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**PASTURE MANAGEMENT TO MINIMISE  
THE DETRIMENTAL EFFECTS  
OF PRE-LAMB SHEARING**

A thesis presented in partial fulfilment of  
the requirements for the degree of  
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### ABSTRACT

The purpose of this study was to examine whether the performance of pre-lamb shorn sheep is influenced by pasture allowance in the immediate post-shearing period and whether the relationship between performance and pasture allowance differed according to whether the ewes were shorn by standard comb (SC) or cover comb (CC). The trial was replicated across two years to allow for climatic variations that occurred between seasons which could markedly affect results. Fifty four ewes were used in each year in a 3x3x2 factorial design with three shearing treatments (ST) (SC, CC, and unshorn), three sward surface height (SSH) (nominal 3, 5, and 7 cm) and two pregnancy-status treatments (single and twin). There was an interaction between ST and SSH which resulted in liveweight gains during the period from pregnancy day 115 (P115) to P135 of 275, 613 and 4518 g; 1557, 2314 and 3997 g; and 3623, 2894 and 3997 g for SC, CC and unshorn (control) ewes set-stocked on 3, 5, and 7 cm SSH, respectively. There were no effects of ST or SSH on lamb weaning weight, ewe wool growth rate or mean fibre diameter. There was no interaction between ST and SSH for lamb birth weight (LBW), but the LBW of lambs born to SC ewes ( $4.9 \pm 0.1$  kg) was significantly heavier ( $P < 0.05$ ) than those of lambs born to unshorn (control) ewes ( $4.3 \pm 0.1$  kg). Rectal temperatures of SC or CC ewes were significantly lower ( $P < 0.05$ ) than those of unshorn (control) ewes on day 2 following shearing (S2), and on S4, S8, and S20. Pasture allowance, however, did not affect rectal temperatures of shorn ewes. Blood concentrations of glucose, NEFA or 3-OHB were not influenced by ST or SSH throughout the days of measurement. There were no effects of ST or SSH on ewe organic matter intake (OMI), except on the 2nd day following shearing where the OMIs of ewes set-stocked on 3 cm ( $941 \pm 147$  g) were significantly lower than those ewes grazing 5 cm ( $1628 \pm 101$  g) or 7 cm ( $1349 \pm 135$  g) SSH pasture. The results suggested that hypothermia, as determined by rectal temperatures and induced by pre-lamb shearing, cannot be avoided by pasture management. Neither the use of a standard comb for pre-lamb shearing, nor a low pasture allowance (3 cm SSH) affected short- or long-term production parameters.

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**LIST OF ABBREVIATIONS**

°C	degree(s) celcius
°S	degree latitude South
µg	microgram(s)
µm	micrometre(s)
%	percentage
3-OHB	3 hydroxybutyrate
CC	cover comb
cm	centimetre(s)
Cr	Chromium
Cr <sub>2</sub> O <sub>3</sub>	chromic oxide
CRC	Controlled Release Capsule
CTRL	control
d	day(s)
D	Digestibility
DM	Dry Matter
FO	Faecal Output
g	gram(s)
GT	Grazing Time
h	hour(s)
HFRO	Hill Farming Research Organisation
HM	Herbage Mass
I	Intake
IB	Intake (weight pasture eaten) per bite
kg	kilogram(s)
l	litre
L	day of lactation (e.g. L80=day 80 of lactation)
LBW	Lamb Birth Weight
LCT	Lower Critical Temperature

m	metre(s)
ME	Metabolisable Energy
meq	milliequivalent
MFD	Mean Fibre Diameter
min	minute(s)
mmol	millimol
MJ	megajoules
NEFA	non-esterified fatty acids
O <sub>2</sub>	Oxygen
OF	oesophageal fistulated
OM	Organic Matter
OMI	Organic Matter Intake
P	day of pregnancy (e.g. P115=day 115 of pregnancy)
RT	Rate of Biting
S	day of shearing (e.g. L-3=3 days prior to shearing)
SBCRU	Sheep and Beef Cattle Research Unit
SC	Standard Comb
s.e.	standard error
SSH	Sward Surface Height
WGR	Wool Growth Rate
WW	Weaning Weight

## **CHAPTER I**

### **INTRODUCTION**

The purpose of this chapter is to provide an overview of the role of pasture management in minimising the detrimental effects of pre-lamb shearing. The first part of the chapter provides the background to this study and is followed by a discussion about the relative benefits of the practice of pre-lamb shearing. Issues that should be considered when pre-lamb shearing is to be adopted are listed in the third section, followed by discussion on ways to minimize the detrimental effects of shearing. Feed intake of pre-lamb shorn ewes is one of the main issues of pre-lamb shearing and therefore the fifth section discusses the factors affecting the herbage intake of grazing sheep with emphasis on pre-lamb shorn ewes. In the latter part of this chapter, the purpose and scope of the study is formulated.

### **BACKGROUND**

Sheepmeats and wool are one of New Zealand's most important export components, accounting for 15 % of the total value of New Zealand exports (SNZ 1995). Unlike the majority of the world's sheepmeat producers, who consume most of their production domestically, New Zealand exports most its production. About 96 and 69 % respectively of lamb and mutton produced in 1994, for example, were exported (NZMWBES 1995). This leads to New Zealand being the main trader of sheepmeats in the world sheepmeat market, accounting for 43 % of the world sheepmeat trade (NZMWBES 1995).

In terms of wool production, New Zealand is the second largest wool-producing country (following Australia) when output is measured on a clean wool basis. The 1994 New Zealand wool clip of 214 million kg of wool accounts for about 15 % of the world's wool production (NZMWBES 1995) and contributes to 7 % of the total value of exports from the country (SNZ 1995).

These notable achievements are, however, not entirely free of constraints. As in most temperate countries, sheep production in New Zealand is driven and is limited largely by seasonal and climatic changes.

### **The Decline in Sheep Numbers**

New Zealand's sheep numbers (mainly breeding ewes) have declined steadily from 70.3 million head in the 1981/1982 season to about 50.3 million head in 1994/1995, the lowest level for nearly three decades. Forestry and dairy, squeezing from opposite ends of the land use spectrum, are thought to be a significant cause of this decline. The position was also exacerbated by severe drought in 1988/1989 and 1992/1993 which affected the east coast regions of both islands and led to forced slaughterings of livestock.

Sheep numbers are acknowledged as one of the most important factors determining total sheep production. If numbers continue to decline, however, and national production of sheepmeat exports and wool are to be improved, or at least maintained, then production per head needs to increase.

### **Lamb mortality**

Lamb mortality is recognised as an important source of reproductive wastage, resulting in a reduction in the volume of lamb for sale. In addition, lamb deaths reduce the options for selection in breeding programmes and for culling to increase flock productivity (Alexander 1984). In New Zealand, about 6 million lambs, or about 15 % of all lambs born, die each year at or about lambing (Knight et al. 1979; Dalton et al. 1980). Lamb mortalities therefore remain at unacceptably high levels, despite considerable effort in the care and management of the sheep flock in New Zealand.

### **Wool quality**

Processing trials have shown that the most important determinants of wool value are quality factors such as staple strength and extent of discolouration (Sumner 1986). Wool from New Zealand crossbred sheep (Romney, Coopworth, Perendale) tends to be tender (Bigham et al. 1983). Tender wools, in modern high-speed processing machinery, generally result in more breakage during the carding process compared with sound wools (Ross 1960; Von Bergen 1963; Ross 1982). Fibre length after carding is one of the most important wool characteristics that determine processing performance (Elliot 1986; Hawker and Littlejohn 1989). Tender wools also have a problem of cotting. These wool faults can result in damage to processing equipment (Ross 1978; Bell 1981) and consequently there is a marked price discount for this type of wool (Joyce 1961; Wickham 1973; Wickham and Bigham 1976). Attempts to increase the suitability of a fleece for a particular processing route and end-use at the on-farm management level are likely to increase a farmer's income from wool.

### **The importance of feeding strategy during pregnancy**

Sheep farming systems in New Zealand are based primarily on grazed pasture throughout the year. Sheep production is, therefore, largely dependent upon herbage availability. Herbage growth (and consequently herbage mass) is affected by climate which is usually more favourable to pasture growth in autumn and spring than in winter and (dry) summers (Jagusch et al. 1981; Korte et al. 1987).

Sheep reproductive activity is determined primarily by seasonal changes in daylength. The normal breeding season in New Zealand is from mid-March to mid-July (Morris 1992). If mating in the first cycle is successful, most ewes lamb in August. Accordingly, feeding during pregnancy is in reality autumn/winter feeding of ewes, when herbage growth is limited. In addition, lactating ewes have a high demand for energy in late winter or early spring when pasture is not abundant. Ewe and lamb weaning weights can be affected by nutritional levels during pregnancy but the effect of nutrition during lactation is usually greater (Rattray and Jagusch 1978). Hence feeding during late pregnancy should be viewed more from the point of view of 'priming the lactational pump' rather than 'feeding the fetus'. In view of these limitations and considerations, pasture management for ewes in late pregnancy requires careful planning.

## **THE ADVANTAGES OF PRE-LAMB SHEARING**

### **Metabolisable Energy Utilisation and Cold-Stress**

Use of Metabolisable Energy (ME) for pregnancy in sheep is a relatively inefficient process (Graham 1964; Rattray 1974, 1986; Robinson 1977, 1982; Bell 1986, 1993). The heat produced as a by-product of this inefficiency of ME use is largely wasted and contributes to a higher heat production in pregnant ewes (Graham 1964). The consequence of this is that the lower critical temperature (LCT) of pregnant ewes tends to be lower than that of non-pregnant ewes (Christopherson and Young 1986).

However, once the pregnant ewes are shorn, metabolic heat contributes to the pool of extra energy required to maintain body temperature (Bottomley and Hudson 1976). Thus the efficiency of total ME use can be considered to increase in pre-lamb shorn ewes compared with that of unshorn pregnant ewes or of shorn non-pregnant ewes. It is, therefore, not surprising to find that LCT of pre-lamb shorn ewes is lower than that of shorn non-pregnant ewes (Christopherson and Young 1986). Cold stress in pre-lamb shorn pregnant ewes is therefore as not severe as in shorn non-pregnant ewes, but pregnant ewes must maintain greater feed intake to support the increased requirements for energy.

## Metabolic Adaptation

In late pregnancy, the demand for glucose increases resulting in increased maternal gluconeogenesis (Wilson et al. 1981, 1983). The extra glucose production during pregnancy is probably derived mainly from endogenous sources even in sheep with a substantial food intake (Lindsay and Oddy 1985). Fat (triacyl glycerols) is released from adipose tissue as non-esterified fatty acids (NEFA) and glycerol in a 3:1 ratio. Glycerol can only be used for glucose synthesis while the corresponding NEFA are being oxidized. Thus, there is little capacity to meet the continuing need for glucose by mobilising additional reserves. The limit to this is set when the energy from NEFA oxidation approaches the total metabolic requirement of the ewe (Lindsay and Oddy 1985).

Glucose is also synthesised from other precursors (amino acids, propionate, lactate and pyruvate) (Bergman 1973). Unlike the gluconeogenesis from glycerol, synthesis of glucose from these precursors involves oxaloacetate (Bergman 1973). Oxaloacetate also has another role as, along with acetyl CoA, it forms citric acid in the TCA cycle. However, in late pregnant ewes, utilisation of oxaloacetate for gluconeogenesis gets priority over production of citric acid. Since oxaloacetate is drawn away for gluconeogenesis, there is insufficient oxaloacetate presented to handle the flux of excessive acetyl CoA into the TCA cycle (Bergman 1973). This condition results in acetyl CoA condensing to form ketone bodies (acetate, acetone, and 3-OHB), and the condition known as "pregnancy toxemia" in late pregnant ewes.

In pre-lamb shorn ewes, the high energy demand for additional thermogenesis leads to increased utilisation of NEFA as the fuel for shivering, shifting the upper limit of NEFA utilisation and resulting in more utilisation of glycerol for glucose. The glucose synthesis from glycerol does not involve oxaloacetate (Bergman 1973), thus oxaloacetate can be used for handling the flux of excessive quantities of acetyl CoA into the TCA cycle. Subsequently, this prevents condensation of acetyl CoA to ketone bodies. This emphasizes that pre-lamb shorn ewes are able to respond to increases in energy requirements without becoming hypoglycaemic or ketotic (Symonds et al. 1986, 1988)

### **Increased Lamb Birth Weight**

One interesting and potentially economic effect of pre-lamb shearing may be an increase in lamb birth weight (LBW). Several experiments using housed sheep fed *ad libitum* found higher feed intakes in shorn ewes than in unshorn ewes and suggested that the increased birth weights of lambs born to shorn ewes are the result of increased voluntary food intake after shearing (Austin and Young 1977; Maund 1980).

Once sheep are shorn, they lose greater amounts of energy to their environment (Armstrong et al. 1960) and therefore have a higher maintenance requirement than unshorn ewes (Graham et al. 1959). If feed intake or energy intake of shorn and unshorn ewes was equalised, energy available to meet the demands of pregnancy in shorn ewes would be less than that in unshorn ewes, and fetal growth might be retarded or reduced as it is when the energy intake of the pregnant ewe is reduced (Robinson 1977). Some researchers, however, have fed shorn ewes the same level as unshorn ewes and found

no difference in lamb birth weight (Russel et al. 1985) or a higher LBW in shorn ewes than in unshorn ewes (Rutter et al. 1972; Thompson et al. 1982; Vipond et al. 1987). This suggests that there is an effect of shearing *per se* which somehow increases nutrient supply to the fetus by altering nutrient partitioning.

### **Lamb Survival**

Starvation-exposure mortality of lambs is caused primarily by the inability of newborn lambs to increase metabolic rate to the level required maintain normal deep-body temperature in a cold environment (McCutcheon et al. 1981). This is partly due to their high ratio of surface area (from which body heat is lost) to body weight (to which summit metabolism is proportional) (McCutcheon et al. 1983). Higher lamb birth weights resulting from the practice of pre-lamb shearing may therefore reduce susceptibility to cold stress in the new born lamb.

Another factor contributing to the high mortality rate in newborn lambs is a lack of ability by the lamb to produce enough heat. Increases in metabolic rate are achieved by activation of brown adipose tissue (non-shivering thermogenesis) and by shivering (Alexander and Williams 1968). Brown adipose tissue thermogenesis is activated before shivering, and so permits a significant increase in metabolism without interfering with the fine muscular movement necessary if the newborn lamb is to find the teat and suckle (Alexander and Williams 1966). However, under conditions of rapid heat loss, the lamb's responses may be inadequate (Alexander 1979) and hypothermia results. If a newborn lamb is to survive it must, therefore, produce enough brown adipose tissue before birth and maximise the thermogenic activity of brown adipose tissue after birth.

Lambs born to pre-lamb shorn ewes have been shown to possess 21 % more perirenal adipose tissue than unshorn controls (Symonds et al. 1992). In addition, at one day of age, lambs born to shorn ewes exhibited a 16 % higher rate of O<sub>2</sub> consumption (per kilogram bodyweight) at an ambient temperature of 23 °C and a 40 % greater metabolic response at an ambient temperature of 7 °C (Symonds et al. 1992). Lambs born to pre-lamb shorn ewes also showed metabolic response to cold exposure without shivering whilst shivering was measured in most lambs born to the unshorn group (Symonds et al. 1992). This implies that pre-lamb shearing of ewes influences not only the birthweight of lambs but also their capacity for heat production, particularly non-shivering thermogenesis.

### **Lamb Growth**

One of the claimed advantages of pre-lamb shearing is to increase lamb growth (Coop and Drake 1948). The rationale is that pre-lamb shearing facilitates first suckling by the newborn lamb and therefore increases the lamb's chance of survival and growth. In addition, in once-yearly post-weaning shorn ewes, the lambs are necessarily separated from their mothers for a period, which causes a check in their development. This is avoided by the practice of pre-lamb shearing (Story 1955).

The main factor affecting lamb growth early in life is milk production of the ewe. This is primarily determined by the ability of ewes both to mobilise their body fat reserves and to increase their feed intake in early lactation. Ewes pre-lamb shorn will by this stage have partly used their reserves for countering the effects of cold stress.

Therefore, ability to utilise body reserves to meet the high demand of lactation is determined by the extent of the previous cold stress and body condition of the ewes at shearing. Pre-lamb shearing has also been shown to increase feed intake during lactation (Parker et al. 1991). It is therefore logical to claim that pre-lamb shearing increases lamb growth. The advantage in lamb growth rates ranges from 14 to 28 g/day in lambs from shorn ewes compared to those from unshorn ewes (Morgan and Broadbent 1972; Kirk et al. 1984; Glanville and Phillips 1986; Phillips et al. 1988; Parker et al. 1991; Cloete et al. 1994).

### **Wool Production of Lambs**

There are few studies relating the effect of maternal cold stress during the last two-thirds of pregnancy to follicle development of the newborn lamb. However, heat treatment in late pregnant ewes resulted in a profound effect on the number of follicles present in the born new lamb and on their degree of development (Cartwright and Thwaites 1976b; Hopkins and Richards 1979). These latter authors found that at birth the mature secondary/primary follicle ratio of lambs born to ewes heat-stressed (rectal temperatures of 40 °C and respiratory rates greater than 180/minute) in the last month of pregnancy was lower at 2.8 than that of lambs born from untreated ewes (controls) at 4.7. This presumably reflects the decrease in glucose uptake by the fetus (Bell et al. 1987) as energy intake of the pregnant ewe is reduced (Cartwright and Thwaites 1976a) or (more likely) is an effect of heat stress *per se* (Andrianakis and Walker 1994).

Cold conditions induce increased maternal glucose concentration and may result in an increased passage of glucose across the placenta to the fetus (Thompson et al. 1982) and induce a variety of endocrine changes in the dam. It is therefore possible that cold environmental temperatures during pregnancy (possibly induced by pre-lamb shearing) might stimulate the secondary follicle development of the newborn lamb. However, there are no reports in the literature attempting to measure the effect of pre-lamb shearing on number of follicles present in the newborn lamb. It can, of course, be argued that an effect of cold-stress is unlikely to be observed unless the cold-stress is sufficient to push the dam outside her thermoneutral range (as was the case with the heat-stress studies).

### **Wool Production of Ewes**

There is substantial research evidence that the annual fleeceweight of ewes pre-lamb shorn annually is similar to that of ewes given an annual post-weaning shear (main shear) (Story and Ross 1960; Sumner and Scott 1990; Dabiri et al. 1994). However, when the practice of pre-lamb shearing involved a twice-yearly shearing policy in July (pre-lambing) and January (post-weaning), clean fleece weight of ewes twice-yearly shorn was greater than that of ewes once-yearly shorn, whether those ewes were shorn in July or January (Sumner and Scott 1990).

The staple strength of wool from pre-lamb shorn ewes is greater than that from ewes given a main shear. Story and Ross (1960) made detailed measurements of month-to-month wool production of Romney breeding ewes and showed that the ewes had a

mean maximum fibre diameter in February of  $42\mu\text{m}$  and a minimum in August of  $28\mu\text{m}$ . Thus once-yearly pre-lamb shearing produces fibres that taper at both ends, and therefore results in a stronger fibre, whereas post-weaning shearing in the summer results in fibres that are thick at the end and have a thin region towards the centre, thus contributing to the reduction in staple strength.

A major problem of the New Zealand wool harvested at main shear is unscourable discolourations, commonly termed "canary yellow" (Henderson 1965; Wickham 1978). The yellow discolourations are most apparent in fleeces which carry a relatively high content of alkaline salts (secreted from the skin) and which have been continuously wet for three days or more, particularly in periods when temperatures have been relatively high (Henderson 1965; Wickham 1978). The greater the staple length, the more prone is the fibre to discolouration due to it being slower drying after wetting (Sumner and Bigham 1993). The practice of pre-lamb shearing therefore potentially solves this problem by providing a shorter staple during the summer months. Such a fleece is easily dried in the spring and early summer, thus avoiding discolouration (Henderson 1965).

These differences (staple strength and brightness colour) are usually reflected in price, the pre-lamb shorn clip typically being priced higher than wool from ewes shorn post-weaning. The net financial return from pre-lamb shearing has been calculated to be higher than the return from post-weaning shearing (Sumner and Scott 1990; Dabiri et al. 1994).

## ISSUES TO BE CONSIDERED

Although, as discussed previously, the practice of pre-lamb shearing offers benefits, shorn sheep are clearly subjected to increased cold stress. Calorimetric experiments with non-reproducing sheep showed that shearing treatment, and therefore cold stress, increases heat production by 13-80 % (Graham et al. 1959; Blaxter et al. 1966; Farrell and Corbett 1970; Bennett 1972; Davey and Holmes 1977; Holmes et al. 1992; Dabiri et al. 1995a). The extent of the increased heat production depends on the environmental temperatures to which the sheep are exposed, the amount of food they consume (Graham et al. 1959), the type of food consumed (Davey and Holmes 1977), the size of the animal (Blaxter et al. 1966) and the depth of wool left after shearing (Panaretto et al. 1968; Dabiri et al. 1995a). Wind of 25 km/h has been shown to increase heat loss by a further 100 %, and therefore to require a similar response in heat production, of shorn sheep exposed at 15 °C compared with sheep exposed to still air at this temperature (Panaretto et al. 1968). The effects of wind and wetting in combination appear to be additive. Heat production by wetted sheep (7 mm fleece depth) exposed to 15 °C and a wind of 25 km/h was six times the basal level of unshorn (100 mm fleece depth) sheep in still air conditions (Panaretto et al. 1968; Alexander 1974). Because voluntary feed intake does not increase immediately after shearing, but rather responds gradually (Wodzicka-Tomaszewska 1963, 1964; Webster and Lynch 1966; Weston 1970; Donnelly et al. 1974; Hawker et al 1985), lipolysis is increased to support the high metabolic demand (Halliday et al. 1969; Aulie et al. 1971; Astrup and Nedkvitne 1988; Symonds et al. 1988; Holmes et al. 1992; Dabiri et al. 1995a) and the consequence is that animals will lose liveweight (Coop and Drew 1963; Elvidge and Coop 1974; Dabiri et al. 1995b).

Severe cold stress and prolonged exposure to cold conditions can result in the animal being unable to generate sufficient heat to compensate for heat loss, resulting in a rapid drop in body temperature and eventual death (lethal cold stress). Geytenbeek (1963) found in a field study in South Australia that 12 % of 42,000 shorn sheep died in the five days after a 48 hour storm. Panaretto and Ferguson (1969), also from Australia, reported having observed losses of 14 % from 25,000 sheep shorn 8-10 days prior to torrential rain, albeit at a temperature of 15-21 °C. Dabiri et al. (1995b), working in New Zealand with late pregnant ewes shorn by a standard comb in winter, showed that mortality of shorn ewes was significantly higher than that of unshorn ewes. A calorimetric study by Panaretto et al. (1968) showed that exposing wetted sheep with a fleece depth of 7 mm to 15 °C ambient temperature and a wind of 25 km/h for one day did not result in any deaths from 20 sheep, but exposure for four days resulted in a 55 % death rate. This evidence highlights the susceptibility of newly shorn sheep to exposure at low ambient temperatures, especially when there is a combination of wind and rain.

Where an animal can cope with cold stress, liveweight will decrease and voluntary feed intake will increase. The magnitude of the feed intake response is therefore dependent on the climatic conditions following shearing. At 16-17 °C ambient temperature, for example, Elvidge and Coop (1974) showed that shearing increased the feed requirements by 18 % in housed sheep and by 24 % for sheep run outdoors. However, at ambient temperatures of 7-10 °C shearing increased voluntary feed intake by 46 % for housed sheep, and by 76-78 % when they were exposed in pens on an unsheltered site (Elvidge and Coop 1974). Responses in feed intake of cold-stressed

pregnant ewes, however, may not necessarily be similar to those of non-reproducing ewes (see "Factors Affecting the Herbage Intake of Grazing Ewes", pages 17-25).

In summary, the detrimental effects of shearing are a decrease in body condition and liveweight, a high risk of sheep deaths, and an increased food intake. These are the main issues that should be considered when deciding whether to pre-lamb shear.

### **WAYS TO MINIMIZE THE DETRIMENTAL EFFECTS OF SHEARING**

The risk of ewe deaths may be the threat of greatest concern when a decision to pre-lamb shear has been taken. In practice, the conditions likely to cause a high mortality rate (including low temperatures, wind plus rain) are usually brought about by a storm. The suitable times for pre-lamb shearing should be therefore based on a long-range weather forecast from the Meteorological Office contacted at least one to two days before shearing is expected to start (Parker 1992).

The significant contribution of wind to total heat loss of cold-stressed animals has been clearly demonstrated so that newly shorn sheep should be placed into sheltered paddocks. Since sheep will walk with the wind until their progress is impeded by a fence, the shelters must be located near the fence area opposed to the prevailing cold winds (Geytenbeek 1962; Lynch 1985). If little wind but heavy rain occurs then the only useful form of shelter is a shed which keeps rain off the sheep. In view of the deaths occurring in shorn sheep within three days after shearing, it is good insurance to place freshly pre-lamb shorn sheep under cover during the first three days post-shearing.

Age of sheep seems to have no effect on cold-induced mortality rate (Geytenbeek 1962; Slee 1966; Dabiri et al. 1995b). Body condition of sheep at shearing did not affect ewe mortality (Geytenbeek 1962; Hutchinson and MacRae 1969). Ewe mortality was, however, associated with the body weight loss during the four weeks prior to shearing (Hutchinson 1968; Hutchinson and MacRae 1969). This suggests that the amount of food consumed a few weeks prior to shearing is important in reducing risk of death.

## **FACTORS AFFECTING THE HERBAGE INTAKE OF GRAZING SHEEP**

Shearing generally increases feed intake, but the magnitude and timing of the increase varies. However, in several cases shearing did not result in an increased feed intake (for example, Minson and Ternouth 1971). The following section reviews literature on factors affecting feed intake of grazing sheep with emphasis on pre-lamb shorn ewes. Factors influencing the herbage intake of grazing sheep can be broadly classified as "facilitatory" and "inhibitory" stimuli.

### **Facilitatory Stimuli**

At a high sward surface height or post-grazing herbage mass, it is generally accepted that ruminants adjust voluntary feed intake to their energy and/or nutrient requirements (Baile and Forbes 1974; Forbes 1992). In growing animals, for example, there is a high demand for nutrients to support tissue deposition, so that food intake is increased and amino acid requirements are likely to be the factors determining food intake level, rather than energy *per se* (Kennedy 1957; Arnold et al. 1982; Hou et al.

1991; Forbes 1992; Webster 1993). This theory has recently been validated in late pregnant ewes. As the foetal and maternal tissues increase in size markedly in late pregnancy, the requirements of the ewe for protein and energy increase rapidly over the last two months prior to lambing (Robinson 1977; Russel 1984; McNeill et al. 1994). Provided that the dietary ME concentration of foods given is high, pregnant ewes select a diet that reflects their enhanced demand for protein in contrast with non-pregnant contemporaries (Cooper et al. 1994). Forbes (1992) has also postulated that, under appropriate conditions, sheep and other ruminants can also develop specific appetites for other nutrients, such as minerals.

### Cold Stress

There is substantial evidence in the literature that feed intake following shearing in wethers increases steadily with a peak at 3-6 weeks post-shearing (Wodzicka-Tomaszewska 1963, 1964; Webster and Lynch 1966; Weston 1970; Donnelly et al. 1974; Hawker et al. 1985). This behaviour obviously fulfils the demand for energy to counteract heat loss.

In lambs, when energy requirements for maintenance increase (e.g. cold stress), less energy is available for growth, and consequently the protein-to-energy ratio above maintenance levels increases and inefficient use of protein results (Ames and Brink 1977; Ames et al. 1980). Apparently, cold exposure increases the demand for energy to the point where a substantial part of the protein must be used as an energy source.

Shearing dry ewes caused an average increase in maintenance requirement of 69 % in the four weeks after shearing, whereas shearing pregnant ewes in the second half of pregnancy (P84) increased feed requirements by only 26 % in the four weeks after shearing (Hudson and Bottomley 1978).

Research into increases in feed intake of shorn housed ewes has shown variable results, some showing a significant increase in ewe intakes (Meadowcroft 1982; Vipond et al. 1987), whereas the others revealed no increase in intake (Rutter et al. 1972; Symonds et al. 1986; Black and Chestnutt 1990a). The difference may be due to the stage of pregnancy when shearing occurs. Hudson and Bottomley (1978) showed that increases in feed intake, four weeks after shearing, of ewes are 26 % greater in shorn than in unshorn ewes when shearing occurs 9 weeks before parturition (pregnancy day 84, P84), whereas such increases were only 9 % when the ewes were shorn 7 weeks before lambing (P112). Similarly, Black and Chestnutt (1990a) designed a trial to examine the effect of shearing at different stages of pregnancy and showed that feed intakes of housed ewes shorn at 12, 9, 6, and 4 weeks prior to shearing increased by 10, 8.5, 5, and 0 % of those of unshorn ewes, respectively. No increase in feed intake following pre-lamb shearing was reported when ewes grazed pasture in studies by Parker et al. (1991) and Dabiri et al. (1995b, 1996).

These data suggest that feed intake responses induced by shearing treatment vary according to the physiological state of the animals. In late pregnancy, pre-lamb shearing generally does not increase feed intake (Black and Chestnutt 1990a; Parker et al. 1991; Dabiri et al. 1995b) until four weeks post-partum (Parker et al. 1991).

### Exercise

The major difference between grazing sheep and those in pens is in feed acceptability and accessibility (Arnold 1970; Hodgson 1985). The energy cost of harvesting the herbage and walking can therefore increase the maintenance requirements of the grazing animal compared with housed animals (Coop and Drew 1963; Arnold 1970; Freer 1981; Hodgson 1982; Penning et al. 1991). Thus, feed intakes of grazing ewes are higher (20-30 %) than those of pen-fed sheep (Coop and Drew 1963).

### Pregnancy and Lactation

Late pregnancy and lactation increase the nutrient requirements of animals (Rattray 1974, 1986; 1992). However, this high requirement cannot be fulfilled from feed intake, even in sheep with a substantial intake (Egan 1984; Lindsay and Oddy 1985). Body fat reserves are therefore mobilised to meet these demands, with a consequential live weight loss. The major increase in requirements, however, does not occur until after lambing with a peak increase in requirements at about 4-9 week of lactation (Hadjipieris and Holmes 1966; Boucquier et al. 1987; Parker and McCutcheon 1992; Morris et al. 1994).

## **Inhibitory Stimuli**

### **Pregnancy**

Voluntary feed consumption can decrease in late pregnancy, especially with twin-bearing ewes (Reid and Hinks 1962; Owen and Ingleton 1963; Morris et al. 1993b). This is not confined to diets that limit intake via physical factors, such as pasture or forage diets, but can equally apply to diets based on concentrates (Forbes 1970, 1971). However, Orr and Treacher (1989) showed that intakes of silage during the last 6 weeks of pregnancy by ewes carrying multiples and singles were 86 and 81 % of respectively lower than their feed intakes at mid-pregnancy. Such decreases were much greater (63 and 71 %) when the ewes were fed on poor quality hay or straw, suggesting that the quality of the forage food has an influence on the severity of the decline in intake.

The lack of increase, or decline, in feed intake in late pregnant grazing ewes has been also noted by Arnold and Dudzinski (1967) and Morris et al. (1993b). The decreased physical capacity of the digestive tract induced by compression of the rumen by the growing uterus, and exacerbated by abdominal fat, may be the main factor limiting feed intake (Forbes 1995). Hormonal factors can also limit feed intake, especially in the few weeks prior to parturition, when oestrogen secretion by the placenta is increasing (Forbes 1971; Bargeloh et al. 1975). During late pregnancy ewes are susceptible to pregnancy toxemia, acetonamia, and hypomagnesaemia, and these metabolic disorders may also induce a decline in feed intake (Seebeck et al. 1971; Weston 1982).

### Sward Factors

Feed intake is a function of the rates of digestion in, and of passage from, the reticulo-rumen (retention time in the rumen) (Ellis 1978). The rate of digestion is mainly determined by the digestible fraction of the diet (pepsin-soluble material plus digestible fibre). Under grazing conditions, Hodgson (1977) found that digestibility exerted a dominant influence on herbage intake.

The relationship between intake and digestibility is not consistent. Osbourn (1967) showed that three different species with the same digestibility had markedly different feed intakes in the order lucerne > ryegrass > timothy. Chemical analysis of these forages showed that the digestible fraction in lucerne contained a higher proportion of pepsin-soluble material, and a lower proportion of digestible fibre, than the digestible fraction in timothy, with the levels in ryegrass being intermediate between those in the other two species.

Dry matter digestibility of leaf and stem of temperate grasses in the early vegetative phase is also similar (Ulyatt 1981). However, a comparison of chemical composition between both plant parts showed that leaf has a higher content of pepsin-soluble material than does stem (Laredo and Minson 1973; Minson 1981). This implies that retention time of stem in the rumen will be longer, and therefore feed intake of stem will be lower, than that of leaf material (Minson 1981; Rattray et al. 1983; Cruickshank et al. 1985; Poppi et al. 1987).

The digestibility of herbage is also driven by season, being high in spring, and declining as the plant matures over the summer months. The cause of this reduction in digestibility is an increase in proportion of stem material while, at the same time, the digestibility of the stem declines (Terry and Tilley 1964; Ulyatt 1981). Maturity also leads to pepsin-soluble material that is a determinant of the passage rate decreasing in stems and remaining constant in leaves. Thus, as a plant matures, the digestibility decreases, retention time of digesta in the rumen increases, and these two effects are responsible for the decline in feed intake.

#### Environmental Factors

Animals adjust their behaviour to avoid unpleasant situations (Hafez 1968; Young 1987). Newly shorn sheep reduced their daily grazing time and changed their grazing patterns as they sought shelter during the three days following shearing when the weather was bad (Webster and Lynch 1966; Hutchinson and MacRae 1969; Phillips et al. 1988). This behaviour is probably associated with the high priority given by the sheep to thermoregulatory behaviour -shivering and huddling- in severe cold conditions.

#### Management Factors

Daily pasture intake (I) in grazing animals is the product of the time spent grazing per day (GT, minutes), rate of biting (RB, bites per minute) and weight of pasture eaten per bite (IB, g OM per bite) (Poppi et al 1987).

$$I = GT * RB * IB$$

Since feed intake of grazing animals is primarily determined by their energy demand (i.e. physiological state), it is logical to assume that a change in any component of feed intake (GT, RB, or IB) will be followed by changes in the other components of feed intake to fulfil the targeted daily feed intake. For example, when livestock are removed from the pasture at night, and therefore grazing time is say 7 hours per day, feed intake can be maintained by eating more rapidly (Smith 1961). Similarly, shorn sheep, subjected to cold stress, graze for less time than sheep in fleece, but eat faster (Arnold 1987; Dabiri et al. 1995b). Another example of fulfilling energy demand involves lactating ewes which increase feed intake by eating faster (Arnold 1963; 1987). These results suggest that energy demand and intake requirements in grazing sheep can be fulfilled by shifting the component variables of feed intake (subject to adequate feed availability). However, when intake per bite is depressed, biting rate seldom increases sufficiently to avoid some reduction in the rate of herbage intake ( $IB * RB$ ) (Hodgson 1981, 1982; Morris et al. 1993b). Grazing duration can compensate but, to some extent, grazing time has an upper limit, depending on the physiological state of sheep (Arnold 1963) and the type of pasture grazed. Therefore feed intake of grazing sheep is very sensitive to changing bite size.

It is now acknowledged that the weight of herbage consumed per bite and therefore intake rate (g DM/min) and ultimately feed intake can be manipulated by altering herbage mass (Black and Kenney 1984; Penning 1986; Penning et al. 1991; Morris et al. 1993b), suggesting that management of herbage mass can have an important influence on potential intake. Increases in intake with increasing herbage mass might be explained either by greater ease of prehension and ingestion of herbage, or by

greater opportunity for selection resulting in a higher nutrient concentration in the diet (Arnold and Dudzinski 1967; Hamilton et al. 1973; Hodgson 1985).

Herbage mass per unit area is the product of sward height and density. Black and Kenney (1984) demonstrated the relationship between sward height and intake rate at a given sward density. For their most dense swards (26,000 tillers/m<sup>2</sup>) intake rate increased up to a sward height of 60 mm and thereafter there was little further increase. At 6,500 tillers/m<sup>2</sup> intake rate increased up to a height of 100 mm and in the least dense sward (1,600 tillers/m<sup>2</sup>) intake rate was still increasing up to height of 220 mm which was the maximum used in the experiment.

Further analysis of the component variables of herbage mass has shown that sward height is a better predictor of feed intake than bulk density (Hodgson 1981, 1982) provided that there is a minimum of 13,000 tillers/m<sup>2</sup> (Black and Kenney 1984; Penning 1986). In the range 20 mm to 80 mm sward height, bite size of grazing late-pregnant ewes increases with increasing sward height (Morris et al. 1993b). Animals grazing swards of 40, 60 and 80 mm all had similar intake rates (Morris et al. 1993b). These were achieved by the sheep changing their ingestive behaviour. Initially biting rate increased as sward height decreased and, when this failed to compensate for declining intake rate, grazing time was increased. However, for ewes grazing on 20 mm sward height pasture, intake was depressed and ingestive and grazing behaviour failed to compensate for the lower sward height (Morris et al. 1993b).

In summary, feed intake of grazing ewes is commonly depressed in sward heights below 40 mm, primarily because of a decreased intake per bite that cannot be compensated for by changing ingestive and grazing behaviour. Pasture management has, therefore, an important role in manipulating feed intake of grazing sheep.

## **PURPOSE AND SCOPE OF STUDY**

Pre-lamb shearing offers some advantages including improved wool quality (Story and Ross 1960), greater spread of seasonal labour requirements and more regular cashflow (Livingston and Parker 1985), heavier lamb birth weights (Thompson et al. 1982; Vipond et al. 1987), and increased lamb survival (Symonds et al. 1992). However, fleece removal during the winter increases susceptibility to cold stress with consequences of increases in feed intake and decreased body condition (Elvidge and Coop 1974), and even death of ewes. In New Zealand, it is commonly argued that sheep which have just been pre-lamb shorn should be given high feed allowances immediately after shearing to provide them with the energy needed to compensate for increased heat loss. However, this assumption may be called into question given that, in many pre-lamb shearing studies, responses in feed intake were not evident for some weeks after shearing (Symonds et al. 1986; Black and Chestnutt 1990a; Parker et al. 1991; Dabiri et al. 1995b).

Furthermore, the cover comb is increasingly being used to reduce the cold-stress of shorn ewes. If increased feed allowance post-shearing is important for sheep pre-lamb shorn by standard comb, it might be expected to be less so for those shorn by cover comb.

The purpose of this study was therefore to examine whether the performance of pre-lamb shorn sheep is in fact influenced by pasture allowance in the immediate post-shearing period and whether the relationship between performance and pasture allowance differs according to whether the ewes were shorn by standard comb or cover comb.

## CHAPTER II

### PASTURE MANAGEMENT TO MINIMISE THE DETRIMENTAL EFFECTS OF PRE-LAMB SHEARING

#### INTRODUCTION

Pre-lamb shearing offers some advantages including improved wool quality (Story and Ross 1960), greater spread of seasonal labour requirements and more regular cashflow (Livingston and Parker 1985), and possibly increased lamb birth weights. However, shearing increases susceptibility to cold stress. Newly shorn sheep have to raise heat production to maintain body temperature, and this is accompanied by increased mobilisation of body reserves and (supposedly) increases in feed intake. The assumed feed intake response has led to the farmer practice of providing ewes which have just been pre-lamb shorn with high feed allowances in the period immediately following shearing (Wickham 1978; Bigham 1982; NZSC 1994). This is difficult to achieve in practice because during the winter, when pre-lamb shearing is normally carried out, pasture growth and availability is limited. Furthermore, in many pre-lamb shearing studies at pasture, responses in feed intake were not evident for some weeks after shearing (Parker et al. 1991; Dabiri et al. 1995b; 1996). This raises the question of whether high feed allowances immediately after shearing are in fact important.

The cover comb, which leaves a greater depth of fleece stubble than the standard comb, is increasingly being used in New Zealand as a method to reduce the detrimental effects of shearing (Holmes et al. 1992; Dabiri et al. 1995a,b). Since sheep shorn by

cover comb exhibit greater resistance to cold stress than ewes shorn by standard comb (Dabiri et al. 1995ab), it might be expected that for ewes shorn by cover comb a high feed allowance after shearing might be less important than for ewes shorn by standard combs.

The main purpose of this study was therefore to examine whether the performance of pre-lamb shorn sheep is in fact influenced by pasture allowance in the immediate post-shearing period and whether the relationship between feed intake, productivity, and pasture allowance differs according to whether the ewes are shorn by standard comb or cover comb.

## **MATERIALS AND METHODS**

### **Experimental Design and Animals**

Two experiments were carried out at the Haurongo Block, Sheep and Beef Cattle Research Unit (SBCRU), Massey University (latitude 41° 10' S), 5 kilometres south of Palmerston North, New Zealand. The design of each experiment, run in consecutive years (1994 and 1995), was a 3x3x2 factorial with three pre-lamb shearing treatments (standard comb, cover comb and unshorn), three sward surface height (SSH) treatments of nominally 3.0, 5.0, and 7.0 cm, and two pregnancy status treatments (single and twin). The purpose of replication of the trial across two years was to allow for climatic variations that occur between seasons and which could markedly affect results.

In each year (experiment), the same experimental procedures were followed. Three harnessed Romney rams were joined with 200 Romney ewes on 29 March (day 0 of pregnancy, P=0). Crayon marks were recorded every three days for 21 days (1 oestrous cycle). Following mating, ewes were fed a maintenance allowance of pasture (4-6 cm SSH) until early July (P105). On day 60 of pregnancy (P60), based on the first appearance of crayon marks, pregnancy status and the number of fetuses carried by each ewe were determined by real-time ultrasound scanning (Carter 1986). Twenty-seven single- and 27 twin-rearing ewes with similar mating dates were selected to be the experimental animals. The selected ewes were two years old and  $52 \pm 1$  kg live weight for the first experiment and ranged from four to eight (average five) years old and  $63 \pm 1$  kg live weight for the second experiment.

On P105, ewes were dosed with a single chromic oxide controlled release capsule (CRC; Captec (NZ) Ltd, Auckland) and drenched with an anthelmintic capsule (Extender 100, Captec Pty Ltd). After stratification on the basis of age, liveweight, and litter size, ewes were randomly allocated to pastures of 3.0, 5.0, and 7.0 cm (nominal) SSH (18 ewes per 1 ha paddock of different SSH). On P115 (day 0 with respect to shearing, S0), ewes in each paddock (SSH treatment) were then allocated at random (within pregnancy status) to one of the three shearing treatments. Thus, there were 6 ewes in each shearing treatment x SSH treatment cell. The ewes remained on these pastures until P135 (S20) after which they were set-stocked onto swards with a SSH of 5.0 cm from lambing until weaning on day 80 of lactation (L80).

## Pasture Preparation and Measurement

The pastures used were composed principally of ryegrass (*L. perenne*) and white clover (*T. repens*). Before P105, the pastures had been prepared over the previous 9 weeks using a non-trial group of ewes. The actual SSH on the initial day of each experiment (P116) as well as herbage mass and botanical composition of the pastures are shown in Table 1. Sward surface height was measured every 7 days from P115 to P140 using the Hill Farming Research Organisation (HFRO) sward stick (Barthram 1986). On each occasion, 50 readings were taken on the same diagonal path within each SSH treatment. Herbage mass (HM) was estimated by cutting eight 0.09m<sup>2</sup> quadrats to ground level in each paddock on P115 and P135. Herbage samples were washed to remove soil contamination, dried at 100 °C to a constant weight and then weighed to determine dry weight. The dry matter yield (kg DM/ha) was calculated as follows:

$$HM = 10,000 \times X/Y$$

where:

HM = herbage mass (kg DM/ha)

X = dried weight of pasture (kg) collected at each site

Y = 0.09 m<sup>2</sup> (area clipped).

Samples of herbage for pasture composition (the proportions by dry weight of grasses, clover, weeds and dead material) were hand-plucked adjacent to the quadrat (Morris et al. 1994), bulked and sub-sampled to about 2.5 g for the measurement of pasture composition.

Table 1. Actual sward surface height, herbage mass, botanical composition of the pasture on P116 in pastures of nominal SSH of 3, 5, and 7 cm.

	1994			1995		
	3	5	7	3	5	7
Sward height (cm)	2.66	5.31	7.11	2.44	5.02	5.86
Herbage mass (kg DM/ha)	469	1375	2232	862	1647	1821
Botanical composition <sup>1</sup>						
grass	0.485	0.670	0.585	0.950	0.869	0.750
clover	0.085	0.025	0.035	0.025	0.016	0.010
weeds	0.005	0.050	0.000	0.000	0.000	0.000
dead material	0.425	0.255	0.380	0.025	0.115	0.240

<sup>1</sup> proportion of dry weight determined by hand-plucking

## Animal Measurements

### Live weight

Unfasted liveweights of ewes were recorded within 1 h of their removal from pasture on days P105, P115, P125, P135, and L80. Lamb weights were recorded within 24 hours of birth (lamb birth weight, LBW) and at L80. Electronic load bar scales (Tru-Test Distributors Ltd, Auckland) were used for weighing ewes and for determining lamb weaning weights, whereas a conventional spring balance was used for measuring LBW.

### Shearing and Fleece Depth

Ewes were shorn by the Chief Instructor of the Wools of New Zealand Shearing School using a standard (conventional) or cover comb on P115, or were left unshorn. The conventional comb had a maximum depth of teeth of 4 mm, while the cover comb had a maximum depth of 9 mm. The treatments would therefore be expected to result in different fleece stubble lengths left after shearing by each method (Dabiri et al. 1995a,b). On each animal, five measurements of fleece depth were taken, two on the back and three on the midside, using a ruler placed on the skin surface. The average length of fleece stubble at these sites for cover- and standard comb- shorn ewes is shown in Table 2.

Table 2. Fleece depth (mm) left after shearing by standard and cover comb (mean  $\pm$  s.e).

Year	standard comb	cover comb
1994	4.7 $\pm$ 0.25	6.1 $\pm$ 0.31
1995	3.9 $\pm$ 0.16	6.5 $\pm$ 0.24

### Blood Metabolites

Samples of blood were collected by venipuncture from the external jugular vein of each sheep using EDTA vacutainers (Nipro Industries, Japan), between 0900 and 1100 hours on days S-3, S2, S4, S8, S13 and S20. These were immediately placed on crushed ice, until the blood plasma could be separated by centrifugation at 3000 g for 20 minutes. Plasma was stored at -20 °C prior to analyses for concentrations of glucose, non-esterified fatty acids (NEFA), and 3-hydroxybutyrate.

The concentration of glucose was determined with an enzymatic colourimetric assay using glucose oxidase (GOD) and 4-aminophenozone (Trinder 1969). The concentration of 3-hydroxybutyrate was determined using the method of Williamson and Mellanby (1974) as modified by Mackenzie et al. (1989). NEFA concentration was determined using an enzymatic colourimetric method (Dalton and Kowalski 1967) as modified by Scott (1989). These plasma metabolite concentrations were measured on a Cobas II autoanalyzer (F. Hoffmann La Roche Ltd., Diagnostics Division, CH-4002 Basle, Switzerland).

#### Rectal temperature

The rectal temperature of ewes was recorded immediately after blood samples had been obtained by inserting a digital thermometer (Becton Dickinson, Ontario, Canada) to a depth of approximately 5 cm into the rectum for about 2 minutes until a constant recording was achieved.

#### Herbage Intake

Herbage intakes of individual ewes were determined by the indirect method using the *in vitro* herbage digestibility (D) of dry matter (DM) or organic matter (OM), and faecal output of grazing animals (FO, g/d DM or OM). Intake (I, g/d DM or OM) was estimated as:

$$I = FO/(1-D) \text{ (Geenty and Rattray 1987).}$$

Ewes were faecal sampled at P112-114, corresponding to S-3 to S-1 (before shearing), P117, P119, P123, and P127 (post-shearing) respectively. The rate of chromic oxide release from the capsules was assumed to be 139 mg/d (Parker et al. 1989). Faecal samples were oven-dried to a constant weight (70 °C for 72 h), and chromium concentration was assessed using atomic absorption spectrophotometry (Parker et al. 1989). Procedures of measurement are described in Appendix I. FO was estimated by dividing the rate of chromium release from the CRC by the concentration of chromium in the faeces (mg Cr/g DM or OM).

Three oesophageal-fistulated (OF) wethers were used to collect herbage samples for determining the *in vitro* digestibility and botanical composition of herbage consumed. Extrusa was collected on P116 and P135 according to the technique of Wait (1972). Extrusa samples taken from each OF sheep and each paddock were subsampled, one subsample being used for measurement of botanical composition of pasture consumed and the other for determination of *in vitro* digestibility. The extrusa samples were immediately placed on crushed ice and stored at -12 °C (Morris et al. 1994) until required for analysis. Measurement of botanical composition followed the technique described by Clark and Hodgson (1986) (Appendix II). The other extrusa samples were freeze-dried and then ground through a 1.0 mm sieve in preparation for *in vitro* digestibility determination using the cellulase incubation method described by Roughan and Holland (1977).

## Wool Growth

Wool growth rate (WGR) was measured as the clean weight of midside wool grown per unit skin area per unit time (Short and Chapman 1965). For initial clearance and clipping of wool samples, ewes lay on a flat surface. An initial patch measuring 20 cm x 20 cm was cleared of wool using Oster clippers (size 001) and size 40 blades on P115 (S0). Wool samples were clipped from the right midside of ewes on L80 and stored in an untied plastic bag. The procedures for washing wool samples and calculating clean wool growth rate are described in Appendix III. The wool samples that had been used for measuring wool growth were also used to estimate mean fibre diameter (MFD) using the airflow technique (Ross 1958). The principles of the air flow technique for MFD measurement are described in Appendix IV.

## **Environmental Measurements**

Data on climatic factors during the experiments (from P115 to P135) were obtained from the nearest meteorological station (6 km from the experimental paddocks). The climatic factors recorded were air temperature ( $^{\circ}\text{C}$ ), wind velocity (km/h), number of days with rain, and number of days ground frost. Air temperature measurements were made 30 cm above the ground surface. Readings of air temperature and wind velocity were recorded once daily at 0900 h and are presented in Appendix V.

## Statistical Analysis

Data on wool growth rate and fibre diameter were subjected to univariate analysis of variance for a factorial design to test effects of year, shearing and SSH treatments, pregnancy status, and their interactions. Shearing and SSH treatments as well as pregnancy status were treated as fixed effects whereas year effects were regarded as random. The error terms used to test the shearing method and SSH treatment effects were the shearing method x year interaction mean square and the SSH treatment x year interaction mean square respectively (Snedecor and Cochran 1967).

The pre-shearing values of feed intake, rectal temperature and blood metabolite concentrations were used as covariates in analysis of the effects of shearing and SSH treatment on corresponding parameters during the study using models equivalent to those described above. Because age and live weight were balanced by treatment, they were not included in statistical models.

Actual litter size rather than diagnosed pregnancy status was used to classify lambs into birth rank. LBW and lamb sex were fitted in the model analysing the effect of treatments (shearing and SSH) on lamb growth rate and lamb weaning weight. Data were analysed using the Statistical Analysis System computer package (SAS 1985). All data were expressed in terms of means ( $\pm$  SEM).

## RESULTS

### Ewe Liveweight Gain, Lamb Production, and Wool Production

Table 3 shows effects of shearing treatment and sward surface height on ewe liveweight gain. There was a significant interaction ( $P < 0.05$ ) between shearing treatment and sward surface height for liveweight gains of pregnant ewes during the treatment period (P115-P135). Thus the liveweight gain of control ewes was not influenced by SSH whereas, in both standard comb- and cover comb-shorn ewes, liveweight gain increased progressively with SSH over the range 3 to 7 cm. Only at a sward surface height of 7 cm did shorn ewes achieve liveweight gains similar to those of unshorn (control) ewes.

Table 3. Effects of shearing treatment and sward surface height on ewe liveweight gain (g) during the period from shearing to twenty days post-shearing (P115-P135) (mean  $\pm$  s.e).

SHEARING TREATMENT	SWARD SURFACE HEIGHT		
	3 cm	5 cm	7 cm
CTRL <sup>1</sup>	4518 $\pm$ 728 <sup>cd</sup>	4789 $\pm$ 632 <sup>d</sup>	3997 $\pm$ 633 <sup>cd</sup>
SC	275 $\pm$ 599 <sup>a</sup>	1557 $\pm$ 632 <sup>b</sup>	3623 $\pm$ 647 <sup>cd</sup>
CC	613 $\pm$ 614 <sup>ab</sup>	2314 $\pm$ 635 <sup>b</sup>	2894 $\pm$ 599 <sup>c</sup>

<sup>1</sup> CTRL=control (unshorn); SC=standard comb; CC= cover comb  
<sup>a,b,c,d</sup> Means with different superscripts are significantly different ( $P < 0.05$ ).

No interaction between the effects of shearing treatment and sward surface height was found for lamb birth weight or weaning weight. Average values of these parameters by treatment are therefore shown in Table 4. Using standard combs to shear pregnant ewes on P115 increased lamb birth weights by 0.6 kg ( $P<0.05$ ) compared to controls, whereas using the cover combs had no significant effect (Table 4). Shearing treatment did not, however, result in a significant difference in lamb weaning weights. Grazing ewes on different sward surface heights during the period from P105 to P135 did not lead to significant differences in lamb birth weights or weaning weights (Table 4).

Table 4. Effect of shearing treatment and sward surface height on lamb birth weights (LBW, kg), 80 day weaning weights (WW, kg), wool growth rates of ewes (WGR,  $\mu\text{g}/\text{cm}^2/\text{day}$ ) and mean fibre diameter of ewe's wool (MFD,  $\mu\text{m}$ ) (mean  $\pm$  s.e).

	SHEARING TREATMENT			SWARD SURFACE HEIGHT		
	CTRL <sup>1</sup>	SC	CC	3 cm	5 cm	7 cm
LBW	4.3 $\pm$ 0.1 <sup>a</sup>	4.9 $\pm$ 0.1 <sup>b</sup>	4.5 $\pm$ 0.1 <sup>a</sup>	4.5 $\pm$ 0.1	4.5 $\pm$ 0.1	4.7 $\pm$ 0.1
WW	20.4 $\pm$ 1.1	21.3 $\pm$ 0.9	21.7 $\pm$ 0.9	22.0 $\pm$ 2.4	20.3 $\pm$ 2.1	21.1 $\pm$ 1.9
WGR	767 $\pm$ 46	897 $\pm$ 40	938 $\pm$ 40	903 $\pm$ 20	827 $\pm$ 19	871 $\pm$ 17
MFD	37.6 $\pm$ 0.5	37.9 $\pm$ 0.4	38.5 $\pm$ 0.4	38.3 $\pm$ 0.4	38.0 $\pm$ 0.4	37.7 $\pm$ 0.3

<sup>1</sup> CTRL=control (unshorn); SC=standard comb; CC=cover comb

<sup>a,b</sup> Mean values within the same row and treatment with different superscripts are significantly different ( $P<0.05$ ).

There were no effects of pre-lamb shearing treatments or sward surface heights, or an interaction between them, on ewe wool growth rate (WGR) or mean fibre diameter (MFD) measured after 80 days of lactation (Table 4).

### Rectal Temperature

There was no interaction between the effects of shearing treatment and SSH on rectal temperatures so means are presented by treatment (Table 5). Shorn animals

Table 5. Effect of shearing treatment and sward surface height on rectal temperatures ( $^{\circ}\text{C}$ ) on the days indicated post-shearing (mean  $\pm$  s.e)

Day	Shearing Treatment			Sward Surface Height		
	CTRL <sup>1</sup>	SC	CC	3 cm	5 cm	7 cm
S1	39.5 $\pm$ 0.1	39.3 $\pm$ 0.1	39.2 $\pm$ 0.1	39.2 $\pm$ 0.1	39.3 $\pm$ 0.1	39.3 $\pm$ 0.1
S2	39.8 $\pm$ 0.1 <sup>b</sup>	39.4 $\pm$ 0.1 <sup>a</sup>	39.5 $\pm$ 0.1 <sup>a</sup>	39.5 $\pm$ 0.1	39.6 $\pm$ 0.1	39.6 $\pm$ 0.1
S4	39.6 $\pm$ 0.1 <sup>b</sup>	39.3 $\pm$ 0.1 <sup>a</sup>	39.1 $\pm$ 0.1 <sup>a</sup>	39.2 $\pm$ 0.1	39.4 $\pm$ 0.1	39.4 $\pm$ 0.1
S8	39.4 $\pm$ 0.1 <sup>b</sup>	39.1 $\pm$ 0.1 <sup>a</sup>	39.1 $\pm$ 0.1 <sup>a</sup>	39.0 $\pm$ 0.1 <sup>a</sup>	39.3 $\pm$ 0.1 <sup>b</sup>	39.3 $\pm$ 0.1 <sup>b</sup>
S13	39.5 $\pm$ 0.1	39.2 $\pm$ 0.1	39.2 $\pm$ 0.1	39.2 $\pm$ 0.1	39.4 $\pm$ 0.1	39.4 $\pm$ 0.1
S20	39.7 $\pm$ 0.1 <sup>b</sup>	39.4 $\pm$ 0.1 <sup>a</sup>	39.4 $\pm$ 0.1 <sup>a</sup>	39.5 $\pm$ 0.1	39.6 $\pm$ 0.1	39.5 $\pm$ 0.1

<sup>1</sup> CTRL=control (unshorn); SC=standard combs; CC= cover combs

<sup>a,b</sup> Means within the same row and treatment with different superscripts are significantly different ( $P < 0.05$ ).

showed consistently lower rectal temperatures on each measurement date than unshorn ewes. These differences were significant on S2, S4, S8, and S20, but were not significant on S1 and S13 although a similar pattern was evident on these days. The rectal temperatures of ewes shorn using the cover comb were not different to those of ewes shorn by standard combs (Table 5).

The average rectal temperatures of ewes set-stocked on pastures of nominal 3, 5, or 7 cm height are also shown in Table 5. Lower rectal temperatures ( $P < 0.05$ ) were found in ewes grazing on 3 cm SSH pasture than in those on pastures of 5 or 7 cm SSH on only one day (S8).

### **Blood Metabolite Concentrations**

An interaction ( $P < 0.05$ ) between effects of shearing treatment and SSH on plasma concentrations of glucose was found on the fourth day after shearing (Table 6). On S4, plasma glucose concentration was not influenced by SSH in the control and cover comb-shorn ewes but was elevated on the 3 cm pasture in standard comb-shorn ewes.

On days S2, S8, S13, and S20 there were no significant interactions between treatments, and so the plasma concentrations of glucose according to the main treatments are presented in Table 7. Neither shearing treatment nor sward surface height affected plasma concentrations of glucose on these days.

Table 6. Effect of shearing treatment and sward surface height on plasma glucose concentrations (mmol/l) on the fourth day after shearing (mean  $\pm$  s.e).

SHEARING TREATMENT	SWARD SURFACE HEIGHT		
	3 cm	5 cm	7 cm
CTRL <sup>1</sup>	3.5 $\pm$ 0.17 <sup>a</sup>	3.8 $\pm$ 0.14 <sup>a</sup>	3.5 $\pm$ 0.14 <sup>a</sup>
SC	4.3 $\pm$ 0.14 <sup>b</sup>	3.5 $\pm$ 0.14 <sup>a</sup>	3.7 $\pm$ 0.15 <sup>a</sup>
CC	3.9 $\pm$ 0.14 <sup>a</sup>	3.8 $\pm$ 0.15 <sup>a</sup>	3.7 $\pm$ 0.14 <sup>a</sup>

<sup>1</sup> CTRL=control (unshorn); SC=standard comb; CC= cover comb

<sup>a,b</sup> Means with different superscripts are significantly different (P<0.05).

Table 7. Effects of shearing treatment and sward surface height on plasma concentration of glucose (mmol/l) on the days indicated post-shearing (mean  $\pm$  s.e)

Day	Shearing Treatment			Sward Surface Height		
	CTRL <sup>1</sup>	SC	CC	3 cm	5 cm	7 cm
S2	4.01 $\pm$ 0.01	4.02 $\pm$ 0.11	4.11 $\pm$ 0.96	4.10 $\pm$ 0.13	4.01 $\pm$ 0.09	4.02 $\pm$ 0.12
S8	3.52 $\pm$ 0.21	4.20 $\pm$ 0.20	3.99 $\pm$ 0.19	3.94 $\pm$ 0.10	3.99 $\pm$ 0.09	3.94 $\pm$ 0.10
S13	3.74 $\pm$ 0.07	3.85 $\pm$ 0.07	3.69 $\pm$ 0.07	3.60 $\pm$ 0.13	3.96 $\pm$ 0.12	3.73 $\pm$ 0.12
S20	3.85 $\pm$ 0.22	4.25 $\pm$ 0.21	3.89 $\pm$ 0.21	3.70 $\pm$ 0.26	4.21 $\pm$ 0.25	4.07 $\pm$ 0.25

<sup>1</sup> CTRL=control (unshorn); SC=standard comb; CC=cover comb

In terms of plasma concentrations of NEFA, no interactions were found between shearing treatment and SSH. Average plasma NEFA concentrations of ewes classified according to shearing treatment and to SSH are shown in Table 8. Neither treatment influenced plasma concentrations of NEFA.

Table 8. Effects of shearing treatment and sward surface height on plasma concentrations of NEFA (meq/l) in pregnant ewes on the days indicated post-shearing (mean  $\pm$  s.e)

Day	Shearing Treatment			Sward Surface Height		
	CTRL <sup>1</sup>	SC	CC	3 cm	5 cm	7 cm
S2	0.58 $\pm$ 0.09	0.39 $\pm$ 0.10	0.36 $\pm$ 0.08	0.55 $\pm$ 0.12	0.36 $\pm$ 0.08	0.41 $\pm$ 0.10
S4	0.20 $\pm$ 0.02	0.19 $\pm$ 0.02	0.21 $\pm$ 0.02	0.23 $\pm$ 0.02	0.21 $\pm$ 0.01	0.17 $\pm$ 0.01
S8	0.15 $\pm$ 0.04	0.23 $\pm$ 0.04	0.20 $\pm$ 0.04	0.21 $\pm$ 0.02	0.20 $\pm$ 0.02	0.18 $\pm$ 0.02
S13	0.17 $\pm$ 0.02	0.13 $\pm$ 0.02	0.18 $\pm$ 0.02	0.13 $\pm$ 0.04	0.18 $\pm$ 0.04	0.16 $\pm$ 0.04
S20	0.26 $\pm$ 0.01	0.21 $\pm$ 0.01	0.22 $\pm$ 0.01	0.20 $\pm$ 0.04	0.20 $\pm$ 0.04	0.29 $\pm$ 0.04

<sup>1</sup> CTRL=control (unshorn); SC=standard comb; CC=cover comb

No interaction between shearing treatment and SSH was found in terms of plasma concentrations of 3-OHB, so average concentrations by main treatment are shown in Table 9. Plasma 3-OHB concentration of ewes grazing on pasture of 3 cm SSH was found to be higher on S2 (the 12th day after set-stocking on the pastures) than

those of ewes grazing on 5 or 7 cm SSH pastures. Shearing treatment did not alter plasma concentrations of 3-OHB of the late pregnant ewes.

Table 9. Effects of shearing treatments and sward surface height on plasma concentrations of 3-OHB ( $\mu\text{mol/l}$ ) on the days indicated post-shearing (mean  $\pm$  s.e)

Day	Shearing Treatment			Sward Surface Height		
	CTRL <sup>1</sup>	SC	CC	3 cm	5 cm	7 cm
S2	1689 $\pm$ 105	1504 $\pm$ 109	1487 $\pm$ 92	1871 $\pm$ 121 <sup>b</sup>	1363 $\pm$ 86 <sup>a</sup>	1446 $\pm$ 113 <sup>a</sup>
S4	950 $\pm$ 84	920 $\pm$ 80	921 $\pm$ 78	1046 $\pm$ 165	939 $\pm$ 156	806 $\pm$ 158
S8	838 $\pm$ 24	892 $\pm$ 24	884 $\pm$ 23	933 $\pm$ 109	894 $\pm$ 103	787 $\pm$ 104
S13	969 $\pm$ 54	934 $\pm$ 52	938 $\pm$ 50	1036 $\pm$ 80	852 $\pm$ 75	953 $\pm$ 76
S20	1030 $\pm$ 67	960 $\pm$ 63	975 $\pm$ 61	1135 $\pm$ 49	924 $\pm$ 46	906 $\pm$ 47

<sup>1</sup> CTRL=control (unshorn); SC=standard comb; CC= cover comb

<sup>a,b</sup> Mean values within the same row and treatment with different superscripts are significantly different ( $P < 0.05$ ).

### Organic Matter Intake

No significant interactions were found between the effects of the main treatments (shearing treatment and sward surface height) on organic matter intake (OMI). In the period from shearing to eight days after shearing, there were no significant differences among shearing treatments in OMI (Table 10). However, at ten days after shearing

Table 10. Effects of shearing treatment and sward surface height (cm) on organic matter intake (g OM/ewe per day) in pregnant ewes on the days indicated post-shearing (mean  $\pm$  s.e)

Day	Shearing Treatment			Sward Surface Height		
	CTRL <sup>1</sup>	SC	CC	3 cm	5 cm	7 cm
S2	1405 $\pm$ 119	1323 $\pm$ 121	1190 $\pm$ 107	941 $\pm$ 147 <sup>a</sup>	1628 $\pm$ 101 <sup>b</sup>	1349 $\pm$ 135 <sup>b</sup>
S4	1137 $\pm$ 62	1280 $\pm$ 60	1223 $\pm$ 60	1071 $\pm$ 99	1346 $\pm$ 95	1224 $\pm$ 93
S8	986 $\pm$ 55	1047 $\pm$ 53	968 $\pm$ 50	947 $\pm$ 74	1032 $\pm$ 67	1022 $\pm$ 71
S10	982 $\pm$ 104	978 $\pm$ 98	994 $\pm$ 94	983 $\pm$ 105	978 $\pm$ 97	993 $\pm$ 97
S13	1385 $\pm$ 64	1212 $\pm$ 61	1138 $\pm$ 57	1278 $\pm$ 183	1220 $\pm$ 167	1237 $\pm$ 175

<sup>1</sup> CTRL=control (unshorn); SC=standard comb; CC=cover comb

<sup>a,b</sup> Mean values within the same row and treatment with different superscripts are significantly different ( $P<0.05$ ).

(S10), there was a difference ( $P<0.05$ ) in the shearing effect on OMI between years. In 1994, the OMIs of ewes shorn by standard or cover combs were not significantly different to those of unshorn ewes. In 1995, however, shorn ewes (especially those shorn by standard combs) showed a higher OMI ( $P<0.05$ ), than that of unshorn ewes (Table 11). At thirteen days after shearing, the OMIs of shorn ewes were not significantly different to those of unshorn ewes (Table 10).

OMIs of ewes grazing on swards of nominal 3 cm height were generally lower than those of ewes on 5 and 7 cm swards but the difference was significant ( $P < 0.05$ ) only at two days after shearing (S2) (Table 10).

Table 11. Effects of shearing treatment and year on organic matter intake (g OM/ewe per day) on day 10 after shearing (mean  $\pm$  s.e.)

Year	CTRL <sup>1</sup>	SC	CC
1994	1160 $\pm$ 81	955 $\pm$ 78	1098 $\pm$ 68
1995	805 $\pm$ 69 <sup>a</sup>	1000 $\pm$ 65 <sup>b</sup>	890 $\pm$ 70 <sup>a</sup>

<sup>1</sup> CTRL=control (unshorn); SC=standard comb; CC=cover comb

<sup>a,b</sup> Mean values within the same row with different superscripts are significantly different ( $P < 0.05$ ).

## DISCUSSION

The main objective of this study was to examine whether the performance of pre-lamb shorn sheep is influenced by pasture allowance in the immediate post-shearing period and whether the relationship between performance and pasture allowance differs when ewes are shorn by standard comb or cover comb. Both long term (ewe liveweight change, lamb birth and weaning weight, wool growth rate and mean fibre diameter) and short term (rectal temperature, blood concentrations of glucose, NEFA and 3-OHB, and feed intake) effects of shearing and SSH treatment on ewe productivity and metabolism were measured to provide a comprehensive picture of possible interactions between effects of shearing treatment and feed allowance.

It was acknowledged that the response to any shearing treatment in the field would be markedly affected by climatic conditions occurring during the experiment. In an attempt to account for this, the present study was replicated over two years to allow for climatic variations and to simulate realistic winter conditions over a two year period in the North Island of New Zealand. Monthly climatic records (mean temperature, wind velocity, days with rain, and days of ground frost) during the study (July and August 1994 and 1995) were within the normal range for the 6 years prior to the trial (1988-1993) (Appendix VI).

## Long-Term Effects

In the current study, ewes on all treatments gained some liveweight during the experimental period. Rattray (1974) found that the weight gains of single and twin fetuses during the period of the current trial (P115-P135) were 2.5 and 4.4 kg, respectively. Therefore it seems likely that, although ewe liveweight (on the scales) increased in the cover comb- and standard comb- shorn groups, for shorn ewes on 3 and 5 cm pastures, herbage intake was insufficient to prevent a net decrease in maternal liveweight because of the substantial increase in weight of the fetuses during late pregnancy.

The interaction between effects of shearing treatment and sward surface height on liveweight gain showed that liveweight gains of shorn animals were very much lower than those of controls on 3 and 5 cm pasture, but less so on 7 cm. There were no differences in organic matter intake between shorn and unshorn ewes, indicating that there was no interaction between shearing treatment and sward surface height. Therefore increasing sward surface height did not allow standard comb- and cover comb-shorn ewes to express a voluntary intake response above that of controls.

Shorn ewes had higher lamb birth weights than control (unshorn) ewes, the difference between those shorn by standard comb and controls being significant. This may indicate that shorn ewes, especially those shorn by standard comb, expend more energy for the heat increment of pregnancy than control (unshorn) ewes. In addition, the

rectal temperatures of shorn ewes were lower than those of control (unshorn) ewes, implying that shorn ewes were in cold stress, and therefore had additional maintenance energy requirements for cold thermogenesis. Furthermore, research has shown that energy expended by standard comb-shorn ewes was higher than that expended by cover comb-shorn ewes (Dabiri et al. 1995b). Sward surface height may contribute to energy expenditure through different grazing activities required to maintain intake. Ewes set-stocked on the 3 cm pasture would have had an increased energy expenditure in harvesting the herbage. The three factors (heat increment of pregnancy, cold thermogenesis, and cost of harvesting herbage) may have accounted for the interaction between shearing treatment and sward surface height whereby the liveweight gains of shorn ewes, especially those shorn by standard comb, were very much lower than those of control (unshorn) ewes on the 3 and 5 cm pastures, but not on the 7 cm pasture.

The shearing treatment effect on lamb birth weight in the present study (Table 4) is similar to the results of most experiments conducted in housed sheep where feed intake between shorn and unshorn ewes was equalised (Rutter et al. 1972; Thompson et al. 1982; Symonds et al. 1986; Vipond et al. 1987; Black and Chestnutt 1990b), but is not consistent with most studies of pre-lamb shearing on pasture (Parker et al. 1991; Dabiri et al. 1995b). The mechanism by which lamb birth weight is increased is unclear. The absence of a shearing treatment effect on organic matter intake in the present study obviously implies that increased birth weight was not associated with an increased feed intake. The lack of difference in plasma glucose concentration between shorn and control (unshorn) ewes suggests that increases in the birth weights of lambs born to

ewes pre-lamb shorn by standard comb do not occur through increased maternal plasma glucose concentration. Shearing must therefore have a specific, and apparently non-nutritional, effect on fetal growth although the mechanism by which this occurs remain unclear. The lack of a sward height effect on lamb birth weight in the present study (Table 4), is in accord with results reported by Morris et al. (1993b,c).

Pre-lamb shearing had no effect on lamb weaning weight, a result consistent with that of Dabiri et al. (1995b). This is also consistent with result obtained by Morris et al. (1993b) who found that live weights at birth (L1), L54 and L77 of lambs born to ewes grazing 2, 4, 6, and 8 cm pasture during late pregnancy were similar.

The effect of shearing treatment on wool growth rate in the present study is in line with those noted by Parker et al. (1991) in that midside patch wool growth was not affected by shearing treatment. Wool growth rate during late pregnancy and lactation is minimal (Wickham 1978; Corbett 1979), and was not apparently increased further by pre-lamb shearing. Shearing treatment had no effect on mean fibre diameter, a result that agrees with Dabiri et al. (1995b). The negligible effect of sward surface height during the three weeks after pre-lamb shearing on wool growth rate or fibre diameter is consistent with the results of Morris et al. (1993b,c).

### **Short-Term Effects**

The rectal temperatures of shorn ewes were consistently lower than those of unshorn ewes. Similar results were noted by Maund (1980), Russel et al. (1985), and Black and Chestnutt (1990b). The similarity in rectal temperatures of ewes shorn by standard comb and cover comb agrees with research results of Holmes et al. (1992) and Dabiri et al. (1995a) who used non-lactating and non-pregnant ewes. The absence of an interaction between effects of shearing treatment and sward surface height implies that hypothermia induced by pre-lamb shearing cannot be prevented by pasture management. Therefore providing additional feed did not prevent hypothermia in standard- and cover-comb shorn ewes. This is presumably because, other than on S2, increased sward surface heights did not lead to an increase in organic matter intake. However, even on S2, increases in sward surface height did not increase rectal temperatures. Thus, in terms of preventing hypothermia, there appears to be no advantage in increasing SSH beyond 3 cm.

There were no effects of shearing treatment on organic matter intake in late pregnant ewes (Table 11). This finding does not agree with other researchers who worked with non-pregnant and lactating ewes (Wodzicka-Tomaszewska 1963, 1964; Webster and Lynch 1966; Elvidge and Coop 1974) where shearing increased feed intake one week following shearing. The result was, however, consistent with many experiments involving late pregnant ewes whether housed in pens (Rutter et al. 1972; Symonds et al. 1986; Black and Chestnutt 1990a) or at pasture (Parker et al. 1991;

Dabiri et al. 1995b, 1996). The consistent result that shearing treatment increases feed intake in non-pregnant and lactating ewes, but does not increase feed intake in late pregnant ewes, suggests that this difference is accounted for by the different physiological states of the ewes.

It is possible that ewes in late pregnancy may eat more than non-pregnant ewes as observed by Hadjipieris and Holmes (1966) and Hudson and Bottomley (1978). In addition, ewes in late pregnancy have a significant heat increment associated with pregnancy. These two additional sources of heat production are probably "wasted" in unshorn late pregnant ewes. However, for the shorn group, these contribute toward the pool of extra heat required to maintain body temperature (Graham 1964; Bottomley and Hudson 1976; Christopherson and Young 1986). This may have accounted for the absence of any increase in feed intake in shorn late pregnant ewes, although it seems unlikely given that the shorn ewes became mildly hypothermic.

Another possible reason for difference in results of the present study compared with those in non-pregnant ewes could be behavioural differences in intake between pregnant and non-pregnant ewes. In late pregnancy, ewes cannot increase their feed intake and in some instances, especially with twin-bearing ewes, feed intake may even decline (Reid and Hinks 1962; Owen and Ingleton 1963; Morris et al. 1993b), although their energy requirements for pregnancy are actually increasing (Rattray 1974). The drive to consume additional feed (to compensate for heat loss) in shorn ewes may also have been counteracted by reduced grazing times consequent upon the need to seek shelter as a response to cold stress.

Organic matter intakes of ewes set-stocked on different sward surface heights during late pregnancy were similar on most measurement days (except on P117). The capability of ewes set-stocked on 3 cm pasture to achieve to a similar feed intake to those ewes grazing higher sward heights must be achieved by ewes by increasing their biting rate or grazing time (Morris et al. 1993b).

## CONCLUSIONS

Pre-lamb shorn ewes, whether standard comb- or cover comb-shorn, suffered some hypothermia as determined by rectal temperature. However, there were no effects of shearing treatment, sward surface height, or interactions between these on ewe organic matter intake. Therefore, hypothermia induced by pre-lamb shearing cannot be avoided by pasture management. The common farmer practice of increasing pasture allowance immediately following shearing to prevent hypothermia does not appear to be justified based on results of the present study, primarily because of the absence of shearing treatment effect on feed intake. However, no comment can be made about the impact of offering sward heights of less than 3 cm in the immediate post-shearing period.

Although shorn ewes on 3 cm pasture had low liveweight gains, the 3 cm pasture did not affect other short-term or long-term production parameters. In addition, ewes pre-lamb shorn by standard comb had a higher lamb birth weight than lambs born to ewes shorn by cover comb. Thus, farmers can give ewes pre-lamb shorn by standard

comb a relatively low pasture allowance (3 cm) without affecting long or short term production parameters.

The results of the present study imply that other methods, for example the use of shelter, to minimise the detrimental effects of pre-lamb shearing are required. Future research needs to address the issue of shelter in the immediate post-shearing period. Farmers should be advised that, provided pastures are greater than 3 cm height, more attention should be given to providing shelter than to increasing pasture allowance immediately after shearing.

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## Appendix I. Measurement of chromium concentration

1. Approximately 0.5 g DM of each crushed faecal sample was weighed and put into a tared and numbered 25 ml pyrex beaker.
2. The beakers were placed in an oven at 105 °C to dry for 24 h.
3. After drying the beakers were weighed to determine the dry matter weight and then the samples were ashed at 550 °C in a muffle furnace for 12 h.
4. The beakers and ash were reweighed and anti-bumping granules, plus 6 ml of acid digestion mixture (MnSO<sub>4</sub>/phosphoric acid solution), were added.
5. The beakers were covered with glass to prevent evaporation of the mixture and heated to boiling (140 °C) in an aluminium heating block for 90 minutes.
6. The beakers were removed from the block, allowed to cool to below 100 °C and then 3 ml of 4.5% potassium bromate was added. The beakers were returned to the heating block, covered and digested to a final temperature of 210 °C.
7. After approximately 45 minutes the beakers were removed from the block and allowed to cool before their contents were quantitatively transferred into 50 ml flat bottomed volumetric flasks.
8. The digest volume was made up to 50 ml with distilled water, shaken to thoroughly mix it, and allowed to settle for 24 h.
9. A 10-15 ml aliquot was poured off into a small plastic bottle. By taking only liquid from the top, a clear sample with minimal suspended material was obtained for spectrophotometry.

**Appendix II. Technique to estimate botanical composition of diet samples collected from oesophageal fistulates (Clark and Hodgson 1986)**

1. Sample was thoroughly mixed then rinsed with tap water through a fine sieve to remove saliva and chlorophyll colouration. Some losses of unidentifiable herbage occurred.
2. Each sample (around 20 g) was placed on a white tray that had marked grids of 200 points. Sufficient water was added to disperse the sample evenly across the tray (some samples needed to be teased out to achieve this).
3. The material was identified at each point within the grid. If material was in several layers a 'first hit' system was used.

**Appendix III. Procedures for washing wool samples and calculating clean wool growth rate.**

1. After clipping, greasy midside wool samples were conditioned to constant weight at 20 °C and 65% relative humidity (RH) and then weighed.
2. Each weighed greasy midside wool sample was placed in an individually labelled terylene mesh bag.
3. The bags containing the samples were placed in the four bowls (3 minutes per bowl) of a scouring machine and submerged sequentially, then the mechanical agitation turned on.
4. At the end of 3 minutes, the samples from each bowl were passed to the next bowl through squeeze rollers.
5. Bowls 1, 2 and 3 contained 32, 16, and 16 ml of the detergent teric GN9 in 36 litres of water at pH 8 and temperatures of 60, 55 and 50 °C respectively, while bowl 4 contained cold water without detergent.
6. Following bowl 4, the samples were placed in a hydroextractor and spun for at least one minute. Then samples were spread evenly in a metal tray and placed in a forced air draught at 82 °C for about 6 minutes.
7. Dried samples were conditioned to constant weight and then weighed.
8. The growth rate of wool was measured as the scoured (clean) weight (g) of wool grown per square centimetre per day, while the method of measurement of patch area was carried out according to Morris et al. (1993a).

**Appendix IV. The principle of the air flow technique for measurement of mean fibre diameter.**

The principle of this method relies on Kozeny's Law which relates to the flow of a fluid (air) through a porous sample (wool sample) to the change in pressure across the sample. As the resistance to flow is a function of the properties of the specimen, wool samples of finer fibre diameter have greater surface area and offer greater resistance to the flow of air compared with that of samples of coarser fibre diameter at the same weights. Therefore for a fixed pressure drop, Kozeny's Law can be expressed as:

$$Q = f (1/d)$$

where;

Q = the fluid flow

d = the fibre diameter.

The pressure drop is measured by the manometer and the flow (Q) by the flowmeter (rotameter). The MFD of the specimen was determined from a calibration obtained measuring samples of known MFD (measured using Projection Microscope) (Teasdale 1988). The components of an airflow instrument are shown in Figure 1 where the specimen is in the specimen chamber.

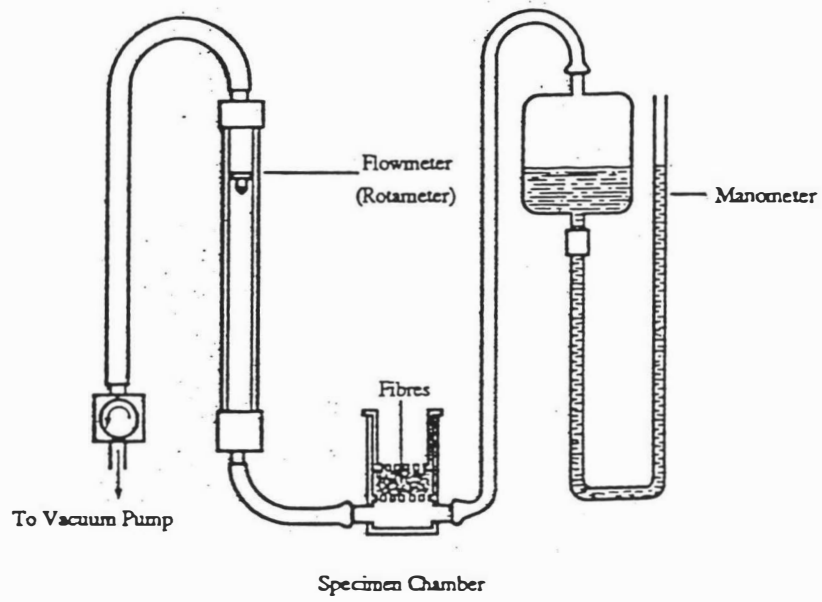


Figure 1. Airflow Instrument

**Appendix V. The mean and range of temperature, wind velocity, days with rain and days with ground frost during the experimental period (P115-P135).**

Climatic Variable	Year	
	1994	1995
Mean Temperature (°C) <sup>1</sup>	10.1	8.1
Range of Temperature (°C) <sup>2</sup>	7.4	7.3
Wind Velocity (km/h)	6	7.5
Days with rain <sup>3</sup>	16	14
Days ground frost <sup>4</sup>	3	7

<sup>1</sup> (mean maximum temperature + mean minimum temperature)/2

<sup>2</sup> mean maximum temperature - mean minimum temperature

<sup>3</sup> 1 mm or above

<sup>4</sup> -1 °C or below

**Appendix VI. The mean temperature, wind velocity, days with rain and days with ground frost in July and August in 1988-1995.**

Year and Month	Mean Temperature (°C) <sup>1</sup>	Wind Velocity (km/d)	Days with Rain <sup>2</sup>	Days ground frost <sup>3</sup>
1988 July	9.5	277	13	9
August	9.8	253	13	9
1989 July	7.7	173	9	17
August	9.3	220	8	16
1990 July	9.0	203	13	1
August	10.1	215	15	5
1991 July	8	171	13	13
August	10.5	246	16	5
1992 July	8.8	252	14	8
August	8.2	222	21	10
1993 July	8.5	146	4	8
August	9.5	165	8	9
1994 July	7.9	164	16	11
August	9.7	174	13	9
1995 July	8.2	193	19	8
August	8.7	195	13	9

<sup>1</sup> (mean maximum temperature + mean minimum temperature)/2

<sup>2</sup> 1 mm or above

<sup>3</sup> -1 °C or below