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Seasonal wool growth patterns and the follicle and fibre characteristics of New Zealand feral sheep

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ABSTRACT

Wool follicle and fibre characteristics, and aspects of their seasonality were assessed in feral sheep from the Hokonui Hills (Merino origin), Campbell Island (Merino x long-wool breeds) and Raglan Peninsula (Romney). Live weight, fleece weight, staple length, crimp frequency, fibre diameter, fibre curvature, follicle density and secondary to primary follicle ratio differed between breeds, reflecting their breed origins. Mean clean fleece weights of the feral breed groups were approximately half that of their modern counterparts. Factors contributing to the low productivity were reduced staple length and follicle density, and a brief cessation of growth by some follicles during spring. The mean amplitude of rhythms in seasonal wool growth and fibre diameter increased with age, and appear to have converged to similar values, contrasting with their modern breed counterparts.

Keywords: feral sheep; Romney; Merino; fibre characteristics; follicle characteristics; seasonality; follicle activity.

INTRODUCTION

The wool properties of domestic sheep have diverged from wild sheep as the result of selection by man for improved fibre properties and increased fleece weight (Ryder, 1987). Feral sheep are derived from domestic sheep but have been subjected to natural selection pressures for survival in the wild. It might be anticipated that, over time, their wool characteristics would revert towards those of wild sheep living in comparable environments. Such evolution of New Zealand feral sheep breeds is evident in reduced wool production associated with short staples, low secondary to primary (S:P) follicle ratios, low follicle densities, low staple strength and high wool bulk compared with modern sheep breeds (Orwin and Whitaker, 1984; Bigham and Cockrem, 1984).

A characteristic of wild sheep which delineates them from modern sheep breeds is their highly seasonal pattern of wool growth linked to fleece shedding in the spring (Ryder, 1973; Ryder, 1987). However, seasonal variation in follicle activities and wool production have not been systematically measured in New Zealand feral sheep. The present study was undertaken to determine the nature of the wool growth rhythm in three feral sheep genotypes and to assess their utility as models for the study of follicle biology and fibre characteristics.

MATERIALS AND METHODS

Animals and husbandry

The feral sheep in this study comprised 71 mixed-age ewes originating from three sites: from a peninsula in Raglan Harbour west of Hamilton (n=19), the Hokonui Hills to the north east of Invercargill (n=28) and Campbell Island, 590 km south of Stewart Island (n=24). The Raglan sheep were abandoned during the 1930s and are of Romney descent (Bigham and Cockrem, 1984). Campbell Island sheep are crossbreds of Merino and long-woolled breeds which survived untended after the collapse of farming on

the island in 1931 (Wilson and Orwin, 1964). The Hokonui sheep are believed to be of Merino origin, released in the wild during the 1860s (Johns, 1980). Small numbers of each breed were collected in 1976 and subsequently maintained on Ministry of Agriculture and Fisheries farms. They were transferred from the Wairakei Research Area to the Whatawhata Hill Country Research Centre in July 1990 to undertake this study. Following joining with rams of their own breeds, 46 lambed in September and October 1991, shortly after the completion of the trial.

Wool and skin sampling

All sheep were shorn and a mid-side wool patch (approximately 10 x 10 cm) established on 30 July 1990. To assess fleece growth rate, wool was clipped from the patch with Oster clippers at 1 to 3 month intervals until August 1991 when the sheep were reshorn. At shearing, greasy fleece weight was recorded and a full length mid-side wool sample collected. Character (a subjective assessment of staple crimp clarity on a scale of 1 to 7; 1 = very poor definition, 7 = regular even crimp to the staple tip), staple length and total number of crimps along the staple of each greasy fleece sample were measured and crimp frequency calculated. Both full-length mid-side and patch wool samples were washed in water and detergent, weighed at 16% regain, and the washing yield of the full-length midside samples calculated. Mean fibre diameter, fibre diameter variation, mean fibre curvature and opacity of the scoured fleece samples were measured by OFDA (Edmunds, 1995). Similarly, mean fibre diameter and fibre diameter variation of a sub-sample of each clipped patch were also measured. Clean wool production for each patch collection period was estimated by partitioning clean fleece weight according to the relative weight of clean wool clipped from the mid-side patch.

Each month between July 1990 and September 1991 a skin snip biopsy (approximately 5 x 12 mm), was collected from the opposite mid-side to the wool patch. The skin samples were fixed in phosphate-buffered 10% for-

malin and embedded in paraffin wax. Serial transverse sections were mounted on microscope slides and stained using the modified Sacpic method (Nixon, 1993). Wool follicles were classed into the growing or resting stages of the follicle growth cycle to estimate percentage activity. Since skin thickness differs between breeds (Carter and Clarke, 1957a), shrinkage factors were determined from 10 mm diameter skin biopsies collected by trephine from 10 ewes of each feral breed. Group means were used to correct estimations of follicle densities for individual sheep.

Data analysis

The relative wool growth and diameter amplitudes were calculated as described in Sumner *et al.*, (1994) using minimum and maximum wool growth rates from September and December 1990 respectively. Percentage wool follicle activity data was logit transformed before analysis. One-way analysis of variance was used to test for differences in wool and follicle characteristics between the three feral breed groups. General linear models were used to test for the effects of breed, age and follicle activity on wool growth and fibre diameter rhythms, and between skin shrinkage and follicle density and breed. The relationships between age and minimum winter follicle activity, and follicle activities between the two winter periods, were compared by linear regression within breed.

RESULTS

Age and live weight

The ewes in the study were aged between 1 and 7 years. Fifteen were 1 year old and nine were older than 4 years. The Hokonui and Campbell Island sheep were similar in live weight and were lighter than the Raglan sheep ($P < 0.001$) (Table 1). Between December 1990 and August 1991 average live weight increased by 3.3 ± 0.4 kg ($P < 0.001$).

Wool characteristics

Greasy fleece weights grown over the trial were approximately half that expected from modern breed equivalents, with Campbell and Hokonui greasy fleece weights being significantly less than the Raglan flock ($P < 0.001$) (Table 1). The difference in clean fleece weight between the breeds was accentuated by the higher washing yield of Raglan fleeces.

Staple length of the Hokonui ewes was shorter than the modern Merino while Raglan ewes were shorter than the modern Romney (Table 1). Mean fibre diameters differed significantly between the feral breeds reflecting the flocks from which they were originally derived ($P < 0.001$). While staple crimp, as reflected in character, was less clearly defined in the feral genotypes, the total number of crimps along the staple did not differ from modern breeds. Crimp frequency and, by inference, fibre curvature were at the high end of the ranges for improved breeds. Fibre medullation was virtually absent, although mean flock values ($< 2\%$) were increased by some high individual values, ranging up to 20% in one Raglan ewe.

Follicle characteristics and seasonal patterns in follicle activity

Skin shrinkage (area of processed skin as a proportion of the biopsy area) differed between breeds (Hokonui: 0.48 ± 0.02 < Campbell and Raglan: 0.55 ± 0.02 , $P < 0.001$) and increased as total follicle density declined ($P < 0.01$). Both primary and secondary follicle densities were at or below the minimum range observed in modern breeds (Table 1). A markedly lower secondary follicle density in Hokonui ewes was reflected in a lower S:P ratio compared with their modern Merino counterparts. Throughout the year a high proportion of primary and secondary follicles were producing fibre (Figure 1). Secondary follicle activity in the Hokonui ewes was close to 100% in all skin samples.

TABLE 1: Mean \pm standard error of the mean (SEM) and range of fibre and follicle characteristics for individual sheep of the feral breeds, and the range of published group means for the modern day, medium type Peppin Merino and Romney.

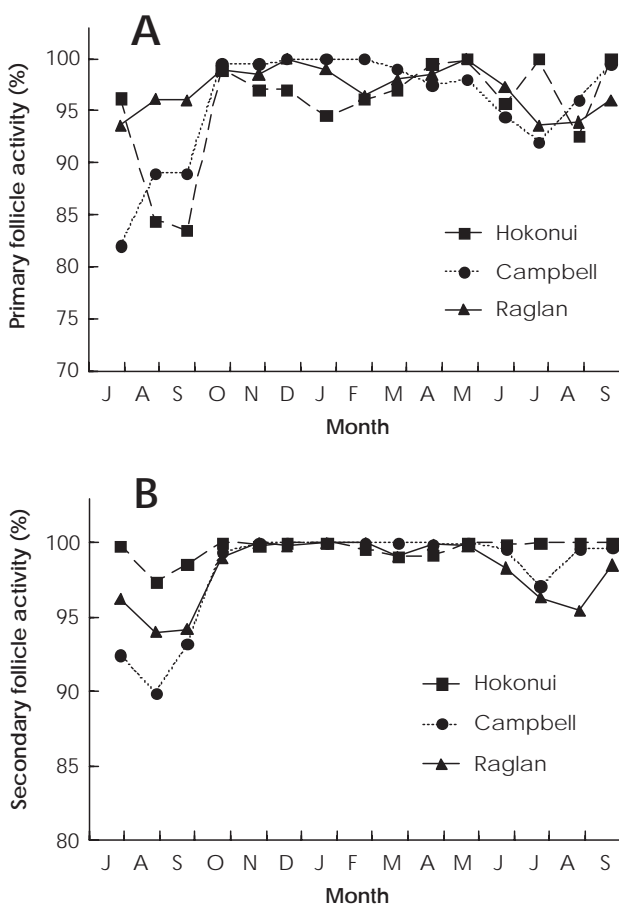
Characteristic	Merino Range	Hokonui (n=28) Mean \pm SEM Range	Campbell Island (n=24) Mean \pm SEM Range	Raglan (n=19) Mean \pm SEM Range	Romney Range	P (between feral breeds)
Age (years)	-	2.9 \pm 0.2 1-6	2.7 \pm 0.3 1-6	3.5 \pm 0.5 1-7	-	ns
Live weight (kg) ¹	45-60 (e)	37.8 \pm 0.9 27.4-45.4	37.2 \pm 0.9 26.8-45.3	46.7 \pm 1.6 32.0-56.0	50-80 (c)	***
Greasy fleece weight (kg)	4.0-5.5 (f)	1.58 \pm 0.12 0.64-2.64	1.73 \pm 0.07 0.98-2.41	2.80 \pm 0.10 2.13-3.48	3.5-5.4 (c)	***
Washing yield (%)	60-70 (l)	66 \pm 2 53-80	66 \pm 1 59-75	71 \pm 1 61-80	70-80 (l)	*
Clean fleece weight (kg)	2.5-3.5 (f)	1.00 \pm 0.10 0.45-2.10	1.15 \pm 0.04 0.68-1.52	1.99 \pm 0.85 1.38-2.69	2.6-4.0 (c)	***
Wool growth rhythm (%)	30-80 ² (h)	76 \pm 4 49-112	84 \pm 4 35-129	93 \pm 5 58-136	50-130 ² (i)	†
Staple length (mm)	60-100 (l)	61.8 \pm 3.5 37-105	80.0 \pm 4.3 50-125	111.1 \pm 5.2 70-140	125-160 (c)	***
Mean fibre diameter (μ m)	20-24 (l)	23.9 \pm 0.4 20.5-27.0	27.8 \pm 0.5 24.3-32.9	34.8 \pm 0.4 30.8-37.1	35-40 (l)	***
Fibre diameter SD (μ m)	2-6 (d)	4.2 \pm 0.1 3.2-5.2	5.7 \pm 0.1 4.8-6.9	7.6 \pm 0.2 6.5-9.5	5-10 (d)	***
Diameter rhythm (%)	10-30 ² (h)	10 \pm 1 0-18	15 \pm 2 6-40	17 \pm 2 3-29	15-60 ² (k)	†
Character grade	5-7 (j)	3.4 \pm 0.1 2-5	2.8 \pm 0.2 2-4	3.1 \pm 0.2 2-4	3-6 (j)	*
Total crimps along staple	20-50 (j)	31 \pm 1 22-46	25 \pm 1 14-36	19 \pm 1 14-28	10-30 (j)	***
Crimp frequency (No/cm)	3-5 (g)	5.2 \pm 0.3 3.4-9.5	3.3 \pm 0.2 1.6-4.4	1.8 \pm 0.1 1.2-2.7	0.8-2.0 (c)	***
Fibre curvature ($^{\circ}$ /mm)	80-130 (d)	119 \pm 3 78-150	97 \pm 3 73-124	68 \pm 2 48-85	50-70 (d)	***
Medullation (%)	-	0.9 \pm 0.4 0.2-10.8	0.6 \pm 0.1 0.2-1.4	2.2 \pm 1.1 0.3-20.0	0-20 (c)	ns
Primary density (No/mm ²)	2-4 (a)	1.5 \pm 0.1 1.1-2.1	1.8 \pm 0.1 1.4-2.2	1.6 \pm 0.1 1.3-2.3	2-5 (b)	***
Secondary density (No/mm ²)	25-70 (a)	13.5 \pm 1.1 6.1-28.7	13.3 \pm 0.7 8.6-22.9	9.4 \pm 0.4 7.0-14.6	12-20 (b)	**
S:P ratio	15-25 (a)	8.8 \pm 0.5 5.4-15.4	7.3 \pm 0.3 5.0-10.6	5.7 \pm 0.2 4.4-7.3	4-8 (b)	***
Minimum primary activity (%) ³	-	90 \pm 2 65-100	84 \pm 4 38-100	86 \pm 3 60-100	-	ns
Minimum secondary activity (%) ³	-	99 \pm 1 88-100	92 \pm 3 52-100	93 \pm 2 74-100	-	***

¹ Mean of 5 weights between December 1990 and August 1991; ² Only one trial, range for individuals; ³ Mean of each individual ewe minimum follicle activity during trial. *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$, † $P < 0.10$, ns not significant.

References: (a) Carter and Clarke, 1957a; (b) Carter and Clarke, 1957b; (c) Dalton and Rae, 1978; (d) Edmunds and Sumner, 1996; (e) Hogan *et al.*, 1979; (f) Robards, 1979; (g) Ryder and Stephenson, 1968; (h) Sumner *et al.*, 1994; (i) Sumner *et al.*, 1998; (j) R.M.W. Sumner, unpublished data; (k) Woods and Orwin, 1988; (l) Wools of New Zealand, 1997.

However, during the late winter and early spring of both years, small reductions in mean follicle activities were observed in all breeds. The drops in primary activity were generally greater than in secondary follicles. Within individual Campbell Island and Raglan ewes, minimum follicle activities were correlated between the two successive winter periods (primary follicles, $r = 0.73$, $P < 0.001$; secondary follicles, $r = 0.59$, $P < 0.001$). Follicle inactivity of both primary and secondary follicles in the winter of 1990 also increased with age among Campbell Island and Raglan ewes ($P < 0.05$).

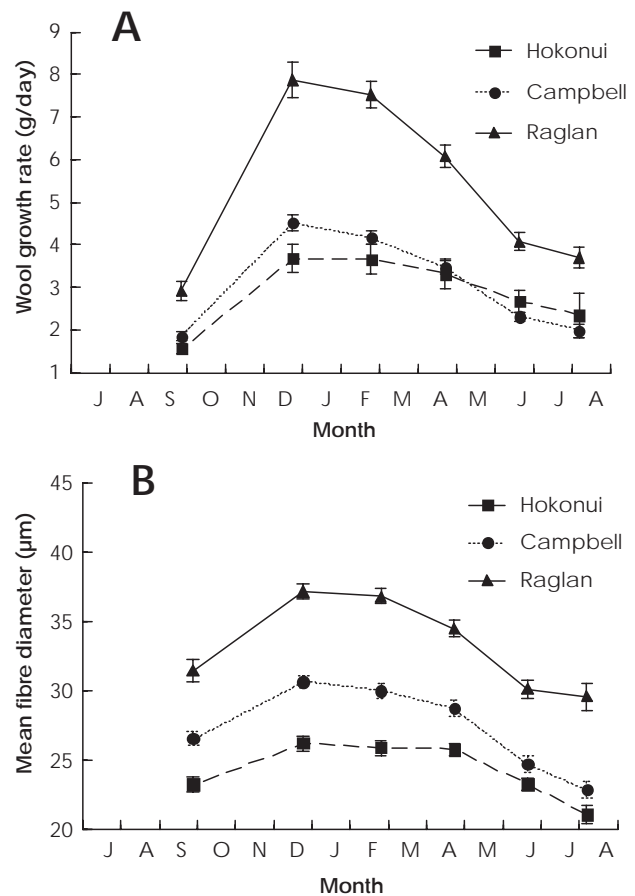
FIGURE 1: Mean percentage of actively growing follicles in mid-side skin of each of the three feral sheep breeds between August 1990 and September 1991, (A) primary follicles (B) secondary follicles.



Clean fleece growth rate and fibre diameter

Clean wool growth rate and mean fibre diameter rose from minimum levels in July–November to a summer maximum in all breeds, then fell after February as photoperiod declined (Figure 2). The amplitude of the wool growth rhythm (Table 1) was significantly associated with breed ($P < 0.001$) and age ($P < 0.001$) with a significant age \times breed interaction ($P < 0.05$) (Figure 3). The inclusion of follicle activity data did not significantly improve the model.

FIGURE 2: (A) Mean (\pm SEM) clean wool growth rate and (B) mean fibre diameter of each of the feral breeds between September 1990 and August 1991.

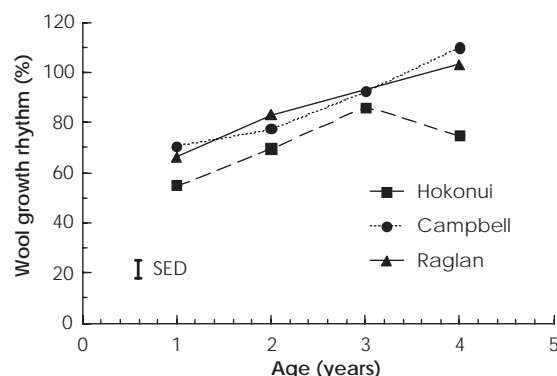


DISCUSSION

Whereas farmed sheep are selected for high productivity, feral sheep have been under natural selection pressure to ensure survival and reproduction in the wild. As a consequence, wool fibre and follicle characteristics appear to have been significantly altered (Table 1). However, without knowledge of the characteristics of their ancestral flocks, the magnitude of these changes cannot be precisely quantified. Presumed differences in wool characteristics such as staple length and diameter have been sufficiently retained to distinguish the feral groups, despite the 40–110 years of existence in the wild. As anticipated from the breed ancestry, the wool characteristics of the Campbell Island sheep were intermediate between those of the Hokonui and Raglan sheep. The low fleece weights recorded in this study appear to be a consequence of lower live weight, shorter staple length, lower follicle density and increased fibre shedding. However, there appears to have been no significant change in mean fibre diameter.

Follicle inactivity, albeit limited, was generally confined to certain Campbell Island and Raglan sheep over the two late winter periods monitored. The transient pattern of follicle inactivity in these feral ewes resembles the Cheviot (Ryder, 1974) and the Scottish Blackface (Ryder, 1975). In contrast, primitive and wild sheep breeds exhibit a high

FIGURE 3: Relationship of the relative amplitude of the wool growth rhythm with age for each of the feral breeds.



percentage of follicle inactivity through the winter, with spring moulting accompanying follicle regrowth (Ryder, 1971; Ryder, 1973). Although shedding did not occur during this study, partial loss had been noted previously in association with constrained winter nutrition at the Wairakei Research Area (R. Hunter, personal communication). Shedding in Arapawa Island sheep, believed to be of Merino origin, has been attributed to seasonal thinning and breakage of fibres rather than brush-end formation (characteristic of resting follicles) and fibre replacement (Orwin and Whitaker, 1984). The limited extent of follicle inactivity observed in this study suggests a similar mechanism. Factors contributing to fibre thinning and breakage in feral sheep populations could include poor winter nutrition, the seasonal decline in growth rate and the inhibitory effects of pregnancy (Pearson *et al.*, 1999).

The annual wool growth and diameter rhythms were similar between the feral breeds. This stands in contrast to the lower seasonality in the modern Merino as compared to long-wool breeds (Bigham *et al.*, 1978; Sumner *et al.*, 1994; Sumner *et al.*, 1998). With a longer period of natural selection, we suggest that seasonality would be likely to increase as winter follicle activity declines further and shedding increases. This is the reverse of the process that has occurred during domestication.

The amplitudes of both the wool growth (Figure 3) and diameter rhythms increased by approximately 50% between one and four years of age. The extent of follicle inactivity during late winter also increased with age in Campbell Island and Raglan breeds. Hints of an age association with increased shedding have previously been noted among Wiltshire Horn (Slee, 1959) and Cheviot (Ryder, 1974) sheep. The basis of this observation merits further study. Other characteristics of feral sheep could also provide insights into the physiological and genetic mechanisms which have been the subject of centuries of artificial selection. These include the differential responses of the components of fleece weight to natural selection, the transitory follicle inactivity during spring, and the developmental processes leading to low follicle density and S:P ratios.

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