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SOME POINTS OF VIEW ON THE ESTIMATION AND IMPORTANCE OF GENETIC CHANGE IN POPULATIONS OF DAIRY CATTLE

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SUMMARY

Some results from a study on genetic changes in milk yield and fat percentage in the *Finnish Ayrshire* (*ay*) and *Finncattle* (*fc*) breeds are discussed. Moreover the economic importance of the genetic change is considered.

The genetic change was estimated in 2 ways: (*a*) from the selection practised in artificial insemination (AI) in 1961-66 and (*b*) from the change in the progeny tests of individual AI sires over the period 1957-68.

The following results were obtained and conclusions drawn:

1) The genetic gain in milk yield was in *ay* *0.80-0.91* % */year* and in *fc* *0.84-0.99* % */year*. In kilograms this corresponds to some 35 and 31.5 kg, respectively.

2) With regard to fat percentage *no* noticeable genetic change could be detected in either breed.

3) As both methods used gave similar results it was concluded that the estimates can be regarded as fairly reliable.

4) In both breeds *about one half* of the increase in average milk yield noted over the period 1957-68 could be attributed to the breeding work.

5) The rate of interest on investments made in breeding was calculated to be *107* %. (The genetic gain achieved in one year was considered permanent, i.e. available also the following years. As costs those pertinent for AI, milk recording and Breed Societies were taken into account. On the return side the average genetic gain in milk yield for the two breeds (0.93 % /yr) was considered and multiplied by the appropriate economic production value).

6) The genetic gain in milk yield could from the level observed in the present study be increased to *1.4-1.5* % */year*. This would require:

a) that the best 1-2 % of the bulls were approved as bull sires (in study 35 % in *ay* and 25 % in *fc*);

b) that as sires of female replacement only 10-15 % of the bulls be approved (52 % in *ay*, 45 % in *fc*);

c) that average generation interval be decreased from the observed 7.3 years to 5.3 years.

INTRODUCTION

A frequent question of debate in many countries with an advanced dairy cattle industry is whether increases in production should be attributed to improvements in breeding or to better feeding and management. Reliable answers to this question have so far been available for rather few dairy cattle populations. Research workers seem to have been more interested in developing new complicated procedures rather than in checking if the hitherto used ones have been effective in practice.

In the following some results from a study on genetic changes in milk yield and fat percentage in the *Finnish Ayrshire* and *Finncattle* breeds will be given and discussed. Detailed results can be found in LINDSTRÖM (1969) ([1]) and therefore only those of general interest will be presented here. Furthermore some consideration is given the economic importance of genetic change.

MATERIAL AND METHODS

The genetic change was estimated in two ways:
1) from the selection practised in AI breeding in the period 1961-66,
2) from the change in the progeny tests of individual AI sires over the period 1957-68.
In 1) the genetic change was calculated from the selection differentials for the four paths along which genes are transmitted from one generation to the next (RENDEL and ROBERTSON, 1950). In (2) only AI sires represented over a time span of at least 6 years, with a minimum of 20 daughters in each proof, were used. The genetic change was obtained both by regression analysis techniques and least squares procedures (SMITH, 1962).

RESULTS

Selection practised in 1961-66

The main results are given in tables 1-2. With regard to milk yield it is seen that in both breeds the selection of bull dams has been rather effective. Also the dams of female replacements have in both breeds been clearly above average.

TABLE 1

Selection practised in 1961-66 with regard to milk yield (ay = Ayrshire, *fc* = Finncattle).
Sélection pratiquée en 1961-66 sur la production laitière (ay = Ayrshire, *fc* = Finncattle).

Selection of	No of animals		Genetic selection differential			
			kilograms		rel. units = %	
	ay	*fc*	*ay*	*fc*	*ay*	*fc*
Bulls to breed bulls (BB)	707	383	345 ± 7	355 ± 14	7.91	10.07
Bulls to breed cows (BC)	824	535	83 ± 2	102 ± 4	1.90	2.89
Cows to breed bulls (CB)	707	383	497 ± 7	364 ± 8	11.40	10.32
Cows to breed cows (CC)	2 118	2 570	92 ± 4	75 ± 3	2.11	2.13
Total			1 017	896	23.32	25.41
Genetic gain/year			35.0 ± 0.4	29.7 ± 0.7	0.80	0.84

([1]) Thesis which has been published in full in *Acta. Agr. Fenn.* as listed in references.

On the other hand the selection of sires, especially of the next cow generation, has been fairly weak, particularly in *Ayrshire*. In *Finncattle* the selection of bull sires has been almost as efficient as that of bull dams. In *Ayrshire*, however, the selection differential of the sires of the next bull generation was some 3.5 % units lower than for the bull dams.

With regard to fat percentage the selection differentials are on the male side in both breeds negative. When picking the dams more attention has obviously been paid to the fat percent, especially in Finncattle. On an average the observed differentials indicate a genetic gain of 0,80 % per year in *Ayrshire* and of 0,84 % per year in *Finncattle* with respect to milk yield, whereas no genetic change can be predicted for fat percentage in either breed.

TABLE 2

Selection practised in 1961-66 with regard to fat percentage and generation interval.
Sélection sur le taux butyreux et l'intervalle de génération pratiquée en 1961-66.

Selection of	No of animals		Genetic selection differential, fat % units		Generation interval years	
	ay	*fc*	*ay*	*fc*	*ay*	*fc*
BB	707	383	—0.118 ± 0.007	—0.129 ± 0.014	9.29 ± 0.11	9.40 ± 0.15
BC	824	535	—0.022 ± 0.003	—0.031 ± 0.005	6.23 ± 0.06	7.06 ± 0.09
CB	707	383	0.046 ± 0.009	0.123 ± 0.011	8.67 ± 0.12	8.62 ± 0.17
CC	1 266	2 570	0.007 ± 0.005	0.032 ± 0.004	*4.87 ± 0.05	5,06 ± 0.05
Total			—0.084	—0.002	29.06	30.14
Genetic change			—0.003 ± 0.0004	—0.000 ± 0.0005	$\bar{x}$: 7.26 /year	7.53

* result for 2.118 dams.

Change in progeny tests

The main results are given in table 3. With regard to milk yield the analyses indicate an annual genetic gain of 0.80 to 0.91 % in *Ayrshire* and of 0.99 to 1.11 % in *Finncattle*. With respect to fat percentage the analyses indicate that no genetic gain has taken place in either breed.

DISCUSSION

Comparison of results

Comparing the results obtained by the two methods we can conclude that, on the whole, the agreement is fairly good. It must be pointed out that the genetic change in a cow population resulting from the selection practised in a certain

TABLE 3

Observed annual genetic change in milk yield and fat percentage (38 ay-*bulls with records in 1957-68 and 39* fc-*bulls with records in 1958-68).*

Gain génétique annuel en production laitière et taux butyreux (38 taureaux Ayrshire *testés en 1957-68 et 39 taureaux* finnois *testés en 1958-68).*

No of records *ay* 36580 *fc* 17 219	Method of calculation			
	Intra-sire regr.		Least squares const.	
	ay	*fc*	*ay*	*fc*
Milk yield (rel. units)				
Regr. coeff.	— 0.400 ± 0.039	— 0.555 ± 0.057	— 0.455 ± 0.011	— 0.496 ± 0.034
Genetic change	+ 0.800	+ 1.110	+ 0.910	+ 0.992
Fat %				
Regr. coeff.	— 0.0002 ± 0.0061	+ 0.0031 ± 0.0016	+ 0.0058 ± 0.0013	+ 0.0053 ± 0.0011
Genetic change	+ 0.0004	— 0.0062	— 0.0116	— 0.0106

year will take place only some 3 years later. Thus the results calculated from the selection intensity in 1961-66 should be compared to the observed genetic change in 1964-69. Separate results for this latter period were not computed as this would have decreased the accuracy. However, judging from the least squares constants for the different years it would seem as if the gain in milk yield in *Ayrshire* after 1964 and in *Finncattle* after 1966 had been less than in the previous period. Consequently one can regard the two methods of calculation to have yielded similar results.

Fat percentage

In the following the discussion will be limited to milk yield. Some comments on the rather poor results for fat percent seem, however, justified. The main reasons for the observed results are probably :

1) the main emphasis in the breeding programmes has been on an increase in milk production. Thus the negative genetic correlation between milk yield and fat percentage will have influenced the results,

2) the price relations between milk and fat percent have not been such as to promote a striving for a higher fat content,

3) no age correction was earlier made when calculating the progeny tests for fat percent. This resulted in positive deviations for many bulls being in fact below average.

Agreement with theoretical calculations

With respect to milk yield how do the results of the present study compare with those theoretically obtainable? From table 4 can be seen that the selection of dams in both breeds agrees well with the theoretical results. On the other hand the observed selection differentials correspond to approval of 35 % of all bulls as bull sires in *Ayrshire* and of 25 % in *Finncattle*, while the theoretical figure is 1-2 %. With regard to the sires of female replacements the observed selection intensity indicates approval of 52 % of all tested bulls in *Ayrshire* and of 45 % in *Finncattle*, compared with the theoretical figure 10-15 %. Thus it is evident that in the planning and use of the bulls one has been far from the optimum situation (SKJERVOLD and LANGHOLZ, 1964).

TABLE 4

Comparison of theoretically obtainable selection intensity with the observed one (milk yield).
Comparaison de l'intensité de sélection théoriquement possible avec celle observée dans la réalité (production laitière).

Selection of	Theoretical selection intensity %	Observed selection differentials correspond to selection intensity % x_1	
		ay	*fc*
BB	1-2	35	25
CC.	10-15	52	45
CB	3-5	6	9
CC.	60-80	75	75

x_1 select. int. (in stand. dev. units) $= I_G / h\sigma_G$
Where :
I_G = observ. genet sel. diff.
h = square root of heritab. of select. index
σ_G = genet. stand. dev.

With regard to the sires of female replacements part of the weak selection intensity noted can be ascribed to the large use (c. 50 %) of unproven bulls (3-4 years of age) in order to satisfy the increasing demand for fresh semen. However, it must also be pointed out that if enough young bulls had been put into AI use a much heavier culling would later on have been possible. In the period 1954-62, on an average, only 10 bulls per year in *Ayrshire* and 6 bulls per year in *Finncattle* were taken into AI use. It is obvious that with such numbers the selection intensity can not be very high. It is interesting to note that this fundamental — proving enough bulls annually — has been neglected in almost all countries, even in those practising progeny testing for many decades.

Generation interval

One of the main reasons for the rather modest gain observed in the present study is the long generation intervals. From table 2 can be seen that the bull sires in both breeds have been 9.3-9.4 years and the bull dams over 8.6 years of age. These are among the highest figures noted in the literature. The age of the sires and dams of female replacements are more in accordance with other reports. However, the relevant question is what generation intervals can be achieved in practice with a good planning of the breeding activities. From table 5 can be seen that it should be possible to reduce the average generation interval from 7.3 to 5.3 years. This would be of first rate importance *as the genetic gain would be sped up by some 37 %.*

TABLE 5

Observed and attainable generation interval.

Intervalles de génération observés et théoriquement possibles.

Selection of	Generation int. val. years		Remarks
	observ. (*ay*)	possible	
BB . . .	9.3	6.6	Prog. test at 5.3 yrs and used only one year (bull dam inseminations done, on an average, in 6 months).
BC	6.2	4.5	Gen. int. val for young untest. bulls c. 2.3 yrs (used to 50 % of cows).
CB	8.7	5.5	Cows with 1-2 yrs prod. also approved as bull dams.
CC	4.9	4.5	
average .	7.3	5.3	

Importance of genetic gain

We can now return to the question of how much of the total increase in milk yield is genetic in origin. This can be seen from (fig. 1). In other words in both breeds *about one half of the increase in average milk yield noted over the period 1957-68 can be attributed to the breeding work.* Economically this means, e.g. at the 4 000 kg herd level that the benefit per cow and year is 36-40 kg milk, i.e. 20-22 fmk.

By considering the costs for AI breeding as investments (LINDHE, 1968) we can calculate the rate of interest (table 6). Here we regard the genetic gain achieved in one year as permanent, i.e. available also in the following years (SKJER-

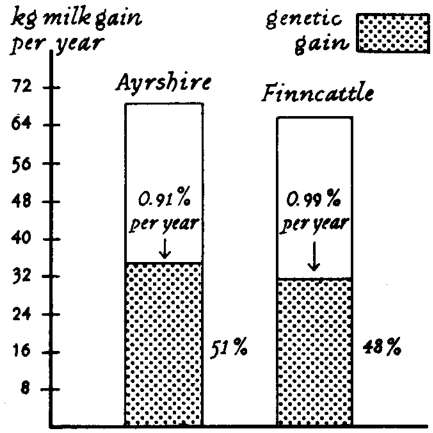

FIG. 1. — *Genetic contribution to total gain in milk yield in period 1957-1968.*
FIG. 1. — *Part du gain de production laitière attribuable à la génétique, dans les années 1957-1968.*

TABLE 6

The returns from cattle breeding in Finland 1968-69.
Recettes en provenance de l'élevage bovin en Finlande en 1968-69.

Costs of breeding work	mill. fmk	Returns from breeding work
Artific. insem.	10.00	Average genetic gain in milk yield 0.93 % /year / cow :
Milk recording	4.25	0.93 % × 3 644 kg (1) × 1 million cows × 0.546 *fmk*
Breed Societies	3.00	
Total.	17.25	*18.51 mill. fmk*

$$\text{Rate of interest} = \frac{18.51 \times 100}{17.25} = 107\ \%$$

(1) aver. proc. (milk with 4 % fat) of all cows in country.

VOLD, 1965). The costs are those for milk recording, AI breeding and the Breed Societies. In the calculation only one half of the total costs for milk recording were taken into account as the other half can be considered costs for the planning of feeding and management. From the total costs in the AI sector the technical costs, i.e. those required just to get the cows pregnant (needed whether natural service or AI is used), were subtracted. These costs made up some 56 % of the total costs. Finally from the Breed Society costs those not directly bearing on the enhancement of the breeding work were subtracted (some 24 %).

We can conclude that, even if the genetic gain could have been larger in our breeds, the investments made in breeding yield a good interest.

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RÉSUMÉ

QUELQUES RÉFLEXIONS SUR L'ESTIMATION ET L'IMPORTANCE DES VARIATIONS DE NIVEAU GÉNÉTIQUE DANS PLUSIEURS POPULATIONS DE BOVINS LAITIERS.

La discussion porte sur les résultats d'une étude concernant les variations de niveau génétique, des races *Ayrshire finnoise* (*Ay*) et *finnoise* (*fc*), pour la production laitière et le taux butyreux. L'importance économique de ces variations est ensuite analysée.

La variation génétique a été estimée de deux façons : *a*) à partir de la sélection exercée en insémination artificielle (I.A.) pour la période 1961-66 et *b*) à partir de la variation des index sur descendance de mêmes taureaux d'I.A. pendant la période 1957-68.

Les résultats et conclusions ont été les suivants :

1. Le progrès génétique annuel pour la production laitière a été de 0,80-0,91 % en *Ay* et de 0,84-0,91 % en *fc*. Soit environ 35 et 31,5 kg respectivement.
2. Aucune variation génétique appréciable du taux butyreux n'a pu être décelée.
3. Les deux méthodes d'estimation ayant donné des résultats similaires, on en a conclu que les estimées sont probablement satisfaisantes.
4. Dans chacune des deux races, environ la moitié de l'augmentation des rendements laitiers individuels sur la période 1957-1968, a pu être attribuée à la sélection.
5. Le taux d'intérêt des investissements entraînés par la sélection a été estimé à 107 %. (Le gain génétique réalisé une année donnée a été considéré comme permanent, c'est-à-dire valable aussi pour les années suivantes; les coûts concernés sont ceux relatifs à l'I.A., en contrôle laitier et aux sociétés d'élevage ; pour évaluer les recettes, on a multiplié le gain génétique annuel moyen réalisé sur la production laitière pour les deux races (0,93 %) par la valeur économique appropriée.)
6. Le progrès génétique annuel sur la production laitière pourrait encore être augmenté jusqu'à 1,4-1,5 % à condition :

a) de ne retenir que 1 à 2 % des taureaux, comme pères des taurillons à mettre en testage (dans cette étude, 35 % en *Ay* et 25 % en *fc*);

b) de ne retenir que 10 à 15 % des taureaux, comme pères des femelles de remplacement (52 % en *Ay*, 45 % en *fc*);

c) d'abaisser l'intervalle moyen de génération de 7, 3 ans actuellement à 5, 3 ans.

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