GENETIC IMPLICATIONS OF ADVANCES IN SEMEN DILUTION

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SUMMARY

The factors responsible for the amount of genetic progress in an artificial breeding scheme, based on a young-bull-sampling programme, are discussed, and the importance of the number of inseminations obtained per proven bull is illustrated. The effect of the advances made in New Zealand in semen dilution since 1960 has been that, in spite of an increase from approximately 500,000 to 1,000,000 cows inseminated per annum in the Board's artificial breeding scheme, the number of proven bulls of the two major breeds used has declined from 109 to 56.

This has meant that the proportion of the inseminations made to unproven bulls has been able to be reduced while at the same time more intensive selection has been possible when these bulls are proven. Largely as a result of this, the production increase to be expected from the use of progeny tested bulls through artificial breeding has doubled.

The smaller number of bulls has, however, increased the likely rate of inbreeding and probably reduced the gene pool available for future selection. The implications of this are discussed.

THE basis of most artificial breeding (A.B.) schemes, including the one operated by the New Zealand Dairy Board, is the widespread use of proven bulls selected by means of a young-bull-sampling programme. Young bulls are selected on pedigree, used sufficiently to enable them to be proven and then laid off.

When proven at five years of age, the bulls are again selected, this time on the basis of their progeny tests. Those selected enter the proven bull team for extensive use while the balance are disposed of.

The effect of such a scheme in increasing production will depend on the following factors:

(1) The methods used to select the young bulls.
These should be selected from within the scheme and in particular they should be sons of the best of the proven bulls from high-producing daughters of good proven bulls.

(2) The proportion of the total inseminations which is made from young bulls.

Provided the resulting daughters are all tested, as is effectively the case under the Board's scheme, this proportion will determine the number of young bulls which can be used and the number of daughters on which they can be proven.

(3) The selection intensity possible when selecting proven bulls.

Once the number of young bulls to be used has been decided, the selection intensity when they are proven will depend on the number of proven bulls required.

To obtain maximum progress through an artificial breeding scheme, therefore, one must optimize several somewhat conflicting aims. The proportion of inseminations made from unproven bulls must be high enough so that sufficient young bulls are proven. But if a large number are proven then this will mean either that an unduly high proportion of the inseminations will have to be made from unproven bulls, or that each young bull will have a very small number of daughters in his proof. In the latter case, this will reduce the accuracy of selection and could mean less progress.

Above all, the number of proven bulls used must be kept as low as possible, while, at the same time, the proportion of the total inseminations made from these bulls is kept as high as possible.

To enable optimization of these various aims to be achieved, in a manner which will lead to a substantial increase in genetic merit, two basic conditions are necessary. The breeding unit must be large and the number of inseminations obtained from each proven bull must also be large. It is because of the absence of these two factors that a scheme of this type does not lead to rapid progress under natural mating (Robertson and Rendel, 1950).

An artificial breeding scheme almost invariably results in the breeding unit being large, but full advantage of this cannot be taken unless a large number of inseminations can be made from each proven bull. Accordingly, as Searle (1962), has pointed out, increasing the number of inseminations that can be made from each proven bull is the direction in which greatest production improvement can be achieved through the use of bull-sampling programmes.

Increasing the number of inseminations obtained per proven bull can be taken advantage of in three ways:

(1) The proportion of the total inseminations made to unproven bulls can be held, but, as fewer proven bulls will be required, the selection intensity can be more favourable when they are proven.

(2) The proportion of the total inseminations made to unproven bulls can be reduced and fewer young bulls proven, with the selection intensity when they are proven remaining the same as before.

(3) The proportion of the total inseminations made to unproven bulls can be held, but fewer bulls proven on more daughters per bull, thus giving greater accuracy of selection but with the same intensity.

In practice, an artificial breeding organization would normally take advantage of greater coverage per bull by a combination of these methods, with emphasis given to each one varying according to circumstances.

THE IMPLICATIONS IN PRACTICE

Shannon (1968) has described the work he has carried out to reduce the number of sperm required per insemination and drawn attention to the resulting marked increase in the number of inseminations per bull in the Board's A.B. scheme, since 1960. The effect of this has been to reduce the number of proven bulls used. This is best illustrated by reference to the Friesian and Jersey breeds. These two breeds are responsible for 95% of the inseminations made, but, between 1960 and 1967, in spite of the fact that the number of cows inseminated increased from 500,000 to approximately 1,000,000, the number of proven bulls used declined from 109 to 56.

This reduction has been taken advantage of in two of the three ways previously mentioned. The proportion of the total inseminations made to unproven bulls has declined and the intensity of selection when they have been proven has increased.

Proportion of Inseminations made from Young Bulls

Prior to 1961, the inseminations made from young bulls were made at random in herds using the service. Accordingly, when determining the number of inseminations to be made, account had to be taken of the fact that many of the herds would not be tested when the daughters calved. Thus, to make a valid comparison of the proportion of inseminations made from young bulls it is necessary to compare the present situation with 1961, when

the sire proving scheme was introduced and 9% of the inseminations were from young bulls.

Since then, in spite of the fact that the number of cows inseminated has doubled there has been a reduction in the number of young bulls purchased annually, and the proportion of the inseminations made from young bulls is now less than 5%.

Selection Intensity

When commercial artificial breeding first commenced in 1950, all the proven bulls used were selected on the basis of natural proofs in individual herds. But, as an A.B. proof normally gives a more accurate indication of a bull's breeding ability than a natural proof does, the Board has replaced naturally proven bulls with A.B. proven bulls as the opportunity offered. As a result, the proportion of inseminations made from A.B. proven bulls has steadily increased. But the intensity with which these bulls could be selected has varied and, in recent years, has been particularly favourable.

To date, 615 Friesian and Jersey bulls, initially selected as young bulls in the years up to and including 1963, have been proven on their A.B. daughters and have been available for selection when proven. Of these, 127 (21%) have been used as proven bulls. But, of the 44 purchased up to and including 1955, 20 (45%) were used; of the 143 purchased between 1956 and 1959, 44 (31%) were used; while of the 428 purchased between 1960 and 1963, 62 (14%) have been used. This percentage is almost certain to decline still further. Of the 89 bulls purchased in 1963 and now proven and available for selection, 9 (10%) were used in the proven bull team in the recent spring mating season.

Production Improvement

The effect of this improvement in the selection intensity has been to markedly increase the average merit of the bulls used. The index used in this country to assess a bull's merit from his progeny test is known as the rating. Bulls which are above average have positive ratings while below average bulls have negative ratings.

The average rating of the bulls used in the A.B. scheme will indicate the production improvement (lb butterfat) which can be expected from their use. In 1960 the average rating of the A.B. proven bulls used was +24 and this was the highest level reached to this stage. Since then,

used is reduced. First, if a bull is used in the proven bull team for more than three years, there is the possibility that he will be mated to his own daughters. Secondly, if progress through selection is to be maximized, the young bulls selected for sampling should be sons of the best of the proven bulls. However, when these sons are themselves used, some of the inseminations made from them will be to related cows and in particular half-sibs.

There are three ways of reducing these two effects in a young-bull-sampling programme:

(1) By selecting young bulls which are sons of bulls which have not themselves been used for artificial breeding.

(2) By dividing the A.B. service into separate breeding units with periodic rotation of bulls between them. This would prevent the closest form of inbreeding, *i.e.*, father-daughter matings and would reduce the number of half-sib matings.

(3) By limiting the number of inseminations made from any one bull. If the required number of inseminations were to be obtained in less than four years then there would be virtually no possibility of father-daughter matings.

But all of these methods would also have the effect of reducing the genetic improvement possible through selection. In the case of method (1) there would be a reduction in the average merit of the young bulls sampled, while methods (2) and (3) would both have the effect of increasing the size of the proven bull team. Hence, the selection intensity could not be as favourable.

At present, the Board is making partial use of two of these methods.

When selecting young bulls, some sons of naturally proven bulls outside the artificial breeding service are purchased while a limitation is placed on the number of sons of a bull which has been used.

The fact that the Board has two artificial breeding centres servicing different areas is taken advantage of to reduce the number of father-daughter matings by periodic rotation of bulls between the two centres.

Whether further steps should be taken depends on two factors, the rate at which the level of inbreeding is likely to increase, and the consequences of this increase.

It has been estimated that, assuming the present composition of the proven bull team, and where the average

number of inseminations obtained per proven bull is 40,000 per year, the annual increment in the inbreeding coefficient is unlikely to rise above 0.4 to 0.5% and that this level of increase would be likely to have negligible effects on performance. Robertson (1954), has estimated that this level of inbreeding should depress milk yield by only one-tenth the expected gain from selection. There is also evidence from actual results that this level of increase is not likely to be an underestimate. Watson (1963), has shown that in the Welsh Black breed, which is a numerically small breed mated largely through artificial insemination, mainly with related bulls, the increase in the level of inbreeding per annum has been approximately 0.2%—considerably lower than might have been expected from theoretical estimates.

Nevertheless, it is clear that continued reduction in the size of the proven bull team must increase the rate of inbreeding. At this stage, it is not considered that any further steps to reduce the rate are warranted but it is planned to continue making estimates of the likely increase in inbreeding in artificially-bred herds. It is considered, also, that further information is required on the effects of inbreeding on the performance of the progeny of highly rated proven bulls and steps are being taken to collect information on this.

Loss of Desirable Genes

One effect which cannot be avoided in the type of artificial breeding scheme described is the reduction of the gene pool from which future selection can be made. This is, of course, the effect of selection, and it must inevitably be accelerated as the number of animals from which selection is made is reduced.

The question is raised whether this might not result in the genes for some desirable character, for which selection may wish to be made in the future, being lost from the population.

If very much attention were given to this then obviously very little progress would be made. There are a number of aspects of the problem however which are notable.

First, efforts are at present made to ensure that selection for production is not at the expense of other economically desirable attributes. Thus, prior to a bull being widely used, reports are received on the bull's daughters in regard to such traits as jaw, feet, udder-conformation, susceptibility to mastitis and bloat, ease of milking and temperament. Investigations are also planned to study the

incidence and importance of these defects in the later life of these animals and to study whether it would be desirable to collect data on the incidence of other diseases, the susceptibility to which might be inherited.

Secondly, work is in progress to determine whether, if the aim of selection should change, for example, from butterfat production to solids-not-fat production, any substantial change in the bulls selected would result.

Nevertheless, it would be desirable to ensure that recourse could always be made in the future to selection from another population when this appeared to be necessary. Such a population could be naturally bred herds within this country or herds in an overseas artificial breeding organization.

CONCLUSION

It is clear that advances in semen dilution which have been made in this country since 1960 have had a very great effect in accelerating the rate of genetic improvement in the Board's artificial breeding scheme.

At the same time, these advances have increased the need to collect data, and make decisions, on other aspects of the artificial breeding service such as increases in the rate of inbreeding.

Shannon *loc. cit.* has mentioned that 100,000 inseminations per bull, per annum, is a distinct possibility. This would mean that the replacement stock required each year by the whole dairy industry could be sired by just twenty bulls. The opportunity for selection, then available, could best be described as fantastic but one is conscious of the responsibility to ensure that the right bulls are used and that no adverse effects result from their use.

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