

New Zealand Society of Animal Production online archive

This paper is from the New Zealand Society for Animal Production online archive. NZSAP holds a regular annual conference in June or July each year for the presentation of technical and applied topics in animal production. NZSAP plays an important role as a forum fostering research in all areas of animal production including production systems, nutrition, meat science, animal welfare, wool science, animal breeding and genetics.

An invitation is extended to all those involved in the field of animal production to apply for membership of the New Zealand Society of Animal Production at our website www.nzsap.org.nz

[View All Proceedings](#)

[Next Conference](#)

[Join NZSAP](#)

The New Zealand Society of Animal Production in publishing the conference proceedings is engaged in disseminating information, not rendering professional advice or services. The views expressed herein do not necessarily represent the views of the New Zealand Society of Animal Production and the New Zealand Society of Animal Production expressly disclaims any form of liability with respect to anything done or omitted to be done in reliance upon the contents of these proceedings.

This work is licensed under a [Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License](http://creativecommons.org/licenses/by-nc-nd/4.0/).



You are free to:

Share— copy and redistribute the material in any medium or format

Under the following terms:

Attribution — You must give [appropriate credit](#), provide a link to the license, and [indicate if changes were made](#). You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

NonCommercial — You may not use the material for [commercial purposes](#).

NoDerivatives — If you [remix, transform, or build upon](#) the material, you may not distribute the modified material.

<http://creativecommons.org.nz/licences/licences-explained/>

Inheritance of foot and jaw abnormalities in sheep

R.L. BAKER, J. N. CLARKE

Ruakura Animal Research Station, Ministry of Agriculture and Fisheries, Hamilton

T.G. HARVEY

Rotomahana Research Station, R.D. 3, Rotorua

H.H. MEYER

Oregon State University, Corvallis, USA

ABSTRACT

Genetic variation of foot and jaw 'abnormalities' in ewe hoggets and ewes has been studied with several breeds and strains at the Rotomahana Research Station. Foot and digit placement, foot roll, pastern angle and degree of hoof growth were scored for all 4 feet of each sheep at 9 months, 18 months and 5 years of age. Teeth occlusion, measured as the distance in mm (+ or -) between the front surface of the central incisors and the anterior edge of the upper pad, was recorded at 18 months and 5 years of age.

Differences in incidence of foot abnormalities at 18 months of age among 2251 ewe hoggets representing 6 Romney strains and Coopworth or Border Leicester x Romney crosses, were significant for all traits except foot roll and digit placement. Border Leicester cross hoggets had a lower incidence of foot placement, pastern angle and hoof growth abnormalities than straightbred Romneys or Coopworth crosses.

In a separate trial, 602 Booroola Merino first cross hoggets out of Romney and Perendale ewes had a significantly higher incidence of foot abnormalities than 480 straightbred Romney or Perendale ewe hoggets for all traits recorded at 18 months of age except pastern angle. There were only small differences among Romney strains and among breeds and crosses for teeth occlusion.

Paternal half sib heritability estimates of foot traits recorded at 9 months of age were low (less than 0.11) and non-significant except for hoof growth (0.18 to 0.29). Similar heritability estimates for hoof growth were found in 18 month ewe hoggets (0.14 to 0.27) with low to moderate estimates for the other foot traits (0.02 to 0.17), and teeth occlusion (0.13 to 0.25). Heritability estimates were similar in 5-year-old ewes for foot traits (0.03 to 0.20) but increased with age for teeth occlusion (0.36). Correlations between foot traits recorded at 18 months and 5 years of age were low (0.08 to 0.25), but were higher for teeth occlusion (0.49).

Foot abnormalities and teeth occlusion were not found to have significant effects on either hogget growth, wool production or ewe reproduction, live weight or wool production.

It is concluded that undue culling emphasis in ewes or rams on teeth or feet abnormalities is not warranted and may be counter productive.

Keywords Feet; teeth; sheep; breeds; heritability

INTRODUCTION

Stud breeders and commercial sheep farmers place considerable emphasis on physical appearance and "structural soundness" when selecting ram and ewe hoggets. A recent survey of Otago and Southland farmers indicated that only one-third were using any form of objective performance measurement to select ewe replacements for their flocks (Butler, 1983). All farmers surveyed were selecting ewe hoggets using subjective eye appraisal either in conjunction with objective selection (33% of farmers) or as the sole means of selection (67%). The 3 most important subjective selection criteria identified were size, wool excellence and breed type. Breed type presumably included both feet and jaw 'abnormalities'.

The efficiency of selection was examined in 8 group breeding scheme flocks using Sheeplan by Dodd *et al.* (1982). Realised selection differentials (the average superiority of those selected as a deviation from the

overall mean of those available for selection) were compared with maximum selection differentials possible if an equivalent number of animals were selected from the top of the Sheeplan index list. Average efficiency of selection for the 8 flocks was 78% for rams and 28% for ewes. An analysis of 6 Romney stud flocks using an index in retrospect approach showed that selection efficiencies were only 36% for rams and 41% for ewes (Eikje and Clarke, 1986). Six of the 27 group breeding schemes surveyed by Dodd *et al.* (1982) ranked structural soundness as their most important perceived selection priority, and the authors suggested that this probably accounted for a large proportion of the loss in selection pressure observed.

It is commonly accepted that the incisors in a normal sheep's jaw should align themselves with the upper pad and that there should be no perceptible ridge between it and the front edges of the teeth (Barnicoat, 1957). In New Zealand incisor teeth projecting forward

of their 'normal' position are described as overshot, those meeting the top pad behind this position as undershot. These terms have been used in exactly the opposite sense in the USA, Australia and Britain (Barnicoat, 1957) and to describe different conditions of mandibular prognathism (Donald and Weiner, 1954). In this paper the term teeth occlusion will be used to describe this condition.

Inheritance of feet or occlusion defects in sheep has received relatively little attention in well designed research programmes. This paper provides information on the inheritance of these traits and on their relationships with both hogget and ewe production.

MATERIALS AND METHODS

Animals and Management

The ewes studied were part of the Strain and Booroola Merino trials initiated at the Rotomahana Research Station in 1979. Rams from 8 sources were used in each of 5 years (1979-83) to mate a base population of Romney ewes, and data from the first cross ewe progeny are analysed in this paper. The ram sources sampled included 3 Romney and one Coopworth group breeding scheme; a Romney research flock selected solely for twinning rate for 24 years; a registered Romney stud flock; and a wide cross-section of industry Romney and Border Leicester rams from registered breeders. Over the trial period each source supplied 23 rams with the exception of the sample of industry Romneys (38 rams) and the Romney stud flock (13 rams) which was sampled for the first 3 years only (1979-81). Ram selection for each except the industry Romney and Border Leicester strains, was made by the individual breeder. Only rams with a Sheeplan average breeding value for dam's fertility and the individual's weaning weight and hogget fleece weight were chosen. Industry Romney and Border Leicester rams were representative animals chosen by a stock and station firm. From large important studs 2 rams were chosen, otherwise one ram was selected from each of those studs with 'influence' in the industry. None of these rams were scored for foot faults or teeth occlusion at Rotomahana. It is safe to assume, however, that while these were average rams for performance traits, they had been screened closely for breed type including teeth occlusion and foot faults.

In the Booroola Merino trial, Romney (R), Perendale (P) and Booroola Merino (M) rams were mated to base generation Romney ewes of common origin to the Strain Trial and Perendale ewes to produce contemporary purebred (RxR and PxP) and first cross (MxR and MxP) daughters from 1979 to 1981. A total of 31 Merino, 29 Romney and 24 Perendale rams were used to generate Phase I progeny. While the Romney and Perendale rams were screened for structural soundness prior to use at Rotomahana

this did not apply to the Booroola Merino rams.

No culling on performance was carried out either in the ewe hoggets or during the evaluation of ewe performance. Except during the mating period, all ewes were given equal treatment by managing them in large grazing groups to avoid management differences contributing to breed or strain differences. Ewe hoggets from both trials were managed as one experimental group.

Observations

Five foot characters were scored on ewes at 9 months, 18 months and 5 years of age.

1. Foot placement. The deviation (in or out) of the foot relative to the median line of the body. This was a non-ordered scoring system with 5 being straight feet, 4 to 1 increasing deviation inwards, and 5 to 9 increasing deviation outwards.
2. Digit placement. A non-ordered scoring system with 5 being parallel spacing of the 2 digits, 4 to 1 increasing placement of the digits inwards to the extreme of crossing of the digits (score 1), and 6 to 9 increasing placement outwards (splaying).
3. Foot roll. The tendency of the foot as a whole to roll either in towards the median line (score 4 to 1) or away from the median line (scores 6 to 9). This was also a non-ordered scoring system with 5 being no rolling of the foot.
4. Pastern angle. An ordered scoring system with 1 being a straight (vertical) pastern and 2 to 5 increasing degrees of pastern angle to the vertical.
5. Hoof growth. An ordered scoring system with 1 being a hoof wall length which would not require trimming and 2 to 5 increasing hoof length.

Each foot was independently scored (with reference to a set of diagrammatic standards) while the sheep was standing as naturally as possible in a raised observation race.

Occlusion was recorded as the horizontal distance in either direction between the front surface of the central incisors and the anterior surface of the dental pad of the gum measured to the nearest 1 mm. When the central incisors met the anterior point of the pad the grading was 0, while undershot positions received positive sign and overshot positions negative signs. In the first 2 years (ewes born 1979 and 1980) all measurements were taken with a ruler. Subsequently measurements were subjectively estimated by a single operator with occasional checking against a ruler but a ruler measurement was always taken when mal-occlusion exceeded 3 mm.

Statistical Analysis

Initially analyses were undertaken for each foot separately for all 5 foot traits scored as defined above. For some traits there was some indication of different means and variances for front v back feet (e.g. pastern

angle) while for other traits these parameters were relatively constant for all feet (Fig. 1). To facilitate interpretation of breed and strain differences for occurrence of foot abnormalities, scores as originally recorded were converted to several different scales.

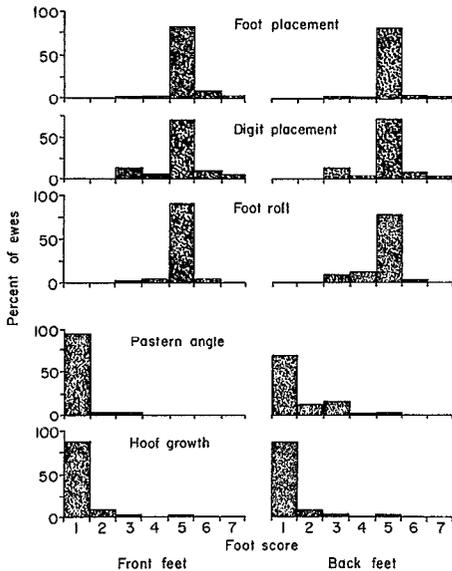


FIG. 1 Distribution of foot traits in 18-month Strain trial ewes.

Firstly the non-ordered foot traits (foot and digit placement and foot roll) were converted to ordered scales (i.e. from best to worst) by recoding score 5 to 1, scores 4 and 6 to 2, scores 3 and 7 to 3, scores 2 and 8 to 4 and scores 1 and 9 to 5. This recoding makes the assumption that deviations in either direction (e.g. codes 3 and 7) are the same trait. To test this, heritabilities were estimated from sheep with 5, 4, 3, 2, 1 scores and compared to heritabilities from sheep with 5, 6, 7, 8, 9 scores. Heritability estimates were very similar in both cases (maximum difference 0.03) and not statistically different, suggesting inwards v outwards deviations are not different traits.

To further condense the data presented, the 1 to 5 scores for each foot trait were summed for front, back and all 4 feet. From the score summed over all 4 feet (range 4 to 20) 2 binomial scores (0 = no faults; 1 = some degree of faults) were constructed. In the first case 4 = 0 and 5 to 20 = 1. In the second case 4 to 7 = 0 and 8 to 20 = 1.

The repeatability of foot scoring was assessed by 3 different operators each scoring 30 Booroola trial ewes 2 times 1 day apart. The 3 operators were staff at Rotomahana, one being experienced (T.G.H.) and the

other 2 relatively inexperienced foot scorers.

A series of fixed and mixed model least squares analyses were undertaken.

1. Strain trial. For the foot traits recorded at 9 and 18 months of age and teeth occlusion recorded at 18 months of age a fixed effect model was fitted for the first cross ewes which included year born (1979-83), strain-cross (8 classes), birth-rearing rank (singles, multiples, born multiple raised single), age of dam (2-tooth v mature ewes) and a covariate for birth date. A mixed model was fitted which included year born x strain subclasses as a fixed effect and sires nested within these as a random effect. Other fixed effects included in the model were birth rearing rank and birth date. Variance and covariance components were estimated by method 3 of Henderson (1953), and heritabilities and genetic correlations were calculated from paternal half-sib covariances. Similar analyses were undertaken for the ewes born in 1979 and 1980 which had both foot traits and teeth occlusion data recorded at the 5-year old stage (1984 and 1985). The foot and teeth data recorded at 18 months of age were included as further dependent variables in these analyses to estimate phenotypic and genetic correlations between the same traits recorded on young and mature ewes. In addition, these analyses included 3 ewe production traits (number of lambs born, number of lambs weaned and fleece weight) for the first 3 parities to estimate residual correlations with foot and teeth traits.

2. Booroola trial. Foot and teeth occlusion traits recorded at 9 and 18 months of age on Phase I ewes were first analysed using a fixed effects model including year of birth (1979-81), breed-cross (4 classes), birth-rearing rank, age of dam and birth date. The mixed model analysis included sires (random) within sire breed x year born subclasses (fixed) and also included birth-rearing rank and birth data as fixed effects in the model. No 5-year-old foot or teeth data were recorded on these ewes.

The statistical problems associated with the analysis of discrete categorical data such as the foot scores considered in this paper have been discussed by Gianola and Foulley (1982), Gilmour (1983) and Gilmour *et al.* (1985) for both binomial and multinomial traits. A logistic linear mixed model methodology was developed by Gilmour (1983). The intraclass correlation in this case is given by

$\sigma_s^2 / (\sigma_s^2 + \pi^2/3)$ where σ_s^2 is the sire variance component and $\pi^2/3$ is the variance of the standard logistic distribution. Binomial foot scores were computed for the strain trial data and analysed both by ordinary least squares procedures and using Gilmour's methodology.

RESULTS

Repeatability

Repeatability of the uncoded scores as originally recorded, i.e. 1 to 9 scores for foot placement, digit placement and foot roll and 1 to 5 scores for pastern angle and horn growth, was only low to moderate for foot scores on different feet of the same animal (Table 1). Thus a fault on one foot did not necessarily indicate faults on other feet. The repeatability of scoring among operators when recording the same trait on a given foot was high for hoof growth (0.92) but low for pastern angle (0.27) with intermediate values (0.41 to 0.58) for the other 3 traits. The repeatability of scoring the same animal at 2 different times followed the same pattern and was high for hoof growth but low for pastern angle. Separate repeatabilities for the 3 operators showed that the most experienced (operator 1) was the most repeatable scorer, particularly for foot placement, foot roll and pastern angle. In a separate study the repeatability of scoring 46 Strain Trial ewes (18 months of age) 2 times for teeth occlusion by the operator responsible for this task was 0.73.

TABLE 1 Repeatability estimates for 5 foot characters.

| | Foot placement | Digit placement | Foot roll | Pastern angle | Hoof growth |
|--|----------------|-----------------|-----------|---------------|-------------|
| Among feet within operator and day | 0.47 | 0.23 | 0.36 | 0.36 | 0.45 |
| Among operators within day and foot | 0.58 | 0.45 | 0.41 | 0.27 | 0.92 |
| Between days, within foot and operator | 0.61 | 0.44 | 0.42 | 0.33 | 0.93 |
| foot | | | | | |
| —Operator 1 | 0.77 | 0.49 | 0.51 | 0.347 | 0.96 |
| —Operator 2 | 0.45 | 0.46 | 0.24 | 0.19 | 0.91 |
| —Operator 3 | 0.46 | 0.40 | 0.40 | 0.24 | 0.92 |

Breed, Strain or Breed-Cross Effects

For all 5 foot traits analyses were carried out both on the 1 to 5 scored traits and the 2 binomial traits (0 = no faults; 1 = some degree of fault). Conclusions from the 3 analyses were similar. Percentages of 18-month old ewes with faults on one or more feet are shown in Table 2 along with mean teeth occlusion. Age of dam, birth-rearing rank and birth date did not affect any of the foot traits in either trial. The effect of 18-month live weight on foot traits recorded at that age was also small except that in the Strain trial heavier ewes had

significantly more hoof growth. Year of birth affected all foot traits ($P < 0.001$) in both trials.

At 9 months of age in the Strain trial, genotypes differed only in foot twist and pastern angle, but at 18 months of age there were significant genotype differences for all foot traits except digit placement and foot roll (Table 2). Relative to the Romney mean, Coopworth crosses had similar foot structure, but Border Leicester crosses had a lower proportion of sheep with foot placement and pastern angle abnormalities. Foot data on 5-year-old ewes are available only for ewes born in 1979 and 1980 in the Strain trial, and no significant differences among genotypes were found for any of the 5 foot traits.

Amongst sheep in the Booroola trial Romneys and Perendales differed only in Perendales having more pastern problems. For all foot traits except pastern angle, Merino-crosses had significantly higher proportions of sheep with abnormalities compared to the straightbred Romneys or Perendales. The Booroola F gene had no effect on any foot trait among Merino-cross ewes which had been classified as F+ or ++ genotypes.

The genotype effects on foot traits reported in Table 2 related to scores accumulated over all 4 feet. Analyses were also undertaken on scores summed over the 2 front and the 2 back feet. In general genotype differences, where they occurred, were manifested in both front and back feet. The exception was pastern angle which was almost entirely a function of abnormalities occurring in back feet (Fig. 1).

Although the differences between genotypes in teeth occlusion (Table 2) were not very large, Coopworth-Romney and Merino-Perendale cross ewes and 2 of the Romney strains (C and E) were less undershot than the other genotypes. The overall mean teeth occlusion of 1.0 mm behind the anterior point of the dental pad was identical in the 2 trials. There were more deviations in the undershot (positive) than in the overshot (negative) direction (Fig. 2).

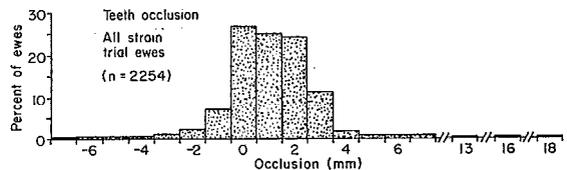


FIG. 2 Distribution of teeth occlusion in 18-month Strain trial ewes.

Heritabilities and Correlations

For records taken at 9 and 18 months of age, heritability estimates (Table 3) are based on 182 sire progeny groups in the Strain trial and 84 sire progeny groups in the Booroola trial with approximately 12

ewe progeny/sire group in both trials. With the exception of hoof growth, low non-significant heritabilities were found for foot traits recorded at 9 months of age. At 18 months of age moderate to low heritabilities were found for all foot traits which in general were similar in both trials. There was evidence of higher heritabilities for hoof growth in the Booroola trial than in the Strain trial. This was not a function of the Merino crosses in the Booroola trial. There was some evidence for higher heritabilities for traits scored on back feet than front feet (not tabulated here), particularly for digit placement, pastern angle and hoof growth.

The phenotypic correlation between scores for the same sheep for a given foot trait at 9 and 18 months of age was low and ranged from 0.10 to 0.24 in the strain trial and 0.13 to 0.41 (hoof growth) in the Booroola trial. When estimable, the genetic correlations were all positive but non-significant (high standard errors) with the exception of hoof growth in the Booroola trial (1.00 ± 0.12).

Teeth occlusion at 18 months of age was lowly to moderately heritable in the Booroola trial (0.13) and in the Strain trial (0.25). In the Strain trial the positive occlusion values (undershot) were analysed separately from the negative values (overshot) and the heritability

TABLE 2 Effect of breed, strain and breed-cross on percentage of sheep with foot abnormalities¹ and teeth occlusion (mm) recorded on 18-month old ewes

| | No. | Foot placement | Digit placement | Foot roll | Pastern angle | Hoof growth | Teeth occlusion |
|----------------------------------|------|----------------|-----------------|-----------|---------------|-------------|-----------------|
| Strain Trial (1979-83) | | | | | | | |
| Romney Strain A | 247 | 16 | 30 | 12 | 18 | 15 | 1.1 |
| B* | 303 | 11 | 28 | 11 | 15 | 17 | 1.2 |
| C | 286 | 15 | 30 | 9 | 19 | 10 | 0.9 |
| D* | 300 | 13 | 30 | 8 | 20 | 6 | 1.2 |
| E* | 290 | 15 | 27 | 11 | 24 | 8 | 0.9 |
| F | 228 | 16 | 33 | 13 | 19 | 12 | 1.1 |
| Romney Mean | 1654 | 14 | 30 | 11 | 19 | 11 | 1.0 |
| Coopworth* x R | 297 | 14 | 26 | 6 | 14 | 13 | 0.9 |
| Border Leicester x R | 300 | 7 | 24 | 7 | 7 | 9 | 1.1 |
| SED | | 3 | 4 | 3 | 3 | 3 | 0.1 |
| Booroola Merino Trials (1979-81) | | | | | | | |
| Romney (RxR) | 216 | 8 | 23 | 5 | 22 | 18 | 1.1 |
| Perendale (PxP) | 264 | 8 | 24 | 5 | 37 | 16 | 1.1 |
| Merino x R | 280 | 23 | 45 | 13 | 27 | 50 | 1.1 |
| Merino x P | 322 | 22 | 41 | 11 | 21 | 48 | 0.8 |
| SED | | 3 | 4 | 3 | 4 | 4 | 0.1 |

¹ Feet scores (1 to 5) summed over all 4 feet and the binomial trait analysed (4 to 7 = 0 = normal; 8 to 20 = 1 = some degree of abnormality)

* Group Breeding Schemes

TABLE 3 Paternal half-sib heritability estimates for foot traits (4 to 20 score) and teeth occlusion recorded on ewe hoggets and 5-year-old ewes

| Trait | Strain trial | | | Booroola trial | |
|-----------------|--------------|-----------|-----------|----------------|-----------|
| | 9mo | 18mo | 5yr | 9mo | 18mo |
| Foot placement | 0.08±0.04 | 0.15±0.05 | 0.03±0.06 | 0.11±0.07 | 0.02±0.06 |
| Digit placement | 0.05±0.04 | 0.10±0.05 | 0.12±0.08 | n.e. | 0.17±0.07 |
| Foot roll | 0.08±0.04 | 0.06±0.04 | n.e. | 0.10±0.07 | 0.17±0.07 |
| Pastern angle | n.e. | 0.13±0.05 | 0.20±0.90 | 0.11±0.07 | 0.07±0.06 |
| Hoof growth | 0.18±0.05 | 0.14±0.05 | n.e. | 0.28±0.09 | 0.27±0.09 |
| Teeth occlusion | — | 0.25±0.06 | 0.36±0.10 | — | 0.13±0.06 |

n.e. Not estimable—negative sire variance components

estimates were 0.16 ± 0.05 and 0.03 ± 0.10 respectively. In the Booroola trial Merino-sired progeny groups were analysed separately from Romney-sired progeny groups and heritability estimates were 0.37 ± 0.13 and 0.13 ± 0.18 respectively.

Data available in the Strain trial indicate that the heritabilities of foot traits in 5-year-old ewes are very similar to those for hoggets (Table 3). The heritability of teeth occlusion was higher in strain trial 5-year-old ewes (0.36) than in the same ewes at 18 months of age (0.25) with phenotypic and genetic correlations between these 2 measurement times of 0.49 and 0.39 ± 0.22 respectively. The average teeth occlusion position for these ewes increased from 0.76 mm at 18 months of age to 1.62 mm as 5-year-old ewes (i.e. they became slightly more undershot). Overall frequencies of foot faults were very similar for all traits in both 18-month and 5-year-old ewes; the phenotypic correlations among measurements at these 2 ages were quite low and ranged from 0.08 to 0.25.

Expression of feet traits as binomial (0, 1) rather than multinomial (4 to 20) scores had no significant effect on the heritability estimates, although in general heritability estimates for binomially scored trait were slightly smaller (Table 4—OLS *v* Table 3 estimates). The binomially scored traits shown in Table 4 were the 4 *v* 5 to 20 construction. Heritabilities of the 4 to 7 *v* 8 to 20 binomial score were very similar and therefore were not tabulated. Similarly, using the logistic linear mixed model (LLMM) procedure gave heritability estimates on the additive underlying scale which were similar to the ordinary least square (OLS) estimates of the binomial traits.

Correlation estimates among foot traits were consistent in both trials. Pastern angle was not correlated phenotypically or genetically with any of the other 4 foot traits. Phenotypic correlations among the other 4 foot traits were low to moderate (0.13 to 0.20), and most genetic correlations were non-significant with high standard errors with the exception of a positive association of digit placement with foot roll (1.05 ± 0.41) and hoof growth (0.45 ± 0.29).

TABLE 4 Heritability of binomial foot traits (all feet) for Strain trial ewe hoggets estimated using different statistical techniques¹

| | 9mo | | 18mo | |
|-----------------|-----------------|------|-----------------|------|
| | OLS | LLMM | OLS | LLMM |
| Foot placement | 0.06 ± 0.04 | 0.07 | 0.10 ± 0.05 | 0.15 |
| Digit placement | 0.07 ± 0.04 | 0.01 | 0.06 ± 0.04 | 0.08 |
| Foot roll | 0.06 ± 0.04 | 0.06 | 0.11 ± 0.05 | 0.08 |
| Pastern angle | 0.03 ± 0.04 | 0.04 | 0.07 ± 0.04 | 0.12 |
| Hoof growth | 0.13 ± 0.05 | 0.18 | 0.05 ± 0.04 | 0.15 |

¹ OLS — Ordinary least squares

LLMM — Logistic linear mixed model

Correlations with Performance Traits

All correlations of foot traits and teeth occlusion recorded at 9 or 18 months of age with hogget performance traits (weaning weight, 12 and 18 month live weights and hogget fleece weight) were non-significant. Phenotypic correlations ranged from 0.03 to 0.01.

Similarly, none of the foot traits or teeth occlusion recorded at 18 months or 5 years of age was significantly correlated genetically or phenotypically, with any of the ewe production traits (i.e. live weights, fleece weights, litter size or weaning rate). Phenotypic correlations ranged from -0.08 to 0.08 and averaged 0.01.

DISCUSSION

Foot Conditions

The finding that Merino-cross ewes have a higher incidence of foot abnormalities than Romney or Perendale ewes was also reported by Alwan (1983). Foot conditions recorded by Alwan (1983) included footscald and footrot and both conditions were more prevalent in Merino-cross ewes. The same result has been found at Rotomahana (Baker, Skerman and Dobbie, unpublished).

Differences among the 6 Romney strains in incidence of foot faults were significant for pastern angle and hoof growth (Table 2). Despite rigorous attention to breed type and structural soundness in breeding programmes in industry studs (Strains A and F) there was no evidence that they had a lower incidence of foot faults than the Ruakura High Fertility line (strain C) or the Romney Group Breeding Schemes sampled (strains B, D and E). The Ruakura High Fertility line has been maintained as a closed flock since 1948 and selected solely on dam's twinning performance with no attention to breed type or structural soundness.

Heritabilities of the foot conditions as visually assessed in this study were in general low, but indicate that some, particularly hoof growth, have a genetic component. Other evidence for the heritability of foot conditions in sheep is relatively sparse. Alwan (1983) studied foot shape, footscald and footrot in Booroola Merino crosses and Perendale sheep recorded at 5, 11 and 17 months of age on New Zealand hill country. Paternal half-sib heritability estimates for foot shape were 0.17, 0.35 and 0.20 at 5, 11 and 17 months of age respectively. Presumably the trait 'foot shape' includes hoof growth which was also moderately heritable in the present study.

Despite limited evidence for a genetic component affecting foot conditions in sheep there is some evidence in other livestock species. Heritability estimates of leg weakness in pigs range from zero to 0.30 as reviewed by Webb *et al.* (1983). In cattle, low heritability estimates of foot scores were reported by Peterse and Antonisse

(1981) and Morris *et al.* (1985), but higher estimates were reported by Brinks *et al.* (1979) and Hahn *et al.* (1978). In common with sheep, hoof growth appears to be one of the more heritable foot scores recorded in cattle.

The absence of any adverse genetic or phenotypic association between feet conditions and hogget or ewe performance traits in this study is consistent with the findings of Napier and Jones (1982). In pigs there are some reports that leg condition and fatness are adversely genetically related but in general no strong relationships with other performance traits such as growth rate or feed efficiency have been reported (Webb *et al.*, 1983). Similarly, Morris *et al.* (1985) concluded that although cattle could be repeatedly ranked on foot and leg scores, these scores were of little use in culling for poor production (live weight) at the ages they were recording (i.e. less than 2 years).

Teeth Occlusion

The breed differences in dental occlusion found in this study, although significant, were relatively small, but do provide some evidence for heritable variation. Breed differences in the position at which teeth meet the upper pad have been reported for sheep by Hitchin (1948) and for cattle by Donald and Weiner (1954) and Weiner and Gardner (1970). The overall mean (and modal) occlusion position of 1 mm behind the anterior point of the dental pad of the gum observed in this study was the same as that reported by Purser *et al.* (1982) in a study of dentition in Scottish Blackface ewes.

Purser *et al.* (1982) reported heritability estimates for occlusion of 0.08 and 0.19 based on paternal half-sib correlation and daughter-dam regression respectively, but neither estimate was significantly different from zero. Nordby *et al.* (1945) suggested that extreme occlusion deviations may be highly heritable and possibly controlled by a few major genes. In the present study, there were more sheep with deviations in the undershot than the overshot direction, as also observed by Barnicoat (1957), but still only 2% of the observations deviated by 4 mm or more (plus or minus) from the mean 1 mm position. In the flocks surveyed by Barnicoat the percentage of sheep with 'undershot tendencies' averaged 52% and ranged from 15 to 77%. In Strain trial ewe hoggets the heritability of the undershot values (0.16) was higher than the overshot deviations (0.03) but these 2 heritability estimates were not significantly different. Barnicoat (1957) stated that the undershot condition was very strongly inherited but did not estimate any heritabilities from his data. Wiener and Gardner (1970) reported reasonably high heritability estimates (0.3 to 0.5) for occlusion in Galloway bulls. They also reported evidence that what is inherited is not only a predisposition to deviate from

normal but a directional deviation i.e. an undershot deviation or an overshot condition, but not both, with the possible exception of very small deviations. Donald and Wiener (1954) reviewed evidence for the genetic control of mandibular prognathism mainly with reference to cattle. They concluded that while heredity may be an important part of the variation observed it is not always of a simple Mendelian type.

No adverse associations of malocclusion with hogget or ewe production traits were found in this study. Purser *et al.* (1982) found low but statistically significant correlations (0.1) of occlusion with ewe live weight and fleece weight for 1½-year-old ewes. For 2½- and 3½-year old ewes correlations of occlusion with ewe live weight, fleece weight and weight of lamb weaned ranged from 0.06 to 0.07, and none was significantly different from zero. Sheep with undershot occlusion have been reported to have greater teeth wear (Barnicoat, 1957; Meyer *et al.*, 1983), but sheep with excessive teeth wear are not necessarily low producers (Barnicoat, 1957; Sykes *et al.*, 1974).

Practical Implications

Traditionally, sheep with sound mouths and normal feet and leg conditions have been assumed to be more productive than those with 'abnormalities'. It is clear, however, at least as far as the relationship of these traits with production is concerned, that the definition of abnormality is somewhat arbitrary. In addition, the fact that both occlusion and foot conditions are to a greater or lesser degree inherited is not in itself a rational reason for culling these animals. In any breeding programme a number of different characters must be considered and the relative economic importance of both production and non-production traits ascertained. While there may be some evidence that extreme deviants from what is regarded as normal may be undesirable and warrant culling (e.g. sheep with extreme malocclusion or excessive hoof growth), these are in fact a very small percentage of the total sheep. Their exclusion would not markedly affect the selection differential that could be applied for other traits and therefore the rate of genetic progress. Unfortunately, the situation that often applies at present is that ewes and rams are culled on relatively minor deviations from what can be considered as normal variation of the traits involved. The present results provide no support for this practice, either as a means of genetically reducing the incidence of the 'abnormalities' or increasing production.

ACKNOWLEDGEMENT

To the Rotomahana staff and J.L. Dobbie for scoring foot and teeth conditions; to A.P. Hurford and S.M. Hickey for technical assistance and to Dr D.L. Johnson for statistical assistance with the logistic linear mixed model analyses.

REFERENCES

- Alwan M.T. 1983. Studies of the flock mating performance of Booroola Merino crossbred ram lambs and the foot conditions in Booroola Merino crossbreds and Perendale sheep grazed on hill country. *M. Agr. Sci. Thesis, Massey University*.
- Barnicoat C.R. 1957. Wear in sheep's teeth. *New Zealand journal of science and technology* **38**: 583-632.
- Brinks J.S.; Davis M.E.; Mangus W.L.; Denham A.H. 1979. Genetic aspects of hoof growth in beef cattle. *Journal of animal science* **49**(Suppl. 1): 152-153.
- Butler B. 1983. Hogget selection survey. *The New Zealand Farmer*: 78-79.
- Dodd C.J.; Milligan K.E.; Wickham B.W. 1982. An overview of New Zealand group breeding schemes. *Proceedings of the World Congress on Sheep and Beef Cattle Breeding*. Eds. R.A. Barton and W.C. Smith Vol. II: 103-112.
- Donald H.P.; Wiener G. 1954. Observations on mandibular prognathism. *The veterinary record* **66**: 479-482.
- Eikje E.D.; Clarke J.N. 1986. Selection in some flocks of New Zealand Romney. II. Selection of replacements and culling on the basis of performance. *New Zealand journal of agricultural research* (in press).
- Gianola D.; Foulley J.L. 1982. Non-linear prediction of latent genetic ability with binary expression: An empirical Bayes approach. *Proceedings of 2nd World Congress on Genetics Applied to Livestock Production* **7**: 293-303.
- Gilmour A.R. 1983. The estimation of genetic parameters for categorical traits. *Ph.D. Thesis, Massey University*.
- Gilmour A.R.; Anderson R.D.; Rae A.L. 1985. The analysis of binomial data by a generalized linear model. *Biometrika* **72**: 593-599.
- Hahn M.V.; McDaniel B.T.; Wilk J.C. 1978. Heritabilities of objectively measured hoof traits of Holsteins. *Journal of dairy science* **61**(Suppl. 1): 83-84.
- Henderson C.R. 1953. Estimation of variance and covariance components. *Biometrics* **9**: 226-252.
- Hitchin A.D. 1948. Relationship of occlusion and paradental disease in sheep. *The dental record* **58**: 251-254.
- Meyer H.H.; Aitken W.M.; Smeaton J.E. 1983. Inheritance of wear rate in the teeth of sheep. *Proceedings of the New Zealand Society of Animal Production* **43**: 189-191.
- Morris C.A.; Cullen N.G.; Packard P.M. 1985. Foot scores of cattle. 1. Variation among subjective scores of Angus cattle from different herds and sire groups. *New Zealand journal of experimental agriculture* **13**: 235-240.
- Napier K.M.; Jones L.P. 1982. Effect of age, maternal handicap, birth and survival type on five fleece and body characters of Corriedale rams. *Australian journal of experimental agriculture and animal husbandry* **22**: 281-287.
- Nordby J.E.; Terrill C.E.; Hazel L.N.; Stoehr J.A. 1945. The etiology and inheritance of inequalities in the jaws of sheep. *Anatomical record* **92**: 235-254.
- Peterse D.J.; Antonisse W. 1981. Genetic aspects of feet unsoundness in cattle. *Livestock production science* **8**: 253-261.
- Purser A.F.; Wiener G.; West D.M. 1982. Causes of variation in dental characters of Scottish Blackface sheep in a hill flock and relations to ewe performance. *Journal of agricultural science, Cambridge* **99**: 287-294.
- Sykes A.R.; Field A.C.; Gunn R.G. 1974. Effects of age and stage of incisor dentition on body composition and lamb production of sheep grazing hill pastures. *Journal of agricultural science, Cambridge* **83**: 135-143.
- Webb A.J.; Russel W.S.; Sales D.I. 1983. Genetics of leg weakness in performance-tested boars. *Animal production* **36**: 117-130.
- Wiener G.; Gardner W.J.F. 1970. Dental occlusion of young bulls of different breeds. *Animal production* **12**: 7-12.