

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

SOME ASPECTS OF WINTER GRAZING
SYSTEMS ON WOOL PRODUCTION

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

COLIN TREVOR HORTON

1978

ABSTRACT

A trial was conducted to investigate the effects that 5 different winter grazing systems had on some wool characteristics of pregnant N.Z. Romney ewes. The grazing systems were: (T1) swedes on a daily break; (T2) three weeks hay, three weeks swedes on a weekly break; (T3) swedes on a daily break providing 75% of the ration, hay daily providing 25% of the ration; (T4) pasture on a daily rotational break; (T5) pasture under set-stocking. The treatments were applied for 6 weeks between mean days 74 and 116 of gestation.

Feed intakes were higher on pasture than on swede crop treatments. Mean period intakes were: 0.68, 0.59, 0.84, 0.9, 1.68kg DM/ewe/day respectively for the 5 treatments, T1 to T5.

Pasture as a winter diet proved to be superior to any of the three forage crop (swede) variations of winter grazing for characteristics associated with wool growth rate. Differences were found between rotational grazing and set-stocking but neither was better over all characters assessed.

Mean fibre diameter changes over the 6 week treatment period were: T1, 32 to 27.3 μ m; T2, 31.2 to 24 μ m; T3, 31.8 to 27.4 μ m; T4, 33 to 31.6 μ m; T5, 31.7 to 33.2 μ m. Corresponding with these fibre diameter changes, tensile strength tests indicated that staples from forage crop treatments were weaker than those from pasture (5.79 v 9.22 kg/g/cm; $\rho < 0.001$). Subjective soundness grades followed a similar pattern. Break usually coincided with the change from the crop back to pasture at the end of the treatment period. Hay with swedes tended to increase the tensile strength (6.25 v 4.75 kg/g/cm) by comparison to swedes alone.

Clean weight of wool per unit area was at least 300mg/cm² greater on pasture than on forage crops over the six weeks ($\rho < 0.001$).

Wool production from older ewes (≥ 5 years) was more strongly influenced by winter grazing than that of young ewes.

Ewes bearing single lambs produced more wool per unit area ($p < 0.05$), had greater fibre diameter ($p < 0.05$), soundness grade ($p < 0.05$), tip grade ($p < 0.05$) and character grade ($p < 0.10$) than those bearing twin lambs.

Other characteristics measured were: fibre length, quality number, staple length, crimp frequency, handle, lustre, colour and coting.

Insufficient numbers of animals involved in the lamb production data meant little significance could be attached to the results obtained.

ACKNOWLEDGEMENTS

I wish to especially thank my Supervisor, Dr. G.A. Wickham for his constructive advice and constant encouragement throughout this study and during the preparation of this thesis.

I am grateful to Mr C. Muir, Mr B. Thatcher and other technicians who assisted from the Sheep Husbandry Department in the collection of pasture and wool samples. My thanks are accorded to Mr M. Divehall who looked after all stock over the lambing period. Without the assistance of Mr P.H. Whitehead, Sheep Farm Supervisor, who ensured that the crop was sown down prior to my arrival at the University and who made stock and staff available for use, this trial could not have been run.

My thanks are accorded to the staff of the Biometrics Division, MAF, Palmerston North, who helped in the period of computer familiarization.

For the final presentation of this thesis I am indebted to Miss Judy McKegg who skillfully typed and deciphered my writing.

Many other people have assisted with the study in providing a source of stimulating discussion and their important contribution is acknowledged here.

The work would not have been possible without the financial assistance granted while the author had a study award from the Ministry of Agriculture and Fisheries.

TABLE OF CONTENTS

	page
ABSTRACT	ii
ACKNOWLEDGEMENTS	iv
TABLE OF CONTENTS	v
LIST OF TABLES	viii
LIST OF FIGURES	ix
LIST OF PLATES	x
LIST OF SCHEDULES	x
LIST OF APPENDICES	x
<u>CHAPTER I - INTRODUCTION</u>	1
<u>CHAPTER II - REVIEW OF LITERATURE</u>	3
A. THE ESTIMATION AND CONTROL OF INTAKE OF GRAZING SHEEP ..	3
(1) The Estimation of Intake in the Grazing Ruminant ..	3
(i) Pasture Sampling	3
(ii) Animal Weighing	5
(iii) Faecal Output Technique	7
(iv) Feed Digestibility Analysis	7
(2) Winter Feeding and Intake	9
B. WOOL PRODUCTION	15
(1) The Control of Wool Growth During Winter	15
(a) The Inherent Rhythm	17
(b) Nutrition	21
(c) Pregnancy and Lactation	23
(d) Hormonal Mediation of Wool Growth	25
(2) Effects of Winter Grazing Systems on Wool Growth and Characteristics	26
(a) Winter Nutrition	27
(b) Winter Grazing Systems	30

	page
C. LAMB PRODUCTION	33
(1) Nutrition	33
(a) Nutrition During Pregnancy	33
(b) Age of Ewe	35
(2) Winter Grazing Systems	36
(a) Pasture Grazing	36
(b) Forage Crop Grazing	37
<u>CHAPTER III - EXPERIMENTAL PROCEDURES</u>	39
A. MATERIALS	39
(1) Experimental Site	39
(2) Layout of Experiment	39
(3) Experimental Animals	42
B. METHODS	42
(1) Swede Crop Management	42
(2) Pasture Management	43
(3) Animal Management	43
C. EVALUATION METHODS	43
(1) Crop Samples	44
(2) Hay Samples	45
(3) Pasture Samples	46
(4) Animal Liveweights	48
(5) Feed Allowance and Feed Budgeting	49
(6) Wool Production	49
(7) Scouring	52
(a) Crutchings	52
(b) Mid-side Samples	52
(8) Pre-scouring Fleece Characteristic Grading	53
(9) Tensile Strength	54
(10) Fibre Length Estimation	54
(11) Fibre Diameter Estimation	55

	page
D. STATISTICAL ANALYSIS	56
<u>CHAPTER IV - RESULTS</u>	58
A. FEED 'INTAKE' AND EWE LIVE WEIGHT	58
B. WOOL PRODUCTION	68
(1) Wool Growth Rate	68
(2) Fibre Diameter.	68
(3) Fibre Length	75
(4) Wool Characteristics	75
C. LAMB PRODUCTION	83
(1) Number of Lambs Born	83
(2) Weight of Lambs Born	83
(3) Number of Lambs Weaned	88
(4) Weight of Lambs Weaned.	88
<u>CHAPTER V - DISCUSSION</u>	93
Pasture and Crop Analysis Methods	93
Intake and Ewe Live Weight	94
Wool Production Measures	97
Wool Production	97
Lamb Production	106
<u>CHAPTER VI - GENERAL CONCLUSIONS</u>	110
SCHEDULES	112
APPENDICES	114
BIBLIOGRAPHY	125

Table	<u>LIST OF TABLES</u>	page
1.	Average Daily Intake for Ewes on Each Treatment	58
2.	Analysis of Covariance of Ewe Live Weights Two-Way Analysis	59
3.	Adjusted Mean Live Weights of Ewes on Each Treatment ..	60
4.	Botanical Composition Changes of Pasture	66
5.	Intake Estimates For Pasture Grazing Treatments	63
6. (a)	Analysis of Covariance for Weight of Wool Per Unit Area Adjusted for Weight at Pre-Trial Sampling	69
6. (b)	Analysis of Covariance for Fibre Diameter Adjusted for Pre-Trial Diameter	69
7.	Adjusted Means of Weight of Wool Produced Per Unit Area	72
8.	Adjusted Means of Fibre Diameter	73
9. (a)	Analysis of Covariance of Fibre Length Adjusted for Fibre Length on Initial Sampling	76
9. (b)	Adjusted Fibre Length Treatment Means	76
10.	Analysis of Variance of Wool Characteristics Using the Two Factor Analysis	78
11.	Analyses of Variance of Wool Characteristics Using the Three Main Effects Model Regressing on Birth Date	80
12.	Least Squares Means for Wool Characteristics	81
13.	Least Squares Means for Wool Characteristics Involving the Three Factor Main Effects Model	82
14. (a)	Analysis of Variance of Lamb Production	86
14. (b)	Main Effects Only Analysis of Variance For Lamb Production	87
15.	Means of Lamb Production Data	89
16.	Least Squares Means of Weight of Lambs Born From the Three Factor Analysis	90
17.	Least Squares Means of Weight of Lambs Weaned From the Three Factor Analysis	91

LIST OF FIGURES

	page
1. Seasonal Growth Rates of Romney Breeding Ewes	15
2. General Experimental Area Layout	41
3. Ewe Live Weight Change for Each Treatment	61
4. Pasture 'Intake' and Associated Ewe Live Weights	67
5. Unadjusted Weight/Unit Area Means of Treatment Groups	70
6. Unadjusted Wool Weight Per Unit Area for Age of Ewe	71
7. Unadjusted Treatment Mean Fibre Diameters	74
8. Unadjusted Fibre Length Treatment Means	77
9. Proportion of Staples at Each Tensile Strength Grade	84
10. Percentage of Non-Sound Staples Breaking at Each Position .. .	85

LIST OF PLATES

	page
1. Pasture Sampling Technique	47
2. Yield Sampled Area Post-Grazing	47
3. Ewe Placement for Wool Sampling	51
4. Patch Wool Harvesting	51
5. 'Daily Break' and Swede Utilisation in T1	62
6. Hay Feeding and Swede Utilisation in T3 (in last week of treatments)	62
7. Hay Feeding in 1st 3 weeks of T2	64
8. Swede Utilisation After 1½ Weeks in T2	64
9. Rotational Grazing (T4) Indicating Pre- and Post- Grazing Yields	66
10. T4 Post-Grazing on a Dry (right) and Wet (left) Day	66

LIST OF SCHEDULES

1. Schedule of Crop, Pasture, and Hay Analysis Work . ..	112
2. Sequence of Animal Sampling	113

LIST OF APPENDICES

I (a) Climatological Data	114
(b) Climatological Data	115
(c) Daily Meteorological Data	116
II Mineral Content of Water After Deionisation	117
III Descriptions of the Fleece Characteristic Grading System	118
IV Wool Copper Analysis	122

C H A P T E R I

INTRODUCTION

INTRODUCTION

One of the principal faults in New Zealand wool is tenderness or break (Ross, 1960). In a survey of New Zealand wools, Henderson (1955) found that 40-50% of the fleeces had a break, the incidence increasing with quality number. There were other faults such as cotting, yolk strain, and dingy wool, which were associated with break. Many of these faults are secondary to the formation of a break.

In 1967, on the instigation of the New Zealand Wool Board, the Southland Wool Quality Improvement Committee (S.W.Q.I.C.) was formed. In the 1966/67 wool season, the New Zealand Wool Commission had to purchase 58% of the Southland clips. This proportion was the highest for any area of New Zealand and it was thought that tenderness was a factor (S.W.Q.I.C., 1970). The wool trade at that stage, was showing little interest in unsound wools as against sound wools, and sound wools showed a premium of up to 7c per lb. The role of the Committee was to investigate reasons for and policies to overcome this tenderness.

Some farms in New Zealand rely heavily on fodder crops for winter feeding, whereas others rely solely on fresh and conserved pasture. Relatively little is known of the effects of winter grazing systems on pregnant ewe wool production. However, it is well established that the rate of wool growth is influenced by the plane of nutrition (Schinckel, 1960, 1963), although seasonal (Hutchinson and Wodzicka, 1961) and breed differences do occur (Doney, 1964, 1966).

On this basis this trial was set up to investigate the result of five winter grazing systems on wool production and wool characteristics of ewes over the mid pregnancy period. The two fodder crop grazing systems, either with or without hay, were seen as the two most common

methods of fodder feeding in the field. The treatment where hay was provided during the initial three week period and then swedes for the remaining three weeks were envisaged to represent a situation where the fodder crops' growth had been poor due to any of a variety of reasons, hay being fed on a sacrifice paddock in the hope for more swede growth over time.

The two pasture grazing treatments opted for were considered the main systems being used in New Zealand at present for this period. Feed budgeting as proposed by Milligan and McConnell (1976) for pasture grazing, was carried out under all treatments to a greater or lesser extent, in the desire to achieve similar ewe voluntary feed intakes.

C H A P T E R I I

REVIEW OF LITERATURE

REVIEW OF LITERATURE

In studies of animal production from any system of grazing management it is difficult to define the limits to which a review of literature should extend to give adequate background information. Principles from both agronomic and animal husbandaries are involved in these studies. The main features of the trial thus decide the review limitations.

Within this trial it is conceivable that of the many variables measured, any one by itself, could be classed as highly important and be in itself the sole purpose for carrying out the trial. It was decided that wool production from the grazing systems was to be the main consideration here. Thus, within the review, sections involving feed intake and lamb production are covered only broadly, and not in the detail of Section B on wool production.

A. THE ESTIMATION AND CONTROL OF INTAKE OF GRAZING SHEEP.

(1) The Estimation of Intake in the Grazing Ruminant

Despite research efforts in the last 30 years, the techniques of grazing intake measurement that are available still appear inadequate. This limits the precision with which grazing studies can be interpreted.

Measurement techniques fall into broad categories based on their ease of assessment. Those not requiring laboratory analyses include pasture sampling and animal weighing techniques. Those requiring laboratory analyses revolve around the estimation of faecal output and feed digestibility. The former type are the main consideration here.

(i) Pasture Sampling

All pastures are dynamic, with varying rates of growth, maturation, senescence, breakdown, and consumption by various herbivores. Consequently

the 'difference' method whereby pasture intake is equated with the difference between the yield of pasture before and after grazing is not precise. This technique, when applied under a 'strip' grazing regime, is reasonable as the difference between the yield estimates is large and pasture growth during the period of grazing is small (Raymond 1969). However, because considerable growth usually occurs during longer grazing periods this is not a satisfactory means of estimating intake under a set stocking policy. Protection of areas from grazing allowed intake to be estimated from the difference between the herbage yields of caged and grazed areas sampled at the end of grazing. Differences in the relative growth rate of protected and grazing areas have been found (Cowlshaw, 1951) and these can be major sources of error in estimating 'intake'.

Problems of matching grazing height with cutting height and also the unevenness of pasture growth over an area tend to increase the imprecision of this technique.

Basically this technique measures the disappearance rather than the consumption of pasture. Disappearance of pasture may have several components (e.g. trampling, death, dung patches, insects and rodents), which 'consume' pasture over and above the animal (Frame, 1976; Wade, 1976). Thus, even if yield measurements are taken with care and precision, intake of the grazing animal under a continuous or set-stocked policy will tend to be overestimated.

Intake is normally measured on a group rather than on an individual basis by this method and even when tight control of both animal and pasture is possible the coefficient of variation of dry matter (D.M.) consumption can easily exceed 20% (MacLusky, 1955; Corbett and Greenhalgh, 1960).

(ii) Animal Weighing

This method of estimating intake has only recently been in vogue even though Erizian (cited by Allden, 1969), some 43 years ago suggested its use. This technique has been used to measure intake over periods of a few hours to allow the rate of eating (Allden, 1962) or digestibility of the pasture (Allden, 1969) to be determined.

Three factors dictate the validity of animal weighings: human error, the precision of the machine, and how accurately apparent change in animal live weight represents real change in the weight of the carcass. With ruminants, the contents of the rumen and reticulum can be at least 10-15% of the total body weight, and the contents of the rest of the gut may add another 2-3% (Hungate et al., 1959). For example, the stomach contents of a very full lamb off pasture can weigh 3.6kg, or about 13-14% of the animals live weight (Kirton et al., 1968), but on high roughage diets, the percentage can be much greater. For example, four hours after a meal of hay and concentrate, the content of the whole alimentary tract of ewes was found to be 23% of live weight. A further four hours later, gut content was still 15% of live weight (Boyne et al., 1956). That is, 8.7-13.7 kg of the apparent live weight of these 58 kg sheep was food material passing through the body. Wool and foetal growth over a period may also change live weights (Wheeler et al., 1971; Kirton, 1973; Hughes, 1976).

At any particular time, the amount of digesta and water in an animals gut depends on the quantity and quality of the feed on offer, on the amount of it eaten, on the time elapsed since the animal last fed, and on the rate of use of food by-products. It also depends not only on the appetite of the animal but on the extent to which grazing management allows appetite to be satisfied (Hughes, 1976).

Quality of feed has an important influence on the weight of digesta.

Digestibility of the ration has been shown to have a much larger effect on the amount of rumen contents than either time elapsed since feeding, or plane of nutrition (Emery et al., 1958). Succulent, highly digestible foods were found in smaller quantity and to have a shorter retention time in the rumen than fibrous food of low digestibility (McLean et al., 1965; Forbes and Boaz, 1965). Thus, the stomach contents of animals on high-quality fodder should add less to live weight than those on poor-quality feed. Cattle data of Balch and Line (1957) confirms this.

Within one paddock the digestibility of forage eaten can vary with the grazing pressure on the pasture (Hughes, 1976). For instance, if ample pasture is available, an animal will select a diet higher in digestibility than the average digestibility of green material in the pasture.

Conversely, if grazing pressure on the herbage is high, as in the case of rotational grazing, the animal is forced to select a diet containing some dead plant tissue and generally of lower digestibility than the average (Hamilton et al., 1973). It follows that over a period of time at high stocking rate, if feed supply declines and grazing pressure increases, the average digestibility of forage intake decreases. Thus, each time animals are weighed the quantity and quality of pasture available needs to be compared between groups and with previous weighings to give meaningful results (Hughes, 1976).

Day to day changes in gut fill and live weight may not only be due to external environmental influences, like food supply, but to internal animal factors. Chance differences in daily behaviour of individual animals in intake or grazing period have resulted in standard deviations of 4.5 kg from regressions of live weight change in individual cattle (Green et al., 1952). Sheep data are lacking.

Hughes (1976) feels that by appropriate management day-to-day variation in live weight can be reduced to about $\pm 0.75\%$ of live weight.

(iii) Faecal Output Technique

Faecal output measurement can be either by total collection of faeces or by the use of external markers. Animal behavioural changes often introduce bias into the levels measured (Hutchinson, 1956) when total collection is conducted. The use of Cr_2O_5 marker and grab sampling of faeces is the most common technique used. Diurnal fluctuations in faeces levels between animals and between days (Lambourne and Reardon, 1963a), between grazing and pen-feeding conditions (Raymond and Minson, 1955), along with pasture quality (Lambourne, 1957), climatic conditions and water consumption (Hardison and Reid, 1953) may introduce bias. Slow dissolving Cr_2O_5 preparations have reduced some of this bias.

(iv) Feed Digestibility Analysis

An inverse relationship between digestibility and level of intake has often been demonstrated although Brown (1966), in his review of this subject, concluded that the extent of decline in digestibility with increasing level of intake varied between diets, between experimental stations, and between trials within experimental stations. Species variation in digestive efficiency has been reviewed by Van Dyne (1968). Cattle were found to digest the fibrous components of low-quality roughages better than sheep, however, within species variation is often as high as between species variation.

Techniques for digestibility are faecal-index, in vivo and in vitro microdigestion, indicator ratios. The faecal-index technique depends on the establishment in pen trials, of regression equations predicting the digestibility of a feed from faecal components. Digestibility of herbage eaten by the grazing animal is then estimated from the concentration of

faecal components.

Many regression equations between intake and digestibility are available (e.g. Van Dyne, 1968) including those for different pasture type and different seasons (e.g. Lambourne and Reardon, 1962). Even though detailed information may be available to allow the prediction errors for the regression to be minimal, application errors, especially when selective grazing occurs, will affect the validity with which these regressions are used (Langlands, 1967). Minson and Raymond, (1958) feel that even when errors are minimal the faecal index technique is unlikely to allow feed intake differences less than 10% to be significant. Soil ingestion during grazing further increases the bias of this technique (Lambourne - cited by Scoffield, 1970).

The basis of the microdigestion techniques revolves around the establishment of a regression equation between in vivo macrodigestibility estimates of a feed and microdigestibility estimates of the same feed. The regression is then used to predict in vivo digestibility of a feed from a measure of its microdigestibility. Interpretation of in vivo microdigestion estimates is difficult since their relationship to an in vivo macrodigestion is seldom assessed (Van Dyne, 1968). Until such relationships are assessed, digestibility estimates obtained by this method are of limited use.

The use of regression equations between in vitro and in vivo digestibility give a more precise estimate of in vivo digestibility than does any other general relationship for the prediction of digestibility (Corbett et al., 1966) although underestimation of in vivo digestibility may occur above 80% digestibility (Arnold and Dudzinski, 1967). If in vivo data for the regression equation were from conditions other than those to which the digestibility estimate is to be applied (i.e. pen fed c.f. grazing) then some error of application will exist.

The ratio technique involves the use of a naturally occurring but indigestible indicator and its' concentration in the feed and faeces gives a measure of its' digestibility. Several indications are available e.g. fibre, silica, chromogens, lignins, indigestible cellulose. This technique necessitates 100% recovery of indicator. Thus lignin being not completely indigestible (McCullough, 1959) was not popular, until Ulyatt et al., (1967)^{suggested} refinements in determining the 'lignin' fraction of the herbage,^{that} allowed near full recoveries.

The main advantage of the ratio-technique would be the elimination of application errors, since digestibility would be determined directly from the grazing animal. However, the tedious nature and imprecision of lignin analyses, provide drawbacks to this technique along with the fact that soil contamination effects have yet to be determined.

The minimum coefficient of variation (C.V.) which is likely to be achieved in estimating herbage intake in practice can be calculated by combining the C.V.'s for the separate determinations of intake factor and faecal output (Scofield, 1970). Where total collection is used the C.V. is likely to be $\pm 4-5\%$ and the value may be increased to $\pm 7\%$ where Cr_2O_3 is used to estimate faecal output (Grimes, 1966). In practice values may approach these (Grimes, 1966; Corbett, 1969) but may rise above $\pm 20\%$ (Lambourne and Reardon, 1963b)

(2) Winter Feeding and Intake

Relatively few trials have been conducted on pregnant ewes fed different diets during winter grazing systems. The majority have involved the use of growing young stock.

Estimates of the energy cost of pregnancy vary widely, but generally indicate an overall increase in dietary energy requirements above maintenance of between 12 and 20% (Graham, 1964; Russel et al., 1967; Sykes and Field, 1972; Lodge and Heaney, 1973), occurring almost

entirely during the last one-third of gestation (Modyanov, 1969; Robinson et al., 1971; Rattray et al., 1974). Many experiments have been conducted to assess the basic maintenance feed level requirements. These have been found to be influenced by the metabolic size, physiological status, and activity of the ewe, along with feed availability as determined by management. Blaxter, Wainman, and Wilson (1961) suggested maintenance varied approximately with metabolic body size ($W^{0.734}$). However in grazing trials with sheep, maintenance has frequently been found to have a linear relationship with bodyweight (Young and Corbett, 1972).

Calorimetric experiments designed to measure energy expenditure of the grazing sheep in its various activities have been conducted (Graham, 1964; Blaxter, 1964; Coop and Hill, 1962; Lambourne and Reardon, 1963b) and indicate increases of 33-37% above indoor estimates. However it is difficult to see how these indoor experiments can simulate precisely all the vagaries of the outdoor environment in a given season.

There is a biphasic relationship between dietary quality and voluntary intake in ruminants (Forbes, 1977), with a positive correlation between the content of available energy and the weight of food eaten with poor and medium roughage feeds, and a negative correlation with high-quality roughage and cereal-based diets (Conrad, et al., 1964; Baumgardt, 1970). For the former situation, when physical limitations of gut capacity are thought to set an upper limit to food intake, this is influenced by the rate of disappearance of digesta and the competition for abdominal space by abdominal fat (Campling, 1970). When energy requirements are below the physical limit, food intake is related to nutrient demand, and changes in this demand (e.g., exposure to a cold environment) will be followed by compensatory changes in food intake. In this situation intake is controlled metabolically (Forbes, 1977).

Various estimates of intake have been made involving pastures and crops either grazed in situ or pen fed to ewes over mid-pregnancy, the

time this study is concerned with. However most involved hoggets with live weight gain being measured.

Rattray and Jagusch (1977) estimated that the maintenance diet of a 50kg ewe during mid-pregnancy on pasture was achieved with an intake of about 0.9kg DM/ewe/day by offering between 2.0-2.3kg DM/ewe/day. Rattray (1977) found over this period intakes of 1.5 and 1.2kg DM/ewe/day for early and late lambers respectively, were achieved when offered 2.3 and 1.9kg DM/ewe/day respectively. This resulted in pasture utilisation figures of 65% and 63% respectively.

In temperate conditions, herbage intake appears to approach the maximum only at levels of daily herbage allowance (measured to ground level) equivalent to 4 times the amount eaten, and declines rapidly when the allowance falls below 40g organic matter/kg live weight/day (Hodgson, 1976). The relationship between herbage intake and allowance appears to result from the increasing difficulty of prehending herbage as the sward is grazed close to ground level (Hodgson, 1976).

Under set-stocking conditions it is very likely that the relationship between allowance and intake is a function of the rate at which animals graze down to some limiting weight (Hodgson et al., 1971) or height (Tayler, 1966) of standing crop, below which the prehension of herbage becomes progressively more difficult. Experiments by Jamieson et al., (1974) and Jamieson (1975) indicate that the weight of individual mouthfuls of herbage falls as animals graze down through a sward under strip-grazing conditions.

Although set-stocked animals will attempt to compensate for reductions in bite size by spending more time grazing, there appears to be very little change in grazing time as herbage allowance is reduced under strip-grazing conditions (Jamieson, 1975). At high stocking rates feed availability per sheep is reduced and this can result in increased

grazing time per sheep (Scofield, 1970).

In large scale trials in New Zealand comparing set stocking and rotational or mob grazing throughout the year, ewe live weights were only superior under set stocking on the Te Awa trial by Suckling, (1959). The rest indicated less variable movement in live weights on the rotational grazing policy (Boswell et al., 1974; Collin, 1966). This was more evident at the higher stocking rates (McMeekan and Walshe, 1963; Walker, 1968).

Few studies have analyzed swede crop intakes and the resultant ewe live weight fluctuations. Thomson and Harbord (1966) have suggested that for 55kg pregnant ewes grazing swedes in situ DM intakes of 0.9-1.14kg were needed to meet requirements. Joyce (1965) at Ruakura, in an indoor pilot trial with 10 pregnant ewes per group, fed chopped swede bulbs ad lib with and without hay. At DM intakes of 0.41kg on swedes alone a live weight loss over 40 days of 1.55kg was observed. By varying the amount of hay in addition to swedes, either .225kg or .454kg, DM intakes of 0.68 and 0.91kg resulted in liveweight increases of 1.36 and 7.3kg respectively. Hay fed by itself at 1.05kg DM/day resulted in a 5.23kg increase in live weight. With hoggets superior live weight gains on turnips were achieved by feeding restricted amounts (100g/head/day) of hay (Lewis, 1960).

Drew (1967) compared pasture with crops as the sole diet over winter. The autumn-saved pasture was inferior to swedes plus hay in promoting winter gain in hoggets (53g v 122g/head/hay^d). However, this autumn-saved pasture was 15-20cm long and, despite its 72% digestibility, might not be considered the ideal autumn-saved pasture for sheep. Studies of this nature involving pregnant ewes are lacking. For crops, the voluntary intake increases with digestibility until levels of 65-70% are reached (Swedes average 90% digestibility v pasture 75%)

(Drew et al., 1974) and intake also increases at DM% increases.

However, with pasture this latter relationship does not hold.

The digestibility of root crops is well in excess of most other feeds, and the volatile fatty acid molar proportions in the rumen fluid of sheep fed root crops have been found to be similar to that achieved with concentrate feeds (Drew et al., 1974). However, stock performance is often not as good as expected (Nicol, 1978). The suggestion that root crops are an unbalanced diet in terms of insufficient protein is not confirmed by New Zealand work. The complete plant (bulbs and tops) have a crude protein level in the range of 15-20% which is adequate to sustain rates of growth higher than that observed (Drew, 1968).

Calcium to phosphorus ratio in swede bulbs is very low (0.5:1; Barry, 1977, cited by Nicol, 1978) compared to that normally recommended for growth of 1:1 to 7:1. Hence mineral imbalance is a possible explanation to the response achieved from hay as a supplement to swedes (Drew, 1967, 1968) but not to turnips (Lewis, 1960) where Ca:P ratio is 2:1 (Barry, 1977 cited by Nicol, 1978). The likelihood of an imbalance is negated in the field where intake of root crops consists of approximately 30% leaf: 60% bulb (Drew, 1967) as leaves of turnips and swedes have a Ca:P ratio of 10:1. For the whole swede plant this represents a ratio of 4:1 and a P intake of 0.25% DM, sufficient to meet phosphorus requirements (Underwood, 1966; 1977).

The maintenance requirements of sheep grazing root crops have been found to be 30-40% higher than similar sheep grazing pasture, and 90% higher than pen fed sheep (Drew, 1967, 1968; Barry et al., 1971). Nicol (1978) proposed three possible reasons for these elevated maintenance requirements: environmental exposure, energy cost of harvesting these crops in situ and the large water intake. During the

winter feeding of these crops ambient temperatures are usually low and often accompanied by wind and rain. These may increase the maintenance requirements as higher growth rates per animal on root and forage crops have been achieved during the summer (Ewer and Sinclair, 1952; McDonald et al., 1977).

To obtain high DM intakes with low DM crops, requires large amounts of wet herbage to be consumed daily. Hogget data suggests this to be energetically very costly (Drew, 1968). Also water requires energy to heat it to normal body temperature, thus ingestion of large amounts of water at low temperature increases the maintenance requirements. Barry et al., (1971) estimated that the energy required to heat water from 5 to 39°C could represent up to 15% of the daily digestible energy of young sheep on turnips or an increase of 20% above basal maintenance requirements. This increase will be dependent on the temperature at which the crop is consumed. Feeding of hay along with a swede ration has been suggested to be beneficial in that the hay's high heat production achieved during digestion offsets the water heating requirement (Barry et al., 1971).

A delay in achieving live weight gain on swedes in young cattle due to short term depression of DM intakes caused possibly by a period of rumen adaption to large water volume consumption has been reported (Kay, 1974). No similar information is yet available for sheep, although Annison et al., (1957) found there were metabolic changes when sheep were transferred to lush spring grass. Conceivably in sheep, because the volume that the rumen occupies will be reduced over the last 5 weeks of pregnancy, intake will be depressed (Forbes, 1968).

B. WOOL PRODUCTION

(1) The Control of Wool Growth during Winter

Early German work cited by Wodzicka (1960) established that wool growth was not uniform throughout the year. This work suggested that up to two-thirds of the yearly growth occurred in the 6 months after spring shearing. Thus the irregularity of wool growth was initially thought to be a shearing effect.

An annual rhythm of wool production is exhibited to a varying extent, in all breeds of sheep, with growth rates usually having a maximum in summer and a minimum in winter. In Corriedale ewes maximum summer growth rate exceeds winter minimum by about 23%, while in Camden Park Merinos by about 44% (Ferguson et al., 1949). On the other hand, little variation in wool growth has been found in Peppin medium-wool Merino's and Tasmanian fine-woolled Merino ewes (Hutchinson and Wodzicka, 1961; Williams, 1964).

In studies with New Zealand Romney ewes fed well throughout the year, summer wool growth was 2-5 times greater than that in winter (Coop, 1953; Story and Ross, 1960; Sumner and Wickham, 1969). Wool growth from Romney ewes has been studied from 14 months to 7 years (Ross, 1965). On average, 47% of the annual production was grown in the 4 months from late November until late March, 29.5% March to July, when most ewes were pregnant, while only 23.5% was grown in the late winter/spring period from July to November, when most ewes lambed and were lactating. Figure 1 shows the seasonal growth rates of Romney Breeding Ewes.

Month	Fibre Diagram	Length Growth (mm/day)	Average Diameter (microns)
November	9%	0.61	37.3
December	12	0.66	40.5
January	12	0.64	41.5
February	12	0.63	41.9
March	11	0.59	40.0
April	10	0.59	38.7
May	9	0.56	38.6
June	7	0.49	35.3
July	4	0.39	31.9
August	3	0.41	28.5
September	4	0.43	30.2
October	6	0.48	34.1

(from Story and Ross, 1960)

Corriedale ewes (some rearing lambs and others barren), when fed on pasture of constant composition, at rates which maintained effective ewe body weights constant, showed the seasonal wool growth rhythm (Coop, 1953; Coop and Hart, 1953). Both fibre length and fibre diameter changes were associated with the changes in wool growth rates. The maximum and minimum fibre diameters occurred some weeks ^{later} than maximum and minimum fibre length growth rates (Story and Ross 1960, Sumner, 1969). This may indicate that length and growth may be under independent control mechanisms, or that there is a delay in the diameter response. During winter, fibre diameter may be reduced to such an extent that fibre breakage occurs (Ross, 1960). Also some follicles can stop producing wool in winter and the fibres shed. However, individuals and breeds, vary in the magnitude of this seasonal response. Merinos appear to have little response while some other breeds have such a marked response that a peak of shedding is produced solely as a result of this seasonal thinning. Most Romneys are intermediate between these two extremes, and need other predisposing factors (e.g. poor nutrition) before this unsoundness of the fibre becomes recognisable.

Three main factors are involved in the annual rhythm of wool growth:

- (a) The inherent physiological rhythm varying in phase with climatic season (Hutchinson and Wodzicka, 1961; Hutchinson, 1965).
- (b) Variation in nutrition (Schinckel, 1963; Doney and Eadie 1967).
- (c) Effects of pregnancy and lactation (Bell et al., 1936; Coop 1953).

(a) The inherent rhythm

Environmental temperature is closely correlated with wool growth (Ferguson et al., 1949; Coop and Hart, 1953). Ferguson et al., (1949) suggested increased wool growth was a result of increased blood flow to the skin; vasolidation being part of the normal heat disposal mechanism in the sheep, hence a greater supply of wool growth promoting nutrients being made available. When unilateral thoracic sympathectomy was carried out to prevent vasoconstriction, a temporary increase in wool growth on that side occurred, for a period of 10 weeks, after which the difference disappeared (Ferguson, 1949). Later Cockrem (1959) reported a similar situation following chemical induction of vasoconstriction in mice.

Coop (1953) maintained a group of sheep for four winter months in a room 13⁰F above the outside temperature, but wool growth was not increased. Reversal of normal ambient temperature cycles also failed to elicit a wool growth response (Morris, 1961; Bennett et al., 1962).

It has been suggested that ambient temperature may exert a local effect on wool growth (Bennett et al., 1962). Doney and Griffiths (1967) supported this theory when they exposed sheep, side on, to an artificially produced wind. The 'chilled' side of the animal showed a depressed wool growth in terms of fibre length.

The exposure of animals to either very high or very low temperatures

caused physiological stress, resulting in depressed wool growth (Nagarcenkar and Bhattacharya, 1964; Slee and Ryder, 1967; Thwaites, 1968; Downes and Hutchinson, 1969).

Early experiments found winter growth increased in Corriedale ewes, when they were subject to constant short day length (i.e. 8 hours light v 16 hours darkness or 4 hours light v 8 hours darkness), (Coop and Hart 1953). Summer growth was not altered but the amplitude of the rhythm decreased. This suggested that photoperiodicity had some influence over the animals rhythm. On the assumption that the eye was the light receptor organ, Hart (1955) hooded animals for a period of two years. Though the animals were exposed to a normal seasonal temperature cycle the wool growth rhythm slowly disappeared. However, animals subjected to constant daylength as continuous light did not change the rhythm, and a considerable amplitude of growth remained between seasons (Hart, 1961).

The discrepancy in these results has been suggested by Hart et al., (1963) to be due to either differing temperature x light interactions in the various environments or to the intensity of the artificial light to which the animals were exposed. Earlier in Rhodesia, Symington (1959) found that with Persian Blackhead sheep, kept in pens roofed with translucent plastic to reduce the intensity of light, the rhythm of shedding was disrupted. Also the fleeces were heavier and denser than those of animals maintained under natural light intensity in tropical daylength. Slee (1965) found shedding inhibited in primitive sheep breeds under diffuse light.

Wool growth rhythms were reversed under accentuated reversed natural light patterns (Morris, 1961; Hart et al., 1963; Bennett et al., 1969). Reversed seasonal daylength reversed seasonal Romney ewe wool growth rhythms (Morris, 1961) but the process was gradual and it took 2 years for a

complete change to a winter maximum. Other workers, using the Corriedale, Southdown, and Peppin Merino breeds, found the change was almost immediate, though in their case the annual rhythm was bimodal. Peaks in June/July and October/November were observed. The peaks of wool growth coincided with the experimental peak of daylength and the natural one in Corriedales (Hart et al., 1963). The other 2 breeds, had peaks coinciding with the experimental light maximum and before the normal peak (Bennett et al., 1969). The difference between Morris and the other researchers may represent a breed difference. Wool growth rhythms in Merino rams, under accentuated reversed light patterns followed feed intake trends closely (Williams, 1964). By reducing the daylength cycle from 1 year to 7 months the wool growth rhythm was accelerated, however it showed a constant lag of 2-3 months behind the light rhythm (Hutchinson, 1965).

It would be expected that the difference between the rate of wool production in summer and winter would increase with increasing latitude on the basis of these findings. The results of Fergusson et al., (1949) and Coop (1953) support this. The former at latitude 34°S fed Corriedale ewes at a constant level to give minimum winter production that was 76% of summer maximum production, whereas the latter at latitude 44°S found winter production only 30-40% of summer production. If seasonal temperature change also plays a part in determining the rate of wool growth, then it could be expected that larger seasonal variations could occur in those regions with large summer/winter temperature ranges.

The rhythm of wool growth is probably a modification of an archiac pattern of shedding, regrowth, and quiescence (Hutchinson, 1965; Ryder and Stephenson, 1968).

Wild sheep shed their coat completely every Spring, and domestic sheep show a wide variation in their tendency to shed. The primitive Soay (Ryder and Lincoln, 1976) and Shetland sheep (Ryder, 1971) have a

complete spring moult whilst almost continuous growth occurs in the highly evolved Merino breed. The shedding phase has been suggested to still occur on the legs (Bennett et al., 1962) and face (Jefferies, 1964) of these sheep. Wool is traditionally obtained from the Shetland sheep by plucking when the fleece begins to shed.

The tendency to shed also varies between individual sheep within a breed, and this is determined genetically. Slee (1959) distinguished the two genetic components as the ability to shed and the extent of denudation of the body. In Wiltshire Horn x Scottish Blackface sheep he found two peaks of shedding in primary follicles, one in Spring and a smaller one in autumn with no shedding in the summer period. The secondary follicles show a steady proportion of shedding throughout the winter, with a peak in the spring. Kemp follicle shedding in Limousine sheep occurred mainly in the winter and to a lesser extent in the late spring/early summer period (Rougeot, 1961). The close association with the yearly light cycle implicated daylength in the control.

The main cycle of shedding in Wiltshire sheep, in which activity starts about the spring equinox and inactivity about the autumn equinox, also implicated changes in daylength in the control of shedding (Ryder, 1969). The autumn equinox when darkness begins to exceed light seems to be the time at which follicles begin to become inactive (Rougeot, 1961; Ryder, 1962). The constant proportion of fibres with brush ends during the winter supports the suggestion by Burns (1953) that the brush ends form in the secondary follicles in the autumn, but that the fibres do not fall out until spring. On the other hand, the peaks of shedding by the primaries showed that the brush ends had not long been formed, thus indicating the different shedding behaviour of the two types of follicles. This could account for some of the breed differences where the ratio of secondaries to primaries differ. In well fed Suffolk

sheep over 30% and up to 60% of the primaries and secondaries respectively, shed (Burns, 1954) whereas in the Shropshire figures were 75% and 84% respectively for the spring period. No marked influence of season on the incidence of shed follicles was found in Merino and Southdown x Merino sheep (Lyne, 1961). Poor nutrition appears to affect secondary shedding more than primary shedding (Hutchinson, 1965).

In the reversal experiments discussed, the rhythm of shedding was more easily reversed than that of wool growth. Differing patterns of response for shedding and wool growth to daylength alterations suggest that these two rhythms may be separate (Hutchinson, 1965). Man by breeding, has apparently changed the cycle of only that part of the coat that is valuable to him, whereas the rest continues the original cycle.

(b) Nutrition

The nutritional effects on wool production are many and complex. For the purpose of this study only winter grazing nutrition will be considered as a modifier of wool growth and wool characteristics.

It has already been indicated that sheep produce less wool during periods of poor feed. Sheep maintained on a low plane of nutrition throughout the year, whilst still showing the inherent wool growth rhythm, will produce less wool at all times of the year than sheep fed ad libitum.

In grazing sheep, the rhythm appears to be greatly influenced by the amount and quality of feed available (Gallagher et al., 1966). It is well known that pasture growth rates vary considerably throughout the year as does the quality of herbage available to the grazing animal. Mean fibre diameter of wool from sheep grazing native pastures in New South Wales, may drop from 22 μ in summer to 16 μ in winter, whereas on improved pasture the drop was only from 23 μ to 21 μ (Johnstone 1955).

Roe et al., (1959) observed low wool growth levels in August and

and peaks in January/February periods with a general decline thereafter.

A relationship between wool growth and available green forage was found, suggesting that wool growth may be more related to green forage available rather than total forage available (Roe et al., 1959; Willoughby, 1959; Reis and Williams, 1965; McFarlane, 1965).

This reflects the very marked preference of sheep for green rather than dead material under Australian pasture conditions (Arnold, 1964).

McManus et al., (1964) observed that this change was associated with the digestibility of the pasture and a reduction in wool growth in summer was associated with a low digestible organic matter intake. Hence it has been suggested that by judicious choice of forages considerable scope for manipulating wool growth in Australia may result (Langlands and Donald, 1977).

Differences between breeds in wool growth response to annual nutritional cycles have been reported as early as 1926 by Joseph. Doney (1966) studied Cheviot and Merino x Cheviot cross sheep, compared at similar feed levels with three variations: either fed so as to simulate the natural intake cycle, or reversed intake cycle, or as a constant daily ration. Seasonal differences in wool growth in the Merino group were largely due to variation in intake whereas the winter wool production of the Cheviots was not significantly affected by intake. However, with the Cheviot sheep, in Doney's study, intake and wool growth were only related during the summer period, so that when the nutritional cycle was reversed the cycle of wool growth was eliminated. This lack of response in wool growth to increased nutritional levels in winter has been noted in other breeds (Scottish Blackface - Doney, 1964), and to a limited extent in the New Zealand Romney (Scofield, 1970).

New Zealand pastures have a marked winter depression in growth. Because of the heavy reliance on pasture as the source of fodder, the

sheep are normally fed less adequately in winter and early spring than during the rest of the year. The lower level of nutrition results in a depressed wool growth rate (Wickham, 1968) which can result in increased tenderness (Ross, 1965). However, severe undernutrition during winter may not result in marked unsoundness if sheep are accustomed gradually to the lower level of feeding (Wickham, 1968). It is possible that sudden changes in nutrition may be more important in causing break (Brown, 1971).

Slower June/September pasture production in New Zealand means a restriction in the diet of the animal at this time. This effect is accentuated by high stocking rates (Sumner and Wickham, 1969). They showed the higher stocking rates tended to result in a more marked seasonal rhythm of wool growth and fibre diameter, with the trough of the rhythm occurring late in the year (September) and the spring rise being delayed by approximately 6 weeks at the higher stocking rates. However, increased stocking rates are not necessarily associated with unsound wool. In Massey trials, sheep were quite capable of producing sound wool (i.e. having less reduced fibre diameter) on extremely short pasture (Wickham, 1968). Also with Merino and Corriedale sheep increases in stocking rate were not associated with increased break or tenderness (McManus et al., 1964). Hence, it is at these higher stocking rates that management techniques are of increasing importance in determining if a break occurs.

(c) Pregnancy and Lactation

In New Zealand, ewes are usually in the late stages of pregnancy when the inherent rhythm of wool growth is at its lowest and feed supplies at their shortest. Pregnancy can lead to a further depression of the winter trough of wool growth by up to 50%, when compared to a non-pregnant ewe (Story and Ross, 1960; Alexander, 1962; Corbett,

1966; Lodge and Heaney, 1973; Corbett and Furnival, 1977). Increased nutritional demands at this time, are expected to influence wool production (Wallace, 1948). Wool growth rate depressions have been seen to occur as early as 28 days post-conception (Henderson, et al., 1970). Over twelve months, pregnancy and lactation can reduce wool production by 5.5% (Mullaney et al., 1969; Corbett and Furnival, 1977).

The lower the level of nutrition during pregnancy the earlier the effects on weight of clean wool, fibre length, and fibre diameter are expressed (Slen and Whiting, 1955). Food demand is greater in July to September because of pregnancy and lactation. They have the effect of shifting the period of minimum growth from June/July into July/August/September, and maximum from December into the post-weaning period of January/February. Since this pregnancy effect almost coincides with the naturally occurring period of minimum growth in mid-winter, the summer-winter ratio of wool growth widens to about 4:1 or even higher in ewes (c.f. 3:1 in barren sheep) (Coop and Hart, 1953).

Where feed intake of pregnant ewes was increased progressively so as to maintain maternal tissue live weight, wool growth declined throughout pregnancy c.f. non-pregnant ewes at constant body weight (Ferguson and Reid; cited by Ferguson et al., 1965). Similar results were found by Coop (1953) with differing levels of feeding during the dry, pregnant, and lactating periods. Thus the effects on wool production during pregnancy may not be completely due to a decreased nutrient supply to the wool follicle but may be partially caused by an altered hormonal balance, Papadopoulos and Robinson (1957).

Field studies have shown that ewes with a single lamb generally produce 10-20% less fleece wool than those that do not become pregnant. The bearing of twin-lambs reduces annual wool production by a further 5-10% (Ross, 1965; Turner and Young, 1969; Bigham et al., 1978).

Lactation appears to have a greater influence on wool growth rates than pregnancy (Corbett, 1964, 1966; Henderson et al., 1970).

The effect of lactation on wool diminishes as time from lambing increases (Corbett and Furnival, 1976), and evidence from observations on ewes rearing twin lambs and those rearing singles, suggests an inverse relationship between milk yield and wool production (Stevens and Wright, 1952; Seebeck and Tribe, 1963; Ray and Sidwell, 1964).

(d) Hormonal Mediation of Wool Growth

Relatively little is known of the hormonal effects on wool growth and wool characteristics. It has been suggested that pituitary hormones may have a role in regulating the seasonal wool growth rhythm (Hart, 1955). However, because of the difficulties of separating various pituitary fractions and the complex interactions with other endocrine glands, knowledge of the role of the pituitary hormones in wool growth is sketchy.

Increase in adreno-cortical activity has been suggested as a factor in the seasonal variation in wool growth (Lindner and Ferguson, 1956). Cortisone administration to normal sheep depresses wool growth, and on resumption after a period of depression, a break often appears in the fleece (Lindner and Ferguson, 1956). Increased levels of glucocorticoids in plasma of physically stressed sheep (Panaretto and Ferguson, 1969), caused depressed wool growth (Lindner, 1959, 1964; Reid, 1962). Ferguson et al., (1965) however, found that seasonal periodicity of wool growth remained in adrenalectomized animals, maintained on constant cortisone dosage and therefore the rhythm is not mediated by changes in cortisol secretion.

The annual rhythm of wool growth could be due to an increase in thyrotrophic activity of the pituitary (Hart, 1955). A 60% reduction in wool growth and reduced feed intake in thyroidectomised sheep has been reported (Ferguson, 1951). Thyroxine administration stimulated wool

length growth of fibres without affecting diameter (Rougeot, 1965).

It has been suggested that wool growth increases after thyroxine treatment to normal sheep, might be due to increased appetite, and also to decrease in storage of protein in body tissue (Ferguson, 1958; Lambourne, 1964).

The increased intake is proportionately greater than increased wool production thus resulting in a lower efficiency of wool production (Lambourne, 1964; Ferguson et al., 1965).

In a review of the effects of hormones in wool growth, Ferguson et al., (1965) showed that in sheep, hypophysectomy had a more profound effect than thyroidectomy. Wool growth was partially restored by thyroxine administration in hypophysectomised sheep independent of dose rate, but the rhythm of wool growth remained, even when sheep were maintained at constant feed intake, temperature and cortisone dosage. They concluded that the pituitary gland exerts stimulatory and inhibitory influences through the secretion of thyrotrophic and adrenocortical hormones respectively. However, neither thyroid nor adrenocortical activity have been definitely implicated in the natural variation of wool growth.

Reduced fibre diameters associated with the winter period and pregnancy and lactation can lead to a decrease in the tensile strength of the fibre over this period (Ross, 1965). Ross (1961) suggested that a 'lambing break' may occur at this time. The massive release of cortisol by the lamb, prior to parturition (Austin and Short, 1972) may be the cause of this effect if it occurs. Release of oxytocin and prolactin also occurs about this time, but injection of 5mg/day of sheep prolactin into hypophysectomised sheep maintained on cortisone and thyroxine, failed to have any effect on wool growth.

(2) The Effects of Winter Grazing Systems on Wool Growth and Characteristics

Little data are available on the effects of winter feeding of

pregnant ewes in the field.

(a) Winter Nutrition

Nutritional restriction during early and mid-pregnancy influences fleece weight and fleece tenderness (Hodge, 1966; Coop, 1968). Crossbred and Romney ewes restricted for either 90 or 108 days of gestation compared to ewes at maintenance for that period, had 0.4 kg and 0.72 kg less wool respectively, along with an increase of 18% and 43.7% respectively, of number of tender fleeces. Coop (1968) in grazing trials with Romney ewes applied a nutritional restriction for one month during either the third, fourth, or fifth months of pregnancy. Restriction during any of the periods resulted in a 20-30% reduced wool growth rate. Winter feeding trials at Invermay and in Southland indicate that ewes fed at a low plane during winter had a higher proportion of poor style wools, reduced staple length, reduced total wool weight (0.41 kg reduction in one case) and lower tensile strength due to a reduced fibre diameter. However, these differences were only represented by a 2.0 cents/kg reduction in price (Monteath, 1971).

For some time it has been realised that sheep grazing different pasture species have differing wool production. Sheep grazing clover or clover-dominant pastures produce more wool (Bublath, 1969). There is evidence of the greater wool production of sheep fed clover in pens compared to those fed grass at similar energy levels of intake (Rattray and Joyce, 1969). It has been suggested that the higher nutritive value of white clover, in contrast to grasses, can be explained by the effect of voluntary intake associated with a change in the fermentation rate, carbohydrate content, and the utilization of nitrogen and volatile fatty acids (Corbett et al., 1966; Butler et al., 1968; Ulyatt, 1969; MacRae and Ulyatt, 1974; Ulyatt et al., 1977).

The major characteristic influenced by pasture type is staple length (Patil et al., 1969; Bublath, 1969; Scoffield, 1970). Stocking rate and seasonal changes in nutritive value can change the effect of various species (Bublath, 1969). At low stocking rates, wool length growth rate of sheep grazing perennial ryegrass/white clover pasture was always superior to that of cocksfoot/clover and cocksfoot alone. At high stocking rates cocksfoot pastures were superior from late September to mid-November. The superiority being minimal at the end of November when the nutritive value is lower than ryegrass (Castle et al., 1962). Pasture types per se had no significant effect on quality number, character, soundness, mid-side colour, and mid-side coting (Bublath, 1969).

Merino and British strong-woolled sheep grazing copper-deficient areas of Australia demonstrate reduced fleece weights, loss of crimp clarity and increased staple lustre (Bennett and Beck, 1942; Marston, 1946; Marston and Lee, 1956). Reduced tensile strength in the wool from copper-deficient sheep has also been reported by Palmer (1947) and Burley, (1960).

Patil et al., (1969) suggested that the poorer crimp of the grass-fed sheep was due to poor utilization of the copper in this diet and copper deficiency, even though the copper levels of the grass and clover diets were similar. They found that giving copper supplements to the grass-fed sheep improved the crimp.

Various fodders have differing levels of copper concentrations (Adams, et al., 1956). Wool copper, unlike liver copper, has been reported to increase when the ewe is grazing pastures high in molybdenum and sulphate (Healy, Bate and Ludwig, 1964; Rish, 1970). It was suggested by these authors that wool may represent a secondary excretory pathway for copper. However, Cunningham and Hogan (1958) demonstrated a reduction in hair and wool copper when increasing dietary

molybdenum levels were fed, this reduction being prevented by additional dietary copper.

Protein levels in feed have been found to influence wool growth, fibre diameter and fibre length (Slen, 1969). Protection of protein against ruminal digestion has lead to increased wool growth responses (Hogan and Weston, 1967; Barry, 1969) Casein, in protected form, fed during late pregnancy/early lactation, and given on a medium plane of nutrition, had a marked effect on wool. The decline in rate of growth and diameter, normally associated with late pregnancy and early lactation was prevented (Barry, 1969; Henderson et al., 1970). However, responses to protected protein have been variable.

Early work by Marston (1935) suggested that the sulphur-containing amino acid content of protein may be important for wool growth since wool protein had high levels of cystine. Various experiments since then have been conducted feeding the sulphur-containing amino acids cyst(e)ine and methionine by various routes. Substantial increases in wool growth rate have been recorded (Reis and Schinckel, 1963; Reis, 1967; Graceva, 1969). The winter wool growth depression has been reduced when L-cysteine was infused intravenously (Dryden et al., 1969). Methionine was effective, as it can be metabolised to cyst(e)ine (Downes et al., 1970).

Dove and Robards (1974) suggested that wool production responses to abomasal supplements of sulphur containing amino acids or casein would be greater if the animal is consuming a high quality diet. This indicated a protein x energy level interaction. Black et al., (1973) suggested there is an optimum ratio of protein to energy absorption required for maximum wool growth. If protein is limiting, an increase in protein absorption stimulates wool growth, but an increase in energy absorption reduces it. Conversely, if protein is in excess, and increase in protein absorption reduces wool growth but it is stimulated by

an increase in energy absorption. When diets are fed per os rumen fermentation tends to prevent variation in protein: energy being an important source of variation in wool growth rate (Hogan and Weston, 1967). However, the response to abomasal protein supplements (Reis and Schinckel, 1961; 1964) suggests that the nutrients absorbed are somewhat deficient in amino acids for optimum wool growth. Feeding higher energy diets per os results in the synthesis of more microbial protein.

(b) Winter Grazing Systems

Winter nutrition is dependent on the grazing system adopted. Winter grazing trials with hoggets have indicated higher fleece weights when grazing autumn saved pasture than when grazing swedes with and without hay (MAF, 1968; Cooney, 1976; pers comm). Little effect was found on colour and handle (MAF, 1968). Few results are available on the effects that winter forage crops or that differing grazing systems have on wool production of pregnant ewes.

Several disorders have been found to occur when sheep were turned out onto lush spring pasture from hay or dry concentrate diets (Annison et al., 1959). The primary causes for these disorders fell into two classes: (i) a failure of the microbial population to adapt itself to the sudden influx of readily fermentable substrate in the pasture, and (ii) the ingestion of substances in the pasture which have adverse effects on the metabolism of the animal. Lush spring pasture is rich in soluble carbohydrates which are rapidly attacked by rumen microorganisms, with the production of excessive amounts of lactic acid and resultant temporary acidosis. However, adaptation by the microbial population to the new diet took only 6 days.

Gradual introduction to a new feed type was found to minimise the degree of tenderness of the wool (Brown, 1971). Greater tenderness was

evident at the lower feeding levels. Sudden release of sheep onto green feed caused a significant increase in tenderness. Rumen microbial population adaptation or a lack of adaptation by the animals' enzymes to the new diet are suggested as the causes (Brown, 1971). The digestive upset may affect nutrient intake, or hormone balance. The stress involved may lead to temporary adrenal cortex hyperactivity which is suggested to be a common physiological mechanism underlying the occurrence of fleece tenderness (Lindner and Ferguson, 1956).

It has been suggested by Story and Ross (1960) that shearing around the time of lowest wool growth may minimise the effects the increased tenderness has on the manufacturing capabilities of the wool.

No consistent differences in weight or length of fleece over 12 months have been ascribed to date of shearing, although a large difference in style grade in favour of pre-lamb shorn wool was found (Story and Ross, 1959; Story, 1959).

A high level of animal production is generally the ultimate of any grazing management system. Any system that increases pasture quality, yield, or spread, will have a resultant influence on animal production, especially as we approach the 'optimum' stocking rate. At relatively high stocking rates it has been suggested that increases in animal production can only be obtained by the use of rotational grazing (McMeekan and Walshe, 1963; Walker, 1968; Robinson and Simpson, 1975). However, the evidence supporting this suggestion is sketchy and no management system can be expected to maintain its beneficial effect at excessively high stocking rates (Young and Newton, 1973). Bishop and Birrell (1975) and Birrell et al., (1978) confirmed that increasing stocking rates had the effect of reducing the herbage on offer. At their high stocking rates of 15-20 sheep/ha, both the deferred and rotational grazing systems provided a better nutritional plane over autumn and winter than a set-stocking

system, with resultant higher wool growth rates.

There is a decrease in per ewe wool production with increasing stocking rates (Bishop and Birrell, 1975; White, 1975), however, total per ha production rises. Character, soundness, coting and staple length were better on those animals grazing at low stocking rates (Bublath, 1969; Sumner and Wickham 1969). Sumner and Wickham, 1969) found that high stocked animals had wool with coarser quality numbers even though fibre diameter was reduced.

This anomaly can be explained in that in the subjective assessment of quality number, lustre received more attention than crimps per inch, and lustre increased with stocking rate (Sumner and Wickham, 1969).

Low stocking rates can result in long pastures that transfer water to fleeces, with the increased fleece humidity leading to discolouration (Bublath, 1969). Very high stocking rates can increase discolouration (Sumner, 1969; Scoffield, 1970), perhaps as a result of dirt contamination, or slower drying of the more-cotted fleeces.

There is little experimental data to indicate the effects of the various systems of grazing management on wool growth and characteristics. Lambourne (1956) found that rotational grazing management of ewes and lambs did not noticeably affect wool production, at stocking rates below 8 ewes/acre, although fewer cotted fleeces were found. However, above 8 ewes/acre, fleece weights were superior to those on a set-stocked policy. Collins' (1966) results suggest that wool production per acre may be slightly better, with fewer cotted fleeces under a mob-stocking compared with a set-stocking system. However, more mob-stocked fleeces exhibited break.

The various permutations of rotational grazing may lead to differing wool production results. Stock movement from 'cleaned-out' pasture to a flush could lead to tender wools, as described earlier. However, by

daily shifting, a more even supply of pasture throughout the winter could be provided, and this might be expected to minimise tenderness.

C. LAMB PRODUCTION

(1) Nutrition

Most studies involving ewe nutrition during pregnancy have been limited to either one of two periods: immediately post-mating (early pregnancy), or late pregnancy, during the period of maximum foetal growth. Few have recorded the effects of nutrition during mid-pregnancy on resultant lamb production. As lamb production is a minor consideration of this thesis a brief review only of work involving ewe nutrition on pasture and swedes or turnip crops is given.

(a) Nutrition during pregnancy

Early reports established that lamb birth weight was associated with differences in nutrition of the ewe during pregnancy (Underwood and Shier, 1942; Underwood, Shier, Cariss, 1943; Wallace, 1948; Thomson and Thomson, 1949; Barnicoat et al., 1949; Coop, 1950; Thompson, 1950; Guyer and Dyer, 1954; Papadopoulos and Robinson, 1957; Schinckel and Short, 1961). With few exceptions, increased levels of nutrition are associated with increased birth weights and the effect is usually more marked in twins than singles. Wallace (1948) was one of the first to show that birth weight of twins was affected by the plane of nutrition after 91 days of gestation but prior to this time nutritive level had no effect. This conforms to the basic pattern of foetal development in the ewe. Davies (1952) describes pregnancy in 3 phases: Phase 1 up to day 22 is the period of the ovum, the pre-attachment of pre-implantation phase lasting until about day 14-15, by which time considerable growth of the embryonic membranes have occurred. The second phase, lasting until about day 40-50 in sheep, is the period of the embryo, during which differentiation of the embryonic parts and the placenta is concluded.

The remainder of pregnancy, the period of the foetus, is primarily a period of growth. It has been found that approximately 70% of total foetal growth takes place during the final six weeks of pregnancy (Russel et al., 1973).

McClymont and Lambourne (1958) underfed ewes for the first four months of pregnancy and then fully fed them for the remaining four weeks, but could not erase the previous underfeeding effect on birth weight. Everitt (1964) also underfed ewes from mating and found that by day 90 foetal weight was significantly depressed. This depression was only partly compensated for by adequate feeding from day 90 to lambing (Everitt, 1966).

Curll et al., (1975) indicated from their experiment with Border Leicester x Merino ewes that good nutrition for the ewe during the 10 weeks of mid-pregnancy had an important effect on birth weight and growth rate of lambs, at least in regions which have a short pasture growing season. This may conflict with the conclusion of Coop and Clark (1969) that restricting food intake to half maintenance level over the same period, in order to conserve pasture for late pregnancy, is sound practice. They had found no treatment effects on the numbers of lambs born. Rattray and Jagusch (1977) also found that with ewes averaging 50kg there was no significant carryover effects, when fed at between sub-maintenance to 1.4 times maintenance levels over mid-pregnancy, in lambing, lamb birth weights or ewe milk production. Lodge and Heaney (1975) found a lamb birth weight difference between ewes fed a maintenance ration throughout pregnancy and those fed at 15% below maintenance post mating and this increasing exponentially to 57% above maintenance by parturition. The latter feeding regime had the heavier birth weights.

The relationships between nutrition in the second half of pregnancy and potential milk production is well established (Thomson and Aitken, 1959),

but there is little information relating specifically to nutrition during mid-pregnancy. Although McClymont and Lambourne (1958) found a positive relationship between the plane of nutrition of the ewe, during early to mid-pregnancy, and the birth weight and growth rate of the lamb, Hodge (1966) and Monteath (1971) did not. However, Monteath's differential live weight gains over the last six weeks of gestation may have obscured some of the treatment effects applied mid-pregnancy. The live weight levels used by Hodge (1966) in mid-pregnancy were appreciably higher than Curll et al., (1975) and again compensatory live weight changes were allowed in the last 6 weeks of pregnancy.

Hodge (1966), in imposing treatments that resulted in a 17% loss in live weight to 108 days of gestation on 3 year old Border Leicester x Merino ewes, found no adverse effect on the number or birth weight of the lambs born. In addition, the weaning weight at 12 weeks of age, was not affected by these treatments. Treacher (1971) found similar results on birth weights with differential feeding over the period 14 weeks post-mating. Here also no treatment effect was found on milk yield or live weight change in lactation, however, the fat content of milk was increased from ewes on the high plane diet (30g DM/kg ewe live weight) in pregnancy. A moderately low plane of nutrition during pregnancy followed by liberal feeding post-partum does not appear to limit milk production (Coop, 1950; Barnicoat et al., 1957; Peart, 1970; Monteath, 1971).

(b) Age of Ewe

Few studies have been carried out to assess the affect of nutritional stress on pregnant ewes of various ages. Bennett et al., (1964) in a study involving undernutrition for the first 90 days of pregnancy, suggested that 2-year-old maiden ewes suffered higher pre-natal loss than mature ewes. However, McKenzie and Edey (1975) found

that young sheep appear just as resistant as mature ewes to embryo mortality induced by short term undernutrition.

Russel and Foot (1972) in a Scottish Hill country study suggested that the considerable loss of weight commonly occurring in primiparous hill ewes during the early stages of pregnancy, may adversely affect lamb birth weight. They suggested that feeding at normal levels during late pregnancy is unlikely to overcome this effect.

(2) Winter Grazing Systems

(a) Pasture Grazing

A high level of animal production is generally the ultimate of any given grazing management system. It consists of combining good pasture husbandry with feed allocation to animals at the desirable levels for that time.

Rotational grazing has been suggested to provide increased animal production by providing extra fodder available at times when fodder amount frequently limits animal production (Morley, 1968). In most cool temperate, environments pasture growth rate and hence fodder availability, is a major limitation from late autumn until early spring. Therefore rotational grazing at this time is likely to be advantageous.

It would seem that advantages from rotational grazing are more likely to be obtained at high stocking rates (Lambourne, 1956; McMeekan and Walshe, 1963; Collin, 1966; Walker, 1968; Smith, 1970; Robinson and Simpson, 1975). At lower stocking rates the differences in animal performance are small and liveweight gains may even be superior under set stocking (Geytenbeck, 1963; Lewis, 1973). However, in Boswell et al's., (1974) experiment comparing set stocking and rotational grazing, the stocking rates of 20/30/40 ewes/ha were higher than for Lambourne (1956) of 9.8/14.8/19.7 ewes/ha, but resulted in no advantage in

rotational grazing or increased lamb production.

Gain per lamb was superior on the continuous grazing system to that on the rotational grazing system, but because of the higher stocking rates on the latter, gain/ha was lower. However, no management system can be expected to maintain its beneficial effect at excessively high stocking rates (Young and Newton, 1973).

Two large scale trials of practical importance comparing set stocking and rotational grazing have been carried out in New Zealand. However, the results were conflicting. Suckling (1959) at Te Awa found a 6% lambing percentage, and 24.88g gain/day in lamb live weight advantage in set stocking. Collin (1966) at Waerenga-o-kuri, on the other hand, found at 12.3 ewes/ha no marked difference between the two grazing systems in animal production, except that set-stocked lambs were appreciably heavier at weaning. But at 16-18.5 ewes/ha rotational grazing was associated with a 15% gain in lambing. These results show that neither system is clearly superior and much depends on the expertise put into the grazing management used.

Davies (1968) in studying two modifications of a continuous grazing system concluded that undernutrition during pregnancy to ensure adequate feed allowance for lactation lead to a higher incidence of pregnancy toxemia, reduced lamb birth weights, and increased neonatal mortality. However, by restricting feed allowance during early pregnancy allowing adequate requirements from day 100 of pregnancy on, these effects were minimized. This method of feeding at a high stocking rate of 26 ewes/ha lead to less pregnancy toxemia than a system of continuous grazing throughout pregnancy.

(b) Forage Crop Grazing

In view of the length of time forage crops have been used in New Zealand agriculture and the relatively important place they play in

feeding stock (approximately 250,000 ha grown per annum - Nicol, 1978), surprisingly little information has been published on the performance of stock fed on root or greenfeed crops. The few studies looking at these crop effects on performance have in the main been confined to dry or growing young stock (Barry et al., 1971; Drew, 1967, 1968; Drew et al., 1974). Few studies have involved the use of pregnant ewes (Scott and Barry, 1972).

Liveweight gains in ewes during mid-pregnancy on forage crops have been recorded. For swedes a gain of 198g/day with 90% utilization was found by Scott and Barry (1972). These liveweight gain figures were higher than that which could be obtained with Turnips, Kale, Mangels, and Fodder Beet, as also was the percent utilization of the crop. From this limited information swedes appeared the better forage for winter feeding of pregnant ewes.

C H A P T E R I I I
EXPERIMENTAL PROCEDURES

EXPERIMENTAL PROCEDURES

A. MATERIALS

(1) Experimental Site

The experiment was set up on the Number 1 Sheep Farm at Massey University. This farm is situated 4 miles south of Palmerston North.

The area was well drained by tiles and mole drains. Although reasonably sheltered from the cold easterly winds off the Tararua Ranges, the site was fairly exposed to most other winds.

Temperature and rainfall records taken at the Massey University weather station, 1 mile away to the north-east of the experimental site are given firstly for the year on a monthly basis, and secondly on a daily basis over the experimental treatment period. See Appendix I (a, b, c,).

(2) Layout of Experiment

The regimes were imposed from 13/6/77 to 25/7/77 and this corresponded to days 74 to 116 (approximately) of the gestation period for the ewes. The regimes were:

Treatment 1: all sheep received 100% of their diet from swedes on a daily break (T1)

Treatment 2: for the first three weeks, 100% of the diet was in the form of medium-quality pasture hay; for the following three weeks, 100% from a crop of swedes allocated on a weekly break (T2)

Treatment 3: for the whole 6 week period 75% of the diet was from a daily break of swedes; the remaining 25% from a daily hay ration (T3)

Treatment 4: 100% of the diet from pasture allocated according to animal requirements (see Section C (5)), on a daily rotational-grazing system with backfencing (T4)

Treatment 5: 100% of the diet was from pasture allocated in one block (set stocking). This allowed a surplus at the beginning and a "deficit" at the end due to slower pasture growth. (T5)

The paddocks for the pasture treatments were separated by the paddock containing the swede treatments. Areas of the paddocks ranged in size from 0.36ha to 0.5ha. The yard where one treatment spent 3 weeks of the total period was 0.06ha. Along the side of most of the yard a shed provided a sheltering wall.

Hay fed in treatments 2 and 3 was placed in hay racks attached to a fenceline. Figure 1 shows the general experimental area layout.

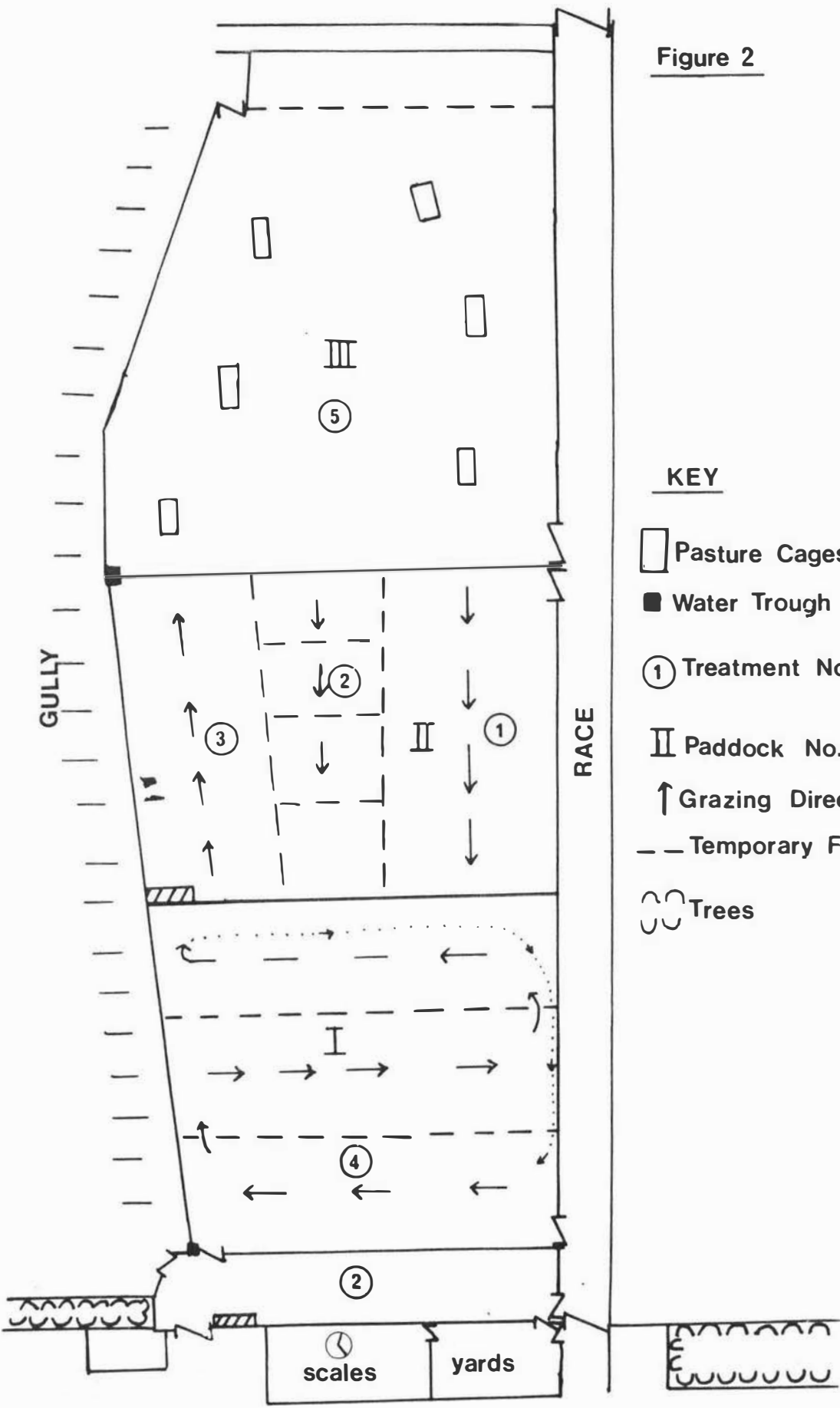
Prior to the final allocation of treatments to areas, pasture and crop were samples to measure total dry matter (D.M.) yields. Using these figures and projected growth figures the size of the area allocated to each treatment was determined for each set of 21 sheep.

Paddock 1 was used for the rotationally grazed group, and was split longitudinally into three, by the use of temporary netting fences. Daily blocks were allocated within these by the use of either electrified netting or electrified 3-wire temporary fences.

Paddock 2 was divided up so that it would accommodate the three swede treatments.

Paddock 3 was used for the set-stocked pasture treatment. After pasture D.M. analysis a temporary fence was erected to correct the area to the right size. It was initially hoped that this

GENERAL EXPERIMENTAL AREA LAYOUT



treatment and that of the rotationally grazed treatment would be of the same area, however, differing pasture D.M. yields meant this could not be the case.

(3) Experimental Animals

All animals were part of the Massey University Romney stud flock. Within each treatment group there were 3-2yr olds, 7-3yr olds, 5 or 6-4yr olds and 5 or 6 ewes having an age range of 5-7 years.

On the basis of tupping records, sheep were also allocated so that 13 sheep per treatment had not returned to the ram after the first oestrous cycle, and 7 returned once. All 2yr old ewes were settled by the ram in the first oestrous cycle. Those ewes selected after returning once were the heavier by weight for this group.

After the required numbers of animals were found, all were weighed, initially on the 23/5/77 and allocated to the treatments. The randomization was restricted to ensure a similar mean live-weight for all the treatments.

B. METHODS

(1) Swede Crop Management

The swedes (Brassica napus L. var 'New Zealand Grandmaster') were sown in late November at a rate of 0.7 kg/ha with 375 kg/ha borated reverted superphosphate. Due to the relatively dry season the crop did not grow well and preliminary cuts on 6/5/77 showed the crop to yield between 4670-4980 kg D.M./ha depending upon the site.

The tops containing 16.5% D.M. and the bulbs 10.5% D.M. By 11/6/77 the range was only of the order of 150 kg D.M./ha, however the average yield was much the same (4800 kg D.M./ha). Tops had dropped to 15.5% D.M. and bulbs to 10.4% D.M.

No chemicals were applied for weed control and this resulted in moderate weed infestation.

(2) Pasture Management

The paddocks in pasture were cleared out by sheep in the autumn period and then spelled from the 11/6/77. Preliminary cuts on 11/6/77 showed them to contain 1700 kg D.M./ha on paddock 1 (rotationally grazed) and 1500 kg D.M./ha on paddock 3 (set-stocked).

Fertilizer treatment was the same as for the rest of the farm at 375 kg/ha of superphosphate applied in the late spring/early summer period.

(3) Animal Management

All ewes had been tupped when set stocked on grass prior to the experiment. Those in the trial were initially weighed on 23/5/77. Once the trial had started all were to remain in their allocated treatment groups until the end of the treatment period on 25/7/77.

Following this date all were brought together with the rest of the Romney stud flock and were rotationally grazed on pasture till lambing. After lambing ewes and lambs were set stocked until the last date of wool collection on 17/10/77. All ewes had belly and crutch wool removed on 4/8/77.

During the experiment some ewes had to be treated for foot

abscesses, scald, or to remove compacted mud from between their toes. Those with foot abscesses were injected with 5 mls of "Streptopen".

Up to seven ewes per treatment had mud removed from between the toes. This was more prevalent after rainfall. It is of note that those animals on swedes did not suffer any more from foot problems than those grazing pasture.

Only one ewe suffered from pregnancy toxaemia. This ewe in treatment two had previously suffered from foot abscesses. She was first treated with glycerol on 25/7/77 and the treatment continued until she died on 5/8/77. A post-mortem showed twin lambs, enlarged adrenals, a fatty liver which also contained some yellow jaundice. However, there was plenty of food within the stomach.

On 29/7/77 all ewes were vaccinated for Blackleg, Malignant Oedema, Tetanus, and Enterotoxaemia.

Lambing commenced on 10/8/77, some 16 days post-treatment. The median lambing date was 27/8/77, 33 days post-treatment. Within the first 20 days of lambing 87% of the ewes lambed.

C. EVALUATION METHODS

(1) Crop Samples

The crop was sampled initially on 6/5/77 to assess total D.M. on offer at that stage. No account was taken of weed or pasture contribution to total D.M. However, by the time of first grazing only pasture on the edge of the paddock could have contributed to total D.M. on offer.

The crop was sampled by taking an area 914mm square at random at 3 different sites where each treatment was to be placed. The

area was marked out and all the crop within it pulled from the ground and collected in plastic bags. This was then washed sparingly in the laboratory and weighed to give a fresh weight of the bulb and leaf components. From these components subsamples were taken and weighed. These were then diced-up in lengths for leaves, and cubes for bulb and dried at 80°C for 24-36 hours to enable dry weights to be taken. From these a D.M.% value of each component could be computed. All weighing was carried out on a "Mettler" PN 323 balance to the nearest 0.001g.

Analyses to assess 'intake' of the crop were carried out on the days listed in Schedule 1. Six sites, each of 914mm square, were sampled such that 3 sites were from an area that was grazed at least 4 days prior to this sampling date. The other 3 were from the area grazed within the last 4 days. What remained of the crop was pulled from the ground and laboratory analyses were carried out as before. Also at each date, 2 samples from the pre-grazed area were taken to see if any total available D.M. differences had occurred and also to allow future feed budgeting of the crop. The difference between before and after grazing was taken as 'intake'. This was calculated out on a per-sheep per-day basis.

(2) Hay Samples

Good medium-quality pasture hay was used for those treatments requiring hay. Hay was initially weighed fresh and the samples underwent drying at 80°C for 24 hours, to determine D.M.%. On the basis of these results, fresh matter fed out was calculated. Several hay samples were tested throughout the trial as per Schedule 1.

In treatment 2 where hay was fed out as ^{the} sole diet for the first three weeks, checks were made as to the disappearance rate of hay per day. This was done by having a known amount of hay in the rack at the start of the day and 24 hours later re-weighing the remains in the rack. An estimate was made of the amount lost on the ground from the amount collected from the ground and weighed (fresh and dry). In this treatment it was thus relatively easy to work out "intake" rates per ewe per day on the basis of disappearance rate and utilisation factors obtained in trial weighings.

(3) Pasture Samples

Pastures were cut at ground level using a "Sunbeam" electric shearing hand piece. The treatments were cut 11/6/77 - pre-trial, to determine the area needed per day. These samples were then placed in labelled plastic bags and returned to the laboratory.

The entire sample was then washed and the water drained off, leaving the sample to drip dry. A fresh weight was then taken. The samples from the same area were bulked and a subsample (approximately 100 grams) taken and re-weighed. This was dried in an oven at 80°C for 24 hours when it was re-weighed. From this weighing, dry weight per unit area was calculated.

At each sampling for the rotationally grazed area 3 samples pre- and 3 samples post-grazing (24 hours later) were taken in order to gauge the "intake" of pasture/ewe/day. Sample areas were at random and each was 914x305mm. Sampling was carried out every 7 days in this treatment. Pasture growth was recorded for both pre- and post-grazed areas. (Plates 1&2 indicate pasture sampling techniques)

With the set-stocked treatment, pasture availability was



PLATE 1 - Pasture Sampling Technique



PLATE 2 - Yield Sampled Area Post-grazing

measured by taking 3 samples from the paddock plus 6 from within cages previously placed at random over the paddock. The pasture inside the cages represents pasture available at last grazing plus growth of pasture since then, or total pasture availability over that period. By deducting pasture available outside the cages this represented an "intake" or 'disappearance' rate of pasture. The cages were moved after each sampling and placed at a "representative norm" for the area. The size of each sample taken was the same as for the other pasture analysis.

Sampling in the set-stocked area was carried out every 7 days until 11/7/77 because of good pasture growth conditions. After this period pasture growth slowed with the lower temperatures (Appendix 1 c) and a 14 day period was used till the end of the experiment on the 25/7/77. Schedule 1 of field work refers also to pasture sampling dates.

Botanical composition of pasture was estimated at 3 samplings to assess relative pasture species changes occurring with grazings. Subsamples were taken from the pasture-availability samples and were weighed. Approximately the same weight was taken from each sample which was then separated into clover components, grass components, weed components, dead matter, and a dirt component. These were then dried for 24 hours at 80°C and re-weighed.

(4) Animal Liveweights

Ewes were initially weighed on 23/5/77, then again on 7/6/77, after which they were weighed every 7th day until the 25/7/77. Weighings after this were on the 15/8/77 (pre-lamb) and 17/10/77 (last date of wool collection). During the treatment period all

animals were weighed out of the paddock in the morning before the next shift of crop or grass. Weighings were carried out, with the exception of one day, on sunny days with dry wool. All weights were recorded on 'Avery' scales to the nearest 0.5 kg.

Lamb birth weights were recorded within 12 hours of birth to the nearest 0.1 kg using a sling suspended from a 'Salter' spring balance. Lamb weaning weights were recorded on the 'Avery' balance to the nearest 0.5 kg on 7/12/77.

(5) Feed Allowance and Feed Budgeting

Total feed availability analysis was necessary to be able to estimate 'intake' or disappearance rate of feed. Figures used for D.M. allowance were based on the estimates of Milligan and McConnell (1976). The allowance planned to result in a pasture intake of about 0.85 kg D.M./day. This was regarded as the maintenance intake for a 55 kg ewe in early pregnancy, grazing a mixed length leafy pasture with a M.E. concentration of 10.8MJ.ME/kg D.M. In the final two weeks of the treatments, intake was designed to rise to 1.3 times maintenance or 1.1 kg D.M./day. The swede crop was assumed to have a ME concentration of 13.5MJ.ME/kg D.M.

Utilisation factors were estimated at 80% for the swede crop and hay treatments, and 65% for the rotationally grazed pasture treatment.

(6) Wool Production

Wool production was measured by means of sequential samples taken from the left hand midside position of the sheep as well as by fleece weights. Midside patches of approximately 100cm² were established on all sheep on 23/5/77, and cut pre-trial again on 13/6/77. After

this, samples were taken at the mid-experimental treatment period (3 weeks), at the end of the treatment period, just before lambing and lastly at main shearing on 17/10/77 (see Schedule 2 of field work). Because of the large numbers of sheep involved it was felt that tattooing boundaries of clipped midsides could be avoided by care in clipping. Wool was removed using "Oster" electric clippers (size 40 blades). (Plates 3&4 show wool sampling)

The lengths of the four sides were measured at the initial clipping to the nearest millimeter. The patch area was then estimated from those dimensions assuming rectangular shape.

On 4/8/77 all ewes had the belly and crutch wool removed. These were weighed separately. The sample from one ewe per age group in each treatment was taken at random and brought back to the laboratory and scoured according to the procedure outlined in 2 (g). On the basis of the clean scoured yield all ewe crutching weights in each age for each treatment were then adjusted and analysed for treatment and age differences. This was to see if there was any significant effect on weight caused by "expected" mud contamination of the belly wool on swede treatments. All greasy crutching weights were measured to the nearest 0.1 kg. All laboratory weighings were carried out on a 'Mettler' PN 323 balance to the nearest 0.001 g.

To indicate the area in the staples during which time the treatments were applied, the dye-banding technique (Chapman and Wheeler, 1963) was used to mark the wool at skin level at the start and finish of the six week treatment period. Dye was applied on the left midside, just in front of the sampling area. A pipette was used to run a fine line of dye solution along the skin ensuring



PLATE 3 - Ewe Placement for Wool Sampling



PLATE 4 - Patch Wool Harvesting

adequate wetting of the base of the fibres. It was found convenient to dye along a line 5-10cm in the opened fleece. The line was in an anterior-posterior line on the sheep. These samples were recovered on 17/10/77, at shearing.

The dye used was an aqueous Durafur-Black R solution which was prepared immediately prior to using by dissolving 0.8g of Durafur-Black R flakes in 100 mls of cold distilled water. When the flakes were dissolved 0.8 mls of concentrated hydrogen peroxide (100 vol) were added as an oxidant. It took approximately 4 hours for the black colouration to appear in the wool.

(7) Scouring

(a) Crutchings

Sample crutchings were divided up into belly and crutching portions and conditioned for 48 hours in a humidity room at 20°C and 65% relative humidity, then weighed greasy. They were then allowed to soak in cold water for 20 minutes. After teasing open or using a mechanical opener, they were then scoured using the four bowl detergent and water scouring method. After emerging from the last bath the samples were 'spin dried', before being placed in a blast of hot air. The samples were then allowed to condition for 48 hours before reweighing after which yield was calculated.

(b) Mid-side samples

The 'greasy' wool samples were conditioned in a humidity room for 48 hours at 20°C and 65% r.h. after which they were weighed. To scour, the samples were placed in small individually labelled nylon bags and scoured in organic solvents. The sequence of solvents in which the samples were placed for three minutes, was petroleum ether, 95% alcohol, and cold deionised water.

(see Appendix 2 for the mineral content of deionised water).

There was little agitation of the bags in the solvents. The samples were dried in a blast of warm air, and again allowed to condition in the humidity room for 48 hours before being re-weighed on the 'Mettler' balance to 0.001 grams. These samples were then stored away in individually-labelled brown-paper envelopes. Final results were expressed for growth as weight per unit area per day ($\text{mg}/\text{cm}^2/\text{day}$).

The dye banded sample that was used in tensile strength tests under went the same scouring treatment.

(8) Prescouring Fleece Characteristic Grading

The full length wool sample that contained both dye-banded and non-dye banded wool was assessed for the following characteristics:

- (i) quality number
- (ii) character
- (iii) staple length
- (iv) crimp frequency
- (v) handle
- (vi) lustre
- (vii) soundness
- (viii) tippiness
- (ix) colour
- (x) cotting

The grading system is as defined by Sumner (1969). Many characteristics being assessed on a (1) inferior to (9) superior scale such that data tended to conform to a normal distribution (see Appendix III).

(9) Tensile Strength

A dye-banded sample was taken and placed along a ruler and measured to the nearest 0.5cm. The position of the dye bands along the staple was noted. In general the width of each dye-band extended no more than 3 mm in length.

The sample staples from each ewe were then taken and conditioned in a controlled humidity room at 20°C and 65% r.h. for 24 hours. They were then tested on a "Hounsfield Tensometer" whilst still in this room, using a modification of the technique of Ross (1960). The butt end was placed in the stationary set of jaws to 2 cms and then a test length of 5 cm from these jaws to a set of moveable jaws was measured and these clamped tight. The test length incorporated both dye-bands. Tension was applied by means of a hand wound screwing device until the staple began to break. The position of the break was noted in the staple, and also the maximum load needed to break the staple. The sample length between the clamped jaws was cut and placed in a small nylon bag for scouring. The value analysed from each sheep was the mean from testing five staples. The samples after solvent scouring were dried and conditioned for a minimum of 24 hours before re-weighing. The maximum load was calculated as kg force per gram of sample per cm of length.

(10) Fibre Length Estimations

For early samples all ewes were tested for fibre length using the method discussed below, but as time available became limiting it was decided to test one ewe at random from each age group within each treatment.

The mean fibre length of these 5 samples was estimated using

the following technique. From the scoured midside samples at each of the testing dates a few fibres taken at random were placed between two pieces of glass and the image projected onto a white wall at 10x magnification using a photographic slide projector. The images were then traced onto paper, measured by means of a cartometer and the mean length calculated. Twenty fibre lengths per ewe were measured. The fibres were too long, in the final sample, to fit between the slides of glass. A piece of carbon paper was placed over a length of metric graph paper. The butt of each fibre was gripped in fine forceps which were drawn along the carbon-covered graph paper until the tip emerged from under a piece of cardboard at the start of the graph paper. The tip of the forceps was forced onto the carbon, leaving a mark on the graph paper underneath. The position of these marks on the graph paper gave the fibre length distribution in the sample.

Fibre length results are given in mm growth per day for the five sampling dates.

(11) Fibre Diameter Estimation

From the scoured midside sample a sub-sample was placed over a piece of curved wood. This was then cut at several different places by a set of two razor blades 1 mm apart. The fibre snippets between the blades were then brushed onto a microscopic slide containing a drop of cedar wood oil and a cover slip was applied. Twenty-five fibres from each slide were measured on a projection microscope following the technique recommended by I.W.T.O. (1961).

From these data the mean and standard deviation of fibre diameter was calculated.

D. STATISTICAL ANALYSIS

Only data from those ewes that lambed were analysed. The data were analysed using the Massey University B6700 computer using three software packages.

At first the data was analysed using the M.A.F. Invermay version pack 'Xalema Omnitab' in conjunction with the pack 'Xalema Teddybear' (J.B. Wilson, 1976). Because of the structure of the data and the relative inflexibility of the Teddybear package only two factors at a time could be analysed. Thus two models, including age and treatment, and then birth and treatment were analysed separately. Using these packages it was found that the two-way interaction terms were non-significant. Where all three main effects were significant, further analyses were carried out using the General Linear Interactive Modelling (GLIM) package described by Nelder (1975).

The analysis of variance models investigated with 'Teddybear' were either:

$$X_{ijl} = \mu + a_i + t_j + (at)_{ij} + e_{ijl}$$

$$\text{or } X_{kjl} = \mu + r_k + t_j + (rt)_{kj} + e_{kjl}$$

where μ = general mean

a_i = effect of the i^{th} age

t_j = effect of the j^{th} treatment

r_k = the effect of the k^{th} birth rank

$(at)_{ij}$ = effect of the interaction of the i^{th} age and the j^{th} treatment

$(rt)_{kj}$ = effect of the interaction of the k^{th} birth rank and the j^{th} treatment

e_{kjl} = residual

All animal and wool characteristics were tested using these techniques. Differences in body weight of ewes were tested by the covariance analysis using the start of the treatment body weights as the independent variable.

Wool growth differences of midside samples in diameter, fibre length, and weight per unit area per day were tested by covariance analysis using diameter, length, or weights of wool samples at the beginning of treatments as the independent variable.

The models used in the covariance analyses were:

$$Y_{ijl} = \mu + a_i + t_j + (at)_{ij} + \beta_1 (X - \bar{X})_{ijk} + e_{ijl}$$

$$\text{or } Y_{kjl} = \mu + r_k + t_j + (rt)_{kj} + \beta_2 (X - \bar{X})_{kjl} + e_{kjl}$$

where the β s = regression coefficients of Y or X.

If all the main effects were significant the data were further analysed using GLIM where the model was:

$$X_{ijkl} = \mu + a_i + t_j + r_k + \beta (X - \bar{X})_{ijk} + e_{ijkl}$$

where μ = general mean

a_i = the effect of the i^{th} age

t_j = the effect of the j^{th} treatment

r_k = the effect of the k^{th} birth rank

$\beta(X - \bar{X})_{ijk}$ = correction for the regression on date of parturition

e_{ijkl} = residual

The significance of differences between mean treatment effects were evaluated by Duncan's New Multiple Range Test (Duncan, 1955).

C H A P T E R I V

RESULTS

RESULTS

A. FEED 'INTAKE' AND EWE LIVE WEIGHT

Average D.M. 'intake' figures for all 5 treatments are listed in Table 1.

TABLE 1: AVERAGE DAILY INTAKE FOR EWES ON EACH TREATMENT

Treatment Number	1	2	3	4	5
Intake ^X (kg DM/ewe/day)	0.68	0.59	0.84	0.9	1.68

A summary of the analyses of covariance of ewe live weight using the two factor analyses are given in Table 2. The treatment affect was highly significant ($p < 0.001$) throughout the trial period until 15/8/77. Ewe age was significant ($p < 0.05$) on 11/7/77 and 18/7/77, when older ewes (≥ 5 yrs) are lighter ($p = 0.05$). Table 3 gives the adjusted live weights over each period for each treatment. Fig. 3 indicates the unadjusted mean treatment live weights throughout the trial.

The birth rank effect approaches significance ($p < 0.10$) on 25/7/77 and is highly significant ($p < 0.001$) at 17/10/77. Ewes bearing singles initially were lighter pre-lambing and heavier post-lambing after correcting for pre-treatment live weight differences, than those bearing twin lambs (60.5 ± 3.5 v 61.1 ± 3.9 and 60.9 ± 3.4 v 56.9 ± 3.9).

In all treatments utilization of feed varied according to weather conditions. On a warm dry day utilization was up to 90% and 82% for swede and grass grazing respectively, but on a wet day this dropped to 30% and 38% respectively. Estimated utilization figures over the total period were: 64%, 67% on hay and 60% on swedes, 70%, and 70% for T1 to T4 respectively. Plates 5 and 6 show utilisation on T1 and T3.

TABLE 2 MEAN SQUARES ANALYSIS OF COVARIANCE OF EWE LIVE WEIGHTS - TWO WAY ANALYSIS

Source of variation	d.f.	20/6/77	29/6/77	4 /7/77	11/7/77	18/7/77	25/7/77	15/8/77	17/10/77
Age	3	0.90	2.84	3.14	9.50	12.12*	9.18	11.88	29.83
Treatment	4	108.91***	93.99***	92.21***	189.65***	177.08***	164.02***	152.87***	7.55
A x T	12	2.42	3.46	3.85	2.87	1.93	2.32	11.20	19.20
Residual	76	1.50	2.25	3.03	3.22	3.90	5.80	13.69	15.48
Birth Rank	1	0.37	1.43	2.76	4.70	4.29	18.95†	6.64	306.68***
Treatment	4	182.12***	113.90***	110.62***	223.61***	207.10***	189.71***	145.38***	14.36
Br x Trt	4	0.80	1.99	0.96	1.26	3.14	2.15	10.77	10.54
Residual	86	1.64	2.44	3.25	3.42	3.90	5.44	13.56	13.34

Throughout the Text the following symbols apply:

- † $p < 0.10$
- * $p < 0.05$
- ** $p < 0.01$
- *** $p < 0.001$

TABLE 3 ADJUSTED MEAN LIVE WEIGHTS OF EWES ON EACH TREATMENT (kgs)

Treatment	20/6/77	29/6/77	4/7/77	11/7/77	18/7/77	25/7/77	15/8/77	17/10/77
1	50.42 A	51.40AB	51.02AB	51.31 B	50.49 B	52.01 A	59.12AB	59.37 A
2	49.75 A	50.17 A	50.79 A	47.88 A	48.47 A	49.20 A	56.08 A	57.79 A
3	51.47 C	52.20 B	51.74AB	51.90 B	52.05 B	55.05 B	60.08BC	57.98 A
4	51.12 B	52.56 B	52.37 B	53.88 C	53.94 C	56.09 B	63.02CD	58.86 A
5	56.61 D	56.83 C	56.90 C	57.40 D	57.33 D	56.72 B	63.55 D	58.44 A

A, B, C, D - figures with differing letters differ significantly at the
0.01% level of significance using Duncan's New Multiple
Range Test.

Figure 3

EWE LIVE WEIGHTS FOR EACH
TREATMENT

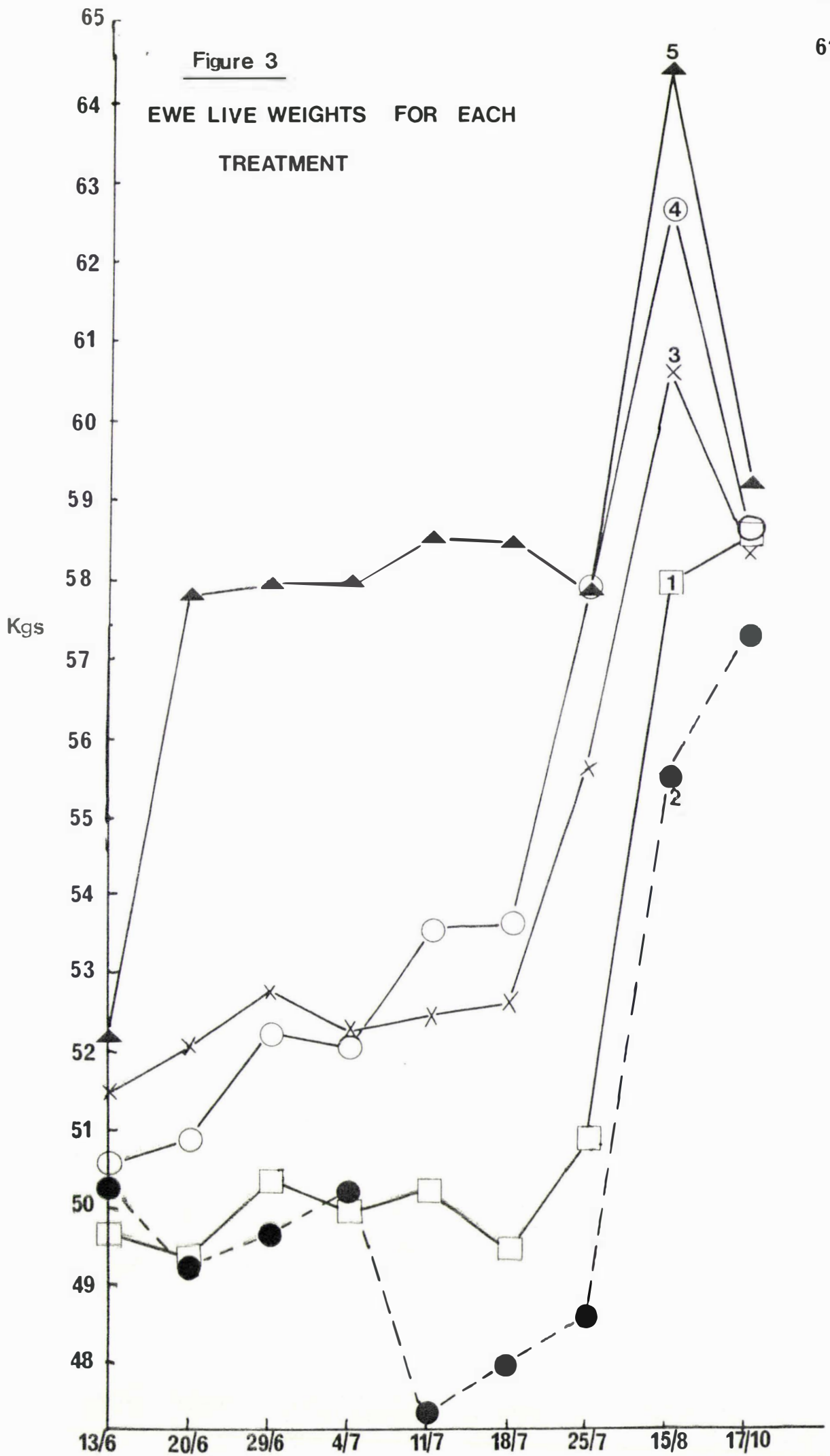




PLATE 5 'Daily break' and Swede Utilisation in T1



PLATE 6 - Hay Feeding and Swede Utilisation in T3
(in last week of treatment)

Utilization figures for T5 could not be calculated. In T2 and T3 hay had an average D.M. % of 86%. Hence for T2, 0.69 kg of 'wet' hay/ewe/day was consumed. Plate 7 shows the ewes in T2 during hay feeding. When this treatment changed over to a swede diet on a weekly break initial utilization was poor (55%), but this improved so that by the end of the 3 week period utilization was similar to that in T1 and T3 (Plate 8 indicates swede utilization after 1½ weeks in T2).

Weekly pasture yield samplings in T4 and T5 indicated that for T4 pasture growth was 34 kg DM/ha/day until 14/7/77. From then until the end of the treatment period this dropped to 19 kg DM/ha/day (Plates 9-10 show T4 pasture utilization). However, in T5 for the same periods, figures were 60 and 19 kg DM/ha/day. Climatological data (Appendix 1 (a)) indicate the relative warmth of the season until 14/7/77. Botanical composition changes of the pasture under the two grazing management systems are given in Table 4. Under both systems the grass component proportionately increased by at least 10%. Clover decreased as the colder temperatures became more frequent (see Appendix 1 (c)).

Estimated 'intake' figures for the rotationally grazed treatment and set stocked treatment over each period are given:

TABLE 5: INTAKE ESTIMATES FOR THE PASTURE GRAZING TREATMENTS
(kg DM/ewe/day)

Treatment	Period					
	20/6/77	28/6/77	4/7/77	11/7/77	18/7/77	25/7/77
4	1.0	0.7	1.18	1.18	0.96	1.1
5	1.76	2.14	1.6	1.36	-	1.4

The 1.76 kg DM figure represents 3.2% of ewe body weight and the 2.14 kg DM represents 3.7% ewe body weight at that time. Corresponding live weight changes for both treatments are shown in Fig. 4.



PLATE 7 - Hay Feeding in 1st 3 Weeks of T2



PLATE 8 - Swede Utilisation after 1½ Weeks in T2

TABLE 4 BOTANICAL COMPOSITION CHANGES OF PASTURE

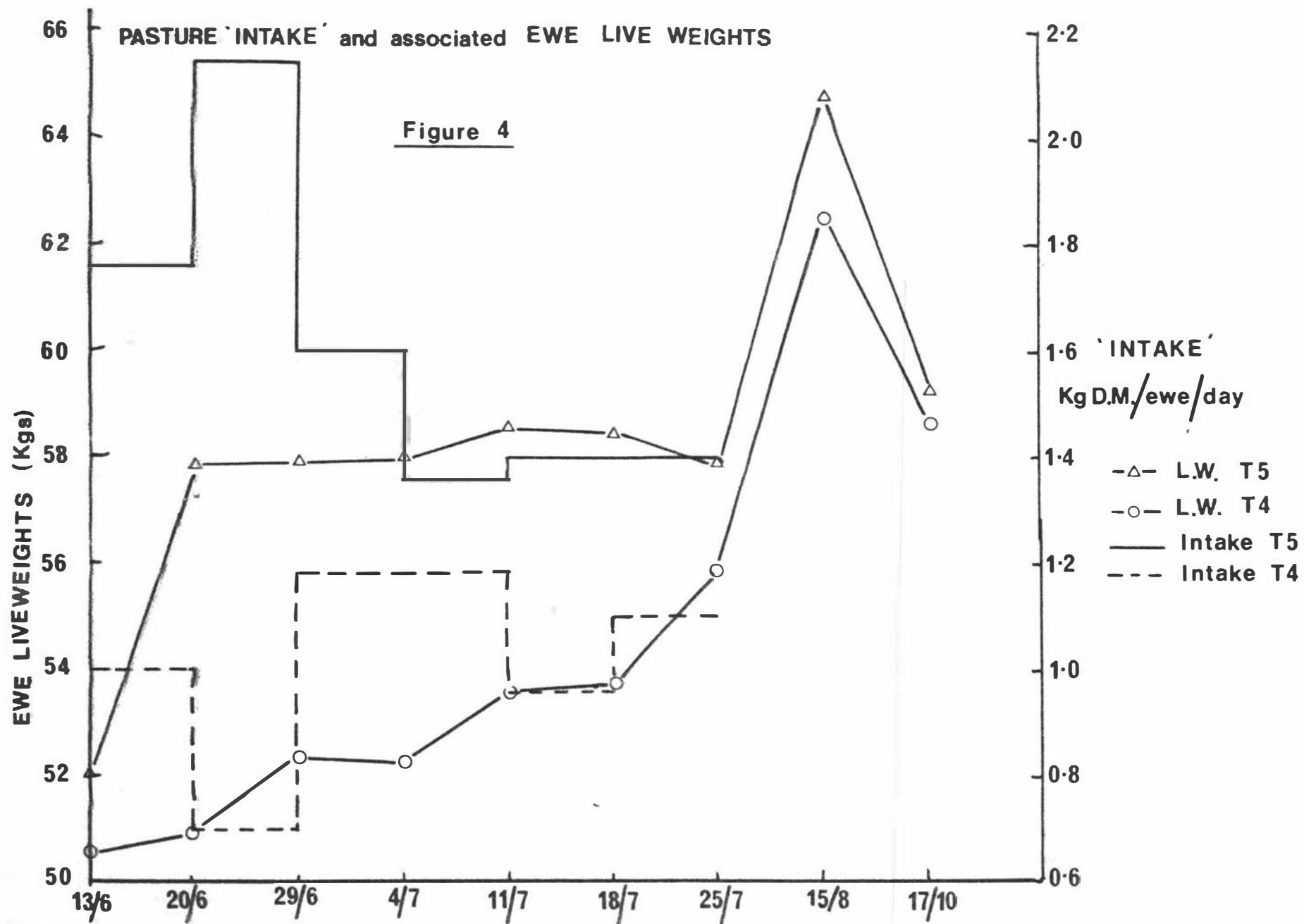
Set Stocking	4 /7/77	11/7/77	26/7/77
Grass	45.6 %	55.3 %	64.9 %
Clover	15.6	19.0	11.7
Weeds	3.7	3.3)
Dead Material	34.3	22.3) 23.4
Soil	0.8	0.1)
Rotationally Grazed	4 /7/77	18/7/77	
Grass	63.0 %	72.7 %	
Clover	9.1	5.7	
Weeds	2.3	0.9	
Dead Material	22.9	19.9	
Soil	2.7	1.3	



PLATE 9 - Rotational Grazing (T4) Indicating Pre- and Post-Grazing Yields



PLATE 10 - T4 Post-Grazing on a Dry (right) and Wet (left) Day



B. WOOL PRODUCTION

(1) Wool Growth Rate

From the three-way main effects only, analysis of covariance (Table 6 (a)) treatment effects were highly significant ($p < 0.001$) for weight of wool produced per unit area, until 15/8/77 (pre-lambing).

T1 and T3 (swede/hay variations) produced significantly less wool than either pasture grazing treatments until 15/8/77. There was no carryover effect of treatment to 17/10/77 (Table 6 (a) and Fig. 5).

Age of ewe increased in significance from $p < 0.05$ to $p < 0.001$ throughout the trial. Older ewes (≥ 5 years) produced less wool throughout the trial (Fig. 6). Birth rank was significant ($p < 0.05$) at 25/7/77 and 15/8/77 and also at 17/10/77 ($p < 0.01$), Table 6 (a). In all cases those ewes with single lambs produced more wool than those bearing twins (Table 7).

The regression on pre-trial growth was highly significant ($p < 0.001$) at 4/7/77 and 25/7/77. This level of significance dropped to $p < 0.01$ at 15/8/77 and the regression was not significant at 17/10/77 post lambing.

Table 7 presents the adjusted means for weight of wool produced per unit area with Duncan's New Multiple Range values at the $p = 0.05$ significance level.

(2) Fibre Diameter

Table 6 (b) of three-way main effects only analysis of covariance for fibre diameter indicates that the treatments had a significant effect ($p < 0.01$) at 4/7/77 and a highly significant effect ($p < 0.001$) at both 25/7/77 and 15/8/77. There was no carryover effect to the 17/10/77. By the end of the treatment period (25/7/77) T4 and T5 had a mean fibre diameter which was significantly greater than any of the forage crop treatments (Table 8). Fig. 7 indicates the unadjusted mean fibre diameters over the experimental period.

TABLE 6(a)

Analysis of Covariance for weight of wool per unit
area adjusted for weight at the pre-trial sampling

Source of variation	d.f.	4/7/77 M.S.	25/7/77 M.S.	15/8/77 M.S.	17/10/77 M.S.
Treatment	4	.3270***	.8522***	.4502***	.0469
Age	3	.0430*	.0783**	.2564***	.6848***
Birth Rank	1	.0215	.1049*	.2780*	.7555**
Regression on 13/6/77		.7420***	.4511***	.3505**	.0899
Residual	87	.0104	.0173	.0415	.0666

TABLE 6(b)

Analysis of Covariance for Fibre Diameter adjusted
for pre-trial diameter

Source of variation	d.f.	4/7/77 M.S.	25/7/77 M.S.	15/8/77 M.S.	17/10/77 M.S.
Treatment	4	36.31**	252.3***	78.57***	13.88
Age	3	11.16	10.35	35.57*	13.64
Birth Rank	1	0.469	24.90†	13.27	12.18
Regression on 13/6/77		527.5***	152.0***	132.2***	96.26*
Residual	87	8.803	8.885	10.63	15.98

Figure 5 UNADJUSTED WEIGHT/UNIT AREA MEANS
OF TREATMENT GROUPS

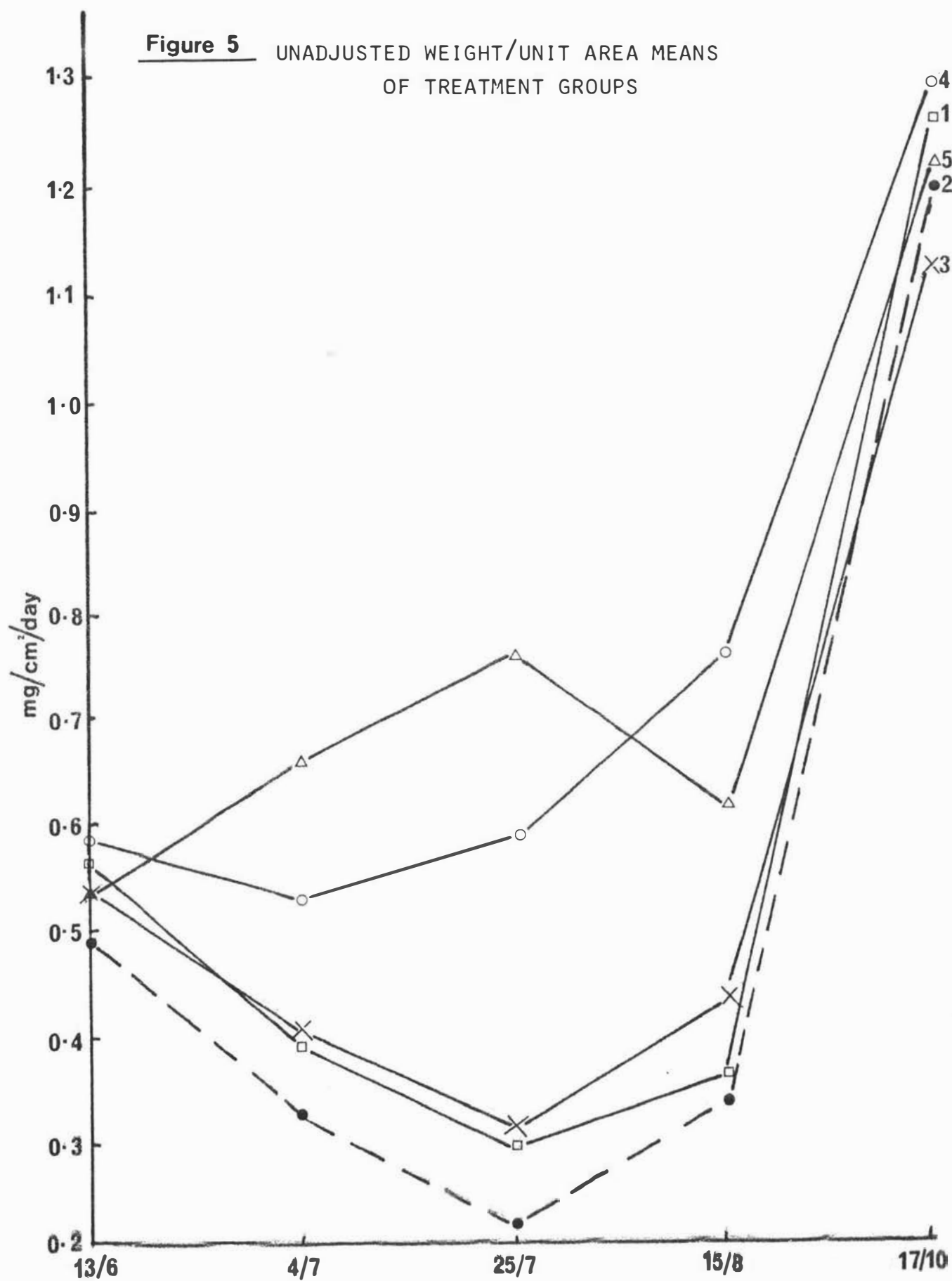


Figure 6 UNADJUSTED WOOL WEIGHT PER UNIT
AREA FOR AGE OF EWE

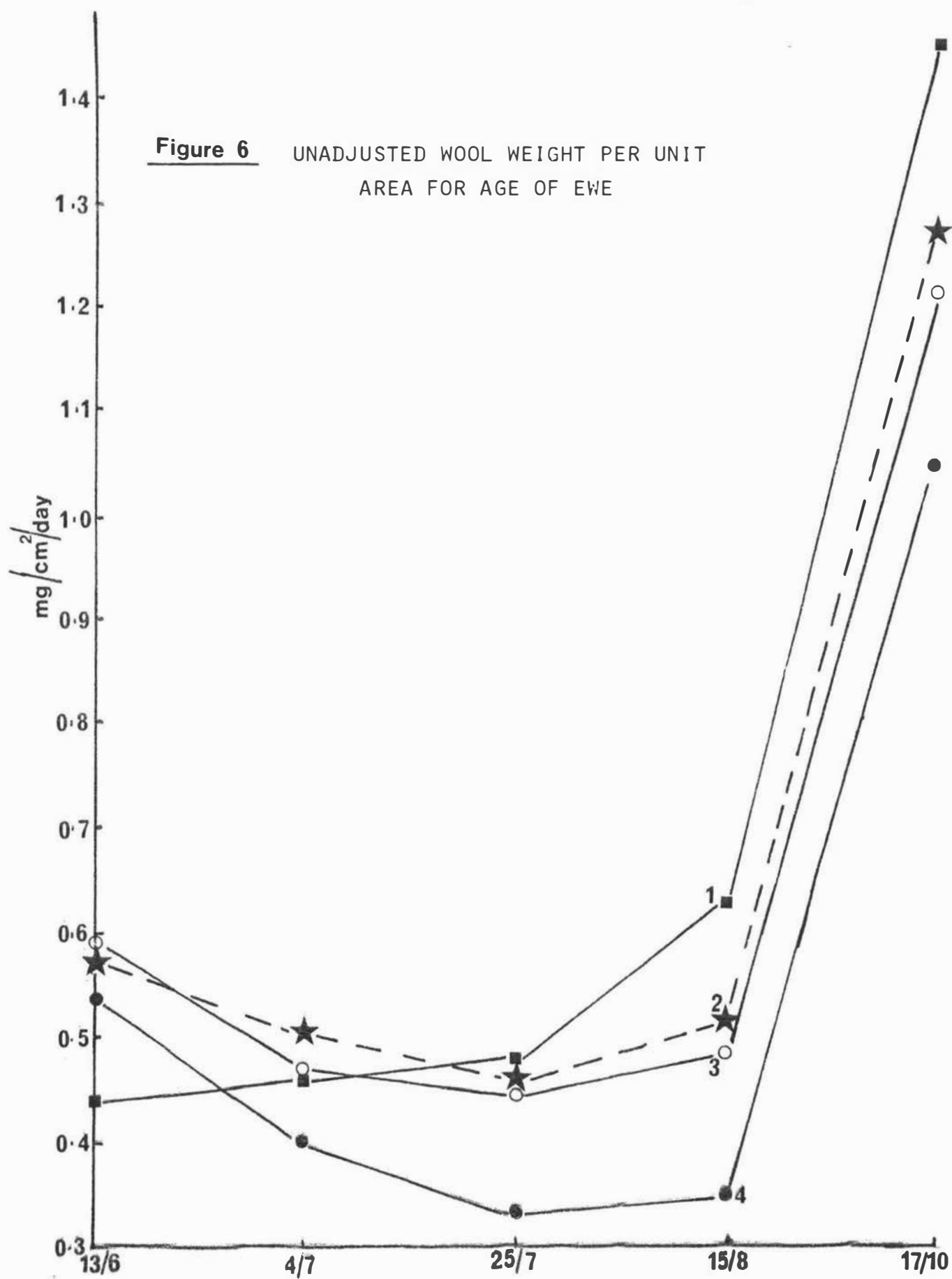


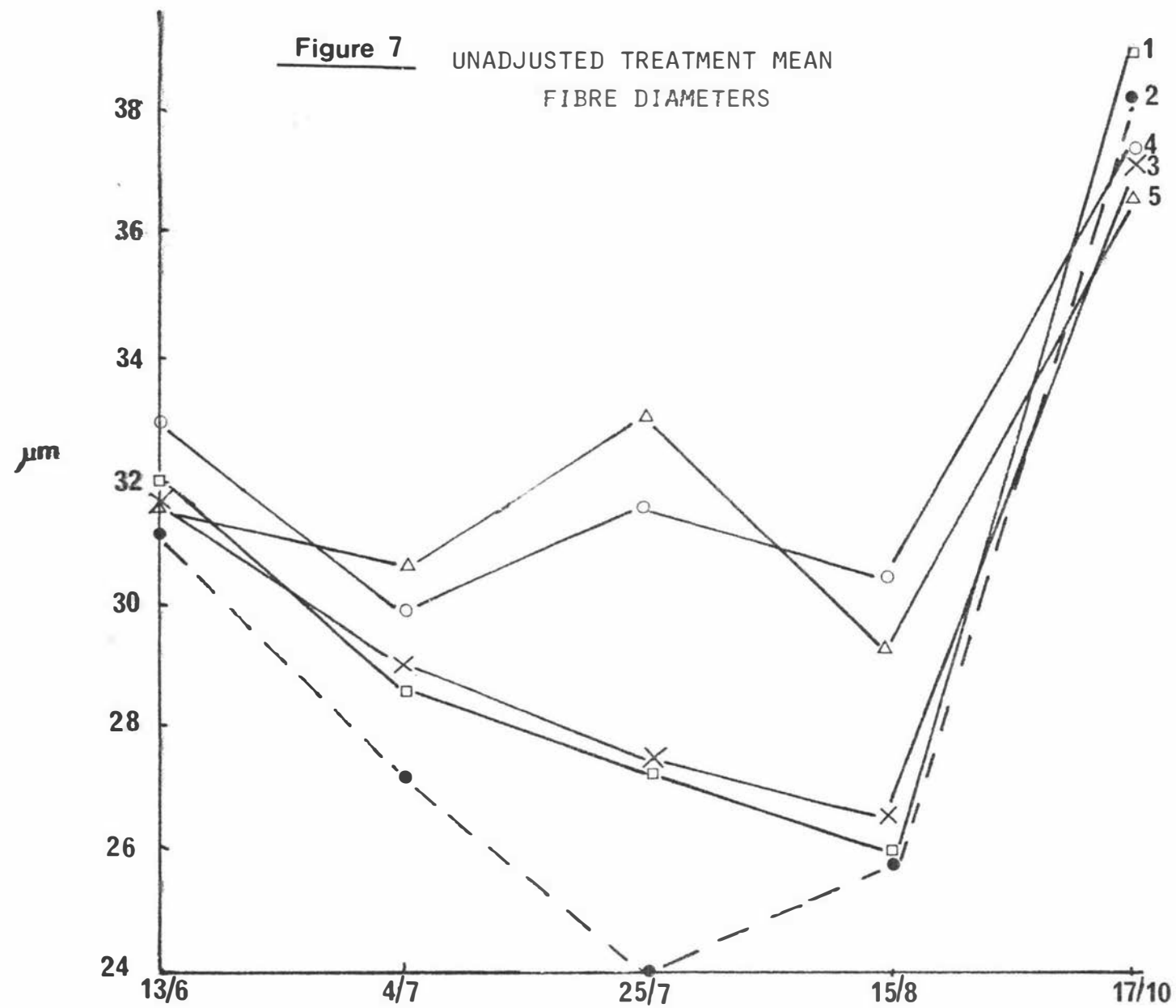
TABLE 7 ADJUSTED MEANS OF WEIGHT OF WOOL PRODUCED PER UNIT AREA
 $\text{mg/cm}^2/\text{day}$

		4/7/77	25/7/77	15/8/77	17/10/77
Treatment	1	.381 ab ¹	.285 a	.366 a	1.244
	2	.318 a	.224 a	.334 a	1.176
	3	.390 b	.303 a	.428 a	1.144
	4	.523 c	.568 b	.707 b	1.254
	5	.683 d	.761 c	.632 b	1.270
Age	1	.464 ab	.471 b	.625 c	1.431 c
	2	.498 b	.451 b	.505 bc	1.258 b
	3	.469 b	.441 b	.479 b	1.120 a
	4	.408 a	.350 a	.364 a	0.982 a
Birth	1	.476	.464 b	.551 b	1.311 b
	2	.443	.392 a	.436 a	1.124 a
General Mean		.459	.428	.493	1.218

¹ a,b,c,d show significance of differences by Duncan's New Multiple Range Test. Those values with differing letters are significantly different from each other at $p = 0.05$ level of significance

TABLE 8 ADJUSTED MEANS OF FIBRE DIAMETER (μm)

		4/7/77	25/7/77	15/8/77	17/10/77
Treatment	1	28.8 ab	27.0 b	26.0 a	39.1
	2	27.1 a	24.0 a	25.7 a	38.5
	3	28.5 ab	27.1 b	26.6 a	37.3
	4	30.3 bc	31.7 c	30.5 b	37.6
	5	31.3 c	33.7 d	29.6 b	37.5
Age	1	28.9	29.1	29.1 b	38.7
	2	28.3	28.8	27.8 ba	37.2
	3	29.8	29.0	27.6 ba	37.2
	4	29.8	28.0	26.2 a	38.4
Birth Rank	1	29.2	29.2	28.1	38.3
	2	29.2	28.2	27.4	37.7
General Mean		29.2	28.7	27.7	38.0



Age of ewe was only significant ($p < 0.05$) at the pre-lambing period (15/8/77). Two-year old ewes had coarser fibre diameters than older ewes (≥ 5 years). Table 8.

Birth rank approached significance ($p < 0.10$) only at 25/7/77. The regression on pre-trial fibre diameter was highly significant ($p < 0.001$) until 15/8/77. At 17/10/77 this was ($p < 0.05$).

(3) Fibre Length

Treatment had a highly significant effect ($p < 0.001$) on fibre length growth rate (Table 9 (a)).

Pasture feeding treatments had greater growth rates than those involving swedes and/or hay (Table 9 (b)). At 15/8/77 the treatment effect was significant ($p < 0.01$) however only T1 was significantly different from T4 and T5 (pasture). By 17/10/77 there was no treatment effect on fibre length.

Age influenced fibre length significantly ($p < 0.01$) at 4/7/77 and 25/7/77 ($p < 0.001$). After this period no age effect was found.

The interaction age x treatment was highly significant ($p < 0.001$) until 17/10/77 when the level of significance fell ($p < 0.01$).

Fig. 8 shows the unadjusted treatment means for fibre length growth rate (mm/day) over the experimental period.

(4) Wool Characteristics

From the analysis of variance (Table 10) using the two way analyses, neither age x treatment nor birth rank x treatment terms were significant.

Age had a highly significant effect ($p < 0.001$) on greasy fleece weight, scoured crutching weight, staple length, and colour, with crimps per centimetre approaching significance ($p < 0.10$).

Treatment was significant for colour only ($p < 0.05$) in the age x treatment analysis. In all the birth rank x treatment only colour

TABLE 9 (a) ANALYSIS OF COVARIANCE OF FIBRE LENGTH ADJUSTED FOR
FIBRE LENGTH ON INITIAL SAMPLING

Source of variance	d.f.	4/7/77 MS	25/7/77 MS	15/8/77 MS	17/10/77 MS
Age	3	23.487**	102.982***	4.897	17.462
Treatment	4	135.141***	118.654***	21.781**	4.474
Age x Trt	12	28.782***	34.893***	30.128***	35.098**
Residual	30	4.184	6.228	5.072	10.617

TABLE 9 (b) ADJUSTED FIBRE LENGTH TREATMENT MEANS (mm/day)

Treatment	4/7/77	25/7/77	15/8/77	17/10/77
1	.3203 a	.3697 b	.3888 a	.4867
2	.3082 a	.3200 a	.4132 ab	.4403
3	.3108 a	.3377 ab	.3990 ab	.5154
4	.3925 b	.4399 d	.4396 b	.5109
5	.4266 c	.4042 c	.4384 b	.4969

Figure 8 UNADJUSTED FIBRE LENGTH TREATMENT MEANS

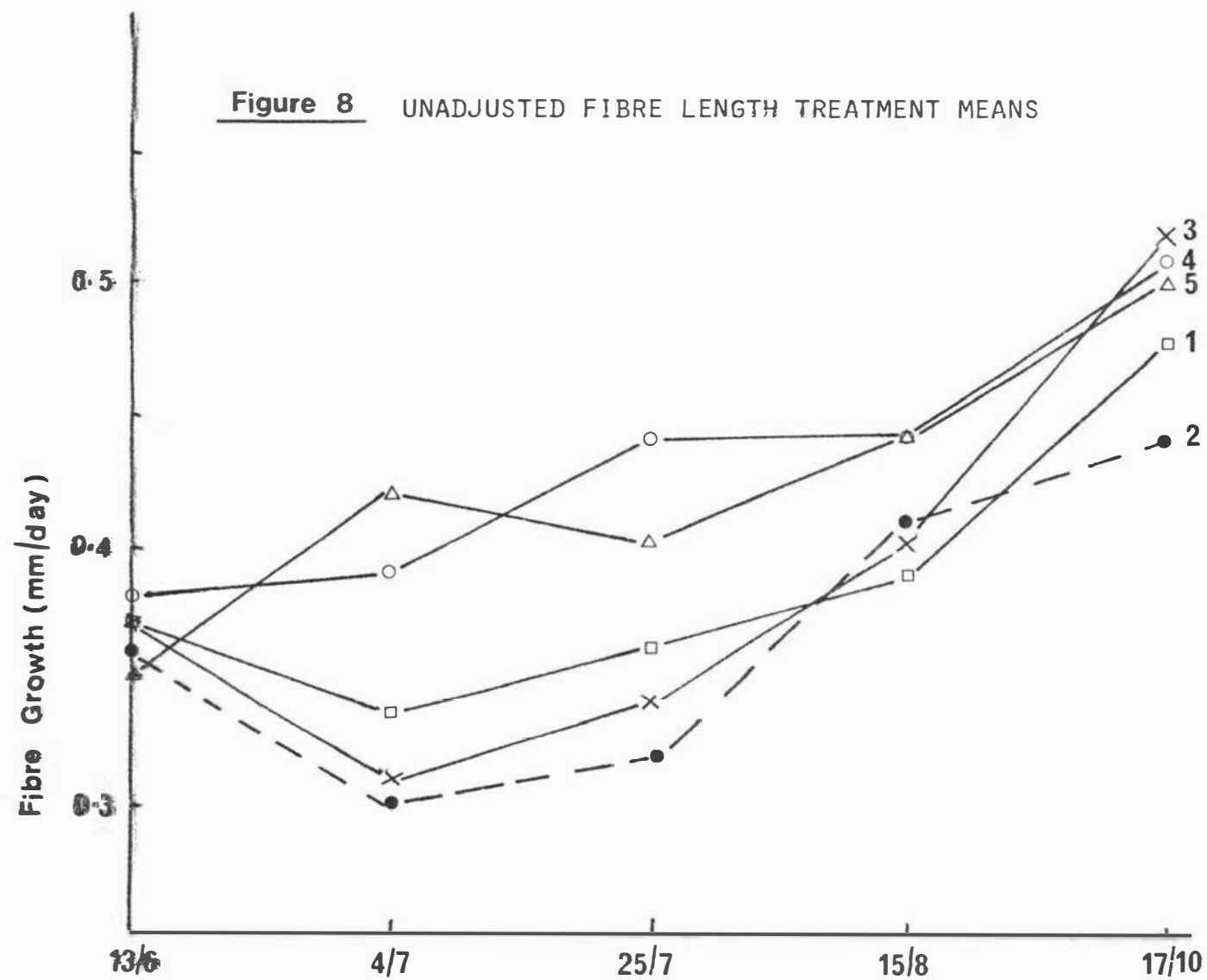


TABLE 10

ANALYSIS OF VARIANCE OF WOOL CHARACTERISTICS USING THE TWO FACTOR ANALYSIS

Source of Variation	d.f.	G.F.W. MS	S.C.W. MS	Quality Number MS	Staple Length MS	C.P.C. MS	Handle MS	Lustre MS	Colour MS	Cott. MS
Age	3	13.4224***	0.8885***	1.0952	160.9287***	0.1034+	0.4006	0.5038	5.3040***	1.0277
Treatment	4	0.6862+	0.0309	1.2229	1.7950	0.0444	0.3100	0.5643	1.3240*	0.7072
Age x Trt	12	0.1341	0.0203	0.3136	1.7028	0.2611	0.6572	0.3120	0.3667	1.1193
Residual	77	0.1883	0.0229	1.4500	2.1833	0.0399	0.6530	0.6167	0.4549	0.8538
Birth Rank	1	0.3245	0.0518	0.5037	0.6642	0.0041	0.0115	0.0282	0.0248	0.2610
Treatment	4	1.1421	0.4662	0.7930	3.6030	0.0519	0.2134	0.5692	1.3316+	1.0925
BR x Trt	4	0.2691	0.4319	2.3389	4.1734	0.0556	0.2744	0.9541	0.8755	1.6208
Residual	87	0.6263	0.5281	1.2524	7.6497	0.0394	0.6661	0.5661	0.5921	0.8757

approached significance ($p < 0.10$). Birth rank was not significant for these characteristics given in Table 10.

On the basis of the initial two way analyses tensile strength, soundness, character, and tip had three factors significant. Further GLIM (main effects only) analyses regressing on birth date were carried out. Tensile strength was influenced by treatment ($p < 0.001$) and age of ewe ($p < 0.01$). Soundness was affected by treatment ($p < 0.001$) and by birth rank ($p < 0.05$). Birth rank was the only effect approaching significance ($p < 0.10$) for character and was significant for tip ($p < 0.05$) as indicated by Table 11 for the analyses of variance.

Table 12 gives the mean values for the characteristics using the two factor analyses. Two-year old ewes had significantly lighter greasy fleece weights (GFW), scoured crutchings (SCW) and shorter staples due to differing shearing dates. GFW of older ewes (≥ 5 years) was lighter than either three-year or four year old ewes.

Two year old ewes had a better colour grade than the other ewes. T3 had a significantly lower colour grade than either T1, T2 or T4.

The swedes alone (T1) and hay/swedes treatment (T2) had significantly lower tensile strengths than the 2 pasture grazing treatments (T4 and T5) as indicated in Table 13.

T3 and T5 were found to be not significantly different in strength, yet T3 differed significantly from T4 (6.26 v 9.9 kg/g/cm). The three-year and older aged ewes (≥ 5 years) had significantly lower tensile strengths than either the two- or four-year old ewes, Table 13. This age effect was not found in the subjective analysis of soundness (Table 13). However the treatment effect was still evident ($p < 0.001$).

Both pasture grazing treatments produced wool of greater soundness than either T1 and T2, but T3 was not significantly different from T4 (Table 13). Those ewes bearing singles had sounder wool than those

TABLE 11 ANALYSES OF VARIANCE OF WOOL CHARACTERISTICS USING
THE THREE MAIN EFFECTS MODEL REGRESSING ON BIRTH DATE

Source of Variation	d.f.	Tensile Strength MS	Soundness MS	Character MS	Tip MS
Treatment	4	123.1***	19.39***	1.293	0.3984
Age	3	69.38**	3.374	0.8156	0.3425
Birth Rank	1	5.156	10.43*	1.960†	2.365*
Regression on	1				
Birth Date		2.2	0.891	0.0025	0.2111
Residual	87	16.62	2.384	0.6873	0.5322

TABLE 12

Least Square Means for Wool Characteristics

		G.F.W. kg	S.C.W. kg	Quality number	Staple Length cms	C.P.C.	Handle Grade	Lustre Grade	Colour Grade	Cott Grade
Age	1	1.99 a	0.22 a	46.2	8.88 a	1.07	5.27	6.27	7.20 b	6.17
	2	3.91 c	0.71 b	46.8	15.84 c	0.93	4.92	5.93	5.92 a	5.69
	3	3.91 c	0.70 b	46.7	14.97 b	0.89	4.99	5.92	6.13 a	6.01
	4	3.59 b	0.65 b	46.5	14.67 b	0.92	4.97	5.88	6.21 a	6.08
Treatment	1	3.30	0.62	46.3	13.66	0.89	4.92	6.20	6.46 b	6.02
	2	3.18	0.51	46.4	13.19	0.93	5.14	5.89	6.50 b	5.64
	3	3.15	0.60	46.7	13.34	1.00	4.88	5.87	5.97 a	6.10
	4	3.49	0.55	46.9	13.73	1.00	5.06	5.85	6.66 b	6.15
	5	3.62	0.57	46.5	14.03	0.94	5.19	6.20	6.24 ab	6.04
Birth	1	3.50	0.60	46.6	14.22	0.94	5.00	5.97	6.28	6.00
	2	3.61	0.64	46.5	14.39	0.92	4.98	6.00	6.25	5.89

TABLE 13 LEAST SQUARES MEANS FOR WOOL CHARACTERISTICS
INVOLVING THE THREE FACTOR MAIN EFFECTS MODEL

		Tensile Strength kg/g/cm	Soundness grade	Character grade	Tip grade
General Mean		6.72 ± 0.7	6.25	4.75	4.51
Treatment	1	4.75 a	5.63 ab	4.33	4.39
	2	3.87 a	4.91 a	4.70	4.48
	3	6.26 ab	6.24 bc	4.76	4.40
	4	9.99 c	7.03 cd	4.95	4.49
	5	8.71 bc	7.48 d	5.02	4.78
Age	1	8.66 b	6.54	4.46	4.59
	2	5.73 a	5.75	4.96	4.36
	3	7.97 b	6.49	4.88	4.60
	4	4.51 a	6.20	4.69	4.44
Birth	1	6.95	6.60 a	4.91	4.67 b
	2	6.48	5.90 b	4.59	4.34 a

bearing twin lambs (6.60 v 5.90).

The staples were classed into four grades as suggested by Ross (1960). These were: sound ($7 + \text{kg/g/cm}$), slightly tender ($4.4-7 \text{ kg/g/cm}$); Tender ($2-4.39 \text{ kg/g/cm}$), very tender ($<2 \text{ kg/g/cm}$). Both T4 and T5 had the highest proportion of sound staples (62% and 55.5% respectively). T3 had twice the number of staples classed as sound as T1, which had similar numbers as T2 (16.6%). T2 had the highest proportion (39%) of staples classed very tender and T5 the least (0%). The trend from most to least staples classed as not sound was (T2, T1) T3, T5, T4 (Fig. 9).

Figure 10 indicates the position of break registered in the tensile strength tests relative to the staple length tested. This figure indicates that the major break occurred at entry to and exit from the forage crop treatments to pasture. The set-stocked treatment (T5) showed an even likelihood to break over the length of the test staple length while in the rotationally grazed group (T4) a greater proportion of staples broke during the last two weeks and at exit from treatments. For T2 a higher proportion of staples broke when the ewes came off the swedes onto pasture rather than when on a sole diet of hay.

Those ewes bearing single lambs had a character grade 0.31 ± 0.18 grades higher than those bearing twins ($4.91 \text{ v } 4.59$), and also a tip grade 0.33 ± 0.16 grades higher ($4.67 \text{ v } 4.34$).

C. LAMB PRODUCTION

(1) Numbers of lambs born (NLB)

No significant effects of age, treatment, or age x treatment were found using the two factor analysis; (Table 14 a and b) of analysis of variance for lamb production.

(2) Weight of lambs born (WLB)

In the treatment x age and treatment x birth rate analyses, age

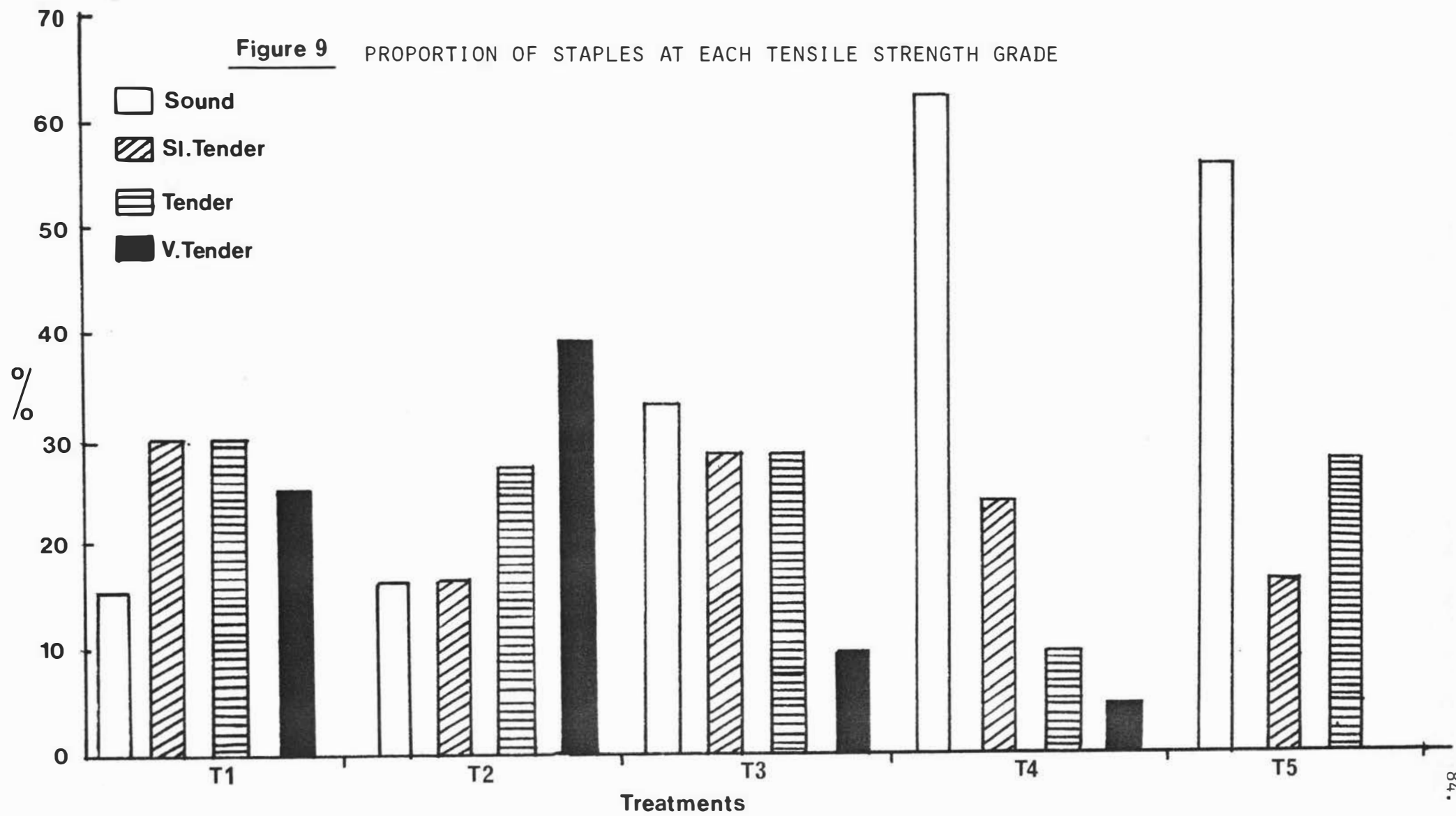


Figure 10

PERCENTAGE OF NON-SOUND STAPLES BREAKING AT EACH POSITION

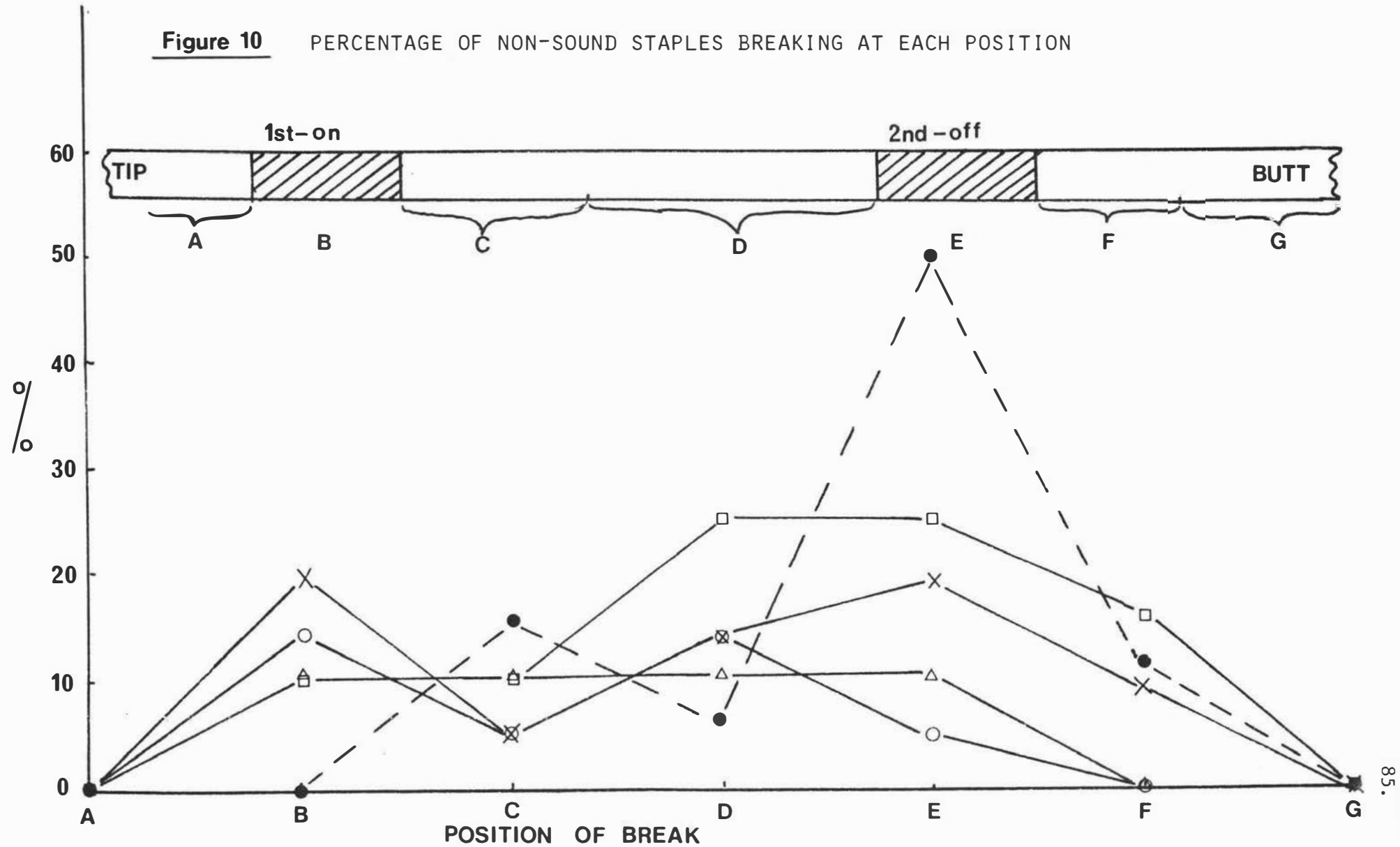


TABLE 14 a

ANALYSIS OF VARIANCE OF LAMB PRODUCTION

Source of Variation	Degrees of freedom (d.f.)	Number of lambs born M.S.	Number of lambs weaned M.S.	Weight of lambs born M.S.	Weight of lambs weaned M.S.
Age	3	0.4512	0.7072	8.0990*	375.6207
Treatment	4	0.1906	0.6800	1.5436	403.8052
Age x Treatment	12	0.2305	0.2217	3.4537	198.3635
Residual	77	0.2475	0.4475	2.4829	313.3419
Birth Rank	1		7.8516***	158.6430***	3071.7899**
Treatment	4		0.8066 †	2.0739	569.9013 †
Birth Rank x Treatment	4		0.4247	0.9594	285.6309
Residual	87		0.3451	1.0968	271.3762

TABLE 14 b MAIN EFFECTS ONLY ANALYSIS OF VARIANCE FOR LAMB
 PRODUCTION

Source of Variation	Degree of freedom (d.f.)	Weight of lambs born M.S.	Number of lambs weaned M.S.	Weight of lambs weaned M.S.
Treatment	4	2.012 †	0.6772	430.8
Age	3	0.516	0.3088	231.0
Birth rank	1	142.1 ***	6.258 ***	2336. **
Regression on birth date	1	10.17 **	0.0146	118.
Residual	87	0.964	0.3539	275.8

Source of Variation	Degree of freedom (d.f.)	Weight of lambs weaned M.S.
Treatment	4	29.20
Age	3	34.16
Weaning	1	6315. ***
Regression on Birth date	1	68.56 †
Residual	68	21.47

appeared significant ($p < 0.05$) and birth rank highly significant ($p < 0.001$) Table 14 (a). Mean values were tested for significance using Duncan's New Multiple Range test (Table 15). The results indicate that the older the ewe the heavier the lamb born, with aged ewes (≥ 5 years) producing significantly heavier lambs than two-year or three-year old ewes ($p < 0.05$). However, in the three factor main effects only model with birth date as a covariate, age was non-significant. The regression on birth date was significant ($p < 0.01$). The dominant effect was birth rank ($p < 0.001$) (i.e. either born as a single or as a twin) in the treatment x birth rank analysis. Total WLB was 7.50 kg for twins and 4.88 kg for singles.

Treatment approached significance ($p < 0.10$) in the three main effects model when adjusting for birth date. Relative to the set-stocked treatment (T5) only the rotational grazing treatment (T4) produced heavier (0.15 ± 0.32 kg) total lamb weights. (Table 16). Relative to T4, T1 and T2 produced lambs 3.06 and 2.57 kg lighter respectively.

(3) Number of Lambs Weaned (NLW)

In the three main effects only model birth rank was the only significant effect ($p < 0.001$).

Ewes giving birth to twins weaned more lambs than those giving birth to singles (136% v 81%), although the survival of twins was lower (68% v 81%).

(4) Weight of Lambs Weaned (WLW)

In the initial birth rank x treatment analyses both birth rank ($p < 0.001$) and treatment ($p < 0.10$) appeared to be affecting WLW. Further analysis using the 3 main effects model adjusting for birth date found only birth rank ($p < 0.01$) to be significant.

WLW for ewes giving birth to twins was 10.3 ± 3.6 kg heavier than for ewes bearing singles although singles were heavier than twins (30.35 v 25.79 kg) Table 17. Also T3 had significantly lighter lambs

TABLE 15 MEANS OF LAMB PRODUCTION DATA

		Number of lambs born	Number of lambs weaned	Weight of lambs born (kg)	Weight of lambs weaned (kg)
Age	1	1.30	0.70	5.69 a	20.93
	2	1.41	1.09	5.61 a	30.03
	3	1.41	1.03	5.98 a b	30.47
	4	1.64	1.17	6.84 b	31.44
Treatments	1	1.50	1.23	5.76	32.68
	2	1.47	0.98	5.81	26.80
	3	1.49	0.70	6.25	20.80
	4	1.26	1.06	5.88	30.72
	5	1.48	1.03	6.47	30.08
Birth	1		0.79	4.88	24.42
	2		1.37	7.50	35.96
Treatments	1		1.22 b	5.78	32.75 a b
	2		1.00 a b	5.94	27.06 a b
	3		0.76 a	6.20	22.33 a
	4		1.27 b	6.61	35.88 b
	5		1.14 a b	6.41	32.95 a b

TABLE 16.

LEAST SQUARE MEANS OF WEIGHT OF LAMBS BORN (kg)From the Three Factor Analysis

Age Birth Rank		1		2		3		4		Average	
		1	2	1	2	1	2	1	2	1	2
Treatment	1	4.48	7.0	4.24	6.76	4.59	7.12	4.85	7.37	4.54	7.06
	2	4.64	7.16	4.40	6.92	4.75	7.27	5.01	7.53	4.70	7.22
	3	4.91	7.43	4.67	7.19	5.02	7.54	5.28	7.80	4.97	7.49
	4	5.20	7.72	4.96	7.48	5.31	7.83	5.57	8.09	5.26	7.78
	5	5.05	7.57	4.81	7.33	5.16	7.68	5.42	7.94	5.11	7.63
Average		4.86	7.38	4.62	7.14	4.97	7.49	5.23	7.75		

Average Set Totals 7.44 kg Twins
4.92 kg Singles

Average Twins 3.72 kg
Singles 4.92 kg

TABLE 17.

LEAST SQUARE MEANS OF WEIGHT OF LAMBS WEANED (kg)

From the Three Factor Analysis

Age Weaned		1		2		3		4		Average	
		1	2	1	2	1	2	1	2	1	2
Treatment	1	28.50	49.73	27.99	49.22	30.65	51.88	27.10	48.33	28.56	49.79
	2	28.99	50.22	28.47	49.71	31.14	52.37	27.59	48.82	29.05	50.28
	3	30.66	51.89	30.15	51.38	32.81	54.04	29.26	50.49	30.72	51.95
	4	31.56	52.79	31.05	52.28	33.71	54.94	30.17	51.40	31.62	52.85
	5	31.72	52.95	31.21	52.44	33.87	55.10	30.32	51.55	31.78	53.01
Average		30.29	51.52	29.77	51.01	32.44	53.67	28.89	50.12		

Average Set totals 51.58 kg Twins
30.35 kg Singles

Average Twins 25.79 kg
Singles 30.35 kg

at weaning than T4. All other treatments showed no significant differences between each other.

When number weaned was included in the 3 factor main effects only model (Table 14 (b)), age of ewe and treatment were not significant. The regression on birth data (age of lamb at weaning) approached significance ($\rho < 0.10$).

CHAPTER V

DISCUSSION

DISCUSSION

In attempting a trial such as discussed here, there are problems with the validity of the methods used, as well as the limit to which the results can be interpreted.

Pasture and Crop Analysis Methods

Pasture and crop availability measures involve a subjective assessment to 'ground level' and this may vary both within and between samplings, as well as with ground conditions. The differences in cutting heights over different times or under differing climatic conditions may also have been a source of error in estimating herbage 'intake' and pasture growth. The complete plant pulling employed when analyzing crop 'intake' meant that this error was minimised. However, trampling of some crop into the mud along with periodical back grazings over the whole treatment period means that 'intake' could be over-estimated initially, because of trampling into mud, and then possibly under-estimated, particularly as the trial approached conclusion when back grazing would be more prevalent.

Measures of pasture availability are static measures of dynamic situations. They represent balances between the rate of DM accumulation and rate of DM disappearance (principally through decomposition and removal by the grazing animal) at a particular point in time. Under a set stocking policy, pasture availability is greatly complicated by pasture growth over time. Caging of an area can lead to different pasture growth (Cowlshaw, 1951).

Pasture yield figures recorded in the trial indicate the difficulty in estimating intake and growth on a set-stocked area. The dead matter component was high until the 11/7/77. This could have accounted for the yield figures of 60kg DM/ha/day compared to 34 kg DM/ha/day for the rotationally-grazed area. Botanical composition at the mid-way point

of treatment was vastly different. The rotationally-grazed pasture was more open and had a larger grass component than the set-stocked pasture. The most likely cause of this was the different pre-trial grazing management employed.

Pasture growth for a particular period was estimated from the difference between yield at the beginning and end of the period. The standard error (± 35 kg DM/ha) of yield indicates the difficulty in 'pairing' areas of similar total DM content. Over half the yield could be accounted for by error in estimating similar yielding sites for growth analyses. Brougham (1959) estimated ceiling pasture growth for this period at 15 kg DM/ha/day on similar soil types, but under a 'normal' winter climate. The increased temperatures experienced lead to increased yields similar to that found by Brougham (1959).

Intake and Ewe Live Weight

High live weight gains resulting from high intake levels in T5, would tend to support the finding that pasture growth was greater than usual. However, it must be remembered that at entry to the treatment, sheep were unlimited in pasture available for grazing thus ad libitum feeding in contrast to T4, resulted. Ewe live weights indicated this did happen. Ewe live weights change can involve tissue composition changes and gut fill changes (Hughes, 1976). Stomach contents of full lambs were found to weigh 3.6 kg or 13-14% of the animals live weight (Kirton et al., 1968). Thus at any weighing, ewe live weight differences recorded could partially be attributable to differing times since last grazing, back grazing on swede treatments, and continuous grazing under set-stocking would tend to increase the live weights relative to the rotational grazing ewes. With T4 most food consumption occurred within six hours of entry to the new break. After this period intakes were minimal.

Ewe live weight differences between T4 and T5 were about the same at the beginning and end of the treatment period, although both were approximately 6kg heavier at exit. T5 live weights indicate feed abundance early in the treatment period then a reduction later as feed became limiting (Table 2). Intakes from 28/6/77 to 11/7/77 for T4 and T5 were similar when considered relative to ewe live weight (2.2 and 2.5% respectively). After 11/7/77 the extra feed allowance to T4 ewes allowed live weight increases of 1kg to occur, to compensate for foetal growth.

The intake levels exhibited in Figure 3 had a coefficient of variation (c.v.) of 30%. Live weight c.v.'s of up to 30% have been recorded within each period (Boyne et al., 1956). This must be taken into account when considering live weight changes of different treatment groups over the trial period. T1 would then show constant live weight over the whole treatment period at an 'intake' of 0.68kg DM/day on swedes. In T3 at 0.83kg DM/day intake, live weight gain was 1kg for 6 weeks for a 51/5kg ewe. In T4, live weight increased from 50.5 to 57.5kg while intake was apparently 0.9kg DM/day. Rattray and Jagusch (1977) only maintained live weight at these 'intake' levels, for ewes of similar body weight, even though pasture utilization was lower. Pasture digestibility has been found to decrease with increasing utilization as the more mature components of the sward are consumed (Corbett, 1969). Therefore it is possible that these differences shown here were due to differing nutritive values of fodder on offer. Swede intakes were similar to those quoted by Thompson and Harbord (1966) although live weight gain only resulted when hay was fed. Joyce (1965) also noted this when swede diets were supplemented with hay.

Intakes of 0.59kg DM/day of good quality hay maintained ewe live weight over the initial 3 weeks of T2. This represented 1.2% of body

weight. Drew (1966) with slightly heavier ewes required 1.36kg DM of similar type hay which was 2.5% of body weight. It is suggested that the shelter and relative season warmth experienced over this time may have partly lead to reduced food requirements to maintain live weight. However, there was an initial drop of 1kg live weight during the first week, as the ewes adjusted to the new feed type.

The differing feed intakes and live weight changes exhibited can possibly be partially explained by the differences between gut fills of different treatments and also due to differences in nutritive values. Drew (1967, 1968) suggested that sheep grazing swedes have a higher maintenance requirement than those grazing pasture. There was no suggestion of this in the present data until the temperatures dropped during the last two weeks of the trial. By this time foetal demands would also be increasing (Modyanov, 1969; Rattray et al., 1974). It is possible that the water content in the swedes was at a lower temperature which would require greater heat to raise it to body temperature (Barry et al., 1971), thus the need for greater quantities of swedes to maintain the energy balance. Hay supplementation with swedes could have, to some extent, counteracted this effect.

The effects of rumen microbe and enzymatic adaptation to swedes on live weight change was minimised by feeding hay. It is suggested that whilst rumen adaptation took place, hay provided carryover energy. Ewe live weights in T1 would suggest that this took only one week. This would agree with the conclusion of Annison et al., (1957). It would be expected that this change would occur at entry to and exit from, the crop to pasture. However, ewe live weights were only recorded 3 weekly after treatment, thus any depression that occurred on exit may not have been noticed at 15/8/77. By this date, large live weight increases in all treatments had occurred and by post-lambing weighing all ewes were

of a similar live weight.

The ewes carrying twins were heavier prior to lambing than those carrying single lambs. Robinson (1973) presented similar results. At 17/10/77 no treatment effect was found although ewes with twins had a lower live weight than those rearing singles. The greater nutritional requirement of those ewes rearing twins compared to those rearing singles is the most likely explanation.

Wool production measures

Variation in wool growth over the experimental period was measured by means of samples taken from defined areas on the mid-side of the sheep, and expressed as mgs of wool per cm^2 of initial patch area. Cockrem (1968) has emphasised that interpretation of such measures of wool growth requires considerable caution. Thus inferences about changes in fleece production of an individual animal can only be made if wool growth on the patch is representative of wool growth over the rest of the fleece area under all experimental conditions. If estimates of actual changes in fleece weights are to be made then a detailed knowledge of the relationship between patch wool production and fleece weight is required. A good relationship exists during defined periods (Bigham, 1974). However, Wodzicka and Bigham (1968) have presented evidence that this relationship is not constant throughout the year. In this experiment the relationship between mid-side wool production and fleece weight was not established, and the possibility that the technique enhances wool growth on the patch (McManus et al., 1964) must also be borne in mind.

Wool production

Greasy ewe fleece weights represent fleece production for some time prior to the treatments being imposed in the experiment. Although treatment approached significance for GFW (in table 10) when considered in the age x treatment analysis, it did not in the birth rank x treatment

analysis, indicating that full control of variation using only two factors was not possible. This is shown by the increase in residual M.S. when only birth and treatment were considered c.f. age and treatment. The validity of these treatment differences is questionable from the earlier fact of pre-treatment differences. Although wool growth on the patch area immediately prior to the treatments was known, prediction of fleece production up to this time was not carried out, nor was the necessary relationships between patch wool growth and total fleece production known. Correction using the initial patch area production as a covariate for GFW was also not carried out.

There were effects of age on GFW, clean wool weight/unit area, fibre diameter, staple length, and fibre length. Two-year old ewes had shorter wool at the commencement of the trial since they were shown only $3\frac{1}{2}$ months previously compared to the rest who had 8 months wool on them. This explains many age effects for GFW and staple length. However, the finding that aged ewes (≥ 5 years) had lighter GFW and shorter staple lengths than three-year-old ewes agrees with other results by Ross (1960) and Bigham *et al.*, (1978). Only at lambing did older ewes have a proportionately greater reduction in fibre diameter over 2-year-old ewes. Brown *et al.*, (1966) have shown that for the Merino breed, fleece weights were heaviest at $3\frac{1}{2}$ years of age, although staple length was longest at $2\frac{1}{2}$ years of age, and fibre diameter increased to $6\frac{1}{2}$ years of age. Breeds appear to differ in this respect (Bigham *et al.*, 1978).

Clean wool weight/unit area results indicated that older ewes (≥ 5 years) had less wool produced than the other ages until lambing. As only one ewe per age group (except two for age 4), in each treatment was analyzed for fibre length, little can be taken from finding a highly significant age effect.

Treatment differences for weight of wool produced per unit area show

that those pasture-fed sheep had higher wool production than those grazing swedes until after lambing. This was probably due to greater nutrient intake although reduction in gut capacity associated with foetal growth (Conrad et al., 1964) may also be a factor in DM intake differences. With the swede treatments this may further be reduced by the low DM content of the diet. To achieve similar DM intakes as those sheep on pasture greater quantities of wet matter must be consumed. At the end of pregnancy this is more difficult due to decreased gut capacity and increased foetal demands. In T2, the hay diet was associated with lower wool production as well as live weight loss. Turner and Young (1969) found a similar result. During the three weeks on swedes, wool production was similar to that of the other swede treatments.

Total average feed intakes for T3 and T4 are similar yet pasture produced higher live weight gains and wool production. Feed quality differences would appear a likely cause. Opposite results have been found for live weight gain in hoggets grazing autumn-saved pasture or swedes plus limited hay (Drew, 1967). No similar data for pregnant ewes have been reported. The two pasture grazing treatments show that intake and wool production are closely related even during winter although winter seasonal depression still occurs. Scoffield (1970) found that the intake wool production regressions were dependent on stocking rate. At high stocking rates digestible organic matter intakes and production were more closely associated than at the low stocking rates. However, Doney and Smith (1961) had found live weight change and wool growth rates did not coincide. The reduced wool production in the T5 groups by comparison to T4 in the post treatment period is probably a reflection of intakes in the final stage of the treatment period.

Single-bearing ewes produced more wool per unit area than those bearing twin lambs. Numerous other workers, including Ross (1965) and

Bigham et al., (1974) have shown an effect of lambs born on fleece weight. Increased nutritional foetal demands are likely to be the cause of this, although endocrine effects could be involved.

Reduced wool production per unit area, was accompanied by reduction in both fibre diameter and fibre length. Coop (1953) showed the seasonal rhythm of wool production differences were due to both the length and diameter changes. Lewis and Ross (1962) found in Romneys it was possible to stimulate length growth markedly with initially no accompanying increases in fibre diameter. However, fibre length has been found to respond earlier than fibre diameter to nutritional changes (Story and Ross, 1960). Ferguson et al., (1949) found that weight changes could be accounted for almost entirely by length changes.

Crop treatments were associated with greater fibre diameter reduction than pasture treatments. The coarsening of diameter on 4/7/77 and 25/7/77 on pasture treatments could be due to higher intakes. Conversely the reductions exhibited on the fodder crop are probably due to lower intakes and also differing nutrient value of the fodder.

Table 9 (b) indicated that fibre length growth responds more rapidly to intake during winter than fibre diameter. Story and Ross (1960) presented similar data. Measurements of the wool grown during the treatment period by the T5 group indicate that fibre length was reduced, but fibre diameter was increased by comparison to T4. This probably reflects the higher level of feeding of the T5 group in the early stages of the treatment and their low level of feeding in the later stages with diameter not responding rapidly to the low feed in the late stages. When all sheep were lambed on grass, no differences in diameter, length or weight per unit area occurred indicating no lasting carryover effect of treatments.

The tensile strength of wool is related to the minimum fibre diameter along the staple (Ross, 1961). Any factor that causes a reduction in fibre diameter is likely to affect staple tensile strength. Those

treatments involving fodder crop grazing had lower tensile strengths than those on rotational grazing of pasture. It is noticeable that in T3 the hay had a beneficial effect in that tensile strengths are not significantly different from T5. However, from Figure 9 the proportion of staples classed as sound in T4 and T5 is significantly greater than any of the other treatments. T3, with hay however, has 16% more sound fleeces than either T1 or T2 yet differences in fibre diameter (except at 25/7/77) were not found.

Tensile strength of staples clearly distinguishes sound from unsound wool although a coefficient of variation of 15% has been found between staples within samples in maximum load (Ross, 1960). The variation was lower with sound wools than with tender wools. The four soundness grades listed in Figure 9 are based on the results of Ross (1960).

However, Figure 10 indicates the break position of staples for only unsound wools. The numbers of unsound staples in T4 and T5 are low (8 and 8) by comparison to T1, T2 and T3 (17, 15, 14 respectively) and percentage changes oversimplify the results. However, from these numbers the same general trend in staple soundness as indicated by the subjective soundness gradings is seen. T2 with 39% of its staples classed as very tender also had the finest fibre diameters throughout the trial.

The transfer of ewes in T2, from hay to swedes, and then to pasture had a more marked effect on fibre diameter than the initial transfer from pasture to hay. Break position figures indicated 50% of tender staples breaking in a portion produced at the time of transfer from crop to pasture. Rumen microbial population has already been discussed with regards to live weight changes at this time, but it is evident that these were more severe on swedes than on hay. It seems the microbial population in the rumen during pasture grazing was also capable of hay digestion but

were not adapted to a swede diet. The high water content associated with swedes may have some influence as found by Kay (1974) for cattle. The beneficial effect of hay with swedes may be due to the role of hay as a source of energy for the animal whilst rumen adaptation occurs. In addition it could also provide energy for heating the high involuntary water intake to body temperature (Barry et al., 1971).

The highest proportion of break occurring in T1 occurred at exit from swedes onto pasture and was accompanied by reduced fibre diameters at 15/8/77 in comparison to T3. A possible reason for the lack of marked break levels at entry to the crop could be that around the swede crop was an area of pasture, against the fence line, which would have provided enough food of a similar nature to that grazed previously, to allow adaptation of rumen population to occur steadily. Thus the result would be similar to T3 with hay. Also the crop had substantial weed contamination. The initial difficulties of restraining sheep, especially two-year-old ewes, from pushing under fence lines for pasture may also have provided a buffer food source. Warmer climatic conditions existing at crop entry would also mean less energy was required both for heating the water of the swedes to body temperature and for maintenance. Sheep maintenance requirements increase with colder, wet conditions (Blaxter 1964).

At the end of the treatment period sudden release onto pasture with a rumen population more adapted to swede digestion probably caused more break to be evident. Brown (1971) obtained a similar result on release of sheep from a hay/concentrate feed to pasture. A digestive upset could have occurred (Annison et al., 1959) and this may affect nutritive intake or have an effect on hormonal balance as was suggested by Lindner and Ferguson (1956).

Depending upon the nature of the previous diet the transfer to

another diet may help determine the magnitude of the response occurring. Having a proportion of the rumen population capable of digesting both pasture and its dried equivalent hay, in T3 could have accounted for the same proportion of break occurring at entry to and exit from the crop. The higher intakes overall and live weights at the end of the treatment period in T3, compared to T1, indicate the beneficial effect of hay. Crop-induced wool 'break' was also suggested by Sumner (1969) to be a source of unsoundness in his studies.

Rotational grazing on pasture did not produce significantly stronger staples than set-stocking, however, tensile strength and soundness for these pasture treatments were significantly better than either T1 or T2. Fibre diameters follow the same association. It is evident that, from those staples classed unsound, a higher proportion broke in T4 at entry to the treatment period. T5 on the other hand had equal likelihood of break over the entire tested length. However, no set stocked staples were classed as very tender, compared to 4.5% of rotational grazing staples. This difference could be due to the lack of accuracy in staple strength tests since the standard error of maximum load was of the order of $\pm 0.7\text{kg/g/cm}$.

A 'lambing break' has been suggested to occur (Ross 1965) but results illustrated in Figure 10 indicate that break occurred before lambing.

It was expected that during the last two weeks of treatment, the set-stocked ewes would be losing weight due to feed shortage and might produce tender wool. This was not the case as higher than normal pasture growth meant that ewe live weights were maintained at the increased levels, and at no time was feed intake limited. Collin (1966) found that more mob-stocked ewes exhibited break than ewes that were set-stocked. However, Lambourne (1956) found no material difference between the two systems at 4, 6, or 8 ewes/acre. Lowered feed intakes during a period

corresponding to the last two weeks of treatment here, resulted in decreased tensile strength and soundness grades for ewes in a trial by Coop (1969).

Equivalent feed allowances were offered in all treatments except T5. However, intakes differed and it could be argued that staple strength and soundness grade are closely related to intake. It would appear that above a certain level (about 0.9 kg DM/ewe/day) of intake, (dependent on live weight) increased fibre diameter, tensile strength, and soundness do not necessarily result. Scoffield (1970) presented similar results where increased feed allowances to Romney hoggets did not result in better wool production. However, his intake levels were lower than in this trial.

No age effects on tensile strengths have been noted before on a trial of this nature. Some two-year-old ewes had a capacity to escape from their allotted treatment areas during the trial and the effects of this on their intakes must be borne in mind when considering the tensile strength results. However, these differences were not discernable by soundness grade. Ross (1960) has found a correlation between maximum load (as a measure of tensile strength) and soundness grade of 0.65.

Tensile strength was unaffected by birth rank although soundness grade indicated single-bearing ewes to have sounder wool. This was in contrast to Ross (1960) where the wool from twin-bearing ewes was 10% sounder than wool from single bearing ewes. Stevens and Wright (1951), Lambourne (1956), Hight et al., (1976) and Bigham et al., (1978) reported increased numbers of unsound fleeces with increasing numbers of lambs born and reared. The trend noted by Bigham et al., (1978) for increased staple unsoundness to be associated with lower fleece weights was also evident here.

In this trial the large amount of subjective data for wool

characteristics make statistical analysis difficult. The gradings are not truly continuous. Increasing the number of grades would have led to differences between adjacent ones being small and hence a large chance element in the allocation to them. With fewer grades excellent repeatability can be obtained but the distribution becomes discrete. The nine levels used here are intermediate between the extremes, and allow the use of standard statistical techniques if used with caution.

In all the full staple gradings it is difficult to see how 6 weeks of nutritional changes during the seasonal period of minimum growth could result in marked changes. Thus quality number was unaffected by treatments over the winter period as was the crimp frequency. Also the character grade which depends primarily on the regularity and clarity of staple crimp (Lang and Skertchley, 1955), was unaffected by treatments. However, it was affected by birth rank with those ewes bearing twins having lower grades than those bearing singles. Lower (1978) found the genetic correlation between character and lambs weaned ranged from -0.66 to + 0.37, depending on ewe age. Nutritional stress can lead to some of the finer fibres being shed (Short *et al.*, 1958; Sumner, 1969). These shed fibres, along with any broken fibres, can entangle and result in cotting. No increase in cotting due to treatment was noticed in this trial. It is probable that fibre diameter was not reduced to the extent that significant shedding occurred.

Lustre, tip and handle were unaffected by treatment. Single-bearing ewes had a more blocky tip than twin-bearing ewes. This is probably attributable to the increased foetal demands for the twin bearing ewes, having an effect on wool growth rate. It was thought that both lustre and handle may have been affected by mud and hay contamination during swede feeding, especially during wet weather. Colour grades indicated that T3 and T5 were inferior with respect to the other treatments.

These two treatments were located in wetter areas and increased mud contamination may have had an effect. The two-year-old ewes had better colour because of the shorter fleece initially. Presumably the shorter fleece enhanced drying after wet weather. The conditions of high humidity that can exist in wet long wool have been found to be predisposing factors for fleece discolourations (Fraser, 1956).

It was possible that swedes may have been lower in copper (Cornforth et al., 1978) which can lead to reduced numbers of crimps and also lower tensile strengths (Burley and Hordern, 1961) with lower fleece weights (Hill et al., 1969). Copper levels of the feeds was not measured but copper levels of wool from two-year and four-year-old ewes in T1, T3 and T4 were measured (Appendix No. IV). No differences were found due to treatment or age even though the levels were considerably lower than reported by other workers (Healy and Zielman, 1966; Stevenson and Wickham, 1975). The age effect on crimp frequency has been noted before (Jackson and Chapman, 1975). Crimp abnormality, seen as irregularity of staple crimp, and more commonly known as 'doggy' wool was seen to increase with age in their study.

Lamb Production

The basic design of this experiment meant that most other research results were not directly comparable to these findings. Also as small numbers of sheep per treatment were involved, differences would have to be large to be significant.

As expected, no significant affects of treatment or age on the NLB or NLW were found. Davies (1968) and McKenzie and Edey (1975) found similar results for treatment and age respectively on NLB. However Hight and Jury (1970) found that lamb survival rate (lambs weaned as a percentage of all lambs born) increased with increasing age of dam for both single- and multiple-born lambs.

Of those lambs born only 67% of twins survived to weaning, compared to 81% of singles. From the total of 28 deaths of lambs born as twins, 16 involved both lambs of a set. Where one died of a set over 50% were either very small or very large by comparison to the other lamb of the set. Dystocia appears the likely cause of death of the larger lambs (Hight and Jury, 1970).

The treatment effect on NLW approached significance ($p < 0.10$) in the birth x treatment analysis, however, this appears to be a result of confounding of age and treatment as when birth rank is included there is a marked reduction in the age effect. When the three main effects were considered together, treatment was non-significant, with age controlling some of the treatment variation. Hodge (1966), Coop and Clark (1969), and Rattray and Jagusch (1977) also could find no effect of nutrition in mid-pregnancy on NLB with greater numbers of ewes and more extreme nutritional treatments than was used in this trial.

Age had a significant ($p < 0.05$) effect on the WLB in the age x treatment analysis. The older (≥ 5 yrs) ewes had heavier lambs at birth than either two-year-old or three-year-old ewes. This could have been due to the older ewes being bigger and heavier. However, analysis of age and treatment effects on birth date indicated age to be significant ($p < 0.01$). Hence age and birth date were confounded and in the three main effects model with birth date as a covariate, age was non-significant.

By taking an account of the date of birth of the lamb greater control over variation was shown for WLB ($p < 0.01$). The later lambing ewes had heavier lambs. This may be a consequence of the longer period on a higher nutritional regime post-treatment, or to the later lambings being associated with a longer gestation. The first ewe lambed only 16 days after the end of the treatment period, and 87% had lambed by 36 days later. Late pregnancy feeding has been found to have a marked influence on birth weight (Wallace 1948; Lodge and Heaney, 1975).

The 0.15 ± 0.32 kg birth weight advantage of rotational grazing over set-stocking is similar to results of McClymont and Lambourne (1958).

Adequate feeding during late pregnancy did not compensate for the mid-pregnancy "deficiency" caused by lower pasture intake (1.4 v 2.1kg DM/ewe/day) in the latter one-third of the set-stocking treatment period.

All the forage crop treatments were inferior to the pasture treatments with respect to WLB. This result was achieved even though the total crops DM available on offer was similar to that on offer in the pasture treatments. However, T1 and T3 only recorded "intakes" on average of 0.68 and 0.84kg DM/ewe/day respectively over the whole period, compared to T4 and T5 of an average of 1.0 and 1.7kg DM/ewe/day respectively.

The loss in ewe live weight in T1 and T2 on entry to the treatment period and for T2 on treatment changeover mid-period, may indicate that fodder type changes experienced by the ewes were sufficient to affect foetal growth. Hay fed in T3 may have buffered this dramatic change in fodder type. Hay, being of high DM% possibly enabled slower passage of the fodder through the rumen, this allowing more opportunity for complete digestion to occur and thus more efficient use of the swede food value. Hodge (1966) with a 17% loss in live weight on pasture did not find this adverse effect.

WLW was unaffected by treatment when the three main effects model with birth date as a covariate was used. Hodge (1966) and Monteath (1971) had similar findings. Adequate nutrition over the late pregnancy/early lactation period probably ensured ewe milk production was unaffected. Also compensatory live weight gains of the ewe over late pregnancy may have obscured some of the mid-pregnancy treatment effects. Monteath (1971) and Curll et al., (1975) obtained similar results.

The expected birth rank effect at weaning for total weight of lambs was evident. However, on average, individual twin weights were lighter than singles, agreeing with many research findings e.g. Davies (1968),

Hight and Jury (1970). The non-significant effect of age of ewe at this time suggests that younger ewes were just as capable of rearing equivalent weight lambs to weaning as older ewes. This is in contrast to Hight and Jury's (1970) findings, based on data from a total of 7727 lambs born. In view of the total number of lambs involved in this study (140) there would have to be very large differences in WLW to be significant. Hence the result obtained is not unexpected.

As the age x treatment interaction was non-significant it seems that the older ewes were at no disadvantage when grazing swede crops as may have been expected if teeth deterioration was evident.

These analyses do not reveal whether swedes or pasture fed during mid-pregnancy will result in different lamb production being obtained.

C H A P T E R V I

GENERAL CONCLUSIONS

GENERAL CONCLUSIONS

This study has indicated some trends that may be expected to occur when various winter grazing systems are carried out.

The climatic conditions experienced during this trial over winter, were mild, and it is possible that with more adverse conditions there would be greater production differences between the systems of winter grazing. Lower temperatures associated with wet winters would lower within-swede water temperatures. Increased heat production required to raise the water to body temperature would reduce the feed value of the crop for ewe maintenance. Thus in adverse winters hay supplementation to swedes may have greater benefits than those shown in T3. The muddy conditions at feeding would also influence characteristics more than they did in this study.

Pasture growth may have approached Brougham's (1959) values had the winter not been mild during the trial. When adverse weather occurred, pasture growth was reduced and feed utilization was lowered. Late winter feed shortages would thus occur and this would probably be more serious under a set-stocking policy in contrast to a rotational-grazing policy where feed supplies are more easily manipulated. This may mean that set-stocked sheep suffer further reduction in fibre diameters, resulting in increased tenderness of the wool. The system of rotational grazing in this trial reduced day to day variation in feed intake and hence period to period variation in live weight, wool production per unit area, fibre diameter and length. Only by withholding some paddocks from grazing under set-stocking would ample feed supplies be made available for increased feed demand in late pregnancy. Feed budgeting, as practised in this trial in T4, should ensure that feed demand is met by feed supply.

The following points can be made as a result of this trial:

- (1) DM 'intake' was greater on pasture than on fodder crop treatments
- (2) The winter pasture grazing treatments provided better wool production than winter fodder crop feeding probably largely as a result of intake differences.
- (3) Feed intakes and ewe live weight changes were closely related.
- (4) Sudden feed type changes had detrimental effects on wool tensile strength and fibre diameters.
- (5) Buffering feed type changes with supplements of a similar feed type from which they came, benefits ewe wool production and characteristics.
- (6) Changes in fibre diameter in response to nutritional changes were slower than corresponding changes in fibre length.
- (7) Wool production from older ewes (≥ 5 years) was more strongly influenced by winter grazing systems than that of ewes of younger ages.
- (8) Winter treatments had no carry-over effect post-lambing.

SCHEDULE 1Schedule of crop, pasture and hay analysis work1977

- 6 May Preliminary crop D.M. analysis.
- 11 June Preliminary crop and paddock pasture D.M. analysis
- 13 June Treatments commence - cages placed in set stocked area.
- 16 June Swede crop disappearance analysis.
- 20 June Swede crop utilisation figures calculated.
Hay utilisation calculated.
Pasture cuts pre and post grazing on treatment 4,
cages newly placed.
- 22 June Hay for treatment 2 utilisation assessed.
- 24 June Visual assessment of swede crop utilisation.
- 28 June Pasture cuts taken, cages newly placed.
- 4 July Treatment 2 onto swedes. Hay final analysis for
Treatment 2.
Pasture samples taken.
- 6 July Swede samples taken pre and post foraging areas.
- 11 July Pasture samples taken.
- 13 July Swedes samples from post foraging areas.
- 14 July Last day of first round of rotationally grazed area.
Pasture of second round sampled.
- 18 July Swede areas measured to give D.M. made available to date.
Only pasture analysis on Treatment 4.
- 25 July Pasture and crop final analysis.
Treatments finish.

SCHEDULE 2Sequence of Animal Sampling1977

- 23 May All animals for trial sorted on tupping colours and weighed.
Ewes midside sample areas cleared.
- 7 June Sheep weighed out of paddock.
- 13 June Sheep weighed, midside sampled, dyebanded, and sorted into groups made on the basis of 23 May liveweights and tupping records.
Trial treatments commence.
- 20 June Sheep weighed.
- 29 June Sheep weighed.
- 4 July Sheep weighed and side sampled.
- 11 July Sheep weighed.
- 18 July Sheep weighed.
- 25 July Sheep weighed and side sampled.
Trial treatments finish - all into one group and grazed on grass.
- 4 August Ewes full belly crutched (crutching weights taken).
- 10 August First lamb born - lamb birth weights recorded.
- 15 August Sheep weighed and side sampled.
- 17 Oct. Sheep weighed, side sampled, dye bands collected.
- 18 Oct. Ewes shorn, greasy fleece weights taken.
- 7 Dec. Weaning weights of lambs taken.

Appendix I (a)

CLIMATOLOGICAL DATA

Collected at Massey University Meteorological Station 61 meters above Mean Sea Level
(Latitude 40°S 23' S, Longitude 175°E) (1977)

Air Temperature in Degrees °C									
1977 Month	Means Max	of Min	Mean Monthly Temp	Absolute Max	Temperatures Date	Min	Date	Grass Mean Temp °C	Comments
	°C	°C	°C	°C		°C		°C	
Jan	26.2	16.1	21.2	23.5	8	3.5	15	13.4	Westerly winds dominant.
Feb	22.2	12.4	17.3	29.6	14	6.5	9	9.6	Normal month.
March	21.1	12.1	16.6	24.5	3	4.4	26	8.9	NW winds dominant.
April	17.9	9.3	13.6	25.9	10	1.8	28	6.5	Northerly winds. 1st frost.
May	13.1	4.7	8.9	16.8	15	-0.3	19	1.2	Easterly winds. Cold days. 13 frosts.
June	12.1	5.4	8.7	16.4	29	0.3	11	2.6	Above 'normal' temps. Good grass growth. 6 frosts. 5 calm days.
July	12.1	5.4	8.7	17.5	1	-0.3	12	2.2	SE winds. 9 calm days. Grass growth slowed. 5 frosts.
Aug.	13.0	6.4	9.7	15.5	25	-1.4	4	3.4	Above 'normal' temps. SE winds. Good grass growth.
Sept.	12.4	4.8	8.6	17.0	14	-1.3	9	1.7	Coldest month for many years. Poor grass growth. 11 frosts.
Oct.	15.3	7.9	11.6	20.0	10	0.9	26	4.5	Below 'normal' temps. Slow grass growth 5 frosts. Westerly winds.
Nov.	17.3	9.2	13.3	22.6	21	0.5	4	6.1	Below 'normal' temps. 2 frosts. NW winds.
Dec.	19.1	10.5	14.8	22.7	28	5.5	24	6.9	Below 'normal' temps. Dominant NW winds.

'Normal' over 30 year average

Appendix I (b)

CLIMATOLOGICAL DATA

Month	Total	<u>RAINFALL IN MILLIMETRES</u>			Bright Sunshine Hours	30 Year Average Rainfall at Palmerston North DSIR
		Number of Days Rain	Maximum Fall Amount	Fall Date		
						(mm)
Jan	66	16	23.4	3	174	86
Feb	44	6	25.2	21	188	69
March	46	8	27.2	23	174	72
April	69	18	15.0	24	135	77
May	113	18	20.3	22	106	84
June	114	17	24.1	26	74	97
July	80	17	12.1	30	108	89
August	51	14	11.3	8	98	84
Sept	108	17	21.5	19	101	70
Oct	48	13	11.8	30	144	86
Nov	77	11	18.3	20	187	81
Dec	94	14	19.1	9	190	102
Total	910					998

APPENDIX 1(c) DAILY METEOROLOGICAL DATA

TEMPERATURE						
DATE	RAIN(mm)	MAX ^o C	MIN ^o C	DAILY AV ^o C	GRASS MIN ^o C	BRIGHT SUNSHINE (Hrs)
13 June	0	13.4	7.2	10.3	5.0	6.6
14	0	14.3	3.0	8.7	-0.9	3.9
15	0.5	14.0	6.4	10.2	6.9	1.2
16	XXX	XXX	9.6	XXX	6.4	0.6
17	12.8	14.9	XXX	XXX	XXX	XXX
18	3.7	10.0	8.9	9.5	7.6	XXX
19	4.3	8.0	4.7	6.3	4.0	0.1
20	1.8	11.7	5.1	8.4	5.0	4.4
21	0.1	10.8	2.8	6.8	7.1	6.2
22	0	13.5	1.2	7.4	-2.4	1.2
23	0	12.2	7.5	9.9	2.0	7.1
24	0	11.4	5.0	8.2	0.9	0
25	0	10.5	0.6	5.5	-3.1	1.0
26	24.1	12.5	3.6	8.1	0.2	0
27	6.5	12.5	9.5	11.0	8.6	0.6
28	8.9	15.8	9.6	12.7	8.6	0
29	4.7	16.4	11.2	13.8	8.1	3.7
30	0	15.4	10.0	12.7	7.2	5.1
1 July	9.4	17.5	4.0	10.8	0.9	6.2
2	3.4	14.0	8.1	11.1	5.5	0.5
3	0	9.4	5.6	7.5	3.9	2.2
4	1.3	10.4	5.2	7.8	4.7	0.1
5	0	10.6	0.7	5.6	-3.0	5.5
6	0	10.8	2.5	6.7	-0.8	5.6
7	0.1	11.8	1.7	6.8	-2.2	4.2
8	0	11.5	4.0	7.8	0.4	4.6
9	0	11.1	3.4	7.3	-0.9	7.3
10	9.9	8.3	6.5	7.4	-0.1	0
11	0	10.8	4.6	7.7	1.5	6.6
12	0	11.0	-0.3	5.3	-4.0	9.1
13	0	12.5	1.3	6.9	-2.7	7.9
14	0	12.9	3.9	8.4	-0.6	7.1
15	0	12.6	7.3	10.0	2.6	8.1
16	0	14.1	6.4	10.3	1.0	7.6
17	0	12.5	1.0	6.8	-2.9	3.0
18	0.7	14.7	4.3	9.5	0.0	1.6
19	11.0	11.9	8.5	10.2	4.0	0.0
20	3.8	13.0	10.4	11.7	9.0	0.1
21	0.4	14.7	9.6	12.2	7.0	2.8
22	0.4	11.6	7.4	9.5	4.4	0
23	0.9	11.5	6.1	8.8	3.2	0
24	2.6	12.4	5.7	9.1	2.5	3.4
25	6.6	10.8	5.6	8.2	2.3	0.2

XXX - Missing data

APPENDIX II

Mineral Content of Water After Deionisation

<u>Deionised Effluent Analysis</u>	<u>Results in ppm</u>
Cu, Fe, NH ₃ , Zn	Not detected
Cl, SO ₄ , CO ₂	Not detected
Silica	Less than 0.1 ppm
pH	6.6 - 7.0

APPENDIX III

Descriptions of the Fleece Characteristic

Grading System

Below are listed descriptions for the fleece characteristic grading system. Standards were kept where possible. The measurement technique is given in cases of measurable characteristics.

GREASY MID-SIDE SAMPLE CHARACTERISTICS

(i) Quality Number

Bradford quality numbers.

Where 46/48 written as 47.

(ii) Character

An extra superior and an extra inferior grade were added to the grading system used by the Sheep and Wool Division of the Ministry of Agriculture and Fisheries.

(iii) Staple length

Average staple selected, measured to nearest centimetre unstretched but flattened.

(iv) Crimp Frequency

The number of crimps over the whole staple were counted, divided by the staple length (cms) and converted to crimps per cm. Estimated on an average staple.

(v) Handle

Assessed without regard to quality number with the sample screened from the view of the assessor. Line first surveyed to obtain samples.

1. Extremely harsh
2. Markedly harsher than average
3. Clearly harsher than average

4. Slightly harsher than average
5. Average handle
6. Slightly softer than average
7. Clearly softer than average
8. Markedly softer than average
9. Extremely soft

(vi) Lustre

Graded with ^{out} reference to fineness.

1. No lustre (Merino)
2. Very slight lustre
3. Low 2nd demilustre
4. 2nd demilustre
5. Low 1st demilustre
6. High 1st demilustre
7. 2nd lustre (English Leicester)
8. 1st lustre (Lincoln)
9. Like coarse Lincoln

(vii) Soundness

Test carried out on a "standard" sized small staple. If unable to be broken staple is divided into half.

1. Much of fleece lost
2. Very weak
3. "Break" present
4. Slight pull to break
5. Good pull to break
6. Slight pull to break ($\frac{1}{2}$ staple)
7. Good pull to break ($\frac{1}{2}$ staple)
8. Good pull to break ($\frac{1}{4}$ staple)

9. Sound ($\frac{1}{4}$ staple)

(viii) Tippiness

1. Like N - type
2. Very tippy
3. Considerable tip
4. Slightly worse than average
5. Average
6. Slightly better than average
7. Very slight tip
8. Basically flat but with a few fibres protruding
9. Absolutely flat and blocky.

(IX) Colour (unscoured)

1. Very bad discolouration - bacterial etc.
2. Bad yellow discolouration
3. Pronounced yellow
4. Yellow
5. Some yellow
6. Slight yellow
7. Slight cream
8. Faint cream tinge
9. Perfectly white

(X) Cotting

An estimate of the degree of fibre entanglement on the mid-side position.

1. Tightly matted, impossible to part by hand
2. Tightly matted, difficult to part by hand
3. Considerable effort required to pull staples apart
4. Some effort required to pull staples apart

5. Slight effort required to pull staples apart
6. Fairly free, pulling apart easily
7. Free, but with sufficient tangling to hold the
weight of the sample
8. Very free, falling apart like pre-lamb shorn wool
9. Very free with no binding between fine staples.

Appendix IV

Wool Copper Analysis

Variation in the copper content of wool has been reported for a wide range of soils in the United States and New Zealand (Burns et al., 1964; Healy et al., 1964; Healy and Zeilman, 1966). Large, between locality differences, reported by workers have been considered to be due principally to variations in soil elemental concentrations. However, different fodder types have differing levels of copper within the same locality (Adams and Elphick, 1956).

This experiment was conducted to see if wool from swedes alone (T1), swedes plus hay (T3), and pasture (T4) diets differed in copper concentrations. Copper deficiency can result in lowered tensile strenghts and crimp frequency in wools (Burley, 1960).

Materials and Methods

The mid-side samples collected from the Romney ewes as described earlier were analyzed. Preparation through to scouring was as described in the materials and methods section. Three ewes from each 2-year-old and 4-year-old sheep in T1, T3, and T4 with a similar pregnancy status were selected. Samples from pre- and post- treatment periods were analyzed.

Samples weighing approximately 200mg were rinsed in copper-free water for 24 hours and any discernable foreign matter was removed as the samples were drained. After drying in a hot blast of air and conditioning for 48 hours at 20°C and 65% relative humidity the samples were reweighed. These were then ashed at 480°C for 8 hours. The ash was dissolved in 5ml of 2M HCl and diluted for subsequent determination of copper concentrations by atomic absorption spectrophotometry under the conditions listed in the Perkin Elmer 306 manual.

Statistical Analysis

The copper concentration data was subjected to analysis of covariance with the pre-treatment levels used as the covariate. Only age and treatment ^lffects were considered.

Results

No significant age, treatment or age x treatment effects were found (Table A)

TABLE A MEAN SQUARES FOR ANALYSIS OF COVARIANCE OF
WOOL COPPER

Source	d.f.	Copper M.S.
Age	1	6.01
Between Treatments	2	0.22
Age x Treatment	2	6.44
Residual	12	6.59

Mean copper concentrations of wool for age and treatment are given in Table B

TABLE B MEAN COPPER CONCENTRATIONS

		<u>Wool Copper Concentrations (ppm)</u>	
		Pre-treatment	Post-treatment
Age	2-year-old	9.7	11.4
	4-year-old	10.3	10.2
	S.E.	<u>± 0.74</u>	<u>± 0.84</u>
Treatment	T1	9.2	10.7
	T3	9.1	11.0
	T4	11.7	10.7
	S.E.	<u>± 1.03</u>	<u>± 0.77</u>

Discussion

Large differences in dietary copper intakes appear to be necessary to affect wool copper. Kapoor et al., (1972) found that copper intakes varying from 6.15 to 9.17 mg/day did not significantly affect wool copper. Thus treatments had no affect here.

The mean copper concentrations found were well below the range of 22-81 ppm reported by Healy and Zeilman (1966) for wool from sheep grazing pasture on a range of New Zealand soils. Stevenson and Wickham (1976) reported a mean level of 25.5 ppm for wool grown in July when wool growth was slow. As ewes were still 4 weeks from lambing at the time the post treatment samples were taken, it is suggested that pregnancy effects were unlikely to influence the copper levels.

In this trial the water used for scouring the wool samples was distilled and deionised (Deionised mineral content of water after delonisation is shown in Appendix II). It is suggested that the water used by other workers for scouring may have been contaminated and that the wool absorbed copper from the water. Water copper concentrations were found to be up to 5ppm.

High between sheep variance has also been found by Stevenson and Wickham (1976). If much of the copper present was absorbed from the washing water this suggests that there may be a marked difference in the ability of wool produced by different sheep to bind to copper.

BIBLIOGRAPHY

- Adams, A.F.R., Elphick, B.L.E. 1956. The copper content of some soils and pasture species in Canterbury. N.Z. Jl Sci. Tech. A 38 : 345.
- Alexander, G. 1962. Temperature regulation in the New Born Lamb IV. The effect of wind and evaporation of water from the coat on metabolic rate and body temperature. Aust. J. agric. Res. 13 : 82
- Allden, W.G. 1962. Rate of herbage intake and grazing time in relation to herbage availability. Proc. Aust. Soc. Anim. Prod. 4 : 163.
- Allden, W.G. 1969. The Summer nutrition of sheep: The Voluntary feed intake, body weight change, and wool production of sheep grazing the mature herbage of sown pasture in relation to the intake of dietary energy under a supplementary feeding regime. Aust. J. agric. Res. 20 : 499.
- Annison, E.F., Lewis, D., Lindsay, D.B. 1959. The metabolic changes which occur in sheep transferred to lush spring grass. I. Changes in blood and rumen constituents. J. agric. Sci., Camb. 53 : 34.
- Arnold, G.W. 1964. Factors within plant associations affecting the behaviour and performance of grazing animals. In "Grazing in Terrestrial and Marine Environments" Ed. D.J. Crisp, Blackwell, Oxford, p133.
- Arnold, G.W., Dudzinski, M.L. 1967. Comparison of faecal nitrogen regressions and in vitro estimates of diet digestibility for estimating the consumption of herbage by grazing animals. J. agric. Sci. Camb., 68 : 213.
- Austin, C.R., Short, R.V. 1972. Hormones in Reproduction. In Reproduction in Mammals. Ed. C.R. Austin and R.V. Short, University Press, Cambridge.
- Balch, C.C., Line, C. 1957. Weight changes in grazing cows. J. Dairy Res. 24 : 11
- Barnicoat, C.R., Logan, A.G., Grant, A.I. 1949. Milk Secretion Studies with N.Z. Romney ewes Parts I-IV. J. agric. Sci., Camb. 39 : 44-237.
- Barnicoat, C.R., Murray, P.F., Roberts, E.M., Wilson, G.S. 1957. Milk Secretion Studies with New Zealand Romney Ewes Parts V-X. J. agric. Sci. Camb. 48 : 9.
- Barry, T.N. 1969. The effect of plane of nutrition and feeding formalin-treated casein on the production, fibre diameter, and tensile strength of wool. Proc. N.Z. Soc. Anim. Prod. 29 : 219.
- Barry, T.N., Drew, K.R., Duncan, S.J. 1971. The Digestion, Voluntary Intake, and Utilization of Energy by Romney Hogget~~s~~ Fed Five Winter Forage Crops. N.Z. Jl. agric. Res. 14 : 834.

- Baumgardt, B.R. 1970. Control of feed intake and energy balance.
In Physiology of Digestion and Metabolism in the Ruminant.
 Ed. A.T. Phillipson. p 235. Oriel Press, Newcastle-upon-Tyne.
- Bell, D.S., Spencer, D.A., Hardy, M.H. 1936. The influence of various factors upon the growth and quantity of fine wool as obtained from Merino sheep. Ohio agric. Exp. Sta. Bull. 571.
- Bennett, H.W., Beck, A.B. 1942. Enzootic ataxia and copper deficiency of sheep in Western Australia. Bull. Coun Sci Industr. Res. Aust. No. 147.
- Bennett, J.W., Hutchinson, J.C.D., Wodzicka-Tomaszewska, M. 1962. Annual rhythm of wool growth. Nature, Lond. 194 : 652.
- Bennett, D., Axelsen, A., Chapman, H.W. 1964. The effect of nutritional restriction during early pregnancy on numbers of lambs born. Proc. Aust. Soc. Anim. Prod. 5 : 70.
- Bigham, M.L. 1974. Effects of shearing interval on fleece weight and wool growth on a delineated mid-side patch. N.Z. Jl agric. Res. 17 : 407.
- Bigham, M.L., Sumner, R.M.W., Dalton, D.C. 1978. Wool production of different breeds of mixed-age ewes on hill country. N.Z. Jl agric. Res. 21 : 119.
- Bishop, A.H. and Birrell, H.A. 1975. Effect of stocking rate, fodder conservation and grazing management on the performance of wether sheep in South West Victoria I. Wool production. Aust. Jl exp. agric. Anim. Husb. 15 : 173.
- Birrell, H.A., Bishop, A.H., Tew, A., Plowright, R.D. 1978. Effects of stocking rate, fodder conservation and grazing management on the performance of wether sheep in South West Victoria II Seasonal wool growth rate, live weight and herbage availability. Aust. Jl exp. agric. Anim. Husb. 18 : 41.
- Black, J.L., Robards, G.E., and Thomas, R. 1973. Effects of protein and energy intakes on the wool growth of Merino wethers. Aust. Jl agric. Res. 24 : 399.
- Blaxter, K.L. 1964. Utilization of the metabolisable energy of grass. Proc. Nut. Soc. 23 : 62.
- Blaxter, K.L., Wainman, F.W., Wilson, R.S. 1961. The regulation of food intake by sheep. Anim. Prod. 3 : 51.
- Blaxter, K.L. and Wainman, F.W. 1964. The utilization of the energy of different rations by sheep and cattle for maintenance and for fattening. J. agric. Sci. Camb. 63 : 113.
- Boswell, C.C., Monteath, M.A., Round-Turner, N.L., Lewis, K.H.G., Cullen, N.A. 1974. Intensive lamb production under continuous and rotational grazing systems. N.Z. Jl Exp. Agric. 27 : 403.

- Boyne, A.W., Campbell, R.M., Davidson, J., Cuthbertson, D.P. 1956. Changes in composition of the digesta along the alimentary tract of sheep. *Br. J. Nutr.* 10 : 325.
- Brougham, R.W. 1959. The effects of season and weather on the growth rate of a ryegrass and clover pasture. *N.Z. J. agric. Res.* 2 : 283.
- Brown, G.H., Turner, H.N., Young, S.S.Y., Dolling, C.H.S. 1966. Vital statistics for an experimental flock of Merino Sheep III Factors affecting wool and body characteristics, including the effect of age of ewe and its possible interaction with method of selection. *Aust. J. agric. Res.* 17 : 557.
- Brown, L.D. 1966. Influence of intake on feed utilisation. *J. Dairy Sci.* 49 : 223.
- Brown, T.H. 1971. The effect of three factors on the incidence of tender wool in deferred grazing management. *Aust. J. exp. Agric. Anim. Husb.* 11 : 607.
- Bublath, A.G. 1969. Some effects of pasture species and stocking rate on sheep and pasture production. *M. Agr. Sci.* Thesis, Massey University.
- Burley, R.W. 1960. Experiments on wool from copper-deficient sheep. I. Some physical measurements on intact fibres and experiments on the dissolution and fractionation of oxidised wool. *Text. Res. J.* 30 : 473.
- Burley, R.W. and Hordern, F.W.A. 1961. Experiments on wool from copper-deficient sheep. III The action of trypsin on oxidised wool. *Text. Res. J.* 31 : 389.
- Burns, M. 1953. Observations on the follicle population of Blackface sheep. *J. agric. Sci., Camb.* 43 : 422.
- Burns, M. 1954. Observations on the development of fleece and follicle population in Suffolk sheep. *J. agric. Sci., Camb.* 44 : 86.
- Burns, R.H., Johnson, A., Hamilton, R.J., McColloch, R.J., Duncan, W.E., and Frisk, H.G. 1964. Minerals in domestic wools. *J. Anim. Sci.*, 23 : 5.
- Butler, G.W., Rae, A.L. and Bailey, R.W. 1968. Influence of pasture species on aspects of animal production. *N.Z. agric. Sci.* 3 : 8.
- Campling, R.C. 1970. Physical regulation of voluntary intake. In *Physiology of Digestion and Metabolism in the Ruminant.* Ed A.T. Phillipson. p 225. Oriel Press, Newcastle-upon-Tyne.
- Castle, M.E., Drysdale, A.D., Weston, J.N. 1962. A comparison between ryegrass and cocksfoot hay for milk production. *J. Dairy Res.* 29 : 199.
- Chapman, R.E. and Wheeler, J.L. 1963. Dye banding : A technique for fleece growth studies. *Aust. J. Sci.* 26 : 53.

- Cockrem, F.R.M. 1959. cited by Sumner 1969.
- Cockrem, F.R.M. 1968. cited by Scoffield, 1970.
- Collin, F.H. 1966. Interim report on results from Tangoio and Waerenga-o-kuri stocking rate trials. N.Z. agric. Sci. 5 : 9.
- Conrad, H.R., Pratt, A.D., Hibbs, J.W. 1964. Regulation of feed intake in dairy cows I. Change in importance of physical and physiological factors with increasing digestibility. J. Dairy Sci. 47 : 54.
- Coop, I.E. 1950. The effect of level of nutrition during pregnancy and during lactation on lamb and wool production of grazing sheep. J. agric. Sci., Camb. 40 : 311.
- Coop, I.E. 1953. Wool growth as affected by nutrition and by climatic factors. J. agric. Sci., Camb. 43 : 456.
- Coop, I.E. 1968. Nutrition and wool tenderness. Lincoln College Research Publication 1968.
- Coop, I.E. and Clark, V.R. 1969. The influence of nutritional level in early pregnancy of the ewe. J. agric. Sci., Camb. 73 : 387.
- Coop, I.E. and Hart, D.S. 1953. Environmental factors affecting wool growth. Proc. N.Z. Soc. Anim. Prod. 13 : 113.
- Coop, I.E. and Hill, M.K. 1962. The energy requirements of sheep for maintenance and gain. II. Grazing sheep. J. agric. Sci., Camb., 58 : 187.
- Corbett, J.L. 1964. Effect of lactation on wool growth of Merino sheep. Proc. Aust. Soc. anim. Prod. 5 : 138.
- Corbett, J.L. 1966. Effects of pregnancy, length of lactation, and stocking rate on the performance of Merino sheep. Proc. Xth Int. Grassld. Congr. p.491.
- Corbett, J.L. 1969. The nutritive value of grassland herbage. "International Encyclopedia of Feed and Nutrition" Pergamon Press, 17 : 593.
- Corbett, J.L., Greenhalgh, J.F.D. 1960. "Production and Use of Grass" Monogr. No. 9, Soc. Chem. Ind., London.
- Corbett, J.L., Langlands, J.P., McDonald, I., Pullar, J.D. 1966. Comparison by direct animal calorimetry of the net energy values of an early and late season growth of herbage. Anim. Prod. 8 : 13.
- Corbett, J.L., Furnival, E.P. 1976. Early weaning of grazing sheep. 2. Performance of ewes. Aust. J. exp. agric. Anim. Husb. 16 : 156.
- Cornforth, I.S., Stephen, R.C., Barry, T.N., and Baird, G.A. 1978. The mineral content of swedes, turnips, and kale. N.Z. Jl exp. Agric. 6 : 151.
- Cowlshaw, S.J. 1951. The effect of sampling cages on the yields of herbage. J. Br. Grassld. Soc. 6 : 179.
- Cullen, N.A. 1974. Intensive lamb production under continuous and rotational grazing systems. N.Z. Jl exp. agric. 2 : 403.

- Cunningham, I.J. and Hogan, K.G. 1958. The influence of diet on the copper and molybdenum contents of hair, hoof, and wool. N.Z. J. agric. Res. 1 : 841.
- Curll, M.L., Davidson, J.L., Freer, M. 1975. Efficiency of lamb production in relation to the weight of the ewe at mating and during pregnancy. Aust. J. agric. Res., 26 (3) : 553.
- Davies, J. 1952. Correlated anatomical and histochemical studies on the mesonephros and placenta of the sheep. Am. J. Anat. 91 : 263.
- Davies, Lloyd. H. 1968. Studies in pasture management for the breeding ewe I. Effects on ewe live weights, incidence of pregnancy toxæmia, lamb birth weights, and neo-natal mortality. Aust. J. agric. Res., 19 : 605.
- Dickerson, G.E., Glimp, H.A. 1975. Breed and age effects on lamb production of ewes. J. Anim. Sci. 40 : (3) : 397.
- Doney, J.M. 1964. The fleece of the Scottish Blackface sheep 4 : The effects of pregnancy, lactation and nutrition on seasonal wool production. J. agric. Sci., Camb., 62 : 59.
- Doney, J.M. 1966. Breed differences in response of wool growth to annual nutritional and climatic cycles. J. agric. Sci. Camb., 67 : 25.
- Doney, J.M., Eadie, J. 1967. The wool growth response to the annual cycle of grazing intake of Cheviot wethers. J. agric. Sci., Camb. 69 : 411.
- Doney, J.M., Griffiths, J.G. 1967. Wool growth regulation by skin cooling. Anim. Prod. 9 : 393.
- Doney, J.M., Smith, W.F. 1961. The fleece of the Scottish Blackface sheep. I. Seasonal changes in wool production and fleece structure. J. agric. Sci., Camb. 56 : 365.
- Downes, A.M., Hutchinson, J.C.D. 1969. Effects of low skin surface temperature on wool growth. J. agric. Sci., Camb., 72 : 155.
- Downes, A.M., Reis, P.J., Sharry, L.F., Tunks, D.A. 1970. Metabolic fate of parenterally administered sulphur containing amino acids in sheep and effects on growth and composition of wool. Aust. J. Biol. Sci. 23 : 1077.
- Dove, H. Robards, G.E. 1974. Effect of abomasal infusions of methionine, casein, starch plus methionine on the wool production of Merino wethers fed on lucerne or wheaten chaff. Aust. J. agric. Res. 25 : 945.
- Draw, K.R. 1966. The in vitro prediction of herbage digestibility. Proc. N.Z. Soc. Anim. Prod. 26 : 52.
- Draw, K.R. 1967. The winter nutrition of Romney Hoggets. Proc. N.Z. Soc. Anim. Prod. 27 : 210.

- Drew, K.R. 1968. Winter Feeding Hoggets. Proc. N.Z. Soc. Anim. Prod. 28 : 94.
- Drew, K.R., Stephen, R.C., Barry, T.N. 1974. The composition and productive features of some forage crops for sheep. Proc. N.Z. Agron. Soc. 4 : 53.
- Dryden, G.M., Wickham, G.A., Cockrem, F. 1969. Intravenous infusion of cysteine and wool growth of Romney sheep. N.Z. Jl agric. Res. 12 : 580.
- Duncan, D.B. 1955. Multiple range and multiple F. tests. Biometrics, 11 : 1.
- Emery, R.S., Smith, C.K., Lewis, T.R. 1958. Effect of hay-concentrate rates on rumen fill as measured by antipyrine dilution techniques. J. Dairy Sci. 41 : 647.
- Everitt, G.C. 1964. Maternal under-nutrition and retarded foetal development in Merino sheep. Nature, Lond. 201 : 1341.
- Everitt, G.C. 1966. Effect of intake of feed by ewes on growth of foetus. Proc. Aust. Soc. anim. Prod. 6 : 91.
- Ewer, T.K., Sinclair, D.P. 1952. Lamb fattening trials on the Canterbury Plains. N.Z. Jl Sci Tech. 33 A : 1.
- Ferguson, K.A. 1949. The effect of sympathectomy on wool growth. Aust. J. Sci. Res. B, 2 : 438.
- Ferguson, K.A. 1951. The effect of hypophysectomy on wool growth. J. Endocrin. 7 : lxi.
- Ferguson, K.A. 1958. The influence of thyroxine on wool growth. Proc. N.Z. Soc. Anim. Prod., 18 : 128.
- Ferguson, K.A., Carter, H.B., Hardy, M.H. 1949. Studies of comparative fleece growth in sheep I. The quantitative nature of inherent differences in wool growth rate. Aust. J. Sci. Res. B, 2 : 42.
- Forbes, J.M. 1968. The physical relationships of the abdominal organs in the pregnant ewe. J. agric. Sci., Camb. 70 : 171.
- Forbes, J.M. 1977. Inter-relationships between physical and metabolic control of voluntary food intake in fattening, pregnant and lactating mature sheep : A model. Anim. Prod. 24 : 91.
- Forbes, J.M. and Boaz, T.G. 1965. Studies in the roughage and water intake of ewes. Anim. Prod. 7 : 289.
- Frame, J. 1976. A comparison of herbage production under cutting and grazing (including comments on deleterious factors such as treading. In Pasture Utilisation by the Grazing Animal. Occ. Symp. No. 8. Br. Grassld. Soc. 1976.
- Fraser, I.E.B. 1956. Observations on the microclimate of the fleece Aust. J. agric. Res. 8 : 281.

- Gallagher, J.R., Watkin, B.R., Grimes, R.C. 1966. An evaluation of pasture quality with young grazing sheep. I Live weight growth and clean wool production. J. agric. Sci., Camb. 66 : 107.
- Graceva, L.V. 1969. Ovtsevodstvo No. 2 p.34. cited in Nutr. Abstr. 39 : 1344.
- Graham, N. McC 1964. Energy exchanges of pregnant and lactating ewes. Aust. J. agric. Res. 15 : 127.
- Green, J.L., Langer, H.J., Williams, T.E. 1952. Sources and magnitudes of experimental errors in grazing trials. Proc. 6th Int. Grassld. Conf., Pennsylvania 1952. : 1374.
- Grimes, R.C. 1966. An estimation of the energy required for maintenance and live weight gain by young grazing sheep. J. agric. Sci., Camb. 6 : 211.
- Guyer, P.Q., Dyer, A.J. 1954. Study of factors affecting sheep production. Miss. Agric. Exp. Sta. Res. Bull. No. 558.
- Hamilton, B.A., Hutchinson, K.J., Annis, P.C., Donnelly, J.B. 1973. Relationships between the diet selected by grazing sheep and the herbage on offer. Aust. J. agric. Res. 24 : 271.
- Hardison, W.A., and Reid, J.T. 1953. The use of indicators in the measurement of dry matter intake of grazing animals. J. Nutr. 51 : 35.
- Hart, D.S. 1955. The photoperiodic and hormones responses of wool growth in sheep. Proc. N.Z. Soc. anim. Prod. 15 : 57.
- Hart, D.S. 1961. The effect of light-dark sequences on wool growth. J. agric. Sci., Camb. 56 : 235.
- Hart, D.S., Bennett, J.W., Hutchinson, J.C.D., Wodzicka-Tomaszewska, M. 1963. Reversed photoperiodic seasons on wool growth. Nature, Lond. 198 : 310.
- Healy, W.B., Bate, B.D., Ludwig, F. 1964. Micro-element content of wool from twin wethers raised on two soils as determined by neutron activation analysis. N.Z. J. agric. Res. 7 : 603.
- Healy, W.B., Zeileman, A.M. 1966. Macro- and micro-element content of New Zealand wool. N.Z. J. agric. Res. 9 : 1073.
- Henderson, A.E. 1955. Faults in New Zealand wool. Lincoln College technical publications, No.12.
- Henderson, A.E., Bryden, J., McG., Mazzitelli, F.E., Milligan, K.E. 1970. Protein supplementation and wool growth. Proc. N.Z. Soc. anim. Prod. 30 : 186.
- Hight, G.K., Jury, K.E. 1970. Hill country sheep production. II. Lamb mortality and birth weights in Romney and Border Leicester x Romney flocks. N.Z. J. agric. Res. 13 : 735.
- Hight, G.K., Atkinson, J.J., Sumner, R.M.W., Bigham, M.L. 1976. Hill country sheep production. VII Wool traits of Romney and Border Leicester x Romney ewes. N.Z. J. agric. Res. 19 : 197.

- Hill, M.K., Walker, S.D., Taylor, A.G. 1969. Effects of 'marginal' deficiencies of copper and selenium on growth and productivity of sheep. N.Z. J. agric. Res. 12 : 261.
- Hodge, R.W. 1966. The effect of nutritional restriction during early and mid-pregnancy on the reproductive performance of crossbred ewes. Aust. J. Exp. agric. Anim. Husb. 6 : 311.
- Hodgson, J. 1976. The influence of grazing pressure and stocking rate on herbage intake and animal performance. In Pasture Utilisation by the Grazing Animal p.93 Occ. Symp. No. 8. Br. Grassld. Soc. 1976.
- Hodgson, J., Wilkinson, 1967. The relationship between live weight and herbage intake in grazing cattle. Anim. Prod. 9 : 365.
- Hodgson, J., Tayler, Lonsdale, C.R. 1971. The relationship between intensity of grazing and the herbage consumption and growth of calves. J. Br. Grassld. Soc. 26 : 231.
- Hogan, J.P., Weston, R.H. 1967. The digestion of two diets of differing protein content but with similar capacities to sustain wool growth. Aust. J. agric. Res., 18 : 973.
- Hughes, J.G. 1976. Short term variation in animal live weight and reduction of its effect on weighing. Anim. Breed. Abst. 44 (3) : 111.
- Hungate, R.E., Phillips, G.D., McGregor, A., Hungate, D.P., Beuchner, H.K. 1959. Microbial fermentation in certain mammals. Science 130 : 1192.
- Hutchinson, K.J. 1956. Techniques applicable to grazing intake studies Proc. Aust. Soc. anim. Prod. 1 : 52.
- Hutchinson, J.C.D. 1965. Photoperiodicity and wool growth. In Biology of the Skin and Hair Growth. Ed. A.G. Lyne and B.F. Short. p.365. Angus and Robertson, Sydney.
- Hutchinson, J.C.D., Wodzicka-Tomaszewska, M. 1961. Climate physiology of sheep. Anim. Breed. Abstr. 29 : 1.
- I.W.T.O. 1961. Specification I.W.T.O. - 8-61 (E). Reprinted 1966. Method of determining wool fibre diameter by the projection microscope. International Wool Secretariat, London.
- Jackson, N., Chapman, R.E. 1975. Response to selection in Australian Merino sheep VI. Inheritance of abnormal staple crimp, estimates of phenotypic and genetic parameters. Aust. J. agric. Res. 26 : 375.
- Jamieson, W.S. 1975. Studies on the herbage intake and grazing behaviour of cattle and sheep. Ph.D. Thesis, University of Reading.
- Jamieson, W.S., Hodgson, J. 1974. The grazing behaviour and herbage intake of Friesian Steer Calves. Proc. Br. Soc. Anim. Prod. 1974. p91.
- Jefferies, B.C. 1964. Changes in face cover of Merino and Corriedale sheep throughout the year. Aust. J. exp. agric. Anim. Husb. 4 : 118.

- Johnstone, I.L. 1955. Pasture improvement and wool production. Wool Tech. 2 : 83.
- Joseph, A.E. 1926. Effect of feeding and management on the tensile strength and elasticity of wool. J. agric. Res. 33 : 1073.
- Joyce, J.P. 1965. Winter feeding of hoggets on swedes and hay. Ministry of Agric. Fish. Res. Report 1967/68 p.153.
- Kapoor, U.R., Agarwala, O.N., Pachauri, V.C., Nath, K., Narayan, S. 1972. The relationship between diet, the copper and sulphur content of wool, and fibre characteristics. J. agric. Sci. Camb., 79 : 109.
- Kay, M. 1974. The feeding value of root crops for ruminants. A.D.A.S. Quarterly Review. 15 : 107.
- Kirton, A.H. 1973. Ruakura agric. Res. Centre cited by J.G. Hughes, 1976.
- Kirton, A.H., Quartermain, A.R., Uljee, A.E., Carter, W.A., Pickering, F.S. 1968. Effect of 1 and 2 days ante-mortem fasting on live weight and carcass losses in lambs. N.Z. Jl agric. Res. 11 : 891.
- Lambourne, L.J. 1956. A comparison between rotational grazing and set stocking for fat-lamb production. N.Z. Jl Sci. Technol. Soc. A. 37 (6) : 555.
- Lambourne, L.J. 1957. Measurement of feed intake of grazing sheep. I. Rate of passage of inert reference materials through the ruminant digestive tract. J. agric. Sci., Camb. 48 : 273.
- Lambourne, L.J. 1964. Stimulation of wool growth by thyroxine implantation. Aust. J. agric. Res. 15 : 657.
- Lambourne, L.J. and Reardon, T.F. 1962. Use of 'seasonal' regressions in measuring feed intake of grazing animals. Nature, Lond., 196 : 961.
- Lambourne, L.J. and Reardon, T.F. 1963a. The use of chromium oxide to estimate the faecal output of Merinos. Aust. J. agric. Res. 14 : 239.
- Lambourne, L.J. and Reardon, T.F. 1963b. Effect of environment on the maintenance requirements of Merino wethers. Aust. J. agric. Res. 14 : 272.
- Langlands, J.P. 1967. Studies of the nutritive value of the diet selected by grazing sheep III. A comparison of oesophageal fistula and faecal index techniques for the indirect estimation of digestibility. Anim. Prod. 9 : 325.
- Langlands, J.P., Donald, G.E. 1977. Efficiency of wool production of grazing sheep. 4. Forage intake and its relationship to wool production. Aust J. exp. agric. Anim. Husb. 17 : 247.
- Lower, R.P. 1978. A study of genetic and environmental variation and covariation in production trials of a flock of Perendale sheep. Ph.D. Thesis, Massey University.

- Lewis, K.H.C. 1960. Turnips as winter feed for hoggets. N.Z. J1 agric. 101 : 577.
- Lewis, K.H.C. 1973. Hogget feeding trials at Invermay - A Review. Proc. Inv. Fmrs. Conf. 1973 : 1.
- Lindner, H.R. 1959. Blood cortisol in the sheep : normal concentrations and changes in ketosis of pregnancy. Nature, Lond., 184 : 1645.
- Lindner, H.R. 1964. Comparative aspects of cortisol transport. Lack of firm binding to plasma proteins in domestic ruminants. J. Endocrin. 28 : 301.
- Lindner, H.R., Ferguson, K.A. 1956. Influence of the adrenal cortex on wool growth and its relation to breaks and tenderness of the fleece. Nature, Lond., 177 : 188.
- Lodge, G.A., Heaney, D.P. 1973. Energy cost of pregnancy in single- and twin-bearing ewes. Can. J Anim. Sci. 53 : 479.
- Lodge, G.A., Heaney, D.P. 1975. Influence of feed allowance during pregnancy on reproductive performance of ewes and growth of suckled and artificially reared lambs. Can. J Anim. Sci., 55 : 533.
- Lyne, A.G. 1961. The post-natal development of wool follicles, shedding and skin thickness in inbred Merino and Southdown-Merino Crossbred sheep. Aust. J. biol. Sci., 14 : 141.
- MacRae, J.C., Ulyatt, M.J. 1974. Quantitative digestion of fresh herbage by sheep II. The sites of digestion of some nitrogenous constituents. J. agric. Sci., Camb. 82 : 309.
- McCullough, M.E. 1959. Symposium on forage evaluations. 3. The significance of and techniques used to measure forage crop intake and digestibility. Agron. J. 51 : 219.
- McClymont, G.L., Lambourne, J.L. 1958. Interactions between planes of nutrition during early and late pregnancy. Proc. Aust. Soc. Anim. Prod. 2 : 135.
- McDonald, R.C., Stephen, R.C., Wilson, K.R. 1977. Animal production on crop versus pasture in the Autumn. I. Weaned lambs. Proc. N.Z. Agron. Soc. 7 : 17.
- McFarlane, J.D. 1965. The influence of seasonal pasture production and grazing management on seasonal wool growth. Aust. J. exp. agric. Anim. Husb. 5 : 252.
- McKenzie, A.J., Edey, T.N. 1975. Effects of pre-mating undernutrition on oestrus, ovulation and pre-natal mortality in Merino ewes. J. agric. Sci., Camb. 84 : 119.
- McLean, J.W., Thompson, G.G., Jagush, K.T., Lawson, B.M. 1965. Lamb growth and development in relation to pasture species. Proc. Ruakura Fmrs. Conf: 34.
- McManus, W.R., Arnold, G.W., Paynter, J.R. 1964. Studies in the wool production of grazing sheep. 2. Variation in wool characteristics with season and stocking rate. Aust. J. exp. agric. Anim. Husb. 4 : 404.

- McMeekan, C.P., Walshe, M.J. 1963. The inter-relationships of grazing method and stocking rate in the efficacy of pasture utilisation by dairy cattle. *J agric. Sci., Camb.* 61 : 147.
- M.A.F. 1968. Winter ewe nutrition and wool production paper to S.W.Q.I.C. meeting 1968.
- Marston, H.R. 1935. Studies on the relationship between nutrition and wool production of Merino sheep. II The effect of the administration of cystine, cysteine sulphur and of methionine on the growth of wool of a Merino ewe on protein poor ration. *J. agric. Sci., Camb.* 25 : 113.
- Marston, H.R. 1946. Nutrition and wool production. *Proc. Symp. on fibrous proteins* p. 207. Soc. Dyers and Colorists, Leeds.
- Marston, H.R., Lee, H.J. 1956. The effect of copper deficiency and chronic over-dosage with copper on Border Leicester and Merino sheep. *J. agric. Sci., Camb.* 38 : 229.
- Milligan, K.E., McConnell, G.R. 1976. Feed budgeting advisory services bulletin. Ministry of Agriculture and Fisheries, New Zealand.
- Modyanov, A.V. 1969. Energy metabolism of sheep under different physiological conditions. *In* *Energy Metabolism of Farm Animals*. Ed. K.L. Blaxter, G. Thorbek, and J. Kielanowski. Oriel Press, Newcastle-upon-Tyne, England.
- Monteath, M.A. 1971. The effect of sub-maintenance feeding of ewes during mid-pregnancy on lamb and wool production. *Proc. N.Z. Soc. Anim. Prod.* 31 : 105.
- Morley, F.H.W. 1968. Pasture growth curves and grazing management. *Aust. J exp. agric. Anim. Husb.* 8 : 40.
- Morris, L.R. 1961. Photoperiodicity of seasonal rhythm of wool growth in sheep. *Nature, Lond.* 190 : 102.
- Mullaney, P.D., Brown, G.H., Young, S.S.Y., Hyland, P.G. 1969. Genetic and phenotypic parameters for wool characteristics in the fine-wool Merino, Corriedale, and Polworth Sheep. I. Influence of various factors on production. *Aust. J agric. Res.* 20 : 1161.
- Nagarcenkar, R., Bhattacharya, P. 1964. Effect of environmental factors on wool growth. I. Effect of normal climatic factors. *Indian J Vet Sci.* 34 : 89.
- Nelder, J.A. 1975. General linear interactive modelling (GLIM). Rothamsted Experimental Stat. Harpenden, Herts.
- Nicol, A.M. 1978. Animal Production from root and forage crops. *In* 'Supplementary Feeding of Livestock in NZ' (Ed. K.R. Drew). *N.Z. Soc. Anim. Prod.* (in press).
- Panaretto, B.A., Ferguson, K.A. 1969. Pituitary adrenal interactions in shorn sheep exposed to cold, wet conditions. *Aust. J agric. Res.*, 20 : 99.

- Papadopoulos, J.C., Robinson, T.J. 1957. Fat lamb studies in Victoria. II. The interaction between pre- and post-natal planes of nutrition on the production of wool and lambs by crossbred sheep. *Aust. J. agric. Res.* 8 : 471.
- Patil, B.D., Jones, D.I.H., Hughes, R. 1969. Wool characteristics as an indication of nutritive attributes in herbage varieties. *Nature, Lond.* 223 : 1072.
- Peart, J.N. 1970. Factors Influencing Lactation of hill ewes. *Rep. Hill Farming Res. Org.* 5 : 55.
- Rattray, P.V. 1977. Effect of lambing date on production from breeding ewes and on pasture allowance and intake. *Proc. N.Z. Grassld. Assn.* 1977. 39 (1) : 98.
- Rattray, P.V., Garratt, W.N., East, N.E., Hinman, N. 1974. Efficiency of utilisation of metabolizable energy during pregnancy and the energy requirements for pregnancy in sheep. *J. Anim. Sci.*, 38 : 383.
- Rattray, P.V., Joyce, J.P. 1969. The utilization of perennial ryegrass and white clover by young sheep. *Proc. N.Z. Soc. Anim. Prod.* 29 : 102.
- Rattray, P.V., Jagusch, K.T. 1977. How much pasture should be offered to sheep. *Proc. Ruakura Fmrs. Conf*: 49.
- Ray, R.E., Sidwell, G.M. 1964. Effects of pregnancy, parturition, and lactation upon wool production of range ewes. *J. Anim. Sci.* 23 : 989.
- Raymond, W.F. 1969. The nutritive value of forage crops. *In* *Advances in agronomy* (Ed. M.G. Brody). Academic Press, N.Y. 21 : 1.
- Reid, R.L. 1962. Studies on the carbohydrate metabolism of sheep XV. The adrenal response to the climatic stresses of cold wind and rain. *Aust. J. agric. Res.*, 13 : 296.
- Reis, P.J. 1967. The growth and composition of wool. IV. The differential response of wool growth and sulphur content of wool to the level of sulphur containing amino acids given per abomasum. *Aust. J. biol. Sci.*, 20 : 809.
- Reis, P.J., And Schinckel, P.G. 1961. Nitrogen utilisation and wool production by sheep. *Aust. J. agric. Res.* 12 : 335.
- Reis, P.J., and Schinckel, P.G. 1963. Some effects of sulphur containing amino acids on the growth and composition of wool. *Aust. J. biol. Sci.* 16 : 218.
- Reis, P.J., and Schinckel, P.G. 1964. The growth and composition of wool. 2. The effect of casein, gelatin, and sulphur containing amino acids given per abomasum. *Aust. J. biol. Sci.*, 17: 532.
- Reis, P.J. and Williams, O.B. 1965. Variations in the sulphur content of wool from Merino sheep on two semi-arid grasslands. *Aust. J. agric. Sci.*, 16 : 1011.

- Rish, M.A. 1970. In Proc. Int. Sym. Trace. Element. Metab. Anim. 1969. pp. 452.
- Robinson, J.J. 1973. Some aspects of ewe nutrition. Vet Rec. 92 : 602.
- Robinson, G.G., and Simpson, I.H. 1975. The effect of stocking rate on animal production from continuous and rotational grazing systems. J. Br. Grassld. Soc. 30 : 327.
- Robinson, J.J., Fraser, C., Bennett, C. 1971. An assessment of the energy requirements of the pregnant ewe using plasma free fatty acid concentrations. J. agric. Sci., Camb. 77 : 141.
- Roe, R., Southcott, W.H., and Turner, H.N. 1959. Grazing management of native pasture in the New England region of New South Wales. 1. Pasture and sheep production with special reference to grazing and internal parasites. Aust. J. agric. Res. 10 : 530.
- Ross, D.A. 1960. Staple strength. I. The measurement of staple strength. N.Z. J. agric. Res. 3 : 503.
- Ross, D.A. 1961. Staple strength. II. Some factors affecting the measurement of staple strength. N.Z. J. agric. Res. 4 : 57.
- Ross, D.A. 1965. Wool growth of the New Zealand Romney. N.Z. J. agric. Res. 8 : 385.
- Rougeot, J. 1961. Comparative effects of annual and semi-annual periodic variations of day length on the follicle cycles of the short kemp fibres of the fleece of Limousine ewes. Relationship with reproductive cycles. Ann. Biol. Anim. Bioch. Biophys. 1 : 385.
- Rougeot, J. 1965. The effect of thyroid hormones on the morphology of the wool cuticle. "Biology of the Skin and Hair Growth" Eds. A.G. Lyne and B.F. Short. p.626. Angus and Robertson, Sydney.
- Russel, A.J.F., Doney, J.M., Reid, R.L. 1967. Energy requirements of the pregnant ewe. J. agric. Sci., Camb., 68 : 359.
- Russel, A.J.F., Foot, Janet, Z. 1972. The effect of level of nutrition at 2 stages of pregnancy on the performance of Primiporous ewes. Proc. Nut. Soc. 32 : 27A
- Russel, A.J.F., Maxwell, T.J., Foot, Janet, Z. 1973. Nutrition of the hill ewe during late pregnancy. Rep. Hill Farming Res. Org. 6, 43.
- Ryder, M.L. 1962. Preliminary observations on seasonal changes in the fleeces of unshorn Merino sheep. Proc. Aust. Soc. Anim. Prod. 4 : 46.
- Ryder, M.L. 1969. The development and structure of and seasonal change in, the coat of some Wiltshire sheep. Anim. Prod. 11 : 467.
- Ryder, M.L. 1971. Wool growth cycles in Soay sheep. J. agric. Sci., Camb. 76 : 183.

- Ryder, M.L., and Lincoln, G.A. 1976. A note on the effect of changes in day length on the seasonal wool growth cycle in Soay sheep. *Anim. Prod.* 23 : 257.
- Ryder, M.L. and Stephenson, S.K. 1968. *Wool growth*, Academic Press, London, 805pp.
- Schinckel, P.G. 1960. Variation in feed intake as a cause of variation in wool production of grazing sheep. *Aust. J. agric. Res.* 11 : 585.
- Schinckel, P.G. 1963. Nutrition and sheep production : a review. *Proc. World. Soc. Anim. Prod. Conf.*, Rome 1 :199.
- Schinckel, P.G., and Short, B.F. 1961. The influence of nutritional level during pre-natal and early post-natal life on adult fleece and body characters. *Aust. J. agric. Res.* 12 : 176.
- Scofield, J.E. 1970. Some aspects of grazing ecosystems. *M. Agr. Sc. Thesis*, Massey University, Palmerston North.
- Scott, R.S., and Barry, T.N. 1972. Winter Forage Crops. 1972. Tussock Grassland and M.L. Inst. Review : 13.
- Seabeck, R.M., Tribe, D.E. 1963. The relationship between the lamb production and the wool production of the ewe. *Aust. J. exp. agric. Anim. Husb.* 3 : 149.
- Short, B.F., Fraser, A.S., Canter, H.B. 1958. Effect of level of feeding on the variability of fibre diameter in four breeds of sheep. *Aust. J. agric. Res.* 9 : 229.
- Slee, J. 1959. Fleece shedding, staple length and fleece weight in experimental Wiltshire Horn-Scottish Blackface crosses. *J. agric. Sci., Camb.* 53 : 209.
- Slee, J., Ryder, M.L. 1967. The effect of acute cold exposure on wool growth in Scottish Blackface and Merino x Cheviot sheep. *J. agric. Sci., Camb.* 69 : 449.
- Slen, S.B., Whiting, F. 1955. Wool growth in mature range ewes as affected by stage and type of pregnancy and type of rearing. *Can. J. Anim. Sci.*, 36 : 8.
- Slen, S.B. 1969. Nutrition in relation to wool production and body growth in sheep. *In* "International Encyclopedia of Food and Nutrition". *Nutrition of Animals of Agricultural Importance.* (Cuthbertson, Ed.) 17 : 593.
- Smith, M.V. 1970. The effects of stocking rate and grazing management on the liveweight and wool production of wethers grazing dryland lucerne pastures. *Proc. Aust. Soc. Anim. Prod.* 8 : 460.
- Southland Wool Quality Improvement Committee 1970. Results of ewe winter feeding trial presented 20 Aug. 1970.
- Stevens, P.G., Wright, G.M. 1952. Some variations in the fleece of Romney Marsh Stud Ewes. *Proc. N.Z. Soc. Anim. Prod.* 11:18.

- Stevenson, J.R., Wickham, G.A. 1975. Seasonal and other affects on copper and zine concentrations in the wool of New Zealand Romney sheep. N.Z. Jl agric. Res. 19 : 217.
- Story, L.F. 1959. Effect of shearing time on wool. V. Effect on processing. N.Z. Jl agric. Res. 2 : 1104.
- Story, L.F., Ross, D.A. 1959. Effect of shearing time on wool. IV. Effect on the fleeces. N.Z. Jl agric. Res. 2 : 1096.
- Story, L.F., Ross, D.A. 1960. Effect of shearing time on wool. VI. The rate of growth of wool and its relation to time of shearing N.Z. Jl agric. Res. 3 : 113.
- Suckling, F.E.T. 1959. Pasture management trials on unploughable hill country at Te Awa. N.Z. Jl agric. Res. 2 : 488.
- Sumner, R.M.W. 1969. A comparative study of the effect of two stocking levels on wool follicle development and wool production of the New Zealand Romney sheep. M. Agr. Sci. Thesis, Massey University, New Zealand.
- Sumner, R.M.W., Wickham, G.A. 1969. Some effects of increasing stocking levels on wool growth. Proc. N.Z. Soc. Anim. Prod. 29 : 208.
- Sykes, A.R., Field, A.C. 1972. Effects of dietary deficiencies of energy, protein, and calcium on the pregnant ewe. III. Some observations of the use of biochemical parameters in controlling energy nutrition. J agric. Sci., Camb. 78 : 127.
- Symington, R.B. 1959. Light regulation of coat shedding in a tropical breed of hair sheep. Nature, Lond. 184 : 1076.
- Taylor, J.C. 1966. Relationship between the herbage consumption or carcass energy increment of grazing beef cattle and the quantity of herbage on offer. Proc. 10th Int. Grassld. Congr. p. 463.
- Thompson, D.S. 1950. The effect of nutrition on the in-lamb ewe. J. Dept. Agric. S. Aust. 53 : 352.
- Thomson, W., Aitken, F.C. 1959. Diet in relation to reproduction and viability of the young. II. Sheep. Tech. Comm. Bureau Anim. Nutr. (Aberdeen) No. 20 : 1.
- Thompson, K.F., Harbord, M. 1966. Swede grazing. In Technical Handbook, Farm Advisory Division, New Zealand Ministry of Agriculture and Fisheries.
- Thomson, A.M., Thomson, W. 1949. Lambing in relation to diet of the pregnant ewe. Brit. J. Nutr. 2 : 290.
- Thwaites, C.J. 1968. Heat stress and wool growth in sheep. Proc. Aust. Soc. Anim. Prod. 7 : 259.
- Treacher, T.T. 1971. Effect of nutrition in pregnancy and lactation on milk yield in ewes. Anim. Prod. 13 : 493.
- Turner, H.N., Young, S.S.Y. 1969. "Quantitative Genetics in Sheep Breeding" McMillan, Australia, 331pp.

- Underwood, E.J. 1966. "Mineral Nutrition of Livestock" F.A.O. and Commonwealth Agr. Bur., Farnham Royal, Bucks, England.
- Underwood, E.J. 1977. "Trace Elements in Human and Animal Nutrition" 4ed., Academic Press, New York.
- Underwood, E.J., Shier, F.L. 1942. The influence of feeding during late pregnancy on the birth weight, growth rate, and quality of the lamb. J. Dept. Agric. W. Aust. 19 : 37.
- Underwood, E.J., Shier, F.L., Cariss, H.G. 1943. The influence of high level of pre-natal feeding in lamb production. J. Dept. Agric. W. Aust. 20 : 288.
- Ulyatt, M.J. 1969. Progress in defining the differences in Nutritive value to sheep of Perennial Ryegrass, Short-rotation Ryegrass, and White Clover. Proc. N.Z. Soc. Anim. Prod. 29 : 114.
- Ulyatt, M.J., Blaxter, K.L., McDonald, I. 1967. The relationship between the apparent digestibility of roughages in the rumen and lower gut of sheep, the volume of fluid in the rumen and voluntary feed intake.
- Ulyatt, M.J., Lancashire, J.A., Jones, W.T. 1977. The nutritive value of legumes. Proc. N.Z. Grassld. Assn. 38 : 107.
- Van Dyne, G.M. 1968. "A practical guide to the study of the productivity of large herbivores: I.B.P. Handbook No. 7 Blackwell, London.
- Wade, M.H. 1976. The growth and losses of herbage in grazed swards. In Pasture Utilisation by the Grazing Animal, Occ. Symp No. 8. Br. Grassld Soc. 1976.
- Walker, B. 1968. Grazing experiments at Ukiriguru, Tanzania.
2. Comparisons of rotational and continuous grazing systems on natural pastures. E. Afr. agric. For. J. 34 : 235.
- Wallace, L.R. 1948. The growth of lambs before and after birth in relation to the level of nutrition. J. agric. Sci., Camb. 38 : 93-243, 367.
- Wheeler, J.L., Reardon, T.F., Hedges, D.A., and Rocks, R.L. 1971. The contribution of the conceptus to weight change in pregnant Merino ewes on pasture. J. agric. Sci., Camb. 76 : 347.
- White, D.H. 1975. The search for an optimal stocking rate : Continuing the saga. J. Aust. Inst. agric. Sci. 1975 : 192.
- Wickham, G.A. 1968. Break and tenderness in wool. Sheep fmg A. 1968 : 73.
- Williams, A.J. 1964. Aust. J. exp. Agric. Anim. Husb. 4 : 124.
The effect of daily photoperiod on the wool growth of Merino rams subjected to unrestricted and restricted feeding regimes.
- Willoughby, W.M. 1959. Limitation to animal production imposed by seasonal fluctuations in pasture and by management procedures. Aust. J. agric. Res., 10 : 248.
- Wilson, J.B. 1976. TeddyBear Statistical Program. Technical Report T5, Edition 2; Botany Dept., University of Otago, Dunedin, N.Z.

Wodzicka-Tomaszewska, M. 1960. Seasonal variation in wool growth and heat tolerance of sheep I. Wool growth. Aust. J. agric. Res. 11 : 75.

Wodzicka-Tomaszewska, M. 1960. Seasonal variation in wool growth and heat tolerance of sheep. II. Heat tolerance. Aust J. agric. Res. 11 : 85.

Wodzicka-Tomaszewska, M., Bigham, M.L. 1968. The tattooed patch technique for measurement of wool growth. N.Z. J. agric. Res. 11 : 943.

Young, N.E., Newton, J.E. 1973. A comparison of set stocking v rotational grazing with sheep at three stocking rates. J. Br. Grassld. Soc. 28 : 183.