A COMPARATIVE STUDY

OF THE EFFECT OF TWO STOCKING LEVELS ON

WOOL FOLLICLE DEVELOPMENT AND WOOL PRODUCTION

OF THE NEW ZEALAND ROMNEY SHEEP

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TABLE OF CONTENTS.

LIST OF FIGURES.

LIST OF TABLES.

INTRODUCTION

A current trend in the New Zealand sheep industry is for farmers to carry increasing numbers of stock. Though there is some evidence that increased intensity of stocking tends to depress fleece weight, there is no reliable information on the possible effects of increased stocking on quality aspects of Crossbred wool.

Two of the more important faults limiting the value of New Zealand Crossbred wools are unsoundness and cotting. It is believed that unsoundness and cotting are due to a similar set of predisposing factors. The factors generally considered to be important are :-

(i) The winter minimum in the inherent seasonal rhythm of wool growth.

(ii) The stress of pregnancy and lactation in the ewe.

(iii) Poorer nutrition during the winter when plant growth is at a minimum.

It is thought that the effects on the animal of the winter trough in pasture growth may be accentuated by higher stocking. However, despite the general belief in farming circles, it has never been clearly demonstrated that increased intensity of stocking will lead to a greater incidence of unsoundness and cotting. There are no quantitative data available on changes in other fleece characteristics under increased stocking in a New Zealand environment.

It has been shown that severe nutritional retardation at the time of foetal follicle initiation will permanently affect the adult fleece (Schinckel and Short 1961). Transient effects may result from a less severe nutritional check (Wildman 1958a). The severity of the check, in respect of follicle development, that can be expected from increased stocking is largely unknown.

Experimentation in the field of wool growth is limited with the result that knowledge is inadequate, particularly in respect of the non-Merino breeds. It was with the aim of learning more of the way in which the Romney sheep and its fleece would react under increased stocking levels that this study was instituted.

CHAPTER 1

REVIEW OF LITERATURE

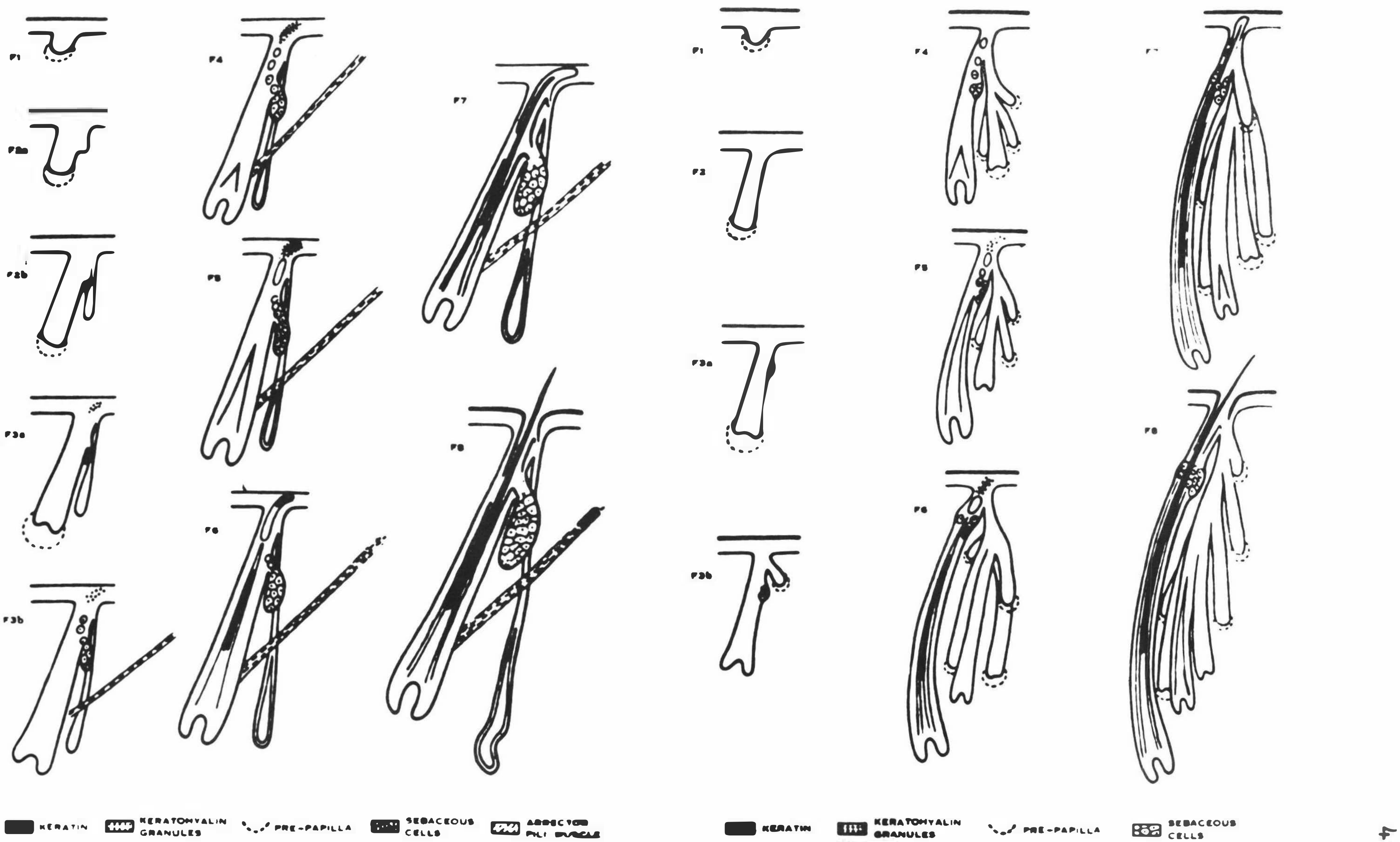
A: WOOL FOLLICLE DEVELOPMENT

1: The Developmental Pattern of the Wool Follicle

During the 1950's there was widespread interest in the development of the wool follicle (Burns 1953, 1954a, 1954b; Fraser 1952a, 1952b, 1953, 1954; Fraser and Short 1952; Margolena 1954; Schinckel 1953, 1955a, 1955b; Short 1955a, 1955b: Ferguson, Schinckel, Carter and Clarke 1956) and a considerable amount of work was carried out to substantiate earlier observations (Duerden and Ritchie 1924; Tänzer 1926; Wildman 1932; Carter 1943; Carter and Hardy 1947).

Prior to 1947 there had been considerable misunderstanding in descriptions of the sequence of development of wool follicles. Hardy and Lyne (1956b) reviewed all the available descriptions and using results from their own work evolved a system of follicle classification according to stage of development, Fig. 1.1. The classification of Hardy and Lyne (1956b) has since been accepted as generally standard nomenclature for both hair and wool follicles. Their terminology (Hardy and Lyne 1956a) is used in the ensuing text. The data of Hardy and Lyne suggest that the development of both primary and secondary wool follicles follow similar timing.

The phenomenon of branching, first reported in sheep by Tänzer (1926), is a further development stage whereby additional follicles may be "budded off" from the ental side of the neck of an existing follicle.



(a) (b)

Fig. 1.1.— Diagram of stages of development of (a) primary wool follicles and (b) original secondary wool follicles in the Merino foetus. Some early stages of derived secondary follicles are also shown (after Hardy and Lyne 1955, 1956b).

The result is that the subsequent fibres produced share a common follicular aperture at the skin surface (Hardy and Lyne 1956b). Due to the difficulty of identifying derived follicles in transverse section the relative timing of branching of both primaries and secondaries is uncertain (Lyne 1957: Wildman 1957a). Fraser and Short (1960) suggest that the occurrence of branching may be an explanation of the second wave of developmental growth observed to pass over secondaries by Fraser (1953) and Fraser, Ross and Wright (1954). They further suggest that due to the similarity of the ratio of secondary fibre containing follicles to primary fibre containing follicles ($\frac{Sf}{Pf}$) at birth for different breeds compared with the high level of variation of $\frac{Sf}{Pf}$ ratio in the adult animal of different breeds, the differences between breeds in the density of the follicle and fibre populations may be predominantly due to the variation in the degree of branching.

The structure of the fully developed follicle, Fig. 1.2(b), has been described in considerable detail by Auber (1950) with particular reference to the formation of the fibre.

2: The Developmental Pattern of the Follicle Group

As early as 1866 von Nathusius noted wool follicles to be in a group pattern. Until about 1939 all work was mainly of a descriptive nature. After 1939, primarily as a result of the work of Carter and his colleagues in Australia, quantitative aspects of the groups received more attention.

The follicle population consists basically of two follicle types: primaries (P) and secondaries (S). This heterogeneity within the follicle population occurs in all breed types and appears to be independent of the type of fleece grown, (Wildman 1932; Galpin 1935; Carter 1939a, 1939b,

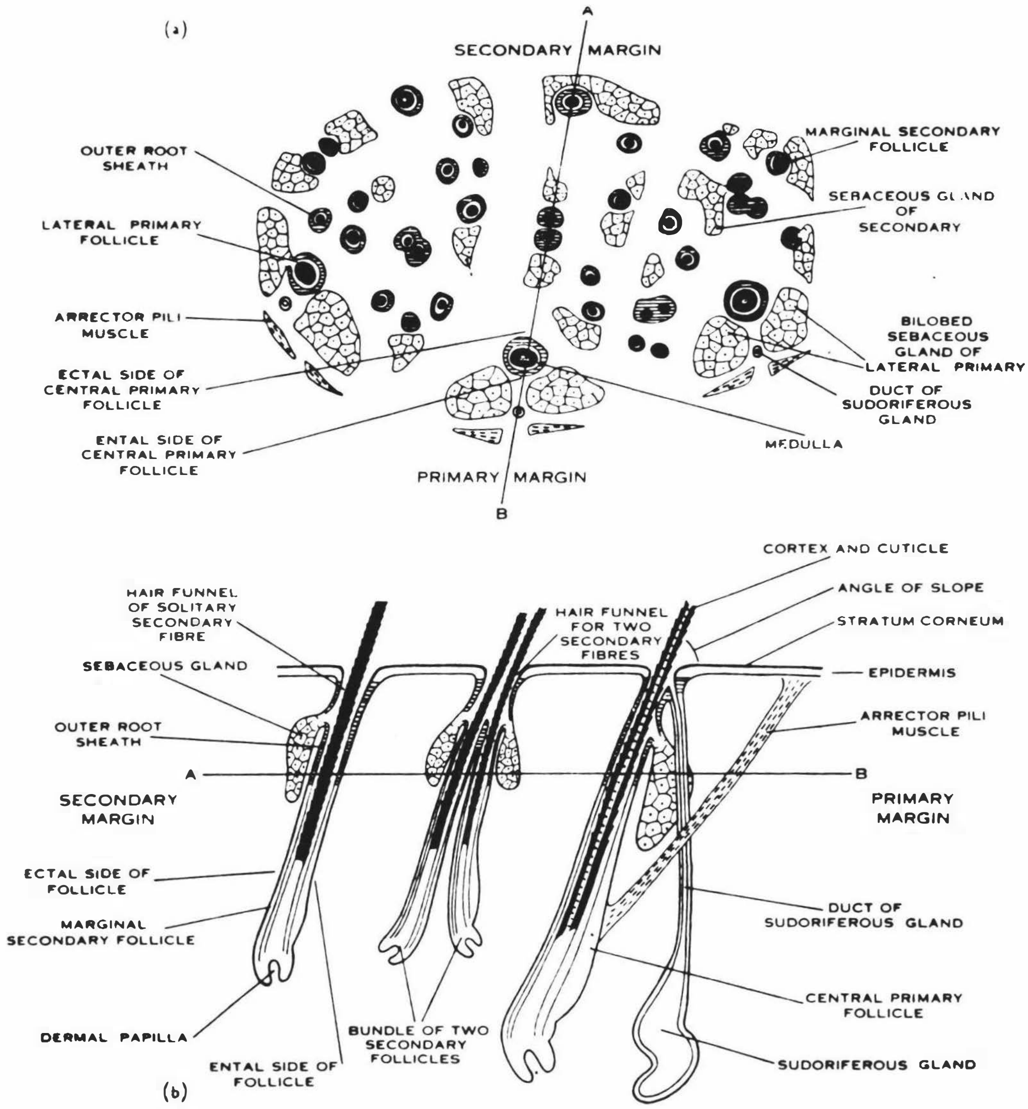


Fig. 1.2 — Diagram of a follicle group (a) in transverse section and (b) in longitudinal section (after Hardy and Lyne 1956b).

1940, 1943, 1955; Carter and Hardy 1947; Margolena 1954; Peart and Ryder 1954; Ross 1954; Hardy and Lyne 1956b; Carter and Clarke 1957a, 1957b; Ryder 1958).

Hardy and Lyne (1956b) reviewed work on the relation of foetal age to stage of development of the follicle group. The quoted ages for developmental changes are mean estimates obtained from data with considerable 'between animal' and 'between observer' variations. It is possible there may also be a 'between breed' variation. The developmental pattern is easiest considered in three overlapping groupings (Carter 1942).

(i) Pre-Trio phase

At approximately 45 days foetal age epidermal plug tissue is apparent on the muzzle. From there a growth wave traverses the body and joins with a similar wave starting on the legs. Thus by 60 days the body is covered by areas of plug tissue which subsequently differentiates to primary central X (PCX) follicles. Between 55 to 60 and 70 days foetal age a subsequent and similar wave traverses the body with the differentiation of primary central Y (PCY) plug tissue.

(ii) Trio Phase

After a lag of a few days pairs of primary lateral (PL) follicles are initiated close to each PC follicle. Again there are two growth waves initiating primary lateral X (PLX) and primary lateral Y (PLY) plug tissue, both of which have passed over the foetus by 80 days of foetal age.

(iii) Post Trio Phase

Approximately 10 days after the initiation of the last PL follicles, secondary follicles begin to form on one side of the trio of primaries. The first to form are situated at the margin of the group. Up to 100 days foetal age only original secondaries have been observed. Branching is known to occur (Lyne and Hardy 1956b; Lyne 1957; Wildman 1957) after this time. Little is known as to the actual proportion of later formed secondaries which develop in this manner, but it seems that in the Merino the proportion is fairly high (Hardy and Lyne 1956b).

Data obtained from the Karakul (Margolena 1954) and the Merino (Schinckel 1955b; Short 1955a) suggest that the potential $\frac{Sf}{Pf}$ ratio is determined before birth. For the British breeds, however, a comparison of the low $\frac{Sf + Si}{Pf + Pi}$ ratio at birth (Fraser and Hamada 1952; Burns 1954a; Wildman 1965) with the adult $\frac{Sf}{Pf}$ ratio suggest this may not be the case.

Knowledge of post-natal follicle changes is limited. In the Merino it is apparent that though secondary maturation may be latent for the first week or so after birth, it rises rapidly, reaching a peak 2-4 weeks after birth before declining as the already established ceiling value is approached, (Schinckel 1953, 1955b; Short 1955a; Schinckel and Short 1961). The ceiling may, however, not be reached for a period of up to 12 months. The situation as regards the British breeds, due to the small numbers of animals used and the small difference between birth and adult $\frac{S}{P}$ ratio in comparison with the Merino, is unclear (Carter and Hardy 1947; Burns 1955).

A mature Merino follicle group is illustrated in Fig. 1.2(a).

3: The Influence of Nutrition on Follicle Development

From the presented experimental evidence based on the Merino it is clear that most, if not all, secondary follicles are initiated pre-natally. Many of these follicles mature between 2 and 4 weeks after birth. It is thus suggested that there are two phases of the growth pattern which may be modified by nutritional influences with visible developmental effects.

(i) Pre-natal Phase

The foetus is completely dependent on the ewe for nutritional demands.

(a) Pre-90 day stage:- initiation of PC and PL follicles.

(b) Post-90 day stage:- initiation of secondary follicles with maturation of all primaries and some secondaries.

(ii) Early Post-natal Phase

The lamb is a separate identity but dependent on maternal milk supply for nutrition. The remainder of initiated secondary follicles mature.

The evidence reviewed by Thomson and Aitken (1959) established that the plane of the ewe's nutrition during pregnancy affected the subsequent birth weight of the lamb. Wallace (1948) suggested that the nutritional demands of a foetus for the first two-thirds of its gestation period are slight. Thus, because of the physiological buffer afforded by the uterine environment, nutritional stress experienced by the ewe at this time is unlikely to be transmitted to the foetus. This would lead to the oonclusion that primary initiation, pre-90 day foetal age, may be immune to nutritional effects. In contradiction Schinckel and Short (1961) found that lambs of well fed ewes had a higher total number of primary follicles than lambs from poorly fed ewes.

Claxton (1963) in extending the work of Stephenson (1959) suggests that the density of PC anlagen at initiation is relatively constant within and between breeds for a particular body position. There is,however, variability in PC follicle density over the body. It is, therefore, apparent that the foetal skin area is the governing factor in the total number of PC follicles initiated. It is also suggested that initiation of all other follicle types is directly controlled by the PC follicle. Everitt (1967), however, was not able to substantiate earlier findings (Schinckel and Short 1961) when subjecting South Australian Merino ewes to four different feeding regimes during pregnancy. The regimes consisted of high and low plane feeding throughout for two groups, while the other two groups were subjected to either high or low plane feeding early in pregnancy and interchanged at about 90 days post-mating. The higher Pf follicle density of the lambs born to the low/low group was sufficient to compensate for the greater skin area of the larger lambs born to the well fed ewes. The primary follicle population was thus not actually reduced. The results also showed that the Pf follicle density in the high/low group was increased, suggesting maternal nutrition is able to delay primary maturation. Though analysis is difficult it has been suggested (Taplin and Everitt 1964; Everitt 1967) that restricted foetal growth prior to 90 days of pregnancy may be partially compensated by adequate nutrition from 90 days of pregnancy to lambing.

A considerable amount of evidence has been advanced on the effects of nutrition on secondary development, using $\frac{Sf + Si}{Pf}$ and $\frac{Sf}{Pf}$ as criteria. Australian workers using Merino sheep and severe nutritional regimes have shown permanent effects on secondary follicle development, while other workers, mostly English, have shown the effects, if present, to be transient.

Of the Australian workers Schinckel (1953) obtained a high positive correlation (r = 0.56) between birth weight and $\frac{Sf}{Pf}$ ratio at birth. He also showed that twin lambs and lambs from young ewes had a lower $\frac{Sf}{Pf}$ ratio at all stages of development. Support was given for this evidence by the calculation (Schinckel 1955b) of correlations between such factors as potential $\frac{S}{P}$ ratio, birth weight, live weight increases over different periods and $\frac{Sf}{Pf}$ ratio at 15 months. Schinckel thus reasoned that the rate of secondary maturation is closely associated with foetal growth rate.

Short (1955b) imposed severe underfeeding during pregnancy with the result that the $\frac{Sf}{Pf}$ ratio at birth was reduced but the $\frac{Si + Sf}{Pf}$ ratio was unaffected. It was thought that the restricted nutritional regime during gestation had a delayed impact on post-natal lamb growth via reduced milk production of ewes. The result was both a lower fibre density and a lowered final $\frac{Sf}{Pf}$ ratio in the offspring of the underfed ewes. The lowered fibre density was associated with longer and coarser 200 day fleeces, but weight per unit area was similar to that of the control animals.

Short suggested that this change in the fleece was due to there being less follicles to compete for a limited supply of nutrient in the skin (cf. Fraser 1951). Later work (Schinckel and Short 1961; Doney and Smith 1964; Weiner and Slee 1965; Everitt 1967) has indicated that poor pre-natal nutrition can lead to a less dense, coarser fleece, while poor post-natal nutrition can result in a finer fleece.

Hugo (1958) working with the South African Merino was unable to show that follicle development was affected by under-feeding. The animals underfed since weaning did, however, produce less wool, which he reasoned to "be ascribed solely to the production of thinner and shorter fibres".

It has been shown in Soviet Merinos (Bazanova 1959) that the feeding of concentrates to pregnant ewes increased the percentage of "rudiments" (immature follicles) and "root hairs" (mature follicles) at birth.

Other workers have not been able fully to substantiate the evidence obtained with the Australian Merino. Henderson (1953) produced a retardation of fleece development and fibre growth as a result of low plane post-natal nutrition but was undecided as to its permanency; he did, however, suggest that "permanent effects of early environment on future productivity take the form of a lesser area on which wool is produced".

Ryder (1955) working with Cheviot ewes failed to obtain a significant difference in the $\frac{Sf}{Pf}$ ratio at birth and weaning in two groups of sheep subjected to different planes of nutrition, Even though the severity of underfeeding was inadequate to illicit a response, Ryder concluded that "for secondary follicle formation the level of nutrition during pregnancy was more important than the level during lactation".

Wildman (1958a) working with English Romney sheep imposed feeding regimes during pregnancy and lactation of a severity sufficient to cause lamb body weight differences at birth and weaning, but was able to show only a slowing in the rate of initiation and maturation of secondary follicles with no permanent effects on the number of mature secondaries in the progeny. Wildman (1965) subsequently observed post-natal changes on the same animals and noted that though a twin pregnancy may impose a nutritional restriction on the foetus, and hence restrict secondary follicle development, this is able to be overcome by adequate post-natal nourishment. He suggested that the level of follicle and fibre ratios may be subject to a genetic maximum.

Doney and Smith (1964), using Scottish Blackface sheep, were unable to show that pre-natal nutritional limitations, as imposed by a twin pregnancy, had any effect on $\frac{Sf}{Pf}$ ratio at 6 weeks of age despite a lowering of the number of secondary fibres present at birth. As a result of severe post-natal feeding restriction, marked non-permanent $\frac{Sf}{Pf}$ differences were able to be induced which lasted for several months.

Using the New Zealand Corriedale, Coop and Clarke (1955) were unable to show, following a year of post-natal feeding restriction, any permanent effect on the animal production after hogget shearing.

Weiner and Slee (1965) following ova transplants between Lincoln and Welsh Mountain sheep, the weight of the former being about twice that of the latter, found that, particularly at birth, transferred Lincoln lambs had a reduced $\frac{Sf + Si}{Pf + Pi}$ ratio. The observed reduction in total follicle density was apparent despite the fact that these lambs were smaller in size than non-transferred Lincolns at birth. A reverse effect would have been expected if the effects resulted from reduced surface area alone. It is thus apparent that the Welsh maternal environment suppressed secondary follicle development in the transferred Lincoln lambs. By contrast the Lincoln maternal environment appeared to have no specific effect on follicle development in the transferred Welsh lambs. Their total follicle density was, however, lower, as would have been expected from their slightly larger body size at birth. Wool production amongst the transferred lambs was not affected, possibly because reduced follicle density was associated with increased fibre length. In a comparison between singles and twins of non-transferred lambs, the twins appeared to suffer a post-natal rather than a pre-natal restriction of secondary follicle development. This may be compared with the predominantly pre-natal effect following egg transfer. An unexplained result was the increased medullation for animals reared in the Welsh maternal environment.

Four possible reasons may be advanced to explain the variation in results obtained with the Merino and with the other sheep.

(i) The Merino has been subjected to a more severe plane of nutrition than the other breeds.

(ii) The Merino is probably different "physiologically".

(iii) The sheep, other than the Merino, have an inherently low $\frac{Sf}{Pf}$ ratio and therefore a larger difference is necessary to be statistically significant.

(iv) The experiments with sheep other than Merino have involved less animals and therefore a larger difference is necessary to be statistically significant.

B: SEASONAL WOOL GROWTH

1: Historical - Pre 1949

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 wool growth occurred in the six months after spring shearing. Thus the irregularity of wool growth was thought to be a shearing effect.

Seasonal wool growth trends, as measured by length, were subsequently reported by other workers (Burns 1931a, 1931b; Hardy and Tennyson 1930; Duerden and Maré 1931). Those workers who observed the larger variations in seasonal wool growth trends were able to correlate wool growth rate with feed availability (Wilson 1931; Bell, Spencer and Hardy 1936). As well as a variation in length growth rates, seasonal variations in fibre diameter were also observed (Hardy and Tennyson 1930; Norris and Claasens 1941). However, in Mediterranean environments, monthly wool growth rates proved relatively constant, (Hackedorn and Sotola 1929; Fraser 1931).

Ewes were observed to suffer a retardation of wool growth during lactation (Nordmeyer 1927; Bell et al 1936).

The possibility of a temperature or humidity effect on wool growth was studied by keeping Rambouillet ewes in a heated environment during a Canadian winter (Bowstead and Larose 1938). The food intake of the animals which was not stated may have been the reason why temperature treatment did not modify wool growth. Galpin (1947), who also failed to give an indication of feeding levels, reported large seasonal differences in the weight of wool clipped from a mid-side patch of a group of Romney sheep.

2: Seasonal Wool Growth Studies Under Grazing Conditions

There have been several recent Australian reports attributing such of the variability in seasonal wool growth to seasonal variation in pasture availability (Marston 1948; Schinckel 1956; Hutchinson and Porter 1958; Roe, Southcott and Turner 1959; Stewart, Moir and Schinckel 1961; Sharkey, Davis and Kenney 1962; Williams and Schinckel 1962; Arnold, McManus and Bush 1964; McFarlane 1965). A.J. Williams (1964) showed that under ad lib feeding conditions a group of Merino rams exhibited a rhythm of wool growth, the variation in which could be largely accounted for by variation in intake. Under restricted feeding there was no defined growth rhythm. This and other work (Slee and Carter 1961; Bennett, Hutchinson and Wodzicka-Tomaszewska 1962b; Hutchinson 1965; Doney 1966) suggest that the wool growth rhythm exhibited by the Merino is almost entirely due to variation in nutrition. Other breeds have been shown to exhibit a marked seasonal wool growth rhythm which is modified rather than controlled by nutrition (Coop 1953; Ryder 1956; Wildman 1957b; Story and Ross 1960; Doney and Smith 1961; Morris 1961; Ross 1965; Doney 1966; Doney and Eadie 1967).

The criteria of wool growth most commonly used is that of weight or weight per unit area. Both length and diameter changes have been shown to contribute to the observed wool growth changes (Coop 1953; Doney and Smith 1961; Ross 1965).

Henderson (1953) theorized that undernutrition of a young animal may result in a permanent effect on productivity through a reduction of the body surface area. He thought that the efficiency of wool growth, however, was unlikely to be affected.

A reduction in winter wool growth rate with a delayed rise in spring production has been shown for pregnant and subsequently lactating ewes by several workers (Coop 1953; Slen and Whiting 1956; Doney 1958; Story and Ross 1960; Stewart, Moir and Schinckel 1961; Ross 1965). It has been observed that the carrying and feeding of twin lambs depressed wool growth more than in the case of ewes with one offspring, (Stevens and Wright 1952; Slen and Whiting 1956; Ross 1965). This would be an expected consequence in view of the large drain on body reserves occurring during pregnancy and particularly during lactation (Wallace 1948). Story and Ross (1960) observed that the maximum and minimum growth in fibre length per day occurred about a month before the corresponding maximum and minimum fibre diameters. This is an indication that either fibre length and fibre diameter may be under independent control mechanisms or that there is a delay in the response of fibre diameter.

Wodzicka (1960) found, in a poorly designed experiment, that the amount of wool grown by sheep shorn monthly was not significantly more than for animals shorn once a year. Ryder (1962) was also unable to show any effect between once a year shorn animals and unshorn animals in the amount of wool grown. On the other hand McGuirk, Paynter and Dun (1966) did show there to be a significant effect from twice a year shearing of Bungaree Merinos.

Short and Chapman (unpublished data, cited by Hutchinson and Wodzicka-Tomaszewska 1961) found that sheep in a low nutritional state showed greatly reduced wool growth when exposed to temperatures around 13°C following shearing. Thus shearing initiated a stress response, possibly associated with adrenocortical activity (Lindner and Ferguson 1956; Panaretto 1967). It has been well demonstrated (Ferguson, Carter and Hardy 1949; Schinckel 1960; Wodzicka-Tomaszewska 1963; Wheeler, Reardon and Lambourne 1963) that there is an increased voluntary feed intake following shearing. It is suggested that this is initiated via a thermoregulatory response. However, the results of Webster and Lynch (1966) do not fully agree with this theory.

There are conflicting reports as to the effect of clipping upon the subsequent growth rate of wool from the clipped area. Coop (1953) and Doney and Smith (1961) have found the growth rate to be essentially unaffected while Sharkey, Davis and Kenney (1962) found the average diameter of the regularly clipped samples to be greater than that of the adjacent full year staples. Also estimates of fleece weight based on the combined weight of periodic clipping were greater than actual fleece weight under medium and low plane of nutrition. Downes and Lyne (1961) have been able to show by autoradiographic means that clipping per se does not affect growth rate when temperature effects were minimized.

3: Seasonal Wool Growth Studies under Conditions of Controlled Feeding

When either the amount and type of feed have been kept constant (Ferguson, Carter and Hardy 1949; Hart 1961; Hutchinson 1962), or the animals have been fed to constant body weight (Coop 1953; Wodzicka 1960), it has been observed that a rhythmical pattern of wool growth still exists.

With the realisation that seasonal climatic factors may affect wool growth Hutchinson (1962) derived figures suggesting that with the use of climatic corrections the nutritional component of the Merino wool growth rhythm could be considerably increased. A.J. Williams (1964) was critical of this approach of deriving correction factors from constant ration pen fed animals and applying them to grazing animals without making allowance for bodily condition or fleece length, the wool growth response to increased intake being dependent on these attributes (Daly and Carter 1955; Ahmed, Dun and Winston 1963).

By means of a regression analysis both Ferguson et al (1949) and Coop and Hart (1953) showed wool growth to be closely correlated with environmental temperature. When explaining their results only the latter workers noted the existence of the correlation between temperature and day length. Ferguson et al, in explaining their results, suggested increased wool growth to be a result of increased blood flow to the skin; vasodilation being part of the normal heat regulating mechanism in the sheep. In extending this theory, Ferguson (1949) destroyed the vasoconstriction response by unilateral thoracic sympathectomy. He observed, as a result, that increased wool growth occurred on the operated side of the animal for a period of 10 weeks. Cockrem (1959) reported a similar situation following a chemical induction of vasoconstriction in mice. Coop (1953) subsequently increased the winter ambient temperature of housed sheep by heating, while Morris (1961) and Bennett, Hutchinson and Wodzicka-Tomaszewska (1962a) reversed the normal ambient temperature cycle. None of the workers were able to elicit a wool growth response.

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).

Bennett et al (1962b) used two shaven patches on each animal, one of which was covered with an insulator pad while the other was left uncovered after shaving. As different wool growth rhythms were observed for the covered and uncovered patches it was suggested that ambient temperature may exert a local effect on wool growth. Further work by Doney and Griffiths (1967) supported this theory. They exposed sheep "side on" to an artifically produced wind with the result that the "chilled" side of the animal showed a depressed wool growth in terms of fibre length. Thus it is evident that while wool growth rhythm is not under the control of temperature a local effect of temperature on wool growth rate probably exists.

In the light of experiments indicating photoperiodic effects on the growth and shedding of hair (Hammond 1951; Yeates 1955), Hart (1953) subjected pregnant and subsequently lactating Corriedale ewes to various treatments with short constant day lengths. The wool growth rhythm was still present though reduced after two years (Coop and Hart 1953). The fact of the animals being fertile may have been of importance (Coop 1953). However, Wodzicka (1960), in her poorly designed experiment using rams, found that exposure to short constant day lengths for one year did not decrease the seasonal wool growth rhythm. The experiments of Wildman (1957b,1958b) may be interpreted in a similar way.

On the assumption that the eye was the light receptor organ Hart (1955) hooded some animals for a period of two years. Though the animals were exposed to a normal seasonal temperature cycle the wool growth rhythm slowly disappeared.

Under conditions of continuous light Hart (1961) found that the rhythm of wool growth was indistinguishable from that of control animals. Hart did suggest, however, that the light treated animals may have been able to distinguish between the types of illumination as the artificial light used at night was of a lower intensity. Radford (1961), however, found no evidence of this in respect to sexual development in Merinos. Symington (1959) and Slee (1965) observed diffused light to inhibit shedding in primitive breeds of sheep.

Following exposure to an accentuated reversal of the natural light pattern (Morris 1961; Bennett <u>et al</u> 1962b; Hart, Bennett, Hutchinson and Wodzicka-Tomaszewska 1963) the wool growth rhythm also became reversed. Morris found that it took two years for the rhythm to show a complete reversal to a winter maximum. For the other workers the change was almost immediate though in their case the maximum was bimodal with peaks in June/July and October/November. The discrepancy in the results has been suggested (Hart <u>et al</u> 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. When the daylength cycle was reduced from a yearly cycle to one of 7 months (Hutchinson 1965) the wool growth rhythm was accelerated but showed a constant lag of 2 - 3 months behind the light rhythm. Rougeot (1961) found the shedding cycle of Limousine sheep, under a six monthly light cycle, to closely follow the light pattern. Under a yearly light cycle he found the main period of shedding to occur during the winter, with a lesser cycle in the late spring and early summer. A.J. Williams (1964) subjected a group of Merino rams to a period of ad lib, followed by a period of restricted feeding, under an accentuated reversed light pattern. He was unable to observe any defined wool growth rhythm in any of his groups. Instead, the wool growth pattern followed feed intake trends. Thus it is evident that photoperiodicity modifies rather than controls the wool growth rhythm.

4: The Control of the Seasonal Rhythm of Wool Growth

Recent work on the nature and control of the hair growth cycle has shown it to possess an intrinsic rhythm (Ebling 1964) modified by systemic control of some form (Ebling and Johnson 1964). Current work on the wool growth rhythm has also suggested the existence of an inherent autonomous rhythm. Accordingly the control of the wool follicle may be similar to that of the hair follicle. The wool growth rhythm is able to be modified by the external stimuli of the animal's immediate environment. Nevertheless, the rhythm appears to be buffered against sudden changes of these stimuli. If the stimulus does not return quickly to its previous form the inertia of the old rhythm diminishes and a new rhythm is adopted.

It has been known for some time that removal of various endocrine glands alters the pattern of wool growth. The current knowledge in respect of hormonal control of wool growth has been reviewed by Ferguson, Wallace and Lindner (1965). Thyroidectomy causes a reduction of 40% in wool growth (Ferguson, et al 1965) while the administration of adequate thyroxine to either thyroidectomized or normal animals causes a stimulation of wool growth rate, at the expense of body weight (Ferguson 1958; Lambourne 1964). The administration of either adrenocorticotrophic hormone or glucocorticoids can cause a suppression of wool growth (Lindner and Ferguson 1956). Sex hormones appear to have a limited effect (Slen and Connell 1958). Wool growth in the intact animal, may be stimulated by crude growth hormone (Ferguson 1954). Replacement therapy of thyroxine to a hypopthysectomized animal, in which wool growth is completely suppressed (Ferguson 1951), will only partially restore growth irrespective of the dose level (Ferguson et al 1965).

Ferguson et al (1965) suggest the existence of an unidentified pituitary factor, free of thyrothrophic activity, able to stimulate wool growth in the hypophysectomized sheep. The evidence is based on wool growth responses which have been obtained with various fractions of pituitary extract following identification of the known hormones present in the fraction. Their results also showed there to be a rhythm in the wool growth of hypophysectomized animals given constant replacement therapy.

5: The Seasonal Rhythm of Associated Glands

The skin of sheep contains both sebaceous glands secreting wool wax or grease and sudoriferous glands secreting water soluble suint. The former are normally associated with both primary and secondary follicles while the latter are associated only with primary follicles.

Ferguson, Carter and Hardy (1949), though estimating the amount of wax and suint present in the monthly wool samples they studied, did not present any production figures. Following extensive wool measurements from the Lincoln, Corriedale, Polworth and Fine Merino, Daly and Carter (1955) observed broad relationships as are presented in Table 1.1.

	Feed Intake	Atmospheric Temperature	Fleece Weight (Extent of Insulation)
Wax Output	+ve	-ve	-
Suint Output	+ve	-	+ve

Table 1.1 - The broad relation between some aspects of the physical environment and the output of associated glands.

Daly and Carter observed the increased intake following shearing to be related to a post-shearing rise in wax and suint output. Hutchinson (1962) in a comparison between grazing and constant diet pen-fed sheep, suggested that this may only occur in the case of suint. The increased wax output may, he suggested, be a direct response of the skin to a temperature change. Hence in Australian conditions output from the glands is similar to the output of wool fibre. Story and Ross (1960) have described the seasonal trend of the measurable amounts of wax and suint separated from monthly clipped wool samples. This is not a true measure of the glands' output as both these substances may be leached from the fleece. The measured amounts of wax and suint present in the fleece of the grazing Romney ewes followed a similar (but less marked) pattern to wool growth. For this reason the yield of winter grown wool is lower than that of summer grown wool.

The results of Ross (1965) suggest that there is no age effect in respect to the yield of the fleeces of adult sheep.

C: WOOL PRODUCTION AND FLEECE CHARACTERISTICS

1: The Effect of Increased Stocking Levels on Wool Production and Fleece Characteristics

It has been well established that the rate of wool growth is influenced by the plane of nutrition (Ferguson, Carter and Hardy 1949; Schinckel 1960, 1963). It is generally assumed that variation in stocking level will alter the plane of nutrition at certain times during the year, if not for all the year. There have been a number of grazing trials, particularly in Australia, which have been orientated towards stock, pasture and farm management under conditions of increased stocking levels, (Walker 1955; Biddiscombe, Hutchings, Edgar and Cuthbertson 1956; Lambourne 1956; Drake and Elliot 1960; Suckling 1964; Davies and Humphries 1965; Monteath 1965; Collin 1966; Lightfoot and McGarry 1966; Lloyd 1966; Willoughby 1966; Spedding, Betts, Large, Wilson and Penning 1967). However, there have been few reports of the effect of stocking level on wool characteristics (Roe, Southcott and Turner 1959; Sharkey, Davis and Kenney 1962; McManus, Arnold and Paynter 1964).

All the stocking level studies have shown that increased stocking results in an almost linear increase in wool production per acre, with an associated fall off in the per head production. The extent of the latter trend, in particular, has varied. Biddiscombe *et al* (1956); Roe *et al* (1959) and McManus *et al* (1964) observed little, if any, reduction in the per head wool production with increased stocking. On the other hand Walker (1955); Drake and Elliot (1960); Sharkey *et al* (1962); Suckling (1964); Davies and Humphries (1965); Collin (1966); Lightfoot and McGarry (1966) and Spedding *et al* (1967) observed a significant reduction. The differences in results reflect the variation in nutrition to which the animals were subjected. This is apparent from the body weight trends.

The breed of sheep concerned may also have been of importance.

From the data of some of the larger studies it is suggested that there is a ceiling value for the amount of wool per acre that can be clipped (Suckling 1964; Morley and Ward 1966). Meanwhile economic studies indicate that estimated monetary returns fall off before the maximum wool per acre production is attained (Monteath 1965; Watson 1965; Lloyd 1966; Willoughby 1966).

Knowledge from the long term effects of increased stocking is lacking as few studies have been carried out for more than four years (Biddiscombe <u>et al</u> 1956; Suckling 1964; Spedding <u>et al</u> 1967).

Davies (1958); Clarke (1963) and Suckling (1964) have noted that the presence of cattle at all stocking levels is of benefit to sheep production.

Under conditions of heavier stocking the system of grazing has not been found to be as important as was originally suggested. Roe and Allen (1945); Biddiscombe <u>et al</u> (1956); Lambourne (1956); McMeekan (1956); Roe <u>et al</u> (1959) and Collin (1966 - Tangoio trial) have noted, following comparisons between rotational (mob-stocked) and continuous (set-stocked) grazing policies, that there is little, if any, advantage to be gained from either system. In contradiction Collin (1966 - Waerenga-o-Kuri trial) has reported a superiority in wool production per acre from a system of mob-stocking.

In view of the subjective nature of most wool characteristics a quantitative assessment is difficult. It has thus only been attempted by a few workers. In the assessing of "break" or "trade tenderness" Walker (1955) and McManus <u>et al</u> (1964) found only a slight increase while Collin (1966) showed a marked increase in unsoundness at the higher stocking levels. Lambourne (1956) found it to be only the twin bearing ewes on the higher stocking level that showed an increased percentage of "break". The New Zealand workers also assessed the percentage of "cotted" fleeces present, and found a similar trend to that of unsoundness. Australian work has shown the between season variation in fibre diameter (Roe et al 1959; McManus et al 1964) and fibre length (McManus et al 1964) of a Merino fleece to be greater than the effect due to the stocking level. The Corriedale, meanwhile, (Sharkey et al 1962) has been observed to exhibit a definite stocking level effect for both these attributes.

McManus et al (1964) was unable to observe any effect due to stocking level following the subjective rating of handle, colour, and character. Style grading has been used as a criteria of freedom from fault. At Tangoio (Collin 1966) an increased stocking level reduced the proportion of B style and better wools while at Waerenga-o-Kuri no effect was apparent. Lambourne (1956) also found the proportion of better styled wools to be less at higher stocking levels.

A meaningful criteria to the farmer of the severity of the stocking level effect is the price a buyer is prepared to bid for his wool. The wool from Walker's (1955) trial was sold by auction. A slightly higher price was received for the wool from the higher stocked group. Walker suggested this to be due to the finer appearance of her high stocking level wool. Sharkey et al (1962) and McManus et al (1964) allocated their wool to appropriate Australian types and estimated the price for each type from the average price of that type over previous years. By this method stocking level had no effect on the price that could be expected to be realised for the wool.

In conclusion, the literature suggests that despite the reduction in per head production of wool grown, the large increases in wool grown per acre, particularly in the early stages, make higher stocking economically worthwhile. The slight deterioration in "quality" of the individual fleece does not appear to be of monetary importance.

2: Phenotypic Inter-relationships between Various Fleece Characteristics

Animal breeding studies have shown many fleece characteristics to be interrelated both genetically and phenotypically. Phenotypic inter-relationships are subject to considerable modification by environmental influences. The extent of change in environmental factors necessary to alter the phenotypic correlations between fleece characteristics is not known with certainty, even for well studied breeds such as the Merino. A limited amount of data is available on phenotypic correlations between the fleece characteristics of the New Zealand Romney (Rae 1958; Ross 1964; Tripathy 1966). The number of characteristics examined in a study of this type has been limited by the problem of assessment of many fleece characteristics in quantitative terms. In the unpublished work of Wickham, Ross and Cockrem (pers. comm.) a greater number of characteristics were studied using subjective assessment of some characteristics. Much of this data is not, as yet, analysed. Henderson and Hayman (1960) carried out a complex statistical analysis on the influence of fleece characteristics on unit area wool production in which they calculated phenotypic correlations for the log of several individual fibre measurements. The available phenotypic correlations for the fleece characteristics of the New Zealand Romney are presented in Table 1.2. The parameters of Rae (1958) and Tripathy (1966) being estimated from hogget data while those of Ross (1964) and Wickham *et al* (pers. comm.) were estimated within a flock of mixed age ewes.

Table 1.2 - Phenotypic correlations between fleece characteristics.

	Greasy Fleece Weight	Fibre Diameter	Quality Number	Crimps per inch	Staple Length	Character	Yield
Body Weight	0.61 - (3) 0.47 - (4)	0.29 - (3)	0.22 - (3)	-0.09 - (3)	0.24 - (3) 0.14 - (4)	0.05 - (4)	-0.01 - (4)
Greasy Fleece Weight		0.53 - (3)	-0.33 - (1) -0.33 - (4)	-0.17 - (3)	0.45 - (1) 0.48 - (3) 0.47 - (4)	0.15 - (1) -0.09 - (4)	0.35 - (4)
Fibre Diameter			-0.63 - (2)	-0.69 - (2) -0.37 - (3)	0.41 - (2) 0.48 - (3)		0.62 - (2)
Quality Number				0.78 - (2)	-0.54 - (1) -0.69 - (2) -0.53 - (4)	0.06 - (1) 0.33 - (4)	-0.20 - (2) -0.43 - (4)
Crimps per inch					-0.59 - (2) -0.63 - (3)		-0.26 - (2)
Staple Length						0.20 - (1) -0.27 - (4)	0.17 - (2) 0.45 - (4)
Character							-0.04 - (4)

References:- (1) Rae (1958)
(2) Ross (1964)
(3) Tripathy (1966)
(4) Wickham, Ross and Cockrem (pers. comm.)

CHAPTER 2

DESCRIPTION OF THE GRAZING UNITS AND THEIR MANAGEMENT

In March 1966 a 25 acre area of land, divided into eight approximately equal sized paddocks, was set aside at Massey University for a long term study of a possible genotype x stocking level interaction in Romney sheep. This unit is subsequently referred to as the Intensive unit. A mixed age flock of 200 Romney ewes were allocated to the farmlet. The overall stocking level was thus 8 ewes per acre. The ewes were obtained by randomization from a larger flock, the remainder of which constituted the Control group. Both flocks consisted of approximately equal numbers of each age group (Table 2.1). No replacement hoggets were run on the Intensive unit over the winter of 1966. The replacements were introduced from the original flock as two-tooths - 1 year old in the summer of 1966/67. Thereafter all stock, except for rams, have been born and bred on the unit. The wether lambs are sold at weaning, or soon after. The grazing system is essentially set-stocking for most of the year. The unit is entirely self-supporting in respect of feed requirements. Hay is saved and cut during the summer for winter feeding. No cattle are run on the unit. The carrying capacity of the unit over the 1967 winter was approximately 10.5 ewe equivalents per acre (Table 2.1).

The slightly larger Control flock, of similar age structure (Table 2.1), was run as one of several flocks on an adjoining University farm. The flock was not confined to a defined area. The farm as a whole was at a stocking level of approximately 5 ewes per acre with cattle

Year	Unit	No. of Ewe Hoggets	No. of Wether Hoggets	Number of Adult Ewes				Total No. of Ewes	Total No. of Sheep	Area (Acres)	Sheep per Acre	Ewe equivalents per Acre (Hgt = 0.6EE)
				($1\frac{1}{2}$ yr. old)	($2\frac{1}{2}$ yr. old)	($3\frac{1}{2}$ yr. old)	($4\frac{1}{2}$ yr. old)					
1966	**Control**	-	-	65 (65)	61 (60)	61 (60)	65 (61)	252 (246)	252 (246)	-	Approx. 5	-
	Intensive	-	-	50 (47)	49 (48)	50 (45)	51 (50)	200 (190)	200 (190)	25	8	8
1967	Control	143 (137)	10 (9)	64 (62)	65 (63)	57 (56)	59 (55)	245 (236)	398 (382)	-	Approx. 5.5	-
	Intensive	93 (91)	10 (10)	62 (60)	46 (45)	48 (47)	45 (42)	201 (194)	304 (295)	25	12.2	10.5

Table 2.1 - Number of stock grazed on the experimental units as at March of each year. The number of stock shorn in the spring is given in brackets.

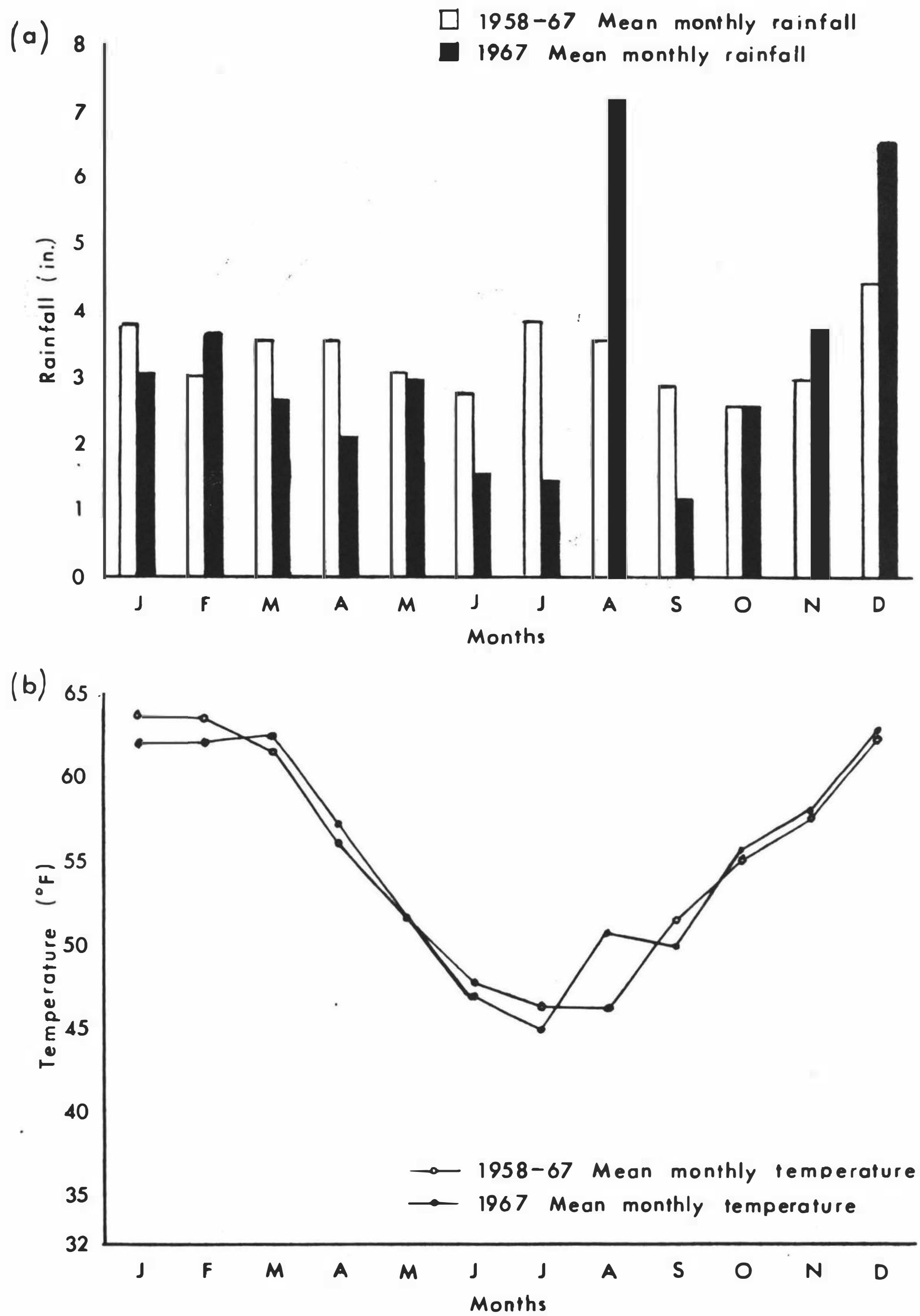


Fig. 2.1 — (a) Monthly rainfall and (b) mean monthly temperature as recorded at Grasslands Division, D.S.I.R., Palmerston North.

being grazed as required to control the pasture. The large farm is self sufficient in respect of feed. Similarly the Control ewe flock is self sufficient except for rams, with the wether lambs being sold at weaning or soon after. The system of grazing employed is one of mob-stocking throughout the year with the young stock having access to a crop of choumoellier for a period during the winter. The carrying capacity of the farm over the 1967 winter was approximately 5.5 ewe equivalents per acre.

The trial area receives a 40 inch average annual rainfall with a fairly even monthly distribution. The mean monthly values recorded, less than a mile away, at Grasslands Division, D.S.I.R., Palmerston North for rainfall and mean temperature over the period 1958 - 1967, and for 1967 are presented in Fig. 2.1.

The grazing areas are situated on Tokomaru silt loam which is liable to pugging after prolonged heavy rain. Pastures on both areas are chiefly Perennial Ryegrass (Lolium perenne) and White Clover (Trifolium repens). Over the two years 1966 and 1967 the Intensive unit was topdressed with 1 ton of lime per acre and 5 cwt. of superphosphate. Over the same time span between $1\frac{1}{2}$ and 2 cwt. per acre of superphosphate was applied to the area grazed by the Control flock.

All operations on the two units were carried out as close together as was practically possible. The number of animals which were shorn in each flock is given in brackets in Table 2.1.

CHAPTER 3

THE EFFECT OF TWO DIFFERENT GRAZING ENVIRONMENTS ON FOLLICLE DEVELOPMENT

A: INTRODUCTION

Work on the pattern of follicle group development has been reviewed by Hardy and Lyne (1956b). Australian work (Schinckel 1955b; Short 1955a; Schinckel and Short 1961) suggests that all, or nearly all, the secondary follicles in the Merino lamb are initiated by birth. Work with British breeds suggests this may not be the case (Fraser and Hamada 1952; Burns 1954a, 1955; Wildman 1965).

The nutritional status of the Merino ewe has been shown to influence the pattern of follicle development of her offspring (Schinckel 1953, 1955a, 1955b; Short 1955b; Hugo 1958; Schinckel and Short 1961; Taplin and Everitt 1964; Everitt 1967). Depending on the severity of the nutritional check the retardation of the developmental pattern may be transient (Hugo 1958; Taplin and Everitt 1964; Everitt 1967), or permanent (Schinckel 1953, 1955a, 1955b; Short 1955b; Schinckel and Short 1961; Allden 1968). Due to the low $\frac{S}{P}$ ratio in the adult animals of non-Merino breeds, and also the small numbers of experimental animals used, the results for non-Merino breeds are inconclusive. It is generally suggested however that a restriction in maternal nutrition slows the rate of secondary initiation and maturation (Henderson 1953; Coop and Clarke 1955; Ryder 1955; Wildman 1958a, 1965; Doney and Smith 1964).

Schinckel (1953) concluded, from his Merino experiment, that the nutritional penalty, imposed upon twins as compared with singles, and upon the progeny of young as compared with older ewes, only restricted follicle development during the animal's first year of life. Few workers have shown these factors to influence follicle development in British breeds (Henderson 1953; Doney and Smith 1964).

As knowledge of the follicle development pattern of the Romney under New Zealand conditions is inadequate, this study was initiated to examine the effect of both single and twin birth rank, and dam age upon the follicle development of animals being grazed at two stocking levels.

B: MATERIALS AND METHODS

The study was carried out as two inter-related parts.

1966 Lambs — A group of ewe lambs born in 1966 were skin sampled at weaning. A repeat sampling was carried out a year later at hogget shearing.

1967 Lambs — A small group of mixed sex lambs born in 1967 were skin sampled on the day of birth. The same lambs were subsequently skin sampled at weaning.

1: Selection of Animals

1966 Lambs - Prior to the 1966 weaning the ewe lambs from each flock were divided, on paper, into groups of singles and twins from 2 year and 3 - 5 year old dams. Ten lambs were randomly selected from each group. In one group (Intensive unit - twins from 2 year dam) there were only nine animals. During processing several samples were damaged. The numbers of animals in their respective groups are given in Table 3.A.

Stocking Level	Birth Rank Group	Dam Age Group	
		2 year Dam	3 - 5 year Dam
Control	Singles	8	9
	Twins	8	10
Intensive	Singles	8	10
	Twins	8	8

Table 3.A. - 1966 lambs skin sample groups.

1967 Lambs - As part of another study (Chapter 4) a group of ewes from each grazing unit were closely studied for body weight trends and wool growth during pregnancy. Skin samples were taken from their off-spring on the day of birth. The animals were divided into singles and twins with the age of the dam being disregarded. During processing several samples were damaged. The numbers of animals in their respective groups is given in Table 3.B.

Stocking Level	Birth Rank Group	
	Singles	Twins
Control	6	8
Intensive	3	7

Table 3.B. - 1967 lambs skin sample groups

2: Sampling

The basic sampling technique used was the same for all animals. The animal was laid on a specially constructed sampling table in a lateral recumbent position. The sampling site, on the left-hand side over the 12th rib, was prepared by close clipping with electric clippers (Oster - 0000 Blades). The sample from the new born animals was taken in the paddock (Fig. 3.1), after the sampling site was prepared by close clipping with curved scissors.

In all cases the skin sample was cut by the use of a 1 cm. biopsy punch (Carter and Clarke 1957a). After a firm twist of the punch the sample was removed by forceps and surgical scissors. The disc of

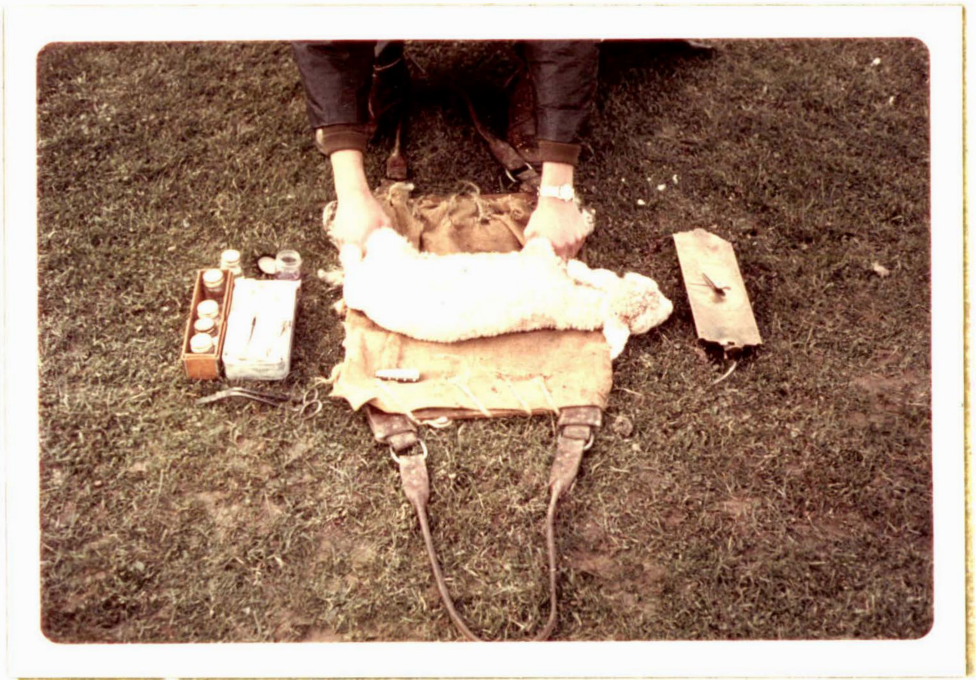


Fig. 3.1 - New born lamb following the taking of a skin section.

skin was pressed, subcutaneous surface downwards, on to a piece of cardboard and fixed in either alcohol or formalin.

All animals were body weighed. A cradle and spring balance (Fig. 3.1) was used for the new born lambs.

3: Histological Techniques.

The samples were processed by a standard technique similar to that reported by Wickham (1958) using an "Elliot" automatic tissue processor. Small squares of cardboard with Indian ink numbers were used for identification.

Embedding was carried out on a glass plate with the skin sample being pushed into the molten wax with a heated glass rod. The wax embedded samples were mounted on a wooden block for sectioning. A 56 C. melting point paraffin wax was used in 1966 but considerable difficulty was experienced with ribboning. Following the addition of 20% beeswax in 1967 much improved results were obtained. Sections of 8 μ thickness, cut through the level of the primary sebaceous glands, were saved.

An adaptation of a staining technique, commonly called Gomori's Trichrome stain was used (Lillie 1954; Gurr 1956; Menzies 1959). The results of the staining technique were :- connective tissue, blue-green; keratizized fibre, yellow; muscle and cytoplasm, red; and nucleii, grey-blue. The sections were mounted in Canada balsam.

4: Measurement of the Follicle Population

Counts of the follicle population were made at x115 using a "Bausch and Lomb" microprojector. The follicle densities of each animal were estimated from the mean of 10 sample fields. In the case of the new born lambs less fields were used. However, due to the greater density of follicles within the skin, more follicles were actually counted over less fields than is the case of the older animals. The sample fields were projected on to a circular area (Appendix I). Each projection was of one square millimetre of the mounted section. The usual convention of structures covered by marginal lines was adopted whereby those follicles crossed by the top margin of the circle were included while those follicles crossed by the bottom margin of the circle were excluded.

As a result of difficulties experienced during sectioning not all sections were at the ideal level for follicle identification. The absolute criteria used for the identification of primary follicles was the presence of a sudoriferous duct. In many samples the presence of a bilobed sebaceous gland and the follicular arrangement were of assistance in primary follicle identification.

As a result of histological preparation all skin samples underwent shrinkage to a varying degree. To obtain a true figure for follicular density it was necessary to apply a correction factor - the ratio, area of the section/area of a circle of diameter 1 cm. This factor was obtained by projecting the whole section at a magnification of x21 with the microprojector and tracing around the projected image. The mean of four diameter measurements was calculated and used as the basis of the correction factor.

The $\frac{S}{P}$ ratio was derived from the total number of secondaries over the 10 fields divided by the total number of primaries. An estimate of the true primary and secondary density was obtained by multiplying the raw densities by the correction factor.

5: Statistical Techniques

The statistical analyses were carried out with the use of an I.B.M. 1620 Computer. For the equal subclass analyses all effects were considered to be of the fixed effect type. For the unequal subclass analyses constants were fitted according to the least squares model. In the following analyses several general models are used.

(i) Analysis of Variance

$$X_{ijk} = \mu + a_i + b_j + (ab)_{ij} + e_{ijk}$$

where a = stocking level effect

b = either birth rank effect or age of animal effect

In cases of unequal subclass numbers when the interaction term was non-significant the model of:-

$$X_{ijk} = \mu + a_i + b_j + e_{ijk}$$

was substituted.

(ii) Within Group Regression Analysis

Prior to an analysis of covariance the sample regression coefficients were tested against the hypothesis:

$$\beta_1 = \beta_2 = \text{----------} \beta_n$$

by means of an F test.

$$F = \frac{\text{Mean squares for regression coefficients}}{\text{Mean squares within samples}}$$

In cases of significance the covariance analysis was still proceeded with following a graphical analysis to interpret the extent and direction of any bias that may be introduced.

(iii) Covariance

$$X_{ij} = \mu + a_i + b_j + \beta(X_{ij} - \bar{x}_{..}) + e_{ij}$$

Where interaction was significant the model used was:-

$$X_{ij} = \mu + a_i + b_j + (ab)_{ij} + \beta(X_{ij} - \bar{x}_{..}) + e_{ij}$$

C: RESULTS

The date and mean age of the groups of animals at each sampling are given in Table 3.1.

1: 1966 Lambs

The data derived from each dam age group were analysed separately to make statistical interpretation more meaningful by reducing the number of possible interaction terms.

(i) Body Weight

The group means of the body weight at each sampling are given in Table 3.2. The values for the animals with 3 - 5 year old dams are unweighted. The mean squares derived from an analysis of variance are given in Table 3.3. It is clear that the Control lambs weaned from the older ewes are able to maintain their superior growth rate after weaning. Similarly single lambs which are significantly heavier ($P < 0.005$) at weaning are still heavier ($P < 0.05$) at hogget shearing when one year old. There is a very pronounced stocking level effect for both dam age groups. This is the result of the low plane of feeding experienced by the Intensive hoggets in the early spring (Chapter 4). There is no indication in this data of the weaning weight being influenced by the stocking level of the dam.

(ii) Primary Density

The group means of the primary follicle density at each sampling are given in Table 3.4. The values for the animals with 3 - 5 year old dams are unweighted. The mean squares derived from an analysis of variance are

Sampling	Date	Mean Age
1966 Lambs		
Weaning	30.11.66	13 weeks
Hogget Shearing	28. 9.67	56 weeks
1967 Lambs		
Lambing	12.8 - 10.9.67	0 weeks
Weaning	20.11.67	13 weeks

Table 3.1 - Date and mean age of animals at each sampling.

Unit	Group	Sampling			
		Weaning		Hogget Shearing	
		2 year Dam	3 - 5 year Dam	2 year Dam	3 - 5 year Dam
Control	Singles	53.0 lbs	58.3 lbs	85.0 lbs	92.8 lbs
	Twins	45.8	51.7	76.0	84.0
Intensive	Singles	55.1	59.0	69.1	70.7
	Twins	42.3	48.6	64.8	67.6

Table 3.2 - 1966 Lambs; Group means for body weight. The values for the animals born to 3 - 5 year old Dams are unweighted.

(a) 2 year old Dam

Source	df	Sampling	
		Weaning	Hogget Shearing
Stocking Level	1	3.78	1471.53***
Birth Rank	1	810.03***	357.78*
Stocking Level x Birth Rank	1	63.28	42.78
Residual	28	27.64	63.37

(b) 3 - 5 year old Dam

Source	df	Sampling	
		Weaning	Hogget Shearing
Stocking Level	1	12.01	3426.04***
Birth Rank	1	654.71***	332.43*
Residual	34	41.06	68.24

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.005$

Table 3.3 - 1966 Lambs; Body weight. Mean squares derived from an analysis of variance.

Unit	Group	Sampling			
		Weaning		Hogget Shearing	
		2 year Dam	3 - 5 year Dam	2 year Dam	3 - 5 year Dam
Control	Singles	3.41	3.34	2.12	2.07
	Twins	3.96	3.66	2.27	2.26
Intensive	Singles	3.55	3.42	2.74	2.40
	Twins	3.33	3.32	2.53	2.54

Table 3.4 - 1966 Lambs; Group mean for primary follicle density (mature follicles per square millimetre). The values for the animals born to 3 - 5 year old Dams are unweighted.

given in Table 3.5. There is neither a stocking level nor a birth rank effect at weaning for either of the dam age groups. At hogget shearing the stocking level effect is significant ($P<0.01$) for the 2 year old dam group while for the group with the older dams the effect is only approaching statistical significance ($P<0.1$). As no primary follicles are initiated after birth this stocking level effect may be considered to be due entirely to skin expansion as a result of body growth. There is a similar trend present in respect to a birth rank effect in all the groups at hogget shearing except the Intensive animals born to the young ewes. Both Schinkel and Short (1961) and Allden (1968) observed there to be considerable within group variation for individual follicle type density estimations. This was the case in this study.

(iii) Secondary Density

The group means of secondary follicle density at each sampling are given in Table 3.6. The values for the animals with 3 - 5 year old dams are unweighted. The mean squares derived from an analysis of variance are given in Table 3.7. As in the case of primary density there is a large within-group variability, particularly at the weaning sampling. Neither of the effects being studied are statistically significant for either dam age group at weaning. The density for the Intensive twins in both dam age groups at weaning is noticeably lower than the other groups. It may be suggested that this reduction in density is due to a slowing in the rate of maturation of some of the later

(a) 2 year old Dams

Source	df	Sampling	
		Weaning	Hogget Shearing
Stocking Level	1	0.49	1.53**
Birth Rank	1	0.21	0.01
Stocking Level x Birth Rank	1	1.17	0.25
Residual	28	0.92	0.18

(b) 3 - 5 year old Dams

Source	df	Sampling	
		Weaning	Hogget Shearing
Stocking Level	1	0.13	0.87
Birth Rank	1	0.13	0.26
Residual	34	0.42	0.22

* $P < 0.05$; ** $P < 0.01$

Table 3.5 - 1966 Lambs; Primary follicle density. Mean squares derived from an analysis of variance.

Unit	Group	Sampling			
		Weaning		Hogget Shearing	
		2 year Dam	3 - 5 year Dam	2 year Dam	3 - 5 year Dam
Control	Singles	15.28	15.58	9.51	9.43
	Twins	15.57	15.40	9.82	9.63
Intensive	Singles	15.24	16.21	12.72	10.62
	Twins	13.17	13.55	11.93	11.70

Table 3.6 - 1966 Lambs; Group means for secondary follicle density (mature follicles per square millimetre). The values for the animals born to 3 - 5 year old Dams are unweighted.

(a) 2 year old Dam

Source	df	Sampling	
		Weaning	Hogget Shearing
Stocking Level	1	11.93	56.71***
Birth Rank	1	6.32	0.45
Stocking Level x Birth Rank	1	11.16	2.40
Residual	28	14.75	3.33

(b) 3 - 5 year old Dam

Source	df	Sampling	
		Weaning	Hogget Shearing
Stocking Level	1	2.98	23.89**
Birth Rank	1	17.44	3.58
Residual	34	12.05	2.66

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.005$

Table 3.7 - 1966 Lambs; Secondary follicle density. Mean squares derived from an analysis of variance.

developing secondary follicles. At hogget shearing there is a significant stocking level effect, as in the case of primary density, which may be considered to be due to skin expansion. It is apparent from an examination of the Intensive twin group means that the later developing secondaries not present at weaning have matured by hogget shearing so that the fibre densities of the Intensive groups are comparable at hogget shearing.

(iv) $\frac{S}{P}$ ratio

For statistical analysis the $\frac{Sf}{Pf}$ ratio was transformed to a logarithmic scale to the base e. This base was chosen as it had previously proved suitable for other similar analyses (Cockrem 1966).

The group means for each sampling are given in Table 3.8. The values for the 3 - 5 year old dam groups are unweighted. The mean squares derived from an analysis of variance of the transformed data are given in Table 3.9. The birth rank is significant ($P \sim 0.05$) in both dam age groups. The trends in the follicle densities constituting the ratio for the Intensive twin groups are clearly a delaying of secondary maturation (Table 3.6). The low $\frac{Sf}{Pf}$ ratio for the Control twin groups stems from a high primary density (Table 3.4). The reason for these high values can only be assumed to be due to large within-group variability and small group size. There are no significant effects in respect to the $\frac{Sf}{Pf}$ ratio at hogget shearing.

Unit	Group	Sampling			
		Weaning		Hogget Shearing	
		2 year Dam	3 - 5 year Dam	2 year Dam	3 - 5 year Dam
Control	Singles	4.49 (1.501)	4.63 (1.532)	4.50 (1.503)	4.57 (1.519)
	Twins	3.96 (1.376)	4.20 (1.435)	4.32 (1.464)	4.28 (1.453)
Intensive	Singles	4.28 (1.453)	4.70 (1.547)	4.67 (1.541)	4.48 (1.500)
	Twins	3.95 (1.373)	4.10 (1.412)	4.73 (1.553)	4.65 (1.536)

Table 3.8 - 1966 Lambs; Group means for $\frac{Sf}{Pf}$ ratio. The values for the animals born to 3 - 5 year old Dams are unweighted. The values in parenthesis have been transformed to a logarithmic scale to the base e.

(a) 2 year old Dam

Source	df	Sampling	
		Weaning	Hogget Sampling
Stocking Level	1	0.005	0.033
Birth Rank	1	0.084*	0.001
Stocking Level x Birth Rank	1	0.004	0.005
Residual	28	0.014	0.011

(b) 3 - 5 year old Dam

Source	df	Sampling	
		Weaning	Hogget Shearing
Stocking Level	1	0.000	0.008
Birth Rank	1	0.122*	0.002
Residual	34	0.016	0.014

* $P < 0.05$

Table 3.9 - 1966 Lambs; $\frac{Sf}{Pf}$ ratio. Mean squares derived from an analysis of variance following a $\log_e$ transformation.

2: 1967 Lambs

(i) Body Weight

The unweighted group means from each sampling and the mean squares derived from an analysis of variance are given in Table 3.10. The dams of these animals experienced a more severe winter nutritional check than the dams of the 1966 lambs on account of the increase in stock numbers carried by the two units over the 1967 winter. Though the stocking level of the ewes did not affect the birth weight of the lambs there was a significant ($P < 0.05$) stocking level effect in the lambs weaning weight.

On account of insufficient numbers the sex effect on birth weight was not estimated. There was however a significant birth rank effect. The unweighted mean of the Intensive singles is made up of only three observations.

(ii) Primary Density

The unweighted group means and mean squares derived from an analysis of variance are given in Table 3.11. Despite the birth rank effect for body weight at birth the effect is non-significant for primary density, mainly on account of the large within-group variation. At weaning this variation is considerably reduced, in comparison with the previous year, and there is a significant birth rank effect. This is in line with the body weight trends as the twin animals have a high primary density due to their smaller surface area.

(iii) Secondary Density

The unweighted group means from each sampling and the mean

(a) Unweighted Group Means

Unit	Group	Sampling	
		Birth	Weaning
Control	Singles	10.4 lbs	51.8 lbs
	Twins	8.7	44.0
Intensive	Singles	10.9	48.0
	Twins	8.3	37.9

(b) Mean Squares derived from an analysis of Variance

Source	df	Sampling	
		Birth	Weaning
Stocking Level	1	0.04	163.32*
Birth Rank	1	22.57**	419.48***
Residual	21	2.28	26.13

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.005$

Table 3.10 - 1967 Lambs; Body weight.

(a) Unweighted group means

Unit	Group	Sampling	
		Birth	Weaning
Control	Singles	9.22	2.88
	Twins	9.41	3.75
Intensive	Singles	8.22	3.37
	Twins	10.62	3.61

(b) Mean squares derived from an analysis of variance

Source	df	Sampling	
		Birth	Weaning
Stocking Level	1	1.14	0.04
Birth Rank	1	5.88	2.24***
Residual	21	3.05	0.14

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.005$

Table 3.11 - 1967 Lambs; Primary follicle density (mature follicles per square millimetre).

squares derived from an analysis of variance are given in Table 3.12. As with primary density there is no clear trend in the group means at birth. There is also a large within-group variability. At weaning the birth rank effect is significant. The secondary density trends shown by these animals are in marked contrast to those observed for the 1966 lambs. The high values of the secondary density for the twin animals suggests that no secondaries have been retarded in their maturation and the effect is due entirely to reduced body growth and a consequently smaller surface area.

(iv) $\frac{S}{P}$ ratio

For statistical analysis the $\frac{Sf}{Pf}$ ratio $\log_e$ transformation was again used. The unweighted group means are given in Table 3.13(a). The mean squares derived from an analysis of variance are given in Table 3.13(b). There is a significant ($P<0.05$) birth rank effect at birth with the twin animals having the lower values suggesting that proportionally less secondaries have matured at birth. It is apparent that the large within-group variability present for both primary and secondary density is partially removed in deriving the ratio allowing the birth rank effect to become significant. This will be due to a removal of the effects of skin stretching. The $\frac{Sf}{Pf}$ ratio differences are in line with the birth weight differences. The fact that all the ratios at birth are lower than those observed later at weaning suggest there to be several immature secondaries within each group at birth. This was clearly apparent

(a) Unweighted group means

Unit	Group	Sampling	
		Birth	Weaning
Control	Singles	31.50	14.22
	Twins	28.80	16.91
Intensive	Singles	29.57	14.72
	Twins	31.40	16.53

(b) Mean squares derived from an analysis of variance

Source	df	Sampling	
		Birth	Weaning
Stocking Level	1	5.95	0.03
Birth Rank	1	5.35	30.68*
Residual	21	22.02	4.01

* $P < 0.05$

Table 3.12 - 1967 Lambs; Secondary follicle density (mature follicles per square millimetre).

(a) Unweighted group means. The values in parenthesis have been transformed to a logarithmic scale to the base e.

Unit	Group	Sampling	
		Birth	Weaning
Control	Singles	3.45 (1.237)	4.91 (1.591)
	Twins	3.06 (1.117)	4.49 (1.502)
Intensive	Singles	3.57 (1.272)	4.39 (1.480)
	Twins	2.98 (1.091)	4.56 (1.518)

(b) Mean squares derived from an analysis of variance.

Source	df	Sampling	
		Birth	Weaning
Stocking Level	1	0.000	0.005
Birth Rank	1	0.114*	0.009
Residual	21	0.017	0.010

* $P < 0.05$

Table 3.13 - 1967 Lambs; $\frac{Sf}{Pf}$ ratio.

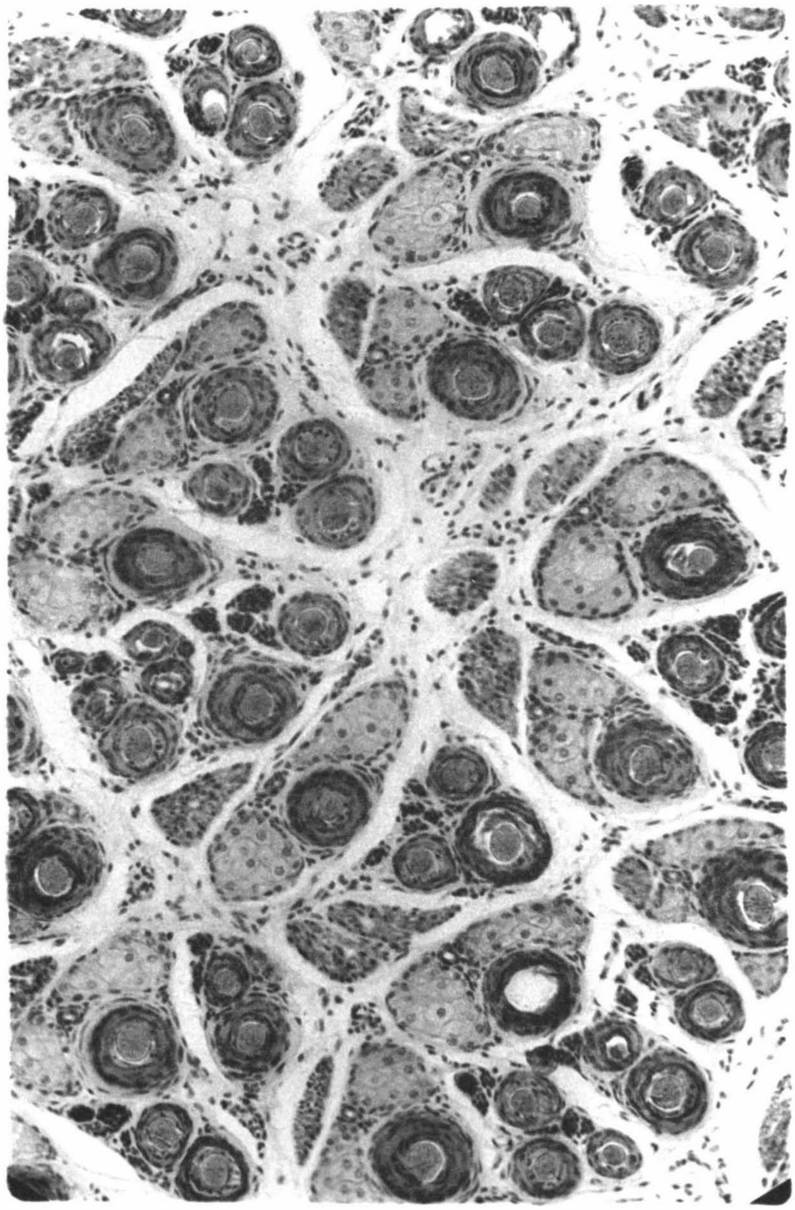


Fig 3.2 - Photomicrograph of skin section at birth of an Intensive twin animal born to a 2 year old dam. (x120)

visually - Fig. 3.2. In contrast to the 1966 lambs there was no birth rank effect apparent at weaning. The values of the ratios in all the groups are comparable with those of the single 1966 lambs. It is therefore apparent that in 1967 the maturation of the later maturing secondaries has not been retarded beyond weaning.

D: DISCUSSION

The pre-natal nutritional restriction to which the animals in the trial were subjected was a direct effect of birth rank rather than stocking level. The birth weight trends of the 1967 lambs provide evidence of this in that the birth rank effect was significant ($P < 0.01$) while the stocking level effect was clearly non-significant. This trial is therefore comparable to those of Henderson (1953), Schinckel (1953), Ryder (1955), Wildman (1958), Doney and Smith (1964) and Wildman (1965). The imposed effects are much less severe than those reported by Schinckel and Short (1961) and Allden (1968). It is reasonable to assume from the work of many authors (reviewed by Fraser and Short 1960) that all primary follicles are fully developed before birth. The ratio of mature secondary follicles to mature primary follicles is therefore a satisfactory measure of the course of development of the secondary follicles in a given group of animals.

A comparison of the $\frac{Sf}{Pf}$ ratio of singles and twins at birth showed a significant ($P < 0.05$) difference in the number of active secondaries. This is in agreement with the findings of Schinckel (1953), Short (1955b) and Schinckel and Short (1961). Ryder (1955) and Wildman (1958) found no significant effect of pre-natal nutrition on follicle or fibre ratio at birth. It is possible that the competition between twin foetuses for nutrients in the later stages of pregnancy was sufficient to retard the maturation of initiated secondary follicles just prior to birth. The stocking level of the ewe was without effect on the $\frac{Sf}{Pf}$ ratio of the lamb at birth. The dams of the Intensive lambs experienced a period of considerable nutritional stress in the early spring (Chapter 4). The demands of a twin pregnancy may therefore be assumed to be of a greater magnitude in influencing the maturation of secondary follicles than a marked reduction in ewe body weight just prior to lambing.

Schinckel (1955b) observed the larger animals at birth to have a greater total number of primaries and also a lower primary density. Though not significant these trends are apparent in this study if birth weight is used as a measure of body size. The lack of significance may be due to a large within-group variability. Similarly the large within-group variability of secondary follicle density at birth is suggested as the reason for no direct effect being observable despite the effect shown by the $\frac{Sf}{Pf}$ ratio.

Despite the early set back in the growth rate of the 1967 lambs the $\frac{Sf}{Pf}$ ratio at weaning was not significantly affected by either a stocking level or a birth rank effect. The primary and secondary density both showed significant birth rank effects. An examination of the group means suggests this to be an effect of skin expansion. It may be concluded from these results that the follicle population of the 1967 lambs has attained adult proportions with neither the stocking level nor the birth rank having permanently affected the population in any way.

The 1966 animals however showed a significant ($P < 0.05$) birth rank effect for the $\frac{Sf}{Pf}$ ratio at weaning. An examination of the group means shows the effect to result from a depression in the maturation rate of the later developing secondaries amongst the twin animals of both dam age groups. The effect is not shown by the secondary density data presumably because of the large within-group variability present. Weaning weight trends indicate there to have been a greater nutritional stress applied to the Intensive animals in 1967 than in 1966. It is therefore difficult to explain the depression of the secondary maturation rate in terms of the pre-weaning plane of nutrition. Wildman (1965) observed for the Romney, over a period of five years sampling of lambs of different ages, that the $\frac{Sf}{Pf}$ ratio tended to reach a maximum by the time the lambs were 90 days of age. He observed between year variability in the rate of attaining this maximum value. At a year of age all animals had a similar $\frac{Sf}{Pf}$ ratio (statistically) with both primary and secondary density showing marked effects of skin expansion. It may therefore be concluded that the secondary maturation delay at weaning was only transient and that, as in the case of the 1967 lambs, the follicle population of these lambs subsequently attained adult proportions with neither the stocking level nor the birth rank having permanently affected the population in any way.

The age of the dam had no noticeable effect on the development of the follicle population at either birth or weaning, though the lambs born to older ewes did show a greater growth rate. This superior growth rate was still in evidence at hogget shearing for the Control animals.

This study suggests that at moderate to high levels of stocking the follicle initiation of the foetal lamb is not permanently affected in any way. The birth rank is however of greater importance than stocking level in regulating the rate of maturation of initiated secondaries. Any delay caused is of a transient nature. As both pre and post-natal effects are confounded in the imposed treatments analysis in these terms is without meaning. Because of the capacity of young sheep to undergo long periods of undernutrition without impairing wool production in later life (Allden 1968), a situation in which permanent changes in the follicle population could be induced would be extremely rare under New Zealand grazing conditions for the Romney sheep.

CHAPTER 4

THE EFFECT OF TWO DIFFERENT GRAZING ENVIRONMENTS ON THE SEASONAL PATTERN OF WOOL GROWTH

A: INTRODUCTION

An annual cycle in the rate of wool growth has been observed by many workers using several breeds of sheep in different environments. The cycle has been shown to be essentially an inherent rhythm (Hutchinson and Wodzicka - Tomaszewska 1961; Hutchinson 1965) able to be modified by (i) nutrition (Ferguson, Carter and Hardy 1949; Coop 1953; Schinckel 1960, 1963; Doney and Smith 1961; Doney 1966; Doney and Eadie 1967), (ii) the immediate physical environment of light (Hutchinson 1965) and temperature (Hutchinson and Wodzicka-Tomaszewska 1961), and (iii) pregnancy and lactation (Coop 1953). The literature reviewed by Ferguson, Wallace and Lindner (1965) suggests that the inherent wool growth rhythm is influenced by the endocrine system. It is apparent that there are considerable breed differences in the magnitude of the cycle which is expressed in terms of changes in both fibre length and fibre diameter growth rates. (Coop 1953; Doney and Smith 1961; Ross 1965).

The associated glands of the wool follicle exhibit an annual cycle in their output which is in phase with the fibre output of the wool follicle (Daly and Carter 1955).

No comparison of the seasonal pattern of wool growth of sheep grazed at different stocking levels has been attempted in New Zealand.

It is likely that there is an association of higher stocking levels with more severe nutritional stresses during periods of low feed availability with a possible association of these stresses with increased wool fault. It was therefore decided to examine the monthly wool growth pattern in terms of wool weight, fibre diameter and fibre length under two stocking levels.

B: MATERIALS AND METHODS

1: Selection of Animals.

The study was carried out during 1967 on two classes of animals; ewe hoggets and adult ewes.

(i) Ewe Hoggets;

Nine animals were randomly selected from each of the four birth rank groups of ewe lambs born in 1966 that were skin sampled at weaning(Chapter 3). The age of the dam was ignored (Table 4.A).

	Group	
	Singles	Twins
Control	9	9
Intensive	9	9

Table 4.A - The ewe hogget monthly sample groups

(ii) Adult Ewes:

A group of two year old and a group of four year old ewes, each of ten animals, were randomly selected from each flock. Two animals died prior to lambing and five did not lamb. The data from these barren animals were not analysed statistically since the small numbers in each group prevented the estimation of the effects of the barrenness.

The groups and their respective numbers are given in Table 4.B.

	Group	
	2 yr. old	4 yr. old
Control	8	10
Intensive	7	8

Table 4.B - The adult ewe monthly sample groups

2: Sampling

Commencing on the 28th December 1966 the animals were sampled every 28 days until the 22nd November 1967. The adult ewes were not sampled on the 31st August (Sampling 9) due to lambing being in progress. The animals were laid on a specially constructed sampling table in a lateral recumbent position. The wool sample was taken from the right hand side of the animal at the standard mid-side position. When the December sampling was taken, (subsequently called Sampling 0) there was sufficient wool growth to be able to easily identify the boundaries of the clipped area. On account of the large number of animals involved it was felt that with care in clipping, tattooing could be avoided.

Clipping was carried out using "Oster" electric clippers (0000 Blades). The lengths of the four sides of the patch were measured by means of vernier calipers with lengthened arms. The animals were body weighed after sampling.

3: Scouring

The "greasy" wool samples were placed in a humidity room for 48 hours before weighing. The room was controlled to 68°F and 65% relative humidity. For scouring the samples were placed in small nylon bags. The samples from the first two samplings were scoured by the four bowl detergent and water scouring method. Even though no agitation was used it was apparent that there was considerable fibre loss. Organic solvents were used for all subsequent scouring. The sequence of solvents, in which the samples were placed for three minutes, was ether, 95% alcohol and cold water. There was no agitation. The samples were dried in a blast of warm air, then allowed to condition in the humidity room for 48 hours, before being reweighed. The loss in weight is subsequently called yolk.

4: Fibre Length Estimation

The mean fibre length of the samples from five randomly selected ewes of each of the four groups was estimated. A few fibres at a time were placed between two pieces of glass and the image projected onto a solid screen by an ordinary photographic slide projector. The magnification was such that one millimeter of fibre was equal to half an inch on the screen. The length of twenty five fibres was measured by means of a map wheel and the mean length calculated.

5: Fibre Diameter Estimation

The mean fibre diameter of the adult ewe samples, for which fibre length was obtained, was estimated by the airflow technique (Anderson 1954).

During the winter months many of the wool samples were less than 2g in weight, the weight for which the original apparatus was calibrated. The apparatus was therefore adapted (Appendix II) and all measurements were carried out using a 1g sample. The diameter was estimated as the mean of four readings of one subsample.

6: Statistical Techniques

The statistical models used are given in Chapter 3, Section B.5.

C: RESULTS

Relevant meterological data are given in Fig. 2.1. The dates of each sampling are given in Table 4.1.

Following a preliminary examination the data, obtained in respect to the weight of yolk present in the samples, were found to be unsuitable for further analysis since the within group regression coefficients to be used in covariance analysis were significantly different. Analysis of yolk production per unit area would be feasible but was not attempted.

1. Ewe Hogget Data.

(i) Ewe Hogget Body Weight.

The unadjusted group means are plotted in Fig. 4.1 (a). The mean squares for an analysis of variance of the group means are given in Table 4.2. The growth curve is typical of that experienced under New Zealand conditions with a plateauing of growth over the winter months. The drop in body weight of the Control animals at Sampling 9 occurred simultaneously with the animals being fed a crop of choumoellier. The nutrition of the Intensive animals was severely restricted in the early part of the spring as a result of confining the animals to as small an area as possible. This practice though enabling the lambing ewes to have access to more pasture retarded the body growth of the hoggets. The graph and table reiterate (Chang 1967) that animals born and reared as singles are superior in their growth rate to animals born and reared as twins, attaining a heavier body weight at a specific age.

In an attempt to study growth rate by removing the effects of the body weight at the start of each analysis period, an analysis of covariance was carried out using data adjusted for each previous sampling.

Sampling Number	Date
	1966
0	29th December
	1967
1	17th January
2	15th February
3	15th March
4	12th April
5	10th May
6	7th June
7	5th July
8	2nd August
9	31st August
	(Ewes not sampled due to lambing in progress)
10	28th September
11	25th October
12	22nd November

Table 4.1 - Dates on which mid-side wool sampling was carried out.

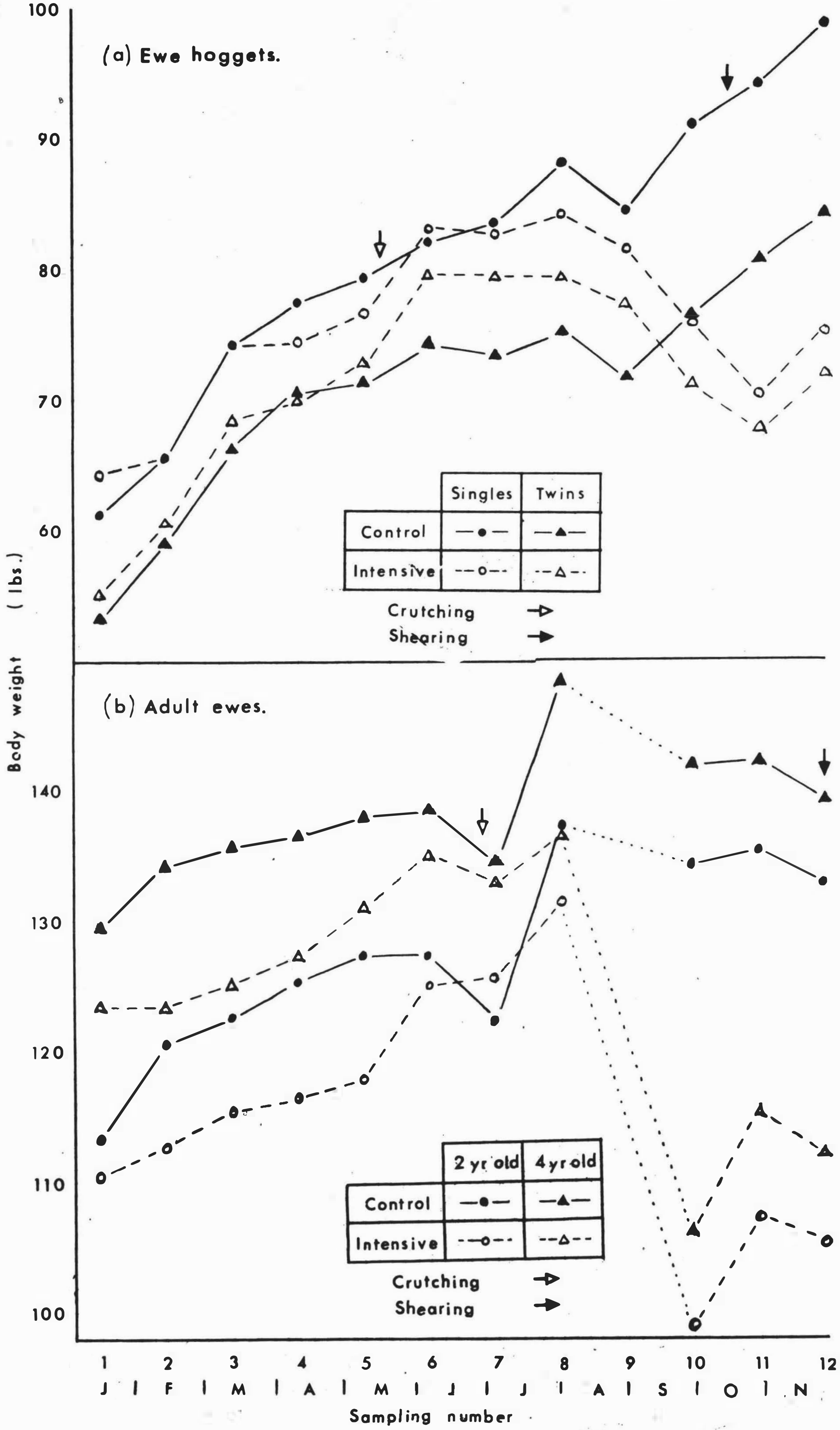


Fig. 4.1 — Seasonal variation in body weight.

Source	df	Sampling Number					
		1	2	3	4	5	6
Stocking Level	1	81.00	4.00	11.11	28.45	3.99	81.00
Birth Rank	1	560.11**	312.11*	400.00*	289.00*	300.44*	255.98
Stocking Level x Birth Rank	1	11.11	7.11	9.00	13.44	44.45	32.12
Residual	32	52.53	61.56	57.65	61.66	68.65	73.53

Source	df	Sampling Number					
		7	8	9	10	11	12
Stocking Level	1	49.00	0.44	13.44	971.35**	3043.36***	2686.69***
Birth Rank	1	427.10*	765.44**	658.77**	831.35**	600.25*	812.24***
Stocking Level x Birth Rank	1	75.12	128.44	169.01	200.71	261.36	330.03*
Residual	32	71.06	77.90	76.65	83.84	84.62	78.49

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.005$.

Table 4.2 - Ewe hogget body weight. Mean squares derived from an analysis of variance.

To test the validity of this step a comparison of within group regressions was also performed. The mean squares for these analyses are presented in Tables 4.3 and 4.4. The within group regression coefficients are significantly different in Samplings 10 and 12. A graphical analysis of the within group regressions at Samplings 10 and 12 was performed. Despite the 1% level of significance for Sampling 10 the stocking level effect means are accurately estimated though the birth rank effect means are biased to the extent of the birth rank effect being diminished. Similarly for Sampling 12 the stocking level effect means are accurately estimated while the birth rank effect is slightly overestimated.

The adjusted means are given in Table 4.5. Following the removal of the birth rank effect at the start of the trial it can be seen that the rates of growth have been comparable. Thus the single animals which are heavier at weaning (Chang 1967) remain the heaviest because both groups share a common growth rate. The significant stocking level effect at Samplings 4 and 6 is thought to be due to day to day grazing management within each unit. As a result of the heavy set-stocking of the Intensive hoggets from mid-August to early October the paddock was soon "eaten out". It is apparent from the table that during September these animals were relying very largely on their own body reserves to keep alive and were thus losing weight. The situation continued until the spring flush of growth started which was about the time they were released.

(ii) Ewe Hogget Wool Weight

The total weight of wool clipped from the patch was used as the criteria for the analysis of wool growth rather than the commonly used criteria of weight per unit area. A graph is presented, however, of trends in wool weight per unit area (Fig. 4.2 (a)). The area used in deriving

Source	df	Sampling Number					
		1	2	3	4	5	6
Btwn. Regression Coefficients	3	-	5.08	5.59	7.00	14.03	0.41
Individual	28	-	7.93	5.10	6.73	6.35	4.59

Source	df	Sampling Number					
		7	8	9	10	11	12
Btwn. Regression Coefficients	3	7.82	4.96	6.09	38.32**	5.53	17.83*
Individual	28	5.96	10.13	13.02	6.48	9.95	5.60

* $P < 0.05$; ** $P < 0.01$.

Table 4.3 - Ewe hogget body weight. Mean squares derived from a within group regression analysis of body weights adjusted for the previous sampling.

Source	df	Sampling Number					
		1	2	3	4	5	6
Stocking Level	1	-	48.49*	2.04	72.23***	11.26	120.51***
Birth Rank	1	-	30.15	11.32	4.25	0.11	1.30
Stocking Level x Birth Rank	1	-	36.34*	} 5.00	6.56	7.15	4.09
Residual	31	-	7.65				

Source	df	Sampling Number					
		7	8	9	10	11	12
Stocking Level	1	3.28	62.72*	18.35	1213.31***	534.85***	2.31
Birth Rank	1	28.15*	49.14*	0.02	16.84	68.14*	27.30
Residual	32	6.29	9.57	12.17	9.32	9.44	6.88

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.005$.

Table 4.4 - Ewe hogget body weight. Mean squares derived from an analysis of covariance of body weights adjusted for the previous sampling.

Sampling Number	Control		Intensive	
	Singles	Twins	Singles	Twins
1	-	-	-	-
2	64.0 lbs	64.1 lbs	59.6 lbs	63.7 lbs
3	71.3	69.9	71.6	70.6
4	74.5	75.1	71.4	72.4
5	75.1	74.0	75.2	76.1
6	77.8	78.6	81.8	81.9
7	81.5	78.5	79.9	79.1
8	84.7	81.3	81.2	79.7
9	78.9	77.8	79.4	80.1
10	85.5	83.8	73.4	72.7
11	82.8	82.9	73.4	75.2
12	84.3	81.2	82.9	82.0

Table 4.5 - Ewe hogget body weight. Group means adjusted for the previous sampling.

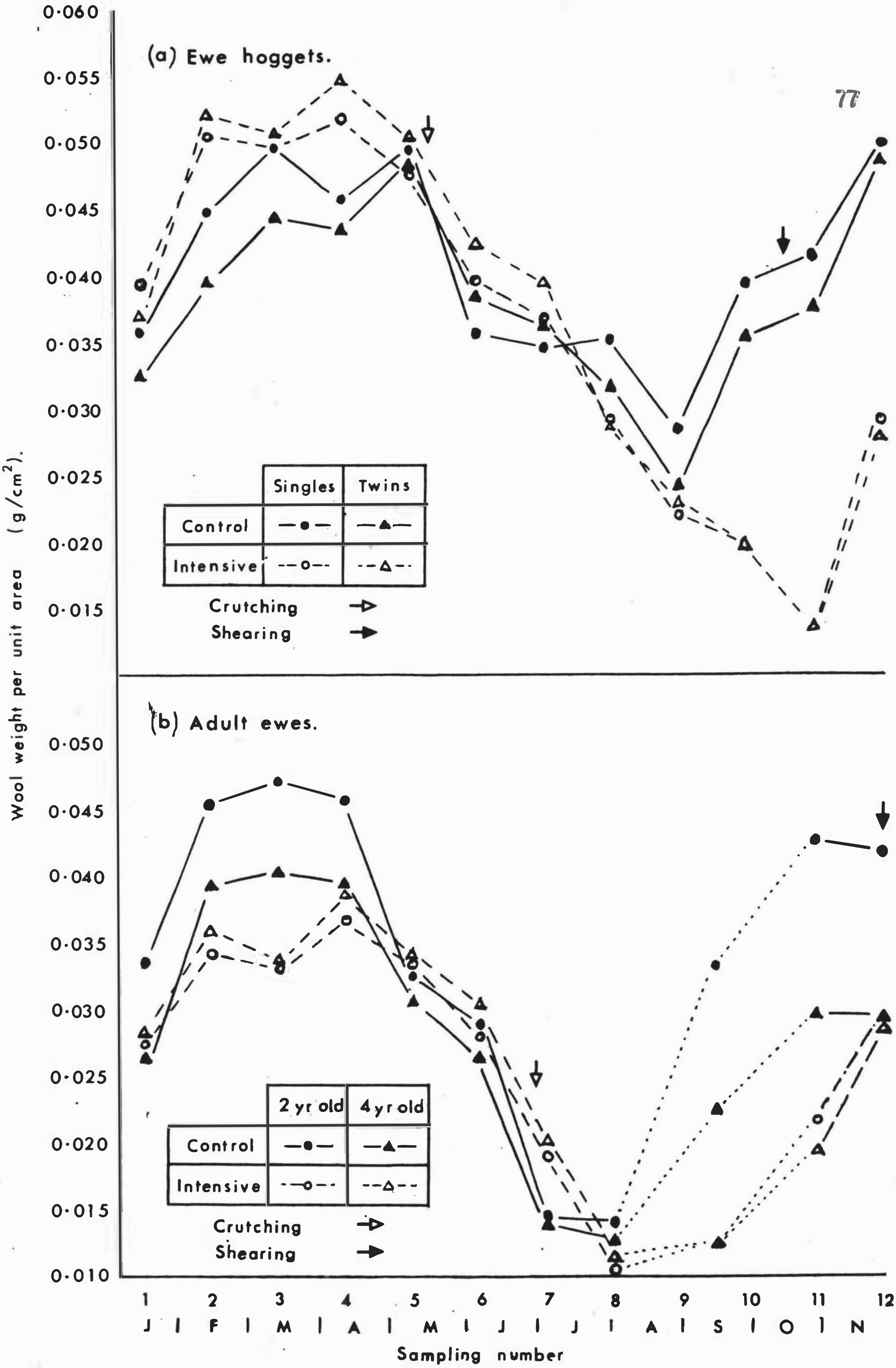


Fig 4.2 — Seasonal variation in wool weight per unit area.

this graph was the area of the patch as measured at the first sampling.

On account of the variability in the area of the clipped patches, particularly between samplings, but also between animals, an analysis of the unadjusted clipped weight of wool is without meaning. The within animal variability, arising from skin expansion as a result of natural growth, may be removed by adjustment of each sampling for an early sampling. Sampling 3 was used as the "base line" on account of a different method of scouring being used for the first two samplings. From an examination of the variability of areas within any group at each sampling it is clear that the between animal variability is unlikely to result in any bias being introduced.

The mean squares for the within group regression analysis for sample weights adjusted to Sampling 3 are given in Table 4.6. The between regression coefficient mean squares are all non-significant.

The mean squares for an analysis of covariance of sample weights adjusted to Sampling 3 are given in Table 4.7. The adjusted group means are given in Table 4.8. There is a pronounced seasonal rhythm of growth with a summer maximum and winter minimum. The results (in conjunction with the weight per unit area means plotted in Fig. 4.2 (a)) suggest that the period of maximum or near maximum wool growth may be maintained until the April-May period, or about a month later than is the case of the adult ewes. The period of reduced wool growth rate is associated with the plateauing of the body weight curve. The sudden drop in wool growth of the Control animals at Sampling 9 occurred at the same time as a drop in body weight when the animals were being fed a choumoellier crop for a short period.

The birth rank effect is not significant at any stage.

Source	df	Sampling Number					
		1	2	3	4	5	6
Btwn. Regression Coefficients	3	-	-	-	0.18	0.30	0.06
Individual	28	-	-	-	0.21	0.29	0.43

Source	df	Sampling Number					
		7	8	9	10	11	12
Btwn. Regression Coefficients	3	0.39	0.32	0.08	0.44	0.30	0.30
Individual	28	0.45	0.39	0.38	0.33	0.30	0.56

All non-significant.

Table 4.6 - Ewe hogget clean wool weight. Mean squares derived from a within group regression analysis of sample weights adjusted for Sampling 3.

Source	df	Sampling Number					
		1	2	3	4	5	6
Stocking Level	1	-	-	-	1.90**	0.95	0.09
Birth Rank	1	-	-	-	0.13	0.30	0.69
Residual	32	-	-	-	0.20	0.28	0.39

Source	df	Sampling Number					
		7	8	9	10	11	12
Stocking Level	1	0.00	3.57**	2.02*	26.82***	54.18***	41.20***
Birth Rank	1	0.56	0.09	0.13	0.02	0.01	0.06
Residual	32	0.43	0.37	0.35	0.33	0.29	0.52

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.005$.

Table 4.7 - Ewe hogget clean wool weight. Mean squares derived from an analysis of covariance of sample weights adjusted for Sampling 3.

Sampling Number	Control		Intensive	
	Singles	Twins	Singles	Twins
1	-	-	-	-
2	-	-	-	-
3	-	-	-	-
4	4.07g	4.20g	4.53g	4.67g
5	4.43	4.65	4.15	4.29
6	3.20	3.67	3.48	3.60
7	3.10	3.46	3.19	3.35
8	3.19	3.06	2.54	2.44
9	2.58	2.29	1.95	1.96
10	3.53	3.42	1.77	1.70
11	3.77	3.60	1.23	1.20
12	4.69	4.57	2.56	2.40

Table 4.8 - Ewe hogget wool weight. Group means adjusted for Sampling 3.

2. Adult Ewe Data

The adult ewes were not sampled at Sampling 9 due to lambing being in progress. The method of analysis of the data was the same as for the ewe hogget data.

(i) Adult Ewe Body Weight

The unweighted group means are plotted in Fig. 4.1. (b). The mean squares derived from an analysis of variance are given in Table 4.9. The results show, in absolute terms, the older ewes to be the heavier. During the winter and spring the difference is not significant. The Control animals are significantly heavier for the period following lambing before the spring flush of growth occurs.

The mean squares of a within group regression analysis of body weights adjusted for the previous sampling are given in Table 4.10. Significance is just attained for the between regression coefficient mean square for Sampling 8. A graphical analysis shows the stocking level effect for the adjusted means of the Intensive animals to be underestimated.

The mean squares for an analysis of covariance of body weights adjusted for the previous sampling are given in Table 4.11. The adjusted means are given in Table 4.12. Once the initial differences are removed the ewes all follow a similar growth curve until August. It is reasonable to assume that the stocking level differences are a carryover effect from the previous year, while the age effect difference is a genuine age effect with no carryover effects directly implicated. During June and July the body weight of the Intensive animals increased more quickly than the body weight of the Control animals. This was possibly an effect of hay feeding. However, from late July onwards the Intensive animals are forced to draw on their body reserves, particularly over lambing. It is

Source	df	Sampling Number					
		1	2	3	4	5	6
Stocking Level	1	141.60	765.77	684.63	660.43	527.29	72.13
Age	1	1668.90*	1187.78*	1039.52*	1009.68*	1110.84*	961.83
Residual	30	257.93	248.11	223.60	226.19	229.51	255.00

Source	df	Sampling Number					
		7	8	9	10	11	12
Stocking Level	1	1.96	667.63	-	10391.44***	6071.33***	6065.29***
Age	1	819.57	578.45	-	447.42	444.51	343.84
Residual	30	225.67	288.91	-	194.91	211.56	240.72

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.005$.

Table 4.9 - Adult ewe body weight. Mean squares derived from an analysis of variance.

Source	df	Sampling Number					
		1	2	3	4	5	6
Btwn. Regression Coefficients	3	-	30.30	3.78	8.00	3.54	3.38
Individual	25	-	23.18	15.88	14.45	5.13	8.59

Source	df	Sampling Number					
		7	8	9	10	11	12
Btwn. Regression Coefficients	3	3.89	56.86*	-	39.17	23.83	6.02
Individual	25	6.61	16.90	-	79.71	24.07	13.82

* $P < 0.05$

Table 4.10 - Adult ewe body weight. Mean squares derived from a within group regression analysis of body weights adjusted for the previous sampling.

Source	df	Sampling Number					
		1	2	3	4	5	6
Stocking Level	1	-	268.87***	0.26	0.34	5.98	216.99***
Age	1	-	10.93	0.00	0.65	2.45	10.80
Residual	29	-	23.13	14.13	13.91	5.34	9.10

Source	df	Sampling Number					
		7	8	9	10	11	12
Stocking Level	1	84.90***	739.64***	-	7712.29***	191.74**	3.59
Age	1	0.00	46.48	-	37.53	0.00	11.89
Residual	29	6.87	20.47	-	73.58	23.43	12.57

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.005$.

Table 4.11 - Adult ewe body weight. Mean squares derived from an analysis of covariance of body weights adjusted for the previous sampling.

Sampling Number	Control		Intensive	
	2 yr. old	4 yr. old	2 yr. old	4 yr. old
1	-	-	-	-
2	127.1 lbs	125.8 lbs	121.3 lbs	120.0 lbs
3	127.8	128.0	127.6	127.8
4	127.3	127.5	127.1	127.3
5	128.7	130.2	128.8	130.2
6	130.4	128.9	136.0	134.5
7	128.0	127.8	131.4	131.2
8	145.1	142.6	136.5	134.0
9	-	-	-	-
10	136.8	134.8	107.0	105.0
11	123.2	123.4	131.0	131.2
12	124.2	123.0	125.2	124.1

Table 4.12 - Adult ewe body weight. Group means adjusted for the previous sampling.

apparent that when the flush of growth comes in October the Intensive animals make the more efficient use of the available grass in the replenishment of their body reserves.

(ii) Adult Ewe Wool Weight

The unweighted group means of wool weight per unit area calculated from the area clipped at Sampling 1 are plotted in Fig. 4.2 (b). As Sampling 10 is the combination of Samplings 9 and 10, the mean $(\frac{\text{Sampling 9 + Sampling 10}}{2})$ is plotted, as the line joining the two samplings would pass through this point. This is also applicable to the case of fibre length.

The mean squares derived from a within group regression analysis of sample weights adjusted for Sampling 3 are given in Table 4.13. The between regression coefficients mean squares are all non-significant.

The mean squares derived from an analysis of covariance of sample weights adjusted for Sampling 3 are given in Table 4.14. The adjusted means are given in Table 4.15. It is clear from Fig. 4.2 (b) that the rate of wool growth starts to decline from March-April onwards - a month earlier than for the hoggets. A noticeable effect, substantiated by the covariance analysis, is the way the wool production of the Control animals decreases more rapidly than for the Intensive animals.

(iii) Adult Ewe Fibre Length

The unadjusted group means are plotted in Fig. 4.3. (a). The mean squares derived from an analysis of variance are given in Table 4.16. The significant interaction term for Sampling 6 is generated by the increase in length growth rate shown by the 2 year old Control animals. There is a definite seasonal rhythm in terms of length growth rate that is similar to that for wool weight. The general trend is for the Control animals to have a greater length growth rate than the Intensive animals.

Source	df	Sampling Number					
		1	2	3	4	5	6
Btwn. Regression Coefficients	3	-	-	-	0.59	0.39	0.50
Individual	25	-	-	-	0.25	0.13	0.22

Source	df	Sampling Number					
		7	8	9	10	11	12
Btwn. Regression Coefficients	3	0.28	0.18	-	1.47	0.77	0.31
Individual	25	0.16	0.08	-	1.30	0.53	0.47

All non-significant.

Table 4.13 - Adult ewe clean wool weight. Mean squares derived from a within group regression analysis of sample weights adjusted for Sampling 3.

Source	df	Sampling Number					
		1	2	3	4	5	6
Stocking Level	1	-	-	-	0.42	3.62***	2.02**
Age	1	-	-	-	0.11	0.08	4.03***
Residual	29	-	-	-	0.28	0.16	0.24

Source	df	Sampling Number					
		7	8	9	10	11	12
Stocking Level	1	2.73***	0.01	-	55.30***	2.67*	0.17
Age	1	0.02	0.03	-	4.78	1.60	0.32
Residual	29	0.17	0.09	-	1.51	0.57	0.47

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.005$.

Table 4.14 - Adult ewe clean wool weight. Mean squares derived from an analysis of covariance of sample weights adjusted for Sampling 3.

Sampling Number	Control		Intensive	
	2 yr. old	4 yr. old	2 yr. old	4 yr. old
1	-	-	-	-
2	-	-	-	-
3	-	-	-	-
4	3.92g	3.81g	4.17g	4.05g
5	2.75	2.85	3.59	3.69
6	2.47	2.53	3.07	3.13
7	1.28	1.30	2.00	2.02
8	1.16	1.22	1.18	1.24
9 } 10 }	2.73	2.34	1.05	0.65
11	3.48	3.01	2.71	2.24
12	3.43	3.01	3.44	3.02

Table 4.15 - Adult ewe wool weight. Group means adjusted for Sampling 3.

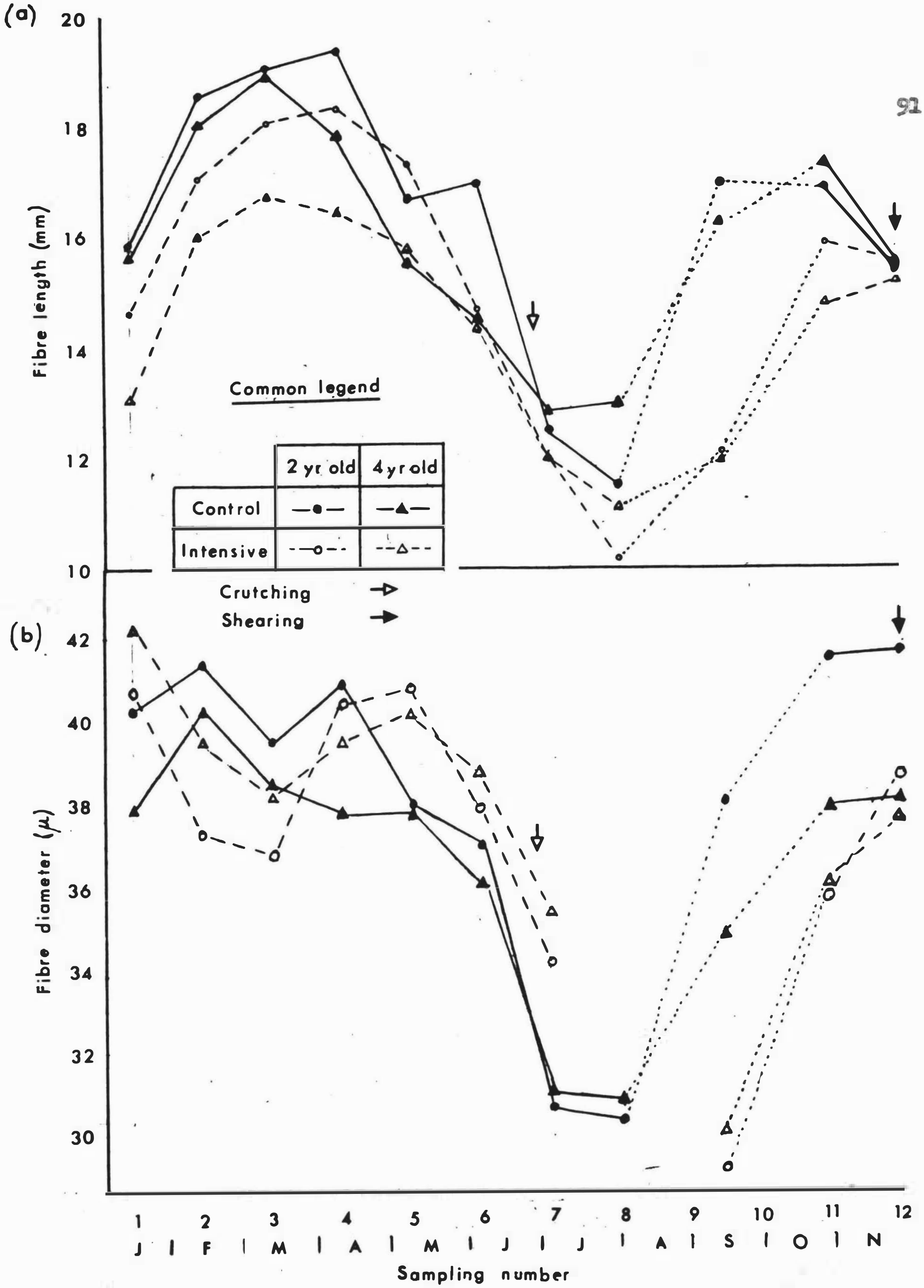


Fig. 4.3 — Seasonal variation in (a) adult ewe fibre length and (b) adult ewe fibre diameter.

Source	df	Sampling Number					
		1	2	3	4	5	6
Stocking Level	1	18.62***	16.20*	14.62**	7.32	1.86	7.81*
Age	1	2.96	3.04	2.38	14.96*	11.10*	9.11*
Stocking Level x Age	1	2.52	0.45	2.11	0.14	0.42	6.84*
Residual	16	0.60	2.18	1.46	3.06	1.41	1.35*

Source	df	Sampling Number					
		7	8	9	10	11	12
Stocking Level	1	2.11	12.17***	-	412.23***	15.49**	0.03
Age	1	0.22	7.20**	-	2.89	0.65	0.07
Stocking Level x Age	1	0.22	0.13	-	1.80	2.89	0.58
Residual	16	1.07	0.81	-	8.23	1.68	1.36

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.005$.

Table 4.16 - Adult ewe fibre length. Mean squares derived from an analysis of variance.

At times of maximum length growth rates the younger animals have the longer fibres, while at times of minimum growth rates they have the shorter fibres.

As neither fibre length nor fibre diameter would be influenced by the scouring technique the data on these attributes has been adjusted for Sampling 1. The mean squares derived from a within group regression analysis are given in Table 4.17. A graphical analysis for Sampling 10 shows the stocking level means to be accurately estimated by adjustment for Sampling 1. The adjusted age effect means are slightly overestimated.

The mean squares derived from an analysis of covariance of fibre lengths adjusted for Sampling 1 are given in Table 4.18. The adjusted means are given in Table 4.19. The significant interaction term in Sampling 6 generated by the 2 year old Control animals is still present. There is no biological explanation for this effect. The order of ranking in terms of stocking level during the autumn is, once the initial variability has been removed, similar to that for wool weight. During the autumn and winter the weight of wool clipped and the fibre length very closely approximate each other.

(iv) Adult Ewe Fibre Diameter

The unadjusted group means are plotted in Fig. 4. 3 (b). The mean diameter measured at Sampling 10 is in effect the mean of the combined Samplings 9 and 10 and is plotted as such. The mean squares derived from an analysis of variance are given in Table 4.20. There is no Sample 8 group mean available for the Intensive animals on account of the samples of wool being too small to use for an airflow estimation of fibre diameter. As in the case of fibre length there is a marked seasonal pattern. In addition there is a pronounced reduction in fibre diameter

Source	df	Sampling Number					
		1	2	3	4	5	6
Btwn. Regression Coefficients	3	-	5.20	2.55	4.46	0.51	1.62
Individual	12	-	1.08	0.69	1.15	1.16	1.23

Source	df	Sampling Number					
		7	8	9	10	11	12
Btwn. Regression Coefficients	3	1.40	0.85	-	25.58**	1.50	0.68
Individual	12	0.89	0.84	-	4.14	1.45	0.86

* $P < 0.05$; ** $P < 0.01$.

Table 4.17 - Adult ewe fibre length. Mean squares derived from a within group regression analysis of individual means adjusted for Sampling 1.

Source	df	Sampling Number					
		1	2	3	4	5	6
Stocking Level	1	-	0.19	0.00	5.50	14.37***	0.24
Age	1	-	0.07	0.00	5.13	8.99**	3.84
Stocking Level x Age	1	-					8.81*
Residual	15	-	1.81	0.99	1.89	0.99	1.31

Source	df	Sampling Number					
		7	8	9	10	11	12
Stocking Level	1	0.01	7.74**	-	146.04***	0.01	4.07*
Age	1	1.16	12.17***	-	11.05	0.59	0.13
Residual	16	0.94	0.79	-	8.21	1.14	0.80

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.005$.

Table 4.18 - Adult ewe fibre length. Mean squares derived from an analysis of covariance of individual means adjusted for Sampling 1.

Sampling Number	Control		Intensive	
	2 yr. old	4 yr. old	2 yr. old	4 yr. old
1	-	-	-	-
2	17.8 mm	17.3 mm	17.2 mm	17.3 mm
3	18.2	18.2	18.2	18.2
4	17.9	16.4	18.7	19.0
5	15.8	14.7	17.8	17.3
6	16.6	14.1	14.7	15.2
7	12.0	12.4	12.2	12.9
8	11.4	12.8	10.2	11.5
9 } 10 }	16.6	16.0	12.2	12.7
11	16.0	16.4	16.1	16.4
12	14.4	14.7	15.8	16.8

Table 4.19 - Adult ewe fibre length. Group means adjusted for Sampling 1.

Source	df	Sampling Number					
		1	2	3	4	5	6
Stocking Level	1	23.44	13.43	11.07	1.71	26.08	11.42
Age	1	0.75	0.01	0.10	17.09	0.38	0.00
Stocking Level x Age	1	16.29	20.58	5.81	5.07	0.16	2.99
Residual	16	12.19	14.27	9.47	9.07	5.81	7.72

Source	df	Sampling Number					
		7	8	9	10	11	12
Stocking Level	1	60.03*	-	-	184.16***	56.31*	12.01
Age	1	3.19	-	-	6.65	10.63	20.89
Stocking Level x Age	1	0.37	-	-	18.03	15.74	7.56
Residual	16	0.67	-	-	10.87	10.70	10.04

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.005$.

Table 4.20 - Adult ewe fibre diameter. Mean squares derived from an analysis of variance.

evident during March in all groups. The growth trend is otherwise similar to that of fibre length though delayed by a month. This result is in agreement with the work of Story and Ross (1960). It is quite clear that, except when the fibre diameter is reduced as a result of stress, the groups with the longer length growth rate are those with the coarser fibres.

The mean squares derived from a within group regression analysis of fibre diameters adjusted for Sampling 1 are given in Table 4.21. A graphical analysis for Sampling 10 shows the stocking level means and the 2 year old effect mean to be accurately estimated while the adjusted 4 year old mean is slightly overestimated.

The means derived from an analysis of covariance of fibre diameters adjusted for Sampling 1 are given in Table 4.22. The adjusted means are given in Table 4.23. The ranking is unaltered as a result of covariance.

Source	df	Sampling Number					
		1	2	3	4	5	6
Btwn. Regression Coefficients	3	-	5.90	14.66	5.67	3.71	8.52
Individual	12	-	4.81	3.11	1.84	2.37	3.10

Source	df	Sampling Number					
		7	8	9	10	11	12
Btwn. Regression Coefficients	3	10.19	-	-	10.96*	7.80	10.23
Individual	12	4.48	-	-	2.62	5.54	6.83

* $P < 0.05$

Table 4.21 - **Adult ewe fibre diameter.** Mean squares derived from a within group regression analysis of individual means adjusted for Sampling 1.

Source	df	Sampling Number					
		1	2	3	4	5	6
Stocking Level	1	-	57.98***	34.77*	4.62	7.06	0.49
Age	1	-	0.50	0.53	12.54*	0.02	0.19
Residual	16	-	4.76	5.08	2.47	2.83	3.94

Source	df	Sampling Number					
		7	8	9	10	11	12
Stocking Level	1	20.44	-	-	271.07***	105.22***	32.63
Age	1	5.80	-	-	4.91	8.21	17.87
Residual	16	5.52	-	-	4.11	5.72	7.07

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.005$.

Table 4.22 - Adult ewe fibre diameter. Mean squares derived from an analysis of covariance of individual means adjusted for Sampling 1.

Sampling Number	Control		Intensive	
	2 yr. old	4 yr. old	2 yr. old	4 yr. old
1	-	-	-	-
2	41.37	41.30	36.94	37.83
3	39.56	39.98	36.47	36.88
4	40.95	39.57	40.19	38.09
5	38.01	39.18	40.54	39.21
6	37.07	37.54	37.67	37.62
7	30.68	32.89	33.96	34.10
8	30.45	32.28	-	-
9, 10	38.11	36.54	28.96	28.61
11	41.56	39.55	35.61	34.95
12	41.76	39.33	38.58	36.79

Table 4.23 - Adult ewe fibre diameter. Group means adjusted for Sampling 1.

D: DISCUSSION

The results clearly demonstrate that a rhythm of wool growth, fibre length and fibre diameter exists under the conditions of this trial. The rhythm is characterized by a summer maximum and a winter minimum. The intensive stocking had no effect on the seasonal rhythm of wool growth in relation to the timing of the maximum and only a slight retarding effect on the timing of the minimum. The level of the minimum was also reduced. The adjusted means indicate that this reduction in the minimum wool growth has accentuated the magnitude of the rhythm of the Intensive sheep.

Many workers in the past have adopted the criteria of body weight as a gauge of the energy balance within an animal. Thus an animal losing weight is on a low or falling plane of nutrition and vice versa. Using this criteria it is apparent that the Intensive adult ewes of this study suffered a further retardation in the quantity and/or quality of available pasture during the early spring period over and above that experienced by both groups during the winter. The Intensive ewe hoggets most certainly suffered a severe reduction in available pasture while they were set stocked during lambing. Appearances suggested that there was a marked drop in the amount of pasture available to the Intensive adult ewes compared with the Controls in the early spring period. It is not possible to comment on the nutritive value of the available pasture. It is obvious that an increase of the number of animals per acre to a level such as were run on the Intensive area has a profound effect on the pattern of pasture availability by delaying the normal spring increase in pasture availability. The outcome of this delay in respect to wool growth is for the winter minimum to be depressed and prolonged. The feeding of a crop to sheep, in reasonable body condition but which are not accustomed to the practice, appears to have a sudden depressing effect on both wool growth and body weight. This depression is assumed to be the result of a period of adjustment during which time many animals refrain from feeding. The effect of crop feeding appears, in this study, to have magnified the low level of nutrition it was originally intended to prevent.

The study confirms that changes in fibre diameter occur later than the corresponding changes in fibre length as shown by Story and Ross (1960) and Ross (1965). The minimum value for fibre length occurred about a month before that for fibre diameter. The fibre diameter trends were similar to those of wool weight. The reduction in fibre diameter during the February-March period is reflected in terms of wool weight. The cause of this reduction in growth rate, presumably is nutrition in the December-January period. It may be due to the mature condition of pasture at this time with a high fibre content and low palatability. Changes in the rate of wool growth have been found to be related to the green fraction of pasture available (O.B. Williams 1964).

The time of onset of the autumn depression in the wool growth rate of the hoggets was in good agreement with observations on Drysdale ewe hoggets run under good grazing conditions at Massey University (Wickham - unpublished data). The results of Coop (1953) suggest that the effect of the plane of feeding on the time of onset of the period of reduced wool growth rate though slight for hoggets is of some magnitude for pregnant ewes. This may explain the results of Story and Ross (1960) where the wool growth fell away from March onwards for Romney ewes grazing at Invermay.

There were insufficient barren ewes in the sampling groups to carry out a valid statistical comparison of the effect pregnancy and subsequent lactation may have had on the winter and spring wool growth rate. A comparison of the ratio of minimum wool growth rate/maximum wool growth rate, between the ewe hogget and adult ewe data, though not strictly comparable, suggests that pregnancy has had a depressing effect on the minimum value. However, allowance must be made for both the extra stress imposed upon the Intensive ewe hoggets and the fact that adult ewe data for Sampling 9 is not available. This is in agreement with other New Zealand work (Coop 1953; Story and Ross 1960; Ross 1965). The timing of the increase in growth rate in the spring varies between stocking levels. There does not appear to be any effect due to either birth rank or age within each stocking level.

There is no evidence on which to base a judgment as to the effect of the onset of lactation on the spring rise of wool production for each stocking level.

The birth rank effect on the wool growth cycle for the ewe hoggets was only statistically significant when unadjusted means were analysed. This is indicative that differences are a carryover from the pre-weaning treatment and not a post-weaning effect due to the imposed treatment.

The overall effect due to age of ewes was for the older animals to be physically heavier and less sensitive to seasonal changes, this being most marked in the case of fibre length. As a general trend the older animals were much slower to recover in the spring. The observations are not in accord with Ross (1965) who reported that the percentage of the annual wool production grown in each of his four monthly sampling periods was approximately constant throughout the lifetime of the Romney ewes he studied. The overall response shown by both age groups, in this study, as a result of increased stocking was similar.

The effect of the stocking level on the wool growth of ewes carrying either a single or a twin lamb was not analysed on account of the small number of animals involved in each group.

CHAPTER 5

THE EFFECT OF TWO DIFFERENT GRAZING ENVIRONMENTS ON WOOL PRODUCTION AND FLEECE CHARACTERISTICS

A: INTRODUCTION

It is generally assumed that an increase in the stocking level will decrease the plane of nutrition of grazing sheep at certain times of the year, if not for all the year. It has been well established that the rate of wool growth is influenced by the plane of nutrition (Schinckel 1960, 1963). All the sheep stocking-rate trials carried out have shown an almost linear increase in per acre production, up to a ceiling value, associated with a fall off in the per head production.

A few Australian reports on the effect of increased stocking on wool characteristics (Roe, Southcott and Turner 1959; Sharkey, Davis and Kenney 1962; McManus, Arnold and Paynter 1964) suggest there may be a slight deterioration in "quality" with little or no influence on the auction price of the wool. There are indications from the limited New Zealand data available (Walker 1955; Collin 1966) that there are increases in unsoundness and cotting. The selling price does not however seem to have been affected.

There is little data available on correlations between fleece characteristics of the New Zealand Romney (Rae 1958; Ross 1964; Tripathy 1966).

The reported trial was designed to evaluate the effect of increased stocking levels on wool production and fleece characteristics

B: MATERIALS AND METHODS

The study was carried out using the fleeces from the adult ewes shorn in 1966 and ewe hoggets and adult ewes shorn in 1967. Data from all animals in both flocks was used. The number of animals in each of the adult ewe and hogget groups is given in Table 2.1.

1: Ewe Hogget Fleece Sampling

As a regular Massey University practice the weight per unit area of wool from the standard mid-side position is measured for the ewe hoggets of the flock from which the animals were obtained.

Prior to shearing the ewe hoggets are sampled on the right hand side standard mid-side position. The same sampling technique is used as described in Chapter 4 - B.2. In 1967 the ewe hoggets which had been monthly sampled (Chapter 4) throughout the year using the right hand side mid-side position were sampled instead on the left hand side. The remainder of the group were sampled on the right hand side. No allowance was made for the side from which the sample was taken. The "hogget shearing" skin sample (Chapter 3) was also taken at this time.

Although 93 ewe hoggets from the intensive group were shorn the data from two animals was rejected on account of loss of the animals' ear identification tag.

2: Shearing

Prior to shearing all adult ewes were marked on the right hand side in 1966 and the left hand side in 1967 at the standard mid-side position with coloured raddle. This procedure allows identification of the mid-side area when the fleece is on the skirting table.

After shearing both ewe hogget and adult fleeces were thrown and weighed on a fleece weighing table. Prior to a light skirting the fleece was graded, on the extent of ootting and discolouration throughout the fleeoe. Grading scales of from 1 (inferior) to 9 (superior) were used. Descriptions of the scales are given in Appendix III. The raddle-marked mid-side sample was removed from the adult ewe fleeces and stored in a plastic bag. These samples along with those clipped from the ewe hoggets were later used for fleece characteristic grading. The fleeces were then rolled in the usual manner and pressed.

Both the ewe hoggets and the adult ewes were body weighed within a week of shearing.

At the 1967 crutching (Hoggets - May, Ewes - June) the individual crutchings were weighed by means of a spring balance and fleece weighing cradle. The weight of crutchings was later added to the fleece weights recorded at the 1967 shearing.

3: Pre-Scouring Fleece Characteristic Grading

The fleece mid-side samples from both the ewe hoggets and the adult ewes were assessed by an Instructor from the Massey University Wool Department and graded for various characteristics. The descriptions, where applicable, are given in Appendix III. The characteristics assessed were :-

(i) Character
(ii) Colour (unscoured)
(iii) Cotting
(iv) Crimps per inch
(v) Handle
(vi) Lustre
(vii) Quality Number
(viii) Soundness

(ix) Staple length (cms)

(x) Tippiness

The grading system was over the range 1 (inferior) to 9 (superior) and was such that the extremes would seldom be attained. This type of grading system allows a normal distribution to form within a population.

4: Scouring

The mid-side samples were weighed greasy after being conditioned to 68°F and 65% relative humidity for 48 hours. They were teased and scoured using a four bowl detergent and water scouring method. After emerging from the last bath the samples were 'spin dryed' before being dried in a blast of hot air. The samples were again allowed to condition for 48 hours before reweighing. The yield was calculated.

5: Post-scouring Fleece Characteristic Grading

Following scouring all samples were assessed for colour (scoured) using the same standards as for colour (unscoured) (Appendix III).

6: Fibre Diameter Estimation

The fibre diameter of the ewe hogget fleeces was estimated by the projection microscope technique on a mid-side sub-sample.

The mean fibre diameter of the adult ewe samples was estimated by the airflow technique (Anderson 1954). The diameter was estimated as the mean of two readings on one sub-sample.

7: Statistical Techniques

The statistical models used for an analysis of variance are given in Chapter 3, Section B5.

C: RESULTS

For purposes of statistical analysis the quality number was coded to a simple continuous scale (46's - 3; 46/48's - 4) and converted back for the presentation of the results.

1. Ewe Hogget Data

The unweighted group means of each of the fleece characteristics studied are given in Table 5.1 (a). The post shearing body weight of the animals is also given. The fleece weight includes crutchings. The mean squares derived from an analysis of variance are given in Table 5.2(a).

It is quite clear that there was a very pronounced stocking level effect on body weight at shearing (Chapter 4). This body weight difference had a pronounced effect on the fleece weight with the Intensive fleece weight being depressed. The Intensive animals however had a higher mean for the weight of wool per unit area. If allowance is made for the logarithmic relationship between body weight and surface area it is apparent that this anomaly is due to the greater surface area of the Control animals. In real terms the Intensive animals have a lower follicular output.

The only subjective fleece characteristics which showed a significant stocking level effect were the two subjective estimates of the extent of discolouration to the unscoured fleece. The Intensive fleeces had a slightly smaller area of discolouration as well as the mid-side samples being superior in the extent of their discolouration. The colour grading after scouring was approaching significance ($P < 0.1$) with the Intensive fleeces exhibiting less permanent discolouration. The stocking level effect for yield approached significance ($P < 0.1$) with the trend being for the Control animals to have a slightly higher yield.

(a) Ewe Hoggets 1967

Unit	Fleece Weight	Weight per Unit Area	Quality Number	Crimps per inch	Staple Length	Tippiness	Lustre	Handle	Character	Yield	Soundness	Cotted Area	Cotting Side	Discoloured Area	Colour (Unscoured)	Colour (Scoured)	Body Weight
	Fleece Characteristics																
Control	9.7 lbs	0.33 g/cm^2	48's	2.31	14.4 cms	7.0	5.2	6.1	5.5	78.0 %	7.4	6.1	7.0	6.2	6.7	5.8	88.1 lbs
Intensive	8.4	0.36	"	2.25	14.4	7.0	5.2	6.1	5.7	76.9	7.6	6.1	7.0	6.4	7.3	6.0	65.7

(b) Adult Ewes 1966

Unit	Age	Fleece Weight	Fibre Diameter	Quality Number	Crimps per inch	Staple Length	Tippiness	Lustre	Handle	Character	Yield	Soundness	Cotted Area	Cotting Side	Discoloured Area	Colour (Unscoured)	Colour (Scoured)	Body Weight
		Fleece Characteristics																
Control	2 yr. old	10.5 lbs	37.6 μ	46/8's	2.36	18.4 cms	5.9	5.6	4.5	5.4	76.6 %	5.8	5.4	5.4	5.4	6.4	6.4	111.4 lbs
	3 yr. old	9.9	38.4	"	2.25	15.5	6.2	5.4	4.6	5.0	73.5	6.3	6.3	5.9	6.0	6.5	6.6	122.0
	4 yr. old	9.2	39.6	"	2.23	14.8	6.3	5.5	4.4	5.0	73.7	6.2	5.7	5.7	5.7	6.5	6.3	124.7
	5 yr. old	9.1	38.4	"	2.18	14.3	6.3	5.4	4.4	4.4	72.1	6.0	5.7	5.7	5.7	6.5	6.6	120.4
Intensive	2 yr. old	11.6 lbs	38.8	46/8's	2.39	18.4 cms	6.4	5.6	4.6	5.9	77.8%	6.5	5.7	5.5	5.7	6.6	6.4	107.7 lbs
	3 yr. old	10.7	39.6	"	2.28	15.9	6.3	5.4	4.7	5.1	75.1	6.4	6.1	6.1	6.0	6.8	6.7	124.0
	4 yr. old	9.9	39.8	"	2.23	15.1	6.4	5.5	4.7	5.0	74.5	6.0	5.7	5.8	5.8	6.4	6.6	125.1
	5 yr. old	9.2	39.3	"	2.14	14.1	6.4	5.2	4.6	4.4	71.9	6.2	5.7	5.9	6.0	6.6	6.4	115.7

(c) Adult Ewes 1967

Unit	Age	Fleece Weight	Fibre Diameter	Quality Number	Crimps per inch	Staple Length	Tippiness	Lustre	Handle	Character	Yield	Soundness	Cotted Area	Cotting Side	Discoloured Area	Colour (Unscoured)	Colour (Scoured)	Body Weight
		Fleece Characteristics																
Control	2 yr. old	13.8 lbs	-	46/8's	1.96	17.5 cms	7.0	5.2	4.8	5.5	77.0 %	4.7	5.7	6.6	5.7	6.9	6.2	124.9 lbs
	3 yr. old	12.0	-	"	1.72	15.5	6.4	5.4	4.9	4.6	75.5	5.5	5.9	6.9	5.8	7.1	6.2	129.4
	4 yr. old	12.0	-	"	1.79	14.2	7.1	5.3	5.0	4.5	74.4	5.6	6.1	6.9	5.8	6.9	6.2	134.1
	5 yr. old	10.9	-	"	1.68	13.9	7.0	5.4	4.5	4.4	73.7	5.9	5.8	6.7	5.6	6.6	6.0	129.5
Intensive	2 yr. old	12.8 lbs	-	6's	1.87	16.9 cms	5.6	5.7	4.6	5.2	78.7 %	4.3	5.7	6.3	5.8	6.5	5.9	101.5 lbs
	3 yr. old	11.4	-	"	1.70	15.4	5.2	5.8	4.4	4.4	76.2	5.5	6.0	6.4	5.9	6.5	5.7	109.8
	4 yr. old	10.6	-	"	1.82	13.9	5.3	5.6	4.7	4.3	74.2	5.1	6.0	6.7	5.9	6.2	5.9	109.2
	5 yr. old	9.7	-	"	1.78	13.7	5.4	5.7	4.6	4.3	74.1	5.4	5.8	6.4	5.7	6.2	5.8	109.2

Table 5.1 - Unweighted group means

Within group correlations were calculated for all possible combinations of the available fleece characteristics including body weight. No correction factors were used. The correlations are given in Table 5.3. Tables are given to enable the testing of the two essential hypotheses of (a) whether ρ is significantly different from zero and (b) whether two sample values of γ are drawn at random from the same population. The correlation differences given for testing (b) were obtained by a t-test following a "z" transformation. It is clear that there are a large number of correlations not significantly different from zero. The calculated correlations are in good agreement with the phenotypic correlations calculated for Romney hoggets by Rae (1958) and Tripathy (1966). Rae reported a significant negative (-0.33) correlation between fleece weight and quality number. No significant correlation was obtained in this study. The correlations of "fleece quality" with other characters as reported by Rae are sufficiently different from those in this study to suggest that though character and "fleece quality" are similar they are probably not the same.

Some correlations were significantly affected by the stocking level. When there was an effect it was normally the Control animals which showed the stronger relationship. In general the changed relationship involved the subjectively assessed characteristics of character, handle and soundness. The changed inter-relationship involving measured characteristics were related to the difference in body weight and fleece weight between the two stocking levels.

2: Adult Ewe Data

(i) 1966 Data

The unweighted group means of each age group for each of the

(a) Ewe Hoggets 1967

Source	df	Fleece Characteristics: Fleece Weight	Weight per Unit Area	Quality Number	Crimps per Inch	Staple Length	Tippiness	Lustre	Handle	Character	Yield	Soundness	Cotted Area	Cotting Side	Discoloured Area	Colour (Unscoured)	Colour (Scoured)	Body Weight
Stocking Level	1	80.02***	0.079***	3.55	0.22	0.05	0.24	0.05	0.26	3.15	70.00	1.58	0.14	0.07	1.85*	16.67***	2.20	27,495.90***
Residual	226	1.52	0.003	2.12	0.39	2.98	1.60	0.92	0.79	1.38	21.30	1.09	0.34	0.24	0.40	1.13	0.65	92.93

(b) Adult Ewes 1966

Source	df	Fleece Characteristics: Fleece Weight	Fibre Diameter	Quality Number	Crimps per Inch	Staple Length	Tippiness	Lustre	Handle	Character	Yield	Soundness	Cotted Area	Cotting Side	Discoloured Area	Colour (Unscoured)	Colour (Scoured)	Body Weight
Stocking Level	1	48.81***	74.83***	0.35	0.00	1.45	3.84**	0.25	3.73*	1.42	80.50	4.09	0.10	2.28*	3.50*	3.44*	0.10	249.50
Age	3	71.88***	45.94**	1.94	0.85**	368.64***	1.39	2.05	0.30	26.67***	498.00***	1.87	8.22***	5.43***	3.58***	0.35	1.25*	4,898.93***
Residual	431	2.04	6.46	2.03	0.21	2.92	0.55	1.04	0.57	0.74	25.19	1.30	0.70	0.56	0.67	0.76	0.39	208.84

(c) Adult Ewes 1967

Source	df	Fleece Characteristics: Fleece Weight	Fibre Diameter	Quality Number	Crimps per Inch	Staple Length	Tippiness	Lustre	Handle	Character	Yield	Soundness	Cotted Area	Cotting Side	Discoloured Area	Colour (Unscoured)	Colour (Scoured)	Body Weight
Stocking Level	1	120.92***	-	31.93***	0.00	12.13*	232.58***	15.16***	5.37*	4.21*	47.90	11.77*	0.09	10.07***	1.61	30.12***	12.05***	51,934.80***
Age	3	167.39***	-	1.58	1.02***	269.47***	4.77*	0.89	1.56	25.53***	360.57***	29.29***	2.03**	1.97*	0.89	3.52***	0.58	1,520.50**
Residual	425	2.71	-	1.57	0.19	2.96	1.46	0.94	1.06	0.90	15.40	2.91	0.51	0.52	0.45	0.51	0.44	202.[illegible]

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.005$;

Table 5.2 - Mean squares derived from an analysis of variance

fleece characteristics studied are given in Table 5.1 (b). The post-shearing body weight of the animals is also given. The fleece weight does not include crutchings. The 2 year old fleece weights are not strictly comparable with the other age groups as the hogget shearing (when the animals were last shorn) is normally 6 weeks prior to the main ewe shearing. The mean squares derived from an analysis of variance are given in Table 5.2 (b).

Body weight shows a significant age effect. There is a pronounced trend for the animals to increase in weight until 4 years of age after which there is a marked decrease. The fleece weight shows a highly significant trend for both stocking level and age effects. The mean fleece weights of the Intensive animals are heavier at all ages than the Controls. When the extra fleece grown by the 2 year old animals is allowed for, there are marked age trends with fleece weight reaching a maximum at 3 years of age. There are also significant stocking level and age effects for fibre diameter. The Intensive animals had the coarser fibres. The age trend is for fibre diameter to be coarsest at 4 years of age whereafter it decreases. The age trends as shown for body weight, fleece weight and fibre diameter are in close agreement with those of Ross (1965). Crimps per inch, staple length and yield, all of which do not show any significant stocking level effect, show a definite decrease with age. The two measures of cotting and also the extent of discolouration show an age trend with maximum values as a 3 year old. Tippiness, handle and colour (unscoured) are the only characters for

(a) Layout of data within Table 5.3

		Year
		1967
Unit	Control	xx
	Intensive	xx

(b) To test $H_0 : \rho = 0$

for Control $P_{0.05}$ $r = 0.17$; $P_{0.01}$ $r = 0.23$

Intensive $P_{0.05}$ $r = 0.21$; $P_{0.01}$ $r = 0.27$

(c) To test hypothesis that two sample values of r are drawn at random from the same population.

Range for lower value irrespective of sign	Minimum value for difference for hypothesis to be rejected		
	P 0.05	P 0.01	P 0.005
0 - 0.2	0.26	0.35	0.37
0.2 - 0.3	0.24	0.33	0.35
0.3 - 0.4	0.22	0.30	0.32
0.4 - 0.5	0.20	0.27	0.29
0.5 - 0.6	0.18	0.25	0.27
0.6 - 0.7	0.16	0.23	0.25
0.7 - 0.8	0.15	0.20	0.22

Explanation of Table 5.3

	Fleece Weight	Quality Number	Crimps per Inch	Staple Length	Tippi-ness	Lustre	Handle	Character	Yield	Soundness	Cotted Area	Cotting Side	Discoloured Area	Colour (Unscoured)	Colour (Scoured)	Weight per Unit Area
Body Weight	0.52 0.50	0.10 0.08	0.04 0.17	0.18 0.01	0.18 0.16	-0.11 -0.04	0.05 0.01	0.26 0.21	0.06 0.11	0.29 0.11	0.28 0.07	0.25 0.08	0.11 -0.01	0.33 -0.06	0.09 -0.30	0.12 0.01
Fleece Weight		-0.07 -0.03	-0.08 0.07	0.51 0.22	0.02 0.18	0.00 0.07	-0.35 -0.32	0.12 0.22	0.29 0.17	0.27 0.26	0.17 0.06	0.23 -0.10	0.03 -0.11	0.03 -0.06	-0.15 -0.26	0.65 0.60
Quality Number			0.83 0.75	-0.49 -0.46	0.54 0.51	-0.74 -0.83	0.43 0.15	0.58 0.39	-0.45 -0.19	-0.16 -0.07	0.28 0.04	0.23 0.20	0.30 0.04	0.15 0.02	0.09 -0.04	-0.20 -0.21
Crimps per Inch				-0.55 -0.40	0.57 0.54	-0.66 -0.62	0.43 0.21	0.61 0.56	-0.35 -0.18	-0.13 -0.07	0.21 0.21	0.25 0.36	0.22 0.03	0.08 -0.03	0.04 -0.08	-0.16 -0.03
Staple Length					-0.47 -0.41	0.38 0.37	-0.43 -0.13	-0.26 -0.11	0.39 0.18	0.32 0.22	-0.09 0.05	-0.02 -0.02	-0.04 0.03	0.13 0.25	0.04 0.14	0.57 0.35
Tippiness						-0.32 -0.32	0.34 0.14	0.66 0.67	-0.11 0.04	-0.08 0.06	0.16 0.21	0.21 0.28	0.12 0.09	0.11 0.07	0.05 -0.01	-0.06 0.13
Lustre							-0.19 -0.06	-0.24 -0.12	0.36 0.12	0.06 0.16	-0.20 0.03	-0.21 -0.11	-0.17 0.05	-0.17 -0.10	-0.08 0.00	0.12 0.17
Handle								0.41 0.11	-0.35 -0.12	0.03 -0.24	0.13 0.11	0.21 0.21	0.19 0.16	0.16 0.05	0.14 0.20	-0.46 -0.22
Character									-0.16 -0.02	0.03 0.15	0.33 0.37	0.32 0.52	0.20 0.01	0.17 0.14	0.15 0.08	0.02 0.24
Yield										0.14 0.02	-0.12 -0.07	-0.07 0.10	-0.11 -0.01	-0.03 0.30	0.03 0.21	0.47 0.40
Soundness											0.16 0.01	0.13 0.09	0.05 0.04	0.25 -0.02	0.24 0.04	0.08 0.18
Cotted Area												0.42 0.39	0.43 0.40	0.18 0.28	0.15 0.18	-0.01 0.12
Cotting Side													0.25 0.08	0.25 0.21	0.06 0.21	0.10 0.07
Discoloured Area														0.24 0.32	0.28 0.26	-0.09 -0.01
Colour (Unscoured)															0.62 0.60	-0.08 0.25
Colour (Scoured)																-0.13 0.16

Table 5.3 - Correlations between the fleece characteristics of the 1967 ewe hoggets.

which there is a significant stocking level effect with no apparent age trends. In all three cases the Intensive animals are superior.

As in the case of the hoggets, within group correlations were calculated for all possible combinations of the available fleece characteristics including body weight. The sums of squares used in the calculation were weighted with respect to the number of animals in each age group. The correlations between the fleece characteristics are given in Table 5.4. A similar table of explanation is given to that for the hogget data (Table 5.3).

(ii) 1967 Data

The unweighted group means of each age group for each of the fleece characteristics studied are given in Table 5.1 (c). The post-shearing body weight of the animals is also given. The fleece weight includes crutchings. As in the case of the 1966 data the 2 year old fleece weights are not strictly comparable. The mean squares derived from an analysis of variance are given in Table 5.2 (c).

It is noticeable that all but four characteristics show a significant stocking level effect indicating that increasing the stocking level to that of the Intensive unit in 1967 induced effects in the fleece characteristics of the animals concerned. Similar age trends were shown by body weight and fleece weight in 1967 to those observed in 1966. There was a highly significant stocking level effect in both cases with the Control animals, this time being superior. The mean quality number of the Intensive animals shows them to be

	Fleece Weight	Fibre Diameter	Quality Number	Crimps per Inch	Staple Length	Tippiness	Lustre	Handle	Character	Yield	Soundness	Cotted Area	Cotting Side	Discoloured Area	Colour (Unscoured)	Colour (Scoured)
Body Weight	0.49 0.42 0.27 0.43	0.12 - 0.18 -	0.04 0.10 0.14 0.07	0.08 0.08 0.16 0.02	0.10 0.13 0.09 0.17	0.00 0.08 -0.04 0.10	0.02 -0.07 -0.20 -0.01	0.00 -0.03 -0.03 -0.03	0.08 0.15 -0.03 0.13	0.07 0.06 0.12 -0.13	0.16 0.05 0.03 0.13	0.10 0.21 0.11 0.01	0.17 0.09 0.04 0.04	0.13 0.02 0.12 -0.04	-0.05 -0.02 -0.05 -0.08	0.05 -0.07 -0.05 0.15
Fleece Weight		0.45 - 0.43 -	-0.21 -0.18 -0.31 -0.30	-0.08 -0.13 -0.16 -0.16	0.39 0.30 0.36 0.38	-0.04 0.03 -0.09 0.01	0.27 0.11 0.27 0.28	-0.18 -0.26 -0.41 -0.31	0.17 0.18 0.05 -0.01	0.17 0.14 0.27 0.16	0.33 0.23 0.28 0.36	0.08 0.04 -0.07 -0.05	0.22 0.04 -0.10 -0.05	-0.13 -0.23 -0.12 -0.11	0.01 0.00 -0.13 0.07	-0.12 -0.18 -0.17 -0.08
Fibre Diameter			-0.50 - -0.50 -	-0.47 - -0.39 -	0.41 - 0.39 -	-0.17 - -0.04 -	0.42 - 0.36 -	-0.48 - -0.63 -	-0.05 - -0.05 -	0.23 - 0.42 -	0.27 - 0.11 -	0.14 - 0.17 -	0.18 - 0.17 -	0.05 - 0.06 -	-0.03 - -0.20 -	-0.09 - -0.15 -
Quality Number				0.70 0.68 0.70 0.65	-0.52 -0.42 -0.46 -0.52	0.39 0.40 0.34 0.40	-0.73 -0.76 -0.84 -0.69	0.47 0.65 0.51 0.64	0.10 0.28 0.08 0.38	-0.22 -0.31 -0.32 -0.27	-0.28 -0.33 -0.17 -0.31	0.18 0.32 0.21 0.11	0.15 0.34 0.16 0.34	0.11 0.29 0.25 0.14	0.03 0.11 0.17 -0.09	0.11 0.11 0.09 0.17
Crimps per Inch					-0.47 -0.41 -0.53 -0.49	0.34 0.47 0.30 0.33	-0.53 -0.49 -0.60 -0.48	0.37 0.62 0.42 0.45	0.17 0.49 0.11 0.37	-0.20 -0.27 -0.32 -0.17	-0.21 -0.16 -0.08 -0.16	0.21 0.30 0.13 0.08	0.13 0.37 0.10 0.23	0.11 0.26 0.12 0.03	-0.02 0.11 0.09 -0.08	0.05 0.08 0.08 0.11
Staple Length						-0.39 -0.31 -0.24 -0.25	0.45 0.36 0.45 0.42	-0.25 -0.27 -0.41 -0.38	-0.04 -0.05 0.05 -0.10	0.22 0.33 0.31 0.21	0.27 0.29 0.13 0.41	-0.06 0.01 -0.05 -0.07	-0.11 -0.21 -0.15 -0.28	-0.12 -0.02 -0.04 0.09	0.09 0.08 -0.06 0.21	-0.05 -0.02 -0.12 -0.16
Tippiness							-0.17 -0.16 -0.23 -0.19	0.27 0.32 0.19 0.34	0.37 0.62 0.34 0.62	0.02 -0.03 0.04 -0.04	-0.05 0.07 -0.01 -0.01	0.08 0.15 0.11 0.07	0.15 0.34 0.20 0.44	0.01 0.15 0.05 -0.02	-0.08 0.19 -0.04 0.08	-0.04 0.02 -0.10 0.09
Lustre								-0.28 -0.39 -0.39 -0.45	0.28 0.03 0.14 -0.13	0.26 0.29 0.32 0.22	0.28 0.34 0.11 0.32	-0.11 -0.21 -0.19 -0.04	-0.11 -0.20 -0.08 -0.21	-0.08 -0.18 -0.15 -0.17	0.01 0.03 -0.02 0.09	-0.09 -0.08 -0.11 -0.10
Handle									0.12 0.30 0.12 0.38	-0.08 -0.25 -0.39 -0.17	-0.13 -0.22 -0.12 -0.29	0.07 0.18 0.10 0.13	0.08 0.29 0.10 0.30	0.04 0.21 0.09 0.11	-0.02 0.14 0.16 0.04	0.17 0.14 0.21 0.10
Character										0.21 0.09 0.20 0.02	0.13 0.11 0.14 0.04	0.12 0.25 0.23 0.18	0.20 0.37 0.26 0.44	0.11 0.09 0.23 0.07	0.12 0.16 0.21 0.16	0.03 -0.02 -0.02 0.08
Yield											0.14 0.22 0.17 0.32	0.00 0.04 0.21 0.07	0.02 -0.02 0.12 -0.03	0.12 0.04 0.15 0.17	0.06 0.25 0.16 0.29	-0.14 0.00 -0.04 -0.15
Soundness												0.20 -0.09 0.11 0.32	0.21 -0.03 0.05 0.05	0.01 -0.09 0.03 0.16	0.01 0.06 0.00 0.15	-0.05 -0.13 -0.03 -0.10
Cotted Area													0.53 0.39 0.53 0.44	0.50 0.39 0.61 0.41	-0.01 0.17 0.21 0.13	0.24 0.20 0.11 -0.03
Cotting Side														0.28 0.31 0.47 0.21	0.18 0.36 0.11 0.10	0.25 0.20 0.04 -0.01
Discoloured Area															0.11 0.40 0.39 0.37	0.20 0.24 0.24 0.04
Colour (Unscoured)																0.22 0.35 0.20 0.00

Table 5.4 - Correlations between the fleece characteristics of the adult ewes

(a) Layout of data within Table 5.4

		Year	
		1966	1967
Unit	Control	xx	xx
	Intensive	xx	xx

(b) To test $H_0 : \rho = 0$

for all data $P_{0.05}$ $r = 0.14$

$P_{0.01}$ $r = 0.18$

(c) To test hypothesis that two sample values of r are drawn at random from the same population

Range for lower value irrespective of sign	Minimum value for difference for hypothesis to be rejected		
	P 0.05	P 0.01	P 0.005
0 - 0.2	0.18	0.25	0.26
0.2 - 0.3	0.17	0.23	0.24
0.3 - 0.4	0.16	0.21	0.22
0.4 - 0.5	0.15	0.19	0.20
0.5 - 0.6	0.14	0.17	0.18
0.6 - 0.7	0.12	0.15	0.16
0.7 - 0.8	0.11	0.14	0.15

Explanation of Table 5.4

coarser. As no fibre diameter estimates were available it was not possible to decide if this was a real effect of a coarser fibre. This would be unlikely (Chapter 4). The crimps per inch, which are much lower than the 1966 values (different assessor), do not show a stocking level effect. The staple length and yield age trends are similar in both years with staple length also showing a stocking level effect. Soundness shows an age effect with no clear trend. The age trends for the cotting and colour gradings are unclear compared with trends shown in 1966. Tippiness, lustre and handle all showed significant stocking level effects which are reflected in the lower character gradings of the Intensive animals. As in 1966 there is a marked age trend for character with the older animals growing a plainer type of wool.

The correlations between the fleece characteristics are given in Table 5.4. They are given in conjunction with those for the 1966 data. As in the case of the 1966 data the sums of squares used in the calculation were weighted with respect to the number of animals in each age group. The calculated correlations are in good agreement with those of Ross (1964) and Wickham et al (pers. comm.) except for those relationships involving character. A similar explanation could be offered to that given for the hogget data. There is a considerable amount of variability between years despite the large number of animals involved. The relationship between measured characteristics were relatively constant. There were no relationships which were significantly affected by a stocking level effect in both years. Where there were significant year effects the 1967 data appeared to be more strongly related. The variability was most apparent for character, mid-side cotting and to a lesser extent, handle. A comparison of the between year means for these characteristics shows only character to have changed to any extent with the 1967 wool being plainer. It would seem therefore that the relationship of these characteristics with others is modified by seasonal conditions.

The strongest correlation is that between lustre and quality number. Lustre is one of the characters, along with handle, crimps per inch and staple length which are assessed when a quality number is placed on a wool sample. Lustre is also strongly correlated with fibre diameter and crimps per inch. Though there is a moderate relationship between the area of cotting and the extent of cotting on the mid-side there is no relationship between soundness and cotting for the mid-side sample. The three colour gradings are essentially unrelated to all characteristics other than cotting. Some degree of positive relationship was apparent between yield and fibre diameter or quality number. This trend is known and used by wool buyers in their assessment of yield. Moderate relationships were present in the trends of staple length, lustre, tippiness and handle with fibre fineness. The strength and direction of the relationship varied as to whether fibre diameter, quality number or crimps per inch were used as the measure of fibre fineness. As would be expected the heavier and longer fleeces tend to be the more sound. There was however little relationship between fibre diameter and unsoundness. It is generally accepted that fleeces with a considerable variability in fibre length growth rate (tippy) also have considerable variability in fibre diameter. Conclusions have been drawn from Short, Fraser and Carter's (1958) work that fleeces with variable fibre diameters are more susceptible to cotting. A moderate correlation between tippiness and mid-side cotting was only apparent in 1967.

D: DISCUSSION

There are two major problems in attempting a trial such as is discussed here. Firstly, a large amount of subjective assessment is involved, and secondly, there are statistical problems associated with analysing the grading systems as they are essentially a small group of discrete variables. Because of this latter aspect any measure of repeatability of subjective assessment may be biased to some extent. If a large number of grades are provided for the assessor the differences between them become so hard to discern that poor repeatability results. With a very few grades excellent repeatability may be obtained, but only large variations can be detected. The choice of nine grades for this study was thought to be intermediate between the two extremes and would allow the use of standard statistical techniques if used with caution. It was apparent, though not measured quantitatively, that repeatability was poor for the samples which were approximately intermediate between two grades. Also, many characteristics showed relatively little variability, though the variability was essentially that of a normal distribution. The lack of variability combined with the poor repeatability of "border-line" samples, though not unduly affecting the group mean, is of greater importance in an analysis of variance and of even more importance in the estimation of a correlation. This is suggested as the reason for the large variability and low values apparent in the correlation estimates.

1967 was the first year that young stock had been grazed on the Intensive unit along with the adult animals. It is evident that the increase in stocking level above that of 1966 resulted in a stocking level effect being measurable for most characteristics in 1967. In 1966 the Intensive adult animals were generally superior to the Control animals in most attributes. As the ewes were randomly selected this effect can only be assumed to result from the management which these animals received. Following the 1967 increase in numbers a stocking level effect appeared abruptly. The effect was most apparent for fleece weight and followed the trends shown by other New Zealand workers (Walker 1955; Suckling 1964; Collin 1966). A sample of these animals was studied monthly during 1967. The results in Chapter 4 suggest that the observed effects on wool weight were a result of the nutritional stress to which these animals were subjected in the early spring. It is difficult to see how some of the characteristics which were examined over the whole staple could be influenced by a nutritional stress lasting only two or three months, at a time when the fleece was almost fully grown. Lustre, handle and character were all inferior for the Intensive animals. It is possible lustre and handle may have been influenced by the contamination resulting from hay feeding and the muddy condition of the pasture during winter. The increase in tippiness may have arisen from the coarser fibres maintaining a greater length growth rate than the finer fibres during the winter months when nutrition was restricted. It is presumably as a result of this restriction that unsoundness and cotting increased.

The Intensive ewe hoggets received an even more serious nutritional check than the adult ewes (Chapter 4), yet this is not reflected in the results. This is particularly surprising in that, despite the significant stocking level effect on hogget fleece weight, neither the staple length nor unsoundness (an indirect measure of winter fibre diameter) were affected. The clean weight of wool per unit area was affected. It may be concluded from these results that the fleece characteristics of a young non-pregnant animal are relatively resistant to change as a result of nutritional stress.

The colour gradings over the three groups of animals are of interest in that they were influenced to a varying degree by the stocking level. The Intensive animals were superior for the colour gradings in the ewe hogget group, the 1966 adult ewe data and also the area of discolouration of the 1967 adult ewes, while the mid-side colour gradings for the 1967 Intensive adult ewes were inferior. Bublath (1969) also observed that hoggets grazing at a low stocking level were inferior in their colour grading to high-stocked animals, this being particularly noticeable on hoggets grazing Cocksfoot (Dactylis glomerata). It may be suggested that the extent of discolouration may be influenced by the length of pasture the animals are grazing. The discolouration may initially form as "water" stain resulting from almost constant contact with wet grass. The animals with a reasonable degree of cotting in the lower regions were observed to also have a pronounced yellow discolouration in the cotted regions. Conditions of high humidity, such as would be found in a wet and cotted fleece, have been suggested to be predisposing factors for the majority of fleece discolourations (Henderson 1968). It is reasonable to assume that as the area of discolouration increases by spreading round the body from the belly and points, so the mid-side area will become progressively discoloured. The means indicate that such a trend may have occurred. The 1967 Intensive ewe fleeces contained a considerable amount of dried mud as a result of the muddy conditions of the pasture during winter, while the Control ewe hoggets were muddy as a result of being fed a crop. It is possible that the presence of the mud contributed to these fleeces being "water" stained. Because of the nature of the stains present in the fleeces it would be expected that much of the staining would be permanent. The colour grading after scouring indicated that this may be so.

Quality number is a composite assessment of several characteristics. The increased lustre, harsher handle, and poorer character of the 1967 Intensive wools may have influenced the assessor to the extent that the mean quality number of the 1967 Intensive ewes was half a quality bracket lower than that of the Control animals, whereas the crimps per inch were unchanged. It seems likely that fibre diameter was unaffected. Measurements on the fibre diameter for the whole flock were not available.

In 1967 the Control animals were only slightly superior in respect of general soundness within the fleeces, while the extent of cotting was unaffected. There was, however, a significant stocking level effect for cotting on the mid-side area. It may be concluded from these observations that the gradual winter nutritional check does not suddenly reduce the fibre diameter (Chapter 4) resulting in general unsoundness but, instead, the effect is gradual with some of the finer fibres being shed (Short _et al_ 1958) and consequently felting or cotting particularly under the wet conditions of the lower areas of the body. The means for the 1967 hoggets however show the level of cotting to be unaffected, while the Intensive wools have less unsoundness. As a result of month by month observation (Chapter 4) of a sample of these animals it is suggested that the unsoundness in the Control fleeces was increased by a "break" at the time the animals were fed a crop.

No style grading was placed on the fleeces in this trial as has been done in other New Zealand trials. However, it may be suggested from an examination of the characteristics which are considered in style grading assessment that only in 1967 would there have been any effect, and then the Intensive ewe fleeces would have had a poorer average style grading. This would be due to the greater discolouration and poorer character of this wool. This drop in style grading of wool from an increased stocking level is consistent with the observation of Lambourne (1956) and Collin (1966).

It was not possible to obtain any estimate of the average price the wools from each unit would be likely to fetch at auction.

The calculated correlation estimates suggest that many of the inter-relationships between fleece characteristics are relatively weak and of little meaning. From an examination of the correlations it is clear that none of the fleece characteristic inter-relationships have been significantly altered as a result of increasing the stocking level. It is apparent that there is variation between years. This is, however, difficult to interpret as some characteristics were assessed by different persons in each of the two years. Even though standards were kept for most of the characteristics it was apparent that there was deterioration in some of them following a year's storage.

Colour is essentially unrelated to all characteristics other than cotting, suggesting that cotting is a major predisposing factor for the formation of the type of discolouration present in this study - namely "water" and "canary" stain. The low correlation between colour before and after scouring for the ewe data suggests that a certain amount of yellow discolouration may be obscured by grease and contaminants in an adult greasy fleece. This relationship for the hoggets is however strongly correlated.

A comparison between the correlations of the 1967 hoggets and the 1967 adult ewes shows there to be some variability in respect of age. The hogget correlation estimates suggest that at the hogget stage there is little relationship between fleece weight and quality number. This is in contrast to the estimate of -0.33 reported by Rae (1958).

This study has indicated some trends that may be expected with increased stocking levels. In the trial the effects of stocking level and day to day management are compounded and difficult to separate. It is likely that at higher stocking levels day to day management is perhaps more important in influencing fleece characteristics than at lower stocking levels in that the effect may be more far-reaching.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Skin and wool characteristics of sheep grazing two farmlets were compared. The two stocking levels were approximately 5 and 8 sheep per acre in 1966 and 5.5 and 12.2 in 1967.

The conclusions were :-

1. At birth the 1967 twin and single lambs differed significantly in $\frac{Sf}{Pf}$ ratio and body weight, but there were no differences due to stocking level.
2. At weaning singles were heavier than twins and the low-stocked animals were heavier than the high-stocked animals. The only significant effect on $\frac{Sf}{Pf}$ ratio was a single versus twin difference in 1966.
3. The differences in $\frac{Sf}{Pf}$ ratio appeared to be transient since they were not significant at hogget shearing (14 months of age).
4. The seasonal rhythm of wool growth was accentuated in the high-stocked animals due to a greater and prolonged winter depression.
5. The seasonal rhythm was of greater amplitude for adult animals than for hoggets, while the rhythm of the older adult ewes was less marked than that of the younger adult ewes.
6. Changes in fibre diameter occurred later than corresponding changes in fibre length.

7. The higher stocked animals showed depressed fleece weights.

8. In 1967, when stocking level differences were greater, wool from the high-stocked adult ewes was poorer for handle, character, soundness and cotting.

9. The increased discolouration in the 1967 ewe mid-side samples is probably a secondary response following increased cotting at the higher stocking level.

10. The fleece characteristics of the hogget wools did not show the effects of the stocking level to the same extent as did the adult animals.

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APPENDIX I

A COMPARISON OF SQUARE AND CIRCULAR SAMPLING AREAS IN THE ESTIMATION OF FOLLICLE POPULATION DENSITIES

A: INTRODUCTION

An estimation of follicle population densities involves the counting of the various follicle types in a specific area. Carter (1939a) first carried this out using an ocular graticule with a square grid and a magnification set to delineate an area of exactly one square millimetre. Later methods have involved the projection of an image (Carter and Clarke 1957a) on to a delineated area of various shapes with a magnification such that the delineated area of the image is exactly one square millimetre.

There has been discussion (Burns 1949, 1955; Wickham 1958) as to the accuracy of various methods of defining sampling areas. Burns suggested that greater accuracy was obtained by a charting method involving whole follicle groups. This method, however, has two major disadvantages in that :-

(i) separate counts are necessary for $\frac{S}{P}$ and density determinations.

(ii) a bias is possible, due to selection of clearly defined groups in the skin of adult animals where follicle groups have stretched during growth. This may tend towards selection of those groups with a lower secondary density and hence lower $\frac{S}{P}$ ratio.

Wickham used a projection method in a comparison of the efficiency of delineated square and circular areas of one square millimetre.

Prior to engaging in a considerable amount of density estimation, it was decided to again attempt to compare the efficiencies of square and circular sampling areas using a slightly different method.

B: MATERIALS AND METHODS

Five randomly selected animals were skin sampled in the mid-side region with a 1 cm biopsy punch (Carter and Clarke 1957a). The skin samples were processed by standard techniques, sectioned and stained by an adaptation of Gomori's Trichrome stain (Lillie 1954).

Primary and secondary follicle densities were counted at a magnification of x115 using a "Bausch and Lomb" micro-projector. The respective follicle densities for each animal were estimated from the mean of 10 sample fields. This was carried out three times using a projection on to a square area and three times on to a circular area, with the toss of a coin to decide the order. Each sample field was of such a size as to be a projection of an area of one square millimetre on the mounted specimen irrespective of which shape was being used. The decision as to the absolute boundaries of the shape was that if a follicle touched the top half of the circle, or the top or left-side of the square it was deemed included while if it touched the lower half of the circle or the lower and right sides of the square it was discarded. A primary follicle was defined as a follicle possessing a sudoriferous duct. A correction factor to compensate for shrinkage of the skin sample, following its removal from the animal and during processing, was applied.

C: RESULTS

From the primary and secondary follicle densities obtained by each method the $\frac{S}{P}$ ratio and total follicle density were derived. The

Measurement	Method	Animal				
		1	2	3	4	5
Primary Density	Square	3.62 ± 0.07	4.18 ± 0.02	3.01 ± 0.04	2.58 ± 0.18	4.50 ± 0.00
	Circle	3.85 ± 0.15	3.99 ± 0.03	2.93 ± 0.09	2.42 ± 0.03	4.33 ± 0.09
Secondary Density	Square	14.72 ± 1.31	18.31 ± 0.33	17.88 ± 0.28	12.25 ± 0.04	19.35 ± 0.07
	Circle	13.78 ± 0.62	18.09 ± 1.32	18.87 ± 0.83	12.25 ± 1.02	19.73 ± 0.42
Total Density	Square	18.35 ± 1.04	22.49 ± 0.51	20.89 ± 0.46	14.83 ± 0.24	23.85 ± 0.06
	Circle	17.63 ± 1.36	22.05 ± 1.00	21.80 ± 0.89	14.67 ± 0.95	24.07 ± 0.24
$\frac{S}{P}$ Ratio	Square	4.08 ± 0.30	4.21 ± 0.01	5.95 ± 0.10	4.80 ± 0.47	4.30 ± 0.01
	Circle	3.59 ± 0.03	4.54 ± 0.24	6.48 ± 0.46	5.09 ± 0.28	4.56 ± 0.21

Table I.1 - Mean and standard error of primary density, secondary density, total density and $\frac{S}{P}$ ratio obtained by the "Square" and "Circle" methods.

Source	df	Primary Density	Secondary Density	Total Density	$\frac{S}{P}$ Ratio
Between Animals	4	3.03**	5.82**	81.38**	4.81**
Between "S" and "C"	1	0.04	0.01	0.01	0.16
"S" and "C" x animals	4	0.79**	0.74	0.61	0.21
Residual	20	0.05	0.45	0.49	0.16

** $P < 0.01$

Table I.2 - Mean squares derived from an analysis of variance on data, the means of which are given in Table I.1.

means and their standard error are given in Table I.1. The large between animal variation is due to selection of animals for the comparison being at random irrespective of any treatments that the animals may have received.

An analysis of variance was carried out on the data, the mean squares of which are given in Table I.2. It is clearly apparent that there is no clear advantage in accuracy of either method on the basis of this test.

A Bartlett's test (Snedecor 1966) for homogeneity of variance was also performed. This again indicated neither method to be superior.

D: DISCUSSION

Within limitations due to the small number of animals involved, the analysis indicates that the use of either a square or a circular area in the estimation of follicle density does not affect the accuracy of the answer. The animal x shape interaction apparent in the counting of the primary follicle density could be put down partly due to chance in view of the relatively small numbers of primary follicles in each sample field at each counting.

The results of Bartletts' tests of homogeneity of variance are indicative that neither method is superior in lowering overall variance, and hence more efficient.

These results provide no evidence to support Wickham's (1958) suggestion that circles could be a more efficient sampling area for analysing follicle populations. It is possible that significant differences could have been obtained using samples from more animals but the advantages of one method over the other seem to be negligible. Probably observation and day to day differences of individual observers have a far more important effect on the accuracy of follicle population determinations.

E: SUMMARY

The projection technique was used to estimate primary and secondary density in sheep skin samples from five animals. From these were estimated the total density and the $\frac{S}{P}$ ratio. Three replications, of both a square and a circle, were used as the one square millimetre projected delineated area.

It was not possible to show either method superior to the other in terms of lowering the inherent variance due to counting.

APPENDIX II

THE RECALIBRATION OF AN AIRFLOW APPARATUS FOLLOWING A REDUCTION OF THE SIZE OF THE CHAMBER

A: INTRODUCTION

An airflow apparatus for the estimation of fibre diameter has been described by Anderson (1954). The errors apparent in its usage have been estimated by Anderson (1954) and Ross (1958). The airflow apparatus in use at Massey University was constructed by the New Zealand Wool Industries Research Institute and is calibrated to estimate the average fibre diameter of a 2g sample of clean scoured wool. It became necessary to estimate the diameter of wool samples less than 2g in weight, clipped monthly from the mid-side area. The apparatus was therefore adapted to enable an estimation of the average fibre diameter of a 1g wool sample.

B: MATERIALS AND METHODS

A small brass "inner bucket" with a perforated bottom was constructed. It was used as depicted in Fig. II.1. The depth of the adapted chamber was obtained by trial and error. The volume of the adapted chamber was 3.11 cc compared with 6.37 cc for the unadapted chamber.

All airflow measurements were the mean of four readings from one sub-sample. The samples were removed from the chamber, check weighed and reteased between each reading. Only a limited amount of teasing was possible due to the shortness of the fibres present in the sample.

For the calibration trial 336 clean scoured samples were used.

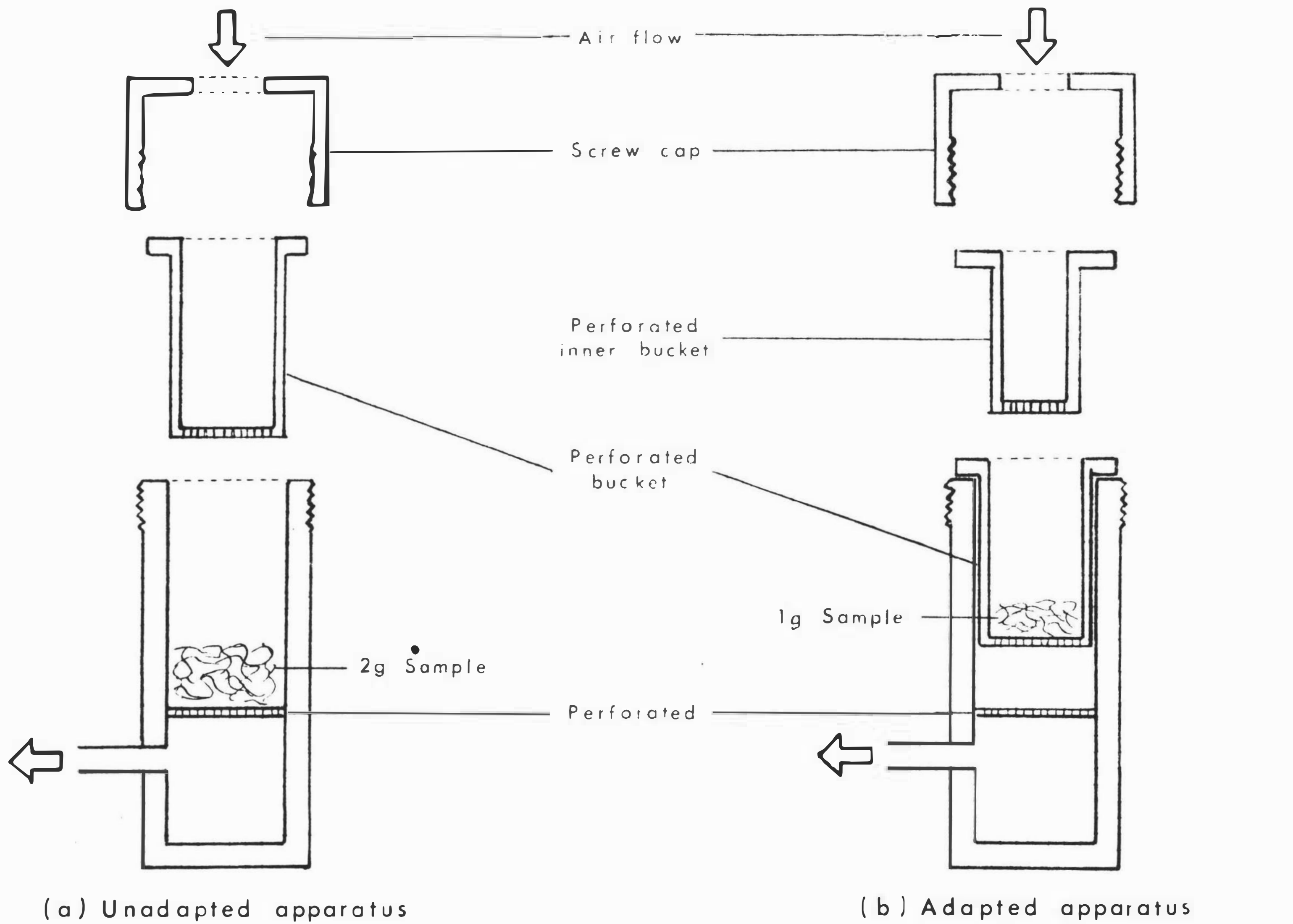

Fig. II.1 — The method of adapting an airflow apparatus to estimate the average fibre diameter of a 1g wool sample.

An average reading was obtained using a 2g sample in the unadapted apparatus and a 1g sample in the adapted apparatus. These readings are subsequently called the "2g" and "1g" diameters.

A regression analysis of the "2g" and "1g" diameters was carried out.

C: RESULTS

A correlation coefficient of $r = 0.99$ was calculated between the "1g" and "2g" diameters. From this it is apparent that there is a near perfect relationship between the two estimates of diameter. The estimated regression coefficient for the regression of the "2g" diameter on the "1g" diameter was calculated as $\hat{b} = 1.11 \pm 0.02$ (Fig. II.2) giving a regression equation of :-

$$\hat{Y} = 1.11X - 3.19$$

where Y = "2g" diameter

X = "1g" diameter.

The two scales of measurement are thus directly proportional.

D: DISCUSSION

The results suggest that no bias would be introduced by the analysis of "1g" diameters for possible statistical significance. The use of this method is in preference to that whereby a proportion of individual means, the diameter of those samples less than 2g, is corrected by use of the regression equation. After the carrying out of statistical tests with the "1g" diameters it is valid to then convert the group mean values to an estimated micron measurement by the prediction equation. The correction of group means rather than individual means lessens the prediction error which may be incurred.

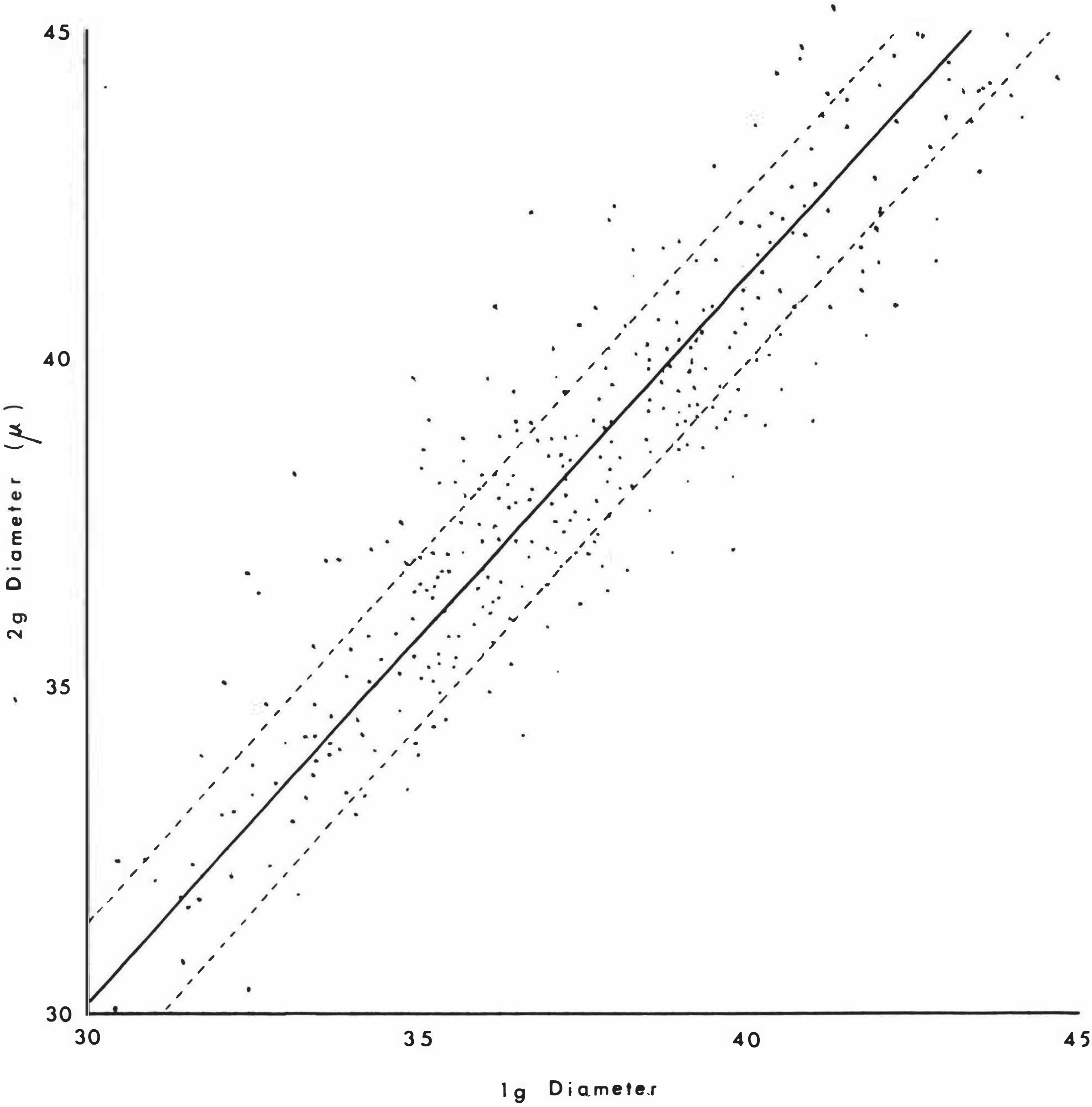

Fig. II. 2 — The relation between the 2g diameter and the 1g diameter.

Since the airflow apparatus is usually used in the estimation of diameter of "full length" fibres an error may be introduced by the use of short monthly sample fibres. Ross (1958) was unable to show conclusively that fibre length affected the airflow reading.

E: SUMMARY

Estimates of fibre diameter based on the use of a 1g wool sample in an adapted airflow apparatus were obtained. No bias was apparent to prevent the use of these estimates in statistical tests. An equation to predict mean fibre diameter from airflow through the modified apparatus was derived.

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.

A: WHOLE FLEECE CHARACTERISTICS

(i) Cotting

The grading is dependent on the degree and extent of entanglement.

1. Extremely hard cott.
2. Hard cott.
3. Soft cott.
4. Borderline soft cott.
5. Markedly webby throughout.
6. Partially webby.
7. Webby on the points.
8. Completely free throughout like pre-lamb shorn.
9. Completely free throughout but with very fine staples.

(ii) Discoloured area

Estimated mainly on the basis of how far the discolouration extends over the fleece with account taken of the severity of the discolouration.

1. Whole fleece very badly discoloured.
2. Whole fleece quite yellow.

3. Whole fleece discoloured but midside not serious.
4. More than half the fleece discoloured.
5. Quarter to half the fleece discoloured.
6. Large area discoloured around the points.
7. Some discolouration on the points.
8. Very slight discolouration on the points.
9. No discolouration present.

B: GREASY MID-SIDE SAMPLE CHARACTERISTICS

(i) Character

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

(ii) 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.

(iii) 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.

(iv) Crimps per inch

The number of crimps over the whole staple were counted, divided by the staple length (cms) and converted to crimps per inch by tables. 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 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) Quality Number

Bradford quality numbers.

(viii) 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).

(ix) Staple length

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

(x) 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.

C: <u>SCOURED MID-SIDE SAMPLE CHARACTERISTICS</u>

(i) <u>Colour (scoured)</u>

Same descriptions used as for Colour (unscoured) - B(ii).