INTEGRATING GENETIC IMPROVEMENT INTO LIVESTOCK DEVELOPMENT IN MEDIUM- TO LOW-INPUT PRODUCTION SYSTEMS

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INTRODUCTION

Medium- to low-input systems dominate ruminant livestock production in developing countries. In arid and semi-arid areas these are pastoral or livestock-crop (agropastoral) systems. Crop-livestock (mixed) systems dominate in the wetter and sub-humid areas (including the sub-tropical highlands). Associated with these and with landless and marginalized households are non-ruminant livestock - mainly backyard or scavenging pigs and poultry. According to Sere and Steinfeld (1996) medium- to low-input systems provide all - or at least the major part of - the livelihoods of the livestock-keeping households, many of whom have few resources beyond their smallholdings and livestock. For many it may be difficult to access markets to buy inputs and services or to sell their livestock products. Therefore an important “improvement” objective of livestock development is to improve the stability of production - and thereby reduce risk – in order to increase the food security and well-being of producer households (Livestock in Development, 1998).

Genetic improvement programmes of local seed stock in low- and medium-input production systems can be the “vehicle” to improved livestock production in a broader sense. Proposals on integrating genetic improvement into livestock development should consider the variation in production environments and the availability of genetic resources. Genotypes should be those that are able to survive and produce efficiently under the prevailing environmental stresses. Long-term strategies for improvement schemes in these production systems should focus on the use of indigenous populations, in purebred or in crossbreeding systems with improved breeds. Genetic material and selection programmes should be carefully chosen according the characteristics of local systems and resource availability and on the basis of well-designed genotype evaluation trials.

INTEGRATION OF GENETIC IMPROVEMENT ACTIVITIES WITH OTHER PROGRAMMES

For genetic improvement programmes to be sustainable, an integrated systems approach is required. Components should include production efficiency, economic viability, environmental compatibility and social responsibility (Moser, 2001). In medium- to low-input production systems in developing countries, animals may serve several functions including food security and generation of cash income (from e.g. milk, hides, fibre), provision of traction, manure and non-monetary functions such as insurance and social roles. Increasing livestock production may be constrained by climatic effects, feed shortage, disease risk and poor access to input and output markets. For livestock improvement programmes to be successful, these constraints must be recognized and addressed so that solutions can be integrated within a balanced holistic approach to improvement that responds both to the needs of producers and their markets. Governments should be made aware of the importance of genetic improvement and encouraged to create favorable conditions through economic incentives, the allocation of resources for applied research, training programmes, etc.

Market incentives. For improvement programmes to be sustained by producers, the benefits from improved production (which may be in the form of income or a more secure food supply) must be tangible in the short-term and preferably experienced all year round. The importance of these market incentives is well illustrated in India. A major stimulus to increase milk production came with the establishment of dairy co-operative societies in villages to ensure year-round remunerative markets to milk producers. The village dairy co-operatives are, in turn, linked to District co-operative federations and thereby to major urban markets. Responding to the incentives offered by the market, milk production in the villages increases through the better feeding and management of animals. However when the genetic potential of the cows limits increased milk production, the smallholder producers look for animals of better genetic potential. At this stage the introduction of crossbred cattle or buffalo, AI, milk recording, genetic evaluation etc. become important and they are easily accepted. The experiences in low- and medium-input dairy systems in South Asia (Kurup, 2002) and Eastern and Southern Africa (Muriuki and Thorpe, 2002) have shown that the demand for genetic improvement is limited and the probability of success of structured programmes is small without a remunerative year-round market for milk. Other examples are the increased income from wool production in the Transkei region of South Africa (Swart *et al.*, 2000) as well as with Ilama breeders in the Bolivian Andes. In common with dairying, a critical issue for the sustainability of these fibre projects is assuring long term contracts with the textile industry to guarantee stable market volume and producer prices.

Farmer involvement and capacity building. As the example of dairy in India illustrates, effective improvement programmes generally require community-based collective action based upon groups of farmers having shared objectives and an effective organizational structure, including its legal status. Increases in productivity in the short-term through management interventions assure farmer motivation well before the first positive breeding effects may be visible. In the Transkei region of South Africa, genetic improvement of wool sheep is achieved through integrating it with an overall wool sheep improvement programme. Shearing sheds were established (Swart *et al.,* 2000) which served as training, management, development and marketing centers. Members were trained in livestock management, health care, wool classing and other non-livestock programmes. As a result of the better classing of the wool, income from wool sales increased dramatically. Subsequently a structured wool sheep genetic improvement programme was established to increase the value of the wool.

According to Valle Zarate (1996) breeding goals should not only take adaptability traits into account, but also farmer participation. It is crucial that livestock development policies encourage the establishment of private professional breeding flocks either owned individually or by a group of farmers who will benefit from the scientific and technical support. Providing relevant information to smallholders who have only a few animals is equally challenging. When a farmer has one or two animals, he/she knows many features of each, and hence a performance report for an individual animal may not add much to what is already known about the animals. However, if the performance of animals is reported in relation to all other animals in the village, the information becomes very relevant. Development of appropriate software that meets the information requirements of smallholders and a data flow procedure assuring fluent feedback of information relevant at farm level, is very important. Coupled with the provision of objective and standardized information of animals, geneticists (or trained technicians) should interact with farmers in order to explain the meaning and use of the information. Experiences to date indicate the need to develop training programs in basic animal breeding (including an understanding of the relative characteristics of available breeds) for farmers, emphasizing the relationship between basic principles and their practical experiences. In many low- and medium-input systems, the formal educational level of farmers is generally low, which means that specific teaching strategies are needed.

Genetic versus environmental development. In practice, breeding strategies generally evolve in response to changes in production systems, farmers' preferences and production objectives, farmers' knowledge about breed characteristics and market opportunities (Amer *et al*., 1998; Jabbar *et al*., 1999). A striking example is Kenya, which amongst developing countries, has one of the most rapidly expanding dairy sub-sectors. Presently, smallholders, living mainly in the highland areas, own about 80% of the estimated 3 million dairy cattle, comprising of mainly high grade Friesian and Ayrshire and their crosses with *Bos indicus* cattle (Small East Africa Zebu, Boran and Sahiwal - Omore *et al.*, 1999). These responses to agricultural policies, human population pressure on land and market opportunities, have resulted in extensive breed substitution of the Small East Africa Zebu (SEAZ). This was accompanied by the keeping of smaller herds with fewer heifers but more cows, while stocking rates were increased through stall-feeding, fodder growing, purchasing of feeds, thus becoming more dependent on external inputs and services (Bebe *et al.*, 2002). As a result, smallholders can sell more milk and capture the benefits for crop production from manure application. This example shows how improved production can be achieved through better management of production resources and the provision of input services interacting advantageously with breed substitution (SEAZ by European dairy breeds) when these changes are responding to markets that link large numbers of small-scale producers to the consumers of their livestock products.

Within production systems where livestock may be communally managed or grazed on common properties, genetic improvement programs have various constraints, namely for example: low numbers per owner, difficulty to identify contemporary groups, free roaming males and early slaughter of males for cultural/financial purposes. In the absence of these constraints, the development of the Dorper sheep and Boer goats in South Africa illustrate what can be achieved. In systems with a limited resource potential for intensification (for example for ruminants and camelids and in semiarid to arid environments or in mountainous regions) the main challenge is link traditional breeding practices with scientific concepts, to be able to adapt to changing environmental and socio-economic conditions.

Policies and institutions for sustainable development. Existence of organizations having the necessary technical know-how and finance, is a prerequisite for effective animal recording and genetic improvement programmes. A large number of smallholders, each having one to five animals are involved in India's Operation Flood. Results have proved that an organization that integrates different functions in the commodity chain (milk procurement, processing and marketing of milk and milk products) as well as the provision of farm supplies (cattle feed, fodder seed, breeding services, farm advisory services etc.) can play a vital role. This also ensures participation of farmers at all levels, provides better prices to producers, avoids exploitation by processors, raises milk production, enhances employment, income, nutritional status and education of producers and integrates more women as participants in decision making on matters important to them. For this to be successful the organization must be managed with integrity and at a high level of technical and economic skill.

The participation of trained technicians also seems to be critical for success. Their advice on management of the environment, animal health, marketing of products, recording of production and selection of replacements are essential for sustainability. Financial support for these technicians as well as for basic recording equipment, must be supplied by institutions (governments). However, institutions disposed to provide this kind of support are not readily identified: governmental support for animal breeding has been reduced on a global scale and NGO's (Non Governmental Organisations) are mostly not in a position to give the long term support needed for successful breeding programmes. Solution may lie in self-sustaining breeders associations (with the capacity for lobbying for subsidies). Initially the provision of complete genetic improvement services may not be economically feasible, but demand-driven priorities will be defined for which farmers will have incentives to pay.

MANAGEMENT OF GENETIC IMPROVEMENT PROGRAMMES

For sustained genetic improvement to occur in an agricultural system, there must be market incentives driving and meeting the cost of both the improvement as well as the increased risks associated with change in genotype and its interactions with environmental factors like diseases or drought. In the same way, increased performance in one trait or function, e.g. leaner meat, may be offset by lowered performance in other traits, e.g. reproductive rate or reduced suitability for traction. Understanding these multiple and often interacting production functions and taking them into consideration when defining improvement goals with farmers are pre-requisites for effective livestock development. For example, many medium- and low-input systems in developing countries are crop x ruminant livestock (mixed) systems with cattle or buffalo. Milk is produced to feed the family and for sale, to produce manure for the support of crop production and to have animals for insurance and financing emergency cash needs and for social status (Udo and Cornelissen, 1998). In some countries, e.g. in Bangladesh, female cattle may also serve as traction animals.

Genetic improvement programmes based on selection within local populations are generally recommended in low-input systems where animals that are well adapted and reasonably productive are required, to preserve the hardiness traits which are supposed to be present in these breeds. It simultaneously may also be an appropriate method for the conservation of local genetic resources (Bichard, 2000). Indigenous populations could be a source of adaptability for specific environmental challenges such as disease and extreme climatic conditions, and a reservoir of worldwide genetic diversity for possible future changes in the current production systems. Also, these populations could be a potential source of the so-called transgressive or cryptic alleles. These alleles are superior genes for some productive traits suppose to be "hidden" in unselected breeds that are inferior for these traits (Notter, 1999).

Through case studies, various improvement programmes have been described, mainly consisting of government or project funded open nucleus breeding systems (ONBS). Establishment of an ONBS may be useful in places where the development of the infrastructure for artificial insemination, recording of production and genetic evaluation may not be feasible in the general population or at least where the incorporation of a significant proportion of the local population in a breeding programme is not practicable. However, the operation of an ONBS programme is very challenging, and only sustainable with adequate financial support and technical backup and the active participation of a group of pilot farmers. And, as yet, there are no documented schemes in developing countries demonstrating their successful implementation.

Both for production in low- and medium-input systems and for the conservation of local genetic resources, a combination of straight- and crossbreeding may be the best solution for assuring sustainability through economic success. Examples can be found for pig breeds in Europe like Cerdo, Iberico in Spain or Schwaebisch-Haellisches Schwein in Germany. The conservation of the local breeds as maternal lines could only be realized in programmes incorporating crossbreeding with terminal sires from lean meat lines for the production of fattening piglets. Stratified crossbreeding is also the solution envisaged in a smallholder pig breeding scheme in mountainous regions of northern Vietnam, reported by Valle Zarate (2000). Local breeds are pre-selected for maternal traits and reproduced in low-input production systems in mountainous regions. Fattening pigs are derived from mating or inseminating these sows with Landrace or Yorkshire sires. Fattening and marketing takes place in lowland conditions with a land shortage, but convenient infrastructure for intensification.

The use of exotic breeds in a crossbreeding program for sheep and goats is often difficult to manage in low-input production systems. Crossbreeding of local breeds with Finnsheep in Egypt (Aboul-Naga, 2000) achieved higher fertility with lower growth rates, carcass traits and survival rates. ¼ Finns outperformed local breeds with faster growth rates and better carcasses but this crossbreeding programme was difficult to sustain at the farmer level. In tropical Latin-American countries, the use of Holstein and other high-producing dairy breeds from temperate climates is very popular for crossbreeding with local Zebu type females for producing F_1 animals for dual purpose systems (milk and meat production). Research shows however, that ¾ European have economical results very similar to the F_1 in most environments (Rege, 1998), suggesting perhaps that a strategy for creating a tropical synthetic breed such as the Siboney in Cuba, could be a reasonable medium to long term strategy.

Nimbkar (2000) reported on a village goat crossbreeding project in India. The object was to increase milk and meat production. The Sirohi breed from Rajasthan was used for its high milk and meat production characteristics. The advantages of this programme were that it fulfilled the needs of village goat-keepers and they approved the physical characteristics of breeding bucks. No sophisticated recording system or selection programme was required. However, in common with many projects of its type, the approach has major risks: the genes of the exotic breed vanish quickly once project or governmental support ends (see also the effect of "operation cock" in Western Africa) or the crossbreeding converts local populations into an unidentifiable mixture, making more difficult the organization of selection programmes (see many cases of formerly Criollos in Latin-America).

RELEVANCE OF ADVANCED TECHNOLOGIES

Reproductive technology. Technologies with potential for impact on genetic improvement programs are available or are currently being developed. Artificial insemination (AI) and multiple ovulation and embryo transfer (MOET), associated or not to in vitro fertilization (IVF), are available as routine techniques and able to contribute to increased selection efficiency of local programs, but, with the exception of AI, have as yet contributed little to improving the majority of low- and medium-input systems. Sexed semen may offer some advantages, particularly for meat producing systems (Benyshek, 1998; Bulfield, 1998; Montaldo, 2002) and for smallholder dairy systems, especially where the opportunities for systems stratification are limited.

Across-breed evaluations. Methodologies such as extensions of the mixed model methods for animal evaluation to include multi-breed or multi-population situations have great potential to serve as a basis for a more efficient selection of mixtures of local and exotic populations found in many systems in developing countries. This could be an efficient strategy to preserve valuable alleles for local conditions, provided rational selection criteria are used (Notter, 1999; Montaldo, 2001). These applications will be dependent upon the availability of performance records, an essential criterion infrequently met in these systems.

Use of molecular genetics in animal breeding. The biotechnologies that currently seem to be particularly useful for medium- to low-input systems are for parentage and animal identification with molecular markers in situations where genealogical recording and animal identification is difficult. The development of AI services and in some cases, particularly in the context of ONBS, the integrated use of MOET and marker assisted selection (MAS) technology seems promising, subject to adequate market incentives and the capacities of local institutions.

Information technology. Successful genetic improvement action requires many decisions, generally by a range of stakeholders, particularly farmers, across time and space. In turn, sound decisions depend upon those involved having ready access to relevant and timely information. In this respect the oncoming information age offers a number of important opportunities for increasing both the efficiency and effectiveness of decision support to breeding programs. These opportunities will only increase, with the issues critical to their use being: what information is required, by whom, when, and in what form is it best provided. Information on the benefits from improved management practices can serve as an important stimulus to generate and sustain farmer involvement in genetic improvement programmes. The application of technical solutions for the identification of individual animals (including implantations allowing the use of remote sensing tools) may facilitate breeding work in conditions up to now excluding application of methods of population genetics, provided the returns to producers outweigh the costs. Also pedigree identification through molecular genetic methods opens up new possibilities of breeding under extensive production conditions. Information systems and application of all kinds of communication tools (from those for illiterates from Rapid Rural Appraisal methods up to internet connected computers) can improve internal flow of information including market statistics for example, breeders associations. Access to computing technology and the internet, as well as reduced costs, open many interesting options for breeding organizations to analyse data with suitable mixed model methodologies and to interchange data in a timely way.

CONCLUSION

In low- to medium-input smallholder production systems the integration of genetic improvement programmes with other livestock improvement activities including the management of environment and animal health, product preparation for market and practical training, is essential. Field experiences have shown that for these programmes to be successful, there must be a very clear definition (through applying participatory approaches) and understanding of producers' multiple objectives and their contribution to breeding goals. Public and private good returns from genetic improvement for resource-poor producers and their incorporation in the design of schemes to maximize the synergy of public and private investments (e.g., in AI for dairy) is a prerequisite. Governments must play a active role in stimulating long term genetic improvement programmes through infrastructure to support animal recording, training, accessibility of input and output markets, etc.

Participation of farmers and their self-organisation within marketing or breeder associations (which may be co-operatives) that focus on their needs, are two important factors required for the success of any genetic improvement programme. Breeding costs must be taken into consideration, given that generally government or NGO support will be limited in amount and duration. To be viable, integrated breeding programmes must generate immediate user benefits, while linking the benefits to obligations and balancing the returns to the costs of the services provided. The investments in genetic improvement must be assessed for its costs and benefits over years, clearly identifying who bears the costs and who benefits. Building supportive institutions and the capacities of producers and the technicians who serve them, are two important policy issues that need to be addressed when designing effective breed improvement programs in medium- to low-input production systems. Organisational and legal support for breeders' associations will be required, including ensuring that they are able to retain their rights to indigenous genetic resources. The ability (either directly or through government support) to meet the costs of knowledgeable technicians is essential, as is assuring access to secure markets for surplus/improved quality production. To sustain the programme, the organisation of reliable and timely information for collective action groups such as breeders' associations and to external sources (from product prices to the contents of international conventions) will be pivotal. Underpinning that information flow will be simple animal recording and evaluation schemes, designed to create functional improvement programmes, serving as the basis for a virtuous circle extending to more farmers and facilitating. In turn they will facilitate the incorporation of more elaborate technologies such as artificial insemination, and where financial returns merit and institutional capacities allow, other technologies such as multiple ovulation, embryo transfer and marker assisted selection.

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