Genetic improvement of livestock in tsetse infested areas in West Africa

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« Remets ton sort à l'Éternel, et il te soutiendra, Il ne laissera jamais chanceler le juste ». Psaume 55

Abstract

Genetic improvement of indigenous breeds can make a significant contribution to the conservation and utilisation of local genetic resources. At present, there is insufficient documentation on phenotypic and genetic performance for important production and reproduction traits under low input production circumstances for indigenous populations. This limited knowledge is putting local animal genetic resources at risk. This thesis has focussed on ways to better utilize local animal genetic resources by developing strategies for the implementation of improvement programmes for trypanotolerant breeds in The Gambia and in West Africa in general. The project was built on the analysis of ongoing selection programmes co-ordinated by the International Trypanotolerance Centre (ITC) in The Gambia. The analysis of this selection programme indicated that genetic improvement programmes in the context of sustainability within the low input production system was feasible and could serve as a model for effective breeding schemes in low and medium livestock production systems in the West African region. Genetic progress was achieved and effectively transmitted to farmers through the involvement of farmers and their communities in the improvement programmes. Genetic progress was realised and the estimated genetic parameters obtained could be used for further improvement of cattle and small ruminant selection strategies. It was recommended to intensify training and capacity building activities for both implementation and further development of the programme. In addition, financial security is important for the long-term sustainability of the programme. For a practical breeding scheme (low input system) for the N'Dama cattle, a young sire scheme was suggested. Model calculations showed that this scheme leads to the best improvements in the overall breeding goal and consolidates efficient dissemination of the genetic improvement to the whole farming population. The project has demonstrated that development of strategies for the implementation of improvement programmes in West African countries is feasible and that they contribute to a better utilisation of trypanotolerant breeds.

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Chapter I

General Introduction

Livestock plays a significant role in the livelihood of rural populations and the agricultural development of sub-Saharan Africa. In this region, animal agriculture is characterized by diverse and complex production systems. Animal agriculture contributes significantly to improved family nutrition and health, and the sale of animals and their products helps to improve and stabilize household income. The intangible products obtained from animals are important in areas lacking formal insurance and developed financial markets (Udo and Cornelissen, 1998). Goat, sheep and poultry are considered as forms of security and sources of independent income especially for poor women (Paris, 2002). Furthermore, animals are used in social cultural functions e.g., in religious ceremonies (Jahnke et al., 1988; Jabbar et al., 1995).

The inescapable trends of increased urbanization, higher income and the ever-increasing population have generated a greater demand for animal products (Bongaart et al., 1998; Delgado et al., 1999). The annual population growth rate of 3.2% in sub-Saharan Africa is the highest in the world (Harrison, 1987). Currently, sub-Saharan Africa has a deficit in animal products and the situation is projected to worsen due to the increasing gap between supply and demand. Increased productivity from livestock is necessary to meet the increased demand for animal products, to alleviate poverty and to improve the livelihoods of resource-poor farmers (Garett, 2000).

Constraints to livestock production

The development of livestock production is constrained by factors at farm level, e.g., capital scarcity, low monetary income and insufficient raw materials. In addition, the future development of livestock production in sub-Saharan Africa is hindered by limited knowledge of the genetic potential of the local genetic resources and on ways to best utilize these resources in a sustainable manner. The genetic makeup of the animal is often associated with low production potential in indigenous animals. However, indigenous animals have not been adequately characterized for their production potential. There is growing recognition of the need to characterize, utilize and conserve indigenous animal genetic resources (AnGR). Ample literature on the production characteristics of indigenous AnGR is available (Kitalyi, 1998; Mourad et al., 2001). However, knowledge of genetic and economic parameters is crucial for the design and execution of programmes aimed at utilizing and conserving these genetic resources. Lack of knowledge is a major limitation to effective genetic improvement of local indigenous breeds. It also limits the decision-making capability of national, regional and international agencies implementing programmes. Because of this lack of information, decisions are often made which have negative consequences on indigenous AnGR (Rege et al., 2002).

Indigenous animal genetic resources

Most indigenous AnGR in West Africa are kept in a production system described as low-input extensive traditional system, characterized by poor animal husbandry, poor management of grazing resources and seasonal feed shortage. Diseases are another key limiting factor with trypanosomosis being the major constraint to livestock production in the sub-humid zone and the non-forested portion of the humid zone of West Africa. Control technologies relying upon the use of trypanocidal drugs and methods of reducing vector density are often inadequately or incorrectly applied (Teale, 1991).

In most parts of West Africa, small-scale livestock production is based on the trypanotolerant N'Dama cattle and West African Dwarf sheep and goat breeds. The production capacity of these breeds has for a long time been ignored and underestimated (Toure, 1976; Starkey, 1984). A more holistic approach to understanding the production systems in the region made research and development communities recognize the production capacity of indigenous AnGR (Agyemang et al., 1988; Jeannin et. al., 1988). Emphasis is now being put on the use of indigenous trypanotolerant breeds of domestic animals as a sustainable approach to livestock development in tsetse-infested areas. N'Dama cattle, Djallonké sheep and West African Dwarf goats have demonstrated their adaptative value in tsetse-infested areas of West Africa (Murray, 1979; Fergusson, 1988).

Genetic improvement of animals suitable for low-input extensive traditional systems has been perceived as an extremely complex problem (Ansell, 1985; Kunzi and Kropf, 1986). In such systems, the breeding goals are far more multifaceted than in intensive productions systems and comprise many aspects other than high productivity with regard to cash products (milk and meat). The other aspects include aesthetic preferences (preferred colour and colour distribution), religious requirements and behavioural aspects, such as a complacent nature, good mothering instincts and ability to walk long distances. Furthermore, the ability of livestock to survive natural calamities (droughts, climatic extremes) in order to avoid risk is an important characteristic in these production systems. The adaptive capacity of animals is more important than high production potential (Köhler-

Rollefson, 2000). A number of breeding schemes have been suggested for the improvement of indigenous breeds, based on within-population selection, crossbreeding or a combination of within-population selection and crossbreeding (Hickman, 1979; Cunningham, 1979). However, successful applications are very limited due to social as well as technical constraints, e.g., lack of good infrastructure needed for recording and performance testing, small herd size, variability between farms and farming systems, and low reproductive efficiency due mainly to poor nutrition (for small ruminants, see Kosgey et al., 2005).

Nucleus breeding schemes and breeding structures

Nucleus breeding schemes (NBS) have been suggested to overcome some of the technical constraints linked to implementation of a breeding scheme for low-input extensive production systems (Smith, 1988; Dempfle, 1993). The design of any improvement programme must be within the context of the ecological zones and prevailing production systems in which the animals are raised. Generally, NBS offer the potential for higher genetic progress than would be obtained by traditional within-herd selection (Smith, 1988). Pedigree and performance recording are an integral part of any genetic improvement programme. In an NBS, recording needs only to be implemented on a small number of collaborating farms or in one or several large private or institutional herds that can be considered as the nucleus. An NBS can therefore be relatively small in size and still have large impact, if well organized and operated properly (Syrstad, 1989). Opening the nucleus to replacements from the village herds might improve the genetic progress and, more important, its chances of success because it encourages more farmer participation (Bondoc and Smith, 1993). There are some examples of open NBS that have been initiated in West Africa. In 1984, a sheep improvement programme was initiated in Côte d'Ivoire to improve growth and live weight of the indigenous Djallonké sheep (Yapi-Gnaorè, 2000). In 1985, a programme to evaluate the productivity of N'Dama cattle under village conditions was initiated in Senegal (Fall, 1992). Following this initiative, other breeding programmes for Peul, Touabire and Djallonké sheep were initiated (Fall, 2000). A comprehensive breeding effort to genetically improve milk and meat production of N'Dama cattle was started in 1981 in Guinea and in 1994 in the Gambia (Diallo et al., 1993; Demple and Jaitner, 2000).

In most breeding structures, a number of tiers can be distinguished, e.g., the nucleus, the multiplier tier and the commercial tier (i.e., the farmers). The genetic improvement is generated in a small fraction of the population (referred to as nucleus animals). In dairy cattle, open nucleus schemes are used, i.e., commercial and nucleus cows are eligible for selection as parents for the next generation of nucleus animals (Van Arendonk and Bijma, 2003). The genetic superiority generated in the nucleus has to be disseminated to the whole population. The rate of genetic progress depends, among other things, on the size of the nucleus and the effectiveness of selection within the nucleus (Wiegel, 2001). In many breeding schemes in developed countries, there is direct transfer of superior germplasm from elite breeders (nucleus) to commercial producers.

In the West African examples, communication between the nucleus management (researchers) and the downstream extension service and farmer groups has been poor. Organization of breeders into co-operatives or associations is regarded as an important step for community-based breed development. Breed associations (societies) have proven effective in industrialized countries. In some non-industrialized countries, support for breeder associations (record keeping, etc.) has proven to be an effective way of increasing interest in local breeds (Ramsay, 2003).

Livestock breeding objectives have to be orientated towards the future and it is therefore important to define appropriate breeding goals that meet the needs of future market and production circumstances. The breeding goal must be considered in relation to the major constraint(s) of the environment and the production system in which genetic improvement is sought (Timon, 1990). Selection of animals for low-input systems (which are characterized by multiple stresses) needs to result in animals that are productive as well as adaptive.

Aim of the thesis

This thesis aims at a better utilization of indigenous animal genetic resources by increasing our knowledge on optimum strategies for the implementation of improvement programmes for trypanotolerant breeds in the Gambia in particular and in West Africa in general. Breeding schemes need to be implemented under tropical conditions where infrastructure is generally poor. The aim is to provide guidance through the analysis of ongoing experiments (which can serve as important demonstration projects) and the evaluation of alternative strategies. Information collected from the genetic improvement programmes executed at the International Trypanotolerance Centre (ITC) on N'Dama cattle, Djallonké sheep and West African Dwarf goat plays an important role in the thesis.

Improving the productivity of local trypanotolerant livestock will contribute to alleviation of poverty, food security of the rural poor, food safety, welfare of urban and, more specifically, rural populations. Improving the productivity of local trypanotolerant livestock is also expected to strengthen the links between traditional livestock breeders, livestock breeding institutions and NARS. This will allow farmers to be directly involved in improving the genetic quality of their animals within the constraints of their environment. The focus should be on development of guidelines to prevent loss of indigenous animal genetic resources by increasing their productivity and utilization in the West African region.

Outline of the thesis

Chapter II presents the current state of knowledge and experiences gained from the development of the N'Dama cattle improvement programme. This chapter demonstrates the role of genetic improvement programmes in the context of sustainable production in a low input system. **Chapter III** presents estimates of the genetic variation and the genetic gain realized for important growth traits in the ongoing nucleus breeding scheme in N'Dama cattle under severe tsetse challenge. This is the first analysis of the genetic improvement programme implemented by ITC in 1994. **Chapter IV** focuses on analysis of the ongoing nucleus breeding schemes in Djallonké sheep and the West African Dwarf goat. Data collected since the start of these experiments are analysed to estimate genetic variation and the genetic gain realized for important growth traits. In **Chapter V** the current N'Dama cattle breeding scheme is evaluated. In addition, alternatives are discussed to improve the current selection strategy. In **Chapter VI,** the results are used in a general discussion on development and implementation of improvement programmes for trypanotolerant breeds in the Gambia and in West Africa in general.

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Chapter II

The N'Dama cattle genetic improvement programme: a review

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Abstract

Genetic improvement of local breeds through selection is an important avenue for improving productivity. This is especially true in the West African sub-humid zones where trypanotolerant breeds, living in harsh environments, have proven to be more productive than previously thought. This paper reviews the successful N'Dama cattle genetic improvement programme implemented in a low input production system at the International Trypanotolerance Centre (ITC) in 1994, in The Gambia. Based on published and unpublished information, the experience gained from achievements during the development and execution of the improvement programme is presented. The first part of the paper presents the genetic improvement programme including the breeding objective, the selection criteria, the genetic evaluation system used and the design of the three-tiered pyramidal structure for dissemination of genetic progress. The second part deals with the analysis of the genetic improvement programme. The success of the genetic improvement programme expressed through genetic progress and the benefits for the farmers is encouraging. Recommendations to strengthen the implementation process in the field are made.

Keywords: N'Dama, Improvement programme, Low input system, Review

Introduction

Sub-Saharan African countries, within the sub-humid zone, have high livestock development potential, which is not yet fully exploited as a result of several constraints (Ogle, 1996). In addition, the wider livestock development context is often poorly understood or contains major policy, institutional, economic or other non-genetic impediments to livestock development (Djemali and Wrigley, 2002). It is therefore necessary to assist national governments in preparing appropriate strategies and the necessary policy framework, if sustainable livestock development is to be attained.

The ability of some local breeds to resist trypanosome infection has been recognised, allowing trypanotolerant stock to be considered as one of the major methods by which sustainable animal production can be developed in the tsetse-infested region (Trail and d'Ieteren, 1992). There is evidence that locally adapted indigenous breeds exhibit a wide variation between animals for traits important for food production (Hill et al., 2001). This suggests that genetic improvement programmes for local indigenous breeds could be very successful if well designed, executed and accompanied by improved nutrition, health and feed resources management.

Various improvement programmes for local indigenous breeds have been undertaken within the sub-humid zone. These programmes are funded mainly by governments and donor agencies. Open nucleus breeding systems (ONBS) have been recommended for genetic improvement in developing countries that lack the money, expertise and structure required to operate an efficient improvement programme based on artificial insemination and field recording throughout the entire cattle population (Smith, 1988). A number of open nucleus breeding systems for cattle and small ruminants have been described (Fall et al., 1982; Oya, 1990; Yapi et al, 1994). Such programmes do not require expensive infrastructure because recording is only done in the nucleus herd. Reports show that among the improvement programmes implemented, few are well designed, but nevertheless they are facing the bottlenecks of long-term sustainability and involvement of local farmers (Kosgey et al., 2005). One example of a successful breeding scheme is the N’Dama cattle genetic improvement programme initiated in 1994 and operational in 1995 at the International Trypanotolerance Centre (ITC) in The Gambia (ITC, 1999).

The objective of the genetic improvement programme is to improve the welfare of livestock owners and their dependants through better performance and increased productivity of their livestock, resulting from participation in the genetic improvement programme. Welfare is expressed as better nutrition, improved livelihoods arising from more secure livestock capital assets, and improved income from sales of livestock and its products (ITC, 1999). The improvement programme of ITC is designed to operate in low-input systems and is based on the concept of an open nucleus breeding system. The programme started in 1994 and is now well established and functioning, and could serve as a model for low cost breeding schemes in low and medium input livestock production systems in this and other regions. Dempfle (1990) has highlighted the need to check the programme, after implementation, to ensure that the scheme is running according to plan and if there are discrepancies that require modification.

This paper reviews aspects of the N'Dama cattle genetic improvement programme implemented at ITC, in The Gambia. The current state of the improvement programme, operating in a low input system, is described and evaluated in order to identify opportunities to strengthen the programme and to implement it in other regions.

Mission and objective of ITC

ITC was created in 1984 with the mission to contribute to livestock productivity and utilization in the West African region through optimal and sustainable use of indigenous breeds of livestock for the welfare of the human population. The general objective formulated was the implementation and the introduction of sustainable, socio-economic and environmentally acceptable, integrated packages at farmer level, for improved livestock health, production and use (ITC, 1999). Since its inception, ITC has made significant contributions to the understanding of trypanotolerance and the factors that affect its expression. Progress has been made towards the development of an N'Dama herd and Djallonké sheep and West African Dwarf goat flocks. Research on livestock systems, animal nutrition, reproduction, diseases (tsetse-borne diseases, tick-borne and tick-associated diseases, endoparasites in ruminants) and socio-economic aspects have been carried out. Training has been conducted on several topics related to animal production. ITC has since built up local, regional and international links with other institutions.

Background of the N'Dama cattle genetic improvement programme

The dominant issues that justified the establishment of the N'Dama cattle genetic improvement programme relate to the problem of trypanosomiasis, reduction of under nutrition, enhancement of food security and the fight against rural poverty (Dempfle, 1993). Table 1 gives the chronological development of the N'Dama cattle genetic improvement programme. Since its inception in 1984, ITC has built up a large institutional herd of about 1100 N'Dama cattle (Dempfle and Jaitner, 2000).

Table 1. Overview of the chronological development of the N'Dama cattle genetic improvement programme.

Event	Period
Inception of ITC	1984
Food and Agriculture Organization (FAO) consultancy mission conducted at ITC	1990
Need for a coherent and comprehensive improvement programme expressed	1993
Proposal to support the organisation of the herd into an open nucleus herd	1993
BMZ agree to financially support the proposal	1993
Launch of the programme	1994
Records on performance	1995
Workshop organized for the breeding goal	1996
Purchase of replacement animals (screening)	1996/1999
Breeding goal agreed	1998
Introduction of an animal model BLUP evaluation	1998
Introduction of mechanism to disseminate genetic progress	2001
Project PROCORDEL: enhance dissemination	2000
OPEC-FID: screening operation	2002
Establishment of two livestock multiplier associations	2002
Survey of farmer acceptance	2003

In 1993, the need for a coherent and comprehensive genetic improvement programme was expressed. It was decided to transform the institutional herd into an open nucleus because it was recognised that it was important to involve local farmers in the initiative and to make best use of the animals in their herds. Taking into account the dominant issues and considering the fact that the Centre itself had no funds, a proposal to support the transition of the herd into an open nucleus scheme, was submitted to the Bundesministerium für Wirtschaftliche Zusammenarbeit (BMZ) of The Federal Republic of

Germany. In December 1993, the BMZ agreed to financially support the proposal. The programme was launched in 1994. In 2000 the improvement programme received funding from the European Union (EU) through the project PROCORDEL (Programme Concerté de Recherche-Développement sur L'élevage en Afrique de L'Ouest). Part of the PROCORDEL funds, and the additional support from The Organisation of Petroleum Exporting Countries Fund for International Development (OPEC-FID) received in 2002, have been used to support further development and evaluation.

Program development and implementation

Approach to define the breeding goal

The breeding goal was discussed and agreed upon with the National Agricultural Research Services (NARS) and the representatives of the target groups (farmers) (ITC, 1999). In 1990, a Food and Agriculture Organization (FAO) consultancy mission was conducted at ITC. The report revealed the importance of traits like disease tolerance, milk production, meat production and ability for traction (Dempfle, 1990). The question of which traits should be included in the breeding goals was revisited by Dempfle and Jaitner (2000). A Participatory Rural Appraisal (PRA) study was carried out in 1996. The objective of that study was to investigate motives of cattle owners to breed, and to provide background information on the role of livestock in rural Gambian households of varying socio-economic status and ethnic origins (Bennison et al., 1997). The results confirmed that traits such as milk, meat, traction and manure were prominent. To validate the results of the PRA, a workshop was organized in 1996. From the discussions, it was concluded that: "the N'Dama cattle will remain the breed of choice for the low-input system and that emphasis for the improvement should be on milk and meat without the loss of disease resistance and other adaptive traits". Based on the results of the PRA study, a bio-economic model was adapted utilizing all known biological and economical relationships (Dempfle, 1986). This economic model was used to obtain an economic definition of the overall breeding goal. After reviewing the literature and the local production system, it was agreed in 1998 that the improvement programme should aim to increase milk and meat production without losing trypanotolerance and other adaptive traits. Table 2 give an overview of the means, phenotypic standard deviations, heritabilities and genetic and phenotypic correlations for the individual traits.

Table 2. Mean (μ), phenotypic standard deviations (σ_p), heritabilities (h^2), economic values in Gambian Dalasi (v), genetic (below diagonal) and phenotypic (above diagonal) correlations for the individual traits.

Trait	μ	σ_p	h^2	v (GMD) per unit	Genetic and phenotypic correlations	
					DWG	MY
DWG (g/day)	150	90	0.30	0.22	–	0.62
MY (kg)	250	70	0.25	0.93	0.10	–

DWG, daily weight gain (g/day) from 15 to 36 months of age under high tsetse challenge conditions and MY, milk yield (kg) milk off-take in the first 100 days of the lactation. (Source: Jaitner and Dempfle, 1998).

The breeding strategy

The breeding strategy follows that of an ONBS, with selection based on individual performance and performance of relatives. It is a three-tier scheme including the nucleus (ITC), multipliers and commercial farmers (ITC, 1999). It is a young sire programme where bulls are selected for breeding at the age of 3 years. A simulation study conducted by Jaitner and Dempfle (1998) showed that the programme was as efficient as the half-sib programme where bulls are selected for breeding at the age of 5.5–6 years. It had the additional advantage of being simple and therefore easier to operate (Dempfle and Jaitner, 2000). Superior genes from the nucleus herd are disseminated through the multipliers herds to the village herds by selected bulls. Upward migration of females from multiplier and commercial herds to the nucleus is allowed. Therefore, screening operations are occasionally carried out to select and introduce male offspring of outstanding cows from the participating farms into the nucleus (Jaitner et al., 2004). The screening of cows is done with a very simple recording system (milk yield) introduced temporarily in the field. It represents a way to introduce fresh blood into the nucleus, and a valuable opportunity to strengthen the farmers' involvement in the improvement programme. Figure 1 gives a simplified schematic representation of the ITC three-tier breeding structure with selection at nucleus, multiplier and commercial farmer levels and possibly upward migration of genetic material.

In the breeding scheme, the following two activities can be distinguished: (1) generation of genetic progress and (2) dissemination of genetic progress from nucleus to local farmers (Van Arendonk and Bijma, 2003). Generation of genetic progress involves development of a successful breeding scheme with a clearly defined breeding goal, the organization of performance recording, genetic evaluation as a means of identifying superior bulls for the next generation, dissemination of selected bulls and preservation of a high selection pressure.

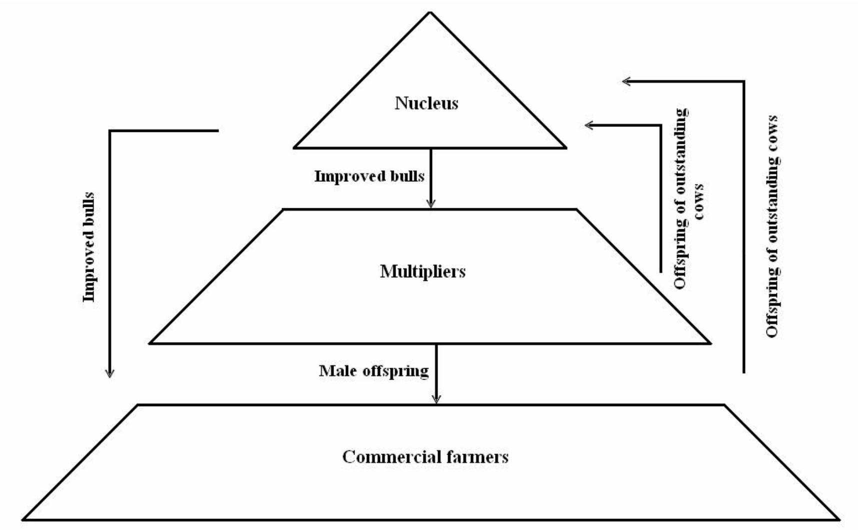

Figure 1. Schematic representation of the ITC three-tier breeding structure with selection at nucleus, multiplier and commercial farmer levels and possibly upward migration of genetic material.

To ensure the farmers use the superior genetic material generated in the nucleus promotion of the improvement programme, communication with farmers and the government is very important. It involved a series of workshops, training, open days, farm visits, films and livestock shows, which demonstrated the benefits from the production of the N'Dama cattle breed.

The implementation and support of other programmes or activities (feed production and feeding system, health management systems) also contributed significantly to the programme. Besides the technical aspects, applied research including socio-economic aspects has also been undertaken. Moser (2001) and Trivedi (2002) have noted the importance of an integrated system approach to achieve a sustainable genetic improvement programme.

Selection criteria

Animals in the improvement programme are maintained under a low input management system (raised as animals under village conditions), details on the production system have been described by Agyemang et al. (1988). Animals are selected from an index containing information on the daily weight gain in the post-weaning period (between 15 months and 36 months in an extreme high tsetse challenge area) and the 0–100 day milk yield (milk off-take, milk extracted for human use) of all lactations. Weight traits are determined by monthly weighing of all animals (males and females), whereas milk off-take is measured weekly (information is taken on females, males are selected taking half sib information into account). Milk off-take is defined as the additional milk not consumed by the calf. The index integrates information on the animal itself and all relatives using animal model BLUP methodology.

Table 3. Overview of the number of animals entering the test period (12 months), the number of animals completing the test (36 months) and the number of males selected per year.

Year	Number of animals entering the test period (12 months)			Number of animals that have completed the test (36 months)			Number of males selected
	Male	Female	Total	Male	Female	Total	
1993	26	24	50	53	69	122	–
1994	32	46	78	24	45	69	–
1995	58	89	147	52	82	134	–
1996	58	61	119	36	59	95	–
1997	56	59	115	34	57	91	–
1998	34	37	71	27	34	61	–
1999	53	81	134	24	67	91	–
2000	42	43	85	24	39	63	8
2001	46	52	98	7	19	26	5
2002	48	59	107	–	–	–	5
2003	38	49	87	–	–	–	8

Selection candidates are located at the ITC's stations Bansang (high tsetse challenge area). The station located at Keneba maintains the breeding herd of five sires and 400 cows (at any time). Each year, approximately 400 cows are mated to produce 100 male and 100 female calves. A minimum number of five bulls is necessary in order to cope with the number of females to be mated. These calves are maintained at Keneba until weaning (at 12 months of age) after which 95 males (90 born on the station and five from the screening operation) and 90 females are moved to Bansang. 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 due to health problems and mortality. At the end of the testing period (at 36 months of age), 84 male and 80 female are available for selection and are moved back to Keneba for selection. An overview of the number of animals tested and the number of animals selected per year is given in Table 3.

Each year one to two males are selected out of 84 candidates for replacement of the breeding males. The second best males (around 10) are designated for use in the multiplication tier, whereas all others are sold to butchers to be slaughtered. Breeding males are used for two to three years in the herds. Males with superior genetic merit are expected to produce better performing sons.

Using males for more than 2 years is likely to reduce the rate of improvement and increase the risk of inbreeding. Males are therefore replaced after 2 years. After their return to Keneba, females are mated and the milk yield of the first lactation is measured. Female selection is almost entirely on milk yield. From the 80 female selection candidates, 75 are selected and mated after which 55 animals are retained based on their first lactation performance. For a more in-depth discussion of the breeding and evaluation criteria, refer to Dempfle and Jaitner (2000).

Dissemination of genetic progress

Livestock farmer's organisations in The Gambia can play an important role in dissemination of genetic progress. For the genetic improvement programme to have an appreciable impact, it was decided in 2002 to support the activities of farmer's organisations. In 2002, two livestock multiplier associations, Gambian Indigenous Livestock Multiplier Associations (GILMA-Saloum and GILMA-Fulladu), were established with funds from the Organisation of Petroleum Exporting Countries Fund for International Development (OPEC-FID). The main objectives of the GILMAs are to (a) make farmers aware of the availability of breeding males in multiplier villages, (b) to purchase male offspring from multipliers and disseminate them to farmers and (c) to organise farmers to be more involved in the breeding schemes. A central point in the programme was intensification of the partnerships among the groups involved (ITC, individual farmers, groups of farmers and the Department of Livestock Services). Meetings to promote constructive policy dialogue and to discuss areas of cooperation are organised regularly with farmer's representatives and the Department of Livestock Services to discuss problems encountered in the field, and to find solutions. These meetings have made a significant contribution to the implementation of the dissemination programme.

The cattle dissemination programme started in 2001. Until 2004, 44 improved bulls have been so far distributed to individual multipliers in 26 villages and 169 offspring are registered in these multiplier herds. The multiplier tier (see Figure 1) plays the most important role in disseminating the genetic progress achieved in the nucleus herds. The multiplier receives superior breeding males from the ITC nucleus herd, uses these breeding males for a specified period and sells the male offspring of these breeding males to commercial farmers in the lower tier. These commercial farmers in the lower tier use these males in order to increase the productivity of their stock. The multiplier tier consists of individual herds that have been selected after several meetings with farmers and communities. To become a multiplier, the farmer needs to fulfil certain conditions and criteria. It is essential that sound management, in terms of improved health care, feeding, reproduction and housing, is applied to reduce morality and reproduction losses. The farmers who are interested should be progressive (open to new technologies). The specific criteria are:

- the herd should contain more than 40 breeding females (above 5 years);
- the farmer should be willing to test innovations and have an authority on decisions (nearly all herds are multi-owners herds) regarding management of the herds;
- the owner or person responsible for the bull should be aware of the main role of a multiplier: selling the male offspring to other farmers.

When the conditions and criteria are fulfilled, a contract with the farmer is signed and agreements for payment of the breeding bull are arranged.

Three approaches can be used for the dissemination (Jaitner et al., 2003): (a) the Village Approach, with the multiplier representing the whole village herd; (b) the Kaffo Approach, with a group of farmers in the village pooling their herds together to form a multiplier; and (c) the Individual Approach, with the multiplier formed by individual farmers with reasonably sized herds.

Training and capacity building

Training was the starting point for strengthening the activities of the improvement programme. The overall objective is to enhance capabilities of implementing genetic improvement programmes, to deal with the issues and problems faced in the management of local indigenous breeds and to cope with new technical developments for the sustainable use of local animal genetic resources. Training activities target managers, livestock specialists, technical staff, extension workers and farmers. Special attention is given to farmers who represent the ultimate beneficiaries of the improvement programmes. The approaches utilized are the training of trainers and training in participatory groups. Two main training workshops were organised by ITC and partners (Dempfle and Jaitner, 1999). Both workshops were organised to facilitate exchange of knowledge and experience through demonstrations, brainstorming sessions, group discussions, and assignments. The first training session was a regional training workshop on animal breeding and genetics and was organised for geneticists and professionals responsible for breeding projects in West Africa. The objective of this workshop was to discuss theories and methodologies that could be used to genetically improve local West African livestock populations in order to promote their utilization. The workshop provided participants with opportunities to share their experiences with their fellow participants.

The second training workshop targeted livestock extension workers and farmers and was on the topic of management of pure breeds and their genetic improvement programme (DLS/ITC, 2002). One of the main objectives was to further explain the genetic improvement programme and the mechanisms put in place to disseminate genetic progress. During the workshop both groups, extension workers and multiplier farmers, had opportunities to ask questions and were also asked to express their views on the genetic improvement programme and on breeding activities in general. Extension workers mentioned that the selection process needed to be re-explained properly to them and to farmers. Suggestions were also made; the most important was to work out a few modalities to prevent farmers from selling breeding males, delivered by the improvement programme, for ceremonial and religious purposes. Farmers were mainly concerned about the limited amount of knowledge they received on breeding and selection activities ongoing at ITC. They emphasised their need to be regularly informed on breeding events and to be trained in breeding and selection.

Opportunities for improvement and evaluation of the scheme

This paper reviews aspects of the ITC N'Dama cattle genetic improvement programme implemented in a low input production system in The Gambia. Evaluation is based mainly on two main interacting functions: the genetic gain achieved during the development of the genetic improvement programme and the uptake of results by farmers. We also want to address the question to what extent farmers and farming communities in Gambia and the West African region benefit from changes brought about by the genetic improvement programme.

Genetic gain

The heritability (h^2) represents the fraction of phenotypic variation that is genetic. This parameter is used to calculate estimated breeding values for individual animals in the nucleus herds. Collection of performance information over 10 years has permitted the estimation of genetic parameters as well as the genetic trends for growth traits. The estimated heritabilities for growth traits recorded in the scheme were moderate to high (Bosso et al., 2002). Heritabilities ranged from 0.28 for weight at 36 months to 0.48 for weight at 15 months. The genetic correlation between weaning weight and weight at 36 months was high (0.69). The genetic correlations between birth weight and weights at later ages were moderate to high and ranged from 0.28 for weight at 36 months to 0.61 for weight at 24 months. Genetic and phenotypic parameter estimates are scarce in purebred indigenous N'Dama cattle populations and coupled to the results of the heritabilities, they support the promise of genetic improvement with respect to growth rates.

The breeding scheme aims at exploiting the genetic variation within a breed in traits of interest. The analysis was also used to determine the genetic trend. Average estimated breeding values (EBV's) of animals were calculated and regressed across birth year of the calves to predict annual genetic trends for body weight at age types birth weight (BW), weight at 12 months of age (W12) and weight at 36 months of age (W36). The increased breeding value for W36, from 1994 to 2004, fluctuated between 0 to 6.32 kg (Figure 2).

W36 months exhibited the largest genetic gain with a response of 0.40 kg per year. The other weight traits also exhibited positive, although smaller, amounts of genetic gain.

Further studies are planned to estimate genetic parameters for other important traits, namely feed intake, feed conversion and milk production (quantity and quality).

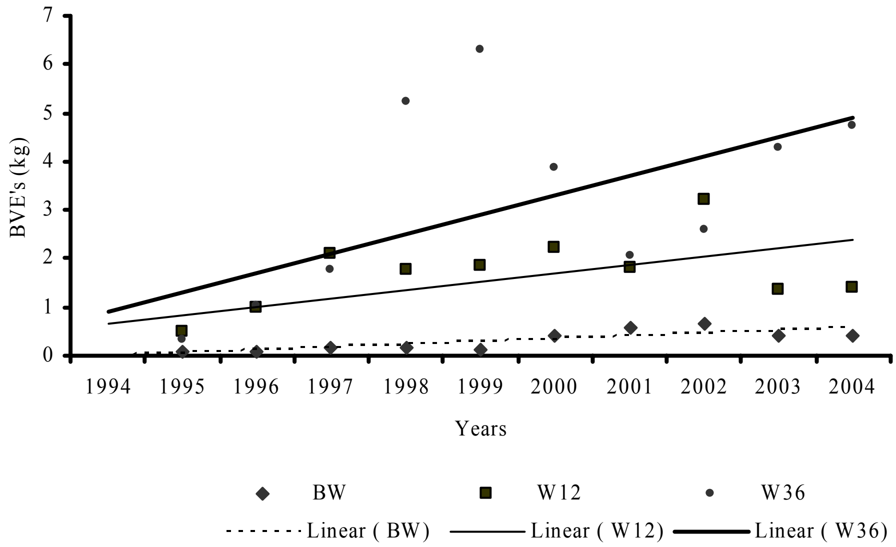

Figure 2. Genetic trend from 1994 to 2004 for body weight traits, showing the correlated selection responses per year for EBV of W36 (weight at 36 months of age), BW (birth weight) and W12 (weight at 12 months of age).

Support to farmers' associations

The crucial role of livestock farmers' associations in the dissemination of genetic material has been well highlighted by Shankariah and Shingi (1997). The newly formed associations remain fragile and more work is needed to strengthen them to improve their access to innovations, markets and services that enhance farm productivity and income. It is also essential to make the members of the associations aware that these associations are first and foremost instruments for them and respond to precise needs.

The newly formed farmers' associations will require technical and financial support in the short term. In the long term, the associations will have to be provided leadership to move the improvement programme towards its final objectives. To fulfil all their management responsibilities, the associations will have to remain in close collaboration and seek assistance from other stakeholders in the breeding structure (Öhlmér, 1998).

Interaction with farmers

Farmers are rich in skills and knowledge in the traditional raising of N'Dama and they have good experience in dealing with their farming system. It is important to realise that there is much to be learnt from the farmers; they can provide a very good base for further development of the programme. A survey was conducted by ITC in participating (taking an active part in the design, implementation and evaluation of the improvement programme) and non-participating villages in December 2003 in The Gambia (Agyemang et al., 2003). The objective of the survey was to assess the adoption and the impact of the genetic improvement programme. From the preliminary results, it can be concluded that the project is starting to achieve its objectives. The results show that in the participating villages, associations and households are pleased with the benefits from the improvement programme. All of the participating respondents indicated that they believed that the use of improved N'Dama bulls will improve their livelihoods. According to the farmers, the distributed breeding bulls have performed well under village conditions and farmers have expressed their satisfaction. One of the most important benefits to farmers is the savings generated by the utilization of improved males; the cost of trypanocide drugs to control trypanosomosis and other diseases is drastically reduced (50%). The resultant healthier and stronger animals have a positive effect on the reduction of medication and further increase the economic benefits to the farmer. The survey further demonstrates that all the farmers have observed that calves obtained from the improved bulls are heavier at birth, are vigorous, have a higher growth rate and survive better than calves obtained from their own old bulls. This is very encouraging and is likely to translate in the future into higher mature live weight of animals and therefore higher sale prices. The participants in the survey have also indicated their willingness to recommend the concept and practice of the improved breeding practices to other farmers not yet participating in the improvement programme.

Utilization of indigenous breeds

The advent of improved exotic breeds has led to neglect, in many parts of the country, of the indigenous breeds (Syrstad, 1989). This creates a threat for the future of the

N'Dama breed. It is important to maintain genetic diversity as an insurance to cover against future contingencies. In 1992, the FAO launched the "Global Programme for the Management of Farm Animal Genetic resources" (FAO, 1998). It underlined the importance of indigenous domestic animals in global biodiversity. Drucker and Scarpa (2003) reported that the utilisation of indigenous livestock populations depends, in large part, on the ability of communities to decide on and implement appropriate breeding strategies. Given the encouraging results of the N'Dama genetic improvement programme in The Gambia, it can play an important role in the conservation and utilisation of N'Dama cattle. The programme has significantly influenced the utilisation and development of the N'Dama breed. There appears to be no doubt that N'Dama cattle will continue to play a very prominent role in the supply of animal protein to the rural communities in The Gambia in the foreseeable future.

Benefits to farmers and cost of the improvement programme

The programme meets the important characteristics required for estimating incremental cost, because (a) it addresses national development goals, (b) it has been shown to be technically feasible, (c) it is an economically attractive course of action, while remaining broadly consistent with political and social constraints, (d) it is environmentally reasonable and therefore does not penalise progressive environmental action in The Gambia, in the West African region and in the globe, and (e) it is financially realistic. The sustainability of the programme is related to questions on whether institutions such as ITC can alone support the incurred costs, and are the benefits generated only for the Gambian population? It appears that the N'Dama cattle genetic improvement programme will also benefit countries other than The Gambia (ITC, 1999). Break-even analysis could be used to show at what point in time the cost of the premium of sales will be recovered.

Conclusion and recommendations

The N'Dama cattle improvement programme demonstrates that genetic improvement programmes for a low input production system are feasible. The success of the programme is expressed by the genetic progress achieved and this success has been transmitted to the farmers through the involvement of farmers and farming communities. It is important to find ways to ensure financial security. The genetic improvement programmes could serve as a model for low cost breeding schemes in low and medium livestock production systems in the West African region.

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Chapter III

Genetic parameters for growth traits in N'Dama cattle under tsetse challenge in The Gambia

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Abstract

Heritabilities and correlations for growth traits in N'Dama cattle under tsetse challenge were estimated using an animal model. Animals were born and weaned in a low to medium tsetse challenge area and, after weaning at 12 months of age, they were transported to a high tsetse challenge area until 3 years of age. Measurements included body weight and growth rate during seasons from 12 to 36 months. Two seasons were defined: the dry season from November to June forming the period of feed shortage and low tsetse fly density; and the wet season from June to November where sufficient feed was available and the tsetse density was the highest. Heritabilities for body weight ranged from 0.28 for body weight at 36 months to 0.48 for body weight at 15 months. For growth rate, the heritability was 0.09 during the dry season and 0.15 during the wet season. Genetic correlations of birth weight with body weight at 12 and 15 months were moderately high (0.49 and 0.51, respectively). Genetic correlations between most body weights and growth rates during seasons ranged from –0.40 to 0.80. The genetic trend due to the selection programme was highest for body weight at 36 months from 1994 to 2004. For growth traits, an increasing genetic trend was observed in growth between 15 months and 36 months and in growth during the dry season from 12 to 36 months. It was concluded that selection for growth should focus on growth during dry and wet seasons.

Keywords: N'Dama, genetic parameters, growth, improvement programmes, selection tropical

Introduction

Increasing awareness of the potential of indigenous livestock breeds is becoming evident in the activities of both national and international organizations in Sub-Saharan Africa. Indigenous livestock breeds have always played an important role in the lives of the people of Sub-Saharan Africa. They contribute to a wide variety of activities; providing sustenance, transport and protection against harsh environments. Indigenous livestock breeds serve to transform feeds into food and marketable products adding value to farming enterprises by increasing income and enhancing the biophysical and economic viability of agriculture (Winrock, 1992).

Few of these indigenous livestock breeds have been introduced in modern genetic improvement programmes that aim to serve the larger livestock farming population and to demonstrate a sustainable approach to livestock development in the region. Examples of genetic improvement programmes show that the potential to significantly improve breeds in terms of productivity do exist in this part of Africa (Diallo et al., 1993; Ebangi et al., 2000). More recently in 1994, the International Trypanotolerance Centre (ITC) in the Gambia implemented a genetic improvement programme for low input systems. The programme aims at a better utilization of the local trypanotolerant N'Dama cattle breed in West African countries, especially in the Gambia. In the genetic improvement programme, the performance of the animals has been monitored since 1995. In 1998, selection of animals based on estimated breeding values for growth rate and milk off-take was introduced.

Genetic and phenotypic parameter estimates are scarce for purebred N'Dama cattle populations. The ITC's genetic improvement programme has placed a large emphasis on increasing growth. Knowledge on genetic parameters in this population was lacking and therefore the design of the programme was based on literature and on experiences from experiments related to trypanotolerance (Trail et al., 1991). Further development of the genetic improvement programme could be achieved once genetic parameters for the population of interest are known. With the genetic improvement programme conducted at the ITC, a unique data set is being collected, which offering the opportunity to estimate genetic parameters in N'Dama cattle and evaluate consequences of selection.

The aim of this study is to utilize the information available from the ITC breeding programme to estimate the genetic parameters for growth traits and evaluate the genetic trends in N'Dama cattle kept under natural tsetse challenge.

Materials and Methods

Production environment

ITC's cattle were originally distributed in herds all over the country. The concentration of the stock in a single nucleus-breeding scheme in two sites (Keneba and Bansang) was achieved in 1994 (Figure 1). All animals in this research are now station based and belong to the ITC. Keneba is situated in the Kiang West District and lies approximately at 80 km from the Atlantic coast. Degraded savannah woodlands, riparian woodlands and long-term fallows characterize the vegetation (Agyemang et al., 1997). The tsetse challenge *(Glossina morsitans submorsitans)* in Keneba is classified as low to medium (Watcher et al., 1994). 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 vegetation consists mainly of woodlands interspersed with more open savannah woodland and fresh water swamps (Agyemang et al., 1997). The tsetse challenge *(Glossina morsitans submorsitans and Glossina palpalis)* in Bansang is classified as very high (Watcher et al., 1994) and the area is infested with high densities of both species.

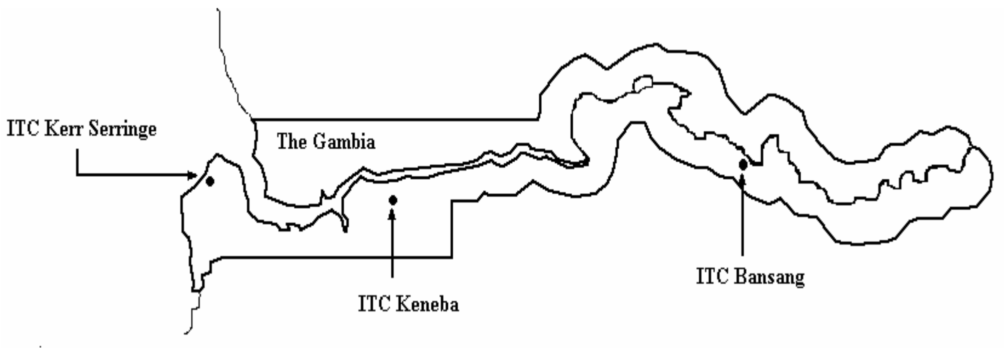

Figure 1. Geographical locations of ITC's research stations in The Gambia (source Agyemang et al. 1997).

Animal type and management

The Gambian N'Dama is slightly taller than the typical Guinean type. The colour varies from foam to white. It is has small body frame and long strong horns. The birth weight of the Gambian N'Dama is on average 18 kg for males and 17 kg for females. Average mature live weight is 295 kg for males and 227 kg for females. Animals in the ITC breeding programme are maintained under a low input management system (raised as animals under village conditions). They are tethered individually overnight, and are accompanied by ITC's herdsmen to graze during the day far away from the station.

Feeding behaviour varies between both locations and animals generally graze from 09:00 to 16:00 h daily over an extensive area (communal grazing) and are not supplemented. Calves stay with the dams for a long time and dam's milk is obtained by natural suckling. From November to June (dry season), the animals generally lose weight, as the quantity and quality of feed is low. They endure serious feed shortages in the late dry season and the beginning of the wet season (April–August). In Keneba (medium tsetse challenge), animals graze on grass in the wet season. During the early dry season, after the harvest, there is a shift to crop residues in the village fields. In the late dry season, animals feed themselves with browse and fruits and graze over extensive areas of burnt bush. In Bansang (high tsetse challenge), the feeding habits are different and the shortage is less accentuated than in Keneba. There is grass available most of the year. A small reduction of grass in the middle of the wet season is noticed. Generally, grass regeneration occurs at the end of the wet season and before the beginning of the early dry season. Details of herd management have been described by Agyemang et al. (1988) and Jeannin et al. (1988).

Trypanosomosis prevalence

During a period of 5 consecutive years (between 1995 and 2000), trypanosomosis surveys were conducted at the ITC's research station in Bansang. Randomly selected cattle were sampled monthly and their blood was investigated using parasitological diagnostic methods. At the same time, the population of biting flies was sampled. This data was used to determine the monthly average prevalence (seasonal change in bovine trypanosomosis) of trypanosome infection in cattle (Figure 2). Trypanosomiasis prevalence was found to vary from very high to very low; the mean annual prevalence ranged from 1% to 52%. Since 1995, the prevalence has decreased considerably.

From Figure 2 it can be seen that the number of tsetse flies starts to rise slowly in July and they becomes abundant between the months of November and March. The peak prevalence is found in November (just at the end of the wet season). Between March and June (late dry season), bush fires destroy tsetse habitats causing a rapid decline in tsetse density to a very low level. Seasonal changes in body condition show that animals reach their maximal body conditions at the beginning of the dry season (November). During the dry season they lose weight and reach their minimal body conditions at the end of the dry season (May). The dry season is also the period when the animals are stressed due to disease and lack of adequate feed.

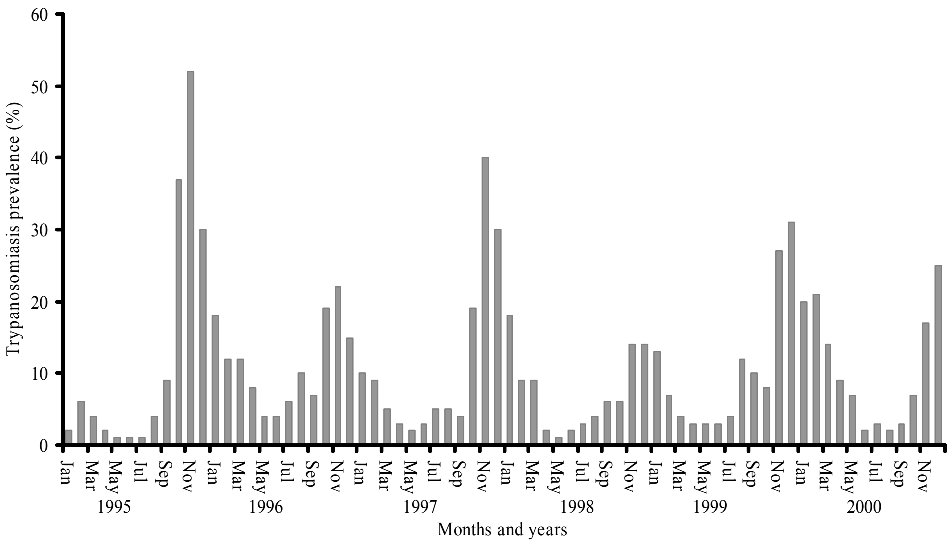

Figure 2. Mean annual prevalence of trypanosomiasis infection in cattle for Bansang from 1995 to 2000.

Breeding strategy

Animals are selected from an index containing information on daily weight gain in the post-weaning period (between 15 months and 36 months in an extreme high tsetse challenge area) and the 0–100 day milk yield (milk off-take). Weight traits are determined by monthly weighing of all animals, whereas milk off-take (for females) is measured weekly. Milk off-take (milk extracted for human use) is defined as the additional milk not consumed by the calf. The index integrates information on the animal itself and all its relatives using the BLUP animal model. Selected candidates are located at the ITC's Keneba station. The breeding herd consists of 5 sires and 400 cows (at any time). In each year, 400 cows are mated to produce 100 male and 100 female calves. The newborn calves are maintained at Keneba until weaning (at 12 months of age) after which approximately 95 males (90 born on station and 5 from the screening operation) and 90 females are moved to Bansang. 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. There is an annual loss of 10% among selection candidates for reasons of health and survival. At the end of the testing period (36 months of age), approximately 84 males and 80 females are available for selection and are moved back to Keneba for breeding. Each year 1–2 males are selected to replace some of the breeding males. Breeding males are used for 2–3 years in the herds. Females are mated at around 4 years of age and the milk yield of the first lactation is measured. Around 75 females are selected and mated after which 55 animals are retained based on their first lactation performance. For a more in-depth discussion of the breeding and evaluation criteria, refer to Dempfle and Jaitner (2000).

Traits evaluated

Body weight records collected monthly at the ITC research stations (Keneba and Bansang) from 1994 to 2004 were available for this study. Traits considered in the analysis included: body weight at birth (BW), at 12 months (W12, weaning), at 15 months (W15, after 3 months of adjustment at Bansang), at 24 months (W24), the final weight of the test period at 36 months (W36); the selection criteria currently used (daily weight gain between 15 months and 36 months, G15–36) and the daily weight gain between 12 months and 36 months (G12–36). It was hypothesised that growth during each season might have a slightly different genetic background. To investigate this, two other traits were defined: growth rate during the dry season from 12 to 36 months of age (GD12–36) and growth rate in the wet season from 12 to 36 months of age (GW12–36). These traits were derived by taking the difference between the first and last recorded weights within seasons. These were accumulated across years (2 years) and divided by the respective accumulated time interval (days) between the weight records. Growth during a season was calculated as:

$$Growth\ during\ season\ =\ \frac{(WL1-WF1)+(WL2-WF2)}{(DL1-DF1)\ +\ (DL2-DF2)}$$

where WL represents the last weight during the respective season, WF represents the last weight during the season; DL represents the last day of recording and DF is the first day of recording, 1 and 2 represent the respective year.

Statistical analysis

The data file included 1711 animals born from 1987 to 2004 and was analysed using the following models: (1) to estimate genetic parameters for body weight traits, growth G15–36 and growth G12–36, and (2) to estimate genetic parameters for growth traits during seasons.

$$Y_{ijklmn} = mu + sex_i + bhd_j + ghd_k + sea_l + sea\times\ yea_{lm} + a_n + e_{ijklmn} \qquad (1)$$

$$Y_{ijklmn} = mu + sex_i + bhd_j + ghd_k + a_n + e_{ijklmn} \qquad (2)$$

where sex_i is the fixed effect of sex (male or female), bhd_j is the fixed effect of the herd in which the animals were born (six herds), ghd_k is the fixed effect of the herd in which the animals were tested (four herds), sea_l is the fixed effect of season, $yea\times sea_{lm}$ is the fixed effect of the interaction between year and season, a_n is the random effect of animal, and e_{ijklmn} is the random residual error.

An animal model was applied to estimate variance components and genetic parameters using ASREML (Gilmour et al., 2000). Ancestors with at least two offspring were included in the relationship matrix. Heritabilities and genetic and phenotypic correlations were estimated using a bivariate model. Average estimated breeding values (EBVs) of animals were calculated and regressed across birth year of the calves to predict annual genetic trends for body weight at age types BW, W12 and W36 as well as genetic trends for G15–36 and growth during dry and wet seasons GD12–36 and GW12–36.

Results

Summary statistics

A summary of the number of animals recorded at different ages, mean, standard deviation, minimum and maximum for each of the traits is presented in Table 1.

The number of records decreased with age. This is partly caused by censoring, i.e. the animals born in the most recent years have not yet reached the age of 36 months. There is a large variation in body weight at different ages. Means and standard deviations for GW12–36 were higher than those for GD12–36. Table 1 illustrates that large phenotypic differences in growth performances were found between animals.

Table 1. Number of animals, mean, standard deviation, minimum and maximum for the data used for the estimation of genetic parameters.

Traits	N	Mean	Std Dev	Minimum	Maximum
BW (kg)	1511	16.47	2.57	10	30
W12 (kg)	1091	79.56	13.82	33	131
W15 (kg)	1072	89.02	15.48	49	150
W24 (kg)	1040	125.88	21.21	70	193
W36 (kg)	750	168.45	26.15	83	261
G15-36 (g/day)	715	126.46	34.92	25.40	288.89
G12-36 (g/day)	715	123.83	30.11	36.11	261.11
GW12-36 (g/day)	715	220.27	107.51	8.45	496
GD12-36 (g/day)	715	61.35	67.45	-168.42	266.67

BW, Birth weight, W12, weight at 12 months (weaning), W15, weight at 15 months (3 months of adjustment when moved to Bansang), W24, weight at 24 months, W36, the final weight of the test period at 36 months, G15–36, the currently used selection criteria (daily weight gain between 15 months and 36 months), G12–36, the daily weight gain between 12 months and 36 months, GD12–36, growth in the dry season between 12 and 36 months of age and GW12–36, growth in the wet season between 12 and 36 months of age.

Fixed effects

The sex effect was significant ($P<0.05$) for all traits except for BW, GW12–36, GD12–36 and G12–36. The herd in which the animals were born had an effect only on BW and W12; the herd in which animals were tested had a significant effect only for W24, W36, G15–36, GW12–36, GD12–36 and G12–36. The season of birth had a significant effect ($P<0.05$) on all traits except W12 and GW12–36. The effect of year on all the traits, except BW and G12–36, was highly significant ($P<0.01$).

Genetic parameters

Heritability estimates with their standard error for each trait, along with estimates of genetic and phenotypic correlations between traits are shown in Table 2.

Heritabilities for body weight traits ranged from 0.28 for W36 to 0.48 for W15. Heritability estimates for growth traits during seasons were low for GW12–36 (0.15) and very low for GD12–36 (0.09).

The phenotypic correlations for body weight traits ranged from 0.17 (between BW and W36) to 0.82 (between W12 and W15). Phenotypic correlation for growth during dry and wet season was –0.09 (between GW12–36 and GD12–36). As to be expected, a high phenotypic correlation (0.89) was found between growth G15–36 and G12–36. Phenotypic correlations between body weights and growth traits ranged from –0.18 (between G15–36 and W15) to 0.85 (between G12–36 and W36).

Genetic correlations between birth weight and weights at later ages were moderate to high and ranged from 0.28 (W36) to 0.61 (W24). The genetic correlation between weight at 15 months and final weight (W36) was high (0.84). Unfortunately, the genetic correlation between growth rate in the dry and wet seasons could not be estimated. The standard errors related to the genetic correlations estimated in general were high.

Table 2. Estimates of genetic parameters (s.e.) for body weight and growth traits with heritabilities on the diagonal, genetic correlations below and phenotypic correlations above the diagonal.

Traits	BW	W12	W15	W24	W36	G15-36	G12-36	GW12-36	GD12-36
BW	0.4 (0.08)	0.28 (0.04)	0.23 (0.04)	0.21 (0.03)	0.17 (0.04)	-0.04 (0.04)	-0.01 (0.04)	0.03 (0.04)	-0.10 (0.03)
W12	0.49 (0.08)	0.47 (0.09)	0.82 (0.	0.61 (0.02)	0.44 (0.03)	-0.14 (0.04)	-0.15 (0.04)	0.05 (0.04)	-0.17 (0.03)
W15	0.51 (0.09)	0.97 (0.01)	0.48 (0.09)	0.66 (0.02)	0.43 (0.03)	-0.18 (0.04)	0.03 (0.04)	0.01 (0.04)	0.03 (0.03)
W24	0.61 (0.14)	0.84 (0.05)	0.90 (0.05	0.39 (0.10)	0.52 (0.03)	0.19 (0.04)	0.30 (0.03)	0.19 (0.04)	0.01 (0.03)
W36	0.28 (0.08)	0.69 (0.11	0.85 (0.05	0.89 (0.08)	0.28 (0.10)	0.80 (0.01)	0.85 (0.01)	0.32 (0.04)	0.10 (0.04)
G15-36	- 0.11 (0.12)	-0.07 (0.21)	-0.40 (0.10)	0.55 (0.27)	0.80 (0.11)	0.24 (0.09)	0.89 (0.01)	0.34 (0.04	0.11 (0.04)
G12-36	-0.26 (0.30)	0.17 (0.30)	0.34 (0.31)	0.85 (0.18)	0.82 (0.09)	0.92 (0.07)	0.11 (0.08)	0.25 (0.05)	0.34 (0.03)
GW12-36	0.16 (0.23)	0.22 (0.26)	0.05 (0.27)	0.18 (0.26)	n.e	0.72 (0.27)	0.83 (0.37)	0.15 (0.07)	-0.09 (0.04)
GD12-36	0.21 (0.26)	0.15 (0.31)	0.61 (0.30)	0.65 (0.26)	0.15 (0.29)	-0.07 (0.28)	n.e	n.e	0.09 (0.05)

n.e = not estimable. See Table 1 for definition of traits.

Genetic trend

Figures 3 and 4 show the trend in mean EBV for body weight and growth traits during seasons from 1994 to 2004, respectively. Figure 3 shows a positive increase in the estimated genetic level for BW, W12 and W36. The average breeding values for W36 increased by 6.32 kg from 1994 to 2004. This corresponds to an annual genetic trend for W36 of 0.40 kg/year. The other body weight traits also exhibited positive, although smaller, genetic trends: 0.06 kg/year for BW and 0.17 kg/year for W12.

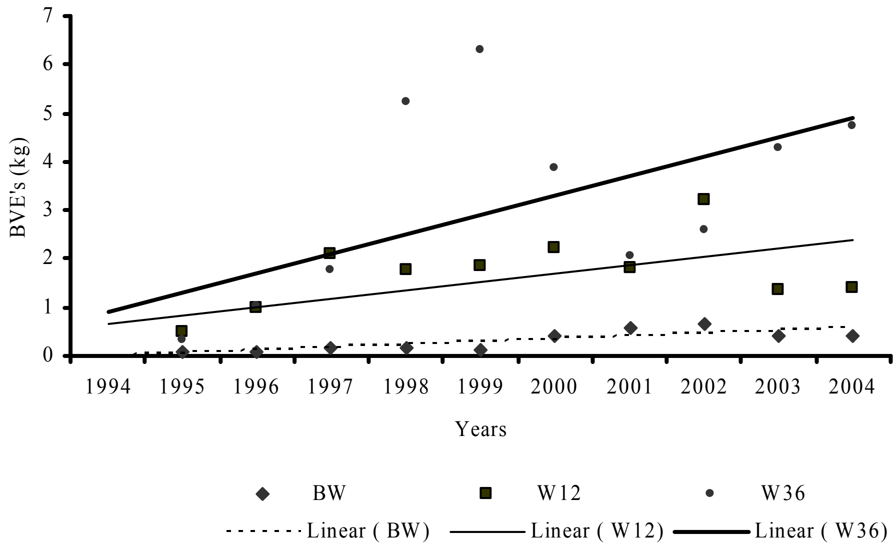

Figure 3. Genetic trend from 1994 to 2004 for body weight traits, showing the correlated selection responses per year for EBV of W36, birth weight and weight at 12 months of age.

The average breeding values for growths traits are presented in Figure 4.

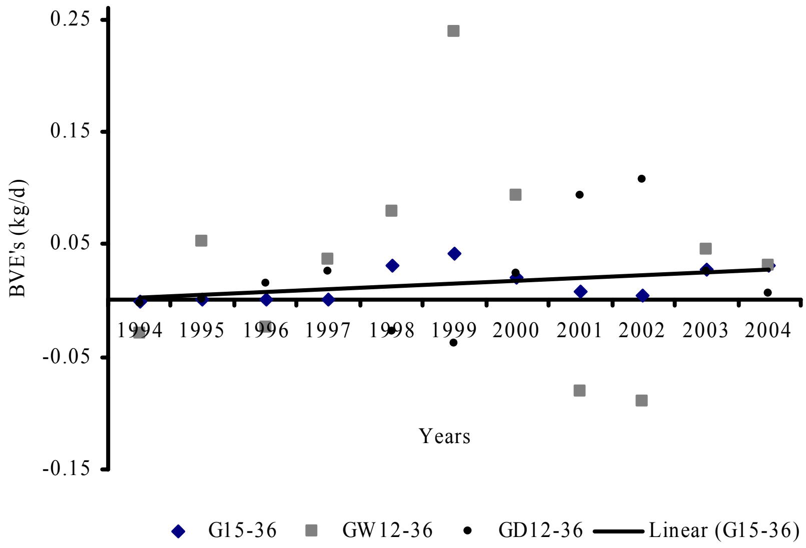

Figure 4. Genetic trend from 1994 to 2004 for growth during seasons, showing the correlated selection responses per year for EBV of G15-36, GW12-36 and GD12-36.

An increasing level for G15–36 is seen from 1994 to 2004. This trait was used as one of the selection criteria and a positive genetic trend in this trait was expected. The pattern in mean EBV for GW12–36 is similar but smaller than that of G15–36. The patterns for the other growth traits showed large fluctuations.

Discussion

Genetic parameters

This study has focussed on the estimation of genetic parameters for body weights and growth traits during seasons in N'Dama cattle and the evaluation of genetic trends. This is the first study to present estimates of genetic parameters for traits of N'Dama cattle under tsetse challenge and during different seasons. The results indicate that additive genetic variance exists for the traits considered.

The heritability estimate for BW is in the range of that found by Ahunu et al. (1997) for the same breed, and of Koots et al. (1994), Burrow (2001) and Mackinnon et al. (1991) for different breeds. The heritability estimate for W12 is slightly higher than for BW and higher compared with those found in other studies (Mackinnon et al., 1991; Eler et al., 1995). This is in contrast with other results in the literature in which the heritability for W12 was consistently lower than that for birth weight. The absence of a maternal genetic effect in our model might have contributed to the high estimate for W12. These effects were inestimable due to the small number of observations and the data structure. Accounting for maternal genetic effects resulted in a lower estimate of the heritability for body weight measured early in the life of the animals (Meyer, 1992). The heritability estimate for G15–36 (0.24) in the present study is consistent with those from previous reports (0.26, Mackinnon et al. (1991)) and (0.22, Burrow (2001)) in other breeds.

Olutogun (1976) reported phenotypic correlations between BW and W12 of 0.19, which is lower than the 0.28 that was estimated in this study. The extensive and adverse conditions under which the animals in this study are reared have a large effect on the growth of the young animals. The major factors playing an important role are the seasonal scarcity of water and feed. The scarcity and low feed quality force the young animals to range further to obtain the necessary amount of dry matter to meet their nutritional requirements. The low negative phenotypic and genetic correlation between GD12–36 and GW12–36 suggests that selection for GW12–36 alone is likely to have negative effects on GD12–36. This is supported by the genetic trend of GD12–36, which is opposite to that of GW12–36. This suggests that selection for GW12–36 might have adverse effects on the ability to maintain growth during times of limited nutrition and parasite challenge. It is important to realize that the weight of an animal under high tsetse challenge is determined by its genetic potential for growth, but also by its level of trypanotolerance (Trail et al., 1992), and, therefore, may have a different genetic background compared to weight under low tsetse challenge. The physiological mechanisms, the nutritional plane and the trypanosomiasis challenge levels are different in the two seasons.

Given the fact that calves are born all year round, with a peak during October and November (Table 3), calves born in these months will spend relatively more time in the wet season than calves born in, for example, January. The consequence of defining the growth period from 15 to 36 months is that the environment the animal will experience from 15 to 36 months differs between animals depending on the month of birth of the calf. For the breeding program, it is important to pay attention to growth during the dry and the wet seasons to ensure that the ability of animals to handle harsh environments does not deteriorate as a consequence of selection on final weight (i.e. the trait of economic interest to the farmers).

Table 3. Overview of the number of births per month out of the total of animals observed for all 36 months

Season	Month	Number of calving
Dry	January	75
	February	30
	March	21
	April	17
	May	20
Wet	June	36
	July	73
	August	89
	September	79
	October	103
Dry	November	112
	December	95

All animals observed for growth during seasons have completed the 24 months in the high tsetse infested area in Bansang. Thus, they have experienced an equal number of months in the wet and dry seasons. Growth during season was defined as the average growth during the entire time the animal was in Bansang during the dry or during the wet season. Furthermore, if an animal arrived in Bansang towards the end of the season, observations for growth during that season were still included in the trait definition. Consequently, for each season considered, an animal had two to three observations, which were subsequently averaged. The problem with this way of defining the growth during a season is that, despite the fact that information is available and is included in the trait definition, the environment in Keneba (where the animal was born) is much less demanding than the environment in Bansang. Therefore, animals arriving in Bansang towards the end of the season may have an advantage over animals that have arrived early in the season. An alternative way to define growth during seasons, therefore, would be to only include the observations of growth during complete seasons in Bansang.

W36 is the trait considered to be the most important (more than growth). In our analysis, W36 was corrected for the seasonal effect when estimating the breeding values of the animals. However, this will only be a correction for the average effect of the season. The genetic and phenotypic correlations between seasonal growth and the opposite sign of the genetic trend of both seasonal growth traits indicate that there is genetic variation in reaction to different seasons. These differences are not exploited when selecting on W36.

The moderate genetic correlations between BW and the other body weight traits are in agreement with results of Davis (1993) and Mackinnon et al. (1991). These correlations indicate that animals with higher birth weight usually also have faster postnatal growth.

We realise that the limited size of our data set results in large standard errors especially for the genetic correlations. However, the phenotypic correlations are estimated more accurately, and could serve as indicators of the magnitude and sign of the genetic correlations (Lynch and Walsh, 1998). Even if insufficient data reduces the accuracy of the estimates, there is evidence of existing additive genetic variance for the body weight and seasonal growth traits. When more records become available, the parameter estimates should be re-evaluated.

Genetic trend

Genetic trends are a very useful tool to evaluate the effects of the genetic improvement programme. Genetic trends for the body weight traits were positive over years but large variations between years were found. The latter result is due to the small number of sires used in the breeding scheme. As expected, there was little improvement during the initial years from 1994 to 1997. Genetic progress was visible after 1997. The genetic trends demonstrated that the selection was effective in realising improvement in BW, W12 and W36. The largest improvement was found in W36. This was expected because the genetic improvement programme placed much emphasis on increasing W36. The genetic trends for the traits characterising growth during seasons were generally positive but of low magnitude, indicating that there has been only small genetic changes in growth during seasons since 1994. Figure 4 clearly shows the increasing trend in G15–36 and GD12–36 suggesting that the genetic improvement programme has been successful in improving growth from 15 to 36 months of age and at the same time improving the adaptability of the animal to the harsh conditions. However, as stated before, it also shows the opposite trend pattern of G15–36 and GW12–36, on the one hand, and GD12–36 on the other hand. The trends confirm the ability of the N'Dama to survive and be productive in tsetse-infested areas without the aid of treatment (Murray et al., 1982), but also point out the necessity to include growth from 12 months onwards.

Conclusion

The results presented in this study indicate that genetic variation exists between the traits. Selection on growth performance should include the clear influence of season, and thus on the genetic background to cope with the season. Further studies are necessary to assess the economic importance of the trait.

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Chapter IV

Genetic and phenotypic parameters of body weight in West African Dwarf goat and Djallonké sheep

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Abstract

The International Trypanotolerance Centre's small ruminant breeding programme was initiated in 1995. The aim was to increase the efficiency of meat production and the trypanotolerance of the animals (sheep and goat). To achieve that goal, selection was based on estimated breeding values for daily weight gain from 4 to 12 months of age measured on trypanotolerance challenge. The purpose of this study was to estimate genetic parameters for growth traits and to evaluate genetic trends in West African Dwarf goat and Djallonké sheep resulting from the breeding programme under a low input production environment. Data for West African Dwarf goat and Djallonké sheep included birth weight (BW), weaning weight (W120), yearling weight (W360), pre-weaning (GR0–4) and post-weaning (GR4–12) growth rate. The data were analysed using an animal model that accounted for fixed effects of sex, year of birth, season of birth, parity of the dam, type of birth and the interaction year by season of birth. Estimates of heritability for BW, W120, W360, GR0–4 and GR4–12 were 0.5, 0.43, 0.30, 0.32 and 0.11 for goats and 0.39, 0.54, 0.21, 0.54 and 0.23 for sheep, respectively. The genetic correlation between BW and W120 was high for goats (0.74) and moderate for sheep (0.47). Genetic correlations between W120 and GR4–12 were high (0.92) for goats and moderate (0.49) for sheep. Between GR0–4 and BW the correlation was positive but low for sheep (0.26) and moderate for goats (0.60). Positive trends were found in mean estimated breeding values for animals born in the period 1995–2002, which demonstrated the effectiveness of the implemented breeding programs.

Keywords: West African Dwarf; Djallonké; Heritability; Growth traits; Gambia

Introduction

Small ruminants (i.e. sheep and goat) have, for a long time, not been considered in livestock development programmes (Glimp and Wiegand, 1991). In sub-Saharan Africa, small ruminants play a crucial role in sustaining agricultural production. According to Lebbie and Ramsay (1999), small ruminants account for 62% of the total number of domesticated ruminant livestock in this region, with 34% and 28% for goats and sheep, respectively. The indigenous trypanotolerant West African Dwarf goat and Djallonké sheep are the most predominant domestic breeds in humid rural areas of West Africa. They are mostly raised for meat but also provide flexible financial reserves and play important social, religious and cultural roles. These small ruminant species are well adapted to the wide range of pastoral and mixed farming production systems and are able to survive and produce in poor environments on low-cost feeds. It is generally accepted that small ruminants require low labour input and are easy to manage, thus contributing towards a sustainable economic stock (Acharya and Battacharyya, 1992).

For genetic improvement, replacement of indigenous breeds by exotic breeds and crossbreeding with exotic germplam have been widely used, but in most cases have been unsuccessful in the traditional low input production systems in the tropics (Kosgey et al., 2005). Within-breed selection of adapted indigenous breeds is a viable alternative. However, little information is available on the results of within-breed selection programmes utilizing indigenous breeds in the tropics (Kosgey et al., 2005).

In 1995, a breeding programme directed at improving the West African Dwarf goat and Djallonké sheep populations for low input production environments was initiated by the International Trypanotolerance Centre (ITC) in Gambia. The objective of the genetic improvement programme at ITC is to increase animal output per head among trypanotolerant small ruminants while retaining their resistance to diseases. Since 1998, selection has been based on estimated breeding values. The genetic parameters used by ITC for the design and subsequent implementation of the improvement programme were derived from the literature on small ruminants. Generally, the information available on the West African Dwarf goat and Djallonké sheep in West and Central Africa has been on description, size, colour, and production and reproduction performances (Ikwuegbu et al., 1994). Little information is available on genetic parameters for performance traits in these breeds. Clement (1999) has reported some genetic parameters for pre-weaning growth rates in West African Dwarf goat and Djallonké sheep raised in villages in Senegal (h2=0.19–0.50 and h2=0.09–0.47, respectively). Knowledge on the growth parameters of West African Dwarf goat and Djallonké sheep is important for adequate genetic evaluation of the animals. But more importantly, this knowledge is needed to optimise the breeding scheme (Smith et al., 1976).

The aim of this study was to estimate the genetic parameters for growth traits and to evaluate genetic trends in West African Dwarf goat and Djallonké sheep resulting from the breeding programme under a low input production environment initiated in 1995.

Materials and methods

The West African Dwarf goat

The West African Dwarf is a goat breed found on the coast of west and central Africa. Dwarf goats measure 40–50 cm at withers and are stocky with short legs. Newborn kids average around 1.20 kg at birth. The reproduction rate is 126% per doe per year, the age at first kidding is 18–24 months under village conditions and the adult weight is 24.5 kg (Agyemang et al., 1990).

Djallonké sheep

The Djallonké is a hair sheep with a thin tail. There are two sub-groups: the Dwarf Forest and the Savannah types. In ITC's breeding programme, the Savannah type is used. The sheep is larger than the Forest type with an average height of 55–65 cm at withers. The birth weight is around 1.40 kg, and the adult weight is 25.2 kg. The reproduction rate is about 108% per ewe per year (Agyemang et al., 1990). Females are early maturing, with first lambing sometimes before one year of age.

Management

The management system for small ruminants (same for sheep and goats) reared at the ITC station in Keneba (low to medium tsetse challenge area) is characterised by a low input system. The animals are maintained and raised under environmental, nutritional and management conditions that reflect the local conditions. Pasture production is markedly seasonal and affects the nutritional status of the animals. Grazing is either done individually (rams) or communally. Females and young animals (between 3 and 4 months) generally graze on communal grazing fields around 6 km from the station. During the short rainy season, grazing is restricted to protect the growing crops. Drinking water is provided by water catchments that are found in the area during the rainy season and the ITC borehole during the dry season. Predominant forages include *Panicum maximum*, *Leucaena leucocephala* and *Andropogon gayanus*. Mineral supplements and on-farm by-products are used when available. Commonly used farm residues are maize and millet stovers and groundnut hay. Weaned and older males are penned and supplemented throughout the dry and rainy seasons. They receive concentrates composed of rice bran, groundnut hay and cake. Heavily pregnant and sick goats stay in their pens and are given feed. Occasionally, they are allowed to browse freely within the extensive fields enclosing the ITC's research station and parts of Keneba village. This is also usually done when pastures are inadequate and when on-farm by-products are unavailable. Young animals are left to suckle their dams during grazing and remain with their mothers until weaning at 4 months of age, when they are self-fed by the same feeding system.

Simple veterinary interventions are carried out and mainly consist of treatment of conditions such as diarrhoea, mange, eye and nasal discharges. Additionally, vaccinations against la Peste des Petits Ruminants (PPR), is carried out and routine strategic deworming is done three times a year. Females, except those excluded for infertility and health problems, are mated at the middle of the dry season and at the beginning of the rainy season so that kidding and lambing occur within the rainy and dry seasons, respectively. Kidding and lambing usually take place from October to November and early April. Within 24 h after lambing and kidding, young animals are identified with numbered plastic ear tags. Birth date, birth weight, birth type, dam ID, sire ID and other relevant information are recorded and stored in a database. Animals are weighed monthly (continuously until the animal exits the nucleus flock) during the last week of each month. At weaning, lambs and kids are separated by sex into different weaner flocks.

Selection criteria and flock structure

The open nucleus selection scheme for small ruminant breeding programmes at ITC focuses on increasing the amount of meat per animal. During the early stages of the programmes (1995), selection emphasis was mainly on visually assessed conformation. From 1998 onwards, males and females were selected on estimated breeding values for production performance traits.

The founding animals (sheep and goats) were bought (randomly) from village flocks across the country to form the nucleus flock. Young mature females (10–12 months) were bought and young males (10–12 months) were bought based on their conformation and physical examination of their reproductive system (for abnormal conditions).

All matings in the nucleus flock are natural (individual), following detection of females in heat by teaser males. Mate assignment is based on a strategy that aims to minimise mating of relatives (son–dam, daughter–sire and full-sib matings are avoided). Males are first used as sires for repeated mating at about 12 months of age. Each ram is paddock-mated to an average of 25–30 identified ewes. The majority of the sires are used for only one productive year (at 2 years of age). Every 3 months the breeding values are estimated and male replacement is provided. Females are used repeatedly until they are culled after 7 productive years (8 years of age). Culling is done mainly for poor health, poor body condition, failure to lamb/kid in subsequent seasons, old age and other abnormalities.

The breeding scheme is divided into three tiers including (1) the top of the pyramid (the ITC nucleus flock), (2) multiplier flocks, and (3) village flocks around the whole country. The genetic material (males) flows from the nucleus flock down to the multiplier flocks and then to the village flocks by selected males. Upward selection of males (not females; females stay within each tier except for the initiation phase) from village or multiplier flocks to the nucleus also takes place. Animals are selected based on average daily weight gain information on candidate own performance and performance of half-sib's expressed between 4 and 12 months of age. Fig. 1 gives an overview of the general structure of the small ruminant nucleus breeding scheme implemented at ITC (ITC, 1999).

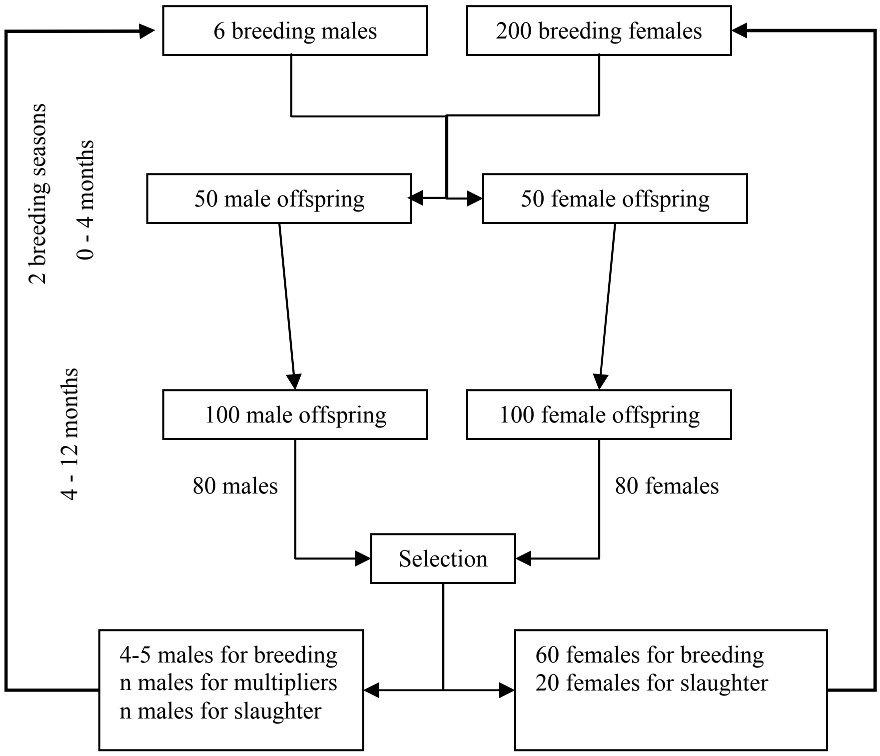

Figure 1. Overview of the small ruminant nucleus breeding scheme implemented at ITC (source: ITC Biennial Scientific Report 1998–1999).

Annually, there are a total of around 400 animals in the nucleus flock (parent and offspring). For each species, six males are used each year to cover the multiplication group of 200 ewes. The six males produce the replacements for the nucleus animals (males and females). Another group of males from the nucleus are used to disseminate genetic superiority through the rest of the population/multiplier (breeding males for the second stratum of the genetic pyramid). In general, two female offspring from each female must be selected in order to produce sufficient animals to replace the parents. After one breeding season, there are not enough offspring to provide replacements, so at least two breeding seasons are needed to obtain the 100 animals that are candidates for selection (both genders). Assuming a mortality rate per year of 20%, there are on average 80 animals of each gender available as selection candidates. This number allows the top 7.5% of the males to be retained in the nucleus herd for further breeding while the next 30–40% best males are transferred to the multiplication flock and the remaining 50–60% are culled. The multiplier flocks normally ensure an increase of the number of males available for distribution to commercial farmers. For the dams, about 25% are culled during each cycle and replaced by 1-year-old females. The other 75% of the females are retained in the nucleus herd for further breeding.

Data collection and traits description

The data analysed consisted of weight performance records of 1314 sheep and 2080 goats collected over a 7-year period (1995–2002) at the ITC's research station in Keneba. The location, climate and vegetation in Keneba have been reviewed by Agyemang et al. (1997). The individual identity and pedigree of the animals, weight at birth and several body weight measurements at monthly intervals were registered. Ancestors with at least two offspring are included in the relationship matrix. The variables considered in this analysis were body weight in kilograms at birth (BW), body weight in kilograms at 120 (W120) and 360 (W360) days. The actual weights measured at monthly intervals were used to obtain the animals' weight at 120 and 360 days by linear interpolation. The growth rate (kilograms) was calculated over two periods: birth to weaning (GR0–4) and from weaning to 12 months (GR4–12) from BW, W120 and W360.

Statistical analysis

The PROC GLM procedure (SAS, 1999) was used to select the main effects (sex, birth type, dam parity, year of birth and season of birth) as well as interactions that influenced the weights and growth rates. Effects that influenced the records significantly ($P<0.05$) were included in the animal model. The genetic and non-genetic effects for each of the weight and growth traits were analysed using the following animal model:

$$Y_{ijklmn} = m + \mathrm{sex}_i + \mathrm{yea}_j + \mathrm{sea}_k + \mathrm{par}_l + \mathrm{typ}_m + \mathrm{yea*sea}_{lk} + a_n + e_{ijklmn}$$

where m is the overall mean, sex_i is the fixed effect of sex (male or female), yea_j is the fixed effect of year of birth (from 1995 to 2002), sea_k is the fixed effect of season of birth (early dry (November to March), late dry (April to May) and rainy (June to October)), par_l is the fixed effect of the parity of the dam (1–6), typ_m is the fixed effect of the type of birth (single, twin, triplet), $yea \times sea_{jk}$ is the fixed effect of the year of birth by season of birth interaction, a_n is the random effect of the animal and e_{ijklmn} is the random residual error. Genetic parameters were estimated using ASREML (Gilmour et al., 2000). Bivariate analysis using the same model was used for estimating genetic and phenotypic correlations. The data structure did not allow inclusion of maternal genetic effects in the model (no pedigree information for dam). Means for estimated breeding values (EBV's) of the animals by year of birth were calculated to evaluate the genetic trends.

Results

Environmental effects

The number of animals, means, standard deviations, coefficients of variation, minimum and maximum for the different traits for West African Dwarf goat and Djallonké sheep are given in Table 1.

The average birth weights for West African Dwarf kids and Djallonké lambs were about 1.57 kg and 2.01 kg, respectively. Kids and lambs were weaned at 5.75 kg and 8.51 kg, respectively. Considerable variation for both species was observed for the body weight traits at different ages and for the growth rates during the two periods.

Table 1. Number of animals, means, standard deviations, minimum and maximum for West African Dwarf goat and Djallonké sheep.

Traits	Number	Mean	SD	Min.	Max.
West African Dwarf goat					
BW (kg)	2054	1.57	0.36	0.50	4.25
W120 (kg)	1070	5.75	1.65	2.00	11.55
W360 (kg)	925	8.04	2.46	2.60	15.48
GR0–4 (kg)	1070	4.38	1.66	0.22	10.39
GR4–12 (kg)	925	2.26	2.95	–5.98	12.83
Djallonké sheep					
BW (kg)	1329	2.01	0.48	0.70	3.30
W120 (kg)	858	8.51	2.44	2.90	19.40
W360 (kg)	494	14.79	3.22	7.00	30.20
GR0–4 (kg)	857	6.84	2.45	1.40	18.17
GR4–12 (kg)	493	3.66	1.63	–0.26	9.26

Genetic parameters

Genetic parameters with their standard deviations are shown in Table 2 for West African Dwarf goat and for Djallonké sheep. The results are discussed for both populations separately.

West African Dwarf goat

The heritability estimates for body weight in West African Dwarf goats tended to decrease with age. The heritability estimates for body weight traits were high to moderate and ranged from 0.50 for BW to 0.30 for W360. Heritabilities for growth rates were moderate for GR0–4 (0.32) and low for GR4–12 (0.11).

Table 2. Estimates of heritability (diagonal), genetic (below diagonal) and phenotypic (above diagonal) correlations, and phenotypic standard deviations between body weight and growth traits at different ages in West African Dwarf goat and Djallonké sheep.

	BW	W120	W360	GR0–4	GR4–12	σ_P
West African Dwarf goat						
BW	0.50 (0.05)	0.30 (0.03)	0.19 (0.03)	0.11 (0.03)	–0.02 (0.02)	0.097 (0.01)
W120	0.74 (0.08)	0.43 (0.07)	0.74 (0.02)	0.99 (0.01)	0.09 (0.03)	2.21 (0.11)
W360	0.73 (0.14)	n.e	0.30 (0.07)	0.72(0.02)	0.74 (0.03)	5.02 (0.26)
GR0–4	0.60 (0.11)	n.e	n.e	0.32 (0.08)	0. 10 (0.02)	2.43 (0.12)
GR4–12	0.70 (0.90)	0.92 (0.24)	0.83 (0.62)	0.85 (0.26)	0.11 (0.05)	8.26 (0.39)
Djallonké sheep						
BW	0.39 (0.06)	0.40 (0.03)	0.23 (0.04)	0.21 (0.04)	0.06 (0.05)	0.13 (0.01)
W120	0.47 (0.13)	0.54 (0.08)	0.65 (0.03)	n.e	–0.07 (0.05)	3.86 (0.23)
W360	n.e	n.e	0.21 (0.11)	0.63 (0.02)	0.82 (0.02)	7.65 (0.65)
GR0–4	0.26 (0.14)	0.98 (0.01)	n.e	0.54 (0.09)	–0.10 (0.05)	3.91 (0.23)
GR4–12	n.e	0.49 (0.30)	n.e	0.26 (0.25)	0.23 (0.10)	4.94 (0.34)

n.e = not estimable

The genetic correlations were moderate between BW and subsequent body weights. The genetic correlations were high between GR4–12 and W120 (0.92), GR4–12 and W360 (0.83) and between GR4–12 and BW (0.70). In general, the phenotypic correlations were lower compared to the genetic correlations.

Djallonké sheep

The heritability estimates for body weight traits were low to moderate and ranged from 0.21 for W360 to 0.54 for W120. Heritabilities for growth rates were moderate (0.23 for GR4–12 and 0.54 for GR0–4). There was a positive and moderate genetic correlation between BW and subsequent body weights. The genetic correlation between GR0–4 and BW (0.26) was low. In general, the genetic correlations were positive and moderate. In general, the phenotypic correlations were also low and positive compared to the genetic correlations.

Genetic trends

West African Dwarf goat

The mean EBV's of newborn individuals in the West African Dwarf goat population show an increase over time for all traits under evaluation between 1999 and 2002.

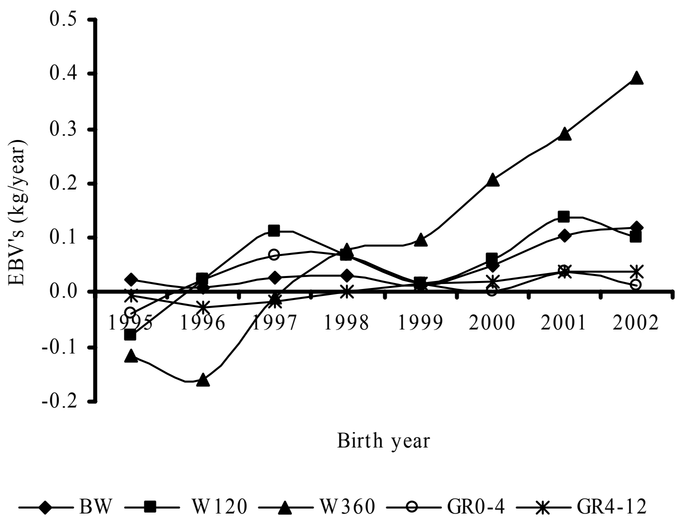

Figure 2. Trend of mean breeding values (EBV's) by year of birth observed for BW, W120, W360, GR0–4 and GR4–12 in West African Dwarf goats.

For all traits, the genetic trend was positive from 1997 onwards. EBV's for BW, W120, W360 increased by 0.01 kg, 0.02 kg and 0.08 kg per year, respectively. Pre- and post-weaning growth rate increased by 0.01 kg and 0.01 kg per year, respectively. For W360 the trends for breeding values accelerated over 1999–2002

Djallonké sheep

As for the West African Dwarf goat, the trends for breeding values for the Djallonké sheep show an increase for all traits under evaluation between 1997 and 2002. For all traits, the genetic trend was positive from 1997 onwards and irregular over the years.

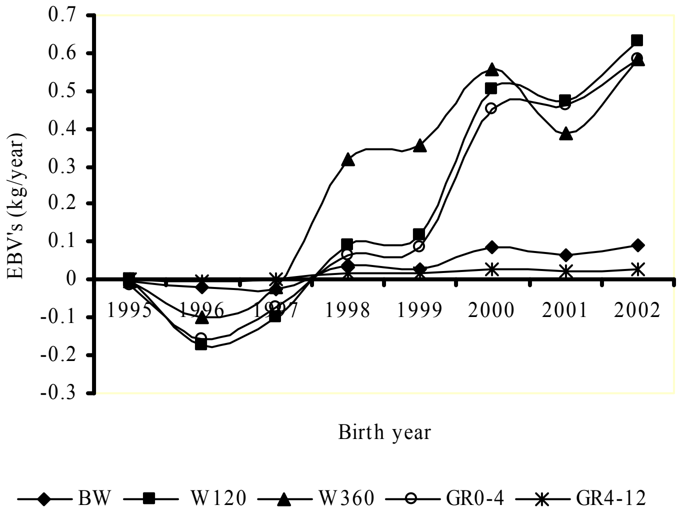

Figure 3. Trend of mean breeding values (EBV's) by year of birth observed for BW, W120, W360, GR0–4 and GR4–12 in Djallonké sheep.

EBV's for BW, W120, W360 increased by 0.01 kg, 0.11 kg, 0.09 kg per year, respectively. Pre- and post-weaning growth rate increased by 0.11 kg and 0.00 kg per year, respectively. For W360, W120 and GR0–4 the trends for breeding values accelerated over 1998–2002.

Discussion

This study reports estimates of genetic parameters for body weight and growth traits in West African Dwarf goat and Djallonké sheep. In addition, the genetic response resulting from the within-breed improvement programmes were analysed and revealed that the programme has successfully increased the performance of the indigenous populations. For some traits, genetic and phenotypic correlations could not be estimated. The reason could be due to the data structure.

Genetic parameters

Heritability

The heritability estimates for body weight and growth rate traits for both species suggested that substantial improvement could be achieved by selection. The decrease in heritability with age is probably explained by the fact that animals at later ages experience a variety of environments that may cause differences in both genetic and environmental variances. The heritability estimates for BW, W120 and GR0–4 were higher than the estimates for W360 and GR4–12. Maternal effects most likely influenced the former three traits. The heritability estimates for birth weight and weaning weight for both species were in agreement with those reported in other studies. Mbah (1988) reported a heritability of 0.33 for birth weight in Djallonké sheep. In Common African and Alpine crossbred goats, Mourad and Anous (1998) found a heritability of 0.68 for birth weight and 0.47 for weaning weight. Edriss et al. (2002) found a heritability of 0.48 for birth weight and 0.30 for weaning weight in Bakhtiari sheep. For Boer goats, Schoeman et al. (1997) reported estimates of 0.60 for weaning weight. The heritability estimate for GR0–4 was in the same range as reported for West African Dwarf goat and Djallonké sheep in Kolda, Senegal, by Clement (1999) (0.19–0.50 and 0.09–0.47, respectively) and by Mourad and Anous (1998) (0.37). The heritability estimates for GR0–4 for both species in the present study were relatively higher compared to those exhibited after weaning. The present estimates largely contradict the results reported by Inyangala et al. (1992). In that study, post-weaning growth generally had higher heritability estimates than pre-weaning growth. This contradiction can probably be explained by the inclusion of maternal genetic effects in their model. The low heritabilities found for GR4–12 indicate that environmental factors have more influence on the trait and that forage based goat and sheep production systems, like the one under study, are associated with slower weight gains. Das et al. (1996) reported that the post-weaning phase of growth in goat and sheep is a critical stage because this is the stage when there is little or no maternal protection and the kid is more exposed to environmental stress, which limits the rate of growth.

Correlations

For both species in this study, moderately positive genetic correlations between birth weight and subsequent weights were found. Mavrogenis et al. (1980) and Martinez (1983) have reported similar results. Selecting for heavier W120 in West African Dwarf goat and Djallonké possibly will result in substantial increases in BW. Increase in birth weight through direct or indirect selection is expected to lead to an undesired increase in frequency of dystocia. In order to avoid dystocia associated with increased birth weight, the emphasis should be on increasing W360 without increasing BW.

When W360 is the objective, the results show that this trait would be better because of the higher heritability. The accuracy of the estimated breeding value can be improved by replacing the selection criteria, currently GR4–12, because the heritability is only 0.11 and 0.23, respectively, for West African Dwarf goat and Djallonké sheep.

BW, W120 and GR0–4 may be candidate traits for a selection index aiming at selection for W360. The traits are moderately to highly genetically correlated with W360 implying that they are genetically similar traits and that selection could consequently be applied on either one or the other.

The total weight of offspring weaned per dam is determined by litter size and survival rate, as well as several other factors such as mothering ability, milk production of the dam and growth potential of the offspring (Snyman et al., 1997). Increasing litter size is of economic importance and deserves more attention. Genetic correlations of litter size with other traits have been reported (Hermesch et al., 2000). Although in this study, our immediate objective was not reproduction traits, under the adverse conditions where the animals live, pre- and post-weaning survival rates are definitely traits of high interest and are important traits to be considered in an index.

The phenotypic correlations between BW and other body weights showed a tendency to decrease with increasing age. This decrease between BW and weight at later ages (W120 and W360) could be partly attributed to environmental influences and partly to genetic factors. In the extensive and adverse conditions under which our animals are reared, environmental factors have a large effect on the growth of kids and lambs.

Genetic trends

Estimates of genetic trends for growth traits of West African Dwarf goat and Djallonké sheep are rare as reported by Mbah (1988) and Kosgey et al. (2005). The genetic trend evaluation gives us an indication of both breed direction and rate of improvement since the start of the genetic improvement programme. The genetic trends from 1995 to 2002 (Figs. 2 and 3) reflect effective selection for daily weight gains from 4 to 12 months of age. Since the inception of the improvement programme, positive genetic trends have been observed from 1999 onwards for most of the traits as shown in Figs. 2 and 3. The period prior to 1997 represents the period when animals were still adjusting to the new situation and when different management strategies were tested. The period post 1997 is characterised by a clear genetic improvement in West African Dwarf goat and Djallonké sheep for body weight at different ages and growth rate during different periods. As the amount of data collected increases, the accuracy of the breeding values for the weight traits will also increase over time. Consequently, genetic response was small in the initial years of 1995–1997, with much larger improvements at the end of 1997 and later. The mean genetic trends became positive in direction and for some traits accelerated (W120, GR0–4 and W360) during 1999–2002, when modern analytical methods were used for breeding value evaluation. The higher genetic trend for W360 reflects the fact that most selection weight was placed on this trait relative to other traits. The genetic trend obtained for GR0–4 compared to GR4–12 suggests greater progress in pre-weaning weight gain than post-weaning.

Conclusion

This study demonstrates that a successful breeding programme for improved growth traits in West African Dwarf goat and Djallonke sheep has been implemented. It is feasible to implement a breeding programme under village circumstances and it serves as an example for other populations and countries. This paper clearly demonstrates that genetic progress has been realised by the breeding scheme implemented by ITC. The data produced by the breeding scheme has been used for the estimation of genetic parameters for the two populations. These estimates can be used for further improvement of the selection strategy. The process of improvement should also include a discussion on the traits to be included in the breeding objective to ensure that the programme meets the needs of the local farmers.

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Chapter V

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, Nucleus scheme, N'Dama cattle

Introduction

N'Dama cattle, an indigenous cattle breed in the West African region, are 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 (Dempfle and Jaitner, 1999 unpublished; 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 (GMD, US$1=GMD28.50). Economic values were those derived by Dempfle and Jaitner (1999, unpublished) using a herd model.

Table 1. Mean (μ), phenotypic standard deviations (σ_p), heritabilities (h^2), economic values (v), genetic (below diagonal) and phenotypic (above diagonal) correlations for the individual traits.

Trait[a]	μ	σ_p	h^2	v (GMD per unit)[b]	Genetic and phenotypic correlations			
					DWG	MY	W36	MW
DWG (g/day)	126.32	66.28	0.30	0.22	–	0.62	0.20	0.23
MY (kg)	450.89	209.70	0.25	0.93	0.10	–	0.10	0.13
W36 (kg)	168.45	26.15	0.40	–	0.40	0.10	–	–
MW (kg)	202.02	29.26	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=GMD28.50.*

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, 400 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.

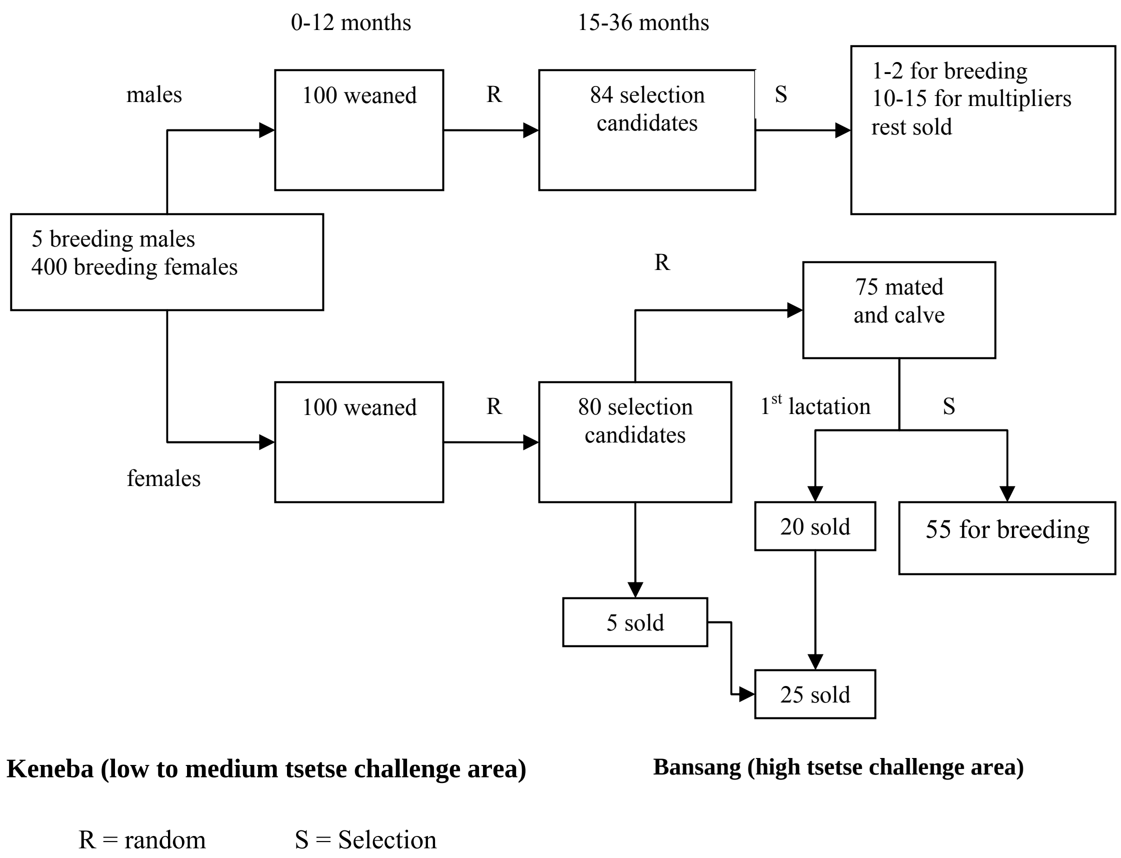

Figure 1. Simplified schematic illustration of the N'Dama cattle nucleus breeding scheme. (source: Dempfle and Jaitner, 2000).

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.

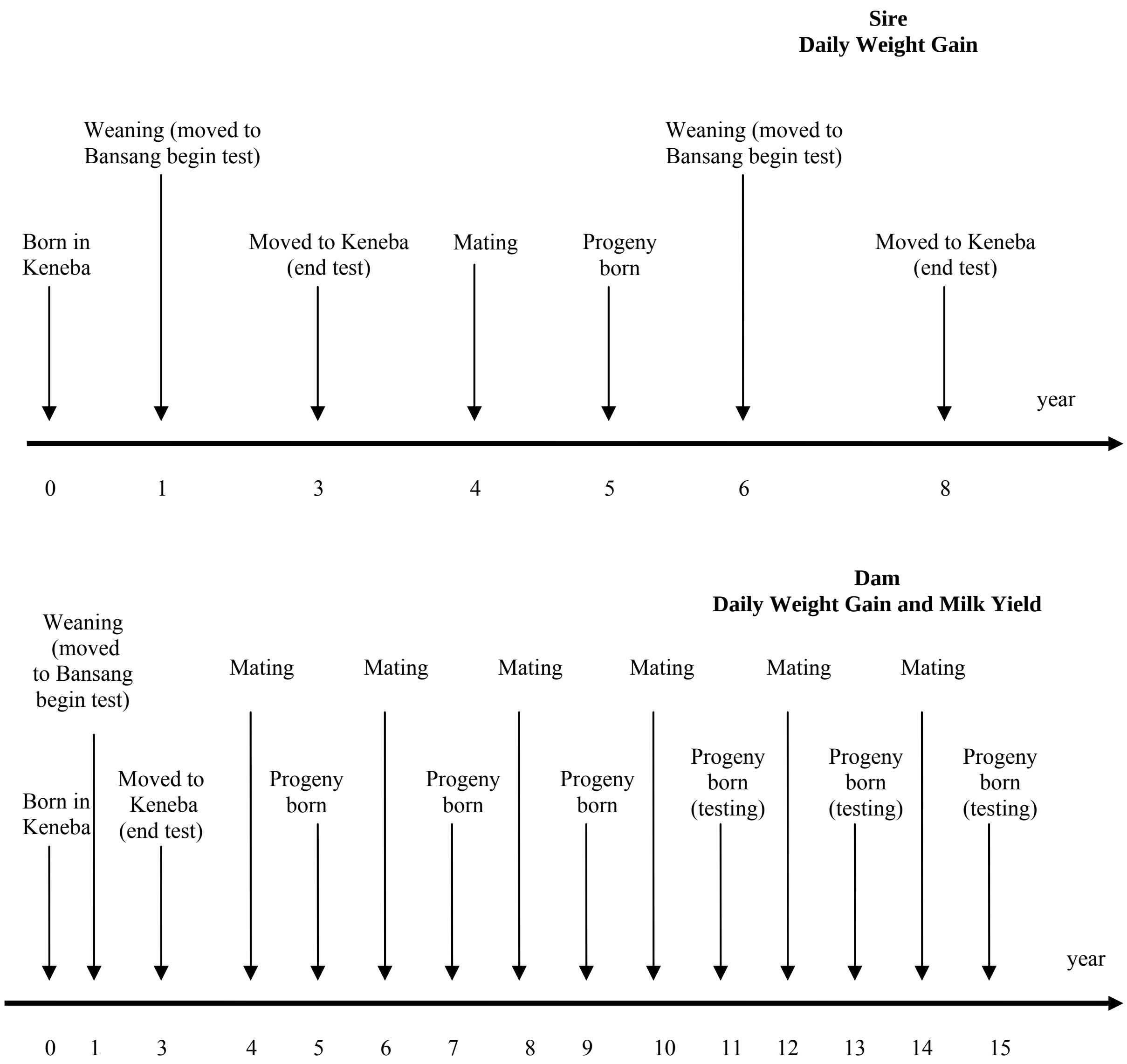

Figure 2. Overview of the type of information available for sires and dams at each age class.

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 (base situation). It was assumed that selection of males was based on 20 male 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 year, total economic response per year (GMD), 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. 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.

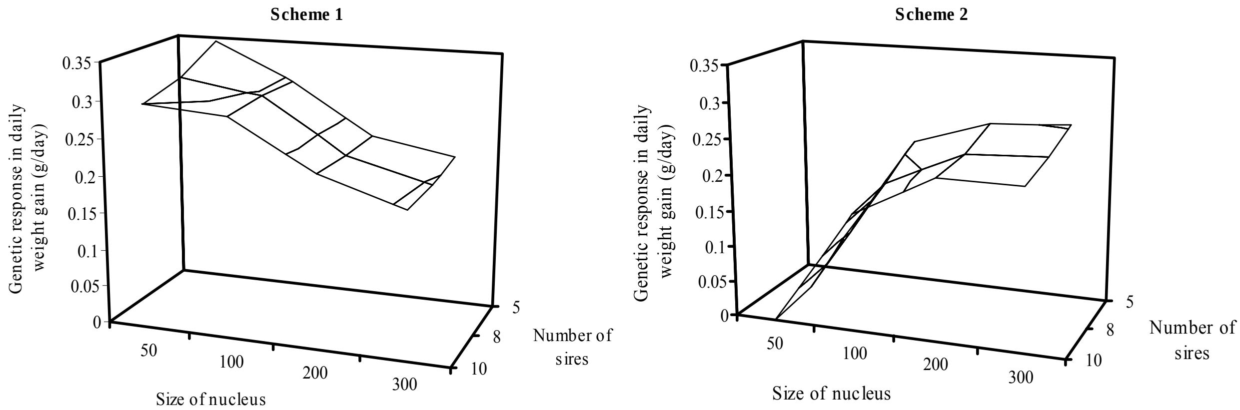

Figure 3. Effect of varying the number of sires and size of the nucleus on the genetic response per year in daily weight gain from 15 to 36 months of age under high tsetse challenge conditions (DWG) under schemes 1(base situation) and scheme 2.

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).

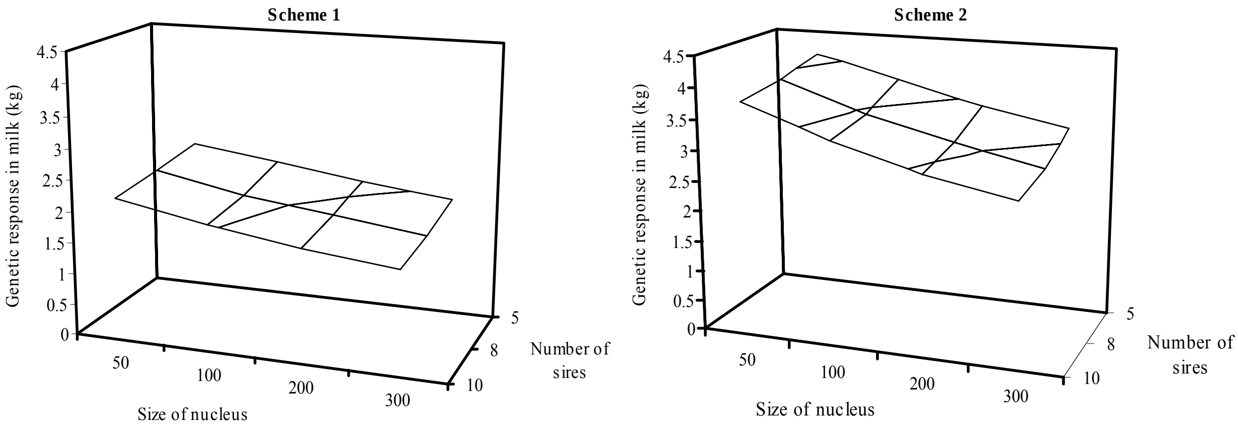

Figure 4. Effect of varying the number of sires and the size of the nucleus on the genetic response per year in milk yield (MY), milk off-take in the first 100 days of lactation under schemes 1 (base situation) and scheme 2.

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. 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.

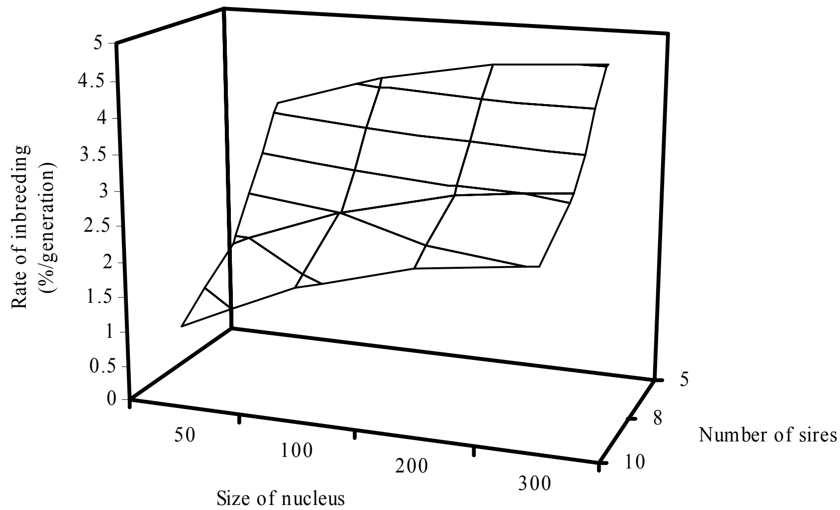

Figure 5. Effect of varying the number of sires and the size of the nucleus on the annual rate of inbreeding under scheme 1 (base situation) with non-overlapping generations.

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 (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%/generation) deserves more attention (Bijma, 2000). More breeding sires are needed to permit adequate selection intensity without increasing inbreeding. The estimate ignores the open nature of the scheme in practice. 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

In this study, alternative selection schemes for the N'Dama cattle improvement programme were evaluated for their genetic and economic efficiency. 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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Chapter VI

General Discussion

Many developing countries have adopted livestock improvement programmes based on crossbreeding with exotic imported breeds. This breeding strategy puts many indigenous livestock breeds at risk. More recently, some governments and development institutions have recognized the value of indigenous breeds and have invested in genetic improvement of indigenous animal genetic resources (AnGR). In West Africa, for example, pure breeding programmes were initiated in Senegal (1972), Guinea (1981), Côte d'Ivoire (1984) and the Gambia (1994). Kosgey et al. (2005) have summarized the experiences with small ruminant breeding programmes in the tropics. However, it remains a great challenge to ensure that farmers participate and benefit from these genetic improvement programmes. It is expected that scientific knowledge of indigenous AnGR in conjunction with government institutions and the working experiences of farmers will provide a foundation of expertise and experience that will ensure the long-term competitiveness of these indigenous livestock breeds and species. This thesis has focused on ways to better utilize local animal genetic resources by developing strategies for the implementation of improvement programmes for trypanotolerant breeds in the Gambia and in West Africa in general. The project had essentially three main objectives: (a) to summarize and evaluate the experiences gained during the development of the N'Dama cattle improvement programme; (b) to estimate the genetic variation and genetic gain realized in ongoing selection programmes for N'Dama cattle, Djallonké sheep and the West African Dwarf goat; and (c) to evaluate the current N'Dama cattle breeding scheme and investigate opportunities for further improvement.

Competitiveness of local genetic resources

Market access and favourable policy

To withstand the challenge of exotic breeds, it is important that indigenous AnGR meet the challenge of providing livestock products on the market. This concern was expressed by farmers and reported in Chapter II. The competitiveness of local indigenous AnGR is challenged due to high input costs (animal health services, milk marketing) and gradual destruction of the environment needed for production. There is, however, great scope for improving this competitiveness (Itty, 1998; Somda, 2003) in the Gambia. The marketability and commercial value of indigenous AnGR have increased since 2001 when the distribution of improved males to farmers started. Farmers purchasing males from genetically improved herds have acknowledged the benefits. The genetic improvement programme implemented in the Gambia demonstrates that a programme applied to low-input conditions can yield a substantial competitive edge and meet farmers' demand for genetically superior animals. A survey conducted in December 2003 revealed that farmers noticed an increase in their production using the acquired improved males. This helps to establish a good reputation for the programme, and consequently helps to attract other farmers and new comers into farming.

For many remote village farmers, it is still difficult to access markets. Furthermore, market facilities are in general inadequate and, when available, are poorly maintained. As a result, distortions and imperfections leading to a dwindling of the price of local indigenous AnGR on the market place occur. There is a need to invest more resources for the improvement of market access by remote farmers and build the technical and organizational capacities of local communities. With the recently created livestock farmers' associations (Chapter II), farmers in the long-term will have access to innovations, markets and services that enhance productivity and income. Experiences in other developing countries have confirmed that organized production and a farmers' community play a critical role in successful programme establishment and consolidation (Trivedi, 2002).

Shift in farmer's objectives and loss of livestock diversity

National breeding objectives largely focus on production characteristics, including milk and meat (Hoste, 2002). However, many farmers value indigenous AnGR in a different way from the primary values assigned by national agricultural policy. They remain attached to local indigenous AnGR populations that are different from the exotic ones. Farmers praise indigenous AnGR that can survive in harsh environments, feed on feeds that have low fibre content and vary in availability during the year. In addition, they pay attention to number of calves, draught power and resistance to disease challenges. In the Gambia, there is a general perceived value of the indigenous AnGR among farmers. Besides the production characteristics (i.e., milk and meat), farmers tend to put emphasis on the importance of characteristics like generation of savings, security and asset protection (Benisson et al., 1997). Breeding objectives for local indigenous AnGR need to incorporate the values and constraints that farmers encounter. The approach used by ITC in defining the breeding goal for indigenous AnGR, described in Chapter II deserves some recognition. In addition, the rapid urbanization occurring in the region is offering farmers an opportunity to produce more for the market.

When the genetic potential of a breed is thought to limit increase in milk production or increase in meat production, farmers look for alternative breeds of animals with better genetic potential. At this stage, the introduction of crossbreeds to produce for the local market becomes more tempting. The introduction of improved exotic species might lead to neglect of the indigenous AnGR in favour of the exotic ones. The resulting increase in productivity of crossbreeds is in most cases associated with an increased susceptibility to diseases, and a reduced tolerance to harsh environmental conditions, especially past the F1 generation (F2 and backcrosses). Crossbreeding is also associated with increased need for external input, specialized training and animal management. The required capital expense and amount of money needed to keep crossbred animals are very often enormous and farmers are exposed to high risks when they engage in crossbreeding. Crossbreeding might be an interesting option in some cases, but in other cases pure breed improvement schemes of indigenous breeds might be more profitable. It is important to inform government as well as farmers on the advantages and disadvantages of these different options in genetic improvement. In cases where higher yielding exotic species are available, there is widespread evidence that many farmers will continue to prefer their indigenous AnGR. This was discussed in Chapter II. Local indigenous AnGR are adapted to the different local environments and have been providing meat, milk and draught power to the farmers for a long time with minimal input and labour.

It is important to create a platform for discussion to include farmers, researchers and policy makers in order to better understand the diversity of breeding objectives. By doing so, it will be possible to bring these objectives together and eventually improve the value, the competitiveness and productivity of local indigenous AnGR.

Diversified production output

Traditional management systems are adapted to the animal characteristics and the local production circumstances. Traditionally, little emphasis was placed on genetic improvement of the local indigenous AnGR. Recently, genetic improvement of these animals has been oriented towards relatively few traits, mostly essentially milk yield and meat. It is important to recognize that the increase of production per animal without taking into account other traits might lead to deterioration of animal health, adaptability and reproductive performance. A good selection policy must consider that ignoring genetic relationships with secondary traits could cause changes in the wrong direction. The production circumstances, under which performance information on animals is collected, must be considered. The problem was highlighted in Chapter V. Here we extend the approach used in Chapter V by including productive lifetime as an additional trait in the breeding goal next to daily weight gain and milk yield. Productive lifetime is the length of the productive lifetime of a cow, i.e., the age at culling minus age at first calving. Information on this trait becomes available late in life and therefore at the time of selection most information needs to come from older relatives. In the analysis, the genetic correlation between milk yield and productive lifetime was set at –0.13 and between daily weight gain and productive lifetime at 0.10 (Sölkner, 1989; Kahi et al., 2004). The sensitivity of the selection response to changes in the economic value of milk was investigated. The effects of changing the economic value for milk yield on the genetic and economic response of daily weight gain and productive lifetime for N'Dama cattle are presented in Table 1.

Table 1. Effects of different economic values for milk yield on the genetic and economic response of daily weight gain and productive lifetime for N'Dama cattle (in the base situation).

Trait	Economic values (GMD)	Trait units	Economic units	Total economic units[a]
Daily weight gain	0.25	1.89	0.48	20.31 (100%)
Milk yield	1.86 (100%)	11.35	21.10	
Productive lifetime	11.58	–0.11	–1.27	
Daily weight gain	0.25	3.86	0.97	19.75 (97.8%)
Milk yield	0.93 (50%)	10.10	9.35	
Productive lifetime	11.58	0.00	0.00	
Daily weight gain	0.25	6.46	1.62	14.64 (72.1%)
Milk yield	0.47 (25%)	5.76	2.71	
Productive lifetime	11.58	0.19	2.21	

[a]*The total economic response was calculated from the genetic response in the different traits and using economic value for milk of 1.86 in all three situations.*

The current economic weights (100%) result in a positive genetic response in milk yield (+11.35 kg), a small but positive genetic response in daily weight gain and a negative genetic response in productive lifetime. When the economic value of milk production is halved (50%), the response in growth rate increases and the genetic level for productive life remains unchanged. This illustrates that, by changing the relative emphasis of traits in the breeding goal, a more balanced improvement of production and other traits can be reached.

Halving the economic value for milk leads to an 11.01% lower response in milk yield. The total economic response is only reduced by 2.8%. A further reduction of the economic value of milk to 25% leads to a favourable response in productive life but a larger (27.9%) reduction in total economic response. Changing the economic weights of traits in the breeding goal influences the response in the traits as well as the total response. In the above example, the economic value for productive life was positive in all cases but a positive selection response in productive life is expected only in the case of a low economic value. This illustrates that discussions with farmers on the desired direction of change of a population should focus on the expected response in the different breeding goal traits rather than the economic values.

Perspectives

Genetic parameters and trends

The development of a consistent breeding strategy relies on accurate estimates of the genetic parameters of important economic traits (Harris et al., 1984). Chapters III and IV present estimates of genetic parameters and genetic trends of N'Dama cattle, West African Dwarf goats and Djallonké sheep for weight and growth traits. These genetic parameters and trends give an indication of the ability of these local indigenous breeds to respond to selection and their potential to evolve in their own natural environment. The genetic evaluations currently used at ITC will be improved by using the breed specific estimates of the genetic parameters. This will lead to more accurate selection of breeding males for nucleus breeding as well as dissemination to multipliers and commercial farmers. Furthermore, information on the genetic parameters will help in making decisions for breeding scheme design. They provide useful information on the genetic variability within the indigenous population. It is of interest also to increase the knowledge of genetic parameters for other important traits, namely feed intake, disease resistance and milk production (quantity and quality). There is a need to fill this knowledge gap to ensure the development of balanced genetic improvement programmes for the breeds.

Estimation of the genetic trends played an important role in evaluating the results of the selection practiced in the different breeding schemes. The results presented in Chapters III and IV reflect the rate of improvement realized in the different breeds. Since the inception of the improvement programme, the trends for most of the traits evaluated show that selection is in the desired direction. Clear improvements have been realized in the traits under selection. The results obtained in Chapter V also indicate that the effectiveness of the selection scheme implemented could be increased. The genetic parameters estimated, and presented in Chapter II, were used for the prediction of the expected genetic response for the N'Dama cattle selection scheme, which addresses the current demand for meat and milk. These results aimed at improving the breeding plan in order to obtain an optimum genetic gain and thereby to increase the efficiency of production in local farms.

Selection on growth performance should include the clear influence of season. It is important to pay attention to growth during the dry and the wet season to ensure that the ability of animals to handle harsh environments does not deteriorate as a consequence of selection on final weight.

Information for policy and capacity building

The West African region is experiencing a fast population growth and urbanization, leading to spectacular increases in the demand for food, especially livestock products (i.e., milk and meat) (Delgado et al., 1999). Policy makers are faced with these challenges in dealing with demographic issues, indicating the necessity to increase livestock production without essentially increasing the number of animals. Increasing the number of animals will affect not only individual animal performance but also the production area (land). Genetic improvement, through selection, of local indigenous AnGR represents an important opportunity to improve the productivity of animals. However, policy makers are at the same time confronted with difficulties in obtaining the information on local indigenous AnGR necessary to guide decision making for genetic improvement activities (Rege et al., 2002). The experience gained during the development and execution of the N'Dama cattle improvement programme at ITC is presented in Chapter II, and recommendations to strengthen the implementation process were made. The analysis in this thesis indicates the success of the programme in generating genetic progress and in farmer satisfaction. This demonstrates that improvement of indigenous AnGR can be achieved. This serves as a proof of principle and should influence the people responsible for making decisions regarding funding of genetic improvement programmes for local indigenous AnGR. The breeding programme of ITC has generated genetic improvement and thereby improved the use of local indigenous AnGR by farmers. Improving the utilization of local indigenous AnGR should be the ultimate purpose of conserving diversity of genetic resources.

The results presented in Chapter II can be used, coupled with proper training activities, communication and extension, to improve the decision making of local farmers, and hence, the overall profitability of their individual farms. There is a recognized training need for technicians, extension workers and also for farmers. Presently, farmers mainly obtain their breeding and selection expertise from family experience, short workshops and interaction with other farmers. They need to be aware of what genetic changes can achieve and how this can occur. The experiences from the ITC programme suggest that these training programmes need to be made more participatory, problem-oriented and practical.

Genetic improvement programme as a business

Genetic improvement programmes are handicapped by being long term and expensive. Results from selection in the nucleus today will take a number of years before it is expressed in a multiplier or even commercial herds. To achieve a long-term genetic improvement programme, sustained funding over a long period of time is necessary. Farmer associations alone can currently not meet the costs involved in the implementation of genetic improvement programmes. Therefore, financial support from external sources will continue to be most essential. As ultimate beneficiaries and in order to be able to claim ownership of the genetic improvement programme, farmer associations need to get financially organized and independent. This represents a huge challenge for the future, but farming, like any other business, involves financial risks. Farmer associations will be exposed to challenges in ensuring the continuity of the genetic improvement programme and in sourcing the capital necessary to operate and maintain the programme. To address the financial concerns, the advisory services of a professional experienced management company or consultant could help to secure finances. A professional manager could be of assistance in making key decisions about the future direction of the genetic improvement programmes by providing financial management, planning and counselling to farmer associations.

Markers for trypanotolerance

Much work has been devoted to finding genetic markers for trypanotolerance. In 1989, the International Livestock Research Institute (ILRI) launched a major international effort to identify and map trypanotolerance genes and to understand their interactions

(Hanotte et al., 2003). Markers linked to trypanotolerance genes will facilitate more efficient selection of the trypanotolerance genotype and therefore enable breeders to ensure that the frequency of desirable alleles at the trypanotolerance genes is improved in the nucleus breeding population. Furthermore, the markers can be used to ensure that animals used for dissemination carry the desirable alleles. The efficiency of using markers in a selection programme has been demonstrated in mice (Koudandé et al., 2005). It remains to be seen how these identified genes can be best exploited in a practical genetic improvement programme and how the knowledge of individual genes will influence an improvement programme for quantitative traits (Koudandé, 2000). A major difficulty is that a pool of genes is involved in the expression of trypanotolerance. Among the genes involved, it is also currently not known which is the most important one to select for within a pure bred population (Van der Waaij, 2001).

Regionalization of genetic improvement programmes

Genetic improvement of indigenous AnGR and promotion of their use among local producers is considered an important component of the development of a viable livestock production industry. Improvement programmes should be regionalized to enhance farmer's access to improved germplasm. The ITC genetic improvement programme is established and functioning, and could serve as a model for low-input improvement programmes in low and medium livestock production systems in the West African region. Each local government of the region should be invited and encouraged to take the necessary steps with the active involvement of the national institutions concerned (i.e., governmental and non-governmental organizations (NGOs) and farmers' livestock associations) to set up a genetic improvement programme. The efforts should, however, be effectively co-ordinated centrally by an institution and collaboration between countries needs to be encouraged. The ITC or the Centre International de Recherche Développement sur l'Élevage en zone Subhumide (CIRDES) are potential candidates to play that co-ordinating role. Co-ordination is important for providing effective support for the National Agricultural Research Services (NARS) partners, and also ensures a link with other regional and global programmes on indigenous AnGR. The regionalization of the genetic improvement programmes could, for example, help to set up an across country herd book for N'Dama cattle, Djallonké sheep and West African Dwarf goats. It could also serve to exchange improved males and reduce risks in case of severe disease outbreaks or other natural disasters like drought. Regionalized improvement programmes could also be a tool to address the wide range of physical environments, distinct constraints and diverse market requirements. However, potential negative aspects of more sophisticated breeding programmes should be carefully monitored, for instance, to avoid the spread of undesirable single genes through extreme use of sires with the highest breeding values (Juga, 2002). Breeding goals will tend to be much more regionally focused but, in general, will include a broader range of important traits geared towards answering the huge demand for food in the region.

Conflicts with conservation of genetic resources

The goal of maintaining the breeds without selection may conflict with that of genetic improvement (Czech et al., 2000). In case of conservation, animals are preserved with their potential economic value and their unique biological characteristics. In other words, this conservation alternative will involve keeping domestic animal herds without major genetic changes for many generations. But can West African countries afford the cost of simply preserving the breed? The main problem with this conservation alternative is that given the economic situation in the West African region, maintenance of animals without improvement is not profitable for the local situation. Genes in the population do not stand still and, furthermore, there is an overall emergency to meet the increasing regional demand for meat and milk products, to improve efficiency of feed utilization and minimize land degradation. It is difficult to see how such aims can be achieved without further improvement in the productivity of the local indigenous species, which includes genetic improvement.

This thesis has demonstrated that there are good prospects for better utilization of local indigenous AnGR in West Africa. The knowledge will support ways of utilizing local indigenous AnGR which indirectly also leads to conservation. The available information needs to be converted into a form that is both user-friendly and easy to access at all levels. There are indications that there is a viable market for breeding animals, but further improvement and additional information on markets is needed to support policy makers and farmers in their decision making. It remains a challenge to convince farmers that local indigenous AnGR are a valuable resource. Evaluation of the results of the improvement programmes as conducted in this thesis will help to convince farmers. Furthermore, it is important to remain focused on the genetic improvement of local indigenous AnGR and to encourage farmers to use the breeds as a viable alternative to increase their competitiveness.

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Summary

Summary

Improving the productivity of indigenous breeds by genetically making them more efficient for the continuously changing conditions is important. This improvement ultimately aims at contributing to poverty alleviation and food security of the rural poor. Lack of knowledge remains a major limitation to genetically improve local indigenous breeds effectively. It also limits the decision-making capability of national, regional and international implementing agencies. This thesis has focussed on ways to better utilize local animal genetic resources (AnGR) by developing strategies for the implementation of improvement programmes for trypanotolerant breeds in The Gambia and in West Africa in general. The project had essentially 3 main objectives: (a) to summarise and evaluate the experiences gained during the development of the N'Dama cattle improvement programme; (b) to estimate the genetic variation and realised genetic gain in ongoing selection programmes in N'Dama cattle, Djallonké sheep and West African Dwarf goat; and (c) to evaluate the current N'Dama cattle breeding scheme and investigate opportunities for further improvement.

Genetic improvement of local breeds through selection is an essential avenue to improve productivity. This is especially true in the West African sub-humid zones where trypanotolerant breeds, living in harsh environments, have proved to be more productive than previously thought. **Chapter II** reviews the successful N'Dama cattle genetic improvement programme implemented, in a low input production system, at the International Trypanotolerance Centre (ITC) in 1994, in The Gambia. Based on published and unpublished information, the experience gained from achievements during the development of the improvement programme is presented. The first part of the chapter presents the genetic improvement programme including the breeding objective, the selection criteria, the genetic evaluation system used and the design of the three-tiered pyramidal structure for dissemination of genetic progress. The second part deals with the analysis of the genetic improvement programme. The N'Dama cattle improvement programme implemented demonstrates that genetic improvement programmes in the context of sustainability within the low input production system is feasible. The feasibility of the programme is expressed through the genetic progress achieved and transmitted to the farmers and through the involvement of farmers and farmer's communities. It is recommended to strengthen the involvement of local farmers via their associations and to

intensify the training and capacity building activities for further development of the programme. In addition financial security is important for the long term sustainability of the programme.

The development of a consistent breeding strategy relies on accurate estimates of genetic parameters. In **Chapter III** and **IV** heritabilities and correlations for growth traits were estimated and genetic trends evaluated in N'Dama cattle, West African Dwarf goat and Djallonké sheep under tsetse challenge.

The results of the estimation of the genetic parameters for growth traits in N'Dama cattle are presented in **Chapter III**. N'Dama calves were born and weaned in a low to medium tsetse challenge area and after weaning at 12 months of age transported to a high tsetse challenge area until three years of age. Measurements included body weights and growth rates during seasons from 12 to 36 months. Two seasons were defined, the dry season from November to June forming the period of feed shortage and low tsetse fly density; and the wet season from June to November where sufficient feed was available and the tsetse density was the highest. The traits were analysed using an animal model. Heritabilities for body weights ranged from 0.28 for body weight at 36 months to 0.48 for body weight at 15 months. For growth rate during the dry season, the heritability was 0.09 and for growth rate during the wet season 0.15. Genetic correlations of birth weight with body weight at 12, and 15 months were moderately high (0.49 and 0.51, respectively). Genetic correlations between most body weights and growth rates during seasons ranged from -0.40 to 0.80. The genetic trend due to the selection programme was highest for body weight at 36 months from 1994 to 2004. For growth traits, an increasing genetic trend was observed in growth between 15 months and 36 months and in growth during the dry season from 12 to 36 months. It was concluded that selection for growth should focus on growth during dry and wet season. Selection on growth performance should better include the clear influence of season, and thus on the genetic background to cope with the season. Further studies need to be conducted to assess the economic importance of the trait.

The results of the estimation of the genetic parameters for growth traits in West African Dwarf goat and Djallonké sheep are presented in **Chapter IV**. The improvement programme for West African Dwarf goat and Djallonké sheep was initiated by the International Trypanotolerance Centre in 1995. The breeding goal is to increase the efficiency of production (meat) and the improvement of the trypanotolerance of the animals. To achieve the set goal, selection is based on estimated breeding values for daily weight gain from 4 to 12 months of age. Data of West African Dwarf goat and Djallonké sheep on birth weight (BW), weaning weight (W120), yearling weight (W360), pre-weaning (GR0-4) and post-weaning (GR4-12) growth rate, were analysed using an animal model. Estimates of heritability for BW, W120, W360, GR0-4 and GR4-12 were 0.5, 0.43, 0.30, 0.32 and 0.11 for goats and 0.39, 0.54, 0.21, 0.54 and 0.23 for sheep respectively. The genetic correlation between BW and W120 were high for goats (0.74) and moderate for sheep (0.47). Genetic correlations between W120 and GR4-12 were high (0.92) for goats and moderate (0.49) for sheep. Between GR0-4 and BW the correlation was positive but low for sheep (0.26) and moderate for goats (0.60). Positive trends were found in mean estimated breeding values for animals born in the period 1995 to 2002. This study demonstrates that the implementation of a breeding programme under village circumstances is feasible and it serves as an example for other populations and countries. This paper also clearly demonstrates that genetic progress has been realised by the breeding scheme implemented by ITC. These estimates can be used for further improvement of the selection strategy. The process of improvement should also include a discussion on the traits to be included in the breeding objective to ensure that the programme meets the needs of the local farmers.

The N'Dama cattle breed is being utilized 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. In **Chapter V**, 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 the 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.

In **Chapter VI** results presented in C**hapter II** to **V** are used to discuss possibilities to better utilize local animal genetic resources. The genetic improvement programmes could serve as a model for low cost breeding schemes in low and medium livestock production systems in the West African region. It is essential that public resources support these programmes in terms of staff training, personnel and running costs at the nucleus level. Estimates of genetic parameters for growth traits obtained are important. They, additionally, give an indication of the ability of the indigenous breeds to respond to selection and thus their potential to evolve in their own environment. They contribute to the better understanding of these breeds consequently a better utilization of local genetic resources. The selection policy should be aimed at a balanced improvement of production and functional traits in order to avoid deterioration and possibly improve functional traits. Discussions with farmers on desired direction of change of a population should focus on the expected response in the different breeding goal traits rather than the economic values. Farmers need access to competitive markets, for many of them; it is still difficult to access markets.

This thesis demonstrated that there are good prospects for better utilization of local indigenous AnGR in West Africa. It is important to remain focused on the genetic improvement of local indigenous AnGR and to encourage farmers to use the breeds as a viable alternative to increase their competitiveness.

Samenvatting

Verbetering van de productiviteit van lokale rassen door selectie neemt een plaats in in de ontwikkelingsstrategie van de dierlijke productie in West Afrika. Deze verbetering beoogt uiteindelijk bij te dragen aan armoedevermindering en voedselveiligheid van de landelijke bevolking. Toch is de kennis over de fokkerij die onder tropische omstandigheden met over het algemeen slechte infrastructuur kan worden uitgevoerd zeer beperkt. In ontwikkelingslanden, zijn in het verleden een aantal ontwerpen voor de verbetering van lokale rassen voorgesteld. Deze ontwerpen zijn wegens technische en sociale beperkingen niet succesvol geweest.

Dit proefschrift bouwt voort op succesvol lopende selectieprogramma's die door het International Trypanotolerance Centre (ITC) in Gambia, worden gecoördineerd.

Het project is gericht op een beter gebruik van lokale rassen door het ontwikkelen van optimale strategieën voor selectieprogramma's voor trypanotolerante rassen in West-Afrikaanse landen. Het project had drie belangrijke doelstellingen: (a) het evalueren van de huidige staat van kennis en de ervaring opgedaan tijdens de ontwikkeling van het N'Dama selectieprogramma; (b) het schatten van de genetische variatie en de gerealiseerde genetische vooruitgang in lopende selectieprogramma's in N'Dama rundvee, Djallonké schapen en de West Afrikaanse Dwerggeit; (c) het evalueren van de huidige N'Dama selectiestrategie en het optimaliseren daarvan door een vergelijking van alternatieven met de huidige selectiestrategie.

De genetische verbetering van lokale rassen door selectie is een essentiële weg om productiviteit te verbeteren. Dit is vooral waar in de West Afrikaanse subtropische streken waar de trypanotolerant rassen, die onder zware omstandigheden leven, productiever zijn gebleken dan eerder gedacht. De studie gepresenteerd in **Hoofdstuk II** evalueert het succesvolle N'Dama selectieprogramma dat in 1994 in een systeem met lage productie input werd geïnitieerd op het International Trypanotolerance Centre (ITC) in Gambia. Gebaseerd op gepubliceerde en ongepubliceerde informatie, worden de ervaringen opgedaan tijdens de ontwikkeling van het verbeteringsprogramma uiteengezet. In het eerste deel van het hoofdstuk wordt het selectieprogramma uiteengezet met het gebruikte fokdoel, de selectiecriteria, het genetische evaluatiesysteem en het ontwerp van de piramidale structuur voor de verspreiding van de genetische vooruitgang. Het tweede deel behandelt de analyse van het selectieprogramma. Er wordt aangetoond aan dat de selectieprogramma's in de context van duurzaamheid binnen een systeem met lage productie input uitvoerbaar zijn. De haalbaarheid van het programma wordt getoetst door de genetische vooruitgang, hoe die aan de boeren wordt overgebracht en door de betrokkenheid van boeren en de boeren verenigingen. Het wordt geadviseerd om de betrokkenheid van lokale boeren via de verenigingen te versterken en de opleiding en de capaciteitsopbouw activiteiten voor zowel uitvoering als verdere ontwikkeling van het programma te intensiveren. Een belangrijk punt is ook een manier te vinden om financiële veiligheid van het programma te verzekeren.

Bij de ontwikkeling van een fokkerijstrategie zijn nauwkeurige schattingen van genetische parameters belangrijk. Hoofdstuk III en IV presenteren de schattingen van de genetische parameters en genetische vooruitgang voor groei kenmerken onder tsetse infectiedruk voor de N'Dama, de West Afrikaanse Dwerggeit en Djallonké schapen.

Het doel van **Hoofdstuk III** was om de informatie die beschikbaar was van het N'Dama selectieprogramma te gebruiken om genetische parameters voor de groei kenmerken te schatten en genetische vooruitgang te evalueren. Daarvoor werd een diermodel gebruikt. Erfelijkheidsgraden en de correlaties voor de groei kenmerken werden onder tsetse infectiedruk geschat. De dieren zijn geboren en gespeend in een gebied waar het niveau van tsetse infectiedruk laag tot middelhoog was. Na het spenen werden de dieren vervoerd naar een gebied met hoge tsetse infectiedruk, waar ze bleven tot ze drie jaar oud waren. De observaties omvatten lichaamsgewicht en groei tijdens de seizoenen tussen spenen (12 maanden) en 36 maanden. Twee seizoenen werden gedefinieerd: Het droge liep van november tot juni en werd gekarakteriseerd door een piek van voertekort en een lage tsetse vliegdichtheid. Het natte seizoen liep van juni tot november en werd gekarakteriseerd door voer beschikbaarheid en de hoogste tsetse vliegdichtheid. De erfelijkheidsgraden voor lichaamsgewichten varieerden van 0.28 (voor lichaamsgewicht bij 36 maanden) tot 0.48 (voor lichaamsgewicht bij 15 maanden). Voor de groei tijdens seizoen varieerde de erfelijkheidsgraad van 0,09 (groei tijdens het droge seizoen) tot 0,15 (voor groei tijdens het natte seizoen). De genetische correlaties van geboortegewicht met lichaamsgewicht bij 12 en bij 15 maanden waren matig hoog (respectievelijk, 0.49 en 0.51). De genetische correlaties tussen de meeste lichaamsgewichten en de groei tijdens seizoenen varieerden van -0.48 tot 0.98. Genetische vooruitgang was het hoogst voor lichaamsgewicht bij 36 maanden vanaf 1994 tot 2004. Voor de groeikenmerken werd een stijgende genetische vooruitgang waargenomen in de groei tussen 15 maanden en 36 maanden en in de groei tijdens het droge seizoen van 12 tot 36 maanden. Seizoen heeft een duidelijk effect op groeiprestatie en daarom werd er geconcludeerd dat selectie voor groei zich op de groei tijdens droog en nat seizoen zou moeten concentreren. Verdere studies moeten worden uitgevoerd om het economische belang van het kenmerk te beoordelen.

Het doel van de studie in **Hoofdstuk IV** was om de genetische parameters en genetische vooruitgang voor groeikenmerken voor de West Afrikaanse Dwerggeit en Djallonké schapen te schatten. Het fokprogramma dat opereert onder een systeem met lage productie input werd door het International Trypanotolerance Centre in 1995 in werking gesteld. Het fokdoel is het verhogen van de efficiency van productie (vlees) en de verbetering van de trypanotolerance van de dieren. Om het vastgestelde doel te bereiken, is de selectie gebaseerd op geschatte fokwaarden voor dagelijkse gewichtstoename vanaf 4 tot 12 maanden leeftijd. De gegevens van de West-Afrikaanse Dwerggeit en van de Djallonké schapen uit het lopende fokprogramma werden gebruikt om genetische parameters en genetische vooruitgang te schatten. Er is gebruikt gemaakt van een diermodel. De te onderzoeken kenmerken waren geboortegewicht, speengewicht (120 dagen), eenjarig gewicht, groei tot spenen en groei na spenen. De erfelijkheidsgraden voor geboortegewicht, speengewicht, eenjarig gewicht, groei tot spenen en groei na spenen waren respectievelijk 0.5, 0.43, 0.30, 0.32 en 0.11 voor geiten en 0.39, 0.54, 0.21, 0.54 en 0.23 voor schapen. De genetische correlatie tussen geboortegewicht en spenen gewicht was hoog voor de geiten (0.74) en matig voor de schapen (0.47). De genetische correlatie tussen speengewicht en groei na spenen was hoog (0.92) voor de geiten en middelmatig (0.49) voor de schapen. Tussen groei voor spenen en geboortegewicht was de correlatie positief maar laag voor de schapen (0.26) en middelmatig voor de geiten (0.60). De genetische vooruitgang voor dieren geboren tijdens de periode 1995 tot 2002 was positief. Deze studie toont aan dat het opzetten van een fokprogramma onder dorpsomstandigheden uitvoerbaar is en dat het als voorbeeld kan dienen voor andere rassen, diersoorten en landen. De studie toont duidelijk aan dat genetische vooruitgang door het fokprogramma gerealiseerd is. De genetische parameters kunnen worden gebruik voor verdere verbetering van de selectiestrategie. Het proces van verbetering zou ook een evaluatie moeten omvatten van de kenmerken die moeten worden gebruikt om ervoor te zorgen dat het programma aan de behoeften van de lokale boeren voldoet.

De N'Dama wordt gebruikt in lage input productiesystemen en het is essentieel om alternatieven te evalueren om een verdere ontwikkeling van het fokprogramma te steunen en, indien nodig, het door opname van alternatieve kenmerken te verbreden. In **Hoofdstuk**

V zijn gegevens van het N'Dama nucleus fokprogramma gebruikt om het huidige selectieprogramma te evalueren en optimaliseren door de huidige selectiestrategie met alternatieven te vergelijken. Een deterministisch simulatiemodel werd gebruikt om de genetische en economische voordelen van verschillende fokprogramma's aan te tonen. Het fokdoel bestond uit dagelijkse gewichtstoename (van 15 tot 36 maanden oud in een gebied gekarakteriseerd door een hoge tsetse infectiedruk, in g/dag) en melkopbrengst (melkafzet in de eerste 100 dagen van de lactatie, in kg). Een wezenlijke genetische respons van 3,40 kg per jaar in melkopbrengst en 0,25 g/dag in gewichtstoename zou kunnen worden bereikt. Resultaten van de simulatie toonden aan dat vroege selectie van nucleus vaders in hogere genetische en economische resultaten resulteerde in vergelijking met alle andere onderzochte alternatieven. Voor een praktisch fokprogramma (laag input productie systeem), zou het alternatief gebaseerd op vroege selectie van nucleus vaders moeten worden geadviseerd omdat dit tot de beste verbeteringen van het algemene resultaat leidt.

In **Hoofdstuk VI** zijn resultaten uit hoofdstuk II tot en met V gebruikt om lokale dierlijke genetische voorraden optimaal te gebruiken. De genetische parameters verkregen voor de groeikenmerken zijn belangrijk. Zij geven een aanwijzing van de capaciteit van de inheemse rassen om op selectie te reageren en zo hun potentieel in hun eigen milieu te verbeteren. Zij dragen door het betere begrip van deze rassen bij tot een beter gebruik van lokale genetische voorraden. De evaluatie van de genetische vooruitgang geeft een aanwijzing van zowel richting als niveau van verbetering en zal zeker de genetische verbeteringsprogramma's vooruit helpen. Het is over het algemeen bekend dat vermindering van de diversiteit van genetische voorraden leidt tot versmalling van de gelegenheid om op veranderingen in het milieu door ziektedruk of stress te reageren. Daarom zou de technologische ontwikkeling op een evenwichtige verbetering van productie en functionele kenmerken moeten worden gericht om verslechtering te vermijden en misschien functionele kenmerken te verbeteren. De boeren hebben toegang tot concurrerende markten nodig. Voor vele boeren, is het nog moeilijk om toegang tot markten te hebben, daarom is een belangrijke doelstelling de stabiliteit van productie te verbeteren en daardoor risico te verminderen om de voedselveiligheid en het welzijn van producenten huishoudens te verhogen. De fokprogramma's zouden in elk land van West Afrika moeten worden gedecentraliseerd naar waar de verschillende rassen en soorten bestaan.

Deze scriptie heeft uitgewezen dat er goede vooruitzichten voor een beter gebruik van de lokale dierlijke genetische voorraden in West Afrika zijn. Het is belangrijk om geconcentreerd te blijven op de genetische verbetering van deze lokale dierlijke genetische voorraden en om veehouders te stimuleren om deze rassen als levensvatbaar alternatief te gebruiken om hun concurrentievermogen te verhogen. Het programma van genetische verbetering kan als model voor de dierlijke productie in de lage of gemiddelde inputsystemen in West Afrika dienen. Het is essentieel dat de overheid en de public sector dit programma ondersteunen door opleiding van het personeel te stimuleren, en door in de kosten op het niveau van het nucleus selectieprogramma bij te dragen.

Résumé

L'amélioration de la productivité des ressources génétiques animales locales par voie de sélection occupe une place de choix dans la stratégie de développement des productions animales en Afrique de l'Ouest. Cette amélioration vise à contribuer, entre autre, à l'allègement de la pauvreté et à accroître la sécurité alimentaire des populations rurales. En Afrique de l'Ouest, un certain nombre de programmes d'amélioration génétique a été suggéré pour l'amélioration génétique des ressources génétiques animales. Ces actions d'amélioration génétique ont été essentiellement mises en oeuvre en station avec très souvent une infrastructure généralement légère. Les résultats démontrent que l'exécution de ces schémas de sélection s'est rarement traduite par des impacts concrets sur le terrain. Les efforts mis dans ces différents programmes d'amélioration génétique n'ont pas entièrement été couronnés de succès en raison de lacunes aussi bien techniques que sociales. Cette thèse s'appuie sur l'analyse des programmes de sélection en cours d'exécution par le Centre International pour la Trypanotolérance (ITC) en Gambie. Elle a pour objectif de répondre aux différents besoins (paramètres génétique, optimisation des schémas de sélection) dans le domaine de la conception et de la mise en place des programmes d'amélioration génétique des ruminants (bovins, caprins, ovins) à travers l'analyse d'expérimentations en cours et par l'évaluation des différentes stratégies de sélection disponibles. Cette thèse vise en général une meilleure utilisation des ressources génétiques animales locales en développant des stratégies optimales pour la mise en application des programmes d'amélioration génétique élaborés pour les races trypanotolérantes dans la région Ouest Africaine. Elle a essentiellement trois objectifs majeurs à savoir: a) synthétiser les connaissances et l'expérience acquise lors de la mise en application et pendant le développement du programme d'amélioration génétique du bétail N'Dama; b) estimer les variations génétiques et évaluer les gains génétiques réalisés dans les différents programmes de sélection bovin (N'Dama), ovin (Djallonké) et caprin (chèvre naine d'Afrique occidentale); et c) évaluer l'actuel schéma de sélection du bétail N'Dama et l'optimiser à l'aide d'une comparaison avec différentes stratégies de sélection.

Le maintien et l'accroissement de la compétitivité dans le secteur de la production animale passe nécessairement par une accentuation des efforts relativement aux enjeux touchant l'amélioration génétique. La sélection comme voie d'amélioration génétique, permet une amélioration progressive et continue de la productivité des races locales, ceci est particulièrement valable dans la zone sub-humide Ouest Africaine. Dans cette zone, les races d'animaux trypanotolérants vivant dans un environnement rustique se sont avérées être plus productives que précédemment supposé. **Le Chapitre II** se donne pour objectif de passer en revue le programme d'amélioration génétique du bétail trypanotolérant N'Dama. Le programme a été mis en application en 1994 et opère dans un système de production à faibles intrants. Basée sur des documents publiés et non publiés, l'expérience acquise pendant le développement et au cours de l'exécution du programme est présentée. La première partie du chapitre fait découvrir le programme d'amélioration génétique comprenant: les objectifs de sélection, les critères de sélection, le système d'évaluation génétique utilisé et la conception de la structure pyramidale à trois niveaux permettant la diffusion du progrès génétique obtenu. La seconde partie traite particulièrement de l'analyse du programme. Cette analyse se base sur le progrès génétique obtenu et les bénéfices que peuvent en tirer les éleveurs. Pour conclure, certaines recommandations pour la consolidation du programme sont proposées. Le programme d'amélioration de la race N'Dama mis en application démontre l'intérêt de maintenir et de valoriser les ressources génétiques locales, compte tenu de leurs caractéristiques zootechniques, pour le développement de systèmes durables d'élevage à faibles intrants en zone tropicale. Le programme se veut pratique premièrement grâce aux progrès génétiques réalisés et communiqués aux éleveurs et communautés d'éleveurs, ensuite grâce aux bénéfices engendrés pouvant répondre aux besoins de ces différents éleveurs. Il est recommandé de renforcer la participation des éleveurs locaux par l'intermédiaire d'associations d'éleveurs et d'intensifier les activités de formations et de renforcement des capacités pour le développement futur du programme. En outre un point important mérite d'être souligné, c'est de pouvoir trouver les moyens d'assurer la sécurité financière du programme.

Le développement d'une stratégie de sélection se fonde également sur l'évaluation des paramètres génétiques. Les chapitres III et IV présentent, pour le bétail N'Dama, la chèvre naine d'Afrique occidentale et le mouton Djallonké, les paramètres et les tendances génétiques des performances de croissance.

Les données accumulées pendant dix ans (1994-2004) par le programme d'amélioration génétique de la race N'Dama ont été analysées et sont présentées dans le **Chapitre III**. Ces données ont permis d'estimer, au moyen d'un modèle animal, les paramètres génétiques des performances de croissance dans des conditions variables d'exposition glossinaire (mouche tsé-tsé). Les animaux nés étaient élevés jusqu'à l'âge de 12

mois (âge auquel ils étaient sevrés) dans une zone à faible exposition glossinaire (Keneba). Après le sevrage, ils étaient transportés dans une zone à exposition glossinaire élevée où ils restaient jusqu'à l'âge de trois ans (Bansang). Les animaux étaient pesés tous les mois à partir de leur naissance. Deux saisons ont été définies. La première, allant de novembre à juin, représentant la saison sèche caractérisée par un manque accru d'aliments et une faible densité glossinaire. La deuxième, la saison pluvieuse s'étalant de juin à novembre, caractérisée par une abondance en aliments et une forte densité glossinaire. Sur les animaux, le poids corporel et la croissance au cours des différentes saisons de 12 à 36 mois ont été mesurés. La valeur estimée de l'héritabilité allait de 0,28 (pour le poids corporel à 36 mois) à 0,48 (pour le poids corporel à 15 mois). Pour le gain moyen quotidien au cours des différentes saisons, la valeur estimée de l'héritabilité s'est étendue de 0.09 (pour la croissance pendant la saison sèche) à 0.15 (pour la croissance pendant la saison pluvieuse). Les corrélations génétiques entre le poids à la naissance et le poids corporel à 12 mois, et celle du poids corporel à 15 mois étaient modérément hautes (0.49 et 0.51, respectivement). Les corrélations génétiques entre la plupart des poids corporels et le gain moyen quotidien au cours des différentes saisons se sont étendues de -0.40 à 0.80. La tendance génétique, de 1994 à 2004, était la plus élevée pour le poids corporel à 36 mois ; concernant le gain moyen quotidien au cours des différentes saisons, la tendance génétique la plus élevée a été obtenue entre 15 mois et 36 mois et au cours de la croissance pendant la saison sèche de 12 à 36 mois. De façon générale, ces valeurs montrent qu'on pourrait obtenir un accroissement en sélectionnant sur la croissance pendant les saisons sèche et pluvieuse. Le choix pour le caractère de croissance devrait donc se concentrer sur le gain moyen quotidien pour les deux saisons confondues. D'autres études devront être entreprises pour évaluer l'importance économique du caractère.

Le programme d'amélioration génétique des petits ruminants a été initié en 1995. Le but est de pouvoir diffuser le progrès génétique enregistré dans le noyau de sélection ouvert ovin et caprin depuis quelques années. Les objectifs opérationnels du programme de sélection des petits ruminants sont: l'amélioration des aptitudes pour la production de viande, la conservation de la rusticité des produits améliorés en l'occurrence la préservation des qualités de trypanotolérance des animaux sélectionnés. Pour atteindre ces objectifs, le critère de sélection choisi est le gain quotidien de poids de 4 à 12 mois. L'objectif de l'étude présentée au **Chapitre IV** était d'estimer des paramètres génétiques des performances de croissance et d'évaluer des tendances génétiques de la chèvre naine d'Afrique occidentale et

du mouton Djallonké. A cet effet, sur les animaux (la chèvre naine d'Afrique occidentale et le mouton Djallonké) ont été mesurés le poids à la naissance, le poids corporel au sevrage, le poids corporels à un an, le gain quotidien de poids pendant la période pré sevrage et le gain quotidien de poids pendant la période post sevrage. L'analyse a été conduite en utilisant un modèle animal. Les valeurs d'héritabilité pour le poids à la naissance, le poids corporel au sevrage, le poids corporels à un an, le gain quotidien de poids pendant la période pré sevrage et le gain quotidien de poids pendant la période post sevrage étaient 0.5, 0.43, 0.30, 0.32 et 0.11 pour les chèvres et 0.39, 0.54, 0.21, 0.54 et 0.23 pour les moutons, respectivement. La corrélation génétique entre le poids à la naissance et le poids corporel au sevrage, étaient élevée pour les chèvres (0.74) et modérée pour les moutons (0.47). Les corrélations génétiques entre le poids corporel au sevrage et le gain quotidien de poids pendant la période post sevrage étaient élevées (0.92) pour les chèvres et modérée (0.49) pour les moutons. Entre le gain quotidien de poids pendant la période pré sevrage et le poids à la naissance, la corrélation était positive mais faible pour les moutons (0.26) et modérée pour les chèvres (0.60). Une évolution positive de la valeur génétique a été observée pour le poids des animaux durant la période 1995 à 2002. Cette étude démontre que l'amélioration génétique des aptitudes pour la production de viande de la chèvre naine d'Afrique occidentale et du mouton Djallonké par la sélection de béliers peut donner de bons résultats dans le processus d'amélioration de la productivité. La mise en oeuvre du programme d'amélioration génétique en milieu villageois au sein des élevages traditionnels est faisable, et il peut servir comme exemple à d'autres populations animales et d'autres pays de l'Afrique de l'Ouest. Ce chapitre démontre clairement que le progrès génétique a été réalisé depuis la mise en application du programme par l'ITC. Ces paramètres génétiques pourront être utilisés pour améliorer d'avantage la stratégie de sélection. Le processus de l'amélioration devrait également inclure une discussion sur les caractères à inclure dans l'objectif de sélection pour mieux s'assurer que le programme satisfait les besoins des éleveurs locaux.

Le bétail N'Dama est utilisé dans les systèmes de productions à faibles intrants ; il est donc essentiel d'évaluer des solutions alternatives pour le renforcement du schéma de sélection et au besoin, élargir l'enregistrement à d'autres caractères. Le programme d'amélioration génétique de la race N'Dama a servi de base pour l'analyse dans l'étude présentée au **Chapitre V**. Depuis 1998, l'évaluation génétique des performances de croissance et des performances laitières se fait et l'utilisation d'un modèle animal a permis d'augmenter les liens entre animaux. L'objectif de sélection est composé du gain quotidien de poids exprimé en g/jour (de 15-36 mois dans des conditions d'exposition glossinaire élevée) et du rendement laitier exprimé en kg (production de lait au cours des 100 premiers jours de la lactation). Ces évaluations génétiques combinées en un indice de sélection permettent l'augmentation de la production en allouant une amélioration modeste aux autres caractères tels que l'adaptabilité et la trypanotolérance. Les données sur le troupeau du noyau de sélection ont donc été utilisées pour évaluer le schéma de sélection de la race N'Dama, et également utilisés pour optimiser ce même schéma de sélection en le comparant à d'autres schémas alternatifs de sélection. Un modèle de simulation déterministique a été utilisé pour démontrer les avantages génétiques et économiques des différents schémas de sélection. Des gains génétiques substantiels de 3.40 kilogrammes pour la production laitière et de 0.25 g/jour pour le gain quotidien de poids ont pu être réalisés. Les résultats ont prouvé que les schémas utilisant les taureaux à bas âge ont eu comme conséquence des réponses génétiques et économiques relativement plus élevées. Pour un schéma de sélection pratique (système à faibles intrants), le schéma de sélection basé sur l'utilisation des taureaux à bas âge devrait être recommandé puisque ce schéma est le meilleur menant à une amélioration de l'objectif de sélection, à la consolidation du programme d'amélioration génétique et également à la diffusion du matériel génétique chez les éleveurs.

Dans le **Chapitre VI**, les résultats présentés au cours des chapitres II à V sont utilisés pour discuter quelques possibilités permettant une utilisation optimale des ressources génétiques animales locales. Les paramètres génétiques de performance de croissance obtenus pour la N'Dama, la chèvre naine d'Afrique occidentale et le mouton Djallonké sont importants. Ils donnent une indication claire de la capacité de ces races indigènes à répondre à la sélection et ainsi donc à leur potentiel de survivre et d'évoluer dans leur propre environnement. Ils contribuent à l'amélioration de ces races et par conséquent à une meilleure utilisation des ressources génétiques locales. Les tendances génétiques évaluées donnent une indication de la direction dans laquelle la sélection s'oriente et également une indication du taux d'amélioration. Ces tendances génétiques auront une importance pour les futures décisions à prendre concernant la sélection dans le programme d'amélioration génétique. Généralement, toute réduction de la diversité des ressources génétiques a une conséquence néfaste sur la capacité à répondre aux changements liés à l'environnement, de résister aux maladies, ou aux divers stress. Par conséquent, le développement technologique devrait être orienté vers une amélioration équilibrée des caractères de production et des caractères fonctionnels afin d'éviter toute détérioration, et encourager plutôt une probable amélioration des caractères fonctionnels. Les éleveurs ont besoin d'avoir accès aux marchés compétitifs. Pour beaucoup d'entre eux, il est encore difficile d'y accéder. Par conséquent, un objectif majeur serait d'améliorer la stabilité de la production et réduire de ce fait les risques liés à la production afin d'augmenter la sécurité alimentaire et le bien-être des ménages des producteurs. Les programmes de conservation et d'amélioration devraient être décentralisés dans chaque pays de la région où les différentes races et espèces existent.

Cette thèse a démontré qu'il y a de bonnes perspectives pour une meilleure utilisation des ressources génétiques animales locales en Afrique occidentale. Il est important de se focaliser sur l'amélioration génétique des ressources génétiques animales locales et d'encourager des éleveurs à utiliser ces races comme alternative viable pour augmenter leur compétitivité. Le programme d'amélioration génétique peut servir de modèle pour la production animale dans les systèmes à faibles ou à moyens intrants dans la région Ouest Africaine. Il est essentiel que les ressources publiques soutiennent ce programme en encourageant la formation du personnel, et en contribuant aux coûts de fonctionnement au niveau du noyau de sélection.

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Finally I wish to thank all the people not cited who have contributed directly or indirectly to the completion of this thesis.

Many thanks to all and may GOD bless all of us.

N'Guetta Austin Bosso

Tuesday, 22 November 2005, Wageningen, The Netherlands.

Curriculum Vitae

N'Guetta Austin Bosso was born in Bouaké, Côte d'Ivoire in December 1967. He arrived for the first time in The Netherlands in October 1989. He immediately enrolled in the Dutch intensive language course at NUFFIC and later at the Gemeenschappelijk Dag en Avond School in The Hague. In 1992, he joined the Agrarisch Hogeschool te Delft were he studied Veehouderij (Animal Husbandry). He obtained his Ing. diploma in 1997. The same year he was accepted at the department of Animal Breeding and Genetics, of the Wageningen University, as M.Sc. student in Animal Breeding and Genetics. In July 1998, he obtained his M.Sc degree with the thesis entitled "Making Marker Assisted Introgression work for cattle breeds in the Humid and Sub-humid zone of Africa". After obtaining his degree, he returned to his country where he joined the ESAM (École Supérieure d'Administration et de Management). For 2 years, he lectured computer science and computer architecture. He was at the same a time database consultant for different companies. In October 2001, he joined again the department of Animal Breeding and Genetics at Wageningen University where he started his sandwich Ph.D. project. In December, of the same year, the Netherlands Foundation for the Advancement of Tropical Research (WOTRO) to enable him to finance the Ph.D. project awarded him a scholarship. From November 2000 until March 2005, he worked at the International Trypanotolerance Centre in Banjul, The Gambia, as a Research Assistant.

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List of Publications

Journals

Bosso, N.A., Corr, N., Njie, M., Fall, A., Waaij, van der E.H., Arendonk, van J.A.M., Jaitner, J., Dempfle, L. & Agyemang, K., 2005. The N'Dama cattle genetic improvement programme: a review. Animal Genetic Resources Information. In preparation for submission.

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Bosso, N.A., Cissé, M.F., Waaij, van der E.H., Fall, A., Arendonk, van J.A.M., 2005. Genetic and phenotypic parameters of body weight in West African Dwarf goat and Djallonké sheep. Small Ruminant Research. Accepted.

Bosso, N.A., Waaij, van der E.H., Kahi, A.K. and Arendonk, van J.A.M., 2005. Genetic analyses of N'Dama cattle breed selection schemes. Animal Science. Submitted

Proceedings

Bosso, N.A., Waaij, van der, E.H. and Arendonk, van, J.A.M., 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.

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Others

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Agyemang, K., Fall, A., **Bosso, N.A.**, Corr N. and Munstermann, S., 2003. Improved Performance in Trypanotolerant Livestock. Final Project Report BMZ/GTZ funded Project. 30 pp.

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Training and Supervision Plan

Graduate School WIAS

Name	N'Guetta Austin Bosso
Group	Animal Breeding and Genetics
Daily supervisor(s)	Dr. E.H. van der Waaij
Supervisor(s)	Prof. Dr. ir. J.A.M. van Arendonk
Project term	from October 2001 until January 2006

The Basic Package (minimum 2 cp)	***year***	***cp****
Academic Master Cluster course on communication skills	2005	1.0
Academic Master Cluster course on presentation skills	2005	1.0
Academic Master Cluster course on ethics	2005	1.0
Academic Master Cluster course on philosophy of science	2005	1.0
Subtotal Basic Package		***4.0***
Scientific Exposure (conferences, seminars and presentations, minimum 5 cp)	***year***	***cp***
7th WCGALP. Montpellier, France, August 19-23 2002.	2002	1.5
27th ISCTRC, Pretoria, South Africa, 29th September - 3rd October 2003.	2003	1.5
54th Annual Meeting of the EAAP, Rome, Italy, 31st August - 3rd September 2003.	2003	1.3
PROCORDEL National Conference, 13-14 November 2003, Banjul, The Gambia.	2003	0.9
ITC/CIRDES/CTA International Conference, 8-12 November 2004, Banjul, The Gambia.	2004	1.5
Seminars and workshops		
Dairy Development in the Tropics, 2nd November, 2002, Utrecht University	2002	0.2
Dietary protein: Physiological constraints to nutritive value, WIAS, 1st October, 2004	2004	0.2
Approaches to sustainable development of animal production, WIAS, 3rd October, 2005	2005	0.1
International Trypanotolerance Centre (ITC) seminars Banjul, The Gambia.		0.3
Subtotal International Exposure		***7.5***
In-Depth Studies (minimum 4 cp)	***Year***	***cp***
Disciplinary and interdisciplinary courses		
The biological basis for improved management and selection tools.	2005	1.0
QTL detection and fine mapping in complex pedigrees.	2005	1.0
Atelier de dialogue régional. Stratégie de gestion des élevages en race pure caractérisation génétique des races et techniques de conservation. 11-13 décembre Cotonou, Bénin.	2003	1.0
Advanced statistics courses (optional)		
Statistics With Applications In Veterinary Research. Regional Training in Applied Statistics.	2001	1.0
Basic Statistical Methods for Longitudinal Data Analysis.	2002	0.2
PhD students' discussion groups *(optional)*		
Animal Breeding and Genetic discussion group (QUANTO)	02/05	0.2
Subtotal In-Depth Studies		***4.4***
Professional Skills Support Courses *(minimum 2 cp)*	*year*	*cp*
How to get Grant Funding.	2001	0.8
Media and mediators, messages and means' Training in media skills for scientific researchers	2004	1.0
Workshop "Scientific Publishing".	2004	0.2
Subtotal Professional Skills Support Courses		***2.0***
Research Skills Training *(optional)*	*year*	*cp*
Preparing own PhD research proposal *(maximum 4 cp)*		
Optimum strategies for the implementation of pure-breed improvement programmes in The GAMBIA	2001	4.0
Special research assignments *(apart from PhD project)*		
Research associate Animal Breeding/Genetics at the International Trypanotolerance Centre (ITC).	01/05	1.0
Subtotal Research Skills Training		***5.0***
Didactic Skills Training *(optional)*	*year*	*cp*
Supervising MSc theses *(maximum 1 cp per MSc student)*		
Co supervision of M.Sc. Mrs Meaza Mebrathu on Estimation of parameters influencing milk and calf body weight traits of N'Dama cattle in the Gambia	2003	1.0
Tutorship		
Training on Data management and Analysis for Mrs Aicha Ali from Tanzania (April-June)	2002	1.0
Training on Genetic and phenotypic parameters estimation for Mr Mohamed Cissé from the Institut de Recherche Agricole de Guinée, Conakry (March-May)	2003	1.0
Preparing course material		
Training workshop for GILMAon applied breeding, performance recording & selection	2002	1.0
Training workshop on screening/selecting purebred livestock	2003	1.0
Subtotal Didactic Skills Training		***5.0***
Management Skills Training *(optional)*	*year*	*cp*
Organization of seminars and courses		
Training workshop on data analysis and management in Boké	2002	1.0
Training workshop on Animal breeding and management in Boké Guinée Conakry	2003	1.0
PROCORDEL atelier de dialogue régional 11-13 décembre 2003 Cotonou.	2003	0.2
International Trypanotolerance Centre Open day	2003	0.1
ITC/CIRDES/CTA International Conference on Animal Agriculture in West and Central Africa	2004	0.4
International Trypanotolerance Centre Open day	2004	0.1
Subtotal Management Skills Training		***2.8***
Education and Training Total (minimum 21 cp, maximum 42 cp)		***30.7***

**One credit point (cp) equals a study load of approximately 40 hours*

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