Sustainable breeding methods for smallholder dairy production under unfavourable conditions in the tropics

Birgit Zumbach & Kurt J. Peters

Humboldt University Berlin, Department of Animal Breeding in the Tropics and Subtropics, Philippstr. 13, Haus 9, 10115 Berlin, Germany;
E-mail: birgit.zumbach@rz.hu-berlin.de ; k.peters@rz.hu-berlin.de

Abstract

A conception for the development of sustainable breeding strategies is presented which consists in -assessment of existing activities and breeders' perception, -analysis of breeding organisations, structures and tasks, -assessment of task efficiency, - analysis of breeding tasks and their efficiency and -derivation of appropriate breeding methods for the formulation of breeding programs and implementable breeding tasks. In this study the analysis of breeding tasks and their efficiency are treated focussing on the modules -performance testing, - breeding value estimation and - breeding bull provision.

Keywords: Breeding strategies, sustainability, smallholder dairy production

1. Introduction

1.1 Problem: Population growth and changing food patterns require an increased production of cattle products, e.g. milk, to meet the demand. As the availability of land for pasture and fodder cultivation is scarce a continual increase in cattle numbers will soon reach its limit. Therefore higher milk yields are rather to be attained by improving management and the genetic potential of the cattle. In general, if environmental conditions are not too harsh, upgrading local breeds with high yielding local or exotic breeds seems to be the quickest and most effective way to raise production levels while the expected genetic progress per year through selection within local populations won't surpass 2% (Horst, 1999). In terms of milk production - given a local population's performance of 1500 kg per year - this means an increase of 30 kg per year, e.g., 36 years to double milk production whereas by crossbreeding the same result can be achieved within one generation. Uncontrolled crossbreeding however could lead to problems like lack of adaptation to tropical stresses of poor nutrition, disease challenge and heat stress (Kahi et al., 2000; Wollny et al., 1998). Thus, sustainable breeding methods for genetic improvement of local resources, existing crossbred cattle and also exotic cattle as well as sustainable crossbreeding strategies are warranted.

1.2 Objective: The objective of this study is to develop a methodology for genetic improvement of dairy cattle at smallholder level under unfavourable conditions, taking into account bio-diversity and social aspects, and to provide suggestions for sustainable breeding strategies for different situations.
1.3 Basic prerequisites: Participation is the magic word for any sustainable development measure. This means first of all to come to know and take into consideration the producers' perceptions and activities. With regard to animal breeding, local knowledge has been mostly ignored for whatever reasons. Further on, farmers have to be willing to genetically improve their animals and take an active part in the development and implementation of any measure from the very beginning. As the experience shows the success or failure of breeding projects in the tropics is always connected with the (missing) involvement and consideration of producers (e.g. Tewolde, 2000; Fall, 2000; Philipsson, 2000). On the other side, a stable organisation is needed for the co-ordination and provision of basic services (e.g., provision of a village bull or semen, insemination service, milk-recording).

2. Conception

2.1 General idea

Breeding programmes in the developed world are well-elaborated and effective and as a result, milk yield per cow has almost doubled in the last 30 years. However introducing those breeding programmes into the developing world, no or even negative results have been stated (e.g. Rege, 1991a,b; Taneja, 2000). Some basic approaches for sustainable breeding programmes for milk production in the tropics are presented by Peters (1999b). As the author points out, there is obviously a lack in research in this area.

The development of sustainable breeding strategies - breeding is to be seen as an organisational process - can generally be divided into two steps: The first step consists in screening and analysing the local conditions, i.e. breeders' perception and the local activities at farmers' and organisational level. The second step which must be derived from the first step's results is to develop sustainable breeding organisations, the formulation of adapted breeding plans and their implementation. The general tasks are the following:

- Assessment of existing activities and breeders' perception (animal recording, selection activities, exchange of breeding animals, etc.)
- Analysis of breeding organisations, structures and tasks
- Assessment of task efficiency
- Analysis of breeding tasks and their efficiency
- Derivation of appropriate breeding methods for
  -Formulation of breeding programs
  -Implementable breeding tasks

In this study the analysis of breeding tasks and their efficiency are treated.

2.2 Analysis of breeding tasks and their efficiency

The principle of animal breeding is to achieve a genetic response (R) which can be described as the product of heritability (h^2) and selection difference (SD: difference between the selected animals and the main population). $R = h^2$ SD. So the main components of any breeding programme, given the population parameters, are performance testing, breeding value estimation and the provision of breeding bulls. These will be considered as different modules in which different scenarios are examined.

2.2.1 Module 1: Performance testing

Performance testing is the prerequisite for any breeding measure. Only when knowing the animals' performance, comparisons can be made and the best ones selected for breeding. The selection (test) criteria are to be derived from the breeding goal - the most decisive step when planning a breeding programme - which is of supreme importance and critical for the success or failure of a breeding programme (Sölkner et al., 1998; Fall, 2000). As above mentioned, farmer participation and an economic evaluation of the goals are the basic prerequisites (Fall, 2000).
The classical form to combine the different selection traits is by using a selection index. At smallholder level, however, production for subsistence and market overlap, so the significance of economical weights is limited (Horst, 1999). An alternative way is the use of composite traits where the inclusion of the reproductive performance into a productivity index is of special importance (Horst, 1999). An example of

such an index might be milk yield per day of life (Horst, 1999). If different breeds or different upgrading degrees are to be compared milk yield imperatively has to be related to (metabolic) body weight per time unit (Peters, 1999a). Given an identification system for cattle on at least a national or regional level the question is how performance test for dairy cattle can be executed with regard to:

-Which animals are to be recorded?

Accounting for field conditions in the (sub)tropics (i.e. seasonal fluctuations, high mortality, poor growth, poor reproduction) recording has to be done on a large scale. Supposed the testers' capacity to test a certain number of cows is the limiting factor, the question is if to consider all cows per farm (number of farms is limited) or to record only the best cows per farm. This last option means, a (subjective) pre-selection made by the farmer takes place and should increase selection intensity.

-What kind of data are to be recorded?

The data recording must primarily concentrate on traits of economic importance. In the case of sustainable milk production milk yield is closely related to reproduction efficiency and - when lack of food (feed costs) - also to (metabolic) body weight. Studies in Brazil for example "indicated that reducing cow weight was even more important than increasing milk yield, even in a dual purpose system. Milk flow, herd-life and age at first calving were important components of the overall economic merit" (Vercesi Filho et al., 1999 and Lobo et al., 1999 cited by Madalena (2000). Thus, the following information or data should be assessed: Birth date, sire, dam, service bull, mating dates, drying off date, calving dates, sex of calf, lactation number, milk yield on test day, body weight fluctuation (linear measurements), milking (calf rearing) procedure, disease incidence (cow and calf), death/culling date and reason (cow and calf). On the basis of these data, performance traits as milk yield and reproduction traits (e.g. age at first calving, calving interval) and viability can be derived. A minimum data set that is desirable for on-farm studies on a meta level is proposed by Baker (1992) where also the essential data for environmental description and recommendations about time and frequency of measurement are listed. In regard to performance traits he suggests: milk yield, body weight, fertility (calving interval, number born, number weaned) and viability.

-Who does the recording?

For carrying out the milk recording there are the following possibilities which have been tested in a field recording programme in India. These are:

"a) Official milk recording. Appointing qualified personnel as regular employees and using them for milk recording.

b) Own recording. Where the farmer does the recording himself.

c) Contract recording. Where part -time milk recorders are engaged on a contract basis" (Unnithan et al., 2000).

Official milk recording is the most cost intensive option especially in view of the small herd sizes, scattered distribution and often difficult accessibility which was also the case in India. When own recording, the correctness and completeness of the data must be granted which might be a problem. In the Indian example it resulted most convenient to engage part time milk recorders on a contract basis recruited from local areas (Unnithan et al., 2000), which might be a model for other countries.

-How often are the cows to be test-milked (interval length)?

The most common milk recording interval in temperate climates is about one month with milking in the morning and evening. And it is also common for tropical climates (Gebre-Wold et al., 1993a,b; Unnithan et al., 2000). Whereas in temperate climates this interval can be prolonged up to 6 weeks without significant losses in accuracy, in the tropics, under field conditions and strong seasonal fluctuations, shorter recording intervals (fortnightly, weekly, bi-weekly) may be more appropriate. Thus, some quick studies for different environments using fairly large date to determine the most appropriate recording frequency should be undertaken (Gebre-Wold et al., 1993b). For the case of large scale dairy farms in Malawi, for example, a two-week-interval is suitable (Chagunda et al., 1999). Dempfle & Jaitner (2000) suggest an interval of one week for the N'Dama cattle herd hold according to local conditions at the ITC in The Gambia.

-How long are the cows to be test-milked (test period)?

The determination of the test period depends - like the interval length - on the shape of the lactation curve that is under unfavourable tropical conditions rather influenced by seasonal fluctuations exceeding the physiological effect of the lactation stage. In this case also local studies have to be executed to find a sufficient accuracy between test period and milk yield performance at the earliest time as possible. For the above mentioned N'Dama cattle, Dempfle & Jaitner (2000) consider as minimum the 0-100 day milk yield (milk off-take) of the 1st lactation.

2.2.2 Module 2: Breeding value estimation

2.2.2.1 General: Van der Werf (2000a) gives a simple and comprehensive definition of breeding value: "the value of an animal's genes to its progeny". The prerequisite for animal breeding is to estimate this value. The common formula for the assessment of an animal's estimated breeding value (EBV) is the deviation of a recorded performance (y) from a reference base (RB), multiplied by a weighting factor b.

EBV = b (y - RB)

In the weighting factor b the are considered • heritability, • number of observations from informants and • the degree of relationship between the informants and the animal under consideration. If we multiply b by σ_P/σ_A we obtain the correlation between the true and the estimated breeding value, the accuracy ($r_{A\hat{A}}$).

$r_{A\hat{A}} = b\ \sigma_P/\sigma_A$

2.2.2.2 Constraints and methods of resolution: In the tropics an accurate estimation of the breeding value is rather problematic as "herds" may consist of one or two cows, there is a want of connection between many herds, few pedigree information available, and there exist great environmental effects which only to a certain degree can be accounted for.

- Herd size and connectivity between herds:

To overcome the problem of herd size Bruns (1992) suggests to cluster farms according to some factors, describing the production level of the farm (e.g. farm size, rainfall, location, production system, etc.) and to replace the herd or farm in the ANOVA by this cluster. By this way, also a connection between within and between clusters can be provided: "So, a paternal half-sib analysis can be carried out on a within-farm cluster basis" (Bruns, 1992).

- Information availability:

The more information we get (sample size) and the closer the informants are related to the candidate at a given heritability, the higher the accuracy of breeding value estimation we achieve, i.e. the more we can rely on the genetic value of the candidate. Some examples of accuracy are presented by van der Werf (2000b), e.g.: $h^2 = 0.10$; own information only, $r_{A\hat{A}} = 0.32$; mean of 5 full sibs: $r_{A\hat{A}} = 0.32$; mean of 10 half sibs; $r_{A\hat{A}} = 0.23$. In the case of unknown sire identification, genetic analysis can be based on full sibs which can lead to biased estimates due to maternal and dominance effects (Bruns, 1992). Misidentification of offspring (paternal and maternal half sibs) reduces heritability, thus accuracy (Van Vleck, 1970, Bruns, 1992). So, under unfavourable conditions where larger sample sizes are required, the availability of recorded animals however is limited, it is of great importance that at least the available data are correct.

-Environmental effects:

The correction of environmental effects is of supreme importance for an efficient breeding value estimation. Taneja (2000) reports: "Poor accuracy of sire breeding values resulted from errors due to no correction for sire's age, exotic inheritance of the crossbred dam, large differences between herds and small herd size. Developing appropriate methodologies for standardisation of field records for sire and cow evaluation should therefore, be a priority." Besides the current environmental effects, also short lactation records (<120 d) should be considered for sire breeding value estimation - as a genetic effect - because in non-improved populations this feature is heritable and its genetic correlation with yield approaches 1 (Madalena, 2000). Deleting such records or adjusting for them reduce heritability and the genetic progress for milk yield (Madalena, 1988).

Using the herd-mate-comparison method results can be poorly correlated with BLUP results as the study of Rege (1991b) shows. Thus, citing Philipsson (2000), "efficient statistical methods for genetic evaluation are needed, so that non-genetic effects can be removed and that optimum use can be made of, for example, the pedigree information."

2.2.3 Module 3: Provision of breeding bulls

In cattle breeding, characterised by a low reproductive rate , especially in the tropics, genetic progress can be achieved in general only by bull selection. Given an efficient breeding value estimation the best bulls disseminate genetic response (R), which is the product of selection intensity (i) accuracy (r_{A}) and additive genetic standard deviation (σ_A):

$R = i\ r_{A}\ \sigma_A$.

In tropical countries artificial insemination is not always feasible for technical and infrastructural constraints. So all kind of mating possibilities are considered and compared in regard to selection intensity, therewith genetic response.

a) Only natural mating is possible

- *Traditional method*: The bull is allowed to run with the females. In temperate climates dual purpose bulls serve on average 12 times a day over a period of several weeks (Sambraus, 1978). Mating is haphazard but generally successful at the first fertile opportunity (Barrett & Larkin, 1974). For the tropics these authors assume that one bull can serve successfully only 30 - 40 females.
- *"Hand service*, that is, secluding the bull from the females and allowing him to serve an animal only at the owner's discretion" Barrett & Larkin (1974). The authors indicate that a bull may be used on 50-60 females since repeat services can be prevented. Since no reference about any time interval is given, we suggest a mating period of about 8 weeks. Thus, basing on the indications of Barrett & Larkin (1974) 6-8 cows per week can be served.

b) Artificial insemination is feasible

- *Use of fresh sperm:* In the case that liquid nitrogen is not available artificial insemination can be done by the use of fresh sperm. Provided an adequate preparation, the semen can be stored up to 5 days at 4° C. In temperate climates an average ejaculate contains about 5000 million sperms while one portion for insemination has to contain only 15 million living sperms (CLAUS & KARG, 1981). In the tropics Abreu (1999) cited by Madalena (2000) found the following sperm characteristics in Gir x Holstein Friesian crossbred bulls: "Based on 12 625 ejaculates and 156 bulls, the average volume was 4.7cc, with 779 x 10^6 sperm cells / cc and 46.4 and 22.4 percent pre- and post-thawing motility, yielding 17.8 pre-thawing doses per ejaculate." If the bull is to be used twice a week, about 35 cows per week can be inseminated. That means within an 8 weeks' period 280 cows can be successfully served.
- *Use of deep frozen sperm:* The calculations for the number of semen portions to be yielded from an ejaculate are the same as for the use of fresh sperm. As deep frozen sperm can be stored for years thousands of cows can be inseminated by one bull (in our calculations 1820 per year) depending on the length of use of a breeding bull.

As shown in table 1, the type of mating influences to a high degree the proportion of bulls to be selected, therewith selection intensity and genetic response. Using AI with deep frozen semen the double of selection intensity can be attained as compared with traditional mating. Also with the use of fresh sperm a high increase in selection intensity can be achieved. In practical there may occur some problems reducing selection intensity like increased infertility of bulls under field conditions in the tropics. Given the same accuracy for all methods genetic response increases proportionally to selection intensity. However, in practice AI results can still be a bit lower as in the study of Taneja (2000) 40 to 70 percent of crossbred bulls had to be eliminated for poor semen quality, libido and freezability. On the part of the cows, a lower conception rate has to be taken into account when using AI.

Table 1: Effect of mating type on mating ratio and selection intensity

	Mating type			
	Traditional method	Hand service	Fresh sperm	Deep frozen sperm
Cows per bull (n)	30-40	50-60	280	1820
Expected number of young bulls per year (n)[1)]	7.5 - 10	12.5 - 15	70	455
Proportion to be selected [%]	10-13	7-8	1.4	0.2
Selection intensity	1.7	1.9	2.6	3.3

[1)] Expected number of young bulls = cows per bull * 1/2 (number of male calves expected * 1/2 (expected survival rate)

As for the derivation of breeding programmes and selection schemes, these should be as simple as possible in order to be implemented properly (Fall, 2000). Such an approach would be the application of just a young bull (AI-) programme with a quick turn over rate of bulls (Philipsson, 2000; Jaitner & Dempfle, 1998; Syrstad & Ruae, 1998. Keeping in mind that only a long term application of such programmes leads to success, a sustainable organisation must be given.

3. References

Baker RL (1992): Research methodology. In: Rege JEO, Lipner ME (eds) African Animal Genetic Resources: Their characterisation, conservation and utilisation. Proc. Research Planning Workshop, ILCA, Addis Ababa, Ethiopia, 19-21 Feb. 1992, pp 101-107

Barrett MA, Larkin, PJ (1974): Milk and beef production in the tropics, Oxford University Press. Ely Hous, London W.1

Bruns E (1992): Synthesis of research methodology. In: Rege JEO, Lipner ME (eds) African Animal Genetic Resources: Their characterisation, conservation and utilisation. Proc. Research Planning Workshop, ILCA, Addis Ababa, Ethiopia, 19-21 Feb. 1992, pp 125-134

Chagunda M, Bruns E, Wollny C, Möllers (1999): The effect of recording intensity on lactation milk yield estimates of Holstein Friesian cattle on large scale dairy farms in Malawi. In Tropentag 1998, Göttingen, Göttinger Beiträge zur Land- und Forstwirtschaft in den Tropen und Subtropen, Heft 133, pp 351-355

Dempfle L, Jaitner J (2000): Case study about the N'Dama breeding programme at the International Trypanotolerance Centre (ITC) in The Gambia. In: Galal S, Boyazoglu J, Hammond K (eds) Workshop on Developing Breeding Strategies for lower input animal production environments, Bella, Italy, 22-25 Sept 1999, ICAR Technical Series No. 3, pp 347-354

Fall A (2000): Peul, Touabire and Djallonke sheep breeding programmes in Senegal. In: Galal S, Boyazoglu J, Hammond K (eds) Workshop on Developing Breeding Strategies for lower input animal production environments, Bella, Italy, 22-25 Sept 1999, ICAR Technical Series No. 3, pp 331-338

Gebre-Wold A, Mosi, RO, Mgheni M. (1993a): Milk recording schemes for smallholder dairy farmers. Proc. 2nd Annual Conference of the Ethiopian Society of Animal Production 26-27 May, Addis Abeba, Ethiopia; Development Opportunities in Livestock Agriculture, pp 15-28

Gebre-Wold A, Mosi, RO, Mgheni M. (1993b): Proposal for a standard milk recording scheme. Proc. 2nd Annual Conference of the Ethiopian Society of Animal Production 26-27 May, Addis Abeba, Ethiopia; Development Opportunities in Livestock Agriculture, pp 29-48

Horst P (1999): Züchtung. In Horst P, Reh I (eds) Tierzucht in den Tropen und Subtropen. Handbuch der Landwirtschaft und Ernährung in den Entwicklungsländern Band 5, Verlag Eugen Ulmer, Stuttgart, pp 119-139

Jaitner J, Dempfle L (1998): A breeding scheme for the indigenous N'Dama cattle. In: Proc. 49th Annual Meeting of the EAAP, Warsaw, 24-27 August 1998, G5.9

Kahi AK, Nitter G, Thorpe W, Gall CF (2000): Crossbreeding for dairy production in the lowland tropics of Kenya. II. Prediction of performance of alternative. Livestock Production Science 63: 55-63

Madalena FE (1988): A note on the effect of variation on lactation length on the efficiency of tropical cattle selection for milk yield. Theor. Appl. Genet. 76: 830-834

Madalena FE (2000): Dairy cattle breeding programme in Brazil development of the Brazilian milking hybrid (MLB). In: Galal S, Boyazoglu J, Hammond K (eds) Workshop on Developing Breeding Strategies for lower input animal production environments, Bella, Italy, 22-25 Sept 1999, ICAR Tech. Series No. 3, pp 365-378

Peters KJ (1999a): Produktionstechnik bei den Nutztierarten: Rinder. In Horst P, Reh I (eds)Tierzucht in den Tropen und Subtropen. Eugen Ulmer, Stuttgart, pp 153-198

Peters KJ (1999b): Die globale Agrarforschungs-Allianz - ein neues Paradigma für die Tierzuchtforschung ? in: In Tropentag 1998, Göttingen, Göttinger Beiträge zur Land- und Forstwirtschaft in den Tropen und Subtropen, Heft 133, pp 243-249

Philipsson J (2000): Sustainability of dairy cattle breeding systems utilising artificial insemination in less developed countries - examples of problems and prospects. In: Galal S, Boyazoglu J, Hammond K (eds) Workshop on Developing Breeding Strategies for lower input animal production environments, Bella, Italy, 22-25 Sept 1999, ICAR Technical Series No. 3, pp 551-562

Rege JEO (1991a): Genetic analysis of reproductive and productive performance of Friesian cattle in Kenya. I. Genetic and phenotypic parameters. J. Anim. Breed. Genet. 108: 412-423

Rege JEO (1991b): Genetic analysis of reproductive and productive performance of Friesian cattle in Kenya. II. Genetic and phenotypic trends. J. Anim. Breed. Genet. 108: 424-433

Sambraus HH (1978): Nutztierethologie. Verlag Paul Parey Berlin, Hamburg

Sölkner J, J., Nakimbugwe H, Valle Zarate A (1998): Analysis of Determinants For Success and Failure of Village Breeding Programmes In: Proc. 6th WCGALP, Armidale (Australia), 11-16 Jan. 1998. Vol.25, pp 273

Syrstad O, Ruane J (1998): Prospects and Strategies for Genetic Improvement of the Dairy Potential of Tropical Cattle by Selection. Trop.An.Health Prod. 30: 257-268

Taneja VK (2000): Cattle breeding programmes in India. In: Galal S, Boyazoglu J, Hammond K (eds) Workshop on Developing Breeding Strategies for lower input animal production environments, Bella, Italy, 22-25 Sept 1999, ICAR Technical Series No. 3, pp 445-454

Tewolde A (2000): Breeding strategies for low input animal production systems: a case study from Central America and Mexico. In: Galal S, Boyazoglu J, Hammond K (eds) Workshop on Developing Breeding Strategies for lower input animal production environments, Bella, Italy, 22-25 Sept 1999, ICAR Technical Series No. 3, pp 387-394

Unnithan NR, Kishan, BN, Kishore, G (2000): Field performance recording of cross-bred dairy cows in Kerala (India). In: Galal S, Boyazoglu J, Hammond K (eds) Workshop on Developing Breeding Strategies for lower input animal production environments, Bella, Italy, 22-25 Sept 1999, ICAR Tech. Series No. 3, pp 469-477

van der Werf (2000a): Estimated breeding values and their properties. In: Kinghorn B, van der Werf J, Ryan M (eds) Animal Breeding. Use of New Technologies, Postgraduate Foundation in Vet. Science of the University of Sydney, pp 56-72

van der Werf J (2000b): Livestock straight-breeding system structures for the sustainable intensification of extensive grazing systems. In: Galal S, Boyazoglu J, Hammond K (eds) Workshop on Developing Breeding Strategies for lower input animal production environments, Bella, Italy, 22-25 Sept 1999, ICAR Technical Series No. 3, pp 105-177

van Vleck LD (1970): Mis-identification and sire evaluation. J. Dairy Science 53: 1697

Wollny CBA, Namwaza AG, Makamba TSW, Küttner K (1998): Zum Stand der Rinderzucht in Malawi. Arch. Tierz., Dummerstorf 41 (1/2): 33-44