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# Genetic analyses of N'Dama cattle breed selection schemes

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## Abstract

Data from the nucleus herd at the International Trypanotolerance Centre (ITC) in The Gambia were used to evaluate the current N'Dama cattle breeding scheme implemented in a low input production system. Opportunities were investigated to further improve the breeding scheme through a comparison of alternatives to the current selection strategy. A deterministic simulation model was used to demonstrate the genetic and economic benefits of the different schemes.

The breeding goal consisted of daily weight gain (from 15 to 36 months of age under high tsetse challenge conditions, DWG, g/day) and milk yield (milk off-take in the first 100 days of lactation, MY, kg). Substantial genetic response per year of 3.40 kg in MY and 0.25 g/day in DWG could be achieved. Simulation results showed that early selection of nucleus sires resulted in relatively higher genetic and economic responses compared to all other schemes investigated. For a practical breeding scheme (low input system), the scheme based on early selection of nucleus sires should be recommended since this leads to the best improvements in the overall breeding goal.

**Keywords:** genetic response, N'Dama cattle, nucleus scheme

## Introduction

N'Dama cattle, an indigenous cattle breed in the West African region, is seen as the breed of choice to meet the increasing demand for meat and milk products (Dempfle and Jaitner 2000). The breed is not as productive as exotic breeds under normal production systems, but possesses important attributes such as heat tolerance, adaptation to harsh environments and ability to survive on poor quality feeds (Murray et al 1991). More importantly, the breed has developed the ability to thrive in tsetse infested areas where there is a high risk of trypanosome infection. These qualities are necessary to achieve sustainable livestock production under the low input conditions prevalent in most of the West African countries where animals have an integral role.

An improvement programme was designed and implemented in 1994 at the International Trypanotolerance Centre (ITC) in The Gambia. The objective of this programme is to genetically improve the N'Dama cattle breed in order to meet future market demands and changes in production circumstances. The programme operates as an open nucleus breeding scheme comprising of a well recorded herd of about 400 breeding females (ITC 1999). The programme has developed a genetic evaluation procedure and strategies for the dissemination of improved genetic material in the population (Dempfle 1991). However, the results of this programme have not been evaluated so far.

The possibilities and constraints for design of breeding programmes in developing countries have been discussed largely in general terms (Rege et al 2001). Nevertheless, designing comprehensive animal breeding programmes for a specific objective remains a complex exercise. As a result, studies on optimum designs of such breeding programmes are few. Jaitner and Dempfle (1998) compared various indices with respect to expected genetic progress and expected profit with a view to optimising the N'Dama cattle breeding scheme implemented at ITC. Kahi et al (2004) evaluated alternative breeding goals and schemes in a dairy cattle breed in Kenya using a two-tier open nucleus system that utilised young sires. However, the potential rates of genetic progress are limited by biological constraints, which along with genetic parameters, determine the structure of breeding programmes to be employed for maximum genetic improvement (Dekkers 1992). Genetic and economic parameters have been estimated for use in the genetic evaluation of the N'Dama cattle improvement programme; Bosso et al 2002). The N'Dama cattle breed is being utilised in low input productions systems and it is essential to evaluate alternatives to support further development of the scheme and, if necessary, widen the recording of alternative traits. The aim of this study was to evaluate the current N'Dama cattle breeding scheme and to optimise it through a comparison of the current and alternative selection strategies, using data supplied by the nucleus herd at ITC.

# Materials and methods

## Breeding goal and breeding system

The long-term breeding goal is to increase milk and meat production without losing trypanotolerance and other adaptive traits, which are indirectly taken into account by recording the daily weight gain of all young animals under severe challenge conditions (Dempfle 1991).

The breeding goal was devised taking into consideration that under current conditions, sires are only used for natural service. The breeding goal consists of daily weight gain (from 15 to 36 months of age under high tsetse challenge conditions, DWG, g/day) and milk yield (milk off-take in the first 100 days of lactation, MY, kg). Table 1 shows the economic values in Gambian Dalasi of the traits in the breeding goal (US$1=28.50 GMD). Economic values were those derived by Dempfle and Jaitner (1999 unpublished) using a herd model.

**Table 1.** Mean ($\mu$), phenotypic standard deviations ($\sigma_p$), heritabilities ($h^2$), economic values (v), genetic (below diagonal) and phenotypic (above diagonal) correlations for the individual traits

| Trait[a] | $\mu$ | $\sigma$p | $h^2$ | *v* (GMD per unit)[b] | Genetic and phenotypic correlations | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | DWG | MY | W36 | MW |
| DWG, g/day | 126 | 66.3 | 0.30 | 0.22 | – | 0.62 | 0.20 | 0.23 |
| MY, kg | 451 | 210 | 0.25 | 0.93 | 0.10 | – | 0.10 | 0.13 |
| W36, kg | 168 | 26.2 | 0.40 | – | 0.40 | 0.10 | – | – |
| MW, kg | 202 | 29.3 | 0.33 | – | 0.47 | 0.23 | – | – |

[a]*DWG, daily weight gain; MY, milk yield; W36, weight at 36 months of age; MW, mature weight*

[b]*US$1=28.50 GMD.*

The breeding system is a three tier scheme including the nucleus, multipliers and commercial tiers. In the nucleus, the genetic gain is generated and sire selection is the main activity. Movements of females to the lower tiers are ignored mainly due to their lower reproductive capacity. There is a downward movement of selected sires from the nucleus through the multipliers, to the village herds (commercial tier). Upward selection (screening with respect to milk yield) from farmers' herds to the nucleus is allowed.

## Model calculations and selection procedures

The computer simulation programme SelAction (Rutten et al 2002) was used in this study. The model is deterministic and is based on selection index theory (Hazel 1943) and accounts for the reduction of variance due to the "Bulmer" effect (Bulmer 1971). Based on genetic, biological and economic input variables, the programme predicts response to selection and rate of inbreeding for practical livestock improvement programmes. To model the breeding schemes, a situation with overlapping generations with truncation selection from each age class in both sexes is used. To date, no methods have been developed to predict the rate of inbreeding for overlapping generations; the rate of inbreeding is approximated using a population under selection with non-overlapping generations.

## Genetic and phenotypic parameters

Table 1 also shows means, phenotypic standard deviations, heritabilities and the genetic and phenotypic correlations used. They are based on values currently used by ITC to estimate breeding values utilised for selection in the N'Dama cattle genetic improvement programme and on estimates from the literature. The principal sources were Koots et al (1994), Wiener (1994), Lôbo et al (2000) and an unpublished analysis by Bosso et al (2002). The consistency of the matrices used was tested following a procedure reported by Rutten et al (2002).

## Population and age class structure

All animals in this research are station based (Keneba and Bansang) and belong to the ITC. Keneba is situated in the Kiang West District and lies approximately 80 km from the Atlantic coast; Bansang is situated approximately 200 km from the Atlantic coast and comprises two adjacent villages situated 1.5 km apart in the Niamina East District. The station located at Keneba (low tsetse challenge area) maintains the breeding herd of 5 sires and 400 dams (at any time). Each year, 200 dams are mated to produce 100 male and 100 female calves. The calves are maintained at Keneba until weaning (at 12 months of age) after which 95 males (90 born on station and 5 out of the screening operation) and 90 females are moved to Bansang, a high tsetse challenge area. Males and females stay in separate herds for approximately 2 years. At any one time, approximately 230 males and 225 female weaners are present at Bansang. Annually there is 10% loss among selection candidates for reasons of health and survival. At the end of the testing period (at 36 months of age), 84 males and 80 females are available for selection and are moved back to Keneba for breeding. Figure 1 shows the simplified N'Dama cattle breeding scheme.

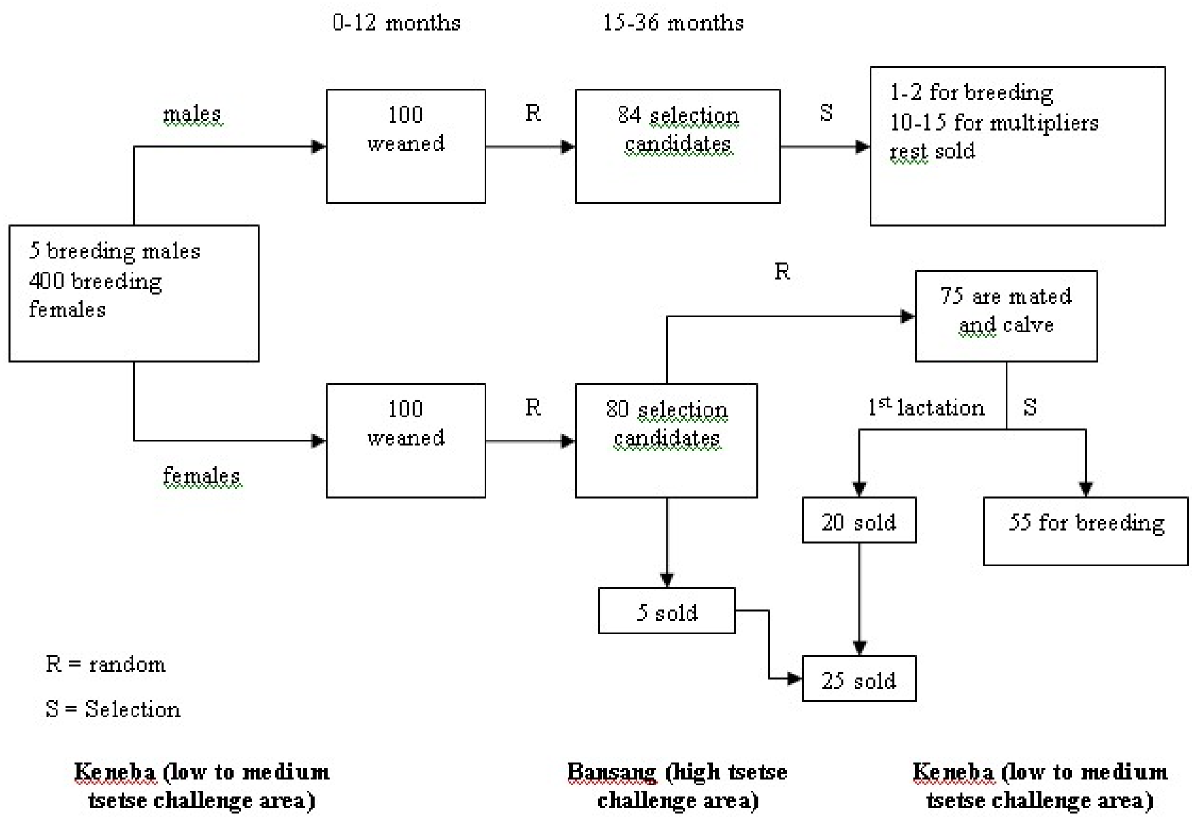


**Figure 1**. Simplified schematic illustration of the N'Dama cattle nucleus breeding scheme

Each year 1–2 males (fixed) are selected to replace the breeding males. The second best males (around 10) are identified for the multiplier, and all others are sold. Breeding males are used for 2 years in the herds. A sire of superior genetic merit should produce better performing sons and therefore use of a sire for more than two years is likely to reduce the rate of improvement in the long run. From the 80 female selection candidates, 75 are selected and mated after which 55 animals are retained based on their first lactation performance.

The animals are late maturing. Cows and bulls are at least 5 years old when their first offspring are born, thus parents cannot be selected from age class one to four because those individuals are not yet reproductive. The calving rate is 80% and therefore a single selected dam is expected to produce 0.4 male and 0.4 female offspring on average per year. Females are kept for a maximum of six calvings and culling takes place after calving number six. Reproduction traits are expressed from the sixth age class onwards and the age classes contribute equally. Females are mated at 54 months of age; the age of females at first calving is 63 months with a calving interval of 24 months. The distribution of dams through lactation one to six was assumed to be 29%, 22%, 17%, 16%, 16% and 13%, respectively. An overview of the type of information for sires and dams available at each age class is given in Figure 2.

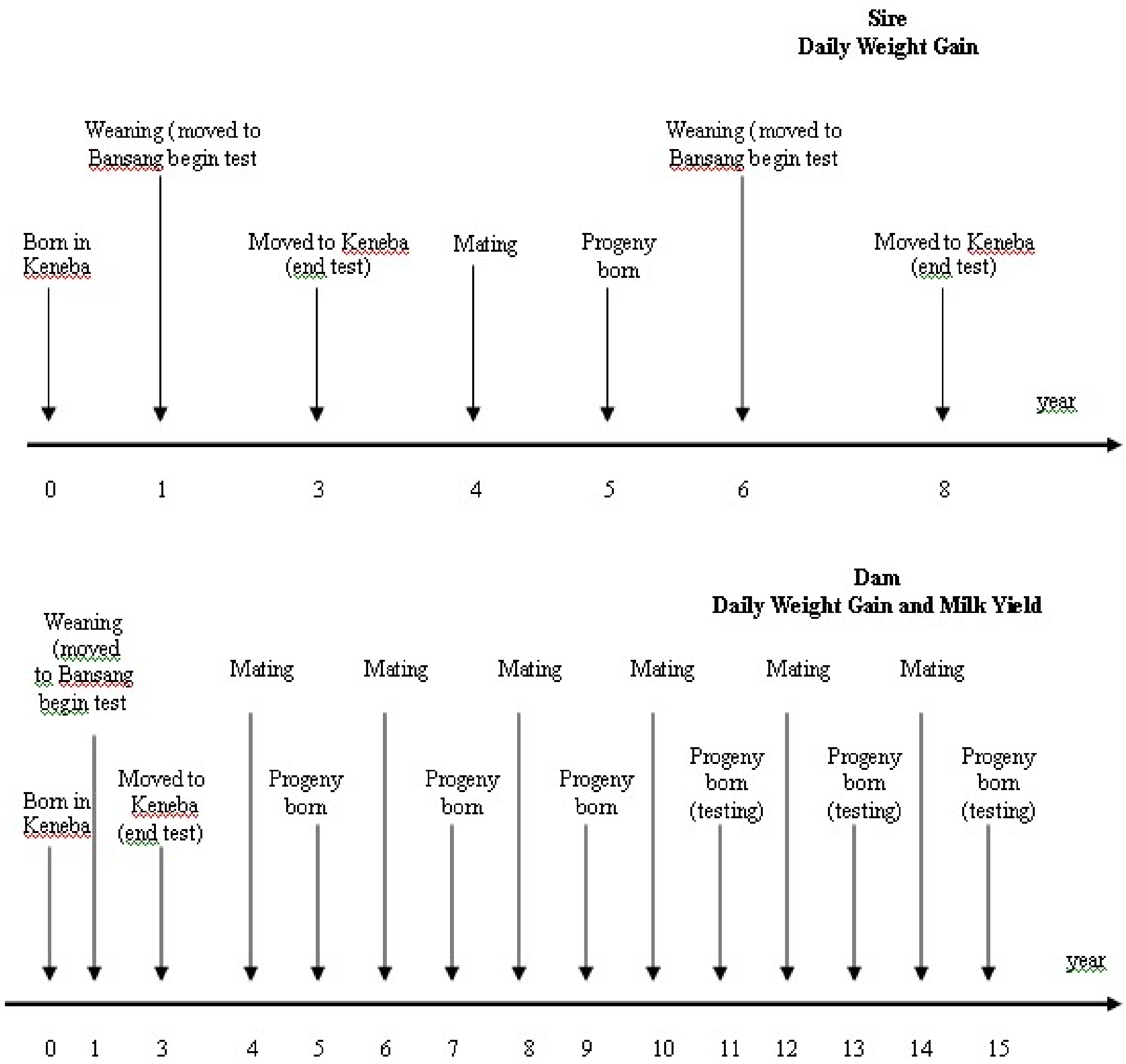


**Figure 2.** Overview of the type of information available for sires and dams at each age class

## Alternative selection schemes

The fixed parameters used were the number of selected sires, the number of selected dams, the number of selection candidates per dam and the selected proportions.

Parameters that were changed were the available groups of relatives (half sibs and progeny) that provided information for breeding value estimation among the selection candidates and the available information sources for each trait for each sex–age class.
In this study, five selection schemes were evaluated for their genetic and economic efficiencies. For each

selection scheme, accumulated genetic response per year and the resulting economic performance were modelled. These alternative schemes were:

***Scheme 1***

This represented the situation where the selection criteria were those currently used in the genetic evaluation system. It was assumed that selection of males was based on 20 half-sibs (HS) and 20 female half sibs (FHS). The selection criteria included measurements of DWG on the individual, HS and FHS and measurements of MY on FHS at 5 years old. These numbers were also assumed for the information sources in the schemes below.

***Scheme 2***

Similar to scheme 1 but assumed that five young sires (3 years old) were selected and used for breeding in the nucleus. This scheme was included to evaluate opportunities of schemes based on young sires.

***Scheme 3***

Similar to scheme 1 but selection of sires was based on additional information on MY from its progeny. Sires were selected when they were 10 years of age based on information from 50 daughters. This scheme was included to examine whether an efficient progeny testing systems based on selection for estimated breeding value for MY could be used to breed the next generation of sires.

***Scheme 4***

The selection criteria included measurements of weight at 36 months of age (W36) on the individual and HS and of MY on FHS. This scheme was chosen to validate the conclusions of the analysis of Bosso et al (2002) that, given the genetic gain achieved and the relatively high heritability for W36, it could be a simple trait to use as selection criteria compared to DWG.

***Scheme 5***

The selection criteria included measurements of mature weight (MW) of the individual and HS (at 4 years of age) and of MY on FHS. Using weak young heifers causes some problems later in their life that show up most frequently as lower milk production. This scheme was introduced to examine whether heifer selection could be based on MW.

## Variations in the nucleus size and number of sires

The effect on genetic and economic responses of varying the nucleus size (number of dams) and the number of sires was investigated. The variations were performed for all selection schemes. The nucleus size was varied from 50 to 300 females and the number of males selected was varied from 5 to 10 males. The effect of changing the nucleus size on genetic and economic responses and the rate of inbreeding was also determined.

# Results

## Comparison of the genetic and economic efficiency of the schemes

Table 2 shows the genetic and economic responses in the individual traits for the different selection schemes using the current population size in the nucleus of 5 sires and 200 dams per year.

**Table 2.** Genetic response per generation, total economic response per generation (GMD), total economic response per year (GMD), percentage of the mean and generation interval for the individual traits in the different selection schemes

| Selection scheme | Trait[a] | Genetic response per year | Total economic response per year (GMD) | Generation interval |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| 1 | DWG, g/day | 0.23 | 2.01 | 5.5 |
| | MY, kg | 2.09 | | |
| 2 | DWG, g/day | 0.25 | 3.23 | 4.5 |
| | MY, kg | 3.40 | | |
| 3 | DWG, g/day | 0.07 | 1.31 | 11.5 |
| | MY, kg | 1.39 | | |
| 4 | DWG, g/day | 0.10 | 2.33 | 5.5 |
| | MY, kg | 2.48 | | |
| | W36, kg | 0.10 | | |
| 5 | DWG, g/day | 0.16 | 2.07 | 5.5 |
| | MY, kg | 2.19 | | |
| | MW, kg | 0.18 | | |

[a] *See Table 1 for description of traits.*

There was a clear relationship between genetic and economic responses per year, with the schemes with the highest genetic responses for respective traits also registering the highest economic responses. When the responses were compared between traits, MY had the highest genetic and economic responses. The responses were highest in selection scheme 2. Genetic response was lowest for DWG in scheme 3. A comparison of schemes indicated that the highest response per year (relative to the base scenario) in both responses was obtained when selection was based on young sires (scheme 2). Scheme 3 had the lowest economic response and the correlated genetic response for MW in scheme 5 was higher than that for W36 in scheme 4. There was also a clear relationship between genetic responses per year and economic responses per year. However, scheme 2 registered the highest and scheme 3 the lowest economic response per year.

## Effect of varying the size of nucleus and number of sires

The effects of varying the size of the nucleus and the number of sires on genetic response in DWG and MY are shown in Figures 3 and 4, respectively.

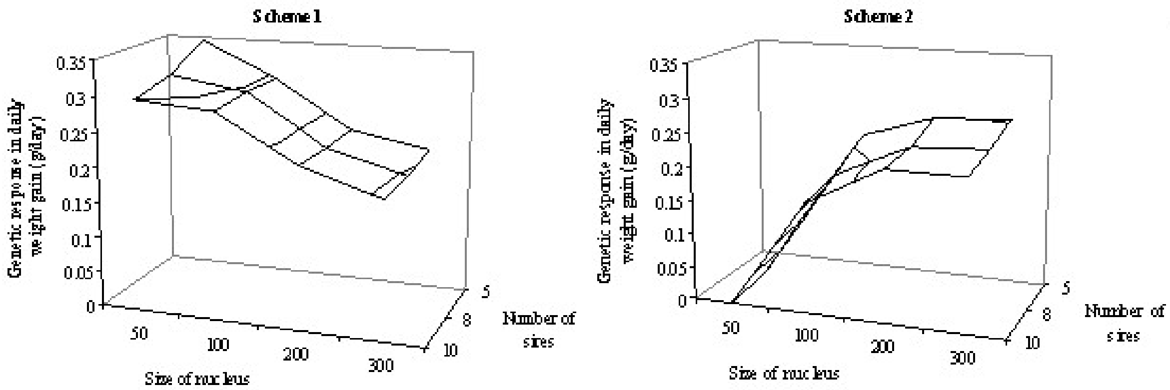


**Figure 3.** Effect of varying the number of sires and size of the nucleus on the genetic response per year in daily weight gain (DWG) under schemes 1 and 2

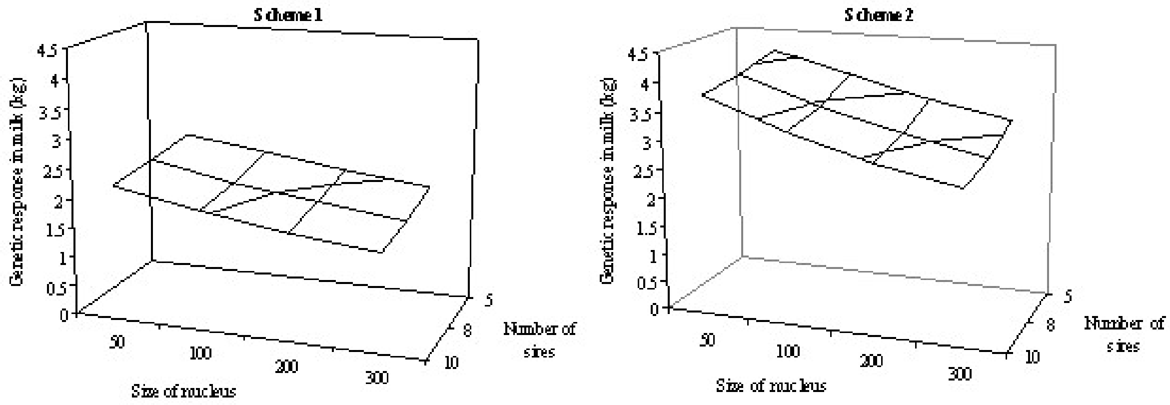


**Figure 4.** Effect of varying the number of sires and the size of the nucleus on the genetic response per year in milk yield (MY) under schemes 1 and 2

Only the results for schemes 1 and 2 are presented since the pattern for the genetic and economic response was the same in the other schemes. For schemes 1 and 2, for MY, an increase in the size of the nucleus was associated with a decrease in the genetic response. The same was observed for DWG for scheme 1. For scheme 2, an increase in the size of the nucleus was associated with an increase in the genetic response. An increase in the number of sires resulted in a reduction in the genetic response. The increase or decrease in genetic response as a result of increasing the nucleus size was sharper than the reduction obtained when the number of sires was increased. A comparison of the genetic response between schemes showed that response for DWG was higher in scheme 1 than in scheme 2 (Figure 3). The converse was true for MY (Figure 4). Scheme 2 was similar to scheme 1 but selection was based on young sires. This means that selection based on young sires will result in greater genetic response per year in MY than in DWG.

The effect of varying the number of sires and the size of the nucleus on the annual rate of inbreeding under scheme 1 is presented in Figure 5.

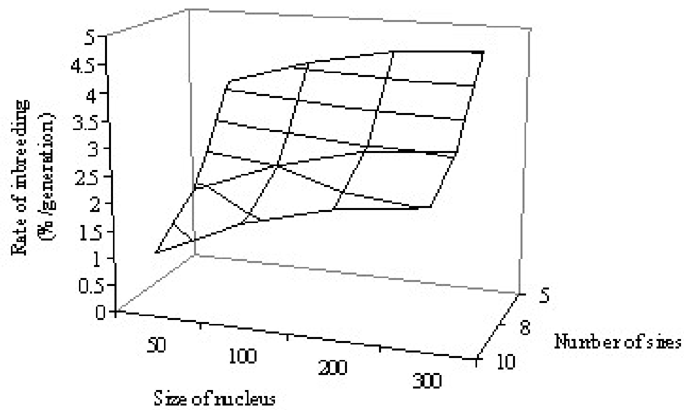


**Figure 5.** Effect of varying the number of sires and the size of the nucleus on the annual rate of inbreeding under scheme 1 with non-overlapping generations

The pattern for the annual rate of inbreeding was the same in all the selection schemes investigated. For the current situation (5 sires and 200 females), the annual rate of inbreeding was estimated at 4.5% per generation. An intensive selection of sires increased the annual rate of inbreeding. Decreasing the selection intensity of sires resulted in a reduced rate of inbreeding; for example the rate was 2.3% when 10 sires were selected to service a population of 200 females.

## Discussion

The aim of this study was to evaluate the current N'Dama cattle breeding scheme implemented in a low input production system and to explore opportunities for improvement. The key result was that early selection of nucleus sires resulted in relative higher economic responses compared to all other schemes investigated. The approach used was deterministic and as such the outputs are determined by the inputs and the assumptions made during the simulation.

An important consideration in assessing the genetic and economic responses is the integration of the nucleus and multiplier tiers, so that responses in the nucleus translate to responses in the multiplier population. As a basis for evaluating the open nucleus structure, the results presented in Table 2 for the current breeding scheme (scheme 1) suggest that a substantial genetic response per year of 2.09 kg in MY and 0.23 g in DWG can be achieved simply by selecting 5 sires and 200 dams (on their first lactation performance) on the basis of breeding value estimates. Considering that the total MY per year is 450.89 kg, this represents an improvement of around 0.46% per year. The genetic response per year in MY is in the range reported for Hariana cattle (Acharya and Lush 1968) and for N'Dama cattle (Jaitner and Dempfle 1998).

The results of the analysis show the comparative merit of the young bull scheme (Table 2). Genetic and economic responses for MY were highest in scheme 2. Chacko (1980) has shown that a young bull scheme could bring about genetic progress equal to that of a sire-selection programme. However, some constraints seem to reduce the apparent merit of both schemes. Reports on success of young sires in selection schemes mention some disadvantages (Korpiaho et al 2003; Strandén et al 2001; Acharya and Lush 1968; Kominakis et al 1997).

The poor quality of the roughage together with the limited availability of concentrate constitutes a low input diet, which makes this scheme very difficult to implement. Furthermore, the young bulls are late maturing and their potential for early sexual maturity is not yet fully known. It is important to realize that the increase in response is as good for MY as for DWG.

There is certainly a considerable increase in the genetic response for this alternative, but the practical importance of the increase in cost for the scheme needs to be taken into account.

The results of the study have demonstrated that selection schemes 4 and 5 had positive effects on the annual genetic response in DWG (Table 2). The difference noted in economic responses between schemes 1, 4 and 5 in Table 2 emphasises the importance of including W36 as a selection criteria. The main problem with the concurrent use of W36 would be the inaccuracy of the measurement due to seasonal influences. It is well known that in The Gambia, as in much of the other Sahel countries, some loss of body weight during the dry season can be tolerated and quickly made good through compensatory growth at the beginning of the rainy season (Sumberg 1992). Nevertheless, due to inaccuracies that may arise from compensatory growth, selection for growth rate on the basis of W36 might be preferable to selection on the basis of DWG (Table 2).

More breed specific parameters are needed for mature weight (MW) to draw appropriate conclusions. For scheme 5, the most critical point is that young females have to reach the desired weight for breeding, and this is partly determined by management and biology. A probable reason why the genetic response for MW had no profound effect on DWG could be the fact that at 4 years old, young females have not yet reached the desired weight for breeding. The weaning season may play an important role in attaining mature weight. In Bansang (a high tsetse challenge area where animals are moved after weaning), due to the severe nutritional stresses, many young females have a slow start and this certainly impacts on their lifetime productivity. Dunsmore et al (1976) have suggested that the losses in weight during the dry season should not exceed 10% of body weight. In The Gambia, greater losses than this are common and adversely affect age at maturity and probably reproductive performance (Dunsmore et al 1976).

Results show that the variability in family size leads to a moderate decrease in genetic response, indicating that a large nucleus size is not always advantageous. Similar results have been reported elsewhere. An increase in the number of sires led to a decrease in genetic responses in DWG and MY (Figures 3 and 4). The potential genetic response per year from selecting dams is limited by the fact that most dams must be kept in the nucleus herd to maintain its size and that the number of offspring is much more limited for dams than for sires.

The rate of inbreeding (4.5%) deserves more attention. More breeding sires are needed to permit adequate selection intensity without increasing inbreeding. The estimate ignores the open nature of the scheme in practise. To find the optimum size of the breeding programme, taking into account short and long term genetic response, requires an in depth economic evaluation. However, the maximum size of a nucleus scheme is dictated by the facilities available. Results show that the variability in family size leads to a moderate decrease in genetic response, but it has a decreasing effect on the rate of inbreeding. A suitable size for a breeding unit that uses about 10 sires selected per annum and about 200 dams will certainly be the best based on facilities (Figure 5). Accumulation of inbreeding in the nucleus herd should be considered as a major concern. Maintaining acceptable rates of inbreeding in the nucleus herd is very important. The current rate was 4.5% and could be attributed to factors such as selection based on BLUP methodology (Bijma and Woolliams 2000), the use of fewer sires, and direct selection on fewer traits (DWG and MY) that are positively correlated. Inbreeding is inevitable and deserves more attention. In the long run, the large population will, with the success of dissemination, be more and more related to the nucleus and will be unable to provide non-related individuals for the nucleus. An option would be to use a scheme with a predicted rate of inbreeding like that described by Meuwissen and Sonesson (1998). Tools to implement such a scheme are available and are recommended in order to avoid an undesirable increase in inbreeding.

To date, the emphasis in the breeding programmes has been to improve production traits (DWG and MY). Improvement in these traits has important consequences for the overall breeding programme since this might result in undesirable correlated responses in other traits of economic importance. Improvement in MY must be accompanied by adequate feed supply, which is not always present under the harsh field conditions in The Gambia. This means that high-yielding dams will be subjected to more metabolic stress due to a greater negative energy balance. High-yielding dams are also more susceptible to diseases and tend to be culled early. High MY in the first lactation is an indicator of a shorter productive life. Enhancing the length of productive life could lead to a decreased need for replacement heifers, fewer health expenses and reduced rearing costs. The challenge therefore is to expand the selection criteria and breeding goal to accommodate functional traits since ignoring relationships with these traits could cause changes in the wrong direction.

## Conclusions

- It was shown that for a practical breeding programme, scheme 3 would be profitable for achieving substantial genetic and economic response per generation. However, when the response per year, which is more meaningful, was considered, scheme 2 seemed to be the most advantageous. Scheme 2 has an additional advantage since it includes traits that can easily be measured by farmers (MY and DWG). Furthermore, it leads to faster improvements in the overall breeding goal and consolidation of the genetic improvement through the whole population.

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## References

**Acharya R M and Lush J L 1968**
Genetic progress through selection in a closed herd of Hariana cattle. Journal of Dairy Science 51: 1059-1064
http://jds.fass.org/cgi/reprint/51/7/1059.pdf

**Bijma P and Woolliams J A 2000**
Prediction of rates of inbreeding in populations selected on best linear unbiased prediction of breeding value. Genetics 156: 361-373.

**Bosso N A Waaij E H van der and Arendonk J A M van 2002** Genetic parameters for growth traits in a pure N'Dama breed in the Gambia. In Proceedings of the 7th world congress on genetics applied to livestock production, 19-23 August 2002, Montpellier, France. Session 25. Developing sustainable breeding strategies in medium- to low-input systems. Volume

33, communication 25-30, pp. 429-432

**Bulmer M G 1971** The effect of selection on genetic variability. The American Naturalist 105: 201–211

**Chacko C T 1980**
The genetic consequences of different selection policies for crossbred bulls for use in AI in Kerala (India). Thesis, University of Edinburgh, Scotland.

**Dekkers J C M 1992**
Structure of breeding programs to capitalize on reproductive technology for genetic improvement. Journal of Dairy Science 75: 2880-2891 http://jds.fass.org/cgi/reprint/75/10/2880

**Dempfle L 1991**
Report on genetic improvement of trypanotolerant livestock in West and Central Africa. Proceedings of the FAO expert consultation on the genetic aspects of trypanotolerance, 3–4 September 1991, Rome, Italy. FAO Animal Production and Health Paper 94 from http://www.fao.org/DOCREP/004/T0558E/T0558E06.htm#ch6.

**Dempfle L and Jaitner J 1999**
Handouts. Regional workshop about animal breeding and genetics for applied geneticists and professionals responsible for breeding programmes, 8–19 February 1999, ITC. Unpublished. 105 pp.

**Dempfle L and Jaitner J 2000**
Case study about the N'Dama breeding programme at the International Trypanotolerance Centre (ITC) in The Gambia. Workshop on developing breeding strategies for lower input animal production environments, 22–25 September 1999, Bella (Italy), jointly organised with FAO (AGAP) and the Swiss Agency for Development and Co-operation. ICAR Technical Series 3: 347-354 http://agtr.ilri.cgiar.org/Casestudy/BellaPDFchapters/CS1_24.pdf

**Dunsmore J R, Blair Rains A, Lowe G D N, Moffatt D J Anderson I P and Williams J B 1976** The agricultural development of The Gambia : an agricultural, environmental and socio-economic analysis. Land Resources Study 22, 450 pp. Land Resources Division, Ministry of Overseas Development, UK.

**Hazel L N 1943** The genetic basis for constructing selection indices. Genetics 28: 476-490.

**ITC 1999** Biennial Scientific Report 1998-1999, pp. 10-14. International Trypanotolerance Centre.

**Jaitner J and Dempfle L 1998**
A breeding scheme for the indigenous N'Dama cattle. Proceedings of the 49th annual meeting of the E.A.A.P., 24–27 August 1998, Warsaw, G5.9.

**Kahi A K, Nitter G and Gall C F 2004**
Developing breeding schemes for pasture based dairy production systems in Kenya. II. Evaluation of alternative objectives and schemes using a two-tier open nucleus and the young bull system. Livestock Production Science 88: 179-192

**Kominakis A, Nitter G, Fewson D and Rogdakis E 1997** Evaluation of the efficiency of alternative selection schemes and breeding objectives in dairy sheep of Greece. Animal Science 64: 453-461

**Koots K R, Gibson J P, Smith C and Wilton J P 1994**
Analyses of published genetic parameter estimates for beef production traits. Animal Breeding Abstract 62: 309-338

**Korpiaho P, Strandén I, Mäntysaari E A 2003**
Bull Selection across Age Classes and Variable Female Reproductive Rates in an Open Nucleus Breeding Scheme for Dairy Cattle. Acta Agriculturae Scandinavica, Section A - Animal Science, 1651-1972, Volume 53, Issue 2, pages 74 - 82

**Lôbo R N B, Madalena F E and Vieira A R 2000**
Average estimates of genetic parameters for beef and dairy cattle in tropical regions. Animal Breeding Abstract 68: 433-462

**Meuwissen T H and Sonesson A K 1998**
Maximizing the response of selection with a predefined rate of inbreeding: overlapping generations. Journal of Animal Science 76: 2575-2583 http://jas.fass.org/cgi/reprint/76/10/2575

**Murray M, Stear M J, Trail J C M, D'Ieteren G D M, Agyemang K and Dwinger R H 1991** In breeding for disease resistance in farm animals (eds. J. B. Owen and R. F. E. Axford), pp. 203-223. CAB International, Wallingford, UK.

**Rege J E O, Kahi A K, Okomo-Adhiambo M, Mwacharo J and Hanotte O 2001** Zebu cattle of Kenya: uses, performance, farmer preferences, measures of genetic diversity and options for improved use, 93 pp. Animal Genetic

Resources Research 1 ILRI, Nairobi, Kenya.

**Rutten M J M, Bijma P, Woolliams J A and Arendonk J A M van 2002** SelAction: software to predict selection response and rate of inbreeding in livestock breeding programs. The Journal of Heredity 93: 456-458(3)

**Strandén I, Korpiaho P, Pakula M and Mäntysaari E A 2001** Bull selection in MOET nucleus breeding schemes with limited testing capacity. Animal Science 51: 235-245

**Sumberg J E 1992**
Livestock development policy in The Gambia: a reassessment. Tropical Animal Health and Production 24: 193-203

**Wiener G 1994** Animal breeding. In the series The Tropical Agriculturalist, pp. 37-51. CTA/Macmillan

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