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Inclusions of selection for nematode resistance in British sheep reference schemes

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SUMMARY – Resistance to nematode infections is heritable and can be measured by Faecal Egg Counts (FEC). Model calculations for British sheep and conditions suggest that an extra 23% gain in growth rate can be achieved with one FEC per lamb. FEC sampling on an individual basis started in 2001 for Texel and Suffolk sire reference schemes. Univariate Estimated Breeding Values (EBVs) were calculated and provided to breeders. Individual faecal samples were collected at 20 weeks of age coinciding with ultrasonic scanning. Lambs had previously been drenched at 16 weeks of age with a non-residual anthelmintic and managed in a similar way. Major components of the recording scheme in the existing selection programmes in most British sheep breeds are body weight measurements and US scanning at about 20 weeks of age of all lambs in a flock. An existing model was adapted to calculate direct genetic effects of selection on FEC as well as phenotypic effects due to cleaner pastures and saving of anthelmintics. It is shown that substantial genetic improvements can be made in nematode numbers. Financial benefits depend on initial levels, carry-over effects and marketing opportunities. The FEC service will be offered to breeders in 2002, but FEC will not be included in the index.

Key words: Sheep, nematodes, genetics, selection, economic benefits, Great Britain.

RESUME – *"Incorporation de la sélection pour la résistance aux nématodes en ovins britanniques des schémas de référence". La résistance aux nématodes est héréditaire et peut être mesurée par comptage des œufs fécaux ou FEC (pour "Faecal Egg Counts"). Des modèles mathématiques élaborés pour les ovins britanniques et leur milieu montrent qu'un gain de croissance de +23% peut être obtenu par un simple contrôle FEC par agneau. Les échantillonnages FEC individuels ont démarré en 2001 avec des Texel et des Suffolk. Les valeurs génétiques (EBVs) à une seule variable ont été calculées et mises à la disposition des éleveurs en 2001. Les échantillons fécaux individuels ont été prélevés à 20 semaines afin de coïncider avec le passage au scanner à ultrasons. Tous les agneaux sont préalablement vermifugés à 16 semaines avec un antihelmintique non résiduel. Un des avantages des systèmes d'enregistrement dans les programmes de sélection existants pour la plupart des races ovines britanniques, est la pesée et le passage au scanner à ultrasons à 20 semaines de tous les agneaux du troupeau. Un modèle existant a été modifié pour calculer les effets directs de la sélection génétique sur FEC, les effets phénotypiques résultant de pâtures moins infectées et l'effet économique induit par la réduction des coûts antihelmintiques. Les calculs montrent qu'une amélioration génétique significative est obtenue sur le nombre de nématodes. L'intérêt économique dépend des niveaux de départ, des effets de report et de l'environnement commercial. Le service FEC sera offert aux éleveurs en 2002 mais le FEC ne sera pas pris en compte dans le calcul de l'index.*

Mots-clés : *Ovins, nématodes, génétique, sélection, intérêt économique, Grande-Bretagne.*

Introduction

Nematode infections have a major impact on the efficiency of sheep production. Estimates suggest that growth in young lambs for instance can be reduced by 25%, without there being any clinical signs of infection (Coop *et al.*, 1985). In infected sheep, the adult worms multiply and lay eggs that, via the animals faeces, become spread over the pasture, only to infect other sheep and continue the parasites impact on the flock. Traditionally, there are two ways to fight nematode infections; grazing management and anthelmintic treatment. Where possible, timely movement of sheep to clean pastures is effective, but for many farmers this is not an option because of limitations on grazing land. The use of anthelmintics is not only expensive, but increasingly meets with problems of worm resistance. This is of particular concern to organic producers as they are limited in their use of anthelmintics.

Research in New Zealand (e.g. Morris *et al.*, 1998) and Australia (e.g. Woolaston and Windon, 2001) has shown that resistance to nematodes has a genetic component. Bishop and Stear (1999) modelled selection for nematode resistance in Scottish Blackface (SBF) lambs and showed that significant benefits exist. No calculations have been published for British terminal sire breeds.

A research project, jointly funded by the British Department of Agriculture (DEFRA) and the Meat and Livestock Commission (MLC) and with contributions from the Elite Texel Sire Reference Scheme was conducted by the Roslin Institute and the University of Glasgow. It confirmed that heritabilities for Faecal Egg Counts (FEC) are similar to those reported earlier (about 0.30). Genetic and phenotypic correlations with production traits were generally very close to 0, but in a desirable direction (Bishop and Stear, 2002; S.C. Bishop, pers. comm.). Based on these results, a pilot scheme was started in 2001 and 1000 Texel and 1000 Suffolk lambs were sampled.

Individual faecal samples were collected at 20 weeks of age coinciding with ultrasonic scanning. Lambs had previously been drenched at 16 weeks of age with a non-residual anthelmintic and treated in a similar way. Faecal samples were weighed and adjusted to a ratio of 1 g to 14 ml of water. Eggs were then counted using an improved modified McMaster technique (MAFF, 1984), where each egg represented 50 eggs per gram. Estimated Breeding Values (EBV) were calculated for the total egg count and provided to breeders for sampled animals and stock rams.

The British sheep industry is based on a stratification system in which hill, longwool and terminal sire breeds each have a specific role in the production of three-way cross slaughter lambs. The terminal sire breeds have the largest impact on the slaughter generation and their breeding goal, called the lean index, is defined as increased carcase lean at constant carcase fat (Simm *et al.*, 2002).

The main issue addressed in this paper is: what are the returns from combining selection for nematode resistance with the current lean index at purebred level and crossbred level?

Methods

The benefits of selecting animals for genetic resistance to nematodes are fourfold:

(i) Direct effect on performance of the animal.

(ii) Reduced pasture contamination within season with associated benefits in terms of performance for other sheep in the flock.

(iii) If sheep use the same pasture year after year, lower pasture contamination from season to season (called the carry-over effect).

(iv) Potential saving of anthelmintics treatments.

Bishop and Stear (1999) developed a model for parasite infection in SBF to include between animal variation (genetic, permanent and temporary environmental) for live-weight gain, food intake, larval establishment rate in the host, worm fecundity and worm mortality rate. Achieved live-weight gain was defined as the sum of potential live-weight gain under conditions of no parasite infection, a trait correlated with food intake and growth-rate reduction due to the infection. The reduction in growth-rate was calculated from cumulative larval challenge and cumulative worm mass in the lamb.

The model takes in account the first three benefits mentioned above. This study follows their method, but will in the end add the benefits from anthelmintic savings.

Calculation of the direct effect on animal performance is performed using traditional selection index theory. Direct selection on FEC as well as selection on correlated traits, will change resistance in the population. In one approach, nematode resistance is not considered a goal, it is an additional index trait that will result in higher progress towards the goal, i.e. increased carcase lean.

Alternatively, nematode resistance can be considered as a goal trait with an economic value. The extra value will be mainly based on the saving in anthelmintics. Since anthelmintic savings will largely depend on initial contamination levels and management, and since relations between the FEC EBV and anthelmintics savings are not linear, it is impossible to calculate an economic value with general validity among a sire reference scheme. In this study, several economic values will be investigated to assess their impact on general progress.

FEC data have a very skewed distribution. Before genetic analysis, data are therefore log-transformed (natural log) after addition of 25, to allow for the stepwise increments in FEC levels. FEC EBVs should therefore be interpreted on a logarithmic scale, e.g. a FEC EBV of –1 means e^{-1} = 0.37 times as many nematode eggs.

The selection index calculations were based on a typical family structure in the Texel sire reference scheme, where all traits were measured on the animal of interest, its two parents, 20 paternal Half Sibs, 3 maternal Half Sibs and 1 Full Sib. The traits considered were weaning weight (about 8 weeks), scan weight (at about 20 weeks), ultrasonic muscle and fat depth and FEC at scanning. Genetic parameters for the standard traits were the same as used in routine analysis, others were based on estimates from the project (Bishop and Stear, 2002; S.C. Bishop, pers. comm.). Genetic parameters are shown in Table 1. The breeding goal is +3 carcase lean –1 carcase fat. The value of an index point is £2.5 or 4 euro per ewe (Simm and Murphy, 1996).

Table 1. Genetic parameters for the Texel breed as used in index calculations (*heritabilities* on, phenotypic correlations above and genetic correlations under the diagonal)†

	W8w	Scan wt	Muscle dp	Fat depth	LnFEC	Lean	Fat
W8w	*0.253*	0.730	0.403	0.313	–0.05		
Scan wt	0.900	*0.406*	0.558	0.446	–0.05		
Muscle dp	0.491	0.467	*0.288*	0.332	–0.03		
Fat depth	0.370	0.378	0.239	*0.374*	0		
LnFEC	–0.10	–0.10	–0.05	0	*0.30*		
Lean	0.828	0.835	0.408	–0.068	–0.10	*0.447*	
Fat	0.670	0.677	0.230	0.552	–0.07	0.383	*0.404*

†W8w = weaning weight adjusted to 8 weeks; scan wt = scan weight (about 20 weeks); muscle dp = ultrasonic muscle depth; LnFEC = natural log of FEC+25; lean = lean in carcase; fat = fat in carcase.

The accurate calculation of effects of nematode resistance on pasture contamination and animal performance requires epidemiological calculations that are beyond the scope of this paper. As an approximation, data from Bishop and Stear (1999) were use to estimate quadratic relations between FEC EBV and FEC level first and then FEC level and live weight. The change in live weight and correlated change in lean and fat were then calculated using these relationships. The effect of cleaner pastures from year to year, the so-called carry-over, was calculated in the same way.

Anthelmintics savings are proportional to nematode levels and can therefore directly be calculated from progress made towards higher resistance. Costs for a typical flock were calculated as £1.68/ewe present (based on 3.5 treatments at £0.40 per lamb and 1.2 lamb per ewe). On average, a ewe in a purebred flock, through sales of her sons to commercial flocks, will have 25 crossbred grand-offspring per year. The genetic progress made in purebred flocks will therefore affect 25 crossbred animals for every purebred ewe, these benefits are included in calculations. Discounting is used to take account of the time lag.

Results

Table 2 shows annual genetic progress in the current lean index and for FEC depending on the relative economic weight of LnFEC compared to 3 for carcase lean and –1 for carcase fat. Because of the overall negative correlations, selection on either index or FEC will result in a desirable correlated response in the other trait, but this is small.

Table 2. Annual genetic progress in lean index and natural log faecal egg count (LnFEC) depending on relative economic weight of LnFEC, where relative weight of carcase lean is +3/kg and for carcase fat –1/kg

Relative economic weight of LnFEC	Annual genetic progress		
	Index	LnFEC	FEC (%)
0	9.20	–0.011	–1
–0.4	9.15	–0.022	–2
–1	8.91	–0.035	–3
–1.4	8.67	–0.043	–4
–2	8.24	–0.053	–5
–3	7.46	–0.066	–6
Infinite	1.11	–0.097	–9

Figure 1 shows the various effects over time for the example of a relative economic value of –1 and initial FEC value of 300 eggs per gram. The index increases linearly from 180 to 314. Nematode levels decrease proportionally; the direct genetic effect is smallest (from 300 to 167 after 15 years), if cleaner pastures within season are taken into account the levels drops more rapidly (to 108 in year 15), but most progress is made when there is a carry-over effect (to 57 in year 15). Because of the proportionality to the initial level, reductions and resulting benefits will be bigger with higher initial levels and smaller when the initial level is lower (results not shown).

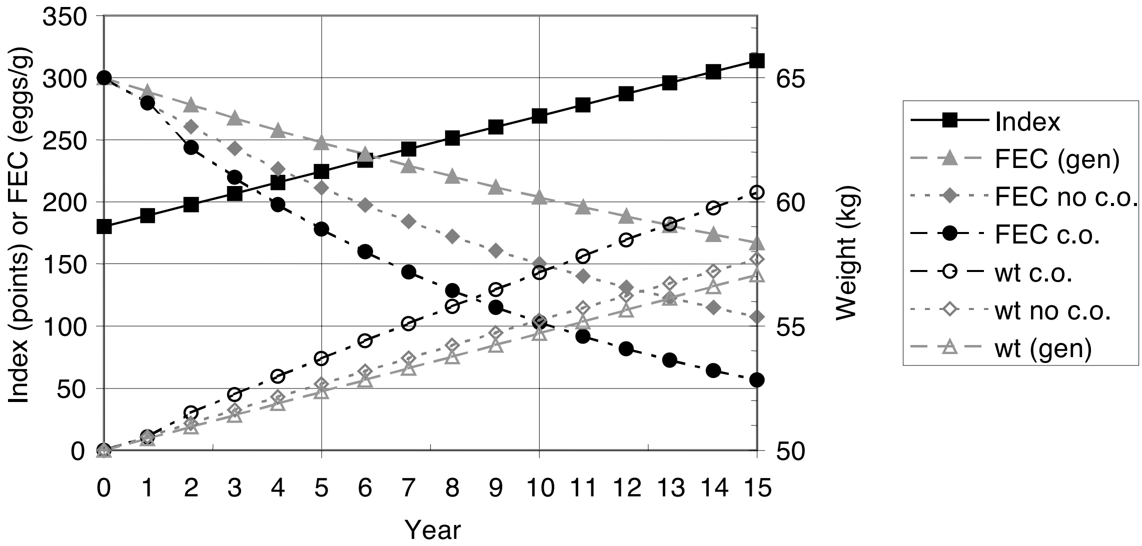

Fig. 1. Development of the lean index, FEC and lamb weight over time in a selection programme that puts a relative economic weight of –1 on LnFEC. Shown are the direct genetic effects (gen), effects in absence of carry-over (no c.o.) and with carry-over (c.o.) in phenotypic terms.

The weight of lambs (shown on the right-hand Y-axis), assumed to be 50 kg initially, increases over time due to selection on the index and the correlated response to FEC (7 kg over 15 years, in-line with current trends), cleaner pastures within season (an extra 0.7 kg) and over seasons (an extra 2.7 kg). The extra weight gain is a result of cleaner pastures, and therefore beneficial to all animals grazing the same. It is, however, based on a genetic effect, where the improved genes are for resistance rather than growth.

Figure 2 compares results for the various scenarios after 5 and 10 year of selection. It confirms that FEC levels, assuming an initial level of 300 eggs per gram, fall faster when more emphasis is put on FEC. Note that the effects of cleaner pasture within and across seasons are important for total counts.

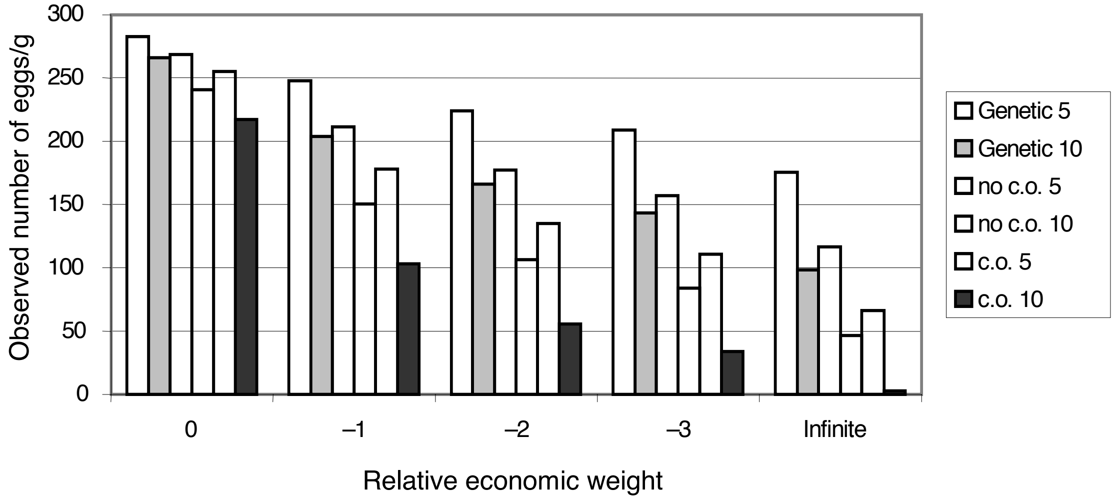

Fig. 2. Effect of various selection strategies on the observed number of eggs after 5 and 10 years of selection.

Addition of FEC to the breeding goal effectively creates a new index, but it is still relevant to monitor the genetic progress for the current lean index (+3 lean –1 fat). Figure 3 shows the development of the current lean index after 5 and 10 years of selection when the effects of higher resistance and cleaner pastures are taken in account. Even when there is no selection pressure on FEC, egg numbers will decrease as a correlated trait and this has some positive effect on the lean index (this ignored currently). Most progress is made after 10 years, taking in account carry over effects and weighing FEC –1. Without carry over, this is also the best scenario, but the weighting has less effect.

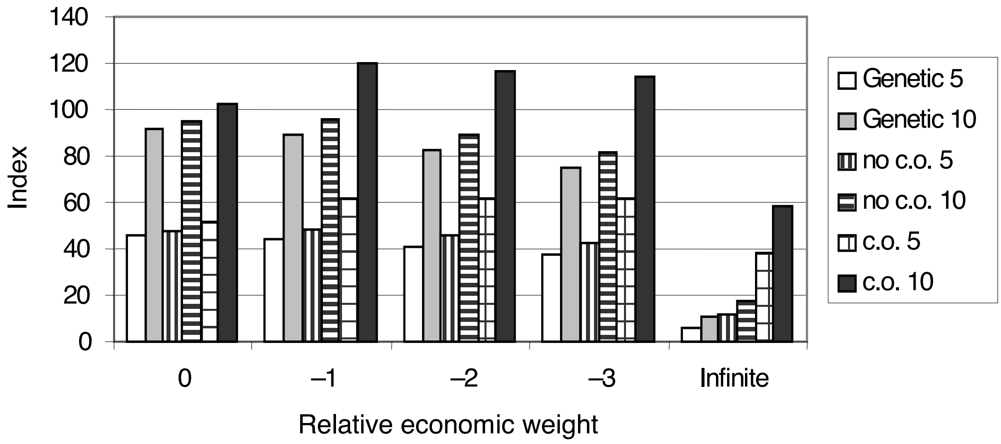

Fig. 3. Effect of relative economic weight of FEC, carry-over and time horizon on the lean index.

It should be borne in mind that the current lean index does not include costs for measuring FEC (£2 per sample) and it would therefore seem to be the most cost effective in terms of development of the lean index.

Costs and benefits were calculated as Net Present Value of cumulative selection efforts and compared with the current lean index (without sampling FEC, but taking in account correlated response). For instance, the 5 year comparison includes all costs made in the first 5 years and all benefits resulting from this, whether they are realised within those 5 years or after and include both purebred and crossbred level. Discounting (with a 5% discount rate) is used to account differences for year of expression.

Figure 4 shows the financial returns. If no carry-over effect exists, the financial returns are small and, if too much emphasis is put on FEC, they become negative. The carry-over effect appears to be essential to obtain significant returns, about £200 in 5 years or £300 in 3 years. Varying the weighting between –1 and –3 has little effect. If selection is on FEC only, less and less reduction will be made in absolute nematode numbers while costs continue, so that results after 10 years are worse than after 5 years. This illustrates that, because of the proportional character of FEC reduction, once a certain level of nematode resistance is attained, it is no longer cost-effective to continue faecal sampling on an individual basis. It is, however, important to continue sampling in order to monitor nematode egg output and "best time" use of anthelmintics. It is vital to point out that parasite resistance does not mean 0 eggs per gram FEC.

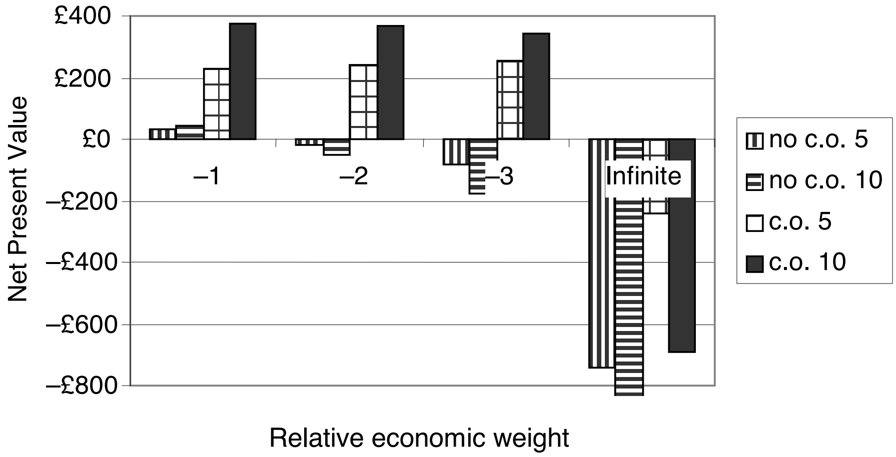

Fig. 4. Net Present Value per ewe depending on relative economic weight, carry-over and time horizon (5 or 10 years selection) compared to the lean index without FEC sampling under the same conditions.

Practical implications

Based on these results, it was decided to continue the service offered in 2001 and possibly extend it to include more breeders and breed groups. Participation of breeders will be voluntary, because farmers would have to pay part or all of the costs themselves and returns will depend on nematode levels in the purebred flock and opportunities to sell more resistant rams for a higher price.

The same protocol will be adopted as in 2001, with sampling around scanning time (about 20 weeks of age). While in 2001 FECs were analysed separately in a univariate PEST run, in 2002 this will be one combined run. Based on the low correlations it would be expected that there is little difference between multi- and univariate analysis. Analysis of 2001 data has confirmed this. Multivariate analysis will be easier logistically and may take out some genotype by environment (G × E) interactions.

In the above calculations and earlier analysis, total sum of FEC in a sample were analysed. From 2002 on, FEC for Strongyles and Nematodirus will be analysed as separate traits with specific genetic parameters to make best use of available data.

In order to sell benefits of improved rams to commercial farmers, emphasis should be on saved anthelmintic costs. For instance, if the average FEC EBV for breeding rams used in a flock is –1, then benefits compared to a team with an average FEC EBV of 0 can be calculated as follows:

(i) Difference in FEC EBV in offspring –0.5.

(ii) Resulting nematode level: $e^{-0.5} = 0.61$ (e.g. reduced from 300 to 183 eggs/g).

(iii) Saving in anthelmintic costs 1 – 0.61 = 39%.

The farmer can thus calculate costs savings based on historic expenditure. Additional benefits will arise from "cleaner" pastures within and across seasons, but these will be difficult to explain and to quantify for individual crossbred flocks. They are not of minor importance however as the vast majority of parasite challenge to animals is present as infective stage larvae on the pasture – this could therefore present an important area for future research to begin to quantify in terms of such additional benefits.

Conclusions

It is possible to reduce levels of nematodes in British terminal sire breed sheep through selection on low FEC. Because of the exponential distribution of the trait, a proportional reduction of absolute numbers will be achieved. Desirable but small correlations exist with production traits. Benefits will depend to a substantial extent on savings in costs for anthelmintics on commercial farms. The optimal selection scenario therefore depends on the initial level of nematodes, the extent to which carry-over effects exist and the possibility to find a market for improved rams.

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