intake.

ME[ ] = ME concentration in the diet.

TPrI = total protein intake.

PPrI = pasture protein intake.

SprI = supplements protein intake.

Pr[ ] = protein concentration in the diet.

MEP = ME concentration in the pasture.

ADFP = ADF concentration in the pasture.

CPP = Crude protein concentration in the pasture.

Leaf = proportion of leaf in the sward.

Clover = proportion of clover in thee sward.

Stem = proportion of stem in the sward.

Dead = proportion of dead material in the sward.

Weed = proportion of seeds in the sward.

Seed = proportion of seed in the sward.

Pre = pre grazing herbage mass.

Post = post grazing herbage mass.

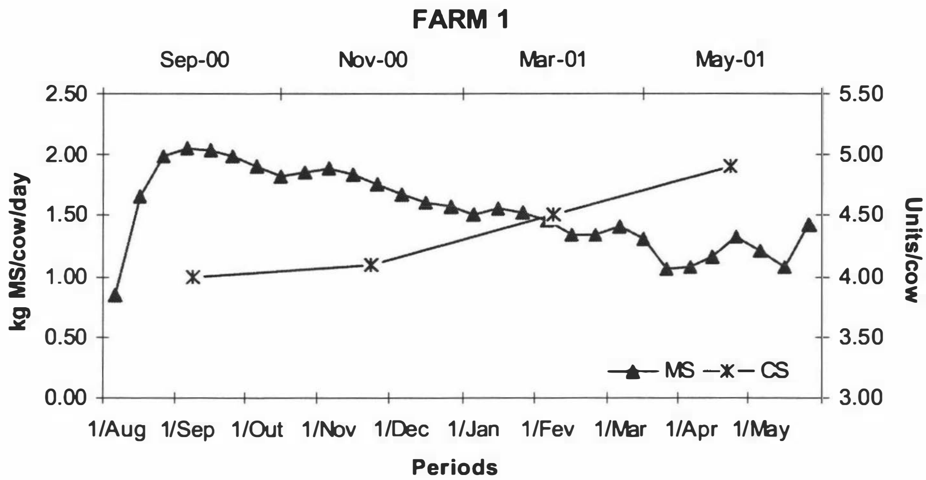
MPdate = period in which mid peak occurred.

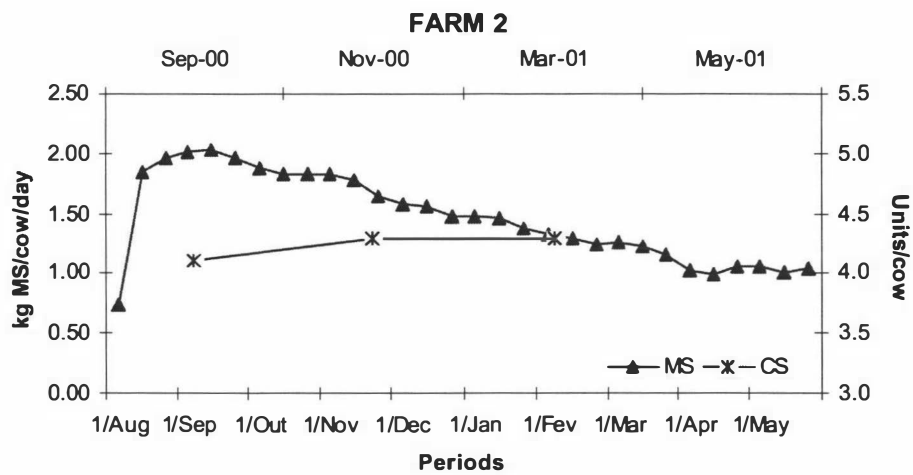
CTMPP = calving to mid peak period (days).

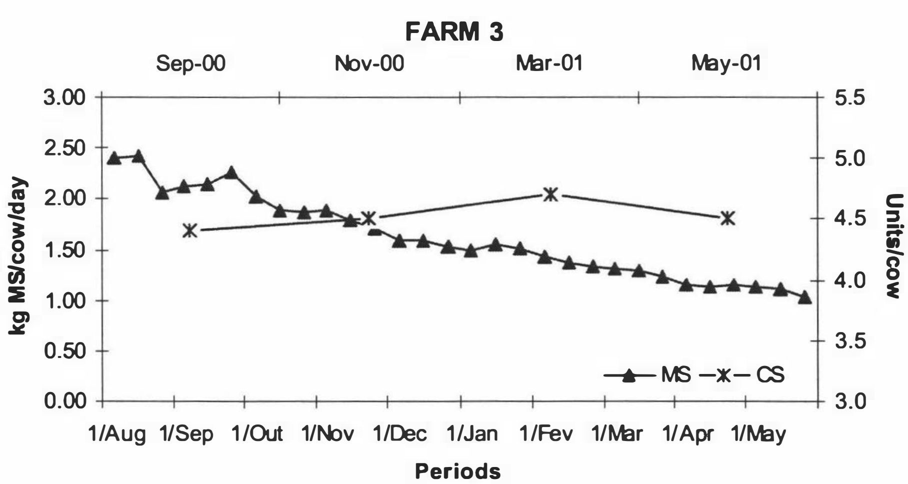
PDU = Peak duration (days).

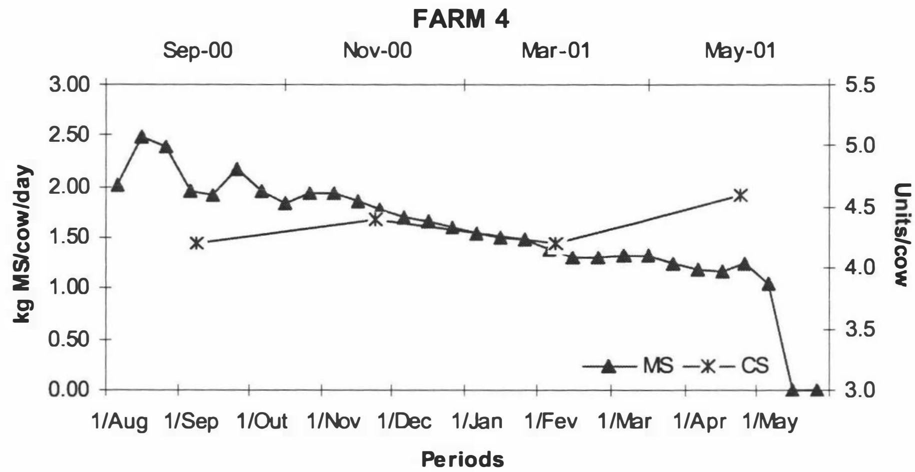
CSP = condition score around peak.

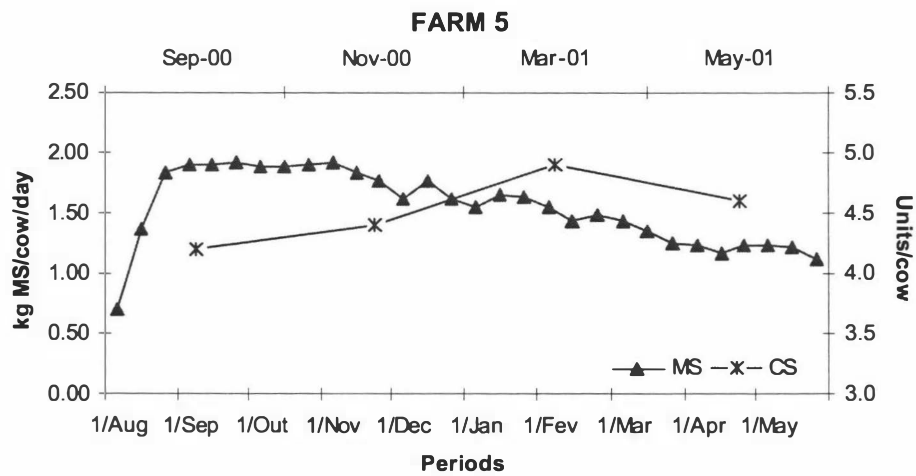
Appendix 6 Values for condition score and MS yield per cow, over the lactation period, for the nine farms involved in this study. It was not possible to take the last measurement for Farm 2.

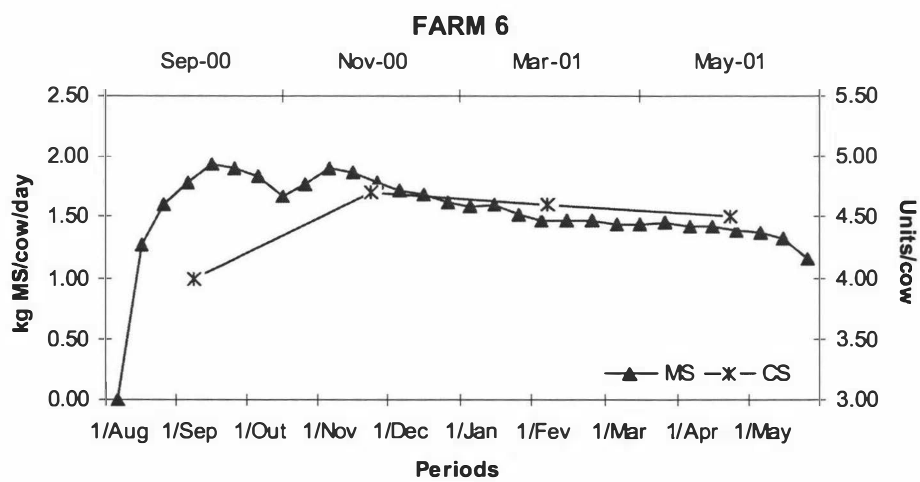


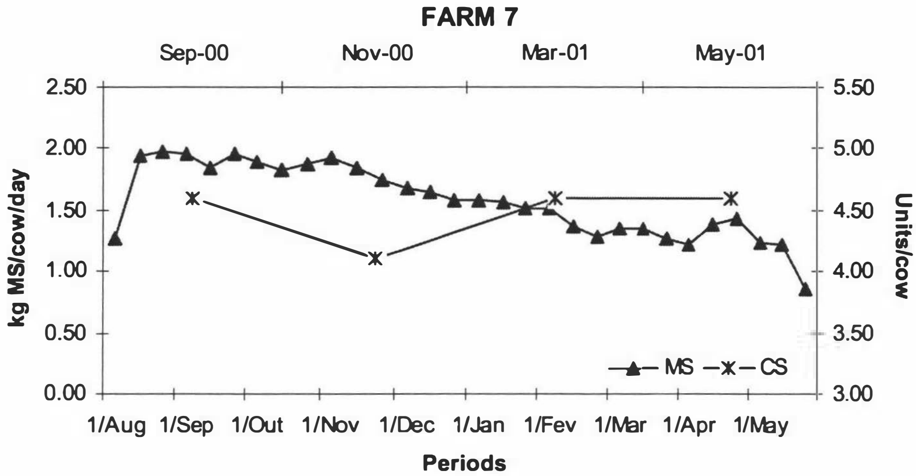


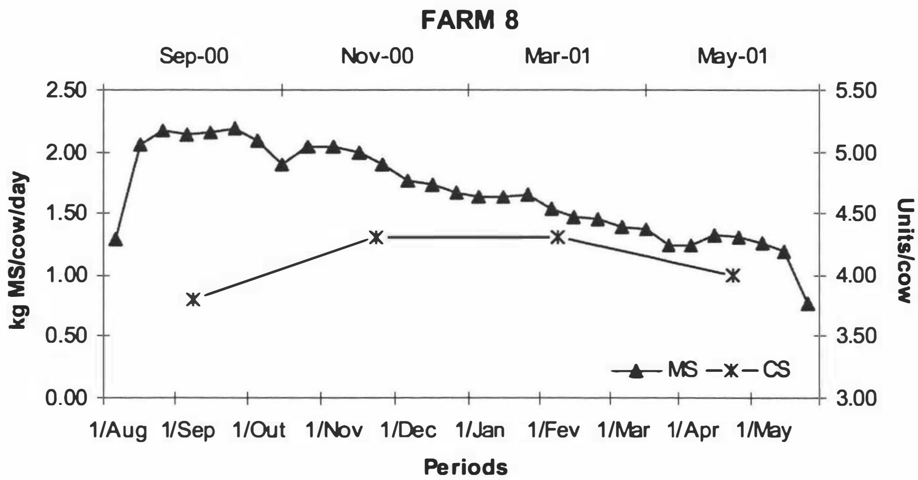


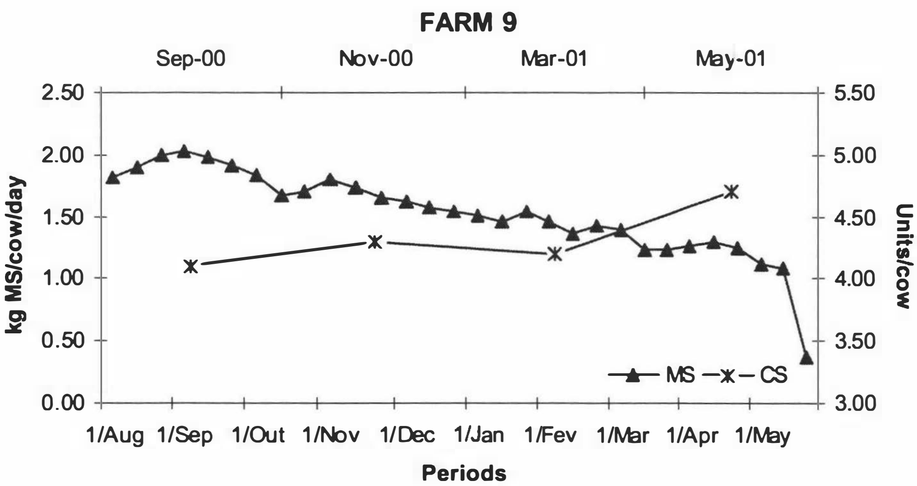

FARM 4
Sep-00
Nov-00
Mar-01
May-01
3.00
2.50
2.00
1.50
1.00
0.50
0.00
kg MS/cow/day
5.5
5.0
4.5
4.0
3.5
3.0
Units/cow
MS
CS
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods


FARM 5
Sep-00
Nov-00
Mar-01
May-01
2.50
2.00
1.50
1.00
0.50
0.00
kg MS/cow/day
5.5
5.0
4.5
4.0
3.5
3.0
Units/cow
MS
CS
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

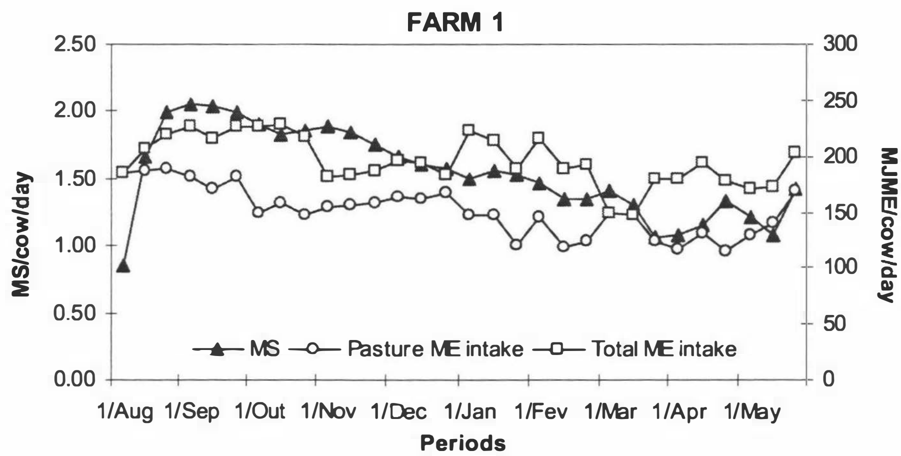

FARM 6
Sep-00
Nov-00
Mar-01
May-01
2.50
2.00
1.50
1.00
0.50
0.00
kg MS/cow/day
5.50
5.00
4.50
4.00
3.50
3.00
Units/cow
MS
CS
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

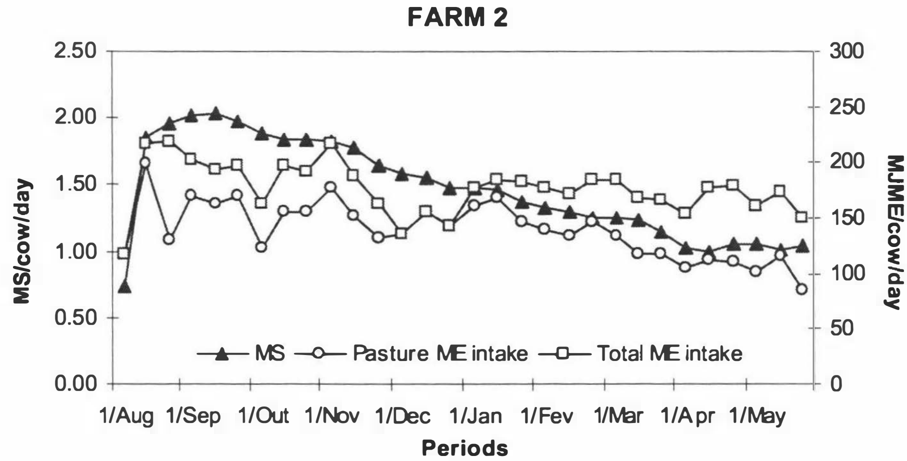

FARM 7
Sep-00
Nov-00
Mar-01
May-01
2.50
2.00
1.50
1.00
0.50
0.00
5.50
5.00
4.50
4.00
3.50
3.00
kg MS/cow/day
Units/cow
MS
CS
1/Aug
1/Sep
1/Out
1/Nov
1/Dec
1/Jan
1/Fev
1/Mar
1/Apr
1/May
Periods

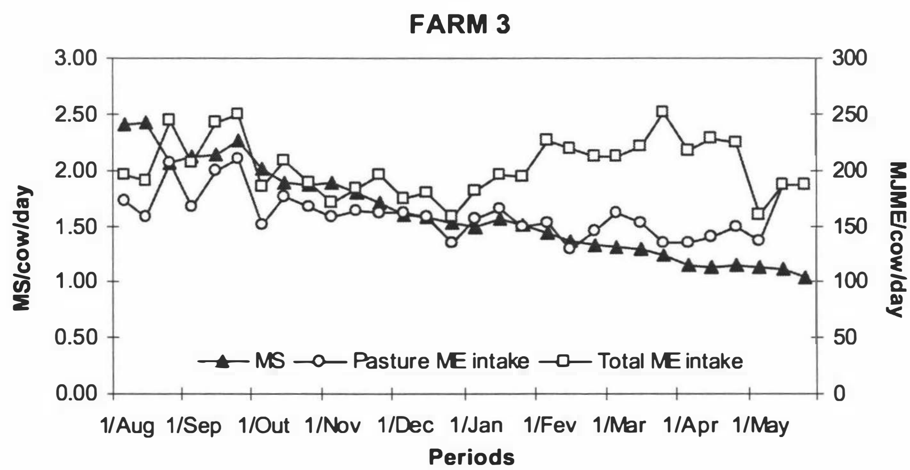

FARM 8
Sep-00
Nov-00
Mar-01
May-01
2.50
2.00
1.50
1.00
0.50
0.00
5.50
5.00
4.50
4.00
3.50
3.00
kg MS/cow/day
Units/cow
MS
CS
1/Aug
1/Sep
1/Out
1/Nov
1/Dec
1/Jan
1/Fev
1/Mar
1/Apr
1/May
Periods


FARM 9
Sep-00
Nov-00
Mar-01
May-01
2.50
2.00
1.50
1.00
0.50
0.00
5.50
5.00
4.50
4.00
3.50
3.00
kg MS/cow/day
Units/cow
MS
CS
1/Aug
1/Sep
1/Out
1/Nov
1/Dec
1/Jan
1/Fev
1/Mar
1/Apr
1/May
Periods

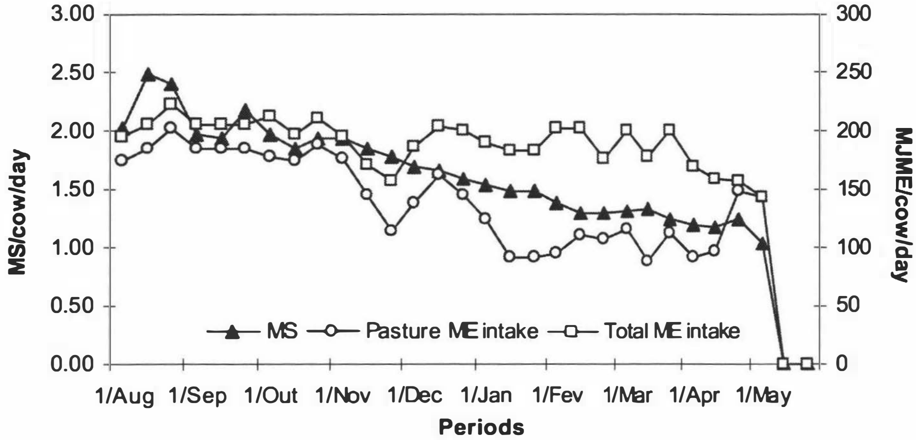
Appendix 7 Values for ME intake from total and pasture ME intakes and MS yield per cow, over the lactation period, for the nine farms involved in this study. Supplements ME intake = Total ME intake – Pasture ME intake.



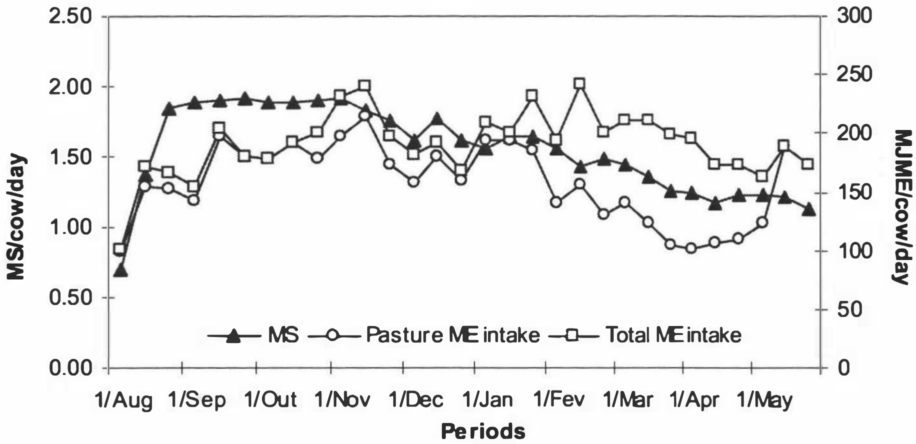




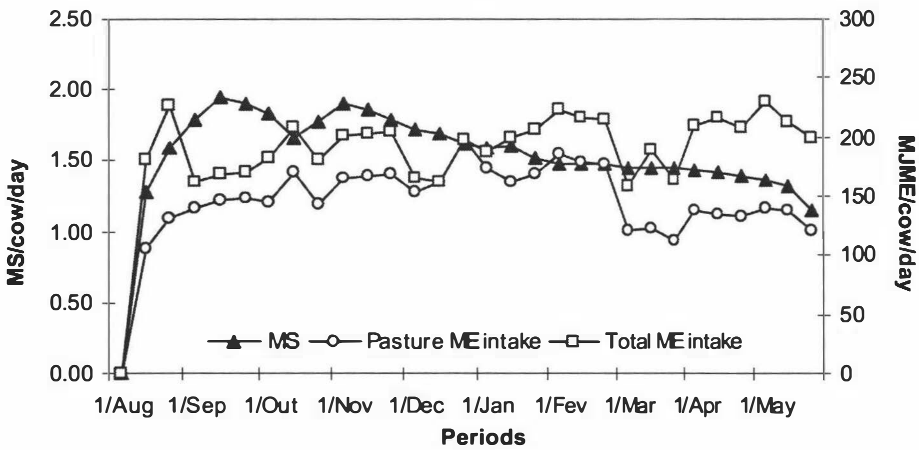
FARM 4

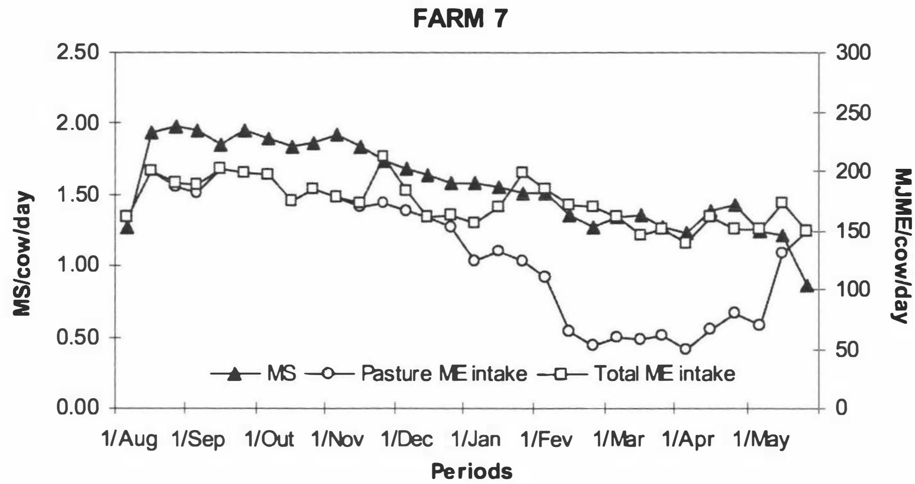


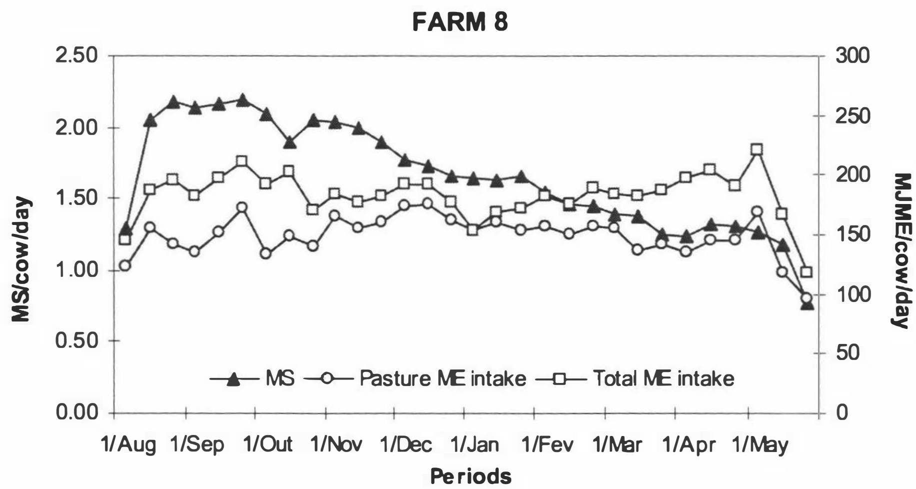
FARM 5

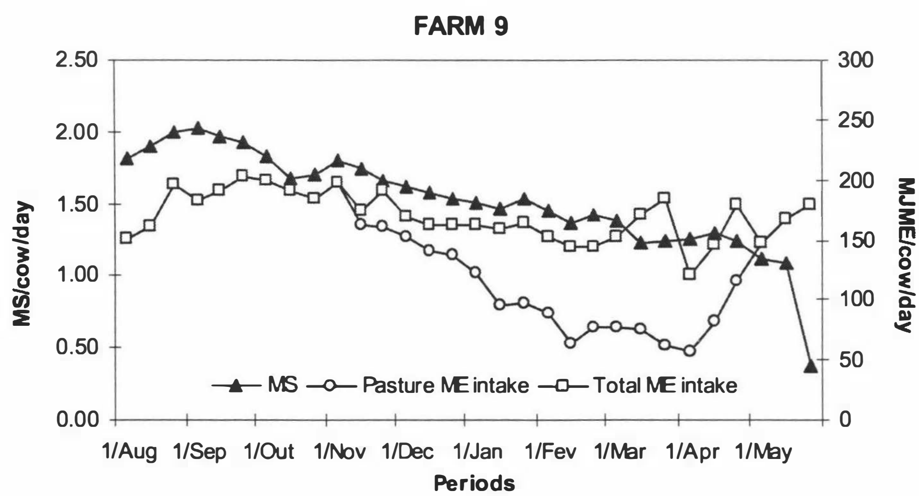


FARM 6

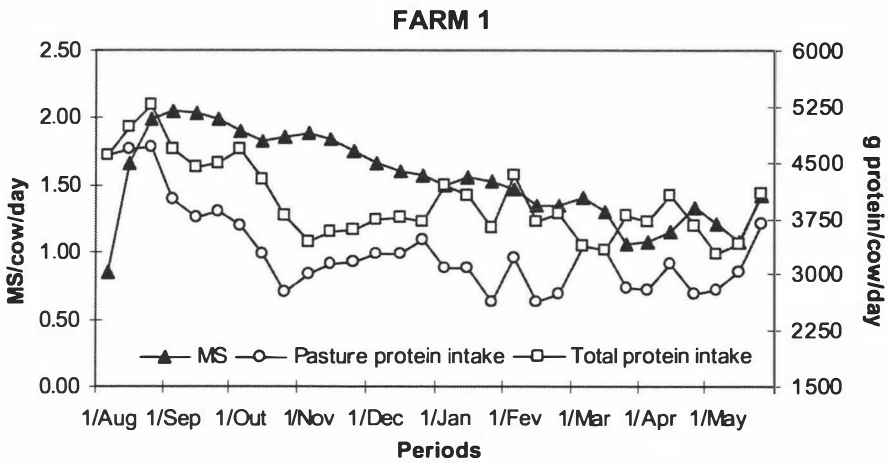


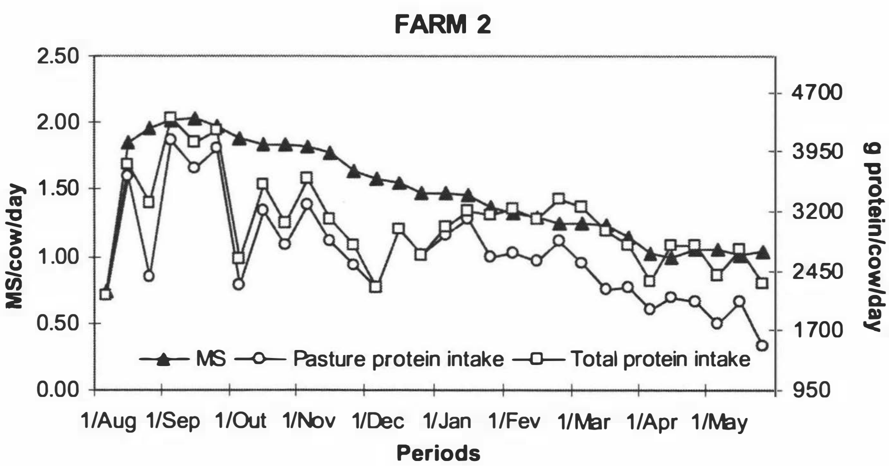

FARM 7
2.50
2.00
1.50
1.00
0.50
0.00
300
250
200
150
100
50
0
MS/cow/day
MJME/cow/day
MS
Pasture ME intake
Total ME intake
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

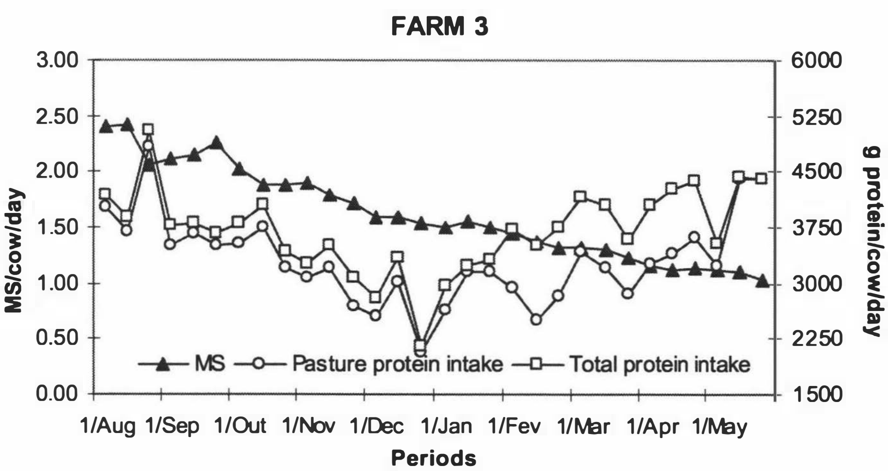

FARM 8
2.50
2.00
1.50
1.00
0.50
0.00
300
250
200
150
100
50
0
MS/cow/day
MJME/cow/day
MS
Pasture ME intake
Total ME intake
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

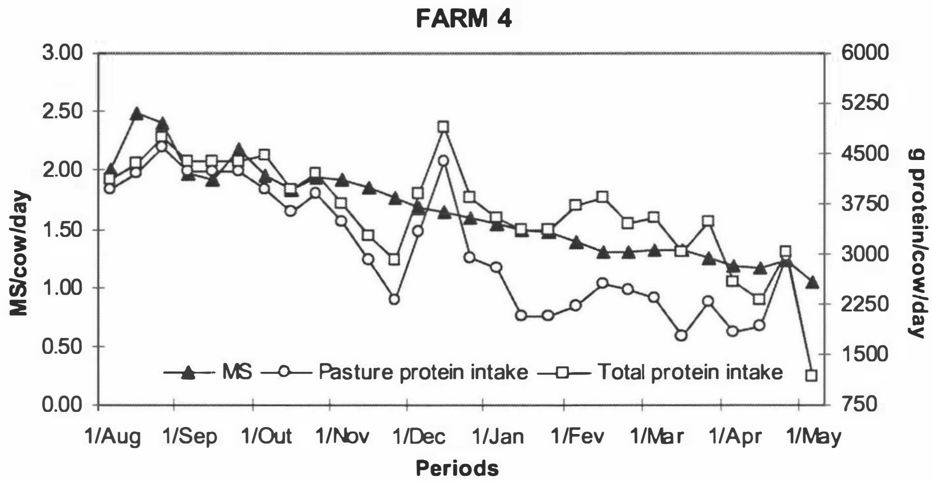

FARM 9
2.50
2.00
1.50
1.00
0.50
0.00
300
250
200
150
100
50
0
MS/cow/day
MJME/cow/day
MS
Pasture ME intake
Total ME intake
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

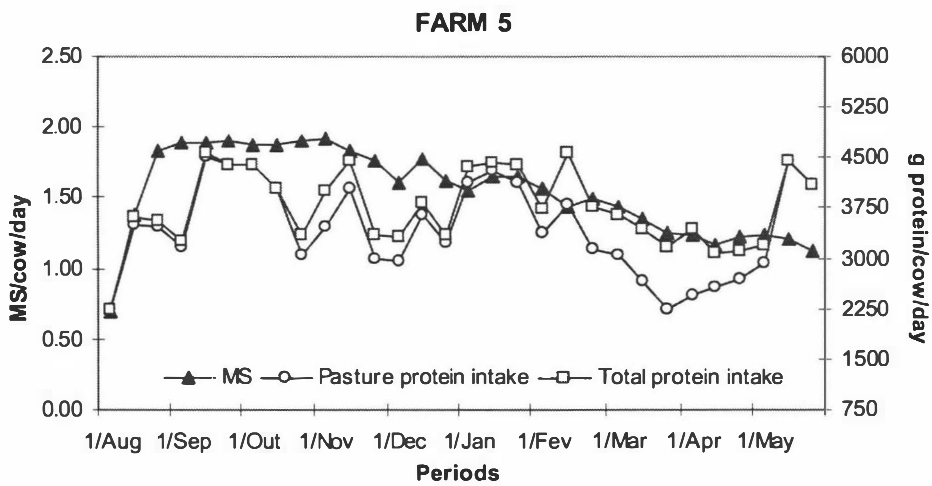
Appendix 8 Values for protein intake from total and pasture protein intakes and MS yield per cow, over the lactation period, for the nine farms involved in this study. Supplements protein intake = Total protein intake – Pasture protein intake.

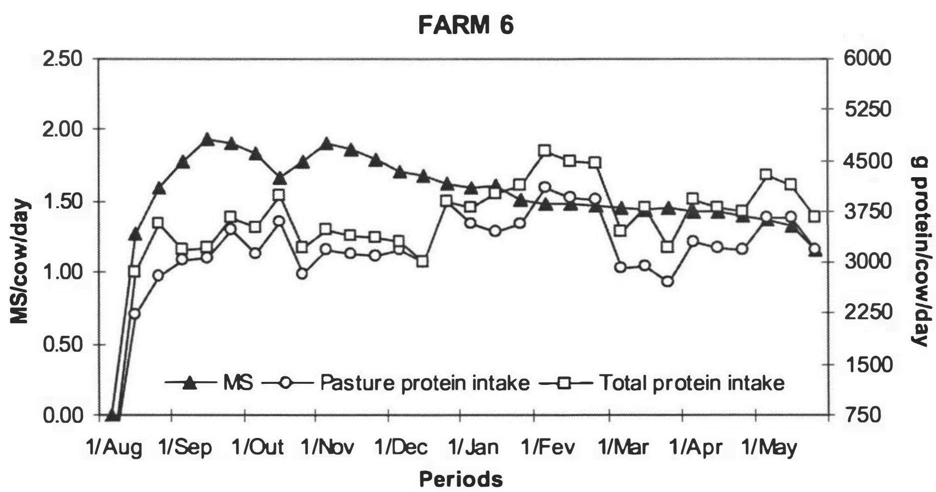


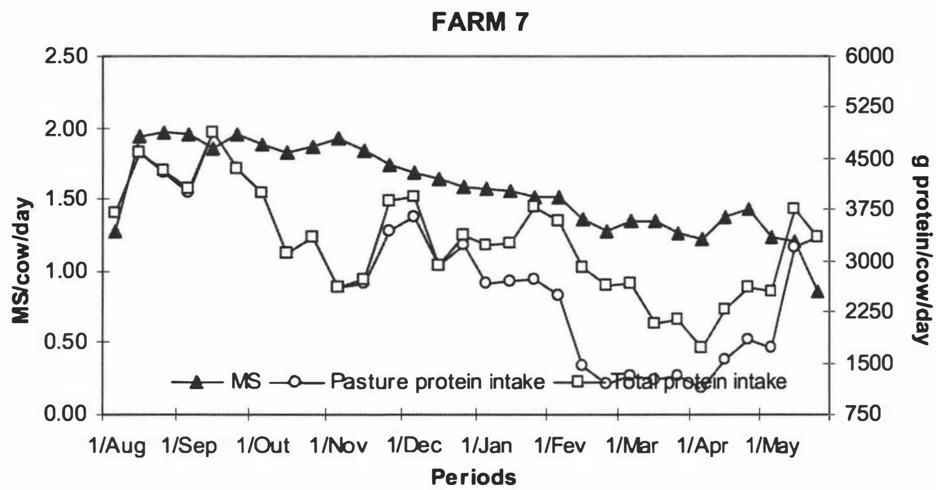


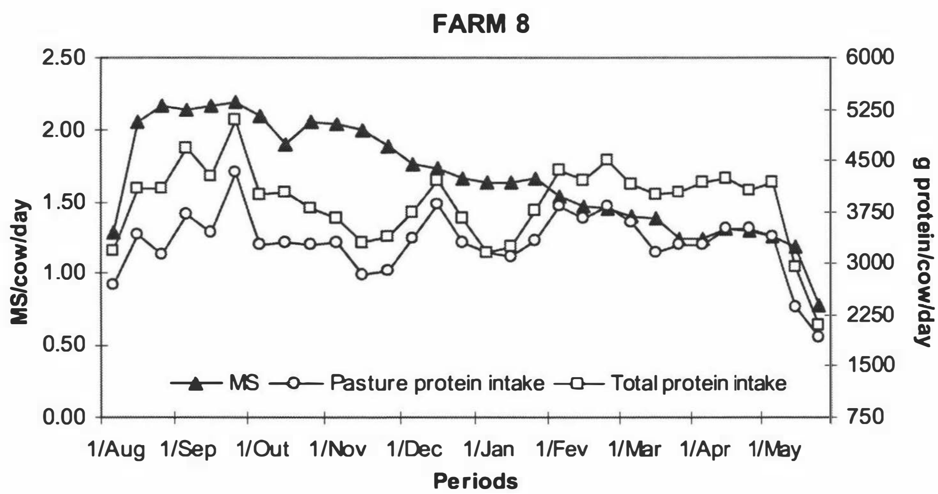


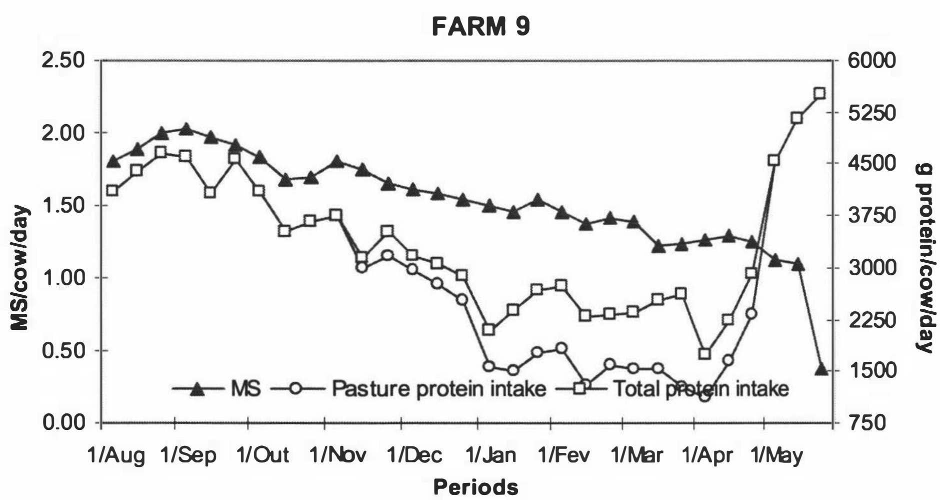

FARM 4
3.00
2.50
2.00
1.50
1.00
0.50
0.00
MS/cow/day
6000
5250
4500
3750
3000
2250
1500
750
g protein/cow/day
MS
Pasture protein intake
Total protein intake
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods


FARM 5
2.50
2.00
1.50
1.00
0.50
0.00
MS/cow/day
6000
5250
4500
3750
3000
2250
1500
750
g protein/cow/day
MS
Pasture protein intake
Total protein intake
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

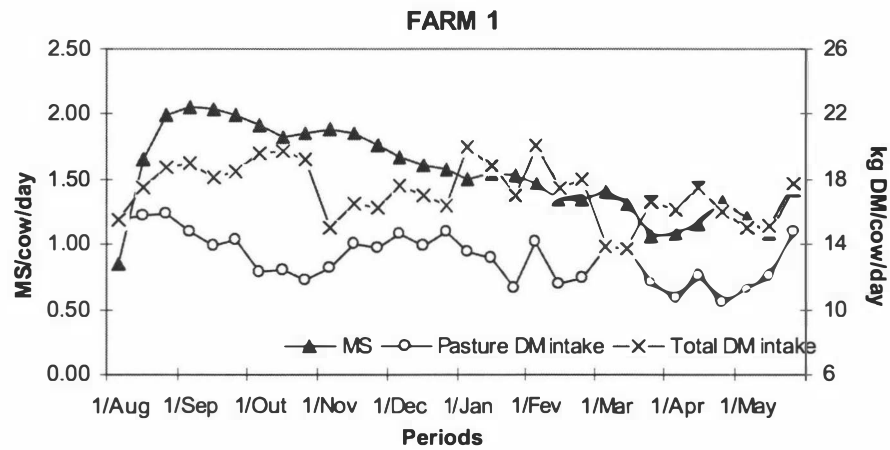

FARM 6
2.50
2.00
1.50
1.00
0.50
0.00
MS/cow/day
6000
5250
4500
3750
3000
2250
1500
750
g protein/cow/day
MS
Pasture protein intake
Total protein intake
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

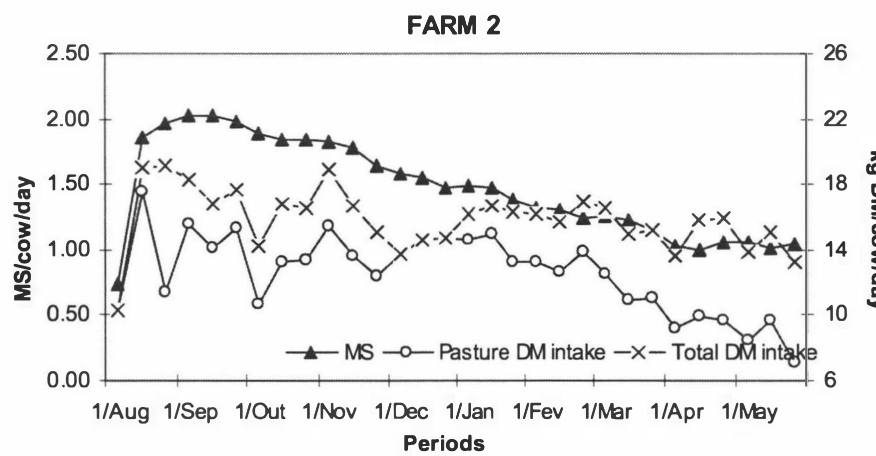

FARM 7
2.50
2.00
1.50
1.00
0.50
0.00
MS/cow/day
6000
5250
4500
3750
3000
2250
1500
750
g protein/cow/day
MS
Pasture protein intake
Total protein intake
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

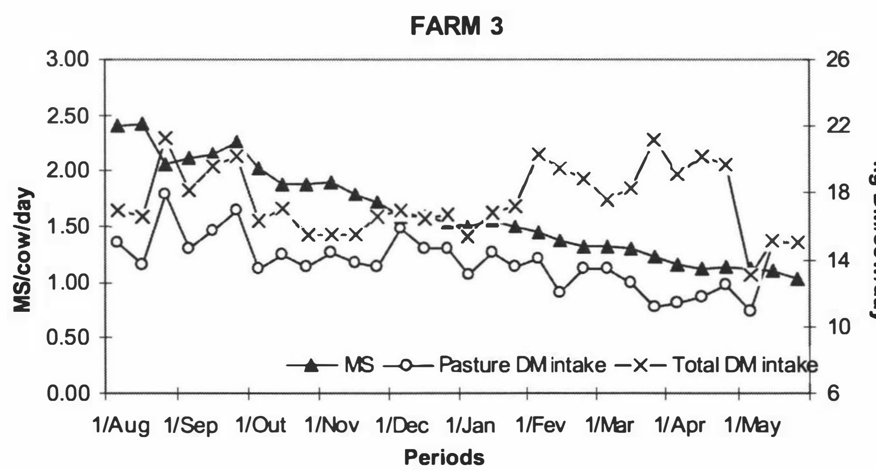

FARM 8
2.50
2.00
1.50
1.00
0.50
0.00
MS/cow/day
6000
5250
4500
3750
3000
2250
1500
750
g protein/cow/day
MS
Pasture protein intake
Total protein intake
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

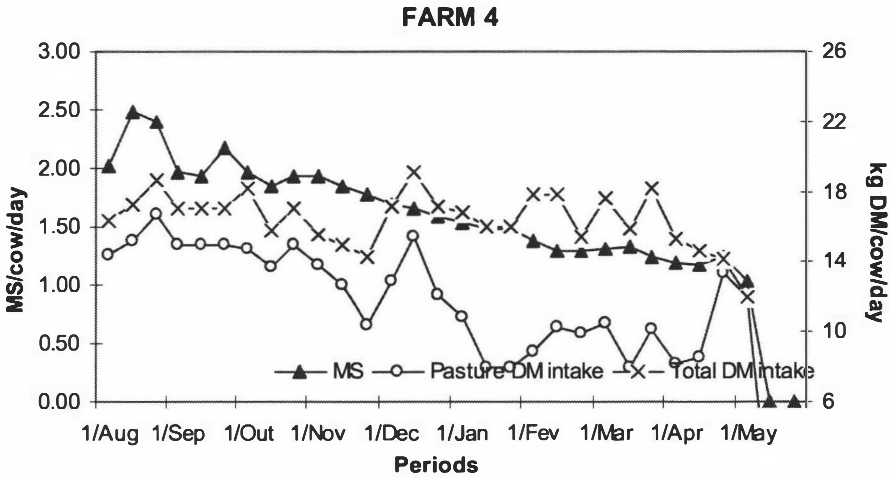

FARM 9
2.50
2.00
1.50
1.00
0.50
0.00
MS/cow/day
6000
5250
4500
3750
3000
2250
1500
750
g protein/cow/day
MS
Pasture protein intake
Total protein intake
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

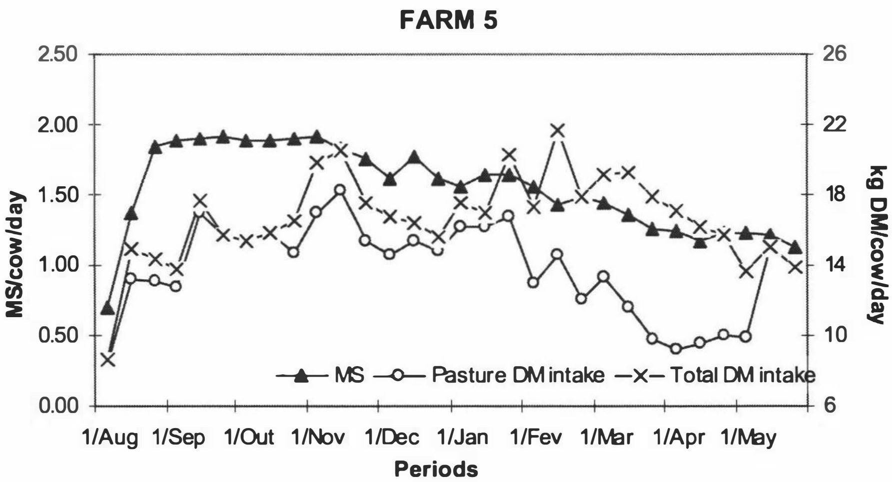
Appendix 9 Values for DM intake from total and pasture DM intakes and MS yield per cow, over the lactation period, for the nine farms involved in this study. Supplements DM intake = Total DM intake – Pasture DM intake.

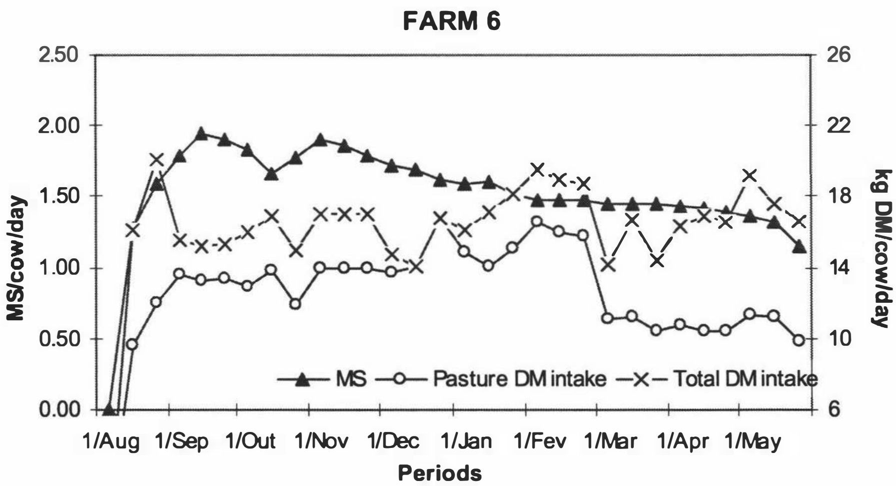




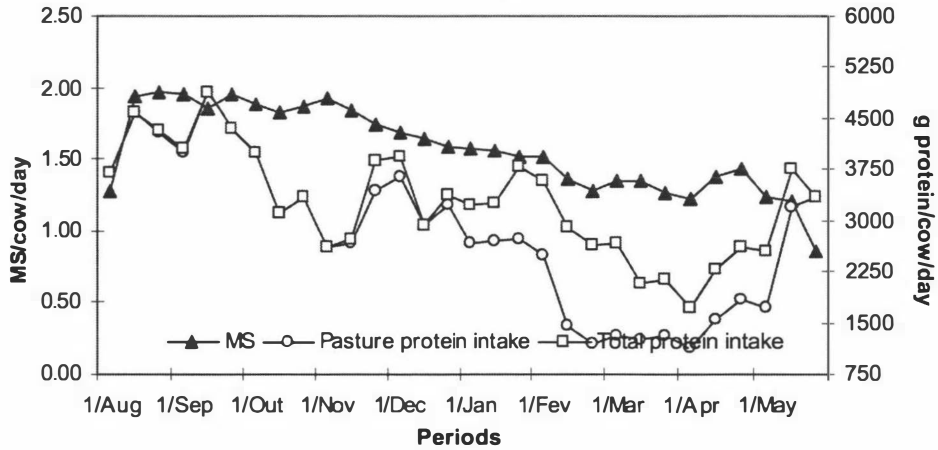



FARM 4
3.00
2.50
2.00
1.50
1.00
0.50
0.00
MS/cow/day
26
22
18
14
10
6
kg DM/cow/day
MS
Pasture DM intake
Total DM intake
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

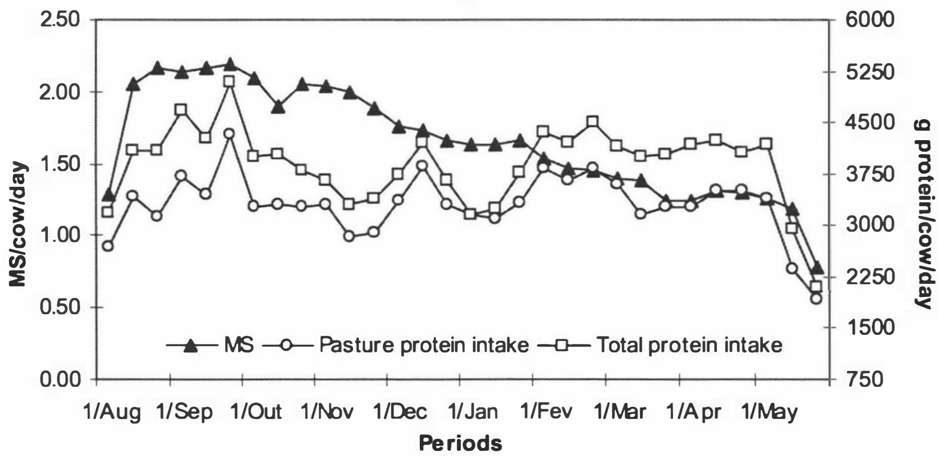

FARM 5
2.50
2.00
1.50
1.00
0.50
0.00
MS/cow/day
26
22
18
14
10
6
kg DM/cow/day
MS
Pasture DM intake
Total DM intake
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods


FARM 6
2.50
2.00
1.50
1.00
0.50
0.00
MS/cow/day
26
22
18
14
10
6
kg DM/cow/day
MS
Pasture DM intake
Total DM intake
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

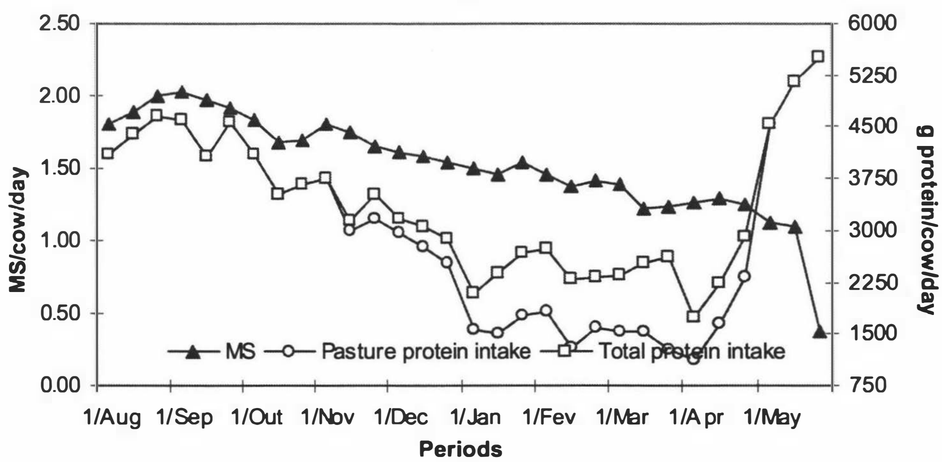
FARM 7



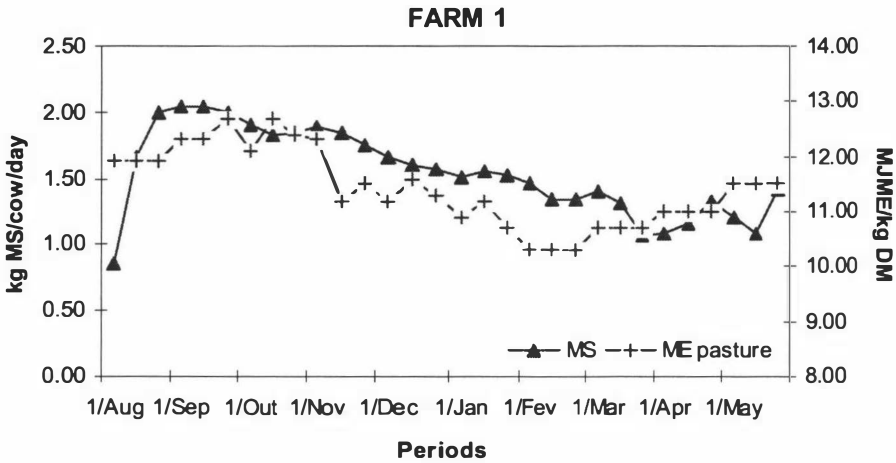
FARM 8

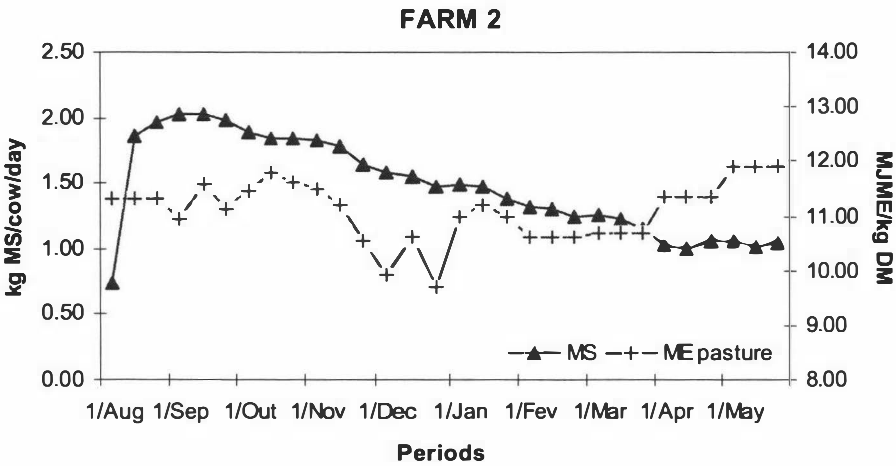


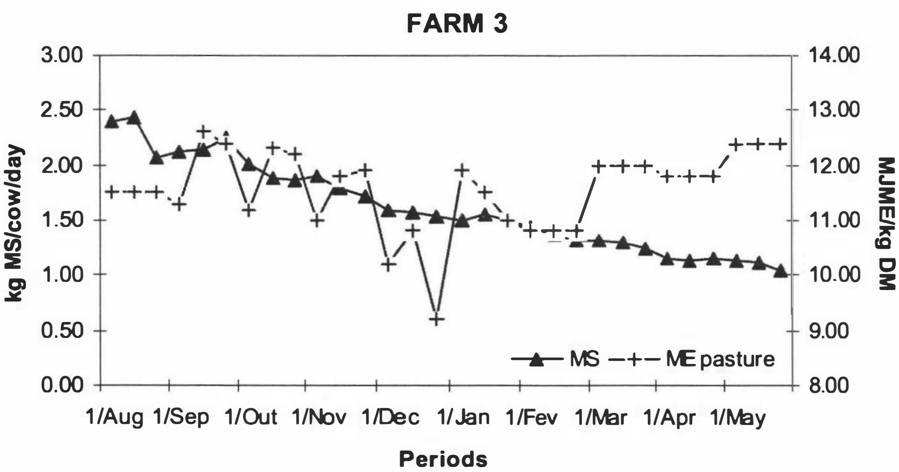
FARM 9

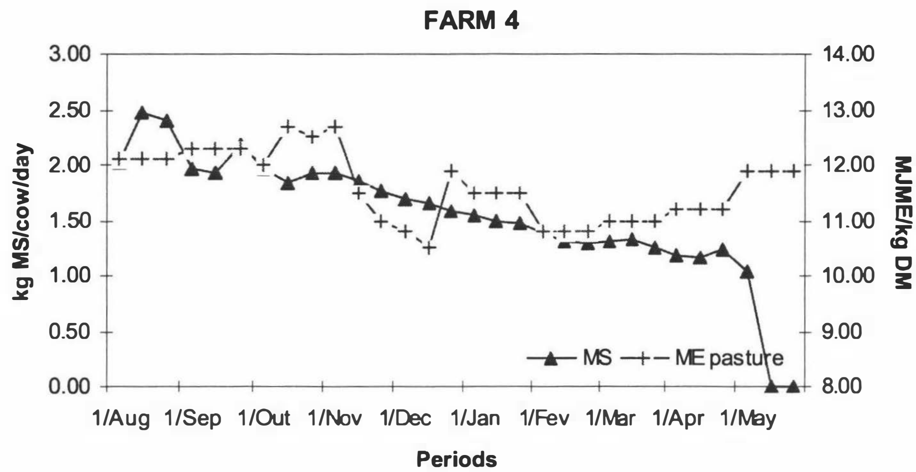


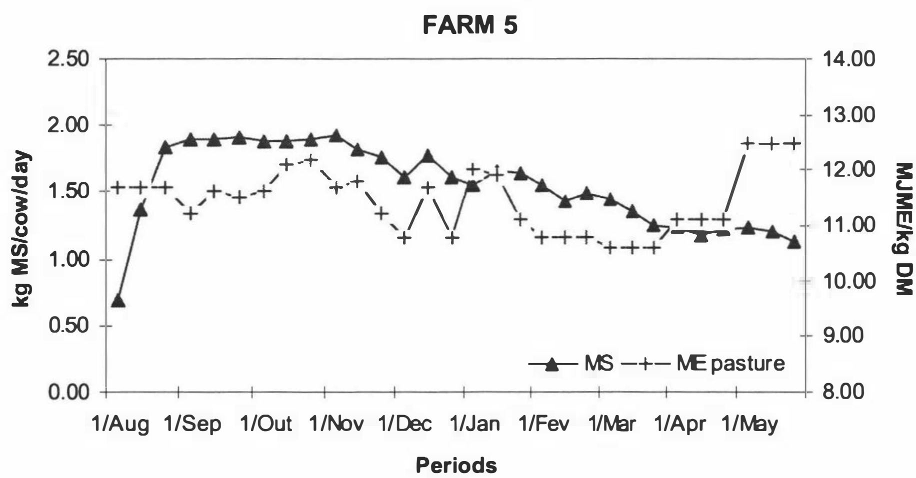
Appendix 10 Values for ME concentration in the pasture and MS yield, over the lactation period, for the nine farms involved in this study.

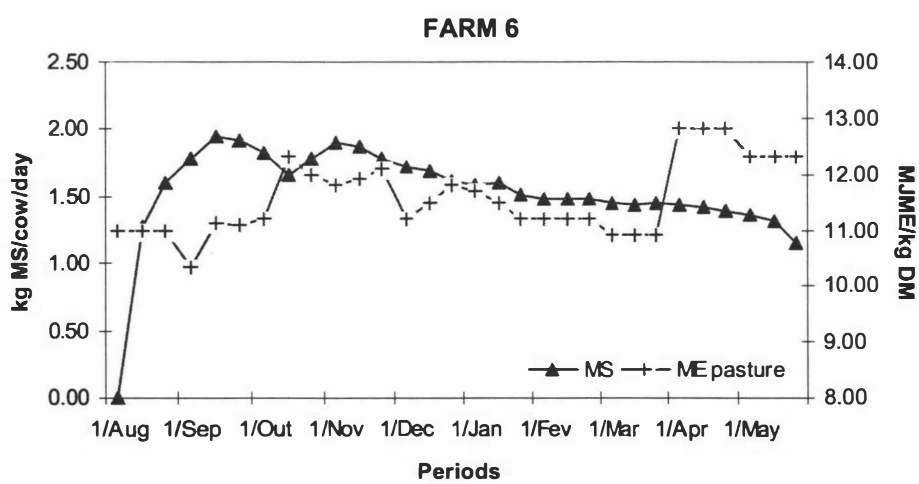


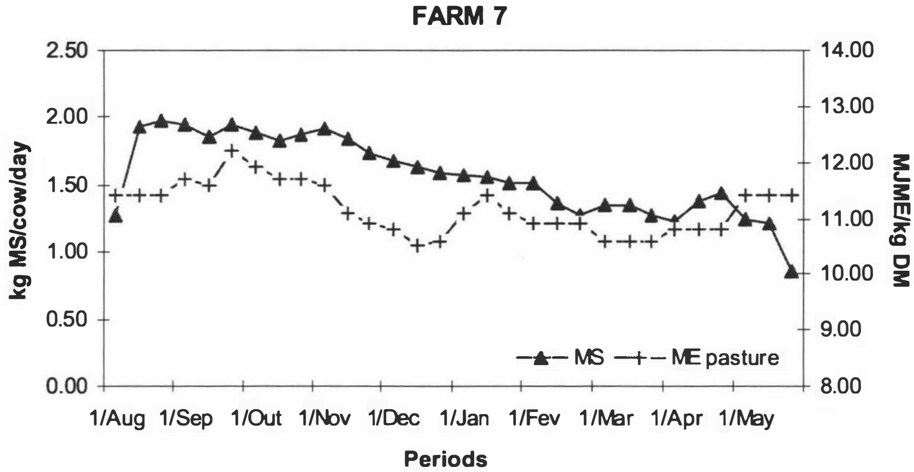


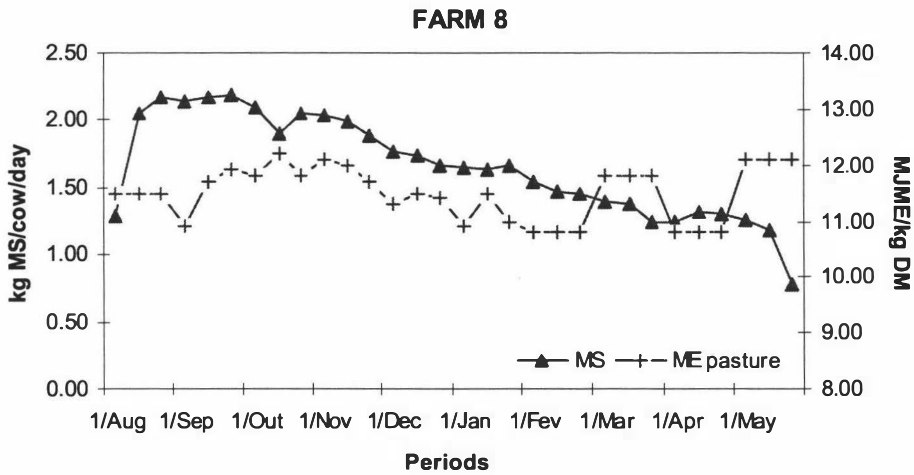


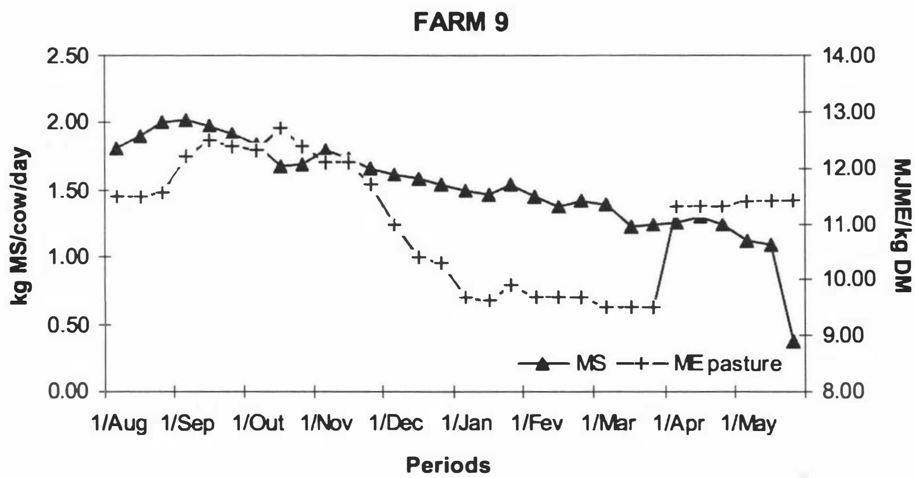

FARM 4
kg MS/cow/day
MJME/kg DM
3.00
2.50
2.00
1.50
1.00
0.50
0.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
MS
ME pasture
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods


FARM 5
kg MS/cow/day
MJME/kg DM
2.50
2.00
1.50
1.00
0.50
0.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
MS
ME pasture
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

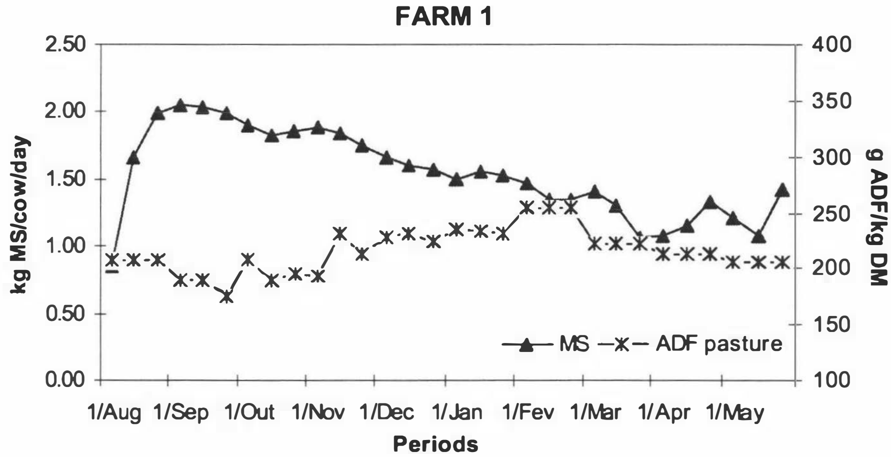

FARM 6
kg MS/cow/day
MJME/kg DM
2.50
2.00
1.50
1.00
0.50
0.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
MS
ME pasture
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

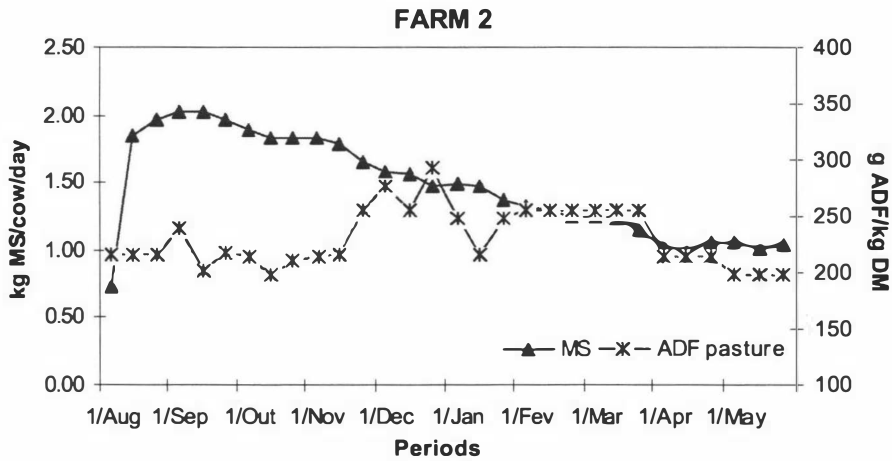

FARM 7
2.50
2.00
1.50
1.00
0.50
0.00
kg MS/cow/day
14.00
13.00
12.00
11.00
10.00
9.00
8.00
MJME/kg DM
MS
ME pasture
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

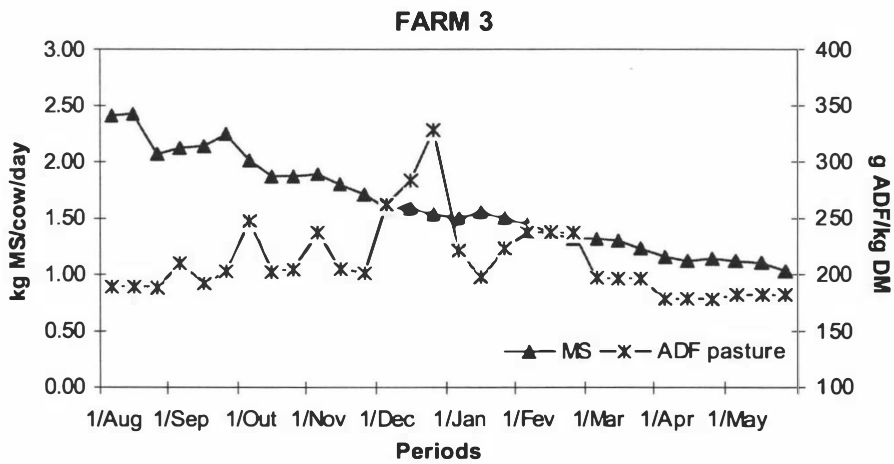

FARM 8
2.50
2.00
1.50
1.00
0.50
0.00
kg MS/cow/day
14.00
13.00
12.00
11.00
10.00
9.00
8.00
MJME/kg DM
MS
ME pasture
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods


FARM 9
2.50
2.00
1.50
1.00
0.50
0.00
kg MS/cow/day
14.00
13.00
12.00
11.00
10.00
9.00
8.00
MJME/kg DM
MS
ME pasture
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

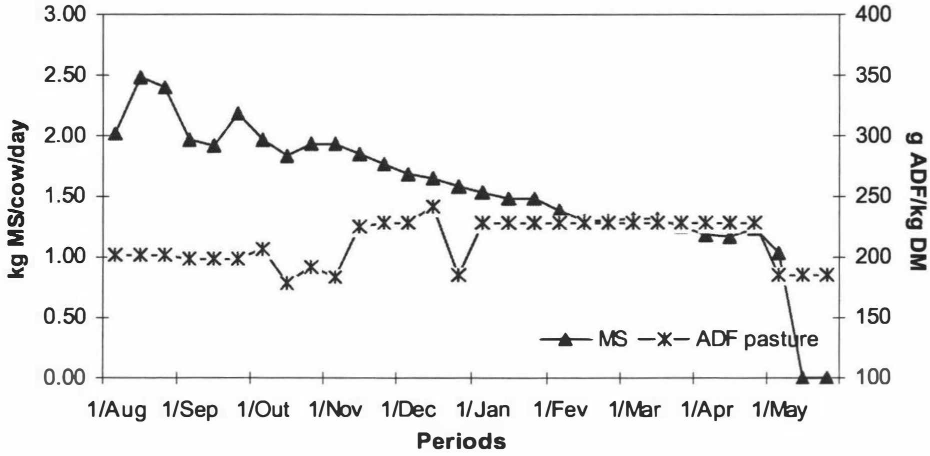
Appendix 11 Values for protein and ADF concentration in the pasture and MS yield, over the lactation period, for the nine farms involved in this study.



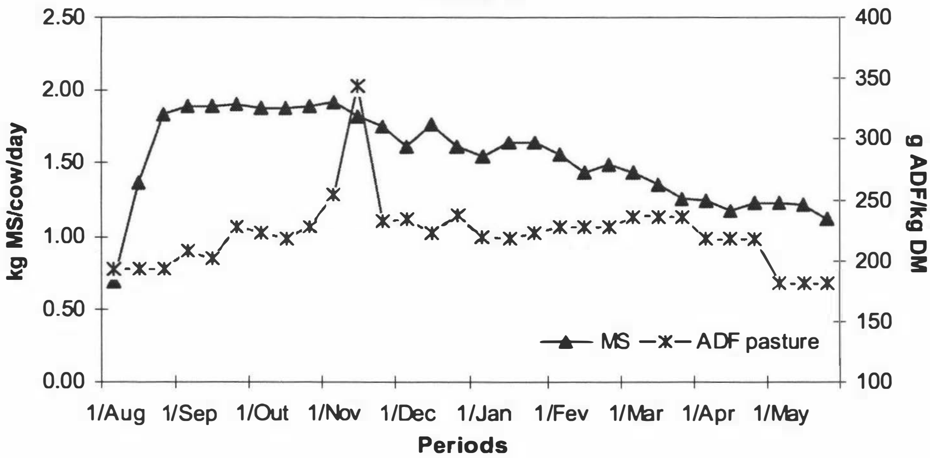




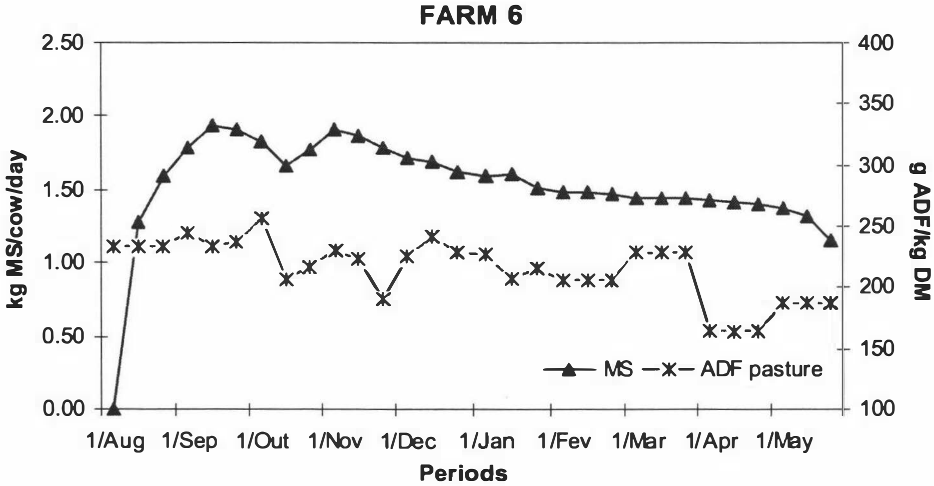
FARM 4

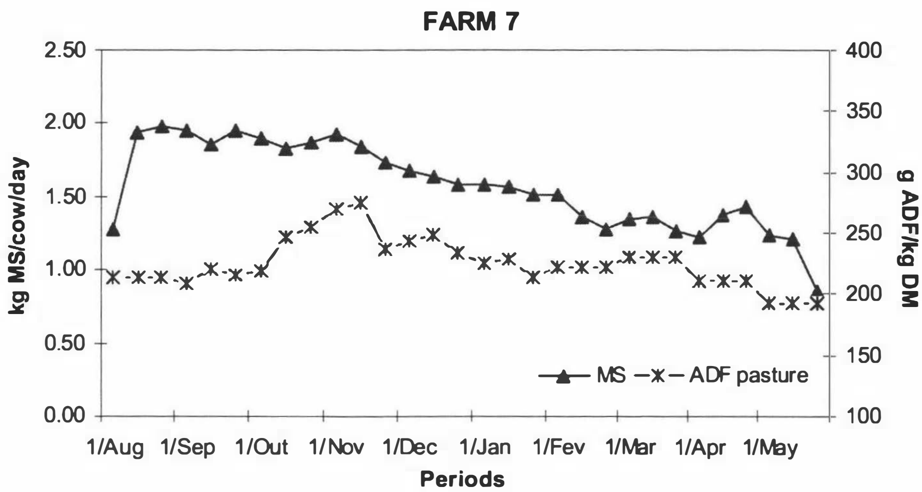


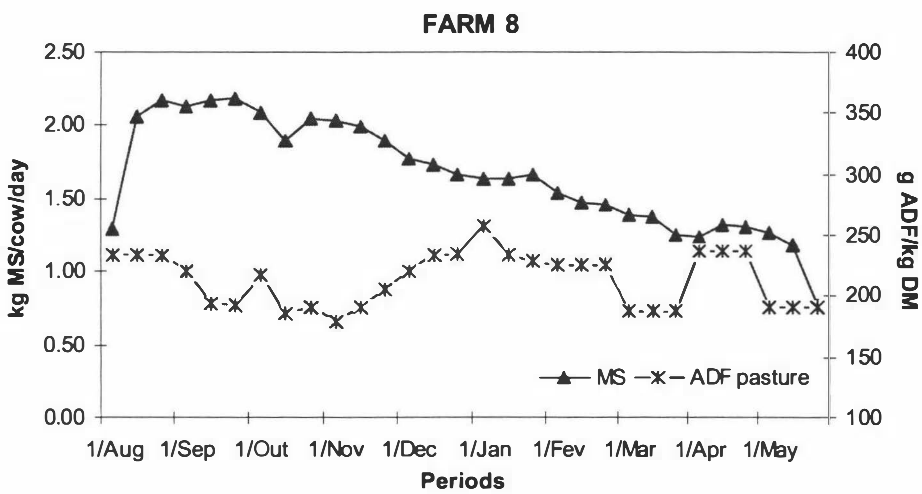
FARM 5

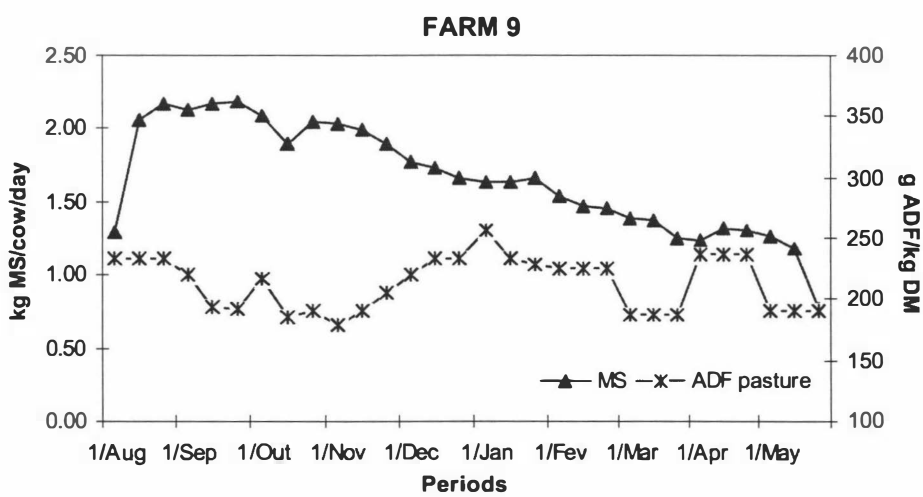


FARM 6

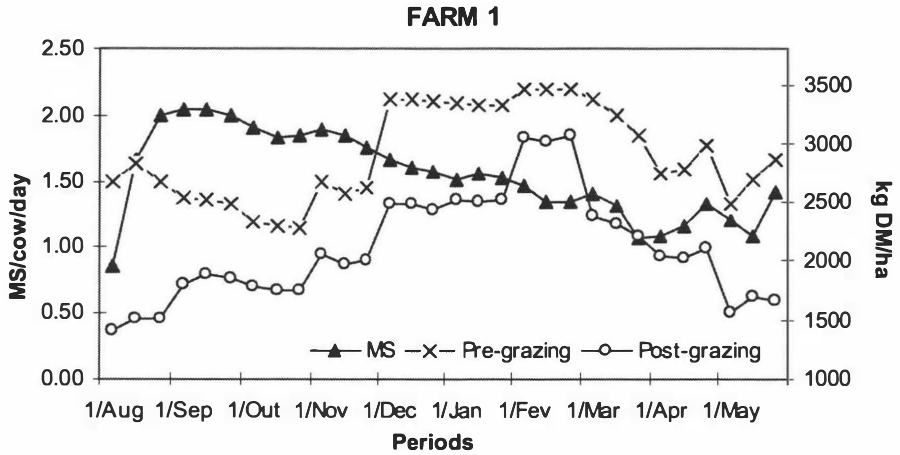


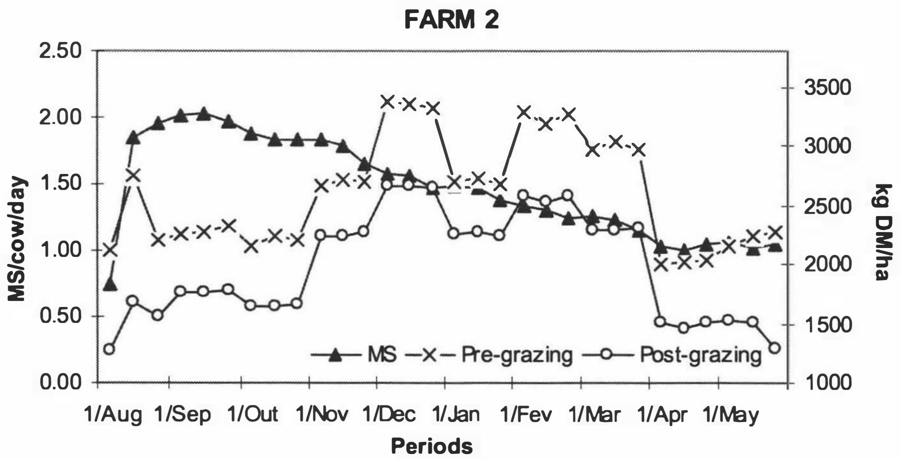

FARM 7
2.50
2.00
1.50
1.00
0.50
0.00
kg MS/cow/day
400
350
300
250
200
150
100
g ADF/kg DM
MS
ADF pasture
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

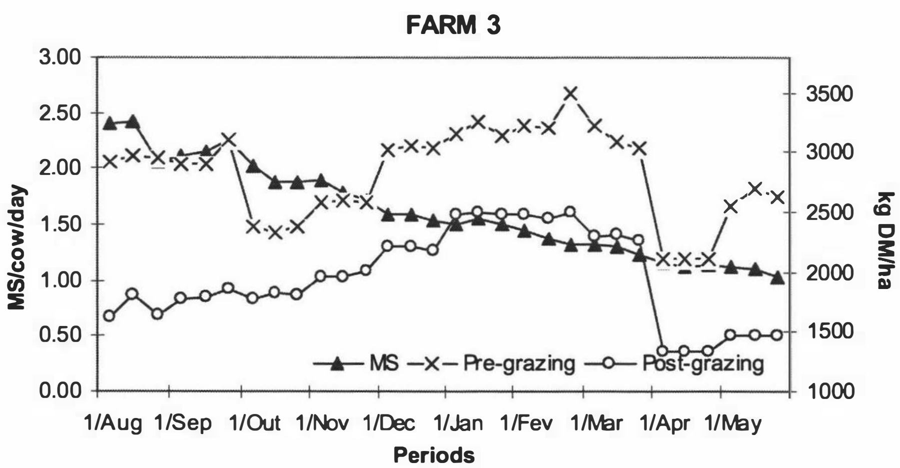

FARM 8
2.50
2.00
1.50
1.00
0.50
0.00
kg MS/cow/day
400
350
300
250
200
150
100
g ADF/kg DM
MS
ADF pasture
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods


FARM 9
2.50
2.00
1.50
1.00
0.50
0.00
kg MS/cow/day
400
350
300
250
200
150
100
g ADF/kg DM
MS
ADF pasture
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

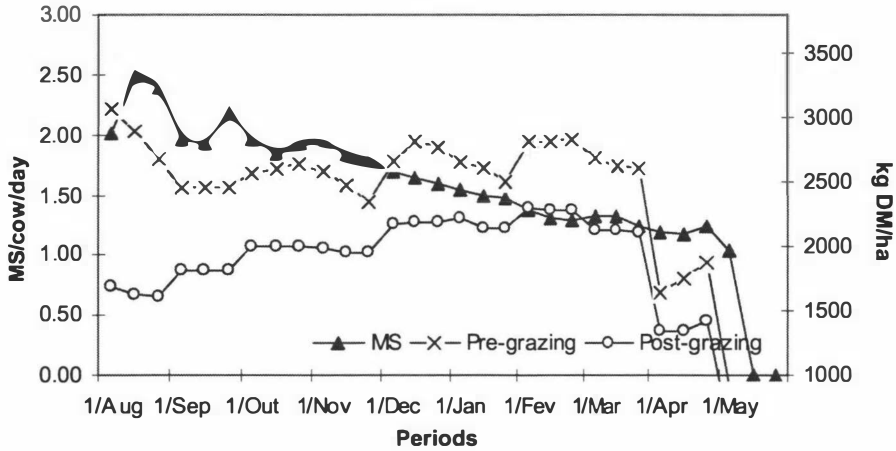
Appendix 12 Values for pre and post grazing herbage masses and MS yield, over the lactation period, for the nine farms involved in this study.



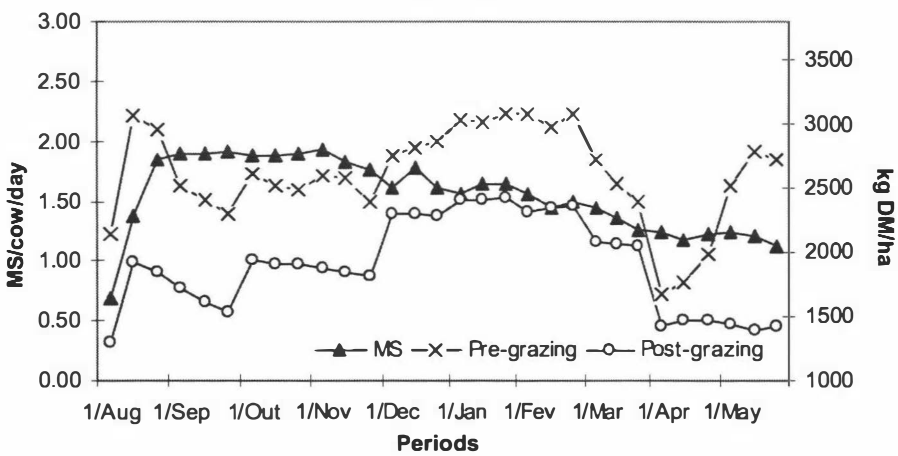




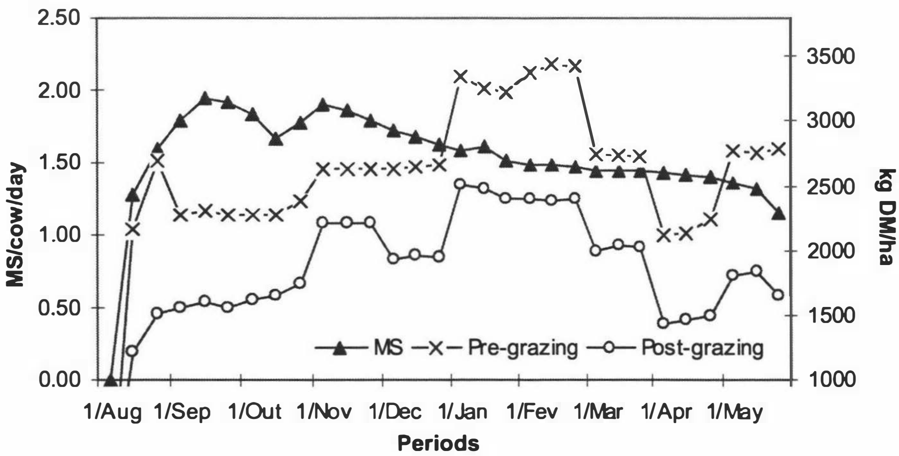
FARM 4

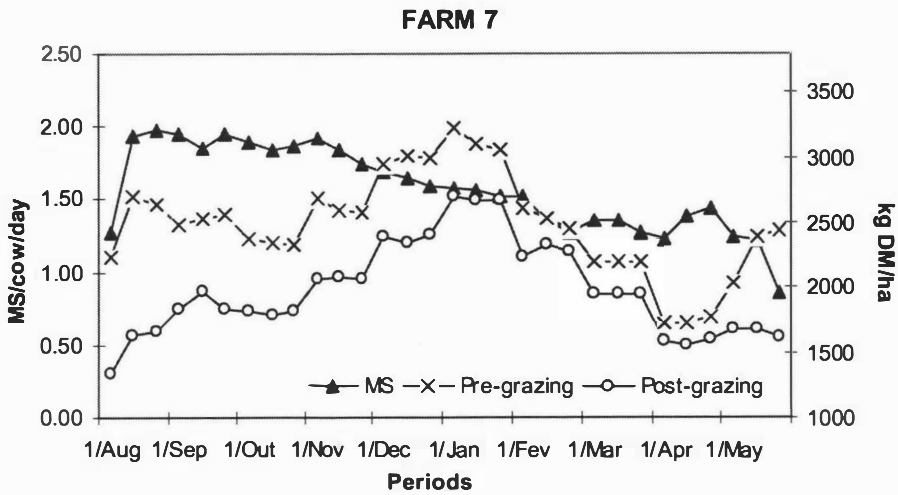


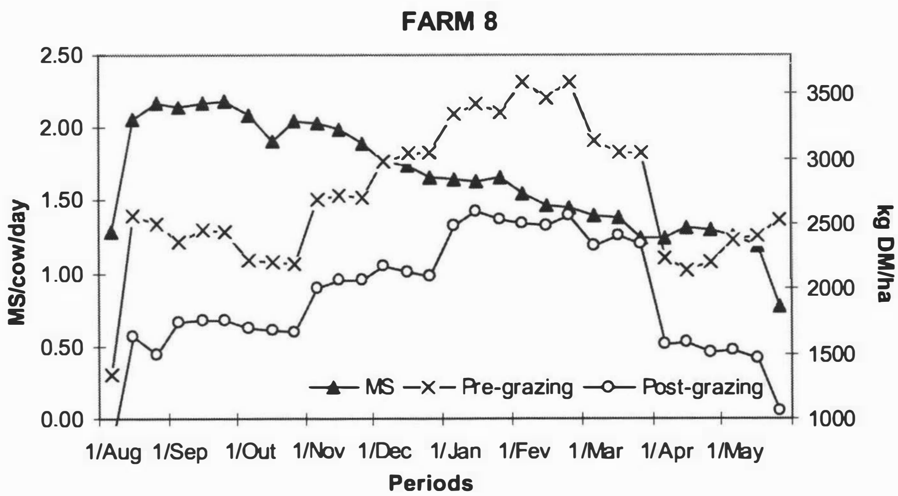
FARM 5

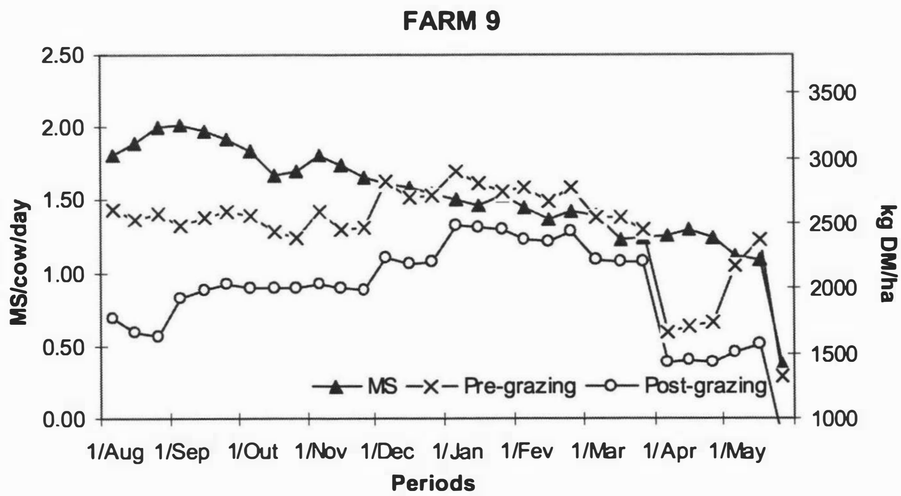


FARM 6

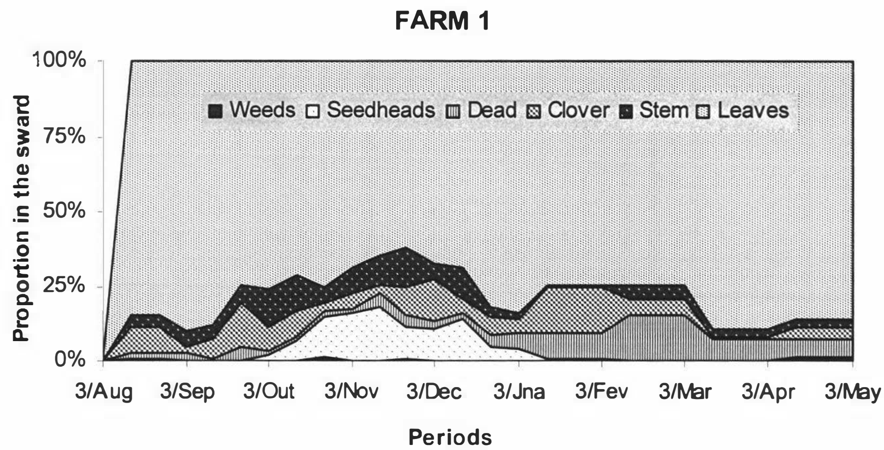


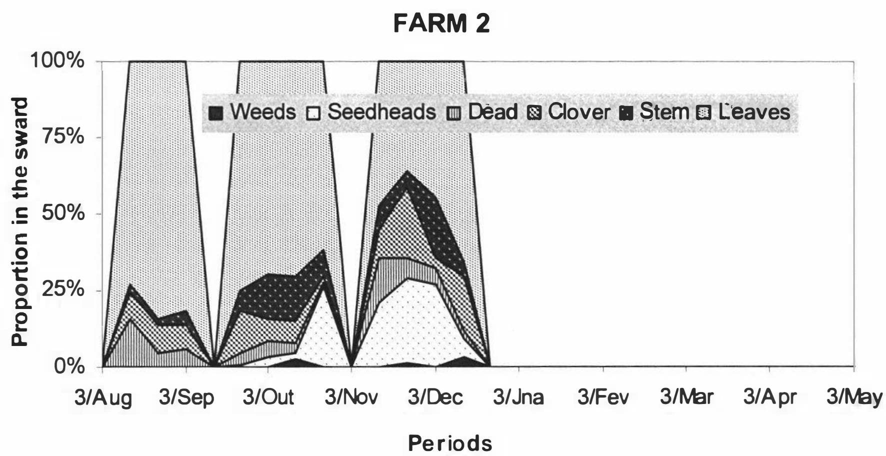

FARM 7
MS/cow/day
kg DM/ha
2.50
2.00
1.50
1.00
0.50
0.00
3500
3000
2500
2000
1500
1000
MS
Pre-grazing
Post-grazing
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

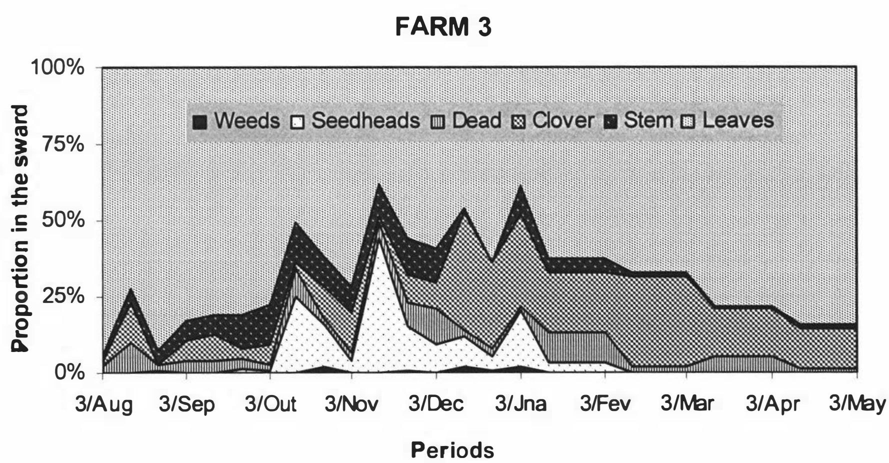

FARM 8
MS/cow/day
kg DM/ha
2.50
2.00
1.50
1.00
0.50
0.00
3500
3000
2500
2000
1500
1000
MS
Pre-grazing
Post-grazing
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

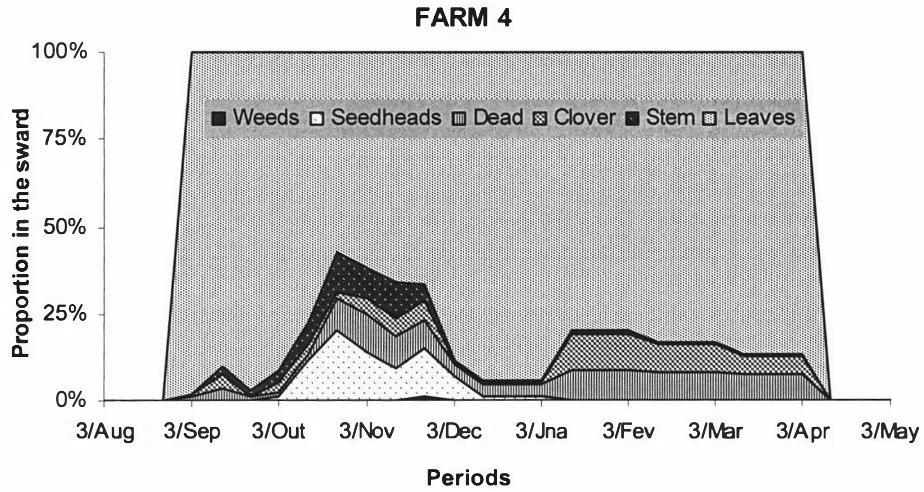

FARM 9
MS/cow/day
kg DM/ha
2.50
2.00
1.50
1.00
0.50
0.00
3500
3000
2500
2000
1500
1000
MS
Pre-grazing
Post-grazing
1/Aug 1/Sep 1/Out 1/Nov 1/Dec 1/Jan 1/Fev 1/Mar 1/Apr 1/May
Periods

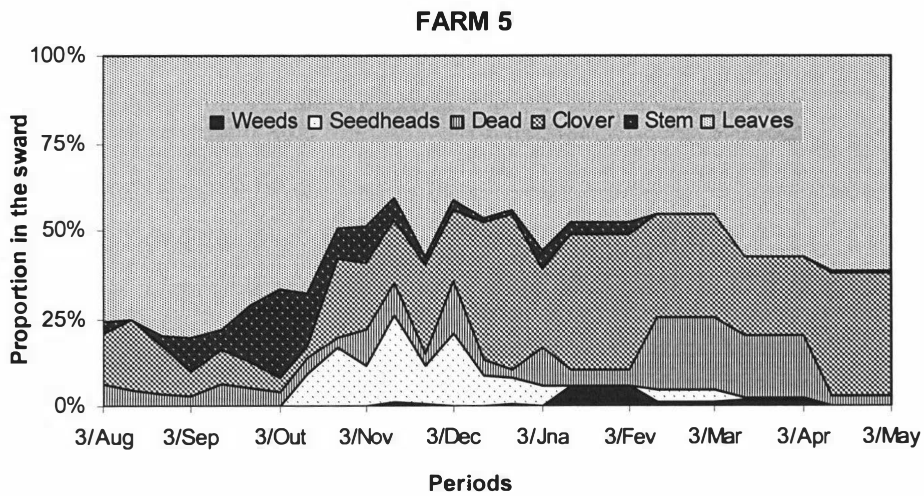
Appendix 13 Botanical composition of the grazed strata, over the lactation period, for the nine farms involved in this study. Measurements were not available for some farms at some stages of the season. In the legend, "Clover" includes stem and leaves of clover, and "Dead" means senescent material.

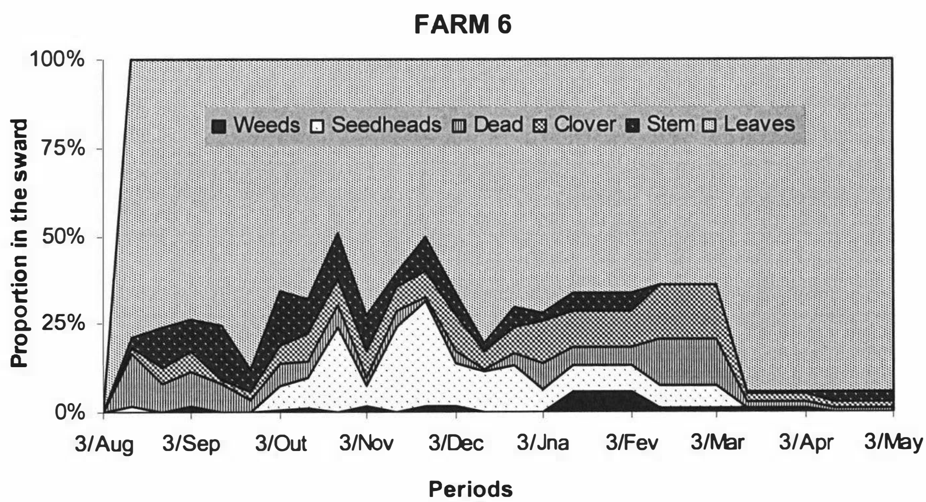


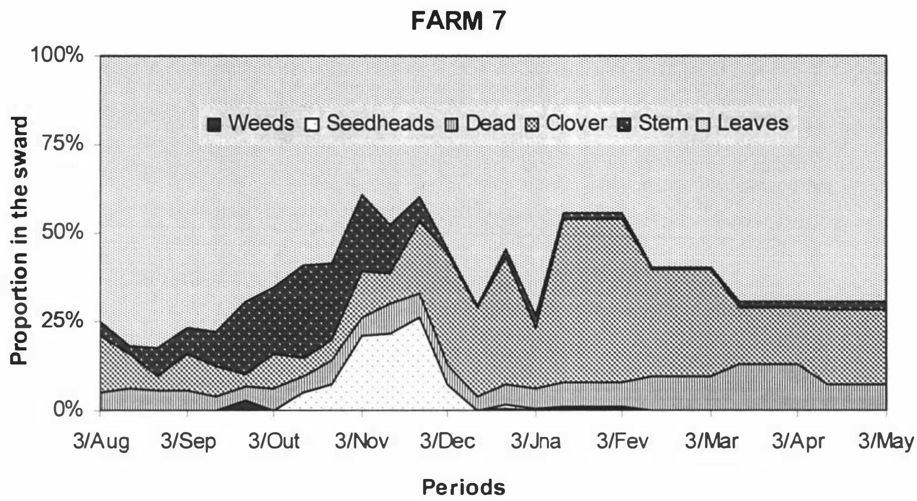


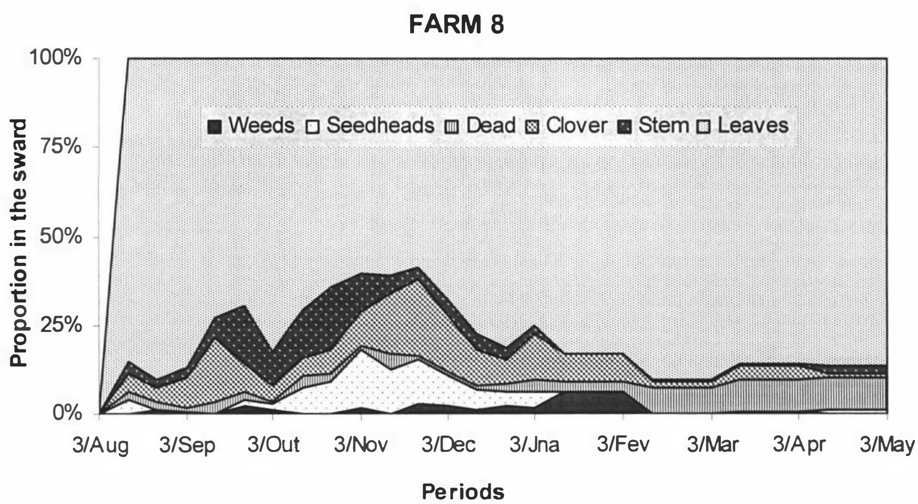


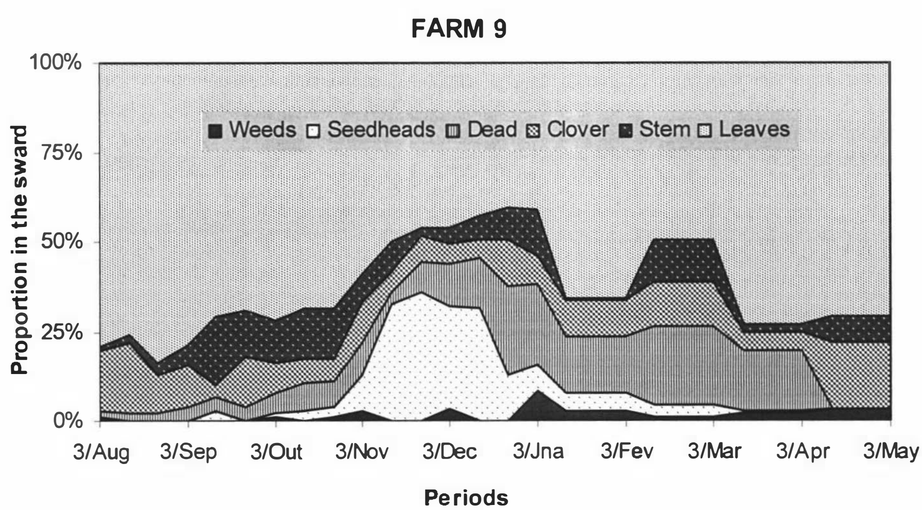

FARM 4
100%
75%
50%
25%
0%
Proportion in the sward
Weeds
Seedheads
Dead
Clover
Stem
Leaves
3/Aug
3/Sep
3/Out
3/Nov
3/Dec
3/Jna
3/Fev
3/Mar
3/Apr
3/May
Periods


FARM 5
100%
75%
50%
25%
0%
Proportion in the sward
Weeds
Seedheads
Dead
Clover
Stem
Leaves
3/Aug
3/Sep
3/Out
3/Nov
3/Dec
3/Jna
3/Fev
3/Mar
3/Apr
3/May
Periods


FARM 6
100%
75%
50%
25%
0%
Proportion in the sward
Weeds
Seedheads
Dead
Clover
Stem
Leaves
3/Aug
3/Sep
3/Out
3/Nov
3/Dec
3/Jna
3/Fev
3/Mar
3/Apr
3/May
Periods

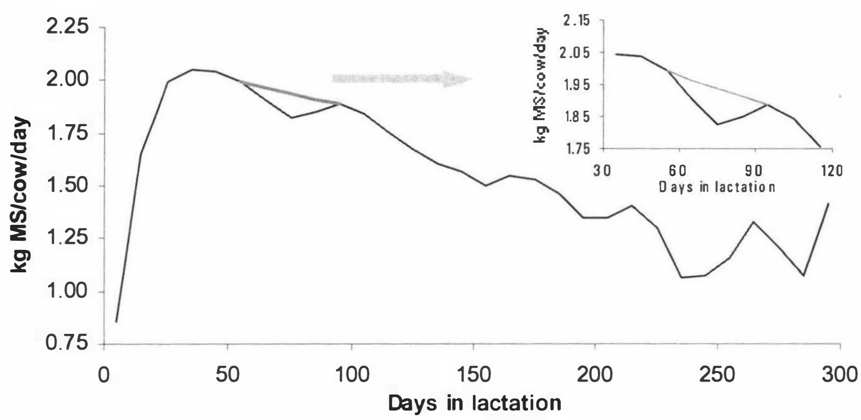

FARM 7
100%
75%
50%
25%
0%
Proportion in the sward
Weeds
Seedheads
Dead
Clover
Stem
Leaves
3/Aug
3/Sep
3/Out
3/Nov
3/Dec
3/Jna
3/Fev
3/Mar
3/Apr
3/May
Periods


FARM 8
100%
75%
50%
25%
0%
Proportion in the sward
Weeds
Seedheads
Dead
Clover
Stem
Leaves
3/Aug
3/Sep
3/Out
3/Nov
3/Dec
3/Jna
3/Fev
3/Mar
3/Apr
3/May
Periods

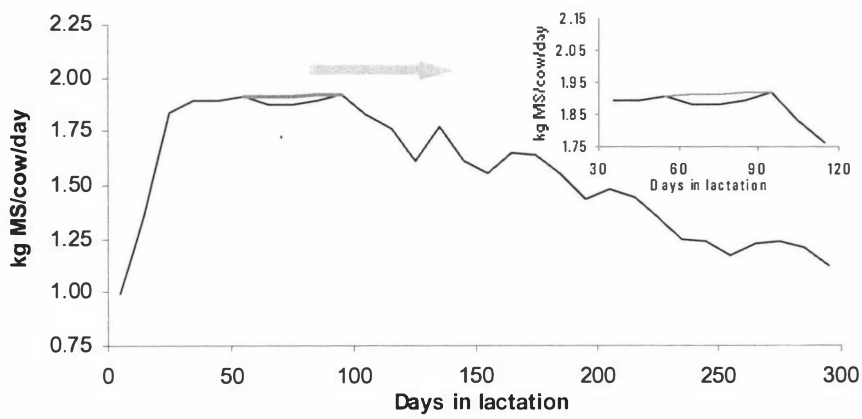

FARM 9
100%
75%
50%
25%
0%
Proportion in the sward
Weeds
Seedheads
Dead
Clover
Stem
Leaves
3/Aug
3/Sep
3/Out
3/Nov
3/Dec
3/Jna
3/Fev
3/Mar
3/Apr
3/May
Periods

Appendix 14 **(A)**: Illustration showing how the MS loss over the temporary decline and recovery period was estimated. **(B)**: Actual data for Farm 5. **(C)**: Actual data for Farm 7. Explanations in the next page.

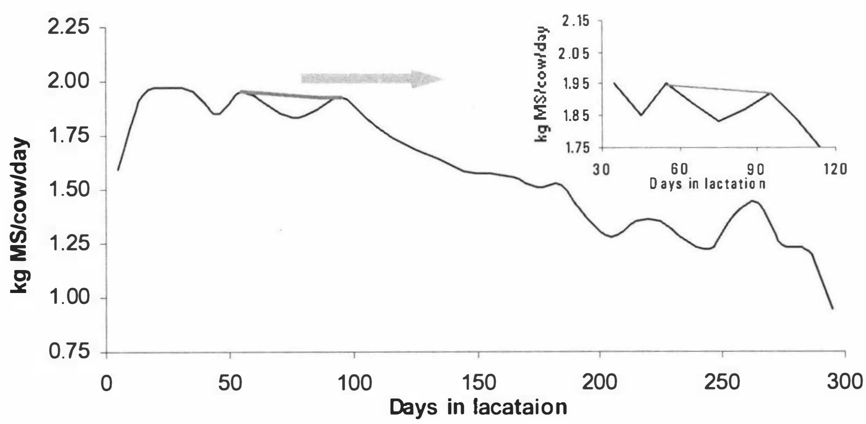
(A)



(B)



(C)



The MS loss (kg/cow over the specified period) is represented by the area formed by the lactation curve and the gray line. The gray line was drawn as a straight line starting from the first point of the decline period to the highest point of recovery period and the points which form this line were interpolated. The area was calculated by the sum of all the rectangular triangles included in the temporary decline and recovery period.

Appendix 15 Correlation matrix for the response variable MS loss and its associated predictor variables.

	MSL	MPY	LTDMI	LDMPI	LDMSI	LTMEI	LPMEI	LSMEI
MPY	0.514							
	0.157							
LTDMI	-0.277	0.305						
	0.471	0.425						
LDMPI	-0.038	-0.258	-0.553					
	0.922	0.503	0.123					
LDMSI	-0.097	0.314	0.815	-0.933				
	0.803	0.411	0.007	0.000				
LTMEI	0.013	0.413	0.886	-0.352	0.625			
	0.973	0.269	0.001	0.353	0.072			
LPMEI	0.060	-0.177	-0.454	0.952	-0.857	-0.145		
	0.879	0.649	0.219	0.000	0.003	0.710		
LSMEI	-0.060	0.318	0.784	-0.946	0.995	0.579	-0.890	
	0.878	0.405	0.012	0.000	0.000	0.102	0.001	
LME[ ]	0.561	0.096	-0.375	0.541	-0.539	0.095	0.740	-0.569
	0.116	0.806	0.320	0.132	0.134	0.807	0.023	0.109
LTPrI	-0.061	0.188	0.358	-0.210	0.308	0.564	0.036	0.238
	0.876	0.627	0.344	0.588	0.421	0.114	0.926	0.537
LPPrI	0.104	-0.062	-0.381	0.629	-0.596	-0.021	0.775	-0.642
	0.790	0.875	0.312	0.070	0.090	0.958	0.014	0.062
LSPrI	-0.177	0.271	0.794	-0.894	0.966	0.638	-0.779	0.939
	0.649	0.481	0.011	0.001	0.000	0.065	0.013	0.000
LPr[ ]	0.098	-0.010	-0.249	0.171	-0.219	0.040	0.362	-0.271
	0.802	0.980	0.518	0.659	0.572	0.918	0.339	0.480
LCCP	0.149	0.280	0.257	-0.514	0.474	0.403	-0.295	0.434
	0.702	0.465	0.504	0.157	0.197	0.282	0.441	0.243
LMEP	0.298	0.252	0.267	0.015	0.105	0.646	0.320	0.034
	0.437	0.512	0.488	0.970	0.787	0.060	0.402	0.932
LADFP	-0.268	-0.436	-0.341	0.373	-0.408	-0.579	0.123	-0.367
	0.485	0.241	0.369	0.323	0.275	0.102	0.752	0.332
Lpre	0.398	0.233	-0.105	0.700	-0.535	0.246	0.794	-0.548
	0.289	0.547	0.788	0.036	0.138	0.524	0.011	0.126
Lpost	0.381	0.075	-0.242	0.658	-0.565	0.186	0.823	-0.597
	0.312	0.848	0.531	0.054	0.113	0.633	0.006	0.090
Lstem	-0.492	-0.652	-0.377	0.468	-0.488	-0.600	0.268	-0.486
	0.216	0.079	0.357	0.242	0.220	0.116	0.521	0.222
Lleaf	0.284	0.534	0.402	-0.357	0.421	0.602	-0.167	0.412
	0.495	0.173	0.323	0.385	0.298	0.114	0.693	0.311
Lclover	-0.287	-0.232	-0.106	-0.027	-0.020	-0.144	0.011	-0.073
	0.490	0.580	0.803	0.949	0.962	0.734	0.979	0.863
Ldead	0.138	-0.513	-0.533	0.432	-0.538	-0.614	0.246	-0.483
	0.744	0.193	0.174	0.285	0.169	0.105	0.557	0.226
Lweed	-0.063	-0.117	-0.349	-0.464	0.175	-0.591	-0.588	0.197
	0.883	0.782	0.397	0.247	0.678	0.123	0.125	0.640

Lseed	0.542	0.541	0.201	-0.068	0.129	0.190	-0.155	0.197
	0.165	0.166	0.632	0.873	0.761	0.652	0.713	0.641

	LME[ ]	LTPrI	LPPrI	LSPrI	LPr[ ]	LCCP	LMEP	LADFP
LTPrI	0.346							
	0.362							
LPPrI	0.795	0.568						
	0.011	0.111						
LSPrI	-0.462	0.493	-0.436					
	0.211	0.177	0.240					
LPr[ ]	0.607	0.812	0.855	-0.016				
	0.083	0.008	0.003	0.967				
LCCP	0.206	0.891	0.340	0.615	0.741			
	0.595	0.001	0.371	0.078	0.022			
LMEP	0.718	0.739	0.542	0.235	0.594	0.582		
	0.029	0.023	0.132	0.543	0.092	0.100		
LADFP	-0.377	-0.725	-0.307	-0.467	-0.527	-0.772	-0.729	
	0.317	0.027	0.421	0.205	0.145	0.015	0.026	
Lpre	0.742	0.078	0.581	-0.529	0.186	-0.205	0.441	0.022
	0.022	0.842	0.101	0.143	0.632	0.597	0.235	0.955
Lpost	0.911	0.184	0.695	-0.533	0.368	-0.053	0.653	-0.328
	0.001	0.635	0.038	0.140	0.330	0.893	0.057	0.388
Lstem	-0.348	-0.628	-0.153	-0.474	-0.379	-0.728	-0.682	0.820
	0.398	0.095	0.718	0.236	0.355	0.040	0.062	0.013
Lleaf	0.315	0.614	0.183	0.430	0.341	0.622	0.671	-0.676
	0.447	0.106	0.664	0.288	0.408	0.100	0.069	0.066
Lclover	-0.046	0.250	0.159	0.095	0.350	0.230	0.111	-0.265
	0.915	0.550	0.706	0.824	0.395	0.584	0.794	0.526
Ldead	-0.038	-0.814	-0.168	-0.643	-0.459	-0.747	-0.668	0.758
	0.929	0.014	0.691	0.086	0.252	0.033	0.070	0.029
Lweed	-0.525	-0.151	-0.388	0.221	0.026	0.209	-0.497	0.191
	0.181	0.722	0.342	0.599	0.952	0.619	0.210	0.650
Lseed	-0.106	-0.404	-0.362	-0.053	-0.553	-0.300	-0.302	0.215
	0.803	0.320	0.378	0.900	0.155	0.471	0.467	0.610

	Lpre	Lpost	Lstem	Lleaf	Lclover	Ldead	Lweed
Lpost	0.797						
	0.010						
Lstem	-0.113	-0.230					
	0.790	0.583					
Lleaf	0.180	0.251	-0.933				
	0.670	0.548	0.001				
Lclover	-0.445	-0.068	0.300	-0.477			
	0.269	0.873	0.470	0.232			
Ldead	0.160	-0.033	0.720	-0.757	-0.085		
	0.705	0.939	0.044	0.029	0.841		
Lweed	-0.855	-0.710	0.189	-0.245	0.281	0.031	
	0.007	0.048	0.654	0.558	0.501	0.943	

```
Lseed       0.420    -0.073    -0.176     0.082    -0.605     0.296    -0.303
            0.301     0.863     0.677     0.848     0.112     0.477     0.466

Cell Contents: Pearson correlation
               P-Value
```

Legend

L= temporary decline and recovering period.

MPY = mid peak MS yield period.

MS = MS loss

TDMI = total dry matter intake.

PDMI = pasture dry matter intake.

SDMI = supplement DM intake.

TMEI = total ME intake.

PMEI = pasture ME intake.

SMEI = supplements ME intake.

ME[ ] = ME concentration in the diet.

TPrI = total protein intake.

PPrI = pasture protein intake.

SprI = supplements protein intake.

Pr[ ] = protein concentration in the diet.

MEP = ME concentration in the pasture.

ADFP = ADF concentration in the pasture.

CPP = Crude protein concentration in the pasture.

Leaf = proportion of leaf in the sward.

Clover = proportion of clover in thee sward.

Stem = proportion of stem in the sward.

Dead = proportion of dead material in the sward.

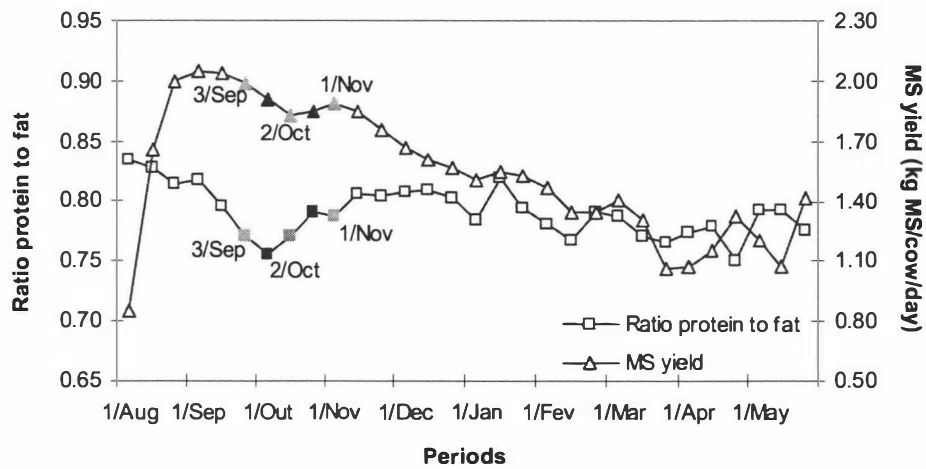
Weed = proportion of seeds in the sward.

Seed = proportion of seed in the sward.

Pre = pre grazing herbage mass.

Post = post grazing herbage mass.

Appendix 16 Example showing how the values employed in the t-test, for change in concentration of fat and protein, and in the ratio of protein to fat, over the decline and recovery period, were calculated.



As most farms presented the beginning of the decline period in the 3rd period of September (3/Sep), this period was considered as the beginning of the temporary decline for all the farms, in order to standardise the measurements. Period 2/Oct was the lowest decline point and period 1/Nov was the peak of the recovery for all the farms. Then, **change in fat and protein concentration, in the ratio protein to fat and in total pasture and supplements ME intakes, over the temporary decline and recovery period, were calculated as follows;**

$$\frac{\textbf{Value measured in 3/Sep + Value measured in 1/Nov}}{\textbf{2}} - \textbf{Value measured in 2/Oct}$$

This procedure was repeated for each one of the farms and the resulting values were utilised in the t test presented in Table 5.11. Note that the signs were changed to make the comprehension easier so **negative values** represent **declines** whereas **positive values** represent **increases** in the values for the components analysed.

Appendix 17 Correlation matrix for the response variable rate of post peak decline in MS yield and its associated predictor variables.

	LD	MPY	LDTDMI	LDPDMI	LDSDMI	LDTMEI	LDPMEI	LDSMEI
MPY	0.731							
	0.025							
LDTDMI	0.232	0.180						
	0.549	0.644						
LDPDMI	-0.134	-0.237	0.562					
	0.732	0.539	0.115					
LDSDMI	0.393	0.443	0.517	-0.417				
	0.296	0.233	0.154	0.264				
LDTMEI	0.052	0.145	0.963	0.540	0.500			
	0.895	0.710	0.000	0.133	0.171			
LDPMEI	-0.205	-0.183	0.617	0.970	-0.325	0.651		
	0.598	0.637	0.076	0.000	0.393	0.058		
LDSMEI	0.286	0.382	0.569	-0.350	0.988	0.580	-0.241	
	0.456	0.310	0.110	0.355	0.000	0.101	0.533	
LDME[ ]	-0.516	-0.037	0.338	0.181	0.183	0.578	0.403	0.307
	0.155	0.925	0.374	0.640	0.637	0.103	0.282	0.422
LDTPrI	0.049	0.125	0.542	0.368	0.215	0.644	0.531	0.253
	0.900	0.748	0.132	0.330	0.579	0.061	0.141	0.511
LDPPrI	-0.211	-0.174	0.549	0.725	-0.147	0.654	0.842	-0.067
	0.586	0.653	0.126	0.027	0.707	0.056	0.004	0.863
LDSPrI	0.564	0.490	0.261	-0.455	0.759	0.235	-0.362	0.689
	0.114	0.180	0.497	0.218	0.018	0.542	0.339	0.040
LDPr[ ]	-0.044	0.169	0.035	0.112	-0.077	0.185	0.280	-0.064
	0.910	0.663	0.928	0.774	0.844	0.633	0.465	0.871
LDCPP	-0.156	0.017	0.287	0.052	0.262	0.463	0.255	0.318
	0.689	0.966	0.454	0.894	0.496	0.210	0.508	0.404
LDMEP	-0.121	0.245	0.465	0.137	0.370	0.655	0.355	0.457
	0.757	0.525	0.207	0.725	0.327	0.055	0.348	0.216
LDADFP	-0.031	-0.459	-0.143	0.086	-0.246	-0.327	-0.128	-0.280
	0.937	0.214	0.713	0.826	0.523	0.391	0.742	0.466
LDpre	0.266	0.304	0.466	0.547	-0.053	0.452	0.591	-0.056
	0.489	0.427	0.206	0.128	0.892	0.222	0.094	0.887
LDpost	0.341	0.033	0.048	0.119	-0.071	-0.115	0.025	-0.174
	0.370	0.932	0.903	0.760	0.856	0.768	0.949	0.654
LDstem	-0.504	-0.438	-0.327	0.256	-0.623	-0.382	0.155	-0.626
	0.203	0.278	0.430	0.540	0.099	0.350	0.713	0.097
LDleaf	0.353	0.514	-0.069	-0.488	0.442	0.025	-0.362	0.418
	0.391	0.193	0.871	0.220	0.272	0.953	0.378	0.302
LDclover	-0.111	-0.356	0.263	0.487	-0.232	0.147	0.366	-0.215
	0.794	0.386	0.530	0.222	0.580	0.728	0.372	0.610
LDdead	-0.331	-0.543	-0.138	0.069	-0.222	-0.229	-0.044	-0.229
	0.423	0.165	0.745	0.871	0.598	0.585	0.918	0.585
LDweed	-0.332	-0.342	-0.210	0.542	-0.800	-0.129	0.558	-0.753
	0.422	0.407	0.618	0.165	0.017	0.761	0.151	0.031

LDseed	-0.493	-0.215	-0.028	0.365	-0.416	0.025	0.360	-0.355
	0.215	0.609	0.948	0.374	0.305	0.954	0.382	0.388
ChangeCS	-0.086	-0.381	0.548	0.504	0.057	0.592	0.560	0.113
	0.840	0.352	0.159	0.203	0.894	0.122	0.149	0.789

	LDME[ ]	LDTPrI	LDPPrI	LDSPrI	LDPr[ ]	LDCPP	LDMEP	LDADFP
LDTPrI	0.620							
	0.075							
LDPPrI	0.627	0.862						
	0.071	0.003						
LDSPrI	0.042	0.495	0.015					
	0.914	0.176	0.969					
LDPr[ ]	0.551	0.845	0.679	0.396				
	0.125	0.004	0.044	0.291				
LDPr[ ]P	0.757	0.877	0.718	0.476	0.841			
	0.018	0.002	0.029	0.195	0.005			
LDME[ ]	0.886	0.804	0.664	0.365	0.699	0.879		
	0.001	0.009	0.051	0.334	0.036	0.002		
LDADFP	-0.715	-0.751	-0.488	-0.490	-0.857	-0.797	-0.861	
	0.031	0.020	0.183	0.181	0.003	0.010	0.003	
LDpre	0.171	0.672	0.583	0.244	0.554	0.292	0.390	-0.471
	0.659	0.048	0.099	0.526	0.122	0.445	0.300	0.201
LDpost	-0.542	0.111	-0.028	0.308	0.073	-0.236	-0.416	0.187
	0.132	0.775	0.943	0.420	0.853	0.540	0.266	0.630
LDstem	-0.329	-0.545	-0.199	-0.690	-0.367	-0.663	-0.615	0.584
	0.426	0.163	0.636	0.058	0.371	0.073	0.105	0.129
LDleaf	0.334	0.562	0.032	0.765	0.691	0.659	0.619	-0.874
	0.418	0.147	0.939	0.027	0.058	0.076	0.102	0.005
LDclover	-0.343	-0.381	0.051	-0.550	-0.609	-0.462	-0.423	0.789
	0.406	0.351	0.905	0.158	0.109	0.249	0.297	0.020
LDdead	-0.392	-0.646	-0.308	-0.451	-0.721	-0.658	-0.760	0.820
	0.337	0.083	0.457	0.262	0.043	0.076	0.029	0.013
LDweed	0.227	0.220	0.603	-0.585	0.401	0.190	0.040	-0.093
	0.588	0.601	0.113	0.127	0.324	0.651	0.925	0.827
LDseed	0.174	-0.392	-0.000	-0.719	-0.380	-0.520	-0.275	0.264
	0.680	0.336	0.999	0.045	0.353	0.187	0.509	0.527
ChangeCS	0.364	0.809	0.788	0.203	0.413	0.588	0.438	-0.233
	0.375	0.015	0.020	0.629	0.310	0.125	0.278	0.579

	LDpre	LDpost	LDstem	LDleaf	LDclover	LDdead	LDweed	LDseed
LDpost	0.511							
	0.160							
LDstem	-0.015	0.336						
	0.972	0.415						
LDleaf	0.305	-0.037	-0.693					
	0.463	0.931	0.057					
LDclover	-0.215	-0.020	0.492	-0.889				
	0.610	0.962	0.215	0.003				
LDdead	-0.553	0.137	0.438	-0.721	0.421			
	0.155	0.746	0.278	0.043	0.299			

LDweed	0.080	-0.190	0.096	-0.228	0.044	0.159		
	0.850	0.652	0.820	0.587	0.917	0.707		
LDseed	-0.112	-0.113	0.471	-0.509	0.121	0.597	0.416	
	0.792	0.789	0.239	0.198	0.774	0.118	0.306	
ChangeCS	0.518	0.187	-0.301	0.187	-0.147	-0.128	0.229	-0.128
	0.188	0.658	0.469	0.658	0.728	0.762	0.585	0.762

Cell Contents: Pearson correlation
P-Value

Legend

L= post peak decline period.

LD = rate of post peak decline

MPY = mid peak MS yield.

TDMI = total dry matter intake.

PDMI = pasture dry matter intake.

SDMI = supplement DM intake.

TMEI = total ME intake.

PMEI = pasture ME intake.

SMEI = supplements ME intake.

ME[ ] = ME concentration in the diet.

TPrI = total protein intake.

PPrI = pasture protein intake.

SprI = supplements protein intake.

Pr[ ] = protein concentration in the diet.

MEP = ME concentration in the pasture.

ADFP = ADF concentration in the pasture.

CPP = Crude protein concentration in the pasture.

Leaf = proportion of leaf in the sward.

Clover = proportion of clover in thee sward.

Stem = proportion of stem in the sward.

Dead = proportion of dead material in the sward.

Weed = proportion of seeds in the sward.

Seed = proportion of seed in the sward.

Pre = pre grazing herbage mass.

Post = post grazing herbage mass.

ChangeCS = change in condition score.

Appendix 18 Correlation matrix for the response variable MS yield in late lactation (80% H on milk) and its associated predictor variables.

	80MSY	MPY	80TDMI	80PDMI	80SDMI	80TMEI	80PMEI	80SMEI
MPY	0.013 0.974							
80TDMI	0.175 0.653	0.539 0.135						
80PDMI	-0.215 0.579	0.445 0.230	0.810 0.008					
80SDMI	0.535 0.138	-0.165 0.672	-0.280 0.465	-0.790 0.011				
80TMEI	-0.171 0.660	0.513 0.158	0.884 0.002	0.907 0.001	-0.559 0.117			
80PMEI	-0.354 0.350	0.433 0.244	0.741 0.022	0.973 0.000	-0.817 0.007	0.926 0.000		
80SMEI	0.544 0.130	-0.091 0.816	-0.144 0.712	-0.668 0.049	0.943 0.000	-0.377 0.317	-0.699 0.036	
80ME[ ]	-0.626 0.071	0.213 0.582	0.273 0.476	0.632 0.068	-0.749 0.020	0.689 0.040	0.766 0.016	-0.574 0.106
80TPrI	-0.056 0.885	0.424 0.256	0.869 0.002	0.956 0.000	-0.657 0.055	0.944 0.000	0.945 0.000	-0.528 0.144
80PPrI	-0.129 0.741	0.327 0.390	0.800 0.010	0.915 0.001	-0.661 0.052	0.931 0.000	0.943 0.000	-0.549 0.126
80SPrI	0.327 0.390	0.510 0.161	0.446 0.228	0.332 0.383	-0.077 0.845	0.199 0.608	0.147 0.706	0.016 0.968
80Pr[ ]	-0.179 0.645	0.295 0.441	0.710 0.032	0.942 0.000	-0.800 0.010	0.883 0.002	0.956 0.000	-0.671 0.048
80MEP	-0.644 0.061	0.109 0.779	0.014 0.972	0.310 0.417	-0.493 0.177	0.423 0.257	0.521 0.150	-0.476 0.195
CCP	0.049 0.900	-0.068 0.862	0.371 0.325	0.346 0.362	-0.178 0.646	0.521 0.150	0.465 0.208	-0.153 0.694
80ADPP	0.599 0.088	-0.120 0.759	-0.124 0.750	-0.245 0.525	0.271 0.480	-0.420 0.260	-0.448 0.226	0.304 0.427
80pre	-0.111 0.776	-0.152 0.696	0.394 0.294	0.442 0.233	-0.312 0.414	0.489 0.182	0.421 0.259	-0.107 0.784
80post	0.281 0.463	-0.354 0.350	0.078 0.842	-0.065 0.868	0.188 0.629	-0.110 0.778	-0.207 0.594	0.297 0.437
80stem	0.395 0.332	-0.209 0.619	-0.004 0.993	-0.270 0.518	0.479 0.230	-0.182 0.666	-0.384 0.348	0.671 0.068
80leaf	-0.344 0.405	0.376 0.359	0.166 0.694	0.425 0.293	-0.586 0.127	0.452 0.261	0.537 0.170	-0.522 0.185
80clover	-0.033 0.937	-0.241 0.565	-0.117 0.782	-0.345 0.403	0.493 0.214	-0.305 0.462	-0.352 0.393	0.322 0.436
80dead	0.525 0.182	-0.407 0.317	-0.265 0.527	-0.424 0.295	0.479 0.229	-0.566 0.144	-0.578 0.134	0.393 0.336
80weed	0.213 0.612	-0.485 0.224	-0.021 0.960	0.049 0.908	-0.110 0.795	-0.156 0.712	-0.052 0.903	-0.187 0.657
80seed	0.440 0.276	-0.187 0.658	0.022 0.959	-0.243 0.563	0.457 0.254	-0.203 0.630	-0.382 0.350	0.623 0.099
80CS	-0.640 0.087	-0.422 0.297	-0.238 0.570	-0.065 0.878	-0.135 0.749	-0.112 0.791	0.026 0.951	-0.310 0.455

	80ME[ ]	80TPrI	80PPrI	80SPrI	80Pr[ ]	80MEP	CCP	80ADPP
80TPrI	0.601							
	0.087							
80PPrI	0.673	0.978						
	0.047	0.000						
80SPrI	-0.241	0.250	0.042					
	0.532	0.517	0.915					
80Pr[ ]	0.728	0.963	0.966	0.132				
	0.026	0.000	0.000	0.736				
80MEP	0.814	0.350	0.499	-0.638	0.470			
	0.008	0.356	0.171	0.064	0.202			
CCP	0.449	0.562	0.693	-0.526	0.577	0.636		
	0.225	0.115	0.038	0.146	0.103	0.065		
80ADPP	-0.617	-0.330	-0.475	0.622	-0.369	-0.909	-0.682	
	0.076	0.386	0.197	0.074	0.328	0.001	0.043	
80pre	0.417	0.489	0.445	0.278	0.517	0.054	0.229	-0.046
	0.264	0.181	0.230	0.469	0.154	0.890	0.553	0.905
80post	-0.312	-0.059	-0.174	0.528	-0.089	-0.642	-0.313	0.558
	0.413	0.881	0.654	0.144	0.819	0.062	0.412	0.118
80stem	-0.350	-0.311	-0.417	0.450	-0.385	-0.689	-0.575	0.598
	0.396	0.453	0.304	0.263	0.346	0.059	0.136	0.118
80leaf	0.705	0.522	0.548	-0.056	0.619	0.700	0.565	-0.505
	0.051	0.185	0.160	0.896	0.102	0.053	0.144	0.202
80clover	-0.503	-0.385	-0.317	-0.361	-0.483	-0.202	-0.130	-0.036
	0.204	0.346	0.445	0.380	0.225	0.632	0.758	0.933
80dead	-0.787	-0.553	-0.615	0.214	-0.613	-0.850	-0.716	0.724
	0.020	0.155	0.105	0.610	0.106	0.008	0.046	0.042
80weed	-0.262	-0.069	-0.048	-0.107	-0.048	-0.369	-0.192	0.419
	0.532	0.870	0.910	0.800	0.910	0.369	0.649	0.302
80seed	-0.424	-0.328	-0.438	0.466	-0.416	-0.776	-0.678	0.696
	0.295	0.427	0.277	0.245	0.306	0.024	0.065	0.055
80CS	0.082	-0.026	0.106	-0.607	0.063	0.408	0.440	-0.537
	0.847	0.952	0.803	0.111	0.883	0.315	0.276	0.170

	80pre	80post	80stem	80leaf	80clover	80dead	80weed	80seed
80post	0.677							
	0.045							
80stem	0.450	0.811						
	0.263	0.015						
80leaf	0.280	-0.301	-0.545					
	0.501	0.468	0.163					
80clover	-0.586	-0.252	-0.001	-0.791				
	0.127	0.546	0.997	0.019				
80dead	-0.275	0.406	0.539	-0.944	0.628			
	0.510	0.318	0.168	0.000	0.096			
80weed	-0.219	0.047	0.071	-0.653	0.558	0.697		
	0.602	0.913	0.868	0.079	0.150	0.055		
80seed	0.276	0.714	0.960	-0.705	0.177	0.704	0.291	
	0.507	0.046	0.000	0.051	0.675	0.051	0.484	
80CS	-0.172	-0.211	-0.504	0.017	0.350	-0.077	0.123	-0.507
	0.683	0.616	0.203	0.968	0.395	0.855	0.772	0.200

Cell Contents: Pearson correlation
P-Value

Legend

80 = Period in which al least 80% of the herd was on milk

80 MS= MS yield at the period in which at least 80% of the herd was on milk.

MPY = mid peak MS yield.

TDMI = total dry matter intake.

PDMI = pasture dry matter intake.

SDMI = supplement DM intake.

TMEI = total ME intake.

PMEI = pasture ME intake.

SMEI = supplements ME intake.

ME[ ] = ME concentration in the diet.

TPrI = total protein intake.

PPrI = pasture protein intake.

SprI = supplements protein intake.

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MEP = ME concentration in the pasture.

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CPP = Crude protein concentration in the pasture.

Leaf = proportion of leaf in the sward.

Clover = proportion of clover in thee sward.

Stem = proportion of stem in the sward.

Dead = proportion of dead material in the sward.

Weed = proportion of seeds in the sward.

Seed = proportion of seed in the sward.

Pre = pre grazing herbage mass.

Post = post grazing herbage mass.

CS = condition scores.