Supplementation of Dairy Cows Grazing to Low and High Post Grazing Pasture Height

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Energy supplementation of pasture fed dairy cows has the potential to increase milk production while increasing nitrogen use efficiency (NUE) thus reducing the negative environmental effects of dairy farming in New Zealand. Urinary nitrogen (N) has an environmental impact due to its contribution to nitrate leaching and nitrous oxide emissions from dairy farms. It should therefore be beneficial to the dairy industry to explore methods of maximising milk production without losing focus on the negative effects of urinary N. This trial was designed to investigate the effects of concentrate supplementation and compressed post grazing pasture height, and thereafter called PGPH, on milk production and N partitioning in pasture fed dairy cows in New Zealand.

The objectives of this research were to measure the milk production and N partitioning responses of supplemented and unsupplemented dairy cows grazing at two different PGPH. It was predicted that supplementation would increase milk production while diluting N intake per kg of dry matter intake (DMI) thus reducing urinary N output per kg of milksolids (MS) produced. It was also predicted that high PGPH would increase milk production while potentially causing some deterioration of pasture quality versus low PGPH.

A total of 32 Friesian x Jersey lactating, spring calving dairy cows were divided into groups of 8 cows and allocated to four treatments; (1) low PGPH (3.5 cm) plus concentrate (LR+); (2) low PGPH (LR); (3) high PGPH (4.5 cm) plus concentrate (HR+); (4) high PGPH (HR). PGPH was recorded using a rising plate meter (RPM). Concentrate was consumed at a average rate of 3.5 kg DM per cow per day for the full length of the trial. Stocking Rate (SR) was 4.9 and 4.4 cows/ha for supplemented and unsupplemented groups respectively. Groups were allocated to 17 and 19 paddocks for supplemented and unsupplemented groups respectively. Paddocks were all of equal area. Cows were blocked on age, days in milk (DIM), liveweight (LW), breeding worth (BW) and previous MS production and grazed plots for 13 weeks from the 15 August to the 15 November 2013. Milk, pasture and concentrate samples were collected weekly. Faeces and urine samples were collected monthly. These data were statistically analysed within each rotation (weeks: 1-5 first, 6-9 second, and 10-13third rotation) using the residual maximum likelihood procedure of GenStat (REML, GenStat 12.2 VSN International).

PGPH remained constant throughout the 13 week period at 3.7 and 4.5 cm respectively. Mean MS production in the first, second and third rotations were 1.97, 2.13 and 1.97 kg MS/cow/day respectively. Mean milk yield in the first, second and third rotations were 22.57, 24.04 and 22.32 kg milk/d respectively. Increasing pasture height from 3.7 to 4.5 cm did not affect pasture quality, MS production or milk yield.

Concentrate supplementation significantly increased average milk yield (23.56, 25.26, 24.04 kg milk/d versus 21.57, 22.83, 20.59 kg milk/d) and average MS production (2.04, 2.20, 2.12 kg MS/d versus 1.90, 2.07, 1.82 kg/d) in rotations 1, 2 and 3 respectively. Average milk response (MR) to supplementation was 140 g MS/kg of dry matter (DM) or 9.96 g MS/ mega joule of metabolisable energy (MJ ME) for the first 13 weeks of lactation. Average milk protein percentage was higher (3.87% versus 3.65%) and average milk urea nitrogen (MUN) was lower (7 mmol/l versus 7.92 mmol/l) in rotation 3 for supplemented than unsupplemented groups. Average total N intake per day over 13 weeks was higher for supplemented (500 g/d) than unsupplemented (406 g/d) groups in rotation 3.
Faecal and urinary N concentrations were higher for supplemented (HR+: 3.50%, 0.58%; LR+: 3.11%, 0.55%) than unsupplemented treatments (HR: 2.84%, 0.31%; LR: 2.83%, 0.55%) in rotation 3 but there was no significant effect of the percentage of N excreted in urine and faeces as a percentage of total N intake. Average body condition score (BCS) gain was higher for supplemented (+ 0.29) than unsupplemented (+ 0.13) groups over the 13 week period.

The implications of this experiment are that a MS response to additional DMI and higher SR in a supplemented farm system averaged 140 g MS/kg DM.

Keywords: supplementation, nitrogen use efficiency, nitrogen, environmental, post grazing pasture height, milk yield, stocking rate.

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List of Abbreviations

ADF	Acid Detergent Fibre
APC	Average Pasture Cover
BCS	Body Condition Score
BW	Breeding Worth
CP	Crude Protein
DIM	Days in Milk
DM	Dry Matter
DMI	Dry Matter Intake
DOMD	Digestibility of Organic Matter in Dry Matter
FME	Fermentable Metabolisable Energy
LURDF	Lincoln University Research Dairy Farm
LW	Liveweight
MCP	Microbial Crude Protein
MJ ME	Mega Joule of Metabolisable Energy
MR	Milk Response
MUN	Milk Urea Nitrogen
N	Nitrogen
NDF	Neutral Detergent Fibre
NH_3	Ammonia
NIRS	Near Infrared Reflectance Spectroscopy

NUE	Nitrogen Use Efficiency
N_2O	Nitrous Oxide
OMD	Organic Matter Digestibility
PA	Pasture Allowance
PGPH	Post Grazing Pasture Height
RED	Relative Energy Deficit
RFC	Readily Fermentable Carbohydrates
RPM	Rising Plate Meter
SR	Stocking Rate
SubR	Substitution Rate
SSS	Soluble Sugars & Starch
TMR	Total Mixed Ration
WSC	Water Soluble Carbohydrates

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Chapter 1
Introduction

1.1 Background to the Study

Perennial pastures form the main source of nutrients for dairy cows in New Zealand. This is in contrast to many other countries where diets are balanced by design. New Zealand dairy production systems are different to most others (Steinfeld and Maki-Kokkonem, 1995). It was demonstrated, by data from nine countries, that milk can be produced at a lower cost where diets include higher proportions of pasture (Dillon *et al.*, 2005). A small sector of the New Zealand dairy industry is balancing the industries greatest asset of abundant pasture with a balanced supplement in an attempt to increase farm profitability. The literature is inconclusive in terms of the profitability of supplementing pasture fed dairy cows in New Zealand over extended periods. Research is well advanced into the nutritional responses of cows with different levels of milk yield when fed concentrate/forage diets, but less is known about the responses under grazing conditions (Mayne and Gordon, 1995).

Energy is the first limiting nutrient for high producing cows grazing high quality pastures as the main feed (Kolver and Muller, 1998). Immediate responses to grain supplementation depend on the relative energy deficit (RED) of the dairy cow and therefore responses may vary. It is important that we can quantify the response to supplementation of dairy cows in terms of milk production and environmental impact so that the economic benefit can be calculated accurately. A short term response of 4.1 g MS/MJ ME was calculated for 1 kg DM extra supplement containing 12 MJ ME (Penno *et al.*, 2002).

Responses to supplementation depend very much on the substitution rate (SubR) of pasture. Substitution of pasture will increase as satiety is achieved. Substitution refers specifically to the reduction in pasture intake (kg DM/cow/day) that occurs for each kg DM supplement consumed (Stockdale, 2001). SubR vary between 0.2 kg DM pasture substituted per kg DM concentrate at very low levels of supplementary feeding to 0.8 kg DM pasture substituted per kg DM concentrate at very high levels of supplementary feeding (Holmes, 1999).

Other strategies to increase DMI involve the manipulation of pasture allowance (PA) and PGPH. DMI was shown to increase as pasture allowance (PA) increases (Stockdale, 1985; Dalley *et al*., 1999; Wales *et al.*, 1999; Wales *et al*., 2001) while defoliation to a lower PGPH increased DM yields (Kennedy *et al.*, 2006) and improved pasture quality (Hoogendorn *et al.*, 1988). It is necessary to be specific in regard to the actual PGPH when considering low/high or hard/lax post grazing scenarios. An optimum PGPH of 4-6 cm was suggested (Irvine *et al*., 2010).

High quality pasture may supply excess protein to dairy cows at certain times of the year. Grain supplements can be used to improve the balance of energy and protein to grazing dairy cows, and reduce N intake which should increase microbial protein production and help to mitigate the environmental effects of excess nitrogen excreta. Rumen pH and ammonia nitrogen (NH_3-N) concentration were decreased with concentrate supplementation (Bargo *et al*., 2002). The use of energy supplements could potentially increase total milk production and reduce nitrate leaching caused by the dairy industry by reducing urinary N excretion per cow. The provision of extra energy should increase NUE resulting in lower urinary N concentrations, although this will depend on SubR. NUE is defined as the conversion of feed N into milk N and it is an important component of sustainable and profitable dairy farming (Cheng *et al*., 2010).

1.1.1 Hypotheses

1. Supplementing pasture fed dairy cows with an energy supplement is predicted to increase milk production and reduce N excretion.
2. Increasing PGPH is predicted to increase MS production.
3. Increasing PGPH is predicted to result in pasture quality deterioration.

1.1.2 Objectives

1. To determine the effects of concentrate supplementation and PGPH on MS production in pasture fed dairy cows.
2. To determine the effects of concentrate supplementation and PGPH on N excretion in pasture fed dairy cows.

Chapter 2
Literature Review

2.1 Pasture Management and Quality

2.1.1 Post Grazing Pasture Mass

Grazing to low post grazing pasture mass improves pasture quality compared to grazing to higher post grazing pasture mass (Hoogendorn *et al*., 1988). As concentrate supplements are introduced to the diet of pasture fed dairy cows it is likely that PGPH will increase if cows are offered the same pasture allowance as they were prior to supplementation. This depends on the SubR and care should be taken to ensure that pasture quality is not compromised by allowing PGPH to increase.

It is important that seed head production is minimized because if the tiller is allowed to reproduce it will inhibit the development of new tillers and die therefore reducing pasture quality. Increasing PA is likely to decrease the quality of the pasture in subsequent rotations because of increased stem production and accumulation of dead material (Stakelum and Dillon, 1990). It is not possible to stop the plant becoming reproductive as this begins at the base of the plant at a very early stage in winter, but it is possible to prevent stem elongation in the early part of the reproductive phase and thus promoting more green leaf production rather than seed head. Defoliating to 30mm during early tiller growth reduced the length of the reproductive phase and allowed the plant to return to vegetative growth earlier than defoliating to 60mm (Hurley *et al*., 2007). Although there is rapid growth occurring in the reproductive tillers in spring there is more stem production than leaf which reduces feed quality. This rapid growth also suppresses clover growth in the sward because the clover cannot compete for light as the sward gets longer. Grazing to lower PGPH should therefore reduce the proportion of dead and low quality stem material in the sward and promote good clover growth resulting in higher feed quality for milk production. Hoogendoorn *et al*. (1988) reported that hard grazing in spring significantly reduced the production of reproductive tillers, in November and December the reduction was greater than 50%. Pasture growth rates were slower initially under hard grazing because stem elongation was prevented when rapid growth would normally occur, but superior growth rates in December showed total yield over the two months was not significantly reduced. The benefit in pasture quality was evident by the increase in the percentage of leaf composition under hard grazing (45%) as opposed to lax grazing (29%) and an 8% increase in clover content (Hoogendoorn *et al.*, 1988). Promoting clover content in the sward is of vital importance, especially in NZ dairying systems where it is heavily relied on as a good quality feed and for reducing nitrogen requirements for pasture growth.

Consistently maintaining PGPH to an optimum height is also important for maximising total pasture yield. Higher DM yields were achieved by all varieties when defoliated to a lower defoliation height (Kennedy *et al.*, 2006). Cumulative DM yield was significantly higher for the lower defoliation height; swards defoliated to 4 cm yielded 1,109 kg DM/ha/yr more than those defoliated to 7 cm. Farmers need to have systems in place to maximize daily herbage intake while maintaining a high quality sward, the challenge they face is maintaining PGPH in the optimum range of 4-6 cm (Irvine *et al*., 2010). Pulido and Leaver (2001) reported that increased PGPH led to increased milk yield persistency, increased herbage dry matter intake, increased grazing time and increased rate of dry matter intake.

2.1.2 Dry Matter Intake

DMI should be maximised to ensure milk production potential is being achieved. Total DMI of dairy cows on pasture only diets is lower than total DMI of dairy cows consuming total mixed rations (TMR) or pasture plus supplements, this indicates that high producing cows on pasture based diets need to be supplemented to achieve their genetic potential for DMI (Bargo *et al*., 2003). Stockdale (1985) and Dalley *et al*. (1999) reported that pasture DMI is closely related to PA. Pasture DMI continues to increase as PA increases up to 15 kg DMI/100 kg of bodyweight (Doyle *et al*., 1996). Pasture DMI increased curvilinearly from 11.2 to 18.5 kg DM/cow/day, with a plateau at a PA of 55.2 kg DM/cow/day (Dalley *et al.*, 1999). As PA increased from 20 to 70 kg DM/cow/day, pasture DMI increased linearly from 7.1 to 16.2 kg DM/cow/day with a pre grazing pasture mass of 3,100 kg DM/ha, and from 9.9 to 19.3 kg DM/cow/day with a pre grazing pasture mass of 4,900 kg DM/ha (Wales *et al.*, 1999). Pasture DMI by high producing dairy cows in early lactation increased from 12.5 to 15.6 kg/d when PA of a ryegrass pasture was increased from 19 to 37 kg DM/cow/day (Wales *et al.*, 2001).

It is likely that many New Zealand dairy cows are being restricted in terms of DMI and although it seems clear that there are benefits of increasing PA in terms of DMI, it has also been reported that offering higher PA can have negative effects on pasture quality. McEvoy *et* *al.* (2009) found that as cows were offered higher herbage masses their production was affected throughout the season due to lower organic matter digestibility (OMD) percentage of the sward caused by higher levels of stem and dead material. High herbage mass had a consistently lower OMD% than medium herbage mass when grazed. Other studies also showed that with lower grazing pressure herbage mass would increase and OMD would decrease due to lower leaf proportion (Stakelum and Dillon, 2007). Stricter pasture management should reduce negative effects created by higher PGPH. Studies conducted with high producing dairy cows on pasture that have evaluated the effect of amount of concentrate supplementation on DMI, and milk production and composition found that pasture DMI decreased and total DMI increased by increasing the amount of concentrate fed (Bargo *et al.,* 2003). A recent review of the literature found that for a range of concentrate supplementation (1.8 to 10.4 kg DM/cow/day) pasture DMI decreased 1.9 kg/d or 13% compared with pasture only diet treatments (14.8 kg/d) (Bargo *et al.,* 2003).

Typically pasture allowance is restricted in New Zealand dairy feeding systems to maintain quality of pasture and to maximize pasture utilisation. It is generally accepted that when access to food is unrestricted, the nutritional requirements for lactation results in DMI increasing rapidly after calving to a peak of 8 to 16 weeks *postpartum*, before steadily declining for the remainder of lactation (Bauman and Currie, 1980). This type of behaviour was not seen in a New Zealand trial possibly because of pasture restriction but an increase of 1.0 MJ ME in metabolisable energy allowance resulted in a linear increase in metabolisable energy intake of 0.68 MJ ME (Penno *et al.*, 2006).

2.2 Supplementation Responses

MR (MR) to supplementation is typically expressed as kg milk/kg supplement, but also can be defined as: 1) overall MR or the increase in kilograms of milk per kilogram of supplement DMI calculated relative to an unsupplemented treatment; and 2) marginal MR or the increase in kilograms of milk per kilogram of incremental increase in supplement DMI calculated for different amounts of supplement (Bargo *et al.,* 2003).

2.2.1 Short Term Milk Response

Energetic theory suggests that 76 MJ ME are required to synthesise 1 kg MS (Holmes and Roche, 2007). It follows that 1 MJ ME of supplement should produce 13 g MS and 12 MJ ME should produce 156 g MS. This is the maximum response possible if all energy is used solely for milk production. Actual responses that have been measured are much lower than this. A short term response of 4.1 g MS/MJ ME was calculated for 1 kg DM extra supplement containing 12 MJ ME (Penno *et al.,* 2002). It was estimated that 1 MJ ME was lost to physical waste, 3 MJ ME were lost due to substitution of pasture for the supplement and 4.5 MJ ME were directed to LW gain, 3.5 MJ ME remained for milk production in the udder which translated to 50 g MS or 4.1 g MS/MJ ME. Some of the short term energy losses could provide longer term benefits if well managed. Substituted pasture not eaten may be used to increase SR but this would increase overall maintenance requirements thus reducing potential profitability gains. Energy used for LW gain could be beneficial for reproductive performance but requires good management to avoid cows becoming excessively fat. Higher BCS allows for longer lactations resulting in extra milk and improving overall MR. Although the short term response only produced an extra 50 g MS, it was calculated that a further 30-50 g MS was produced over the longer term giving an overall response of 80-100 g MS/kg DM. The short term response was greater in early lactation due to increased partitioning of energy to milk production rather than LW gain at this stage of lactation (Penno *et al.,* 1998).

The short term response is the immediate increase in milk production when pasture-fed cows are supplemented. Short term responses depend on relative energy deficit (RED) so a greater response should be seen when cows are provided with extra energy. When RED is high SubR should be lower apart from in the first few weeks *post partum* (Holmes and Roche, 2007). The magnitude of total MS response can largely be predicted by the magnitude of the potential energy deficit (Penno *et al.,* 2001). MR ranged from 0.60 (Sayers *et al.,* 1999) to 1.45 kg milk/kg concentrate (Gibb *et al.,* 2002).

2.2.2 Long Term Milk Response

To successfully increase milk production it is necessary to increase the metabolisable energy intake of the dairy cow to meet energy requirements. The increase in milk production immediately following supplementation is the short term response. Over a longer period an increase in milk production may be seen due to improved cow condition and more conserved pasture largely through enabling longer lactations, i.e. the long term response. The response of MS to supplementary feeding was determined by the extent that total metabolisable energy intake was increased by supplementary feeding rather than stage of lactation or form of supplement (Penno *et al.*, 1998). Stage of lactation affects how energy is partitioned within the cow, in early lactation more energy is directed towards milk production than LW gain while in late lactation more is partitioned to LW gain. This also depends on the LW status of the cow. Kolver *et al.* (1997) also agreed that the supply of metabolisable energy was the first limiting factor for milk production from high quality pasture rather than metabolisable protein or amino acids and found that when more than 20% of the diet consisted of maize grain the amino acids methionine and lysine became limiting. Compared with pasture only diets, increasing the amount of concentrate supplementation up to 10 kg DM/d increased total DMI 24%, milk production 22%, and milk protein percentage 4%, but reduced milk fat percentage 6% (Bargo *et al.*, 2003).

Penno *et al.* (1999) compared rolled maize grain, maize silage and a nutritionally balanced ration as supplementary feeds for grazing dairy cows over three seasons. The supplements were offered whenever it was estimated the herds were eating less than 15 kg DM/cow/day or were leaving a post grazing residual of less than 1800 kg DM/ha. Responses of 98, 77 and 99 g MS/kg DM respectively were recorded for the three types of supplement. The responses were directly proportional to the increase in metabolisable energy supplied by the supplement. It was concluded that responses of approximately 7.5 g MS/MJ ME can be expected over the complete lactation when supplements are offered to dairy cows grazing restricted pasture. An average response of 80 g MS/kg DM additional feed and increased SR was also reported (Dalley *et al*., 2005). These responses are in line with the calculations of Holmes and Roche (2007) where a long term response of 80-100 g MS/kg DM was calculated when 1 kg DM was equivalent to 12 MJ ME.

LW gain achieved from supplementation should increase days in milk (DIM) and improve reproductive performance which contributes to the overall response achieved from feeding supplements. Supplements should not be used to replace pasture or to improve the nutritional value of the diet as this is not profitable (Holmes and Roche, 2007).

2.2.3 Substitution Rate

When concentrates are fed to grazing animals, their pasture intake can be depressed. This is known as substitution and is a major factor contributing to the variation seen in MRs to supplementation. The SubR is defined as the decrease in pasture intake per kg of supplement fed (Kellaway and Harrington, 2004).

SubR, or the reduction in pasture DMI per kilogram of concentrate, is a factor which may explain the variation in MR to supplementation (Bargo *et al*., 2003). The rate of substitution is determined by pasture allowance and diet quality. If the quality of pasture is similar to that of the concentrate and PA is unrestricted SubR should remain low however if pasture quality is poor and PA is restricted SubR should increase. In experiments where these principles of supplementation have been observed, annual SubR in farmlet systems over a whole year was 0.22 and 0.53 at medium (0.84 t DM/cow) and high (1.7 t DM/cow) levels of concentrate feeding in Australia (Fulkerson, 2000). Results suggest that only 30-40% of the variability in SubR can be explained by pasture intake at the time the supplement was fed, and the LW or feed demand of the cow being fed, implying other factors are involved, as yet unquantified or unknown (Holmes and Roche, 2007). Some substitution may be desirable in terms of increasing pasture cover without affecting total energy intake when feeding supplements.

Supplementation of pasture fed dairy cows is likely to alter rumen function and reduce grazing time. The SubR may be produced by negative associative effects in the rumen of grazing cows supplemented with concentrates (Dixon and Stockdale, 1999). When grain is introduced into the diet of ruminants fed forage there are usually changes in the rumen micro-organisms present and their activity (Dixon and Stockdale, 1999). The number of amylolytic bacteria which digest and utilise readily fermentable carbohydrates (RFC) tends to increase, and the number of fibrolytic bacteria tends to decrease when cows are supplemented with grain (El-Shazly *et al.,* 1961). This may cause the efficiency of microbial protein synthesis to be affected causing further substitution.

When pasture DMI declines as a result of substitution there is likely to be a reduction in total daily grazing time. SubR may be related to reductions in grazing time when cows on pasture are fed supplement (McGilloway and Mayne, 1996). Feeding concentrates reduced grazing time by 22 minutes/day per kg concentrate fed (Marsh *et al*., 1971) and 23 minutes/day per kg concentrate fed (Cowan *et al*., 1977). Supplemented treatments had lower rumen pH, lower rumen degradation rates of pasture and lower fibre digestibility and also spent less time grazing than unsupplemented treatments (Bargo *et al*., 2002).

Some research has been conducted to investigate the influence and interactions of sward height and concentrate level on milk yield (Pulido and Leaver, 2001; Pulido and Leaver, 2003). Post grazing sward heights of 5-7 and 7-9 cm were compared in a rotational grazing system with (6 kg/d) and without concentrate supplementation (Pulido and Leaver, 2003). The effects of sward height were not significant except for yield of milk protein, which was significantly higher with higher post grazing sward height. In contrast, concentrate level significantly increased milk yield, milk persistency and yields of milk fat, milk protein and milk lactose. However, there have been no studies conducted to investigate the interaction between concentrate supplementation and PGPH in pasture fed dairy cows in New Zealand.

2.3 Mitigating Nitrogen Losses

Pasture based diets in NZ contain very high protein concentrations, usually above the animals requirements even when in peak lactation. NZ pastures can contain 18 - 30% crude protein (CP) depending on species and season. The requirements of lactating dairy cows are in the order of 15 - 18% in early lactation and drop off to 12 - 15% later in the season (AFRC, 1993). Total dietary CP concentrations of greater than 20% are surplus to requirements. Excess protein is converted to urea and excreted contributing to nitrate leaching and nitrous oxide emissions. Nitrogen excretion is strongly correlated with N intake (Tas, 2006). This creates the potential for nitrogen excretion to be reduced by feeding balanced diets with lower CP concentrations. In other countries where diets meet the animal's nutritional requirements more closely there is less concern about the levels of N excreted. As pasture is the cheapest and most profitable feed in NZ it will continue to be a major part of the dairy cow's diet but as pressure mounts on NZ to reduce its environmental impacts from dairy farming, new techniques need to be integrated to mitigate N losses.

Ammonia is required for the production of microbial protein and is absorbed from the reticulorumen as well as the abomasum, small intestine and the caecum (MacDonald *et al.*, 2002). The reticulorumen is the largest absorption area. Ammonia is also used by the liver as well as the mucosal cells of the rumen. Ammonia is a weak base and can penetrate the lipid layer of the rumen mucosa allowing for rapid absorption across the rumen wall (MacDonald *et al.*, 2002). Rumen fluid is not very effective at buffering other alkaline compounds and therefore if high levels of dietary N are fed a rapid accumulation of ammonia may occur in the rumen fluid resulting in a rise in rumen pH (MacDonald *et al.*, 2002). If the rate of ammonia absorption exceeds the capacity of the liver to convert it to urea then toxic levels of ammonia may be present in the blood. Ammonia is required for the production of microbial crude protein (MCP) but sufficient fermentable metabolisable energy (FME) is also required. When there is an excess of ammonia it is converted to urea in the liver and excreted. This increases the urea concentration of the urine which contributes to nitrous oxide (N_2O) emissions through N volatilisation and nitrate leaching. This issue may be partly managed after excretion through applications of nitrification inhibitors to pastures. Average annual nitrate leaching was reduced by 27% when a nitrification inhibitor (*eco-n*) was used to reduce nitrate leaching losses from a pasture soil of the Taupo region (Cameron *et al*., 2007). This provides a partial solution but cannot be used anymore and therefore it may be more effective to target the animal's digestive system in order to maximise NUE. The use of nitrification inhibitors was banned in New Zealand this year as a result of the detection of compound residues in dairy products intended for export. This compound had been widely used over the last decade to increase pasture production while reducing the N fertiliser requirement, especially in the south island of New Zealand. If the energy content of the diet can be increased to provide more FME to the rumen and therefore increase MCP production then the quantity of excess ammonia should be reduced and therefore less urea excreted. Higher dietary energy concentrations, in addition, reduce the amount of N in excreta (Kebreab *et al*., 2002) as a result of a better rumen function (Tamminga, 1996). This may be achieved by feeding supplements of high energy and low protein concentrations such as grain or maize silage to achieve an optimum dietary protein concentration. It is also argued that in pastoral systems N efficiency can be significantly improved by feeding low-N conserved forages rather than increasing energy intake (Valk, 1994; Ledgard *et al*., 2000).

Urinary N concentrations were nearly halved when a 50:50 mixture of grass and maize silage were fed (198 g/day) compared with only feeding grass silage (361 g/day) to dairy cows (Steg, 1988). This was a result of a more favourable energy and protein balance in the diet reducing the quantity of ammonia produced and increasing NUE from 17% to 24%. If NUE can be increased on farm through diet manipulation it is likely that N_2O emissions can be reduced. High protein pasture is the major component of dairy cow diets in New Zealand and the cheapest high quality feed available. For this reason it may be difficult to reduce nitrate leaching through dietary manipulation unless some incentive is available to compensate farmers for increased feeding costs if the level of pasture feeding is reduced. For higher input systems it may be easier to increase NUE through the use of high energy supplements to balance the energy and protein supply to the rumen.

2.4 Conclusions

1. Grazing to low PGPH improves pasture quality when compared to higher PGPH.
2. The level of milk production response to feeding energy supplements depends on the RED of the animal.
3. Energy supplements provide a useful tool for reducing urinary N concentrations in pasture fed dairy cows by increasing NUE.

Chapter 3
Materials and Methods

3.1 Time and Location

The experiment was carried out between 15 August and 14 November 2012 at the Lincoln University Research Dairy Farm (LURDF) in Canterbury, New Zealand (43°38’S, 172°27’E). This experiment was carried out under the authority of Lincoln University Animal Ethics Committee #482.

3.2 Experimental Design

Thirty two mixed parity, spring calving, Friesian x Jersey dairy cows from the Lincoln University Research Dairy Farm (LURDF) were allocated to one of four treatments (n=8 per treatment) in a completely randomised design of 2 x 2 factorial for approximately 13 weeks to test the effects of concentrate supplementation and PGPH on milk production and nitrogen utilisation. The four groups were :(1) low PGPH (3.5 cm; equivalent to 7 clicks on the rising plate meter (RPM)) (LR); (2) low PGPH plus concentrate (LR+); (3) high PGPH (4.5 cm; equivalent to 9 clicks on RPM) (HR); (4) high PGPH plus concentrate (HR+), were each allocated to one of four farmlets.

Cows were blocked into groups based on age (4.8 ± 0.2 years), DIM (15 ± 2 days), LW (427 ± 13 kg), BW (121.5 ± 7.5 BW), and previous MS production (389 ± 7 kg MS/cow/year). Following the colostrum period (early to mid August), cows progressed to their groups as they calved.

3.3 Management

3.3.1 Concentrate Allocation

One week prior to the commencement of the trial, cows were offered 1 kg DM/cow/day of a pelleted concentrate in the milking parlour to encourage rumen adaptation and to ensure cows were familiar with the concentrate when the trial began. The concentrate consisted of wheat (56.9%), maize (15.2%), canola (10.9%), peas (13.0%), molasses (1.0%) and minerals, vitamins and additives (3.0%). The level of concentrate feeding was gradually increased over the first 2-3 weeks post calving to a consistent average of 4 kg DM/cow/day across both supplemented groups. Supplemented groups were fed twice daily through an automated concentrate feeding system. Cows were offered an average of 2 kg DM of the concentrate daily allowance in the morning and 2 kg DM in the afternoon at milking. The level of concentrate feeding varied between cows, with cows receiving either 3 or 5 kg DM/cow/day with both supplemented groups being fed an average of 4 kg DM/cow/day. Four of the cows in each group were offered 3 kg DM concentrate per day and the other four were offered 5 kg DM per day after the first 4 weeks. This was to done to minimise refusals and was based on refusal levels. Both groups had an equal number of cows being offered 3 or 5 kg DM/cow/day. Refusals were recorded every second day. Approximately 50 g sodium bicarbonate/4.5 kg DM concentrate was included as a buffer to aid in the prevention of ruminal acidosis.

3.3.2 Farmlet Structure

A total 6.91 hectares of perennial ryegrass (*Lolium perenne*; cv Trojan, heading date + 16 days) and white clover (*Trifolium repens*; cv Weka) pasture were allocated as the total milking platform for 32 cows. None of the paddocks were in the effluent application area. The area was divided into 4 farmlets which accommodated 8 cows each. Each treatment group was confined to its own farmlet throughout the duration of the trial. Temporary electric fences were used to divide each farmlet into a practical number of paddocks to imitate a real farm situation. Seventeen paddocks were assigned to each of the supplemented groups and nineteen paddocks to each of the unsupplemented groups. SR was 4.4 cows/ha for the unsupplemented groups. The SR for the supplemented groups was 4.9 cows/ha to ensure pasture PGPH was maintained at the specified level and to prevent a large increase in average pasture cover (APC) as it was assumed some pasture substitution would occur with supplemented groups. Pasture and supplement allocation was estimated at 14 kg DM/cow/day above target PGPH at the commencement of the trial and was increased to 18 kg DM/cow/day by 1 kg DM/cow/week.

3.3.3 Grazing Management

PGPH was monitored throughout the day and cows were moved to a new paddock when the desired PGPH was met according to the treatment group. This meant that the time spent in each paddock was not consistent throughout the entire period of the trial. Daily pasture allocations were given after the afternoon milking for the first four weeks, however, new pasture allocations were offered only when cows reached their target PGPH. Target PGPH was 3.5 cm for LR and LR+ and 4.5 cm for HR and HR+ groups. Pasture height was measured weekly using a rising plate meter (Jenquip EC-09 Electronic Pasture Meter) to determine APC and pasture growth rates. A minimum of thirty RPM readings were taken in each paddock to determine pre or post grazing pasture height. Pasture growth rates were calculated and a feed wedge produced for each treatment group to show surplus and deficits. PGPH was monitored very closely for the first few weeks to ensure cows were achieving specified PGPH on a daily basis. When pasture surpluses were identified a decision was made to cut certain paddocks in an effort to maintain pasture quality. Pasture was cut to the desired PGPH according to treatment group. Three paddocks from each of the low PGPH treatment farmlets were mown to desired PGPH in rotation 3 as pre grazing mass exceeded ideal pre grazing mass. These paddocks were then grazed by the main herd of LURDF to remove surplus pasture. Lucerne silage was fed throughout the first rotation to maintain rotation length. Quantities fed were calculated based on estimated DMI during the first few weeks post calving and pre grazing pasture mass. Cows consumed an average of 1.5 kg DM/cow/day during the first rotation. Nitrogen was applied, as urea, at 40 kg N/ha after grazing during the first rotation and reduced to 30 kg N/ha for both subsequent rotations. Gibberellic acid was also applied for the first rotation at the rate of 8 g of active ingredient/ha in the form of Progibb. Nitrogen and gibberellic acid were applied at the same rate across all treatments.

3.4 Measurements

3.4.1 Pasture Mass

Calibration of the rising plate meter

Calibration of the rising plate meter was achieved through calibration quadrats (0.245 m^2) cut to ground level with hand shears. Sixteen pre and post grazing samples were cut each week to ensure accurate RPM calibration. Each sample was weighed fresh, dried in an oven at 65 °C for 48 hours and reweighed to ascertain dry matter. The LINEST function in Microsoft Excel was used to fit the data to a linear regression equation using the pasture masses and RPM readings. The calibration cuts were taken weekly throughout the experimental period and two regression equations were used for each of the different post grazing treatment types. The equation used for the high PGPH groups was: Pasture mass/ha (kg DM/ha) = (RPM height x

134) + 104 (r^2 = 0.84). The equation used for the low PGPH groups was: Pasture mass/ha (kg DM/ha) = (RPM height x 125) + 73 (r^2 = 0.81).

Chemical and botanical composition

To determine the chemical and botanical composition of the pastures two pasture samples were collected twice weekly before the new pasture allocation was offered. The first subsample of approximately 100-200 g was separated into botanical components (perennial ryegrass, white clover, weed, dead material, reproductive material), and the fresh weight of each component recorded. The botanical components were dried in an oven at 65 °C for 48 h to ascertain the dry matter of each component. A second subsample of approximately 100-200 g was taken from each of the pasture samples and frozen at -20 °C. This subsample was freeze-dried and ground to 1 mm for analysis using near-infrared spectrophotometry (Feed and Forage Analyser, FOSS Analytical, Hilleroed, Denmark). Samples were bulked weekly and dried at 60^{o}C for analysis of nutrient composition. Samples were analysed for ash, acid and neutral detergent fibres (ADF, NDF), lipid, crude protein (CP) and soluble sugars and starch (SSS). Pasture ME (MJ/kg DM) = 0.016 DOMD, where DOMD = g digestible organic matter per kg dry matter obtained from Near Infrared Reflectance Spectroscopy (NIRS) analysis, McDonald *et al.* (2002).

3.4.2 Supplements

Concentrate was sampled weekly for full nutritional analysis. The samples were freeze dried for 48 hours and then ground to 1 mm (ZM 200, Retsch). Samples were then measured by NIRS for DM, CP, crude fat, NDF, ADF, MJ ME/kg DM (Foss Feed & Forage Analyser 5000). Water soluble carbohydrates and total sugar content were measured using the Anthrone Reaction based on the extraction method of Pollock and Jones (1979). Concentrate ME (MJ/kg DM) = 0.138 DOMD + 0.272 EE + 0.86, where DOMD = g digestible organic matter per kg DM and EE = ether extract obtained from NIRS analysis (CSIRO, 2007).

Table 3.1 Chemical composition of supplements

	Feed Type	
	Concentrate	**Lucerne Silage**
DM, %	87.00	45.00
NDF, % DM	17.20	31.20
ADF, % DM	6.50	23.90
WSC, % DM	5.80	2.07
CP, % DM	17.75	21.50
ME, MJ	13.73	10.80
DMD, %	90.70	76.60
OM, %	95.62	83.90

3.4.3 Milk Samples

All cows were milked twice daily, in the morning (07:00 h) and in the afternoon (15.00 h). Milk yield (l) was recorded daily for each cow using an automatic milk recording system and samples were taken for milk composition from consecutive evening and morning milking every 7 days. Two milk samples were taken on every sampling day, one sample was sent to LIC (Livestock Improvement Corporation) for analysis of fat, lactose and protein percentages using the Milk-o-scan infrared analyser (Foss Electric Ltd). The other sample was centrifuged at 3500 x g for 10 m at room temperature (22 ^{o}C), before being refrigerated for a further 10 m to solidify the fat layer. After 10 m the fat layer was removed and a subsample of the skim milk was pipetted into a clean microcentrifuge tube and this skim milk sample was frozen at –20 ^{o}C. The sample was later measured for milk urea N content with the Enzymatic Kinetic UV assay using the Randox Kinetic Kit (Randox Rx Daytona, 2010). The MUN was calculated as the molar concentration of milk urea multiplied by two.

3.4.4 Liveweight and Body Condition Score

LW was recorded daily using a walk over scale post milking. Body condition score (BCS) (1-10 scale; Roche *et al.*, 2004) was recorded three times during the period of the trial (Aug 28, Oct 4 and Nov 15). The scoring was performed on all three occasions by Brenda Lynch, Dairy NZ.

3.4.5 Estimating Dry Matter Intake

Pasture dry matter intake was calculated by dividing ME requirement from pasture by pasture ME concentration. ME requirement from pasture was calculated as the sum of ME requirements of maintenance, activity and lactation less the energy supplied by the supplement (Holmes and Roche, 2007). SubR (kg/kg) = (pasture DMI in unsupplemented treatments minus pasture DMI for supplemented treatment)/supplement DMI (Clark and Woodward, 2007). Pasture DMI = pasture ME requirement/pasture ME. Pasture ME requirement = (ME maintenance + ME activity + ME lactation) – (MEI concentrate + MEI silage), where MEI = metabolisable energy intake.

3.4.6 Urine Samples

Urine sampling was performed monthly immediately after consecutive afternoon and morning milkings were complete. Urine samples were taken mid-stream after manual stimulation of the vulva, then acidified below a pH of 4.0 using concentrated sulphuric acid to prevent volatilization, and then frozen at -20 ^{o}C until analysis. Urine samples were analysed for total N, creatinine, urea-N, ammonia N and purine derivatives. Samples for creatinine analysis were kept at 4 ^{o}C and analysed within 96 h of sampling. Samples for N were acidified and kept at -20 ^{o}C until analysis. Urine and faecal N%, as well as urine ammonia, urine urea and plasma urea concentrations, were determined using an N-analyser (Vario MAX CN, Elementar Analysensysteme, Hanau, Germany). Creatinine concentration of urine was determined by the Jaffé method (Bartels and Böhmer, 1971; Cobas Mira Plus Analyzer, Roche Hitachi, Basel, Switzerland). Urinary nitrogen was calculated using an equation developed by Pacheco *et al.* (2009), where total urine collection was performed in lactating pasture fed dairy cows: Urinary N (g/d) = ((21.9 x BW)/creatinine (mg/kg)) x N (g/kg).

3.4.7 Faecal Samples

Faecal sampling was performed monthly immediately after consecutive afternoon and morning milkings were complete. Samples were collected in plastic containers (250 ml) after voluntary defecation or after stimulation of defecation by rubbing the rectal wall. Faecal samples were then frozen at – 20 ^{o}C. Samples were later defrosted and subsampled. Two subsamples were taken, one was weighed and then dried at 100 ^{o}C for 48 hours and then re-weighed to determine faecal DM%, the second subsample was freeze dried before being ground through a 1 mm screen to reduce particle size and ensure uniformity of particle dimension. This sample was then analysed for N content in the LU lab by combustion under oxygen supply and high temperatures using the Variomax CN Analyser; Elementar.

3.4.8 Milk Response

The MR was calculated as the difference between the total milk production per hectare of the supplemented group less the total milk production per hectare of the unsupplemented group divided by the total quantity of concentrate consumed per hectare during the 13 week period. The MR was calculated separately for high and low PGPH and the mean MR was the average of the two.

3.4.9 Statistical Analysis

Pre and post pasture mass and pasture height, botanical and chemical composition of pasture, milk yield and composition, LW, BCS, forage DMI, total DMI, N partitioning and N utilisation were analysed within each rotation (weeks: 1-5 first, 6-9 second, and 10-12 third rotation) using the residual maximum likelihood procedure of GenStat (REML, GenStat 12.2 VSN International). PGPH and concentrate and their interaction were used as fixed terms in the model and cow was included as a random effect. Standard errors of chemical composition variation were determined for herbage samples across paddocks and for each bulk batch of concentrate.

Chapter 4
Results

4.1 Pasture Mass

Mean pre and post grazing pasture mass and height were averaged over 13 weeks (Table 4.1). Pre grazing pasture mass was significantly higher for high than low PGPH. Pre grazing pasture mass was significantly lower for supplemented groups than unsupplemented groups. Post grazing pasture mass was significantly higher for high than low PGPH groups. Pre grazing pasture height was significantly lower for supplemented than unsupplemented groups while pre grazing pasture mass was significantly higher for high than low PGPH groups. Post grazing pasture mass was significantly higher for high than low PGPH groups. Analysis showed significant interactions for post grazing pasture mass and PGPH, post grazing pasture mass and PGPH were less for supplemented than unsupplemented groups at low PGPH. However, at high PGPH, post grazing pasture mass and PGPH were greater for supplemented than unsupplemented groups .

Table 4.1 Pre and post herbage mass and height of pastures grazed to low and high post grazing pasture height with and without supplementation.

	Treatment					P Value		
	LR[1]	LR+[2]	HR[3]	HR+[4]	SEM	Conc[5]	PGPH[6]	Conc x PGPH[7]
Pasture mass (pre), kg DM/ha	2455	2325	2881	2668	47.59	<0.001	<0.001	NS[8]
Pasture mass (post), kg DM/ha	1005	986	1276	1308	11.76	NS	<0.001	0.002
Pasture height (pre), RPM clicks	19.06	18.02	20.78	19.19	0.37	<0.001	<0.001	NS
Pasture height (post), RPM clicks	7.46	7.31	8.77	9.01	0.09	NS	<0.001	0.002

[1]LR = Low PGPH unsupplemented; [2]LR+ = Low PGPH supplemented; [3]HR = High PGPH unsupplemented; [4]HR+ = High PGPH supplemented; [5]Conc = Main effect of concentrate supplementation, [6]PGPH = main effect of PGPH, [7]Conc x PGPH = concentrate supplementation by PGPH. [8]NS = Non-significant.

4.2 Pasture

4.2.1 Botanical Composition

There were no significant differences between the botanical compositions of the pastures consumed by each of the groups in any rotation (Table 4.2). Pastures were dominated by ryegrass (90%) and white clover (8%) with small amounts of weed (1%) and dead material (1%).

Table 4.2 Botanical composition of pastures grazed to low and high post grazing pasture height with and without supplementation.

		Treatment					P Value		
	Rotation	LR[1]	LR+[2]	HR[3]	HR+[4]	SEM	Conc[5]	PGPH[6]	Conc x PGPH[7]
Ryegrass, %	1	88	90	91	92	3	NS[8]	NS	NS
	2	84	93	88	92	4	NS	NS	NS
	3	86	90	91	94	3	NS	NS	NS
White clover, %	1	7	6	6	6	3	NS	NS	NS
	2	15	6	10	5	4	NS	NS	NS
	3	13	9	7	5	3	NS	NS	NS
Weeds, %	1	1	1	0	0	1	NS	NS	NS
	2	1	0	2	2	1	NS	NS	NS
	3	0	0	0	0	0	NS	NS	NS
Dead, %	1	4	3	3	2	2	NS	NS	NS
	2	1	0	0	0	0	NS	NS	NS
	3	1	0	1	1	1	NS	NS	NS

[1]LR = Low PGPH unsupplemented; [2]LR+ = Low PGPH supplemented; [3]HR = High PGPH unsupplemented; [4]HR+ = High PGPH supplemented; [5]Conc = Main effect of concentrate supplementation, [6]PGPH = main effect of PGPH, [7]Conc x PGPH = concentrate supplementation by PGPH. [8]NS = Non-significant.

4.2.2 Chemical Composition

The NDF% of the pastures was significantly lower for supplemented than unsupplemented groups in rotation 1 (Table 4.3). The water soluble carbohydrate (WSC) percentage of the pastures was significantly lower for supplemented than unsupplemented groups in rotations 2 and 3. The CP% was significantly higher in the pastures grazed by the supplemented than unsupplemented groups in all 3 rotations.

Table 4.3 Chemical composition of pastures grazed to low and high post grazing pasture height with and without supplementation.

		Treatment					P Value		
	Rotation	**LR[1]**	**LR+[2]**	**HR[3]**	**HR+[4]**	**SEM**	**Conc[5]**	**PGPH[6]**	**Conc x PGPH[7]**
DM, %	1	17.00	17.00	18.00	18.00	0.96	NS[8]	NS	NS
	2	18.00	18.00	19.00	18.00	0.71	NS	NS	NS
	3	17.00	18.00	18.00	16.00	0.49	NS	NS	NS
NDF, % DM	1	38.38	35.79	36.61	36.05	0.55	0.01	NS	0.04
	2	37.44	36.62	37.63	38.58	1.11	NS	NS	NS
	3	40.11	39.04	41.36	42.86	1.73	NS	NS	NS
ADF, % DM	1	20.54	19.23	19.46	19.21	0.50	NS	NS	NS
	2	20.28	19.66	20.32	20.36	0.51	NS	NS	NS
	3	22.32	21.41	22.72	22.98	1.00	NS	NS	NS
WSC, % DM	1	28.83	28.98	29.65	28.02	1.55	NS	NS	NS
	2	27.91	25.79	25.10	23.37	1.14	0.03	0.01	NS
	3	24.41	24.26	26.82	21.60	1.53	0.03	NS	0.03
CP, % DM	1	16.83	18.92	18.11	19.64	0.83	0.02	NS	NS
	2	18.59	21.33	20.51	22.03	1.22	0.03	NS	NS
	3	17.99	19.64	16.13	19.35	1.43	0.03	NS	NS
MJ ME	1	12.52	12.65	12.75	12.62	0.16	NS	NS	NS
	2	12.68	12.66	12.51	12.47	0.09	NS	NS	NS
	3	12.13	12.26	12.16	11.99	0.15	NS	NS	NS
DMD, %	1	82.59	83.33	83.85	83.40	0.67	NS	NS	NS
	2	82.76	83.11	82.46	82.37	0.53	NS	NS	NS
	3	80.37	81.05	80.08	79.52	1.02	NS	NS	NS
OM, %	1	91.39	91.60	91.76	91.27	0.66	NS	NS	NS
	2	92.43	91.92	91.52	91.33	0.23	0.05	<0.001	NS
	3	90.91	91.14	91.45	90.84	0.26	NS	NS	0.04

[1]LR = Low PGPH unsupplemented; [2]LR+ = Low PGPH supplemented; [3]HR = High PGPH unsupplemented; [4]HR+ = High PGPH supplemented; [5]Conc = Main effect of concentrate supplementation, [6]PGPH = main effect of PGPH, [7]Conc x PGPH = concentrate supplementation by PGPH. [8]NS = Non-significant.

4.3 Milk Production and Composition

Milk yield and MS production were significantly higher for supplemented than unsupplemented groups in all three rotations (Table 4.4). There was a significant interaction for milk yield in rotation 3. This was due to better utilisation of nutrients provided when cows were less restricted. Milk protein percentage was significantly higher for supplemented (LR+, 3.89%; HR+, 3.84%) than unsupplemented groups (LR, 3.62%; HR, 3.67%) in rotation 3. MUN concentrations were significantly lower for supplemented than unsupplemented groups in rotations 2 and 3. There was a significant interaction for MUN in rotation 3. MUN, in rotation 3, was decreased by supplementation at low PGPH but increased by supplementation at high PGPH.

Table 4.4 Mean milk parameters of cows grazed to low and high post grazing pasture height with and without supplementation.

	Rotation	Treatment				SEM	P Value		
		LR[1]	LR+[2]	HR[3]	HR+[4]		Conc[5]	PGPH[6]	Conc x PGPH[7]
Milk Yield, kg milk/d	1	21.37	22.86	21.77	24.26	0.73	<0.001	NS[8]	NS
	2	22.84	24.53	22.82	25.98	0.85	<0.001	NS	NS
	3	21.13	23.34	20.05	24.74	0.83	<0.001	NS	0.048
Protein, %	1	3.53	3.57	3.62	3.61	0.08	NS	NS	NS
	2	3.65	3.75	3.70	3.71	0.09	NS	NS	NS
	3	3.62	3.89	3.67	3.84	0.12	0.017	NS	NS
Fat, %	1	5.17	5.01	5.31	5.14	0.17	NS	NS	NS
	2	5.48	5.05	5.34	4.92	0.18	0.003	NS	NS
	3	5.17	4.97	5.19	4.89	0.18	NS	NS	NS
MS, kg/d	1	1.87	1.96	1.93	2.12	0.04	<0.001	<0.001	NS
	2	2.08	2.15	2.06	2.25	0.06	0.004	NS	NS
	3	1.85	2.08	1.78	2.17	0.06	<0.001	NS	NS
MUN, mmol/l	1	8.27	8.16	9.27	9.08	0.38	NS	0.002	NS
	2	8.98	7.92	8.94	7.89	0.42	0.002	NS	NS
	3	8.61	6.22	7.23	7.79	0.47	0.012	NS	<0.001

[1]LR = Low PGPH unsupplemented; [2]LR+ = Low PGPH supplemented; [3]HR = High PGPH unsupplemented; [4]HR+ = High PGPH supplemented; [5]Conc = Main effect of concentrate supplementation, [6]PGPH = main effect of PGPH, [7]Conc x PGPH = concentrate supplementation by PGPH. [8]NS = Non-significant.

4.4 Liveweight and Body Condition Score

There was no significant difference in LW gain across all groups over the entire duration of the trial (Table 4.5). BCS gain was significantly higher for supplemented (LR+, 0.13; HR+, 0.44) than unsupplemented groups (LR, 0.19; HR, 0.06) during the entire trial.

Table 4.5 Liveweight and body condition score of cows grazed to low and high post grazing pasture height with and without supplementation.

	Rotation	Treatment				SEM	P Value		
		LR[1]	LR+[2]	HR[3]	HR+[4]		Conc[5]	PGPH[6]	Conc x PGPH[7]
LW, kg	1	418	445	422	444	16.35	0.046	NS[8]	NS
	2	435	458	439	457	14.63	NS	NS	NS
	3	442	470	447	466	15.65	0.048	NS	NS
LW Gain, kg		24	25	26	22	6	NS	NS	NS
BCS	1	3.81	4.25	3.63	4.00	0.26	0.035	NS	NS
	2	4.13	4.19	3.88	4.38	0.24	NS	NS	NS
	3	3.63	4.38	3.69	4.44	0.29	0.001	NS	NS
BCS Gain		0.19	0.13	0.06	0.44	0.18	0.012	0.035	NS

[1]LR = Low PGPH unsupplemented; [2]LR+ = Low PGPH supplemented; [3]HR = High PGPH unsupplemented; [4]HR+ = High PGPH supplemented; [5]Conc = Main effect of concentrate supplementation, [6]PGPH = main effect of PGPH, [7]Conc x PGPH = concentrate supplementation by PGPH. [8]NS = Non-significant.

4.5 Dry Matter Intake

Forage DMI was significantly lower for supplemented than unsupplemented groups throughout all three rotations (Table 4.6). Forage and total DMI were greater for supplemented than unsupplemented groups in rotation 1. Concentrate supplementation significantly increased total DMI throughout all 3 rotations. The analysis only showed significant interactions for forage DMI and total DMI in rotation 3. The LR group had the highest forage DMI in rotation 3 (15.08 kg DM/d) while HR+ had the highest total DMI in rotation 3 (16.84 kg DM/d).

Table 4.6 DMI of cows grazed to low and high post grazing pasture height with and without supplementation.

		Treatment					P Value		
	Rotation	LR[1]	LR+[2]	HR[3]	HR+[4]	SEM	Conc[5]	PGPH[6]	Conc x PGPH[7]
Forage DMI, kg	1	14.96	13.34	15.16	14.12	0.3154	<0.001	0.039	NS[8]
	2	15.20	13.20	15.45	13.42	0.34	<0.001	NS	NS
	3	15.08	12.27	14.65	13.20	0.30	<0.001	NS	0.005
Total DMI, kg	1	14.96	15.34	15.16	16.12	0.32	0.007	0.039	NS
	2	15.20	15.80	15.45	16.56	0.34	0.002	NS	NS
	3	15.08	15.92	14.65	16.84	0.30	<0.001	NS	0.005

[1]LR = Low PGPH unsupplemented; [2]LR+ = Low PGPH supplemented; [3]HR = High PGPH unsupplemented; [4]HR+ = High PGPH supplemented; [5]Conc = Main effect of concentrate supplementation, [6]PGPH = main effect of PGPH, [7]Conc x PGPH = concentrate supplementation by PGPH. [8]NS = Non-significant.

4.6 Substitution Rate

SubR was higher for low PGPH groups throughout all 3 rotations (Table 4.7). The mean SubR (on DMI basis) was 0.63 for LR and 0.23 for HR. The mean SubR (on MEI basis) was 0.55 for LR and 0.24 for HR.

Table 4.7 Substitution rate measurements of cows grazed to low and high post grazing pasture height with and without supplementation.

		Treatment			
	Rotation	LR[1]	LR	HR[2]	HR
SubR DMI[3]	1	0.35		-0.36	
	2	0.77		0.64	
	3	0.77		0.40	
Mean SubR DMI			0.63		0.23
SubR MEI[4]	1	0.27		-0.28	
	2	0.72		0.60	
	3	0.65		0.39	
Mean SubR MEI			0.55		0.24

[1]LR = Low PGPH; [2]HR = High PGPH; [3]SubR DMI = Substitution rate (Dry matter intake basis); [4]SubR MEI = Substitution rate (Metabolisable energy intake basis).

4.7 Urine

Urine urea N and urine N concentration were significantly higher for supplemented than unsupplemented groups in rotation 3 (Table 4.8). The analysis showed significant interactions in rotation3 for urea N, creatinine and urine N concentration. Urea N, creatinine and urine N concentrations were lower in HR than LR, LR+ and HR+ in rotation 3.

Table 4.8 Mean urine parameters of cows grazed to low and high post grazing pasture height with and without supplementation.

		Treatment					P Value		
	Rotation	LR[1]	LR+[2]	HR[3]	HR+[4]	SEM	Conc[5]	PGPH[6]	Conc x PGPH[7]
Urea N, mmol/l	1	131	168	134	155	25	NS[8]	NS	NS
	2	146	128	112	178	16	0.048	NS	0.001
	3	128	121	61	124	13	0.005	0.002	<0.001
NH_3, mmol/l	1	0.70	0.70	0.73	0.81	0.18	NS	NS	NS
	2	0.63	1.18	0.97	1.56	0.24	0.003	0.043	NS
	3	1.61	2.70	1.81	2.33	0.72	NS	NS	NS
Creatinine, mmol/l	1	2.69	2.95	1.95	2.68	0.53	NS	NS	NS
	2	2.80	3.55	1.55	2.11	0.47	NS	<0.001	NS
	3	3.25	2.95	1.84	3.62	0.46	0.034	NS	0.005
Urine N, %	1	0.52	0.64	0.50	0.56	0.09	NS	NS	NS
	2	0.58	0.52	0.42	0.64	0.06	NS	NS	0.002
	3	0.55	0.55	0.31	0.58	0.06	0.003	0.019	0.003

[1]LR = Low PGPH unsupplemented; [2]LR+ = Low PGPH supplemented; [3]HR = High PGPH unsupplemented; [4]HR+ = High PGPH supplemented; [5]Conc = Main effect of concentrate supplementation, [6]PGPH = main effect of PGPH, [7]Conc x PGPH = concentrate supplementation by PGPH. [8]NS = Non-significant.

4.8 Faeces

Faecal N% was significantly lower for supplemented than unsupplemented groups in rotation 2 but significantly higher for supplemented than unsupplemented groups in rotation 3 (Table 4.9). Faecal N% was significantly higher for high than low PGPH groups. There was also a significant interaction between supplementation and PGPH in rotation 3 for faecal N%. Faecal ash% was significantly higher for high than low PGPH groups in rotation 1 but significantly lower for high than low PGPH groups in rotations 2 and 3.

Table 4.9 Mean faecal parameters of cows grazed to low and high post grazing pasture height with and without supplementation.

		Treatment					P <[5]		
	Rotation	LR[1]	LR+[2]	HR[3]	HR+[4]	SEM	Conc[5]	PGPH[6]	Conc x PGPH[7]
Faecal DM, %	1	11.59	13.72	14.08	14.06	1.13	NS[8]	NS	NS
	2	9.69	13.09	11.50	11.30	0.95	0.027	NS	0.014
	3	10.56	14.18	11.77	10.73	1.38	NS	NS	0.026
Faecal N, %	1	3.60	3.32	3.29	3.35	0.11	NS	NS	0.037
	2	3.76	3.47	3.96	3.68	0.14	0.011	NS	NS
	3	2.83	3.11	2.84	3.50	0.10	<0.001	0.012	0.015
Faecal Ash, %	1	28.83	29.52	32.70	33.37	1.64	NS	0.003	NS
	2	25.04	25.36	22.34	24.70	1.06	NS	0.036	NS
	3	26.91	28.32	25.65	23.75	1.49	NS	0.012	NS

[1]LR = Low PGPH unsupplemented; [2]LR+ = Low PGPH supplemented; [3]HR = High PGPH unsupplemented; [4]HR+ = High PGPH supplemented; [5]Conc = Main effect of concentrate supplementation, [6]PGPH = main effect of PGPH, [7]Conc x PGPH = concentrate supplementation by PGPH. [8]NS = Non-significant.

4.9 Milk Response

The average MR from supplementation and higher SR was 0.14 kg MS/kg DM for the first 13 weeks of lactation (Table 4.10). The response was greater at high PGPH (0.16 kg MS/kg DM) than low PGPH (0.12 kg MS/kg DM). Short term profitability was greater at high PGPH than low PGPH. At $500/t concentrate, $7/kg MS and with high PGPH it was profitable to produce 1 kg MS by $2.83.

Table 4.10 Milk response, cost of production and margin over feed costs of cows grazed to low and high post grazing pasture height with and without supplementation.

Milk Response	Treatment [1]LR	Treatment [2]HR	Mean
Milk Yield, kg milk/kg DM	1.48	1.95	1.71
MS, kg MS/kg DM	0.12	0.16	0.14
MS, g MS/MJ ME	8.51	11.41	9.96
Cost of Production ($/kg MS)			
Cost of Concentrate			
$400/t ($460/t DM)	3.94	2.94	3.36
$500/t ($570/t DM)	4.88	3.64	4.17
$600/t ($690/t DM)	5.91	4.41	5.05

[3]*MOFC ($/kg MS)*	Milk Payout ($/kg MS)								
Cost of Concentrate	*$6*	*$7*	*$8*	*$6*	*$7*	*$8*	*$6*	*$7*	*$8*
$400/t	2.06	3.06	4.06	3.06	4.06	5.06	2.64	3.64	4.64
$500/t	1.12	2.12	3.12	2.36	3.36	4.36	1.83	2.83	3.83
$600/t	0.09	1.09	2.09	1.59	2.59	3.59	0.95	1.95	2.95

[1]LR = Low PGPH, [2]HR = High PGPH, [3]MOFC = Margin Over Feed Costs.

4.10 Nitrogen Utilisation

Forage N intake was significantly higher for high than low PGPH groups in all 3 rotations (Table 4.11). Forage N intake was significantly lower in rotation 1, for supplemented than unsupplemented groups. There was a significant interaction in rotation 3 for forage N intake. Forage N intake was lower for supplemented than unsupplemented groups at low PGPH but higher for supplemented than unsupplemented groups at high PGPH. Total N intake was significantly higher for supplemented than unsupplemented groups and for high than low PGPH groups in all 3 rotations.

Faecal N%, as a percentage of N intake, was significantly higher for supplemented than unsupplemented groups in all rotations. Urinary N%, as a percentage of N intake, was significantly higher for high than low PGPH groups in rotation 2. Milk N%, as a percentage of N intake, was significantly higher in all rotations for supplemented than unsupplemented groups. There were significant interactions for faecal N%, urinary N% and milk N% as a % of N intake in rotation 3. There was also a significant interaction effect for NUE in rotation 3, NUE was higher in supplemented than unsupplemented groups at low PGPH, however, NUE was lower in supplemented than unsupplemented groups at high PGPH.

Table 4.11 Efficiency of nitrogen utilisation of cows grazed to low and high post grazing pasture height with and without supplementation.

		Treatment					P Value		
	Rotation	**LR[1]**	**LR+[2]**	**HR[3]**	**HR+[4]**	**SEM**	**Conc[5]**	**PGPH[6]**	**Conc x PGPH[7]**
N Intake, g/d									
Forage	1	437	419	468	454	10.38	0.041	<0.001	NS[8]
	2	452	450	507	473	13.20	NS	<0.001	NS
	3	434	386	378	409	10.09	NS	0.031	<0.001
Concentrate	1	0	57	0	57				
	2	0	74	0	89				
	3	0	103	0	103				
Total	1	437	475	468	511	10.38	<0.001	<0.001	NS
	2	452	524	507	562	13.20	<0.001	<0.001	NS
	3	434	489	378	512	10.09	<0.001	0.029	<0.001
N Excretion, g/d									
Faecal N	1	156	152	134	191	15.79	0.026	NS	0.013
	2	144	236	142	140	14.73	<0.001	<0.001	<0.001
	3	165	168	114	218	13.82	<0.001	NS	<0.001
Urine N	1	162	195	211	182	15.07	NS	NS	0.009
	2	178	144	233	272	15.40	NS	<0.001	0.003
	3	149	179	149	145	14.74	NS	NS	NS
Milk N	1	119	128	123	138	3.49	<0.001	0.01	NS
	2	130	144	132	151	4.43	<0.001	NS	NS
	3	120	142	116	149	4.82	<0.001	NS	NS
N, % N Intake									
Faecal N	1	36	33	29	37	3.20	NS	NS	0.02
	2	32	45	28	24	3.19	0.035	<0.001	<0.001
	3	38	34	30	42	3.29	NS	NS	0.003
Urine N	1	37	41	45	36	3.31	NS	NS	0.018
	2	40	27	46	49	3.03	0.039	<0.001	0.002
	3	35	37	40	29	3.08	NS	NS	0.008
Milk N	1	27	27	26	27	0.35	NS	0.044	NS
	2	29	27	26	27	0.38	NS	<0.001	<0.001
	3	28	29	31	29	0.68	NS	0.006	0.007
NUE	1	0.27	0.27	0.26	0.27	0.003	NS	0.044	NS
	2	0.29	0.27	0.26	0.27	0.004	NS	<0.001	<0.001
	3	0.28	0.29	0.31	0.29	0.007	NS	0.006	0.007

[1]LR = Low PGPH unsupplemented; [2]LR+ = Low PGPH supplemented; [3]HR = High PGPH unsupplemented; [4]HR+ = High PGPH supplemented; [5]Conc = Main effect of concentrate supplementation, [6]PGPH = main effect of PGPH, [7]Conc x PGPH = concentrate supplementation by PGPH. [8]NS = Non-significant.

Chapter 5
Discussion

The experiment was designed to test the effect of energy supplementation and different PGPH on milk production and N utilisation of New Zealand dairy cows. This was achieved by comparison of cows offered a concentrate supplement at milking times and grazing to a high or low PGPH with cows fed only pasture grazing to a high or low PGPH. Supplemented groups consumed on average 4 kg DM/d of a pelleted concentrate. Measurements of pasture, DMI, milk, urine and faeces parameters in response to treatments gave the following key results:

1. Concentrate supplementation significantly increased average milk yield (24.04 kg milk/d versus 20.59 kg milk/d) and average MS production (2.13 kg/d versus 1.82 kg/d) compared with unsupplemented groups across 3 rotations.
2. Average MR to supplementation and higher SR was 1.71 kg milk/kg DM or 0.14 kg MS/kg DM or 9.96 g MS/MJ ME.
3. Average milk protein percentage was higher (3.87% versus 3.65%) and average MUN was lower (7 mmol/l versus 7.92 mmol/l) in rotation 3 for supplemented groups compared with unsupplemented groups.
4. Average total N intake was higher for supplemented groups (495 g/d versus 406 g/d) compared with unsupplemented groups in rotation 3.
5. Average BCS gain was higher for supplemented than unsupplemented groups (0.29 versus 0.13) over the whole period.
6. PGPH did not affect milk production or pasture quality in the first 13 weeks of lactation.

5.1 Milk Yield and Milksolids Production

The calculated MS response ranged from 0.12 kg MS/kg DM to 0.16 kg MS/kg DM with an average MS response of 0.14 kg MS/kg DM. The responses reported in this study are short term only (first 13 weeks of lactation) as this study did not measure any long term responses.

The long term response may be significantly greater than the short term response measured in this trial.

Milk yield and MS production increased with concentrate supplementation in all 3 rotations. The response to supplementation at low PGPH was 1.48 kg milk/kg DM of concentrate. The response to supplementation at high PGPH was 1.95 kg milk/kg DM of concentrate. The mean response was 1.71 kg milk/kg DM of concentrate. The response to concentrate supplementation was a result of increasing individual cow performance and increasing milk production per hectare through SR adjustment. Increasing SR for supplemented groups was necessary to avoid pasture wastage. These responses are slightly higher than those reported in a recent review of the production and digestion of supplemented dairy cows on pasture (Bargo *et al.,* 2003) which ranged from 0.60 (Sayers, 1999) to 1.45 kg milk/kg concentrate (Gibb *et al.,* 2002). The calculated MRs also account for differences in SR to allow for accurate comparisons of the different farmlet systems. An average response of 80 g MS/kg DM additional feed and increased SR was also reported when SR was 3.8 cows/ha and 5.0 cows/ha for unsupplemented and supplemented groups respectively (Dalley *et al*., 2005).

Marginal MR decreased above 3 to 4 kg DM/d of concentrate in some studies, but this is not consistent and occurred primarily when pasture quality and quantity were not limiting and with cows of moderate genetic merit (Peyraud and Delaby, 2001). The increased milk production can probably be explained by the increase in total DMI providing extra energy for milk production. Total DMI increased by 0.60 kg DM/cow/d at low PGPH and 1.42 kg DM/cow/d at high PGPH as a result of concentrate supplementation over the 3 rotations.

There was little effect of increased PGPH on milk yield and MS production. Other work has shown increasing PGPH from 3.5 to 4.5 cm increased milk and MS yield as a result of greater herbage DMI (Ganche *et al*., 2013) and that milk yield was negatively correlated with PGPH (Lee *et al.,* 2008), however this was not the case in this study. Any effect of PGPH will depend on herbage DMI and quality. In this study the calculated herbage DMI was greater at high than low PGPH in rotation 1 and 2. Further there was little effect of PGPH on pasture quality, ME was calculated from DOMD% and was unaffected by PGPH. This is consistent with other work where cows were able to select pasture of similarly high quality (mean 12.3 MJ ME/kg DM) grazing to low (5-7 cm) or high (7-9 cm) PGPH (Pulido and Leaver, 2003).

The fate of energy in the "average" response to 1 kg DM (12 MJ ME/kg DM) extra feed using the average values for short term responses from Penno (2002), plus probable events and average values for whole system responses from six long term studies in New Zealand was calculated (Holmes and Roche, 2007). The short term MS response was calculated to be 50 g MS/kg DM while a long term response of 80 – 100 g MS/kg DM was calculated. Potential energy losses, from pasture wastage and pasture quality decline, and potential benefits such as increased BCS, improved fertility and increased DIM were considered in the calculation. The full (long term) response to supplements therefore depends not only on the short term response, but also on the final fates of extra LW gained and the substituted pasture (Holmes and Roche, 2007). If some of these are utilised in the current, or even the next lactation, then the final total response to the extra energy eaten will be greater than the short term response (Holmes and Roche, 2007).

Of note is the higher MR of cows grazing to the high than low PGPH. This may be a result of increased nutrient absorption due to more constant rumen fill as these cows were not required to spend extra time and energy grazing into the lower horizon of the sward which may also have been of lower energy value.

5.2 Milk Composition

Milk protein percentage increased with supplementation, at both low and high PGPH. Several other authors have reported that increasing the amount of concentrate supplementation increased milk protein percentage (Hoden *et al*., 1991; Sporndly, 1991; Wilkins *et al*., 1994; Sayers, 1999; Reis and Combs, 2000; Valentine *et al.,* 2000; Bargo *et al.,* 2002). This is a result of increasing energy intake which increases milk protein content through increased yields of microbial protein in the rumen. Stockdale (1994) summarised results from 27 experiments in Victoria where a wide range of feedstuffs had been used. He reported that starch based supplements, such as cereal grains and compounded concentrates are the best way to improve milk protein content. This improvement is believed to be due to an increase in the proportion of propionate produced in the rumen and an increased microbial crude protein synthesis (Beever *at al.,* 2001).

There was no effect of PGPH on milk composition in this study as measured by protein and fat percentage. This is in contrast to other studies where it has been reported that milk protein percentage increased with increasing PGPH (Lee *et al.,* 2008) and that decreasing PGPH decreased milk fat and protein concentrations in early lactation. The reason for no change in this study can probably be explained by the fact that pasture DMI was very similar in unsupplemented groups and there was little effect of PGPH on botanical or chemical composition of the pastures.

5.3 Substitution

SubR ranged from 0.23 for high PGPH treatments to 0.63 for low PGPH treatments when calculated on a DMI intake basis. These values are higher than those calculated in other early lactation supplementation trials. Penno *et al.* (2006) reported SubR of 0.17, 0.35 and 0.29 in early, mid and late lactation respectively. It makes sense that larger responses are expected with lower SubR as total energy intake should increase to a greater extent as was the case in this trial where a greater MR was seen at high PGPH. Pasture quality deterioration was not evident due to SubR of pasture in supplemented groups. Increasing SR combined with strict pasture management meant quality did not decline during the first 13 weeks of lactation in this trial. This is consistent with other work where the quality of pasture on offer did not decline with increasing SR (MacDonald *et al*., 2008).

5.4 Pasture Quality

There was no effect of PGPH or supplementation on pasture quality. This is in contrast to previous studies, Hoogendoorn *et al.* (1988) reported increases in leaf proportion and clover content under hard grazing (1,000 – 1,500 kg DM/ha) compared to lax grazing (2,000 – 2,500 kg DM/ha). Defoliating to 30mm during early tiller growth reduced the length of the reproductive phase and allowed plant to return to vegetative growth earlier than defoliating to 60mm (Hurley *et al.*, 2007). The difference in this trial was that all treatments were consistently returned to their respective PGPH either by grazing or mowing if APC became too high. The PGPH compared in this trial were both at the lower end of the scale used by Hoogendoorn *et al.* (1988) and remained low throughout the trial.

The CP concentration remained higher for supplemented than unsupplemented treatments throughout all 3 rotations. This may have had a small effect on total N intake between treatment groups, however, it is noteworthy that the CP concentration of all pasture approached the adequate level for milk production.

5.5 Liveweight and Body Condition Score

Body condition score gain was greater for supplemented groups over the 3 rotations. Supplemented groups gained on average 0.28 BCS while unsupplemented groups lost on average 0.06 BCS. Pulido and Leaver (2001) reported no significant effects of concentrate level on mean LW or condition score when cows were supplemented with 0, 3 or 6 kg/ d. The gains in this study were probably due to increased total DMI for supplemented cows resulting in higher daily energy intake. Positive effects on reproduction may be achieved through reducing the *post partum* anoestrous interval (Holmes and Roche, 2007).

5.6 Urinary Nitrogen Percentage and Losses

Urinary N concentration ranged from 0.31% to 0.64%. These are similar values to those reported by Bryant *et al.* (2010) for early lactation cows fed pasture only where urine N concentrations ranged from 0.38% to 0.60%. The N% of urine was greater for supplemented groups for high PGPH only in rotations 2 and 3. The reason for this is unclear. It does not appear to reflect simply greater N intake as increases in N intake occurred at both low and high PGPH with supplementary feeding.

There were inconsistent effects of urine N% at different levels of supplementary feeding and PGPH. N excretion is often linked to N intake (Steg, 1988). Based on this, greater N excretion would be expected for supplemented groups with higher N intake. However, of note is that N excretion in urine is not measured but rather calculated through creatinine and it is unclear how robust this method is.

The small effect of supplementation on N excretion indicates little value of using this type of supplement to reduce N excretion or N leaching. This will be accentuated by the fact that in this study supplementation use was associated with higher SR which would also contribute to more urine patches per hectare but also showed no difference. This result is specific to the pasture used in this trial and different results may have occurred with higher pasture N concentrations.

There may have been some small effects on N excretion resulting from the feeding of lucerne silage and the application of gibberellic acid to pasture during the first rotation. Gibberellic acid causes stem elongation and potentially may have caused small differences between rotations.

5.7 Faecal Nitrogen Percentage and Losses

The effects on faecal N percentage were inconclusive. Faecal N values (g N/d) were calculated for leftover N assuming no LW gain. These calculations averaged 155, 186, 130 and 183 g N/d for LR, LR+, HR and HR+ respectively. A subsequent calculation based on digestibility and N% of diet showed N values of 123, 112, 122 and 126 g N/d for LR, LR+, HR and HR+ respectively.

5.8 Nitrogen Partitioning

N intake was greater for supplemented than unsupplemented groups at high than low PGPH. An average of 28% of N intake was partitioned to milk across all treatments. These values are slightly higher than other studies (Bargo *et al.*, 2002). There was little effect of supplementation or PGPH on N% in milk which may be due to overall low N intake.

5.9 Long Term Response

In this study longer term responses to supplementation were not measured. Long term responses may reflect other benefits resulting from energy supplementation. Additional long term factors should also be considered in any economic evaluation, including increases in SR on the farm, improvement in pasture utilisation, positive effects on BCS and reproduction, increase in lactation length, and positive effects on milk composition (Kellaway and Porta, 1993).

5.10 Economics

This trial showed that the feeding of concentrate supplements in pasture based dairy farming systems is profitable. The cost of the supplement and the price of milk must be considered when calculating profitability. In this trial profitability was greater at high PGPH. This was explained by a greater MR to supplementation at high PGPH. The milk payout was $7.50/kg MS at the time of writing (13/8/13). Therefore, in the current climate it is clear that concentrate supplementation is profitable and profitability increases as the milk payout increases and the price of concentrate decreases. Further economic benefits may be achievable through improved fertility as a result of better body condition score for supplemented cows but this was not measured in this trial.

Chapter 6
Conclusion

6.1 Research Contribution

6.1.1 Concentrate Supplementation

Financial gain is possible through energy supplementation of pasture based dairy cows; however, this is dependent on milk pay out and the price of grain. Concentrate supplementation was shown to increase milk yield, milk protein and MS production in this trial. Environmental benefits were not obvious throughout the course of this trial due to similarities of CP concentration of the pasture and the supplement, but may have become evident in later lactation under similar circumstances.

6.1.2 Post Grazing Pasture Height

There is an on-going debate in the dairy industry about the most beneficial PGPH for maximising milk production and maintaining pasture quality. There were no obvious differences found in this experiment. Neither milk production differences nor environmental benefits were discovered in this trial as a result of two different PGPH.

6.2 Potential for Further Research

6.2.1 High Protein Pasture

The CP concentrations of dairy pastures in New Zealand are typically considerably higher than the pastures grazed in this experiment, especially in spring. It might be expected that irrigated, spring pastures in Canterbury would be in the region of 25% CP. If this had been the case for this experiment it would have been expected that supplementation would have diluted total N intake and therefore reduced urinary N output. It would be of interest to conduct such an experiment as pressure mounts on the dairy industry to reduce its environmental footprint.

6.2.2 Reproductive Effects

The reproductive effects of supplementation are unknown for this experiment. The extra energy provided by the supplement in this trial may have increased reproductive performance during this lactation but may also have an effect on the subsequent mating due to increased BCS of supplemented cows. Further research may shed some light on the potential benefits of supplementation for reproductive performance of pasture fed dairy cows.

6.2.3 Milk Response in Mid and Late Lactation

A greater effect of supplementation may be expected in mid and late lactation, in terms of milk production, as the production of unsupplemented cows drop off while supplemented cows reach a higher peak and hold production for longer. The potential benefits in BCS may also become more noticeable as lactation progresses with the expectation that supplemented cows would maintain better body condition throughout lactation.

Chapter 7

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