SIMULTANEOUS ON-FARM TESTING OF SHEEP BY USE OF MIXED MODEL EVALUATION TECHNIQUE

Testage sur-ferme simultané des ovins par l'utilisation de la technique d'évaluation de modèle mixte

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INTRODUCTION

The main opportunities for selection in a sheep population occur (i) among lambs before the year's crop of lambs are slaughtered, and (ii) among rams used in breeding. Among adult ewes the possibilities for selection gain are very limited since the usual culling of 15-20 per cent in the ewe flock is determined mainly by non-genetic reasons and often occurs late in the ewes' lives.

Normally about 20-35 per cent of all ewe lambs are needed for replacement of ewe stock. In the nordic countries ewe lambs are recruited almost exclusively from within the flock and the evaluation of them can therefore be carried out on a purely within-flock basis. Among ram lambs the selection can be considerably more intensive. Unless flocks are extremely small and the total number of rams needed therefore high, less than 2 per cent of all ram lambs are needed for breeding purposes. This replacement of males allows about 50 per cent selection among adult rams every year. In contrast to the situation on the female side the total space for selection among males can be quite freely distributed between lamb and adult stages by varying the proportion of ram lambs selected, without causing substantial drawbacks in production capacity of flocks.

Exploitation of the possibilities for intensive selection of male sheep requires strategies for simultaneous evaluation of a large number of individuals. The objective of this paper is to suggest an organisational model for large-scale evaluation of male sheep in which information from field recording is utilized along with computational procedures based on best linear unbiased prediction (Henderson, 1973). Such strategies are under implementation in Sweden, where lamb production (meet and for one breed also fur-skins) with purebred stock is the production aim and a sheep recording scheme is available for all flocks.

EVALUATION PROBLEMS WITH SMALL FLOCKS

The structure of sheep production in Sweden is characterized by a fairly low total number of sheep (~150 000 ewes), a large number of small flocks (~10 000 with aver.size 15 ewes) and many breeds (17 breeds and lines). Sixty per cent of all ewes are in flocks with less than 50 ewes. However, breeding activities are favoured in than 46 per cent of the total sheep population is connected to the national sheep recording scheme. The average size of recorded flocks is 35, but still about half the recorded population is found in flocks.

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with less than 50 ewes. About two-thirds of recorded ewes belong to the main
breed, Swedish Pelt-sheep. One consequence of many breeds and a low total
number of sheep in the country is fairly long distances between flocks having
the same breed.

A small average flock size interferes in many ways with evaluation and
selection of male sheep:
- A large number of small flocks increases the proportion of ram lambs for
  breeding since every flock needs at least one ram.
- The maximum intensity of within-flock selection is lower in smaller flocks.
- The genetic level of flock-mates is more affected by sampling in smaller
  flocks, which makes individuals evaluated in different flocks less comparable.
- There are few possibilities to compare rams within the same flock.
- Difficulties arise in the efficient utilization of "elite" rams.

In short, strategies for evaluation across flocks become more necessary as
average flock size decreases. Progeny testing of rams is therefore of consider-
able interest in sheep breeding also for traits, which can be measured with
sufficient accuracy on living lambs. In Norway progeny testing has been exten-
sively practised for a long time. Recently 2300-2500 rams have been tested per
year (15 per cent of all rams) in about 100 ram circles and progeny-tested
rams are sires of 60 per cent of all selected ram lambs (Steine, 1980; Danell
et al., 1980). In Sweden it has been possible to organize this type of progeny
testing only on a limited scale because of the more scattered structure. How-
ever, application of mixed model evaluation procedures seems to provide new
prospects resulting from the ability to handle more flexible and larger designs
for the testing of rams and possibility to include simultaneous evaluation of
lambs across flock as a by-product in ram evaluation.

ORGANIZATIONAL STRATEGY FOR LARGE PROGENY TESTING DESIGNS

The evaluation of rams by best linear unbiased prediction procedures is
based on direct comparison of rams with progeny in the same flock. In the mixed
model equations set up for the evaluation these comparisons are connected to
comparisons within other flocks through rams used across the flocks.

Connections between flocks can be produced in several ways:
- Use of common sires through AI
- The norwegian type of ram circle, where a group of sires is rotated between
  flocks during the whole mating season
- Exchange of ewes between flocks during the mating season in order to get them
  mated by rams staying in other flocks
- Occasional exchange of single rams between flocks during the mating season.

Information on relationships between rams included in the BLUP evaluation proce-
dure can provide additional ties for comparisons across flocks.

With the population structure we have in Sweden it seems most convenient
to organize the body of the progeny testings as test of own rams within single
flocks. Along with these a part of each flock is reserved for rams shared with
other flocks through some of the methods mentioned above. Within the same test
design several of the methods can be used in parallel in order to form a network of connections. Such a network is most efficiently created by using AI but ram circle designs and exchange of ewes can also be used to form the central structures in the test design. These "nucleus" parts may then be connected through mutual exchange of rams or by participation with some of the flocks in several "nucleus" networks. Single flocks can be attached to central parts by exchanging rams.

The rams used across flocks through AI or in ram circles may be rams under test as well as elite rams in heavy use. When flock is treated as a fixed effect in the evaluation procedure no problems are introduced by choice of certain rams for a flock from a batch of AI rams as long as the choices do not create disconnected or loosely connected parts in the total design. Of course selection of ewes for certain AI rams may introduce bias in the evaluations.

The same principles concerning the sampling of dams for progeny groups and treatment of progenies are valid here as in traditional methods of progeny testing and need not to be considered in detail. However, some potential problems may occur in the method suggested here.

The first concerns the use of ewe lambs as dams in the testing. In Sweden it is a common practice to mate females already as half year old lambs, but they usually come in season later than older ewes. There is therefore a risk that connections between flocks through AI or ram circle rams will concern only older ewes. If ewe lambs are used as test dams for the flocks' own rams a varying degree of special treatment of the youngest dams as well as seasonal effects on their progeny will influence the comparisons. These effects are difficult to pre-correct for in the data since they may be very different from flock to flock. Instead they can be removed by dealing with two flock by age class effects instead of flock effects in the computations. However, at least two test rams in the flock must have ewe lambs in their dam-groups, otherwise the progenies of the youngest ewes will not contribute to the comparison of rams.

The other potential complication is a bias due to seasonal effects when test rams are not used in parallel in the flock. Such effects may well occur within common lengths of the mating season (e.g. birth dates for progenies) due to different length of indoor feeding period of progenies and different age at start of grazing period, parasite infections, climatic changes, rearing etc. This is mainly a problem when flocks are connected through rams used during a very short period (i.e. AI rams) or when connections are established by a single exchange of rams. This can be handled by dividing flock effects into flock-season effects in the computations. Thus for example a partitioning of flocks at the time when rams are exchanged will create connections between the "early" part in one flock and the "late" part in another through the exchanged rams and between "early" and "late" parts in the same flock through rams not exchanged.

A crucial question for the comparisons across flocks is the amount of overlapping needed between flocks. This has to be a compromise between the number of rams which can be tested with a given set of flocks and the accuracy of the comparisons over flocks. Because clear-cut knowledge is not yet available on this point the rule of thumb used in practice has been that progenies for connecting the flock should be as many as the number of progenies of own test rams, but need not exceed 60-80. This probably leaves a wide safety margin and is often not reached in practice. Consideration of relationships between rams in the evaluation procedure is one way of reducing the need for overlapping. The strength of the connections needed will be studied further.
SIMULTANEOUS EVALUATION OF LAMBS ACROSS FLOCKS

The statistical model used for the evaluation of the progeny tests always contain effects of ram and flock (or flock-age-class, flock-season, flock-age-class-season). Inclusion of other effects like genetic groups of ram (elite or test ram, breed) and breed of ewe may also be necessary. In addition sex of lamb is included in the model for pelt characters but effects of age of lamb, age of dam and litter size are eliminated by pre-correction of data.

Once estimates for all these effects in the model are available, a remaining unexplained effect \( e_{ij} \) for each lamb can be estimated as

\[
\hat{e}_{ij} = y_{ij} - \hat{P},
\]

where

- \( y_{ij} \) is the observation of \( j \)-th progeny within sire \( i \),
- \( \hat{P} \) represents estimates for other fixed effects in the model.

The estimate of the reminder effect \( \hat{e}_{ij} \) can be further partitioned into an additive genetic effect \( p_{ij} \) corresponding to the lamb's own genotype after removal of sire's effect and a "random error" \( \varepsilon_{ij} \), which among others include maternal effects. An prediction of the additive genetic part \( p_{ij} \) can be computed as

\[
\hat{p}_{ij} = \frac{s_{ij}^2}{(a_{ij}^2 + e_{ij}^2)} \cdot \hat{e}_{ij},
\]

where

- \( s_{ij}^2 \) is the additive genetic variance within progeny groups,
- \( a_{ij}^2 \) is the error variance and
- \( a_{ij}^2/(a_{ij}^2 + e_{ij}^2) \) corresponds to \( 3/4 \) of heritability.

An estimated breeding value for the lamb can then be calculated as

\[
\hat{p}_{ij} + \hat{e}_{ij}.
\]

This is one of the procedures proposed for evaluation of dairy cows on first lactation records and for evaluation of performance tested beef bulls (e.g. Eriksson et al., 1978). By this procedure progenies can be evaluated across flocks with inclusion of the genetic differences between flocks caused by the sires used. (Genetic differences due to dams are confounded with flock effects and can therefore not be considered). Sib information is automatically included through sire's prediction. In addition the comparisons of lambs within the flock is improved by the simultaneous control of the progeny group structure among contemporaries.

In a population consisting of fairly small flocks a major advantage of this extension is the possibility for more intense selection of ram lambs. In a situation where flocks are too small to allow simultaneous progeny testing of a sufficient number of rams an advantageous strategy would perhaps be to organize connections between flocks as described above and concentrate the efforts on evaluation of lambs.

A high selection intensity is possible already with farily few flocks connected and therefore this evaluation strategy may well be organized in smaller units than the progeny testings, e.g. as cooperation between flock in limited areas.

CONCLUDING REMARKS

Judging from the absence of reports evaluation by mixed model procedures has not yet been applied much to sheep. This technique, however, seems to offer...
efficient tools for handling many difficult evaluation problems under the special circumstances occurring in sheep production (Danell, 1980). In beef cattle several applications have been described for situations similar to those in sheep (e.g. Schaeffer & Wilton, 1975; Quaas & Pollak, 1980).

The approach described in the present paper has turned out to be very successful in practical application. For many years sheep farmers have been encouraged to apply progeny testing but, partly due to the practical difficulties in organizing traditional test designs which include a sufficient number of rams, usually less than 100 rams were progeny tested per year in the whole population (<5% of all ram lambs selected for recorded flocks). With the more flexible designs allowed by the new evaluation method the number of tested rams increased to 165 in 1981. In 1982 about 230 rams are under test and about 140 flocks participate in this activity. The largest test design in 1981 involved 75 rams and 56 flocks. During 1982 about 165 rams can be evaluated simultaneously in the largest design, where the central network of connections is formed by 57 rams used through AI.

Similar approaches to allow use of large bodies of data simultaneously in the estimation procedure are possible also for other traits than lamb weight and pelt characters. They may be worthwhile in particular for traits like maternal capacity and fertility, which are difficult to handle with traditional methods in practical breeding. The advantages of applying this kind of methodology are probably larger in sheep than in many other farm animals because of the structure of the data used.

SUMMARY

In sheep production the main opportunities for selection are among lambs before slaughter age and among rams used in breeding. In a population consisting of small flocks large-scale strategies for evaluation across flocks are essential for the selection of males. Organisational models are suggested in which information from field recording is utilized along with computational procedures based on best linear unbiased prediction. For simultaneous comparisons of large numbers of rams used in different flocks, ties between flocks are created by the use of AI-rams, ram-circle designs, exchange of ewes between flocks during mating season and occasional exchanges of single rams. The network of ties can be improved by including relationship information in the computations. The strategy can be extended to simultaneous ranking of progenies across flocks and, at the same time, improve comparisons within flocks by consideration of genetic structure among contemporaries.

RESUME

Dans l'élevage ovin les possibilités principales de sélection sont parmi des agneaux avant l'âge à abattage et parmi des béliers reproducteurs. Dans une population qui est constituée par des petits troupeaux, des stratégies comprenant l'évaluation à travers des troupeaux sont essentielles pour la sélection des mâles. Des modèles d'organisation sont proposés dans lesquels des données de testage en ferme sont utilisées avec des méthodes de calcul basées sur "best linear unbiased prediction (BLUP)". Pour des comparaisons simultanées des grands nombres des béliers qui sont utilisés dans des troupeaux différents, des liaisons sont créées par l'utilisation des béliers d'IA, des modèles de rotation des béliers, des échanges des brebis entre troupeaux pendant la lutte et des échanges occasionnels des béliers uniques.
Cette stratégie peut aussi être étendu afin de ranger simultanément la progéniture à travers des troupeaux. En même temps, des comparaisons au sein des troupeaux sont améliorées par la considération des liaisons entre contemporains.

REFERENCES

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