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Genetic parameters for faecal egg count following natural nematode infections and correlation with productive traits in Polish Heath sheep

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ABSTRACT

Over a 4-year period, from May (1995) or June (1996-1998) to November, in a flock of Polish Heath sheep, faecal samples from 246 ewes, 9 rams and 429 lambs were examined for gastrointestinal nematode eggs by the McMaster method. Faecal cultures were run to identify the nematode species present. The prevalence of positive egg counts was, on average, 43 to 69% in ewes and 68 to 80% in lambs. Two nematode genera predominated: *Haemonchus contortus* and *Trichostrongylus colubriformis*. In the last three samplings in 1998 increased frequency of *Ostertagia (Teladorsagia) circumcincta* infections was noticed.

Animal model restricted maximum likelihood was used to estimate the heritability and repeatability for faecal nematode egg count (FEC) and correlations with productive traits.

The obtained values of these parameters were 0.128 (±.0.011) and 0.068 (±0.005) for repeatability and heritability, respectively. A negative influence of faecal worm egg count on fleece weight of ewes and weight gain from birth to 3rd month, from 3rd month to 12th month and during 12 months of lambs' life was observed. The estimated genetic correlations were: - 0.014 (±0.053), - 0.197 (±0.046), - 0.204 (±0.073), and - 0.174 (±0.074), respectively.

KEY WORDS: sheep, nematode infection, genetic parameters, wool yield, weight gain

INTRODUCTION

Infections of ruminants with gastrointestinal nematodes can cause huge losses, in the case of sheep, up to 60% of all economic losses (Kloosterman et al., 1992).

In New Zealand 60% of all sheep farms carry parasites resistant to anthelmintics and annual production losses are up to $270 million (Morris et al., 2000). In Poland the prevalence (percentage of infected animals) of gastrointestinal nematodes among sheep reaches 100% (Bouix et al., 1998). Nematodes, such as *Haemonchus contortus*, causes a protein-losing gastroenteropathy, exacerbated by anaemia. Protein losses are due to anorexia, damaged digestive glands and the loss of protein through disrupted cell junctions (toxaemia etc.). A result of gastrointestinal nematode infection among young animals is considerably lower body weight gain compared to uninfected animals (Coop et al., 1985). In extreme cases death can result.

One relatively cheap and simple method of reducing the effects of nematode infection is the selective breeding of nematode-resistant sheep (Baker, 1998; Bishop and Stear, 1999). This requires knowledge of the repeatability and heritability of faecal egg counts as well as genetic correlations with production traits. Many scientists have estimated the heritability (h^2) of cattle and sheep resistance to endoparasite infections, using nematode faecal egg counts as an indicator trait (Baker et al., 1988; Eady and Woolaston, 1995; Hanrahan and Crowley, 1999; Morris et al., 2000). However, these values may vary among breeds of sheep and different locations.

The aim of this study was to estimate the repeatability, heritability and correlation with wool yield of ewes and body weight gain of lambs of faecal nematode egg count in a flock of Polish Heath sheep.

MATERIAL AND METHODS

Animals

The study was carried out in 1995-1998 on prolific Polish Heath sheep (Romanov type) from a Warsaw Agricultural University experimental flock. Ewes (246 animals) were 2-5 years old, lambs (total number 429) were 3-6 months old. The number of recorded individuals is given in Table 1.

Parasitological data

Parasitological investigation of the basic flock of ewes was held every month, six times during the pasture season, from May to October. Each year 25 to 30 two-year-old ewes replaced the culled animals. Lambs were examined annually (each year individuals from a new litter) four times from August to November. In the case of stock rams the degree of gastrointestinal nematode infections was checked in years 1997-1998 three times – in April, July and November. The gastrointestinal faecal egg count (FEC) of recorded animals was determined using McMaster's

TABLE 1

Prevalence of gastrointestinal nematode infections among Polish Heath sheep

Month	Ewes								Lambs						Rams			
of	1995		1996		1997		1998		1996		1997		1998		1997		1998	
sampling	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
IV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	11.0	9	0
V	-	-	98	93.9	57	15.8	69	57.9	-	-	-	-	-	-	-	-	-	-
VI	150	84.9	122	7.3	91	76.9	74	90.5	-	-	-	-	-	-	-	-	-	-
VII	114	95.2	113	33.6	89	76.4	72	61.1	-	-	-	-	-	-	9	33.3	9	66.7
VIII	140	67.4	108	66.7	94	86.2	67	35.8	114	44.8	128	47.7	147	80.3	-	-	-	-
IX	159	54.2	109	19.3	87	58.6	68	45.6	136	73.5	131	87.8	132	82.6	-	-	-	-
X	157	42.2	115	37.4	85	65.5	81	56.8	134	76.1	120	85.0	162	84.6	-	-	-	-
XI	-	-	-	-	-	-	-	-	123	79.5	117	79.5	161	74.5	9	33.3	9	66.7
x	68.8		43.0		63.2		57.9		68.5		75.0		80.5		25.9		44.5	

n – number of examined animals
% – percentage of infected animals

method (Bairden, 1991), in which each nematode egg counted represented 50 eggs per gram of faeces.

Because of the large number of eggs in faeces, in May 1996 sheep were drenched with Systamex (Oxfendazole) at the dose rate recommended by the manufacturer. The drenching was repeated in December 1996. In the following years sheep were drenched at the end of grazing in November.

Faeces were cultured to identify parasite genera on the basis of morphological criteria characteristic of larvae (Anonymous, 1986). In each year, the faecal samples from the same sheep were used for nematode egg counts and larval cultures.

Productive traits

With the purpose of determining the influence of the nematode infection rate on production traits, correlations of FEC with wool yield of ewes and body weight gain of lambs in three periods were estimated for the periods from birth to the 3rd month of life, 3rd to 12th month of life, and during the whole first year of life. In the studied flock, ewes were sheared twice a year, in the spring before lambing and during the autumn. In the study only the autumn shearing was taken into consideration, as the growth of wool after spring shearing occurred between the first and the last parasitological measurement.

Statistical analysis

The distribution of the FEC trait is considerably different from normal distribution (Morris et al., 1997; Baker et al., 1999). Logarithmic transformation was used to increase the similarity to normal distribution: LFEC = log(FEC + 1) (Bishop et al., 1996; Romjali et al., 1997). In the first stage of analysis, the effects of the type of birth (number of lambs in the litter), sex and year of birth were examined for each trait separately in a general linear model with the GLM procedure of the SAS package (1990). Statistically significant effects were included in the genetic analysis.

Genetic parameters were based on REML (Patterson and Thompson, 1971) estimates of (co)variance components. Variance components were obtained on the basis of single trait animal model. The following linear model was used for FEC and wool yield:

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Z_a a} + \mathbf{Z_{pe} pe} + \mathbf{e}$$

where:

b is the vector of unknown fixed effects of sex and year for FEC and year for wool yield

a is the vector of unknown genetic additive random effects such that $\mathbf{a}\sim N(\mathbf{0},\mathbf{A}\sigma_a^2)$, with **A** and σ_a^2 being the additive genetic relationship matrix and additive genetic variance, respectively

pe is the vector of unknown random permanent environmental effects, $\mathbf{pe}\sim N(\mathbf{0},\mathbf{I}\sigma_{pe}^2)$, where σ_{pe}^2 is permanent environmental variance

e is vector of random residuals, $\mathbf{e}\sim N(\mathbf{0},\mathbf{I}\delta_e^2)$, where δ_e^2 is residual variance

X and $\mathbf{Z_a}$ and $\mathbf{Z_{pe}}$ are known incidence matrices relating the corresponding effects to the observations.

In the analysis of lamb body weight gain, a reduced model was used with the vector of permanent random effects excluded and effects of type of birth, sex, and year considered as fixed. Estimates of heritability (h^2) and repeatability (t) were obtained as $h^2 = \sigma_a^2/(\sigma_a^2+\sigma_{pe}^2+\sigma_e^2)$ and $t = (\sigma_a^2+\sigma_{pe}^2)/(\sigma_a^2+\sigma_{pe}^2+\sigma_e^2)$, respectively. Additive genetic covariances (σ_{aij}) and residual covariance (σ_{eij}) were estimated in bivariate analysis with individuals nested within traits. Additive genetic and residual covariance dispersion matrices were $\mathbf{A}\sigma_{aij}$ and $\mathbf{I}\sigma_{eij}$, respectively. Additive genetic correlations were calculated as $r_g = \sigma_{aij}/(\sigma_{ai}\sigma_{aj})$. For covariance estimation, mean values of repeated records were analysed instead of individual observations and for FEC mean represented average value of transformed measures. The computations were performed using the REMLF90 package (Misztal, 1999).

RESULTS AND DISCUSSION

In each year of examination the prevalence of positive faecal egg counts (Table 1) varied. The smallest percentage of ewes in which nematode eggs were detected was noted in 1996, while the highest percentage occurred in 1995. For lambs the prevalence was least in 1996, and highest one in 1998.

The mean nematode egg count was independent on the prevalence of positive faecal egg counts (Figure 1). In most studies *Haemonchus contortus* and *Trichostrongylus colubriformis* were inversely proportional, while the faecal egg count for all sheep groups (ewes, lambs and rams) significantly decreased with time.

In faecal cultures of sheep in 1996-1997 the following nematodes were found: *H. contortus*, *Trichostrongylus* spp., more recently – *Ostertagia* (*Teladorsagia*) spp., *Cooperia* spp., *Nematodirus* spp. and *Chabertia* spp. These results were confirmed by the parasitological section studies held in November 1997. The following parasite species were isolated from the abomasum and intestine: *H. contortus*, *N. battus*, *O. circumcincta*, *T. colubriformis* and *T. vitrinus*. Also other individuals belonging to previously mentioned genera were isolated, but they could not be classified to any specific species. In other studies, *H. contortus* and *Tri-*

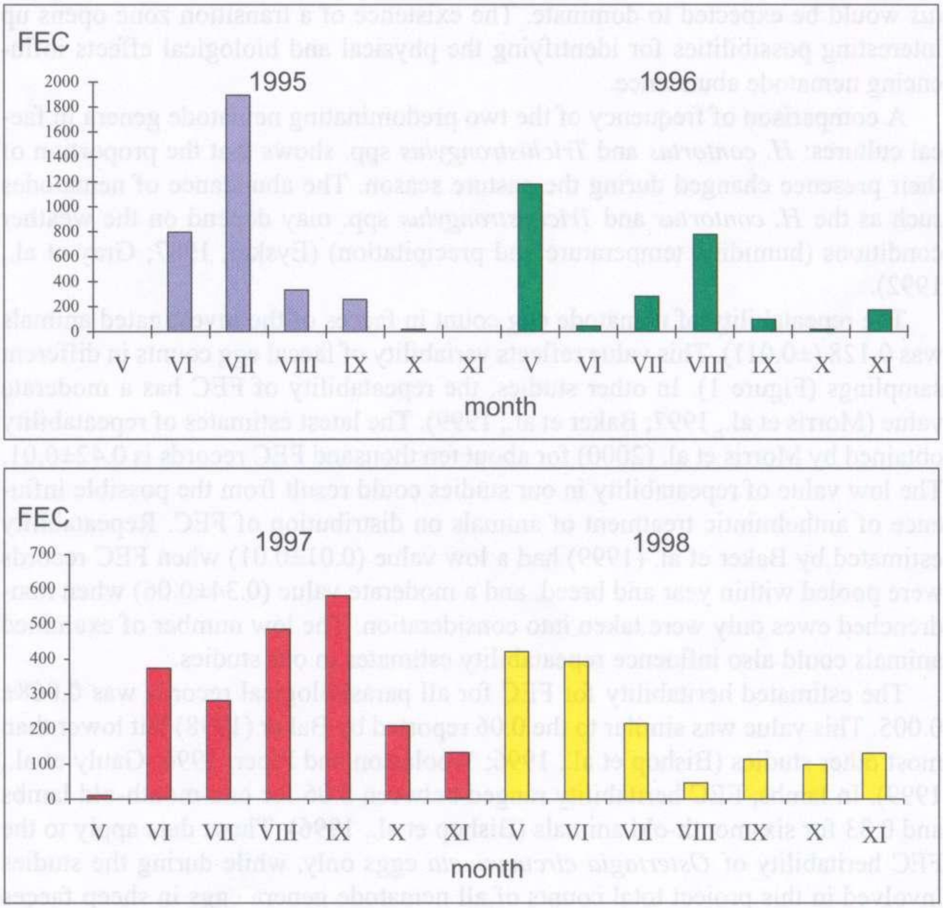

Figure 1. Faecal egg count in Polish Heath sheep

chostrongylus spp. (mainly *T. colubriformis*) were also the dominant parasites among sheep from many European, Asian and American countries (Gray et al., 1992; Raadsma et al., 1997; Waller 1997). On the other hand, in more temperate climates, such as Northern Europe, or Southern Australia one of the most common nematodes is *Ostertagia* spp. (Stear et al., 1998). Sheep flocks from north Britain are infected mainly with *O. circumcincta* (Stear et al., 1995), but the most common nematode among flocks from southern parts of England is *H. contortus* (Mitchell, 1996).

In the examined sheep flock, *Ostertagia circumcincta* occurred with a various frequency, in 1996-1997 it was observed in 5-7% of all sheep. In 1998 a considerable increase of the number of sheep infected with this nematode was recorded, with about 31% of faecal cultures containing it. The variable proportion of *O. circumcincta* may indicate that this area of Poland lies in a transition zone. Further North *O. circumcincta* might predominate while further South, *H. contortus* would be expected to dominate. The existence of a transition zone opens up interesting possibilities for identifying the physical and biological effects influencing nematode abundance.

A comparison of frequency of the two predominating nematode genera in faecal cultures: *H. contortus* and *Trichistrongylus* spp. shows that the proportion of their presence changed during the pasture season. The abundance of nematodes such as the *H. contortus* and *Trichostrongylus* spp. may depend on the weather conditions (humidity, temperature and precipitation) (Eysker, 1987; Gray et al., 1992).

The repeatability of nematode egg count in faeces of the investigated animals was 0.128 (±0.011). This value reflects variability of faecal egg counts in different samplings (Figure 1). In other studies, the repeatability of FEC has a moderate value (Morris et al., 1997; Baker et al., 1999). The latest estimates of repeatability obtained by Morris et al. (2000) for about ten thousand FEC records is 0.42±0.01. The low value of repeatability in our studies could result from the possible influence of anthelmintic treatment of animals on distribution of FEC. Repeatability estimated by Baker et al. (1999) had a low value (0.01±0.01) when FEC records were pooled within year and breed, and a moderate value (0.34±0.06) when non-drenched ewes only were taken into consideration. The low number of examined animals could also influence repeatability estimates in our studies.

The estimated heritability for FEC for all parasitological records was 0.068± 0.005. This value was similar to the 0.06 reported by Baker (1998) but lower than most other studies (Bishop et al., 1996; Woolaston and Piper, 1996; Gauly et al., 1999). In lambs, FEC heritability ranged between 0.06 for one-month-old lambs and 0.33 for six-month-old animals (Bishop et al., 1996). Those data apply to the FEC heritability of *Ostertagia circumcincta* eggs only, while during the studies involved in this project total counts of all nematode genera eggs in sheep faeces were taken under consideration.

The relatively low heritability in our study may result from pooling samples from the beginning of the grazing season before immunity developed (Bishop et al., 1996) or samples that vary in the composition of nematode species. However, more research is needed to test these possibilities. In other studies the heritability of particular nematode species egg counts was higher, e.g. *H. contortus*: 0.34±0.10 (Muggli, 1991, according to Kloosterman et al., 1992), 0.30±0.10 (Albers and Gray, 1989), 0.27±0.13 (Piper, 1987), *T. colubriformis*: 0.41±0.19 (Windon and Dineen, 1984).

Improving sheep resistance to gastrointestinal nematodes requires an understanding of costs and expected benefits. A major influence on expected benefits is the genetic basis of the selected trait: a single major gene or polygenes each of minor additive effect. Albers and Gray (1989) carried a simulated genetic progress; the only objective was to improve sheep resistance to gastrointestinal nematodes. They showed that with average heritability of this trait (0.29), in the case of its polygenic character, a 30% improvement in the resistance to nematode infections is possible after about 12 years of screening. However, a 60% increase in resistance would be achieved after one year, by using rams homozygous for a dominant resistance gene.

Estimates of the correlation coefficient between FEC and production traits (wool yield of ewes and body weight gain of lambs) are shown in Table 2. All correlation coefficients, except genotypic correlation between FEC and wool yield, estimated using the GLM procedure from the SAS package, are statistically significant ($P \leq 0.05$). Previous estimates made with the least square method gave higher correlation values. In these estimates, however, fewer parasitological measurements (1995-1997) were used (Charon et al., 1998).

Genetic correlations between FEC and liveweight are very variable, ranging from strongly negative (Bishop et al., 1996; Bouix et al., 1998; Gauly et al., 1999) to moderately positive (Eady and Woolaston, 1995). Our results fall in the middle of the range. Differences among various studies may reflect different species of parasite, breed of sheep or management conditions.

TABLE 2

Phenotypic (r_p) and genetic (r_G) correlations between FEC and production traits of Polish Heath sheep

Traits	r_p	r_G
FEC and body weight gain of lambs:		
– from birth until 3rd month	- 0.074 ± 0.047	- 0.197 ± 0.046
– from 3rd until 12th month	- 0.049 ± 0.076	- 0.204 ± 0.073
– from birth until 12th month	- 0.079 ± 0.075	- 0.174 ± 0.074
FEC and wool yield of ewes	0.017 ± 0.058	- 0.014 ± 0.053

FEC – faecal egg count

The low positive phenotypic correlation between FEC and wool yield is consistent with the results of other studies (Morris et al., 1997, 2000). The decrease of wool yield in animals with low FEC can be a consequence of the immune system reaction to nematode infection. Sulphur-containing amino acids, such as cysteine, are required for both wool production and immune responses, so it is possible that a more intense immune response to nematode infection leads to reduced availability of these amino acids for fleece production (Miller et al., 1998). In contrast with other studies, the genetic correlations between FEC and wool yield were negative, though still low. This could reflect real differences between breeds or differing conditions (parasitological, management, etc.) among experiments.

CONCLUSIONS

A longitudinal parasitological investigation showed that flock of Polish Heath sheep had a high prevalence of gastrointestinal nematode infections. The mean percentage of positive faecal nematode egg counts in ewes ranged in separate years from about 43 to about 69%, for lambs from about 68 to about 80%. *Haemonchus contortus*, *Trichostrongylus colubriformis* were the main nematodes infecting sheep, but in the last three samplings in 1998 *O. circumcincta* dominated.

Although the repeatability and heritability of the FEC (0.128 and 0.068, respectively) was low, it nevertheless suggested the possibility of selective breeding to improve sheep resistance to nematode infections.

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STRESZCZENIE

Parametry genetyczne liczby jaj nicieni w kale owiec narażonych na naturalne infekcje i korelacje z cechami produkcyjnymi u owiec rasy wrzosówka

W ciągu 4 lat od maja (1995) lub czerwca (1996-1998) do listopada oznaczano liczbę jaj nicieni żołądkowo-jelitowych metodą McMastera w kale matek, tryków i jagniąt rasy wrzosówka. W celu identyfikacji gatunków nicieni występujących w kale badanych zwierząt prowadzone były hodowle kultur kałowych. Średnio od 43 do 69% matek i od 68 do 80% jagniąt było zarażonych. Najczęściej występującymi pasożytami były: *Haemonchus contortus* i *Trichostrongylus colubriformis*. W trzech ostatnich badaniach w 1998 roku stwierdzono wzrost częstotliwości infekcji *Ostertagia (Teladorsagia) circumcincta*.

Oszacowana z zastosowaniem modelu osobniczego powtarzalność liczby jaj nicieni w kale (FEC) wynosi 0,128 ± 0,011, natomiast odziedziczalność 0,068 ± 0,005.

Stwierdzono ujemny wpływ infekcji pasożytniczych na masę wełny matek i przyrosty masy ciała jagniąt od urodzenia do 3. miesiąca, od 3. do 12. miesiąca oraz w ciągu 12. miesięcy życia. Oszacowane genetyczne korelacje wynoszą odpowiednio: - 0,014 (± 0,053), - 0,197 (± 0,046), - 0.204 (± 0,073), i - 0,174 (± 0,074).