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RELIABILITY OF BLUP METHOD AND MODIFIED CC TEST FOR ESTIMATING BREEDING VALUE OF AI BULLS

The precise estimation of bulls' genetic value in artificial insemination (AI) has a fundamental importance in dairy cattle breeding. The improvement of bull progeny testing procedures has proceeded parallel to the development of computers which enable the processing of large amounts of data and the using of complicated mathematical procedures. Theoretically, better methods for sire evaluation have been known for a long time (Henderson, 1973, 1984; Fimland, 1976; Van Vleck, 1977; Danell et al., 1978; Thompson, 1979), yet practical application of computers has been available only in ten recent years, in Estonia only since 1988.

The contemporary comparison method (CC test) in estimation of AI bulls' breeding value has been applied by Robertson and Rendel (1950, 1954) and widely used in many countries (Pirchner, 1983; Brade, 1984). In Estonia, the modified CC test has been used in AI bulls' evaluation since 1983 (Тейнберг, Савели, 1989). The CC method includes the assumptions that the average genetic merit of the herdmates is the same for all bulls, and, secondly, that all bulls are mated to cows of the same average genetic merit. Genetic trend in the population is assumed not to exist, which makes a correct comparison of old and young bulls impossible.

In the early seventies Henderson (1973, 1974, 1975) proposed a linear model, the so-called Best Linear Unbiased Prediction (BLUP) for estimating the breeding value of sires. He pointed out that BLUP is taking into account genetic trends, different genetic levels among areas and farms, nonrandom distribution of sires across herds, environmental differences as well as seasonal differences of data. It also makes it possible to eliminate bias due to selection and culling.

So, the BLUP method gives the best linear unbiased predictions of random elements in the model, and the probability of a correct ranking of bulls is maximized. The BLUP model, as a rule, eliminates the effects of herd-year-season (HYS), sire's generation, sires of herdmates and sires of mates. Thus, random use of sires is not indispensable and sires of different generations could be accurately evaluated when the genetic trend exists in the population (Danell, 1981; Eriksson, 1981). The final breeding value is estimated as a relation to the mean of the corresponding genetic group to which the bull belongs.

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In Estonia, first attempts to use BLUP programmes for estimating AI bulls' breeding value were made in 1989 (Певкур, Тейнберг, 1989). Now the plan of the practical application of the BLUP has found realization at the Estonian Institute of Animal Breeding and Veterinary Science.

Material and Methods

With a view to compare the reliability of the CC test and the BLUP method, milk production data of 12533 daughters of 140 Estonian Black and White bulls' and 71 bulls' 4617 daughters' of the Estonian Red breed were included. All were first lactation cows, having calved during 1989 and 1990, and they finished their 305-day control lactation before April 1st, 1991. All the bulls were ranked according to their daughters' breeding value as regards milk fat and protein production, determined by both the CC and the BLUP method. All bulls' daughters in either breed separately were randomly divided into two equal groups and estimating the breeding value estimation was done in both groups by two methods. In this way we compared the reliability of methods, computing the correlation coefficients between the breeding value estimates received by using both methods (Pirchner, 1983). We also compared the final ranking of bulls evaluated by the two methods.

The method of estimating breeding value by modified contemporary comparison method (CC test) has been described in detail earlier (Тейнберг, Савели, 1989). The predicted difference (*PD*) between a bull's daughters and their herdmates (contemporaries) was calculated by the formula

$$PD=\frac{0.25\sum w\cdot h^2\cdot \bar{d}}{1+(\sum w-1)0.25h^2},$$

where $\sum w$ is the sum of effective daughters of a bull;

h^2 — heritability of milk yield (0.3);

$\bar{d}$ — weighted difference between milk yield of the bull's daughters and their contemporaries.

As a basis of the BLUP method we took the following mixed linear model with fixed and random effects (Henderson, 1984):

$$y=X\beta+Zu+e,$$

where y is the observable data vector with n elements;

X and Z — a known, fixed, $n\times p$ matrices, concerning effects to be estimated;

β — fixed, $p\times l$ vector of effects generally unknown (for example herd, year, season, genetic group, etc.)

u — random, $q\times l$ vector of unknown effects with zero means (for example the additive genetic effect of a bull);

e — random, $n\times l$ vector of unknown residual (unfixed) effects, with zero means.

Predicted difference (ω) is estimated as

$$\omega=P\beta+u,$$

with $E(\omega)=P\beta$,

where P is a matrix that includes all fixed effects.

The requirements for the estimated $\hat{\omega}$ in the BLUP procedure are (Кузнецов и др., 1987):

1) linearity $\hat{\omega}_i = b'_i y$;

2) unbiasedness $E(\hat{\omega}_i) = E(\omega_i)$;

3) best $E(\hat{\omega}_i - \omega_i)^2 \to \min$.

The linearity means that the expected $\hat{\omega}_i$ is calculated as the weighted sum of single elements of observed vector y. The weights are included in the vector b'_i.

The unbiasedness means that in repeated estimating of $\hat{\omega}_i$ in other samples of the same population, the average estimation of $\hat{\omega}_i$ coincides with the real value of ω_i. This allows to call it the "best". The main problem is to estimate the vector b'_i which fulfils the requirements 2 and 3. So the BLUP method is similar to the modified selection index.

The estimates of $\hat{\beta}$ and $\hat{u}$ are calculated by using matrices (Henderson, 1984; Кузнецов и др., 1987; Певкур, Тейнберг, 1989).

Results and discussion

The coefficients of correlation between the estimates of the breeding value of the two randomly selected daughter groups of bulls are presented in Table 1.

Table 1

Coefficients of correlation between two random daughter groups of bulls by CC and BLUP method

Breed	Method	Number of bulls	Number of daughters	Coefficient of correlation
EBW	CC	140	12533	+5.580
	BLUP			+0.724
ER	CC	71	4617	+0.564
	BLUP			+0.551

As it may be concluded from Table 1, the correlation between random samples in the BLUP method are considerably higher in Estonian Black and White breed (EBW) than in the CC test. It indicates to a higher reliability of the BLUP method. In Estonian Red breed (ER) the numbers of cows were, evidently, insufficient for splitting the population into two parts. The correlations here were practically equal. Analogical results have been published by Pirchner (1983) and Eriksson (1981), who confirm that the BLUP method gives the highest correlation between estimates and the real values of genetic merit of animals, thus maximizing the probability of correct ranking of animals. Dempfle and Hagger (1979) split progenies of Bavarian Brown bulls and computed correlations between the groups. The BLUP values agreed more closely ($r=0.8$) than the estimates from a modified CC test ($r=0.6$). When the conditions were more favourable (homogeneous population, large, randomly distributed progeny groups) Schneeberger et al., (1980) found little difference in the ranking of sires. Similar conclusions were drawn by Powell and Freeman (1974). At the end of the eighties, therefore, most countries with a well-developed dairy cattle breeding have replaced the conventional CC test by the BLUP procedure.

Table 2

The comparison of ranking EBW bulls by the sum of milk fat and protein kilograms, using the CC and BLUP method

CC method			BLUP method		
Rank of bulls by CC	Rank of bulls by BLUP	Breeding value by BLUP	Rank of bulls by BLUP	Rank of bulls by CC	Breeding value by BLUP
1	1	52.7	1	1	52.7
2	2	51.1	2	2	51.1
3	3	37.4	3	3	37.4
4	5	35.3	4	12	35.0
5	6	35.2	5	4	35.3
6	7	34.9	6	5	35.2
7	21	14.6	7	6	34.7
8	8	33.9	8	8	33.9
9	29	9.4	9	16	26.6
10	36	8.4	10	20	20.0
Average BV by BLUP		31.3			36.2
Difference					+4.9

In Table 2, the comparison of ranking EBW bulls by the BLUP and CC breeding value estimates according to milk fat and milk protein sum are presented. Only ten best bulls were included on the basis of both methods.

As it can be seen in Table 2, the ranking of bulls on the basis of their daughters average breeding value (kg fat + kg protein) is the same in the first three bulls. Some differences in their rank numbers can be observed in the next bulls. Ranking by the BLUP gives a higher average breeding value estimation (+4.9 kg). It indicates that the better bulls, those with higher breeding value, were selected rather in the case of using the BLUP, than by the CC method. Similar results were received by Halluf (Халлуф, 1990): breeding value of milk yield by the BLUP was higher +139 kg, and milk fat yield +1.3 kg as compared to the CC test. The author recommends to apply the BLUP in practice as a more stable method.

Similar results were received in the Estonian Red breed. The difference in breeding value received by the BLUP and the CC method was here 6.7 kg of milk fat and protein. The ranking of bulls, however, differed more widely in the two methods than in the case of the EBW breed.

As a result of the comparison of the BLUP and CC methods, it can be concluded that the BLUP gives more reliable results in evaluating bulls than does the modified CC method which was used in Estonia until now. According to our recommendation, starting with the beginning of 1992, the BLUP method for estimating AI bulls' breeding value will be introduced in both the Estonian Black and White and the Estonian Red breeds.

REFERENCES

Brade, W., 1984. Aktuelle Methoden der Auswertung der Nachkommenprüfergebnisse für Vatertiere — genetische Grundlagen und Berechnungsmöglichkeiten. — Arch. Tierz., 27, 491—511.

Danell, B. 1981. Evaluation of sires on first-lactation yield of Swedish dairy cattle. — Report 51, Swedish Univ. Agric. Sci., Uppsala.

Danell, B., Eriksson, J.-A., Elofson, L., Danell, O., 1978. Possible advantages of direct sire comparison in Sweden in relation to present dairy sire evaluation. — Proc. Conf. on Dairy cattle breeding in the eighties, SHS medd., 89, 27—45.

Dempfle, L., Hagger, C. H., 1979. Untersuchungen über Effizienz und Korrekturfaktoren bei der Zuchtwertschätzung von Bullen. — Z. Tierz. Züchtungsbiol., **96**, 135—142.

Eriksson, J.-A., 1981. Best linear unbiased prediction of breeding values with regard to related contemporaries and selection of records. — Report 50, Swedish Univ. Agric. Sci.

Fimland, E. A., 1976. Estimation of sire's breeding value. VI. Different linear prediction methods discussed in the context of the breeding structure of the population. — Z. Tierz. Züchtungsbiol., **93**, 14—30.

Henderson, C. R., 1973. Sire evaluation and genetic trends. In: Proc. of the Animal Breeding and Genetics Symp. in honour of Dr. J. L. Lush, ASAS and ADSA, Champaign, Illinois, 10—41.

Henderson, C. R., 1974. General flexibility of linear model techniques for sire evaluation. — J. Dairy Sci., 57, 963—972.

Henderson, C. R., 1975. Best linear unbiased estimation and prediction under a selection model. — Biometrics, **31**, 423—447.

Henderson, C. R., 1984. Applications of linear models in animal breeding. Univ. of Guelph.

Pirchner, F., 1983. Population genetics in animal breeding. 2nd ed., Plenum Press, New York and London.

Powell, R. L., Freeman, A. E., 1974. Estimators of sire merit. — J. Dairy Sci., **57**, 1228—1236.

Robertson, A., Rendel, J., 1950. The use of progeny testing with artificial insemination in dairy cattle. — J. Genet., 50—62.

Robertson, A., Rendel, J., 1954. The performance of heifers got by artificial insemination. — J. Agric. Sci., **44**, 184—192.

Schneeberger, M., Freeman, A. E., Berger, P. J., 1980. Costs and risks for sire selection strategies in artificial insemination. — J. Dairy Sci., **63**, 491—499.

Thompson, R., 1979. Sire evaluation. — Biometrics, **35**, 339—353.

Van Vleck, L. D., 1977. Theoretical and actual genetic progress in dairy cattle. — Proc. Intern. Conf. Quant. Genetics, Iowa State Univ. Press, 543—567.

Кузнецов В. М., Шестиперов А. А., Егорова В. Н., 1987. Методические рекомендации по использованию метода BLUP для оценки племенной ценности быков-производителей. Ленинград.

Певкур А., Тейнберг Р., 1989. Результаты сравнения разных методов оценки генетической ценности быков-производителей. — Изв. АН ЭССР. Биол., **38**, 3, 169—172.

Тейнберг Р. Р., Савели О. Р., 1989. Усовершенствованная система оценки быков-производителей. — Вестн. с.-х. н., 3, 103—108.

Халлуф Н. М., 1990. Методы оценки изменчивости молочной продуктивности коров и племенной ценности быков. Автореф. дис. канд. с.-х. Ленинград.

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BLUP-MEETODI JA CC-MEETODI USALDUSVÄÄRSUS SEEMENDUSPULLIDE ARETUSVÄÄRTUSE HINDAMISEL

Kontrolliti BLUP-meetodi (parim lineaarne veatu prognoos) ja CC-meetodi (eakaaslaste võrdlus) usaldusväärsust seemenduspullide aretusväärtuse hindamisel nende tütarde keskmise jõudluse põhjal (piimarasva + piimavalgu toodang, kg). Kokku analüüsiti 12 533 eesti mustakirjut tõugu I laktatsiooni lehma (140 pulli tütred) ja 4617 eesti punast tõugu lehma (71 pulli tütred).

Selgus, et korrelatsioonikoefitsiendid kahel meetodil kahe juhuslikult valitud kogumi vahel olid eesti mustakirjul tõul 0,580 CC-meetodil ja 0,724 BLUP-meetodil, eesti punasel tõul vastavalt 0,564 ja 0,551 (tab. 1). Pullide paremusjärjestus kahel meetodil määratud aretusväärtuse põhjal langes kümnel esimesel pullil hästi kokku (tab. 2), kusjuures BLUP-meetodil määratud aretusväärtus oli suurem (eesti mustakirjul tõul +4,9 kg ja punasel tõul +6,7 kg valgu + rasva võrra). Soovitatakse kasutusele võtta BLUP-meetod.

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ДОСТОВЕРНОСТЬ МЕТОДА BLUP И МОДИФИЦИРОВАННОГО СС-МЕТОДА ПРИ ОЦЕНКЕ ПЛЕМЕННОЙ ЦЕННОСТИ БЫКОВ ДЛЯ ИСКУССТВЕННОГО ОСЕМЕНЕНИЯ

Проверена достоверность BLUP-метода (метод наилучшего линейного прогноза) и СС-метода (метод сравнения сверстниц) при оценке быков-производителей по средней продуктивности дочерей. Исследовались данные 12 533 дочерей от 140 быков эстонской черно-пестрой породы и 4617 дочерей от 71 быка красной эстонской породы.

Выяснилось, что коэффициент корреляции между двумя случайными выборками дочерей быков эстонской черно-пестрой породы был 0,580 и 0,724 соответственно по методам СС и BLUP и выборками дочерей быков красной эстонской породы 0,564 и 0,551 (табл. 1). Ранги быков по продуктивности дочерей (молочный жир + + молочный белок, кг) по двум методам у 10 лучших по племенной ценности быков хорошо совпадали (табл. 2), причем оценка была выше при использовании метода BLUP (у эстонской черно-пестрой породы 4,9 кг и у красной эстонской породы 6,7 кг соответственно). Таким образом, рекомендуется использовать BLUP-метод.