Environmental effects, heritability estimates and genetic trends in a Western Cape Dohne Merino nucleus flock

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Data from 1390 to 1902 Dohne Merino progeny of a nucleus flock were used to evaluate environmental influences, and to obtain heritability estimates for live weight at birth, weaning and yearling age and for yearling fleece traits. Estimated breeding values for yearling live weight, clean fleece weight and fibre diameter were obtained by backsolution, averaged for birth years, and used to reflect genetic trends. Rams and singles were generally heavier with heavier fleeces ($p < 0.05$) than ewes and multiples. Rams and multiples produced stronger ($p < 0.05$) wool than ewes and singles. Age of dam only affected live weight traits significantly ($p < 0.10$). Expressed relative to the total phenotypic variation, parameter estimates for birth weight were 0.04 ± 0.03 for direct additive genetic variation, 0.10 ± 0.06 for maternal additive variation, and 0.17 ± 0.05 for maternal permanent environmental effects. Only direct additive effects (0.06 ± 0.04) and maternal permanent environmental effects (0.21 ± 0.04) resulted in an improvement in log likelihood values for weaning weight. Only direct additive effects were required for yearling live weight and fleece traits. Direct heritability estimates were 0.24 ± 0.06 for live weight, 0.35 ± 0.06 for clean fleece weight, 0.66 ± 0.05 for clean yield, 0.35 ± 0.06 for staple length and 0.43 ± 0.07 for fibre diameter. Genetic changes over the period 1980 to 1994 amounted to 0.145 kg p.a. ($r = 0.85$) for yearling live weight, 0.010 kg p.a. ($r = 0.96$) for clean fleece weight and –0.011 μm p.a. ($r = -0.38$) for average fibre diameter. It was concluded that adequate genetic variation exists for the genetic improvement of traits measured at yearling age, as reflected by the observed genetic trends.

Keywords: Dohne Merino, genetic trends, live weight, wool traits, yearling performance.

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Introduction

The Dohne Merino breed is a synthetic breed developed in South Africa from the Merino and the then German Merino (presently known as the SA Mutton Merino). The breed was originally intended for semi-intensive farming in the Eastern Cape grassland regions (Kotzé, 1951). It has since proved itself as an adaptable breed with easy-care properties, able to thrive under widely divergent conditions. This has resulted in a sustained growth in numbers for the breed, and its expansion to other areas (Laas, 1982). Within the last number of years, Dohne numbers have also increased markedly in the Western Cape. So far, no genetic parameters have been estimated for

Dohne Merinos under Western Cape conditions. In fact, only a few references have reported genetic parameters for live weight and fleece traits in this breed (Fourie & Heydenrych, 1982b; Laas, 1982).

Industry requirements have resulted in potential sires being evaluated at younger ages in Australia (Ponzoni *et al.*, 1995). This practice is also being implemented in South Africa by breeders wishing to auction their rams at approximately 17 months of age in full fleece. Performance testing is thus carried out at ages ranging from 10 to 12 months. Selection decisions are often based on performance records obtained at this age, with 5 to 7 months of wool growth. At this stage, there is limited information regarding the importance of specific environmental effects on production. There is also little knowledge about the heritability of traits under these conditions. Significant maternal additive effects, albeit small in magnitude, have recently been reported for live weight and fleece weight at 16 months in Merino flocks (Olivier *et al.*, 1994; Snyman *et al.*, 1996). At this stage it is uncertain if such effects would also exist in Dohne Merino sheep performance tested at a younger age of approximately 11 months.

The purpose of this study was, therefore, to investigate the effects of environmental factors on performance of a Dohne Merino nucleus flock under typical Western Cape conditions, to estimate heritabilities of live weight and wool traits for this breed, and to determine their genetic trends.

Material and methods

Animals and locality

Data were obtained from the nucleus flock of the Western Cape Dohne Merino Club. The flock was founded in 1979, with 131 ewes donated by 15 club members. At first sires were obtained from breeders, but since the 1984 joining, only rams bred in the nucleus flock were used for breeding. Members continued to provide female breeding material. Approximately 40% of replacement ewes were donated by them in later years, while 60% were selected from within the nucleus flock. The selection policy stipulated by the Dohne Merino Breeders' Association, as described by Laas (1982) was used for selection decisions. Performance records were available for a 15-year period from 1980 to 1994. During this period the flock was run on the Kromme Rhee experimental farm near Stellenbosch. The climate at the experimental site is mediterranean, with cool, wet and windy winters and hot, dry summers.

Management and recordings

The animals mostly utilised irrigated kikuyu pastures during summer, while dryland oat fodder crops were established for utilisation in the winter months. Pregnant and lactating ewes also received a supplement of 0.5 kg production pellets daily. Lambs were weighed and identified with their dams within 24 h of birth, and weaned at an average (± SD) age of 101 ± 10 days. Details regarding birth date, sex (male or female), age of dam (2–7+ years) and type of birth (single or multiple) were available for individual lambs. Ram and ewe progeny were subsequently separated and shorn for the first time at approximately 5 months of age. Performance was recorded at the following shearing at approximately 11 months of age. The pasture utilised by young sheep was supplemented with 250 g production pellets daily. Traits recorded at this stage included live weight and greasy fleece weight. A wool sample was taken to allow the measurement of clean yield, average fibre diameter and staple length. Clean fleece weight was calculated from greasy fleece weight and the percentage clean yield, before being adjusted to a constant growth period of 183 days.

Statistical analysis

Environmental effects were quantified by fixed model least squares procedures (Harvey, 1990). These included birth year, sex, dam age, birth type and birth date (as a linear covariable) as well as significant two-way interactions between fixed effects. Traits analysed were live weight at birth, weaning and yearling age, as well as yearling fleece traits.

The DFREML program (Meyer, 1989; 1991) was subsequently used to estimate variance components in univariate analyses on live weight and wool traits. Fixed effects found to be significant ($p < 0.05$) in the preliminary analyses, were included. The following models were fitted to the data:

$$y = Xb + Z_1a + e \quad (1)$$
$$y = Xb + Z_1a + Z_2c + e \quad (2)$$
$$y = Xb + Z_1a + Z_2m + e \quad (3)$$
$$[Cov(a,m) = 0]$$
$$y = Xb + Z_1a + Z_2m + e \quad (4)$$
$$[Cov(a,m) = A\sigma_{am}]$$
$$y = Xb + Z_1a + Z_2m + Z_3c + e \quad (7)$$
$$[Cov(a,m)=0]$$
$$y = Xb + Z_1a + Z_2m + Z_3c + e \quad (8)$$
$$[Cov(a,m)=A\sigma_{am}]$$

with y being a vector of observations for live weight or wool traits; b, a, m and c vectors of fixed effects, direct additive genetic effects, maternal additive genetic effects and maternal permanent environmental effects respectively; X, Z_1, Z_2, Z_3 the corresponding incidence matrices relating the respective effects to y; e the vector of residuals; A the numerator relationship matrix, and σ_{am} the covariance between direct additive and maternal additive genetic effects.

It was assumed that:

$$V(a) = A\sigma^2_a; \; V(m) = A\sigma^2_m; \; V(c) = I\sigma^2_c; \; V(e) = I\sigma^2_e;$$

with I being an identity matrix; σ^2_a, σ^2_m, σ^2_c, σ^2_e the direct additive genetic variance, maternal additive genetic variance, maternal permanent environmental variance and environmental variance, respectively.

Log likelihood tests were conducted to determine the most suitable model for each trait. An effect was regarded as significant if its inclusion improved the log likelihood significantly ($p < 0.05$), as tested by the Chi-squared test (Snyman *et al.*, 1995b). Approximate sampling errors for each trait were obtained for the most suitable model by fitting a quadratic or cubic function to the profile likelihood (Meyer & Hill, 1992).

Estimated breeding values for yearling live weight, clean fleece weight and average fibre diameter of individuals were obtained from backsolutions and averaged within birth years. These means were represented against birth year in graphs, depicting genetic change in the respective traits.

Results and discussion

Environmental effects

Live weights were generally above those reported for Eastern Cape Dohne Merinos by Fourie & Heydenrych (1982a), suggesting that the flock was run under favourable environmental conditions.

Coefficients of variation for live weight traits and clean fleece weight were above 15%, while they were below 10% for clean yield and average fibre diameter (Table 1). These results accord with previous results for Dohne Merinos (Fourie, 1981) and for other wooled breeds (Walkley *et al.*, 1987; Olivier *et al.*, 1994; Snyman *et al.*, 1995b; 1996).

All traits except staple length were affected ($p < 0.05$) by birth year, sex and birth type (Tables 2 and 3). Rams were generally heavier and produced more clean wool with a stronger fibre diameter and a lower yield than ewe contemporaries. Significant ($p < 0.01$) interactions between birth year

Table 1 Means, standard deviations and coefficients of variation for the traits analysed

Trait	Number of records	Mean ± SD	Coefficient of variation
Birth weight (kg)	1902	4.65 ± 0.86	18.5
Weaning weight (kg)	1390	28.1 ± 5.8	20.6
Yearling weight (kg)	1902	55.8 ± 10.2	18.3
Clean fleece weight (kg)	1902	1.95 ± 0.39	20.1
Clean yield (%)	1902	66.6 ± 6.3	9.4
Staple length (mm)	1678	111±14	12.8
Fibre diameter (μm)	1902	21.8 ± 1.5	6.9

Table 2 Least squares means (± SEs) depicting the influence of fixed effects on live weight traits

Fixed effect	Birth weight (kg)	Weaning weight (kg)	Yearling weight (kg)
Overall mean	4.81 ± 0.02	29.0 ± 0.1	57.3 ± 0.2
Birth year	***	***	***
Sex	***	***	***
Ram	4.95 ± 0.03	30.3 ± 0.1	64.6 ± 0.2
Ewe	4.68 ± 0.03	27.7 ± 0.1	50.1 ± 0.2
Age of dam	***	ns	*
2 years	4.57 ± 0.05	28.5 ± 0.3	56.6 ± 0.3
3 years	4.81 ± 0.05	29.1 ± 0.3	57.6 ± 0.4
4 years	4.91 ± 0.04	29.4 ± 0.2	58.1 ± 0.3
5 years	4.62 ± 0.04	28.9 ± 0.2	57.2 ± 0.3
6 years	4.95 ± 0.04	29.1 ± 0.2	57.4 ± 0.3
7+ years	4.79 ± 0.05	29.1 ± 0.2	57.2 ± 0.3
Birth type	***	***	***
Single	5.18 ± 0.03	31.2 ± 0.2	58.3 ± 0.2
Multiple	4.45 ± 0.03	26.8 ± 0.1	56.4 ± 0.2
Regression on	**	***	*
birth date	0.05 ± 0.02	–0.15 ± 0.01	–0.026 ± 0.013

ns Not significant ($p > 0.05$); * Significant ($p < 0.05$); ** Significant ($p < 0.01$);
*** Significant ($p < 0.001$)

Table 3 Least squares means (± SEs) depicting the influence of fixed effects on wool traits

Fixed effect	Clean fleece weight (kg)	Clean yield (%)	Staple length (mm)	Fibre diameter (μm)
Overall mean	1.96 ± 0.01	66.5 ± 0.2	111 ± 1	21.8 ± 0.1
Birth year	***	***	***	***
Sex	***	***	ns	***
Ram	2.13 ± 0.02	63.8 ± 0.2	111 ± 1	21.9 ± 0.0
Ewe	1.81 ± 0.02	69.1 ± 0.2	112 ± 1	21.7 ± 0.0
Age of dam	ns	ns	ns	ns
2 years	1.93 ± 0.03	66.8 ± 0.3	110 ± 1	21.8 ± 0.1
3 years	1.99 ± 0.03	67.0 ± 0.3	112 ± 1	21.8 ± 0.1
4 years	1.96 ± 0.03	66.6 ± 0.3	111 ± 1	21.8 ± 0.1
5 years	1.97 ± 0.03	66.1 ± 0.3	111 ± 1	21.9 ± 0.1
6 years	1.94 ± 0.03	66.3 ± 0.3	111 ± 1	21.7 ± 0.1
7+ years	1.97 ± 0.03	66.0 ± 0.3	112 ± 1	21.7 ± 0.1
Birth type	***	*	ns	***
Single	2.01 ± 0.02	66.8 ± 0.2	112 ± 1	21.7 ± 0.0
Multiple	1.90 ± 0.02	66.1 ± 0.2	111 ± 1	21.9 ± 0.0
Regression on birth date	ns 0.00 ± 0.01	ns 0.01 ± 0.01	ns 0.04 ± 0.04	ns 0.00 ± 0.01

ns Not significant ($p > 0.10$); * Significant ($p < 0.05$); ** Significant ($p < 0.01$); *** Significant ($p < 0.001$)

and sex were observed for all traits except birth weight. Expressed relative to ewes, the weight advantage of yearling rams ranged from 44% in 1981 to 16% in 1985. The interaction between sex and birth year stems from the fact that rams and ewes were kept in separate flocks from weaning. It was obviously impossible to maintain similar grazing conditions for these flocks. It is, therefore, not surprising that an interaction between sex and birth year is often found in the literature (Heydenrych, 1975; Snyman *et al.*, 1995a). For practical purposes these effects are of little consequence, as selection is mostly done within sex and birth year groups (Walkley *et al.*, 1987; Fourie & Heydenrych, 1982a).

Dam age only affected ($p < 0.05$) birth and yearling live weights (Tables 2 and 3). Literature reports have often found that live weight of weaners or yearlings reared by 2-year-old ewes was lower ($p < 0.05$) than that of contemporaries reared by 3–6-year-old ewes (Fourie & Heydenrych, 1982a; Snyman *et al.*, 1995a). The lack of a significant age of dam effect for clean fleece weight accorded with a previous finding that 18 months greasy fleece weight was independent of age of dam in Dohne Merinos (Fourie & Heydenrych, 1982a). The lack of age of dam influences on fleece weight, average fibre diameter and clean yield was also reported by Walkley *et al.* (1987).

Singles were heavier and cut heavier fleeces with a higher clean yield and a lower average fibre diameter than multiples ($p < 0.05$; Tables 2 and 3). Birth type effects on live weight and fleece traits accorded with literature reports (Heydenrych, 1975; Fourie & Heydenrych, 1982a; Walkley *et al.*, 1987; Snyman *et al.*, 1995a). Performance levels of yearling Dohne Merinos should thus be corrected for birth type before selection (Fourie & Heydenrych, 1982a).

The regression of yearling live weight on birth date approached significance ($p = 0.052$), while it was significant at earlier ages. Walkley *et al.* (1987) found that the birth date of South Australian Merino hoggets influenced live weight and clean fleece weight. In Afrino sheep this effect was found to diminish with age but it did not disappear completely (Snyman *et al.*, 1995a). The wool traits were independent of birth date.

Log likelihood values and heritability estimates

Model 7, fitting direct and maternal additive effects, as well as maternal permanent environmental effects, fitted the data best for birth weight. The addition of random effects apart from maternal permanent environmental effects did not result in an improvement in log likelihood values for weaning weight. Random effects other than direct additive effects correspondingly did not significantly improve log likelihood values for any one of the yearling traits investigated (Table 4). A number of recent studies reported maternal additive effects for 2-tooth live weight and clean fleece weight in Merinos (Olivier *et al.*, 1994; Snyman *et al.*, 1996). Although these effects were significant, they were small in magnitude (generally below 5% of the total phenotypic variance).

Table 4 Log likelihood values for the different models fitted to the data

Trait*	Model 1	Model 2	Model 3	Model 4	Model 7	Model 8
Birth weight (kg)	–330.15	–296.40	–299.15	–298.07	**–294.78**	–293.04
Weaning weight (kg)	–2349.9	**–2334.4**	–2341.9	–2341.4	–2334.5	–2334.4
Yearling weight (kg)	**–3946.4**		–3945.0	–3945.0	–3944.9	–3944.6
Clean fleece weight (kg)	**–56.541**		–55.688	–55.541	–55.688	–55.547
Clean yield (%)	**–3082.3**		–3082.3	–3081.7	–3082.0	–3082.1
Staple length (mm)	**–5136.9**		–5136.2	–5135.9	–5135.8	–5135.8
Fibre diameter (μm)	**–1462.9**		–1462.4	–1462.4	–1462.4	–1462.8

* Bold figures represent the 'best' model

Heritability estimates for birth weight (Table 5) were within the range, albeit on the lower end of the range of values reported in the literature (Burfening & Kress, 1993; Maria *et al.*, 1993; Van Wyk *et al.*, 1993; Tosh & Kemp, 1994; Conington *et al.*, 1995; Neser *et al.*, 1995; Snyman *et al.*, 1995b). Direct heritability estimates reported by these authors ranged from 0.04 to 0.34. Corresponding ranges were 0.08 to 0.65 for maternal additive effects and 0.10 to 0.57 for maternal permanent environmental effects. The latter effect was likely to be associated with the uterine environment and the effect of multiple births (Snyman *et al.*, 1995b), as well as voluntary intake during late gestation (Maria *et al.*, 1993).

The direct additive genetic component of heritability for weaning weight (Table 5) was relatively low compared to literature estimates (0.09 to 0.22 — Burfening & Kress, 1993; 0.34 — Maria *et al.*, 1993; 0.14 to 0.39 — Tosh & Kemp, 1994; 0.12 — Conington *et al.*, 1995; 0.19 — Hall *et al.*, 1995; 0.11 to 0.30 — Neser *et al.*, 1995). The estimate for maternal permanent environment was on the higher end of the range of 0.07 to 0.20 reported in the literature (Maria *et al.*, 1993; Tosh & Kemp, 1994; Conington *et al.*, 1995; Hall *et al.*, 1995). There was no evidence of maternal additive genetic variance for weaning weight in the flock under study, which is in contrast with the majority of literature findings (Burfening & Kress, 1993; Maria *et al.*, 1993; Tosh & Kemp, 1994; Snyman *et al.*, 1995b).

The heritability of yearling weight (0.24; Table 6) accorded with literature estimates for German

Table 5 Variance components and heritability estimates for live weight traits

Parameter	Birth weight	Weaning weight	Yearling weight
Number of:			
Animals	1902	1390	1902
Sires	76	62	76
Dams	828	485	590
Variance components: (kg^2)			
σ^2_a	0.01794	0.6388	6.0151
$\sigma^2 m$	0.04821	–	–
σ^2_c	0.08369	2.1901	–
σ^2_e	0.34959	7.8324	18.7360
σ^2_p	0.49943	10.6612	24.7511
Heritability:			
$h^2 \pm$ SE	0.04 ± 0.03	0.06 ± 0.04	0.24 ± 0.06
$m^2 \pm$ SE	0.10 ± 0.06	–	–
$c^2 \pm$ SE	0.17 ± 0.05	0.21 ± 0.04	–

σ^2_a, σ^2_m , σ^2_c, σ^2_e, σ^2_p — Direct additive, maternal additive, maternal permanent environmental, environmental and phenotypic variances, respectively

Table 6 Variance components and heritability estimates for wool traits

Parameter	Clean fleece weight	Clean yield	Staple length	Fibre diameter
Number of:				
Animals	1902	1902	1678	1902
Sires	69	69	68	69
Dams	590	590	566	590
Variance components:	(kg^2)	(%^{2})	(mm^2)	(µm^2)
σ^2_a	0.1392	16.5937	66.356	0.7988
σ^2_e	0.2598	8.5972	122.763	1.0538
σ^2_p	0.3990	25.1908	189.119	1.8526
Heritability:				
$h^2 \pm$ SE	0.35 ± 0.06	0.66 ± 0.05	0.35 ± 0.06	0.43 ± 0.07

σ^2_a, σ^2_e, σ^2_p — Direct additive, environmental and phenotypic variances, respectively.

Merinos (0.29 — Abdel-Aziz *et al.*, 1978) and Australian Merinos (0.27 — Lewer *et al.*, 1994 for ram yearlings; 0.27 — Rose & Pepper, 1996). It was lower than the estimate of 0.46 reported by Ponzoni *et al.* (1995) for South Australian Merinos. Corresponding estimates for 12-month-old Dohne Merinos reported by Laas (1982) and Fourie & Heydenrych (1982b) were, respectively, 0.39 and 0.40. The present estimate is also well within the range of 0.13 to 0.82 tabled in the comprehensive review by Fogarty (1995).

Only the direct additive genetic effects made a significant contribution to wool traits (Table 6). The heritability estimate of 0.35 for clean fleece weight was substantially higher than the estimate of 0.15 reported by Laas (1982), but in agreement with the estimate of 0.29 published by Fourie & Heydenrych (1982b) for 18-months greasy fleece weight in Dohne Merinos. It also accorded with the estimate of 0.39 reported by Abdel-Aziz *et al.* (1978) for greasy fleece weight in German Merinos. Recent heritability estimates for yearling clean fleece weight in Merinos, ranging from 0.26 to 0.59 (Walkley *et al.*, 1987; Lewer *et al.*, 1994; Ponzoni *et al.*, 1995; Swan *et al.*, 1995; Rose & Pepper, 1996), were in close correspondence with the present value. Heritabilities of clean fleece weight at 14 to 18 months in South African Merinos also closely resembled the present estimate (Olivier *et al.*, 1994; Snyman *et al.*, 1996).

Clean yield was highly heritable (Table 6), as was also reported in the literature with estimates ranging from 0.45 to 0.67 (Laas, 1982; Walkley *et al.*, 1987; Mortimer & Atkins, 1993; Lewer *et al.*, 1994; Ponzoni *et al.*, 1995; Swan *et al.*, 1995; Rose & Pepper, 1996). The estimate for staple length was also within the range (0.30–0.45) of estimates reported in the literature (Laas, 1982; Walkley *et al.*, 1987; Mortimer & Atkins, 1993; Ponzoni *et al.*, 1995; Swan *et al.*, 1995).

The heritability of fibre diameter was 0.43; an estimate which was substantially higher than the 0.29 reported by Laas (1982) for Dohne Merinos. It accorded with estimates (0.45–0.67) reported for Merinos in South Africa (Olivier *et al.*, 1994; Snyman *et al.*, 1996) and Australia (Walkley *et al.*, 1987; Mortimer & Atkins, 1993; Lewer *et al.*, 1994; Swan *et al.*, 1995; Ponzoni *et al.*, 1995; Rose & Pepper, 1996).

Genetic trends

Live weight, clean fleece weight and fibre diameter are regarded as being the most important traits to be considered in the selection of Dohne Merinos (Laas, 1982). The genetic improvement in live weight amounted to 0.145 kg p.a. (r = 0.85), which represented 0.26% of the overall phenotypic mean (Figure 1a). The corresponding change in clean fleece weight was 0.016 kg p.a. (r = 0.96), which amounted to 0.81% of the overall phenotypic mean (Figure 1b). The genetic change in fibre diameter was much slower, being only –0.011 μm p.a. (r = –0.38; Figure 1c). This change was in the right direction, although it only amounted to 0.05% of the overall phenotypic mean. The selection policy of the Dohne Merino Breeders' Association clearly emphasized fleece weight, while maintaining fibre diameter at acceptable levels. Progress was generally faster than in the study of De Klerk (1990) on the Dohne Merino stud maintained on the Dohne experimental station. Genetic change in the latter study was 0.059 kg p.a. for 18-months live weight and 0.004 kg p.a. for greasy fleece weight measured at the same age. Genetic change in clean fleece weight was slower in the current study than the 1.1% p.a. found in a single trait selection experiment on South African Merinos by Cloete *et al.* (1992). However, selection based on breeding values in the Grootfontein Merino stud resulted in greater increases of 0.631 kg p.a. for live weight, and a higher reduction of 0.157 μm p.a. for fibre diameter (Olivier *et al.*, 1995) than obtained in the present study.

Conclusions

Yearling live weight and fleece traits in Dohne Merino sheep were heritable and should respond to directed selection. The available genetic variation should preferably be exploited after correcting for the effect of birth type. Selection practices applied in the nucleus flock resulted in substantial genetic improvements in yearling live weight and clean fleece weight. Moreover, genetic change in the average fibre diameter was also in the right direction. Genetic change in traits with economic

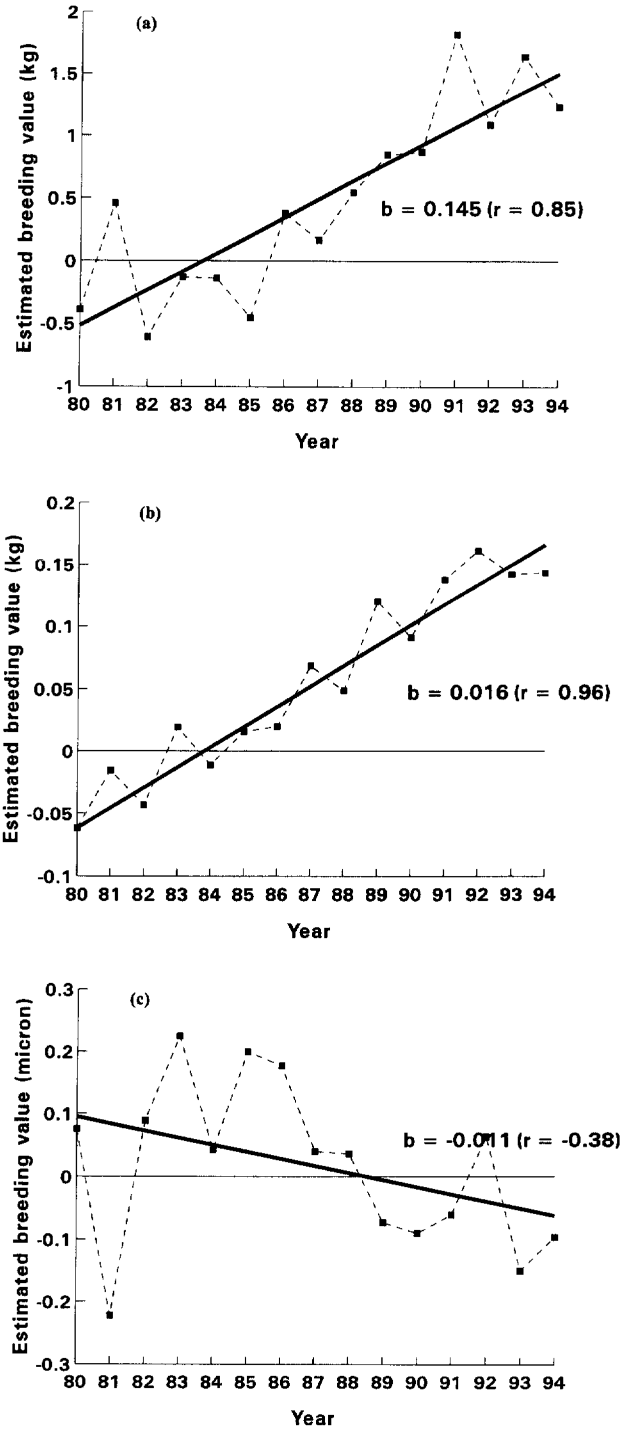

Figure 1 Genetic trends for yearling live weight (a), clean fleece weight (b) and average fibre diameter (c) in the Kromme Rhee Dohne Merino nucleus flock.

importance thus seems feasible in Dohne Merino sheep subjected to performance testing at the yearling stage. Genetic gains in the desired direction can be markedly accelerated if selection decisions are based on breeding values (Olivier *et al.*, 1995). The effects of a strategy based on selection of Dohne Merinos at a relatively early age on ewe lifetime productivity is uncertain at present, and requires further investigation.

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