The development of breeding strategies for the large scale commercial dairy sector in Zimbabwe
Ntombizakhe Mpofu (2002)
ZaBelo Livestock Consultancy, P.O. Box 911, Bulawayo, Zimbabwe

Background

The Zimbabwean population gets milk from three sources:

1. The majority of the population, which is in the communal areas, produces milk for its own domestic use using indigenous cattle breeds.

2. The commercial smallholder sector supplies milk to the urban centres and to rural settlements with growing human populations. This is a new sector, which started commercial milk production after independence in 1980; its contribution to commercial milk supply is still small. This sector uses indigenous breeds and crosses of these breeds with foreign dairy breeds.

3. The commercial large-scale sector is the main dairy sector and it dominates the supply of milk to the Zimbabwean urban centres and some rural areas. Milk produced by this sector is also exported to neighbouring countries, contributing to the country’s foreign earnings.

The large-scale commercial sector uses purebred foreign dairy breeds for milk production. The breeds include the Holstein–Friesian (in over 80% of herds), Jersey, Guernsey, Red Danes and Ayrshire. Production levels in this sector in 1998 were just under 7000 kg/cow per 305-day lactation. The major methods of genetic improvement that have been used are selection within and across herds and the importation of animals, semen or embryos mainly from the USA, but also from Europe, New Zealand and Australia. Selection of animals locally was based initially on phenotypic records collected through the milk recording scheme. In 1986, however, a scheme was initiated to estimate genetic values of animals and use these values, instead of phenotypic records, to rank animals for dairy production and to estimate genetic progress made. At the same time, a progeny testing scheme was initiated to test young bulls sired by both local and foreign-born bulls.

The problem

The aim of introducing the progeny testing scheme was to test bulls under local conditions and to avoid continuous importations of genetic material, as such importations required the use of scarce foreign currency. The required breeding infrastructure for progeny testing already existed. This included: a milk recording scheme which had been running since 1929; the Zimbabwe Herd Book, an organisation that recorded pedigrees and ancestry; privately run and reliable artificial insemination and embryo transfer services; trained personnel; and computing facilities to estimate the breeding values. Running a local scheme would allow further development of the local infrastructure. However, there was a realisation that progress made through progeny testing can be slow and that running such schemes is costly. The Zimbabwean dairy cattle population was small when compared with dairy populations in developing countries that were running testing schemes for the same breeds. Selection intensity is low in
small populations resulting in slow genetic progress. There was a further realisation that the major exporting populations (e.g. the USA) were ahead of Zimbabwe’s population in so far as genetic improvement of dairy breeds was concerned. It was, therefore, suspected that the rate of progress through progeny testing would be slower than that possible through imports from advanced populations. Furthermore, imports are not only recommended when the exporting population is genetically better than the importing population, but also when selection objectives in the exporting and importing populations are similar and when genotype by environment interactions are not important. It then became necessary to evaluate both genetically and economically feasible breeding strategies for the large-scale commercial sector in Zimbabwe, some based on local selection and some based on imports. Since most of Zimbabwe’s imports for the Holstein breed were from the USA, the exporting country was assumed to be the USA.

**Description of breeding strategies**

Breeding strategies for the commercial dairy sector were identified and evaluated in a simulation study by Mpofu (1992). The breeding strategies studied were as follows: three strategies based on local progeny testing of bulls; one strategy based on nucleus multiple ovulation and embryo transfer (MOET) schemes; four strategies based on continuous importation of semen; and one strategy based on continuous importation of embryos. The description and assumptions made for each strategy are given below and Table 1 summarises the major features of each strategy.

**Progeny testing strategies**

The first strategy was a closed progeny testing scheme (PT1) i.e. all test bulls were born in Zimbabwe. The proven bulls produced through the scheme were used on the whole dairy population. The second strategy combined progeny testing to produce local bulls to sire 70% of the cow population with semen imports to sire 30% of the cow population (PT2). The imported semen was from above average bulls. Imports allow the use of foreign bulls, which have been selected more intensely and from a population that is genetically superior to the Zimbabwean one. Importing from other populations also introduces genetic variation which can be exploited in the progeny testing programme. For the third strategy (PT3), semen from elite bulls was imported to produce test bulls. Therefore, small doses of semen were imported to inseminate only the bull dams. The price per dose was set higher for semen from elite bulls than for semen from above average bulls, but overall costs for semen imports were lower for the third than for the second strategy.

**Nucleus schemes**

The fourth strategy was a MOET nucleus scheme (NMOET) set up to produce and test bulls. The nucleus herd was founded by screening and selecting stock with the highest estimated breeding values from the exporting population. The initial genetic mean of the nucleus was therefore higher than that of the Zimbabwean base population. Thereafter, selection was within the herd. The bulls selected from the nucleus were mated to the whole population. This scheme involves high start-up costs. Its advantages are as follows: there is an initial genetic lift; testing is done within one herd as opposed to field testing, as is done for strategies one to three; and the generation interval is reduced as sire rather than progeny information is used.
Strategies based on continuous semen imports

For these strategies, there was no local genetic improvement programme. Zimbabwe would rely entirely on semen imports from a dairy population that is genetically superior to her own. The amount of semen imported was varied. For the fifth strategy (CSI30), only 30% of the cow population was sired by foreign bulls. The rest of the population relied on untested bulls that were produced locally. For the sixth (CSI50) and seventh strategies (CSI), the proportion of the population sired by foreign bulls was increased to 50 and 100%, respectively. For the eighth strategy (ELITE), local cows were evaluated using their records collected through the milk recording scheme. Elite cows were selected, MOET used to collect more embryos per cow, and the cows bred using semen from elite foreign bulls. The male progeny from such matings are expected to be of high genetic merit and were, therefore, used untested to breed the rest of the population. Imports for this strategy, therefore, would be small quantities of elite semen.

Continuous embryo imports (CEI)

Highly selected bull-dams in the exporting country were mated to elite bulls to produce embryos for export to Zimbabwe. Bulls from these embryos were used untested on the assumption that they were of high genetic value as both of their parents were elite. The bulls are expected to be of higher genetic merit than bulls produced through the ELITE strategy.

Table 1. Summary of features and assumptions for the breeding strategies evaluated.

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Description of strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT1</td>
<td>Progeny testing with all test bulls born in Zimbabwe</td>
</tr>
<tr>
<td>PT2</td>
<td>Progeny testing combined with semen imports to sire 30% of cow population</td>
</tr>
<tr>
<td>PT3</td>
<td>Progeny testing with test bulls sired by elite foreign bulls</td>
</tr>
<tr>
<td>NMOET</td>
<td>Closed MOET nucleus with herd founded by screening and selecting stock from exporting population</td>
</tr>
<tr>
<td>CSI30</td>
<td>No local testing – continuous imports of semen from above-average bulls to sire 30% of the cow population, the rest of the population mated to untested purebred bulls that were born in Zimbabwe</td>
</tr>
<tr>
<td>CSI50</td>
<td>No local testing – continuous imports of semen from above-average bulls to sire 50% of the cow population, the rest of the population mated to untested purebred bulls that were born in Zimbabwe</td>
</tr>
<tr>
<td>CSI</td>
<td>No local testing – continuous imports of semen from above-average bulls to sire the whole cow population</td>
</tr>
<tr>
<td>ELITE</td>
<td>Elite local cows (selected using milk records) mated to foreign elite bulls and their male progeny used untested as assumed to be of high genetic merit</td>
</tr>
<tr>
<td>CEI</td>
<td>Continuous imports of embryos from highly selected parents and males from the embryos used untested as assumed to be of high genetic merit</td>
</tr>
</tbody>
</table>
Evaluation of the breeding strategies

Genetic evaluation

Parameters for the Zimbabwean dairy population were obtained from literature and some estimated using data collected through the milk recording scheme. Since most of the imports of dairy cattle genetic material were from the USA, it was assumed that the exporting population was the USA. The genetic correlation between the Zimbabwean and USA dairy population and the genetic superiority of the USA dairy population over the Zimbabwean population were estimated using information for bulls with daughters in both Zimbabwe and the USA. The effectiveness of the different breeding strategies was assessed by predicting the genetic progress possible by adoption of each strategy using deterministic simulation procedures. The evaluation period was 25 years. The strategies were compared with PT1, the closed progeny testing scheme for which there were no imports. The results are given in Table 2.

Table 2. Genetic response and net present value (NPV) at 25 years for the nine strategies.

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Genetic response at 25 years</th>
<th>NPV at 25 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SD</td>
<td>As % of PT1</td>
</tr>
<tr>
<td>PT1</td>
<td>2.1</td>
<td>–</td>
</tr>
<tr>
<td>PT2</td>
<td>3.3</td>
<td>+57%</td>
</tr>
<tr>
<td>PT3</td>
<td>3.0</td>
<td>+43%</td>
</tr>
<tr>
<td>NMOET</td>
<td>3.5</td>
<td>+66%</td>
</tr>
<tr>
<td>CSI30</td>
<td>1.8</td>
<td>–14%</td>
</tr>
<tr>
<td>CSI50</td>
<td>2.8</td>
<td>+33%</td>
</tr>
<tr>
<td>CSI</td>
<td>4.5</td>
<td>+114%</td>
</tr>
<tr>
<td>ELITE</td>
<td>3.4</td>
<td>+62%</td>
</tr>
<tr>
<td>CEI</td>
<td>4.1</td>
<td>+95%</td>
</tr>
</tbody>
</table>

SD = Standard deviation.

For the strategies based on local selection, the ranking, in descending order of genetic progress achievable, was NMOET, PT2, PT3 and PT1. The genetic progress achievable through the NMOET strategy was 66% higher than that through PT1 at 25 years, largely because of the initial genetic lift with NMOET (Table 2), PT2 and PT3 benefited from imports.

The strategies based on continuous semen imports for the ‘sire to breed cows pathway’ were CSI30, CSI50 and CSI. Strategy PT2, although based on local selection, also imported semen for the sire to breed cows pathway. The strategies ranked, in descending order of merit, were CSI, PT2, CSI50 and CSI30. With the exception of CSI30, these strategies were better than PT1 at 25 years. However, CSI30 was ahead of PT1 up to 20 years.

The strategies involving imports to produce bulls are CEI, ELITE and PT3, although the bulls produced for PT3 were tested. These strategies ranked, in descending order of merit, CEI, ELITE and PT3. All the three strategies were better than PT1.
Looking at all the strategies together, the ranking, in descending order of merit, at 25 years was CSI, CEI, NMOET, ELITE, PT2, PT3, CSI50, PT1 and CSI30. Local progeny testing strategies and import strategies involving low import rates ranked low.

A sensitivity analysis was done to study the effect on ranking of strategies of the initial genetic difference between the importing and exporting population, and of the genetic correlation between the populations. As the initial genetic difference between populations narrowed, the advantage of import strategies over PT1 decreased and as the genetic correlation between populations tended towards unity, the advantage of import strategies increased.

**Economic evaluation**

An economic, rather than a financial, analysis was carried out. The net present value (NPV) was calculated for the strategies over the 25-year period. The benefits were estimated using the predictions of the value of the genetic improvement. However, the values for the genetic improvement obtained in the genetic analysis were halved for each strategy (although the ranking was kept the same) to allow for inefficiencies in running the strategies that could result from technical and other problems that could occur in practice. Secondary benefits due to genetic improvement were not considered. Such benefits are likely to be more with strategies based on local selection, as such strategies result in development of testing infrastructure. The cost estimate for the strategies were obtained from the Zimbabwean dairy industry, i.e. from the milk recording scheme, AI companies, the Zimbabwe Herd Book and the National Association of Dairy Farmers.

The strategies that were found to be economically viable were CEI, ELITE, PT3 and PT1, ranked in this order of descending merit (Table 2). The ranking of strategies for NPV differed greatly from ranking on genetic merit. Ranking on genetics considers only the benefits, whereas ranking on NPV considers both benefits and costs. There was a large difference in costs among schemes. CEI and ELITE had the advantage of high rates of genetic progress and, at the same time, had lower total costs because of the limited amount of foreign germplasm needed despite high unit costs for this germplasm. In relation to economic benefits, costs of some schemes were high. PT2, CSI30, CSI50 and CSI involved high volumes of semen imports and the NMOET strategy had high establishment costs.

A sensitivity analysis showed that as the Zimbabwean currency got weaker, the only viable strategies were ELITE, PT1 and PT3, ranked in descending order. These are strategies based on local selection programmes involving no imports (PT1) or low levels of imports (ELITE and PT3).

**Conclusion**

Progeny testing schemes do not exist in many developing countries due to lack of breeding infrastructure. Setting up of such infrastructure has not taken place because of the costs, both capital and running costs. In the absence of the required breeding infrastructure, MOET nucleus schemes have been recommended (Smith 1988). This study evaluated a situation where breeding infrastructure already existed. For such situations, setting up a nucleus MOET scheme is not recommended as running a progeny testing scheme is more viable. Before a local testing scheme was set up in 1986, Zimbabwe adopted a strategy similar to CSI30. Estimation of genetic trends using data for the period 1970–1985 showed that only limited progress was made and the slow progress was explained as being due to lack of well-defined national breeding goals. Given the results of this study, we can conclude that the slow progress was partly due to the strategy chosen. CSI30 had higher genetic gains than PT1 for the first 20
years, but in 25 years it ranked below PT1. It means, therefore, that a strategy based on continuous imports of semen for the ‘sire to breed cows pathway’ may be best during the early years of a development programme (even if it is at a high cost) and then a switch to one of the alternative viable strategies later. In 1986, Zimbabwe switched from the CSI30 type strategy to adopt a strategy based on imports for both the ‘sire to breed bulls’ and ‘sire to breed cows’ pathways. This strategy lies in between PT2 and PT3. As the Zimbabwean currency continues to lose value, a strategy inclined more towards PT3 or ELITE than PT2 is advisable. All viable strategies require the presence of livestock identification and recording and reliable artificial insemination services.

Knowledge gaps

1. For many countries in sub-Saharan Africa, there are no livestock recording services and breeding infrastructure is not well developed. It will be worthwhile to compare the introduction of a nucleus MOET scheme with the introduction of a progeny testing scheme together with setting up the required breeding infrastructure.

2. In some African countries, genetic material is imported to produce crossbred cows for the smallholder sector. Such imports include both imports of live bulls and semen. In Tanzania and Malawi, semen is collected from imported bulls and distributed to farmers. The bulls are imported either from developed countries (e.g. New Zealand, Europe) or from neighbouring countries (e.g. Kenya, Zimbabwe or South Africa). In some countries, for example Kenya, smallholder farmers use semen imported mainly from the USA. Zimbabwe has a smallholder commercial dairy sector that was introduced at independence. Possible breeding strategies for this sector need to be evaluated. Options include sourcing their genetic material from within Zimbabwe from the large-scale commercial sector. This sector is divided into two – the ordinary commercial herds and breeder herds that produce the country’s top genetic material. They can also import genetic material from overseas. This concept of sourcing genetic material from within Zimbabwe can be taken even further and strategies encompassing the dairy industry as a whole evaluated. Such evaluation would consider the flow of genetic material from the elite large-scale commercial herds to the ordinary large-scale commercial herds and to the smallholder sector: the flow of genetic material from the ordinary large-scale commercial herds to the smallholder sector and imports of genetic material by the three subdivisions of the dairy sector.

3. The problem that has arisen from the crossing of dairy bulls with indigenous cattle for dairy production is that with continued use of dairy bulls, high levels of exotic inheritance are reached in the smallholder herds. Low production and high levels of mortality have accompanied this increase in exotic inheritance as high grades are not suited to production conditions in some of the smallholder farms. Backcrossing to indigenous bulls may result in even lower levels of production. The use of crossbred bulls needs to be investigated (Preston and Murgueitio 1992). Their continued use will result in the levels of exotic inheritance being maintained at around 50%.

Discussion questions

1. What information would you need to and how would you estimate genetic differences and genetic correlations between populations?

2. What are the breeding strategies that have been used to improve milk production in your country and why is it important to evaluate breeding strategies?
3. How does an economic analysis differ from a financial analysis? Which analysis is suitable for evaluating breeding programmes in developing countries, and why?
4. To calculate net present value, you need to use a discount rate. What rate would you use to analyse long-term breeding strategies?

References and related literature


