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Selection and Breeding of Cattle in Asia: Strategies and Criteria for Improved Breeding

Prepared under the Framework of an RCA Project with the Technical Support of the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture

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FOREWORD

The International Atomic Energy Agency (IAEA) and the Regional Cooperative Agreement for Asia and the Pacific Region (RCA), with the technical support of the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture, implemented a Technical Cooperation (TC) project entitled Integrated Approach for Improving Livestock Production Using Indigenous Resources and Conserving the Environment (RAS/5/044).

The 23 project counterparts and the IAEA technical officer, based on the lack of standard practices in the region with regard to selection of cattle for breeding purposes, and the need to properly manage the genetic resources within each country for improving the productivity of the existing stock while maintaining the unique and beneficial genetic characteristics of the indigenous breeds, agreed during the first meeting to request the IAEA to recruit a group of experts with the task of preparing guidelines for the selection and breeding of cattle and buffalo on the Asian continent.

To address these recommendations, an experts meeting on Selection Criteria for Breeding Heifers was organized and held in Mymensingh, Bangladesh. The meeting was hosted by the Faculty of Veterinary Science of the Bangladesh Agricultural University (BAU) from 6 to 10 February 2006. It was attended by six foreign experts and two local experts, and was supported by the technical officer of RAS/5/044. The experts from countries participating in RAS/5/044 gave presentations on the current state of cattle breeding in their countries and two experts working in industrialized countries within the region (New Zealand and Australia) informed the participants about the existing cattle breeding programmes in their respective countries and offered their perspectives on how similar approaches could be transferred to the Member States participating in RAS/5/044. All experts also made a field visit to a prominent dairy-producing region, to experience at first-hand some of the current programmes for management of cattle genetic resources in Bangladesh and Asia in general. After in-depth discussions about the presentations, taking into account the experiences of the field visit, and identifying the target audience for guidelines of this type, an outline of the guidelines for cattle selection criteria and breeding programmes was developed. Each expert was assigned to assist in the preparation of a specific chapter of the guidelines.

The present manual will assist livestock personnel in Asia to apply the guidelines to improve existing management systems for local cattle genetic resources and develop new systems that are efficient, cost effective, and sustainable for different livestock farming systems under varying socioeconomic environments.

The IAEA officer responsible for this publication was P. Boettcher of the Animal Production and Health Section of the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture. He was assisted by B.M.A.O. Perera (Sri Lanka) in the final editing of this publication.

CONTENTS

Summary 1

The current status of cattle breeding programmes in Asia.. 3

H.M.S.P. Herath, S. Mohammad

Selection criteria and breeding objectives in improvement of productivity of cattle and buffaloes.. 11

A.K. Jain, M. Muladno

Proposed breeding structure for cattle development in countries in the South Asia Pacific region 25

M.G. Jeyaruban, M.H. Rahman

Technologies to assist in selecting replacement females 35

H.T. Blair

List of participants.. 47

SUMMARY

A consultants meeting was organized by the IAEA and hosted by the Department of Surgery and Obstetrics of the Faculty of Veterinary Science of the Bangladesh Agricultural University (BAU) in Mymensingh, Bangladesh from 6 to 10 February 2006. The experts were M.H. Rahman and M. Shamsuddin (Bangladesh), A.K. Jain (India), M. Muladno (Indonesia), S. Mohammad (Malaysia), H.M.S.P. Herath (Sri Lanka), H.T. Blair (New Zealand), and M.G. Jeyaruban (Australia), plus the IAEA technical officer P. Boettcher. The task of this group was to establish suitable criteria for the selection and breeding of cattle and buffalo in Asia.

Most of the South Asian and Pacific countries have similarities in setting the policy and execution of dairy and beef cattle genetic improvement programmes. Historically, governments have played a major role in cattle farming and breeding activities; nowadays, however, the initiatives of the private sector or of non-government organizations are modifying the needs of farmers for support from the government. About 90% of the contribution of the livestock sector is from small holders and this proportion is highly consistent across countries.

Both artificial insemination (AI) and natural service are practiced as methods of breeding. AI services are more widely available near cities and coverage varies from 20 to 90% depending on the country, and replacement females are usually from the heifers bred within the same herd. The absence of coordinated systems for data collection and record-keeping and the maintenance of databases for the livestock sector, including a mechanism for feedback and exchange among the stakeholders for development of livestock-related policies have been identified as a major constraint.

There is a need to improve current practices in Asia with regard to selection of cattle for breeding purposes, for both dairy and beef production. For many years, most of the countries in the region have been importing cows, bulls, and semen, largely from the temperate regions of the world, and using them to ‘upgrade’ the genetics of their existing herds of indigenous cattle for producing ability. However, and based on current evaluation of production levels and the productivity of cattle and buffalo, some doubts exist regarding the need and wisdom to continue this practice. Because the importation has been ongoing for up to 50 years, in some cases, and because the exotic breeds are not naturally adapted to the climatic and management conditions that prevail in the region, the current local populations may already contain a sufficient proportion of exotic genetic material to support efficient productivity and yet withstand the local environments. The primary current need is to properly manage the genetic resources within each country, by developing selection programmes to improve the productivity of the existing stock while maintaining the unique and beneficial genetic characteristics of the indigenous breeds.

Breeding programmes have to consider important phenotypic traits that have an economic value (those that affect either the income obtained or the costs of production), although traits that provide a less tangible utility for cultural or other reasons may also be considered important. Among them and depending of the purpose of the animals, production traits like milk and fat yield, and body weight, reproduction traits like age at first calving and calving interval, and others like disease resistance, milk let-down, temperament, udder characteristics, skin colour and body size and shape. Breeding goals and objectives should be established based on the economical value of different traits and their genetic parameters. Although quantifying the amount of emphasis is not easy, approximately 50% emphasis on production traits seems reasonable and would be consistent with many of the breeding goals

used in industrialized countries. On this approach, participation of farmers in establishing breeding objectives is critical.

Most Asian countries are implementing crossbreeding programmes to upgrade the local cattle population to 75% or more of exotic genotype, but they are often not successful due to incompatibility of the genotypes with farmers' breeding objectives and the production systems. Choice of the exotic breeds usually depends on milk production, early maturity, and compatibility with local breeds, especially related to body size. Exotic animals used in crossbreeding are not naturally adapted to local conditions, so large scale crossbreeding in Asian countries should be carried out with caution; also, crossbreeding tends to decrease the population of local breeds, and therefore, there is an urgent need to conserve the uniquely adaptable, heat tolerant, draught and disease resistant local breeds.

An open nucleus breeding programme, where animals from the general population can be part of the nucleus, has been proposed for faster genetic improvement. Because this scheme is not restricted to animals already in the nucleus (as is the case with a closed nucleus), it allows for greater selection intensity and is often quoted as the preferred method of operation for quick genetic gain. This scheme can be recommended as an alternative to the progeny testing scheme, and can be achieved either by grouping high production animals at the farmer level (Group Nucleus Breeding Structure), or by assembling all animals at a highly organized location (Central Nucleus Breeding System).

A number of technologies are required to identify the genetically most superior animals to keep as parents or to bring into a herd. The estimation of an animal's genetic merit requires the accurate identification of two groups of animals within the population: those that will contribute to genetic gain, and those animals that will be measured to provide data from which genetic evaluations will be generated. There is a wide range of methodologies that are applied for animal selection and breeding, depending on the purpose, varying from very simple ones like weighing the animal or milk in a scale to others that require a laboratory setup, including molecular, nuclear and nuclear-related techniques such as CT and DEXA scanning, radioimmunoassay, ELISA, doubly-labeled water, DNA/RNA-based tools, genetic markers and genetically modification of animals.

The present manual includes information about trends in livestock production and cattle breeding management in Asia; the important traits for dairy and beef cattle, their selection criteria, and breeding objectives; proposed systems for operating a cattle breeding and genetic improvement programme in Asia; and an overview of current and future technologies for improvement of cattle breeding. In all cases, the role of nuclear and related technologies was noted. It is aimed at all levels of cattle breeding in Asia, from farmers to breeders and artificial insemination organizations, to administrative and technical personnel involved in the management of cattle genetic resources in Asia, including Ministries of Agriculture/Livestock/Environment, Directorates of Livestock and Veterinary Services, local authorities responsible for livestock development services, and Faculties of Agriculture, Veterinary and Animal/Plant/Soil Sciences in Universities.

THE CURRENT STATUS OF CATTLE BREEDING PROGRAMMES IN ASIA

H.M.S.P. HERATH
Animal Breeding Division
Department of Animal Production and Health
Peradeniya, Sri Lanka

S. MOHAMMAD
Malaysian Agricultural Research and Development Institute
Kuala Lumpur, Malaysia

1. INTRODUCTION

Most of the South Asian and Pacific (SAP) countries have similarities in setting the policy and execution of dairy and beef cattle genetic improvement programmes, but the degree of involvement by the state and the private sectors varies with their socioeconomic priorities. Dairying plays an important role in socioeconomic development in India, Bangladesh, Sri Lanka and Myanmar, while the economic output from livestock in Indonesia and Malaysia is dominated by the beef industry.

Dairy development tends to be more strongly supported by the public sector in the countries that aim to use dairying to alleviate poverty, hunger and provide livelihood support in terms of income and employment generation to the millions of landless and smallholder dairy farmers. In part due to this support, milk production in SAP has increased steadily over the last decade. Bangladesh, India, Pakistan and Sri Lanka have realized annual growth of 1.5%, 4.1%, 4.9% and 0.6% respectively, in total national milk production from 1993 to 2003. Consumption of milk and dairy products has been expanding dramatically with income growth, population growth, urbanization and dietary changes [1, 2].

Approximately18% of the global cattle population is from SAP. Out of this, the largest share is from India, which has about 10% of the world's population by itself. In Asia, about 90% of the contribution of the livestock sector is from small holders and this proportion is pretty consistent across countries. The respective agriculture policies of the countries show a serious commitment of governments to improve the general economy through the livestock sector, with particular support to smallholders. Studies have shown that having multiple farming objectives, including meeting the need for more milk, ensuring adaptability to local feed conditions and diseases, and the provision of non-market returns such as through manure, insurance and financing roles of cattle, is a sustainable practice and underlies smallholders' breeding decisions [3]. Mixed crop and livestock production systems have become popular among the farmers. Animals are obviously an integral component in these systems. For example, the dairy sector can provide its products either directly to the household in the form of milk and meat, or supply in bulk to the market as value added products and yield inputs for crop production in the form of organic fertilizer (dung and the farm refusals).

Various attempts have been made in the tropics to improve the milk production of native Zebu cattle through selection and crossbreeding. Over four decades of artificial insemination (AI) services in the Asian countries have resulted in a population that includes about 15 to 20% of crossbred and upgraded cattle. However, beyond a general willingness to promote crossbreeding, in most of the cases, except in India, there is no established long term policy in livestock development. After the initial success of crossbreeding programmes in the 70s in augmenting the milk yield by two to three times in comparison to Zebu cows and decreasing the age at first calving, large scale crossbreeding programmes have been launched by different organizations in the countries without making sufficient preparation for proper feeding and management of high yielding cows, biosecurity of sensitive animals, maintenance of records on genetic structure of animals and assurance of adequate health cover, leading to many problems in the improvement of the national herd. Therefore, indigenous breeds were largely neglected and the primary undesirable characteristics of the zebu cattle, the indigenous breed of the tropics, such as late puberty, long calving interval, short lactations and low average daily milk yield have yet to be adequately addressed and improved upon.

2. FARM STRUCTURE

In the process of formulating breeding programmes for genetic improvement, the structure of the herd has a special role to play. Considering the characteristics of herd structures found in the Asian countries, farms can generally be categorized into four groups, which can be based mainly on the size of the herd, but these groups also tend to differ in the size of the land holding and type of the labour employed (Table 1). As mentioned previously, most of the dairy herds in Asia are owned by smallholders, with three or fewer milking cows, comprising about 90% of the farmers. However, in general, all four types of farming systems can be observed in all the countries in SAP.

3. MANAGEMENT

The breeding programmes that have been carried out in most of the countries have a history of well over 40 years in practice, resulting in a mixed population of purebred, crossbred and upgraded cattle with variable genetic make up. There is a vast diversity in breeds in Asian countries. Table 2 lists breeds of cattle locally adapted to a group of Asian countries. Due to importation of exotic genetics, approximately 15 to 20% of the cattle population in these countries has germplasm from Holstein Friesian, Jersey, Brown Swiss, Hariana, Tharpakar, Ongole, Sahiwal and Sindhi. Exact levels of exotic blood in these animals are not known. Depending on the agro-ecological zones, social structures, type of the breed, feed availability, the economic status, the knowledge on animal husbandry of the farmer and his or her interest in breeding and management, the average genetic makeup of cattle varies. Cattle with high proportions of exotic temperate blood tend to be managed intensively. In part, this is out of necessity, as exotic breeds are by definition not well-adapted to the local climate, feed resources and management systems and require some level of environmental modification to remain reasonably healthy and productive. The indigenous and exotic zebu types, on the other hand, are managed more extensively, allowing free grazing during the day and night paddocking. Intermediate crosses of the temperate breeds are most commonly kept under semi-intensive management systems.

In most of the Asian tropics, cattle production systems are primarily grass-based with cows either allowed to graze freely or confined and provided with cut-and-carry harvested forages. However, in some countries other farming and feeding strategies are predominant. For example, in India milk is produced mainly on crop residue based systems. In Bangladesh, most small holders also have a plot of rice and they collect the straw for feeding of cattle, supplemented with cut-and-carry fodder. In Malaysian beef production, the animals in the fattening stage are kept in oil palm plantations.

TABLE 1. CHARACTERISTICS OF CATTLE FARMING SYSTEMS IN ASIAN COUNTRIES

Attributes	Smallholder < 3 cows	3–10 cows	10–20 cows	Large dairy > 20 cows
Labour	All family	Mostly family	Some off farm	Exclusively off farm
Genetic value of cattle	Generally low, non-descript genetics	Variable due to some crossbreeding	Variable, more crossbreeding	Crossbreeding with variable genetic value
Feed resources	Little or no concentrates or cropland	Crop residues, some concentrates and some grass, forage	Crop residues, more concentrates and green fodder	Crop residues and concentrates. Still limited by climatic factors
Animal health resource	Minimum	Mostly in an emergency	More access to regular animal health resources	More access to regular health resources
Education about animal husbandry	Little	Slightly higher	Variable	Variable
Reproductive management	Poor	Average	Good	Not much attention to young heifers
Access to financing	Low	Some access	Good	Good

TABLE 2. EXAMPLES OF LOCALLY ADAPTED BREEDS OF CATTLE FOUND IN VARIOUS COUNTRIES IN THE SOUTH ASIAN AND PACIFIC REGION

India	Bangladesh	Sri Lanka	Malaysia	Indonesia	Myanmar
Indian Zebu	Indigenous Zebu	Indigenous Zebu	Kedah	Bali cattle (*Bibos sondaicus*)	Pyar Sein
Gir	Pabna	Nondescript indigenous	Kelantan(KK)	Madura	Pyar Phu
Red Sindhi	Chittagong Red	Lankan or Batu harak	Local Indian Dairy(LID)	Grati	Shwe Ni
Sahiwal	North Bengal Grey	White cattle	Mafriwal		Shwe-ni-gyi
Tharpakar	Hariana	Cape or “Hatton”	Droughtmaster		Shan
Deoni	Mushiganj		Brahman		Kyaukphu
Nagori	Dhaka-Fardipur		Brakmas		Kadonta
Gaolao			Charoke		
Khillari					
Amritmahal					
Hallikar					
Kangayam					
Krishna Valley					
Umblachery					
Gangtiri					
Kenkatha					
Malvi					
Kherigarh					
Ponwar					

In many of the Asian countries, the calf is often kept with the cow and is allowed to continue suckling for at least 6 months. This practice is particularly done with breeds for which the presence of the calf is needed to stimulate milk let down. Although this practice ensures better nutrition for the calf and thus increases survival, it decreases the amount of milk that can be marketed. This practice generally applies to female calves; the bull calves typically get less attention and are often left to starve or are just sold for fattening by other farmers. Neglect of bull calves may be particularly common in countries where religious beliefs preclude the consumption of beef.

4. BREEDING

In most of the countries in the SAP, both AI and natural service are practiced as methods of breeding. Access to AI services within a country depends heavily on geographical location, being more widely available near cities or ‘milk pockets’ and being less available in areas with low farm density. Artificial insemination coverage varies widely, from 20 to 90% in different Asian countries.

The AI centres are usually government-operated or run through private organizations that are contracted with and monitored by the government official responsible for animal improvement. In some cases, non-governmental organizations also provide AI services. Organized private AI service, independent from the central government, is also available in some countries and is often closely linked with a cooperative milk marketing system. The AI delivery system operated by Anand Milk Cooperative Union Limited in India is a good example. The Union runs an AI centre at Anand and sends semen to AI subcentres at village milk societies. Secretaries of these societies who are also trained in AI deliver the service free of charge for members of societies as well as for non-members who in turn become members. A subsidy is given by the union to each society which provides AI facilities. The union operates a free mobile veterinary service and assists farmers to cultivate fodder for their animals.

Options in the absence of AI are natural service through the use of a community bull (usually at no cost), one’s own bull, or privately-owned bulls for which fees must be paid to the owner. A majority of cattle farmers prefer AI to natural service, but buffalo farmers generally prefer natural breeding because of the difficulty in heat detection and poor conception rate. Of course, exceptions to these rules can be found, depending on the location within the country, especially location with respect to existing AI centres. Nevertheless, some farmers keep a bull even when AI service is available to help ensure the timely conception of their cattle and buffalo, and a common practice is to breed cattle in estrus both naturally and artificially. Often farmers may keep a bull primarily for fattening, but then use it for breeding in emergency situations, such as when AI is not available at the time the cow is in estrus. When selection of a stud bull is possible, it’s mostly by phenotypic selection on the performance of the bull. When pedigree is accounted for, the bull’s dam is given more consideration than the sire. However, from the point of view of the farmer, the convenience in the availability of the bull or AI service is usually more important than the genetic make up of the animal. This is a logical decision, especially in the short term, as increased calving intervals are associated with decreased income through longer dry periods and fewer calves over a lifetime.

5. SOURCE OF REPLACEMENT FEMALES

The replacement females for the cattle herd are usually from the heifers bred within the same herd regardless of the size of the farm, but this rule is especially true for small holders. Larger herds will have a higher percentage of replacement heifers purchased from ‘outside’ sources, but also sell more females. The reason for this is tied directly to size. First, larger herds are often in phases of expansion, and thus need more females than could have been produced by the existing herd of cows. Second, the larger farms are usually more market oriented and will have more available cash flow. Finally, large farms may choose to specialize and direct their attention to milking adult cows and may thus sell off young female calves to be raised by others.

The transactions for exchange of females are most frequently handled by a middleman, through whom prices will be fixed for both seller and buyer. The middleman usually applies some quality control over these deals. Two types of middlemen exist. First, there are cattle traders engaged in the business, who will actually take temporary ownership of the animals, not necessarily having in mind a specific buyer for each animal purchased. Second, there are cattle brokers, who are primarily ‘dealmakers’. The job of these middlemen is simply to put together the buyers and sellers of the replacement animals, for a portion of the selling price. The market for heifers is usually easily accessible but the highest quality animals may not be available either from smallholder or large farms. Farmers will rarely sell their high quality animals. Similar to the situation for bulls, buyers are primarily searching for a female to add to the herd, not for genetic improvement. In addition, pedigree and performance recording systems are essentially non-existent, so there is usually nothing concrete beyond phenotypic appearance upon which to base the payment of a premium for a higher quality animal.

6. MILK COLLECTION AND MARKETING

A general rule is that larger farms have more access to marketing and smaller farms may have little to none. However, large farms will usually be located in regions where a milk market already exists or milk dealers will be drawn to large farms. Smallholders may have access equivalent to that of large farms depending on location and their ability to organize. Larger farms are often capable of collecting, chilling and marketing both their own milk and that of smaller farms. Nevertheless, for both large and small farms, often only one market is available and thus little competition exists. Even when there are many possible outlets for milk, all will typically compete for the same organized dairy structure at the field level rather than expanding to untapped areas. Hence, overall the opportunity of rural communities of smallholders to the formal market grid is rather low. Some governments may provide assistance or incentives in terms of credit facilities or in kind to those farmers that contribute to marketing. Informal markets may also be available in areas where the farmers sell the milk themselves to their own customers and probably make more profit than supplying to a formal market where standards of milk is emphasized. Pricing systems for milk are not highly sophisticated, but some companies pay variable rates per litre of milk depending on the quality. In such cases, the fat concentration is the most often used measure of quality, but solids-not-fat are also considered in the price structure offered by some milk collectors.

7. BEEF MARKETING

The marketing of beef is usually handled by a local authority, under the supervision of government veterinary personnel, but often a private middleman plays the major role in organizing the transaction. The meat is then sold at the market places as either fresh or frozen.

The demand for beef can vary greatly throughout the year. In some countries, such as Bangladesh, the majority of the beef sold will be associated with certain religious holidays that involve feasting. Organized cattle markets are also available in many countries. Some countries, such as India and Malaysia, have well-established meat processing companies that are often linked to export markets. In general, sale prices are based solely on the weight of the animal, with no consideration of meat quality. Some informal bargaining based on phenotypic aspects such as coat colour or body condition may occur, however.

8. ROLES OF PUBLIC AND PRIVATE SECTORS IN CATTLE BREEDING

Historically, the governments in the various countries of SAP have played a major role in cattle farming and breeding activities. Although the ways in which the government intervention occurs will likely evolve over time, its importance will likely continue to remain high. One common goal of the governments has been to improve the diets of their people, increase food security and to approach self-sustainability, searching to eventually eliminate the need for imports. These goals were the basis for many government sponsored policies and projects for supporting crossbreeding with exotics. Initially, most of the AI services in SAP were coupled with veterinary services and were organized and managed by government institutions. Vaccinations ensuring the health status of the herd were also typically part of the state-sponsored activity. In addition, nucleus and demonstration farms were usually under the direct control of government and restocking programmes, either by way of importing live animals or by importing genetic material such as semen or embryos, have been the practice of the state sector.

Nowadays, however, the initiatives of the private sector or of non-government organizations are modifying the needs of farmers for support from the government. While the state sector enforces the rules and regulations to maintain the stability of public concern, the successful implementation of programmes has been obtained through other organizations such as non-governmental organizations, cooperatives and private companies. Importation of genetic material will still usually require government approval, at least for veterinary health reasons and occasionally for concerns about suitability of breeds and threats to indigenous resources. Successful implementation of AI services in specific areas through non-governmental cooperatives has provided a model and given the inspiration necessary to support the replication of the system in other regions and countries. Many of these services are tied to milk marketing cooperatives. Milk unions, or large local cooperatives, have become direct suppliers of many services to their members, replacing some of the needs from the government. All the services related to breeding, health, management of cattle and marketing may be provided through the well-organized cooperatives. These services can range from credit facilities, to feed sales and to veterinary service. Supply of genetic material through AI is a natural extension. By providing veterinary services and feed sales, the cooperatives can help ensure higher milk quality and production efficiency. The same is true for supply of genetic material. In addition, the cooperative can more precisely provide the genetic material best adapted to the local conditions, either through thoughtful breed selection for crossbreeding, or development of an in-house breeding programme. Such a programme benefits the state, which can then direct their efforts elsewhere. Therefore, this mode of operation must be encouraged and included in the government policy in all the countries in Asia. AMUL in India and MILKVITA in Bangladesh are examples that demonstrate the success of cooperative organizations.

Setting policies that support a sustainable dairy industry is the major commitment of the governments. Import and export regulations are to be enforced without disturbing the stability of the local production. Price stabilization on essential commodities is another aspect on which the governments pay attention. In many countries in SAP, very minimal regulations on food safety are in place, however. In addition, the state is still the logical provider for a large number of other services. Policies of interest to the entire country, meaning both for farmers and consumers, should be the responsibility of the government. For example, conservation of breeds and maintenance of indigenous knowledge are beneficial to an entire society and should be addressed in state-wide policies or even regional policies, if possible. Universities can provide extension and training of both farmers and professionals and efficiently be under the responsibility of government. Government involvement in supplying plant genetic material in the form of forage cuttings and seeds, and general technology transfer, exhibiting results from the best farmers, can be highly positive and empower the dairy farmer towards more profitable ventures.

9. CONSTRAINTS TO CATTLE BREEDING IN THE ASIA-PACIFIC REGION

The absence of coordinated systems for data collection and record-keeping and the maintenance of databases for the livestock sector, including a mechanism for feedback and exchange among the stakeholders for development of livestock-related policies have been identified as a major constraint for many countries in SAP. Such data recording, even on a limited scale, is critical for genetic improvement of livestock.

Partially due to the paucity of data upon which to base policies and selection decisions, the lack of planned breeding programmes is highlighted in most of the countries in the SAP region [4]. Many countries have adopted policies to support upgrading with exotics to more quickly improve productivity, but indiscriminate use of exotic germplasm in the national herds has led to drastic reduction of indigenous livestock genetic resources in many countries. While some countries (e.g. Malaysia and Indonesia) have a problem associated with a small base population of dairy cattle and buffaloes that precludes rapid multiplication, others have the opposite constraint of having a very large animal population size (India) with unknown and variable genetics due to long term unplanned crossbreeding practices. Both situations limit the ability for intensive selection for genetic improvement.

Policies on breeding and crossbreeding often vary across countries and are prone to change within country at each election of a new government. Tepid and variable commitments of government to long term breeding programmes have been identified as an additional constraint in sustainability of genetic improvement. Little coordination and poor linkage among government agencies and other stakeholders, little access to technologies and meagre training on animal breeding for technicians has influenced the rate of genetic gain further. Necessity of conserving local genetic resources is yet to be considered in many countries. Breed conservation should be recognized realizing that some valuable breeds have already become extinct.

Small herd size with wide dispersion is common to all countries and is another recognized difficulty. First, this leads to complexity in providing services. Availability of too few AI technicians and veterinarians and the difficulty in placing veterinarians in rural areas has exaggerated the situation. Furthermore, with many small farms, spread across a wide area, difficulties arise in the control over the movement of animals with different genetic composition. Large animal population with little or no records or non-systematic record-keeping on breeding and related activities has led to a negative impact on genetic improvement. Though AI is a popular mode of breeding in many countries, low AI coverage has been emphasized as one of the major constraints in the poor genetic gain of the cattle population. From an operational and statistical standpoint, small herd sizes limit the number of contemporaries available for direct comparison and the possibility of using reference sires in many herds. The costs of data collect are also increased, as only a small amount of data can be collected from each site.

Even if supportive policies and record-keeping and genetic evaluation programmes were in place, the resulting improved set of animals would likely not express its full genetic potential due to environmental constraints. First, nutritional constraints are important, as the lack of high quality forages and nutritional supplements is prevalent. Climatic factors also introduce difficulties in the survival and productivity of the improved animals. Heat can be excessive and severely decrease fertility. Parasites and other diseases also contribute to reduce productivity and longevity. Losses due to high mortality of animals, particularly in calves, also constrain genetic gain in the population by decreasing selection intensity. In addition, the best young males (dairy) are often sold for beef due to lack of means to identify best animals. Farmers often have a relatively low level of formal education and may have variable knowledge of husbandry to help overcome the problems in managing improved genetic material, as their indigenous knowledge was most applicable to the raising of local breeds.

With the increase of human population, the land availability for agriculture is continually abridged. As urbanization has decreased the proportion of populations in rural areas, government attention to rural area has decreased in the relative sense. Finally, when farms are far from these urban centres, formal market access, poor transportation, and communication difficulties in many parts of the countries contribute to unprofitable dairying by decreasing the motivation to increase productivity. Although there are organized milk marketing systems in many countries, the milk processing facilities are still inadequate and involvement of brokers and middleman is unavoidable.

In conclusion, improving the productivity of cattle in SAP will required a multi-faceted set of interventions that will involve not only proper management of local animal genetic resources, but also strengthening of local institutions for support of farming activities, including not only breeding-related services, but also services related to nutrition, health care, milk marketing and social services. These services are to be provided by a combination of governmental, non-governmental, and private institutions. A contribution by the government for policy setting and support in management of local resources is necessary to ensure sustainability and fair exchange of germplasm between countries.

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SELECTION CRITERIA AND BREEDING OBJECTIVES IN IMPROVEMENT OF PRODUCTIVITY OF CATTLE AND BUFFALOES

A.K. JAIN
Department of Animal Breeding and Genetics
Punjab Agricultural University
Ludhiana, India

M. MULADNO
Institute Pertanian Bogor
Fakultas Peternakan
Raya Pajajaran No. 1
Bogor, Indonesia

1. INTRODUCTION

Breeding objectives for improving the productivity of or conserving particular breeds or genetic groups of livestock depend upon many factors. Among these factors are the agro-climatic conditions of the area of inhabitation (including endemic diseases), agricultural and livestock systems in vogue, availability of feedstuffs — including crop by-products, herd size, marketing structure and locally available animal genetic resources, socio-cultural and economic level of the livestock owners, available infrastructure and facilities, desire and capabilities of farmers and the political and administrative will of the state to bring about change in animal productivity to improve the living standard of livestock farmers. The religious sentiments of some populations attached with animals, especially cows, shall also not be ignored in defining breeding objectives. In addition, breeding objectives must not only consider the present status of these factors, but also take into consideration the future needs for quantity and quality of animal products. As the generation intervals of livestock, particularly of cattle and buffaloes is quite long, the impact of breeding plans are not expected to be realized for several years, by which time the requirements may be different.

2. TRAITS OF IMPORTANCE

One of the first steps in developing a breeding programme is to consider which phenotypic traits are of importance. From a practical standpoint, traits with a measurable or at least readily recognizable economic value are generally to be given the most emphasis, although traits that provide a less tangible utility for cultural or other reasons may also be considered important. The economic traits are typically those that affect either the income obtained or the costs of production. In the South Asia Pacific region (SAP), the sale or home consumption of milk, meat, dung, and skin of the animals and the sale of surplus animals for breeding and meat are the main sources of economic returns of cattle and buffalo farmers. In addition, many farmers use themselves or rent out their animals for draft purposes, either providing an additional source of income or saving the costs of contracting out for these services. Some of the important traits that need to be included currently for both dairy and beef cattle and buffaloes are listed in Table 1. Traits associated with income are typically called *production* traits. For dairy cattle and buffaloes, these traits are those that are associated with milk production. In most of the countries in the SAP, farmers are paid according to the kilograms of milk sold, so milk yield is obviously a trait of high economic importance. When milk is sold in a formal market, the price paid per kilogram may be adjusted based on concentrations of milk solids. Fat content is almost always considered under such a system, but payment for protein or solids-not-fat is becoming increasingly common. The milk of buffaloes is priced 1.5 to 2 times than cow milk due to its greater concentration of milk solids

(17 to 19% versus around 13%) and in certain areas it may be mixed with cow milk to increase the thickness of cow milk and, in turn, improve its market acceptability.

TABLE 1. TRAITS OF ECONOMIC IMPORTANCE IN DAIRY AND BEEF BREEDS OF CATTLE AND BUFFALOES

Important traits	Dairy cattle/Buffalo	Beef cattle/Buffalo
Production	Milk yield Concentration of milk solids	Body size or weight Growth rate Carcass quality Age and weight at slaughter Leanness, carcass percentage
Reproduction	Age at first calving Calving interval Age at first collection of semen	Age at first calving Calving interval Mothering ability Scrotal circumference
Health	Disease resistance	Disease resistance
Management	Longevity Milk let-down	Calving ease Temperament
Physical appearance	Body colour, shape, and dimensions, udder characteristics, structural traits and body condition	Body colour, shape, dimensions, structural traits and body condition

For beef cattle, economic value of a cow or buffalo is logically based on the amount of meat expected to be obtained from the animal. In contrast to industrialized countries, the sale price is not always based on formally weighing the animal and paying a certain price per kilogram. Rather, the animal is often priced as a whole. Nevertheless, larger animals fetch a higher price, so some measure of body weight is of particular importance. Reaching a mature weight as quickly as possible is advantageous, so weights at different ages, such as weaning, one year-of-age, and slaughter, can be taken to evaluate growth rate. Age at slaughter can also be used to account for growth rate; younger animals would be favoured. Birth weight is also often considered important for beef cattle, but largely for calving difficulty rather than production, so smaller birth weight may be preferred. Carcass quality traits can be important for some of the countries in the SAP, but in most cases this variable is not considered in the sale price, so a farmer can not economically justify considering it in a selection goal.

Traction is also an important output of cattle and buffalo in the SAP. Animals with long legs, straight barrels and tight skin are generally assumed to be stronger and thus favoured for draft purposes. The *Bos indicus* males with large humps and well-developed dewlaps are preferred because of more dissipation of heat due to a larger surface area and more body reserves for drought periods.

Reproduction traits are also important more so in dairy animals. For beef cattle, the number of offspring produced determines the number of animals available for sale. Consistent reproduction is also important for dairy cattle and buffaloes because daily yield is highest in the months immediately following parturition and because longer dry periods (resulting from failure to conceive quickly) result in greater costs for maintenance without any income. Both late age at first calving (AFC) and long intervals between calving, especially in *Bos indicus* cows and riverine buffaloes, have been often cited as constraints to profitability in cattle farming in the SAP [1, 2].

Animal health is important for a number of reasons. First, sick animals require costs for treatment. Healthy animals also tend to produce more meat and milk and reproduce more regularly. The climatic conditions of many of the SAP countries can be demanding, with high temperatures, both extremes in precipitation and high risk for disease, so animals that are naturally resistant to problems associated with these adverse conditions are of high value.

Traits associated with management may also be worth considering. Increased longevity is important for a number of reasons. If their animals live longer, farmers can have the opportunity to sell excess animals or expand their herds, both of which would increase the potential for income. Increased longevity also allows for more opportunities for genetic selection. Because disease often leads to death or culling, the animals that live the longest are often those most resistant to health problems. For many indigenous cattle breeds, the presence of or suckling by a calf is necessary to ensure milk let-down. The milk consumed by the calf can obviously not be sold. In truth, this may not result in much waste, inasmuch as the milk consumed can improve both the health and growth rate of the calf, but selecting for milk let-down without this source of stimulation would at least allow farmers to choose between selling the milk and feeding it to the calf. Calving difficulty can cause losses to both the calf and the cow, so this trait may be important, especially when crossing with exotic breeds with larger body sizes than indigenous breeds or with known dystocia problems. Temperament is important in any situation where interaction with humans is critical, especially when animals are used for draft purposes or when animals must be milked regularly.

Finally, different aspects of physical appearance may be important. As already mentioned, body size is important for both beef and draft purposes. Coat colour or traits of the horns may be of importance for traditional or cultural reasons and thus may affect the market value of an animal. Udder traits may be associated with milk production, resistance to mastitis or ease of milking [3].

Although Table 1 divides traits into dairy and beef or draft, some overlap may occur. This is already obvious in the fact that some traits, such as those related to reproduction are listed in both columns. In addition, sale of male dairy animals can be a significant source of income and some animals may be used for draft purposes. The relative importance of these traits will be different in different areas and is important in determining the final breeding objectives.

3. BREEDING OBJECTIVES

In the strictest theoretical sense, breeding goals and objectives should be established based on formal studies that consider the value (expressed in economic terms) of different traits and their genetic parameters [4]. In many cases, using such an approach for formal derivation of a precise selection goal will not be feasible in developing countries. For this reason, waiting to adopt a breeding programme until such a formal approach can be applied is not recommended. Existing indigenous and other knowledge can likely be amassed and sufficiently organized to develop a reasonable selection objective by using an ad hoc and participatory approach. In fact, many industrialized countries develop breeding strategies based, at least in part, on the wishes of farmers. A safe conclusion is that production traits merit significant emphasis. Although quantifying the amount of emphasis is not easy if some sort of numeric index selection is not applied, which will often be the case, approximately 50% emphasis on production traits seems reasonable and would be consistent with many of the breeding goals used in industrialized countries [5]. The remaining selection could be placed on traits associated with reproduction, health and longevity, body characteristics and cultural preferences. However, assigning a precise relative value to the latter types of traits may be difficult, however.

The beef and dairy cattle production industries in the SAP are of interest to a wide variety of stakeholders. These stakeholders include the livestock farmers themselves, cooperatives, non-governmental organizations (NGOs), various private agencies, the government and consumers. Ideally, all of these stakeholders would have the same objective, but they often differ for breeding programmes in the developing countries. For example, the farmers have the objective to get maximum returns from their livestock rearing, while governments may be more interested in food security and conservation of some of the particularly important indigenous breeds. The private companies will be primarily interested in more profits and consumers will like to have low prices and good quality and while ensuring safety of the products.

Although differences in opinions among stakeholders may exist, participation of the farmers in the establishment of a breeding objective is critical. However, because they will play a primary role in applying the breeding objective, farmers are reluctant at applying an approach to selection for which they see no returns. They may also consider as important traits that have no obvious economic value from one who is uninformed, but may be important for management or cultural reasons. If farmers are not participating in selection programmes, then the programme will have a difficult time achieving success. The government needs to watch and check the distortion of the market by interested parties. The government may intervene to stabilize the market when necessary. Economic studies related to a specific breeding programme can be undertaken by governments, institutions, researchers or scholars to justify the potential benefit of investment in the breeding programme. Such studies can make useful thesis topics for students pursuing advanced university degrees. Frequent interactions among the different stakeholders are necessary for redefining the goals of breeding programmes.

4. BREEDING AND SELECTION CRITERIA

Because of wide variability in the amount of information available for selection of cattle and buffaloes in different countries in the SAP, a number of different methods of selection of females and males may need to be used by the various stakeholders. The primary stakeholders performing selection will be farmers and artificial insemination (AI) service providers, which include government agencies, NGOs, cooperatives and private organizations, and the approaches available will likely differ among these groups, even within the same country.

4.1. Selection criteria by farmer

4.1.1. Female selection

Even under the best management, the low reproductive rate of cattle (relative to other livestock species) limits opportunities for genetic selection of females by the herd owner. The opportunities for selection are further decreased by high AFC and long calving interval found in the SAP. In addition, an absence of performance records makes accurate selection difficult. Most selection that will be done, especially within a farmer’s own herd, will be effectively culling of unwanted animals, rather than selection of the best animals. When the opportunity for selection among females is available, such as when females are purchased, farmers should select females on the basis of expected milk or meat producing ability or (considering the conditions under which the animal will be raised), reproduction, health and structural traits. Meat producing ability will primarily be based on body size and appearance of muscularity.

In most countries in the SAP, no formal records will be available upon which to base selection. However, exceptions to this general rule can be found, records exist in some parts of some countries, and efforts are underway to increase record-keeping. Thus, it pays to set down selection guidelines for situations both with and without records.

When no records are present, selection for producing ability must be based on the physical characteristics of the animal. Certain physical attributes can give a clue to milk producing ability. In countries where crossbreeding is practiced, breed characteristics will be a strong indicator of producing ability. Animals with a greater proportion of exotic inheritance will generally have greater producing ability. Such animals will have characteristics such as larger size, a more angular form, and distinct colour markings (e.g. Holstein-Friesian crosses will tend to be nearly solid black, or black and white, depending on the other breed in the cross). Depending on the environment and resources available, one may want to avoid selecting animals with characteristics of exotic breeds that are too distinct, however, as this may indicate that the proportion of exotic inheritance is too high and it may be difficult to feed such animals adequately and they might be prone to health problems. Within breeds, udder capacity of adult cows is likely the most accurate physical indicator of genetic ability for production [6]. Large udders are desirable only up to a certain point, however, and increased capacity resulting from greater width and length of the udder is clearly preferred over increased udder depth and cattle with large, pendulous udders should be avoided. Such udders can be a forewarning of related health problems or indicate advanced age.

If a farmer decides to begin a record-keeping programme, a minimum amount of data must be kept to be of value for future selection decisions. The International Committee on Animal Recording offers guidelines on animal recording in developing countries [7]. Once an animal is born, it should be assigned some form of identity (either a name or number) and the date of birth should be recorded. In addition, the identity of the mother and father should be noted, along with an indication of breed or genetic type of the offspring and its parents. For cattle raised for beef production, body weight should be periodically recorded as the calf grows. Few, if any farmers will have a scale for weighing cattle, so a weight-tape can be used. Other body measurements, such as height at the shoulders or hips could be taken as well. This recording can be done at specific age milestones, such as weaning or one year of age, or at times that have no particular meaning. The important factor, especially in the latter case, is to also record the date when the measurement was taken. For dairy cattle, essentially no data needs to be recorded (in a minimal recording system), until puberty is reached. At puberty, farmers should record when a heifer is bred and to which bull the she is mated. The primary benefit of this is to help in accurately recording the sire of the resulting calf, but can also be used for reproductive management. Once the offspring is born, the date of calving should be recorded for the cow, and a record set of data should be created for the offspring, with the same information described earlier. For beef cows, from this point the primary data needed will be records of breeding and calving. Information on the growth of offspring will also be useful, but this data will be contained in the calf’s own record sheet. For dairy cows, records of production should be taken. If one is to follow the practice of record-keeping services in industrialized countries, milk production will be recorded monthly. However, this level of frequency is not absolutely necessary for accurate selection. Even as few as two records per lactation can provide 60% of the information of monthly records. When few records are taken, they should be recorded at the same stages of lactation for all cows that will be compared together, such as at the time of maximum production (30 to 60 d), and mid-lactation

(100 to 200 d). Otherwise, the date of recording must be recorded and the days since calving must be accounted for in a statistical procedure. Recording of breeding and production information should continue for the life of the cow.

When records are available, selection can be made on the animal's own performance if the animal is an adult, or records of relatives if the animal has not yet calved. Let us consider two levels of record availability: (1) where some individual information is available, but no formal comparison of animals has been made, and (2) where some sort of statistical analysis for genetic evaluation is possible.

When only individual phenotypic records are available, past and current production should be examined. If possible, records should be compared to that of animals in the same herd and calving in same season, inasmuch as this factor could affect the availability and quality of feed. When animals from two herds are compared, the difference in production could be due in part to differences in management between the herds, rather than real producing ability of the cows. The effect of the age of the animal should also be considered, as cows tend to produce more milk in each successive lactation, until they reach maturity. In addition to producing ability, the AFC, lactation number and current age should be reviewed to evaluate reproduction and the remaining lifespan. For heifers, records on relatives may be limited to that of the dam, if they are available at all, and then one should evaluate records as if he or she was purchasing the mother. If sire records are available, then these should usually be emphasized over those of the mothers, because they would be based on the average of multiple daughters (i.e. half-sibs of the animal considered for selection) and thus be more precise estimates of the sires' genetic value than single production records of cows.

Selection decisions are made simpler when formal genetic evaluations are considered. With a genetic evaluation, records are collected at a single location and evaluated statistically to estimate genetic values for each animal. Proper genetic evaluations will account for factors such as age and season of calving and compare animals within the same herd. Depending on the complexity of the system employed, the genetic potential of all of the relatives will also be considered. Thus, a farmer can simply rank the animals based on the index available and select the highest ranking animal among the selection candidates.

Regardless of the level of record-keeping done and the information available for selection on producing ability, the cow or heifer should be free from any obvious health problems, including having reasonable body condition considering the feed availability. These aspects are of importance primarily for phenotypic reasons, as they will impact cost of production and longevity of the cow herself, but such traits are, nevertheless, under some genetic influence and thus could have some association with the future performance of the cow's offspring.

4.1.2. Male selection

The male pathway of selection theoretically offers more opportunity for increasing intensity of selection but, unfortunately, the livestock farmers in the SAP often have little or no choice when selecting males for breeding. In some cases, only a single bull is available for a community or village. With AI, the selection of semen from the AI centres, which are usually run by government or one of its agencies, is often very limited and inseminators may either not offer much choice or will make the selection decision on their own. In situations of low sire variety, factors other than the genetic potential of the bull must take precedence. One factor is genetic relationship of the bull to the cow and the desire to avoid inbreeding.

Inbreeding can be a particular problem in areas where bull availability is limited. Also among the factors that farmers may need to consider are the breed and age of the bulls. In countries where crossbreeding is practiced, a farmer may simply want to ensure that a bull of an exotic breed is used, to 'upgrade' their stock consisting of unimproved local animals. In contrast, he or she may want to specifically avoid using an exotic sire, to prevent reaching a level of foreign genetics that has been found to be incompatible with environmental (climate and endemic diseases) conditions. Alternatively, the breeder may be attempting rotational crossing, and may have a specific breed in mind. With regard to age, choice of the youngest available bull may be optimal in many situations. As mentioned, many AI centres in the SAP have only a limited number of bulls that service a community of farmers for many years. Thus, using the youngest bulls tends to decrease the chance that the bull had already been used within the same herd (perhaps even to produce the animal to be inseminated) and thus decrease the likelihood of inbreeding. Also, if the AI centre imports its bulls, younger sires are likely to be genetically superior, due to continual genetic improvement in the originating country.

When farmers have a group of sires from which to make a choice, the goal of selection should be similar to that for selection of females. That is, producing ability of the daughters should be emphasized, while avoiding problems that increase production costs. For beef traits, which are not sex-limited, the bull's phenotype can be considered and growth rate, size and muscularity are traits of importance. For dairy traits, some sort of progeny test should be applied if possible, even if it is ad hoc. If information is available, a sire index, such as the average production of daughters (preferably based on more than 10 offspring) should be considered. If a formal progeny test is not available, and if a farmer is a member of an AI cooperative with a large number of members concentrated in a small area, the farmer may be able to conveniently visit a few neighbouring farms and see several daughters of bulls considered for selection as sort of an informal progeny test. Of course, such opportunities will be limited in areas where little record-keeping is done and may only be feasible in communities served by small cooperatives with few bulls. Again, one must continue to consider that the repeated use of a common bull should be avoided to prevent inbreeding.

When natural service is inevitable, due to non-availability of AI services in the area or poor conception rate by AI, such as with buffaloes, the service bull needs to be selected on the basis of its pedigree performance, its breed characteristics and structural and health condition.

4.2. Selection by local AI service providers

4.2.1. Female selection

Mothers of bulls will likely be chosen from two sources, depending on the resources available. Cows will either be obtained from farmers or selected from within a single nucleus herd operated by the AI service provider (which could be government-owned) or a cooperating organization. Selection from farmers will usually increase the pool of animals from which to select from, whereas a nucleus herd can allow for more control and increased accuracy of data. A nucleus herd may also allow for recording of special data. As mentioned previously, excessive AFC is a factor restricting profitability of dairy production in SAP countries. Although management and nutrition affect AFC, rate of maturity also contributes. The heritability of AFC has been found to be in the range of 0.10 to 0.25 [8, 9]. Heifers that begin to show ovarian activity sooner are more likely to have their first calf at a younger age. Testing of progesterone by using radioimmunoassay (RIA) or enzyme-linked immunosorbent assay (ELISA) can be used to monitor heifers to determine when they initiate reproductive cycling. Application of such a procedure would be difficult for heifers spread out on many different farms, but comparatively straightforward with a central nucleus.

When animals are selected from farmers' herds, ideally farmers involved in the selection programme will have several cows, so that animals can be compared both within and across herds. When purchasing bull calves or females for future bulls, AI service providers have to consider the production and reproduction records, general appearance, breed makeup and pedigree performance of the cow. The most accurate way to select the best cows will be to perform a statistical analysis to obtain a genetic evaluation. Many factors other than genetics will affect an animal's production. Among these factors are herd management, age, and time when the record is taken. These factors should be recorded for each phenotypic record and included as 'fixed' effects in a statistical analysis.

If a formal statistical analysis cannot be done, then data 'adjustment' must be done. Consider the case for records of daily milk yield. Assume that available are four daily milk yields per cow from cows of different ages (in terms of different parities) in different herds. For simplicity, assume that the four records were taken at similar stages of lactation for all cows. Obtaining data allowing for direct comparison of cows across herds and parity numbers would require three steps. First, for each cow, the average production over the four records is obtained. Then, each record should be multiplied times a 'conversion factor' or 'adjustment factor' to account for the fact that milk production increases in each successive lactation. We will use a mature cow as our basis for comparison. Based on information from developed countries, 1.20 is a reasonable adjustment for cows in first lactation. This factor assumes that mature cows give 20% more than cows in their first lactation. Thus, records from cows in their first lactation would be multiplied by 1.20. For cows in their second lactation, 1.10 (10%) is a reasonable adjustment factor. (Ideally, these factors would eventually be estimated using data within the country.) The final step is to account for differences among herds. To make this adjustment, average production should be calculated for each herd. Then, this value should be subtracted from the record of each cow in that corresponding herd.

This process can be summarized in the following equation for a cow *j* in first lactation in herd *i*:

$$am_{ij} = \{ [(m_{ij1} + m_{ij2} + m_{ij3} + m_{ij4})/4] \times af_1 \} - ham_i$$

where, am_{ij} is the adjusted milk record for a first parity cow *j* in herd *i*, m_{ij1} to m_{ij4} are the four unadjusted milk records from a first-parity cow in herd *i*, af_1 is the adjustment factor applied to first-parity records (e.g. 1.20), and ham_i is the herd average milk yield in herd *i*.

A similar process can be done with records for beef production. For example if the m_{ij1} to m_{ij4} are records of body weight taken at different ages. In such a case, if the four data points were taken at similar ages for all animals, the *af* in the equation above could either be set to 1.00 for all animals, or be used to adjust for another factor, such as differences in the age of the mother. (A specific set of adjustment factors would be needed.)

As indicated previously, in most situations, animals should be selected for more than one trait, i.e. not only milk yield for dairy cattle and buffaloes and body weight for beef. Using minimum culling levels on phenotypic characteristics other than production may be the only feasible way that one can consider a number of different traits simultaneously, especially when formal genetic evaluations are not available. With minimum culling levels, the AI service provider would first rank potential bull mothers based on production traits and then eliminate from consideration the cows with problems in reproduction, health, breed characteristics and general appearance and selecting the highest ranked cows that remain. For example, poor body condition can be an indicator of both health and reproductive problems and one should avoid the use of cows that are too thin as mothers of bulls.

4.2.2. Male selection

Currently, many of the local AI service providers in the SAP rely on the purchase of exotic bulls and semen. Selection of animals for these purchases should be based on the multiple-trait indexes from the genetic evaluation system of the exporting countries. Such indexes will generally consider both production and functional traits [5]. For young bulls, the indexes will be based on the pedigree, whereas older bulls (likely for purchase of semen only), progeny test data will be available. When purchasing semen from progeny tested bulls, paying a premium to obtain semen from the absolute highest ranking sires in the exporting country may not be financially justifiable. Interactions between genotype and environment will likely be present, so the highest ranking bull in the exporting country will likely not maintain the same advantage in the importing country. Genetic correlations of the same trait in different countries have been shown to be less than 1.00 (an indication of interaction) between industrialized countries with relatively similar management [10]. Considering the wide difference in climatic and management conditions between the SAP countries and industrialized countries, bulls are almost certain to differ in genetic value when their genetic material is imported into SAP countries. In addition, most exotic bulls will be used in crossbreeding programmes in SAP countries, but for purebreeding programmes in developed countries. The complementarity and performance of bulls in crosses with different breeds may differ from that when bred to animals of the same breed. Therefore, selecting semen from a team of 5 to 10 above-average (say, >75th percentile) proven bulls or of young bulls with high pedigree indexes will be a more robust (and economical) strategy than buying many doses from the highest ranked bull.

To ensure long term sustainability, AI service providers that currently use only imported bulls and semen should plan to start a progeny-testing programme of local bulls and buffaloes for a genetic improvement programme based on the animals in the local population. Crossbreeding will lead to an initial jump in genetic merit for productivity, but the trend will likely not continue with additional use. A number of reasons can explain this lack of sustained genetic gain. First, the initial cross yielding animals of 50% exotic and indigenous genetics have the maximum heterosis. As proportions of exotic genetics increase, heterosis will decrease and adaptability to local conditions may decrease as well. Also, although genetic progress is continual in purebreeding programmes in developed countries, the same trend is not likely to be obtained through continual use of exotic bulls in the SAP, due to the aforementioned possibility of genotype by environmental interaction.

A programme based on local livestock will allow for selection of animals in the environment to which their offspring will be exposed. Such a programme would likely have to start small and simple and then be expanded as feasible. The programme could either use a nucleus breeding approach [11] or be based on the farmers that have the best management and willingness to do record-keeping. The farmers could be encouraged to be involved in the progeny testing programme by giving them some motivating incentives like some quantity of supplementary feed, mineral mixture, veterinary health care, and semen of available progeny tested bulls for part of their herds. This strategy carries some risks, however. Offered incentives and compensation to farmers to test the semen from progeny test bulls, may make them suspicious of the quality of the semen and, therefore, reluctant to use it. A proper balance has to be reached in this regard.

Ideally, multiple traits would be considered for selection, such as milk yield, AFC and longevity, to consider both production and functionality. Such a plan might be difficult to implement quickly, so, for more simplicity, evaluation could initially be based on 'likeability' scores assigned by the farmer. To evaluate likeability, farmers would be asked to assign an animal a score of from 1 to 5, where 1 and 5 indicate an extremely poor or good cow, respectively. Such a trait would comprise a mixture of productivity, reproduction and health. Studies have shown that such a trait has a heritability near that of directly measured milk yield (around 0.20), and is highly genetically correlated with production and longevity [12]. If individual milk weights were recorded, a single objective measure such as the total milk produced by a given age (e.g. 42 months) could be used to accomplish a similar objective. Using this measure, the highest ranking cows would be those that calved at a young age and produced multiple lactations separated by a very short dry period.

4.3. Crossbreeding

Crossbreeding has been taken as a major tool for improving the animal productivity in different Asian countries. *Bos taurus* cattle have been used as exotic breeds and mated with local *Bos indicus* cows to introduce genes for higher productivity, resulting in much faster advances in productivity than could be obtained through selective pure breeding of local animals. The crossbreeding also brings in added advantages of heterosis. In dairy cattle, Holstein-Friesian is most commonly used and seems to nick well with most of the *Bos indicus* breeds. In beef cattle, there are several *Bos taurus* breeds such as Simmental, Limousine, and Shorthorn which have been used to mate with local breeds in different countries. Crossbreeding between different breeds of buffaloes with sizable genetic variance needs to be studied.

Choice of the exotic breeds to be used in breeding programme usually depends upon the purpose of crossbreeding. In case of dairy cattle, selection of exotic breeds depends upon its milk production, early maturity, and compatibility with local breeds. Because crossbreeding dilutes the gene pool of the indigenous breed, the exotic breed should provide clear advantages over the performance of the native dam breed. In beef cattle, even though body weight is mostly considered to be a trait of economic importance for breeding objective, size of the exotic breed to be used in crossbreeding programme should not be too large to avoid dystocia.

The choice of local breed depends upon availability in a particular region. Preferably, only the non-descript local animals and very lowly productive animals of recognized breeds should be used for crossbreeding. The destruction of valuable indigenous breeds with unique adaptability characters for those particular agro-climatic conditions should be avoided. Indigenous animals should be properly characterized prior to initiating crossbreeding to identify breeds with particularly valuable characteristics.

The exotic animals used in crossbreeding are not naturally adapted to the SAP conditions, so large scale crossbreeding in these countries should be carried out with caution. The need for proper feeding and management of these high yielding animals, biosecurity of sensitive animals, special requirements for health, and proper policies for disposal of surplus males and unproductive animals must be considered. In the remote areas, the government must insure proper health coverage for the livestock by providing mobile veterinary health care. In many instances, the proportion of exotic germplasm in the crossbred animals should be maintained at around 50% for better adaptability. To sustain the genetic improvement in the crossbred animals, the progeny testing of the crossbred bulls should be initiated at the earliest in all the countries, either independently or jointly under some international collaboration.

The livestock farmers that rear crossbred animals should be given adequate training in feeding and management of high yielding animals, biosecurity of their farms, AI, pregnancy diagnosis, clean milk production, and health coverage of livestock. Government institutions and AI service providers should provide this training if they are directly promoting crossbreeding by importing and distributing exotic germplasm.

4.4. Special considerations for breed conservation

With the introduction of crossbreeding on large scale in different Asian countries, the population of the recognized zebu breeds has decreased alarmingly. Thus an urgent need exists to conserve the uniquely adaptable, heat tolerant, disease resistant, draught compatible animals of local breeds of zebu cattle. As there are a large number of zebu breeds, the choice for conservation of some of the breeds will depend upon various factors such as their capacity for economic sustainability and true desire of the people to conserve the breed for social and religious purposes. Table 2 lists some of the cattle and buffalo breeds in the SAP area that warrant specific programmes for selection and conservation.

Conservation of a particular breed requires proper justification. Breeds with reasonable productivity, special characteristics and a core of interested and motivated breeders should be maintained in situ as a breeding population of commercial animals. The characterization and identification of the zebu breeds is essential for making an effort in their conservation. Formal selection programmes should be implemented to maintain genetic diversity within the breed and improve its economic competitiveness with exotic breeds. Breeding objectives should be based on improvement of productivity while maintaining distinct breed characteristics.

Conservation of particularly threatened breeds of cattle and buffaloes needs also to be taken into account in order to maintain diversity in the species. Although management and genetic improvement of a breed in situ is generally regarded as the best way to ensure its survival, some buffalo breeds such as the Toda and South Canara are already in small number and thus needs to be conserved simply to save them from extinction. Ex situ conservation programmes, such as the construction of cryogenic banks of semen, embryos, or a combination of the two [13] can also be used to complement in situ approaches for the preservation of these breeds. Conservation of somatic cells has been proposed as a low cost alternative, if funds are not sufficient to collect and store semen or embryos [14]. A general guideline is to preserve genetic material to obtain at least 25 unrelated animals of each sex [15].

TABLE 2. ZEBU BREEDS TO BE CONSERVED THROUGH EITHER IN SITU OR EX SITU MEANS

Dairy cattle	Dairy buffalo	Draught cattle	Beef cattle	Dual purpose (milk+draught)	Dual purpose (beef+draught)
Gir	Murrah	Nagori	Pesisir cattle	Hariana	Bali cattle
Deoni	Nili-ravi	Krishna Valley	Kedah Kelantan (KK)	Ongole	
Sahiwal	Toda	Amrit mahal		Kankrej	
Red Sindhi	South Canara	Malvi		Mewati	
Red Chittagong					

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PROPOSED BREEDING STRUCTURE FOR CATTLE DEVELOPMENT IN COUNTRIES IN THE SOUTH ASIA PACIFIC REGION

M.G. JEYARUBAN
Animal Genetics and Breeding Unit
The University of New England (Home Institution)
NSW
Armidale 2351, Australia

M.H. RAHMAN
Artificial Insemination and Fodder Cultivation
Department of Livestock Services (Home Institution)
Krishi Khamar Sarak
Dhaka, Bangladesh

1. INTRODUCTION

Livestock plays a significant role in poverty alleviation and in improving the livelihoods of the rural farmers in the South Asia Pacific (SAP) region. Country reports presented at the IAEA workshop in Mymensingh, Bangladesh in February 2006 revealed that the livestock development programmes implemented by various organizations had very little influence on the genetic improvement of the local cattle population [1]. About 50 to 70% of the cattle in the region are still unimproved, non-descript cattle. Inexistence of herd recording, lack of efficient breed improvement programmes similar to the progeny testing schemes in developed countries, and non availability of proven superior quality breeding animals are among the factors that contribute to the slow progress in improving the genetic merit of local cattle populations in the region [2].

Most of the countries in the SAP are implementing crossbreeding programmes to upgrade the local cattle population to 75% or more of exotic genotype [3]. Crossbreeding programmes involving temperate breeds are often not successful due to incompatibility of the genotypes with farmers' breeding objectives and the production systems. Furthermore, these poorly adapted genotypes often require greater capital investment, thereby increasing the economic burden to the cattle farmers, which has resulted in farmers showing less enthusiasm toward crossbreeding programmes in some instances. Despite the less than universal success of crossbreeding programmes in many of the countries, examples can be found of effective programmes that have emerged from well-structured crossbreeding programmes in the region. The Sahiwal crossbreeding programme in Pakistan and the Operation Flood programme in India are the two prominent programmes that have been implemented by the farmers in these countries.

A controlled structured crossbreeding programme in Pakistan has been used to produce crossbred Sahiwal cows whose average lactation yield is double that of a pure Sahiwal, and are much more in demand by farmers in Pakistan than are the pure Sahiwal cattle [4]. Operation Flood, a development programme originally financed in cooperation with the European Union, created an organization that integrated different functions in the community chain and ensured participation of farmers in all levels of animal improvement, production and marking, which led to a successful smallholder production system in India [5]. The success of these programmes highlighted the importance of implementing structured genetic improvement programmes involving farmers, breeding organizations and marketing agents to generate desirable genotypes for cattle development in the SAP region. Based on the results from these two programmes, a three-way approach consisting of Central Nucleus

Breeding System (CNBS), Group Nucleus Breeding Structure (GNBS) and Crossbreeding (CB) is proposed as a feasible approach for sustainable cattle genetic improvement in this region.

An open nucleus breeding programme, where animals from the general population can be part of the nucleus, has been proposed for faster genetic improvement in livestock species. Because one is not restricted to animals already in the nucleus (as is the case with a closed nucleus) the open nucleus breeding scheme allows for greater selection intensity and is often quoted as the preferred method of operation for quick genetic gain [6, 7]. Therefore, the open nucleus scheme has been recommended as an alternative to a progeny testing scheme in the developed countries [8–10]. Establishment of open nucleus breeding in countries in SAP can be achieved either by grouping high production animals at the farmer level, a GNBS, or by assembling all animals at a highly organized location, CNBS. These organized breeding structures will enable the establishment and application of proper breeding objectives and selection criteria according to the cattle production system in the locality. The breeding objectives and selection criteria for various cattle production systems in the region have been discussed in Chapter 2 of this publication [11]. These nucleus breeding structures are essential for producing purebred or crossbred animals, which can be supplied to organized commercial breeders to achieve sustainable livestock development in the local region around the location of the CNBS or GNBS.

2. CENTRAL NUCLEUS BREEDING STRUCTURE

The CNBS is a feasible breeding structure for implementing genetic improvement in the SAP and has a number of advantages over other possible systems that make it ideal to serve as the focus of a breeding programme, where the most intense selection is performed and the most genetic response is obtained. Among these advantages is the elimination of differences due to herd management effects and of heterogenous within-herd variance, which can introduce bias and imprecision in genetic evaluation. In addition, within CNBS, one can more easily apply advanced nuclear, molecular and assisted reproductive technologies effectively as discussed in Chapter 4 of this publication [12] and record of performance and pedigree data more accurately. These factors will facilitate the implementation of an unbiased genetic evaluation system and thereby, yield more precise estimates of animal breeding values. In addition, the recording of traits that are more difficult and expensive to measure can also be justified.

Countries within the SAP have imported exotic genes for faster livestock improvement and most of these counties have established simple nuclear farms to primarily multiply the imported exotic breeds or produce improved crossbred cows from the exotic germplasm [3]. Nevertheless, the level of sophistication has generally not been high and emphasis has been on multiplication rather than selection, so effectiveness of breeding plans in the nucleus has been very low. Very few countries in the SAP have achieved the efficiency similar to the progeny testing programmes common for cattle, especially dairy cattle, in the developed countries. Given that the physical infrastructure exists, these existing nucleus herds can be reorganized to form CNBS in a two-tier structure where an elite nucleus of selected cows produces offspring for the commercial population. The existing facilities that have been used to house the exotic breed or their crosses could be expanded, if necessary, to house 250 to 300 selected breeding cows. The structure and the flow of genetic material in the proposed CNBS is given in Figure 1.

The CNBS is initiated by screening the commercial population for outstanding cows according to phenotypic measurements of traits of economic importance. Then, genetically superior cows from both within the CNBS and the commercial population will be used to regenerate the nucleus in successive generations. Likewise, genetic material will move from the nucleus to commercial population to regenerate and genetically improve the commercial population (Fig. 1). The best sires could be used in both populations, although the best females would usually remain in the nucleus. Transfer of outstanding breeding animals from the commercial population at regular interval will improve the genetic gain in the nucleus herd [6]. This transfer may also allow inbreeding in the nucleus to be maintained at acceptable levels [13]. Rate of inbreeding in the nucleus is minimized and the long term genetic gains can be maximized when 25% of the nucleus parents are selected from the commercial population [13]. Furthermore, avoiding the mating of close relatives in the nucleus will further reduce the rate of inbreeding or formal selection procedures can be adopted to achieve maximum genetic gain for a pre-determined and acceptable level of inbreeding [14]. Implementing nuclear-related molecular approaches to increase accuracy of selection [12, 15] and assisted reproductive technologies [12, 16] in the CNBS could improve the genetic gain.

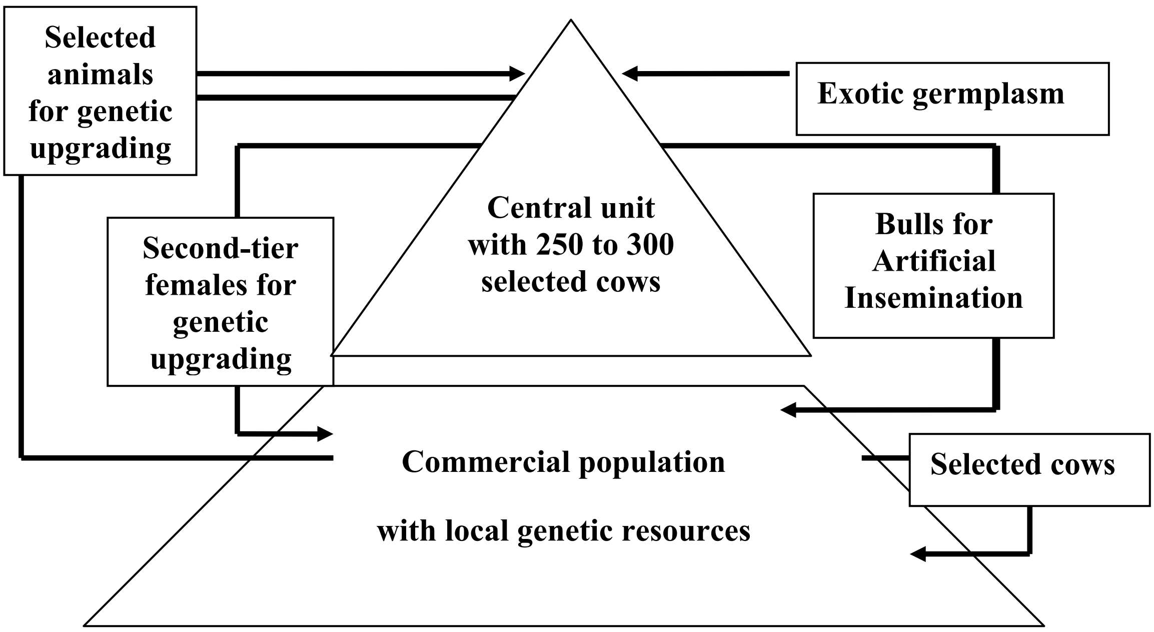

FIG. 1. Structure and flow of genetic materials in a Central Nucleus Breeding Structure to produce bull mothers and AI bulls in the proposed genetic improvement programme for cattle development in the South Asia Pacific region.

One disadvantage of the CNBS is that its initial establishment would require high investment for infrastructure and human resource development, even if the previously described multiplier nucleus herds were in existence. Cost of maintaining a CNBS might tend to limit the number of breeding animals in a nucleus and this in turn will reduce the number of contemporaries, the selection intensity and, thereby, the accuracy of evaluation. Inbreeding would also be expected to increase. Therefore, it is important to maintain a nucleus at reasonable size to obtain adequate genetic gain without compromising the economic viability. By considering the existing facilities in the region, a nucleus size of 250 to 300 cows would be recommended to produce bull mothers and AI bulls for the national cattle improvement programme. Breeding organizations can be responsible for the operation of CNBS. Government agencies may also provide financial and technical support to breeding organizations to implement genetic improvement programme in the nucleus. Furthermore, involvement of government agencies will ensure that the farmers obtain high genetic merit animals at reasonable price. Dissemination of high genetic merit animals at an affordable price is essential for faster genetic improvement in the commercial herds. Non-governmental organizations could contribute by promoting the benefits of AI to their members and supporting the training of AI technicians as part of a programme to create employment opportunities as well as to improve services for farmers.

TABLE 1. LIST OF INFORMATION TO BE RECORDED IN THE NUCLEUS AND THE BASE POPULATION FOR CATTLE IMPROVEMENT IN THE PROPOSED CENTRALIZED NUCLEUS BREEDING SCHEME, GROUP NUCLEUS BREEDING SCHEME AND CROSSBREEDING PROGRAMME

Centralized Nucleus Breeding Scheme and Group Nucleus Breeding Scheme	
Basic identification	Farm ID[a], Animal ID, Sire ID, Dam ID, Birth date and Sex
Breeding data	1st breeding date, Weight and Body condition score, Number of inseminations, Calving date 1, Condition score, Likeability 1, Calving date 2, Condition score, Likeability 2, Calving date 3, Condition score, Likeability 3
Production data	Milk yield 1[b], Yield date 1, Milk yield 2, Yield date 2, … , Yield Date *n*, Milk yield *n* Weight at birth, at weaning, and at yearling
Disposal	Date of removal and reason Lactations
Crossbreeding programme	
Identification	Farm ID, Animal ID, Sire breed or ID, Dam breed or ID, Birth date and Sex
Breeding data	1st breeding date, Weight and Body condition score, Number of inseminations, Calving dates, Body condition score, Likeability
Production data	Milk yields , Weight at birth, at weaning, and at yearling
Disposal	Date of removal and reason Lactations

[a] ID = identification code (number or name)
[b] Concentrations of milk constituents such as fat, protein and solids-not-fat may also be useful, assuming farmers are paid according to milk components.

Recording of performance and pedigree data is essential for the implementation of selection and genetic improvement in the CNBS and this will make way for progeny testing and unbiased prediction of breeding values. An example of the important information to record on each animal to ensure success of a breeding programme and subsequent economic viability of cattle development in the SAP is given in Table 1. These traits can be combined in a multi-trait model to consider the correlation among traits so that the information from one trait can contribute to the evaluation of another. Genetic and environmental variations for the implementation of genetic evaluation in the CNBS have to be estimated from the population and Best Linear Unbiased Prediction (BLUP) could be used to predict breeding values and accuracies [17]. An economic index comprising the economic values and breeding values would be a way forward to select the replacement animals in the nucleus [18]. A measure of accuracy is desirable for any evaluation system. Contemporary group size and number of sires with daughters in a single contemporary group are responsible for determining the accuracy level in an evaluation. Accuracy could be increased by 20% to 60% by simply increasing the number of sires with offspring in a contemporary from one to five [19]. Therefore, in order to have adequate linkage, high selection intensity and acceptable rate of inbreeding in the nucleus, at least 10 to 12 selected sires should be used in the nucleus.

Services of highly skilled technical officers are essential for efficient implementation of structured breeding programmes at the CNBS. Identification of individual animals and determination of their pedigrees and proper recording of performance as identified in Table 1, are essential for unbiased estimation of genetic parameters and the breeding values in the CNBS. Furthermore, skilled technicians are required in the routine management of the nucleus herds. However, the management practices and selection programme implemented at the CNBS should not be widely different from the practices followed at commercial farms. Otherwise, the breeding objectives between the nucleus and the commercial farmers could differ, introducing of environmental variation between the nucleus and commercial farms and causing re-ranking of animals between the two production environments. Representation of farmers or farmers' organization in the management and selection committee could decrease the possibility of any deviation of management practices.

3. GROUP NUCLEUS BREEDING STRUCTURE

Genetic improvement of cattle in the SAP has mainly been hampered by non-availability of national and regional performance recording schemes, small herd sizes, no community-level breeding programmes to pool small herds, and lack of genetic evaluation schemes [2]. However, recent developments in the involvement of cooperative societies in marketing of milk in the region has opened new opportunities. In the SAP, the dairy cooperative has been recognised as an important means for dairy development in rural areas [20]. These are mainly in operation for milk marketing and processing, but can also be responsible for routine management, health and reproductive activities. Strengthening of existing dairy cooperatives and enhancing greater member participation will facilitate the formation of GNBS for dairy development at the village level.

Group Nucleus Breeding Structures were originally widely used in New Zealand and Australia in their sheep genetic improvement schemes [6, 21]. GNBS in countries in the SAP can be formed by grouping into multiple units of high producing animals from farmers who are willing to record their flock and to select the best animals from their herds. These organized breeding structures will enable the establishment and use of proper breeding objectives and selection criteria according to the cattle production system in the locality while farmers maintain their ownership for the animals. The breeding objectives and selection criteria for various cattle production systems in the region are given in Chapter 2 [11]. This plan will also enable the dissemination of improved genetic material to become part of the breeding structures.

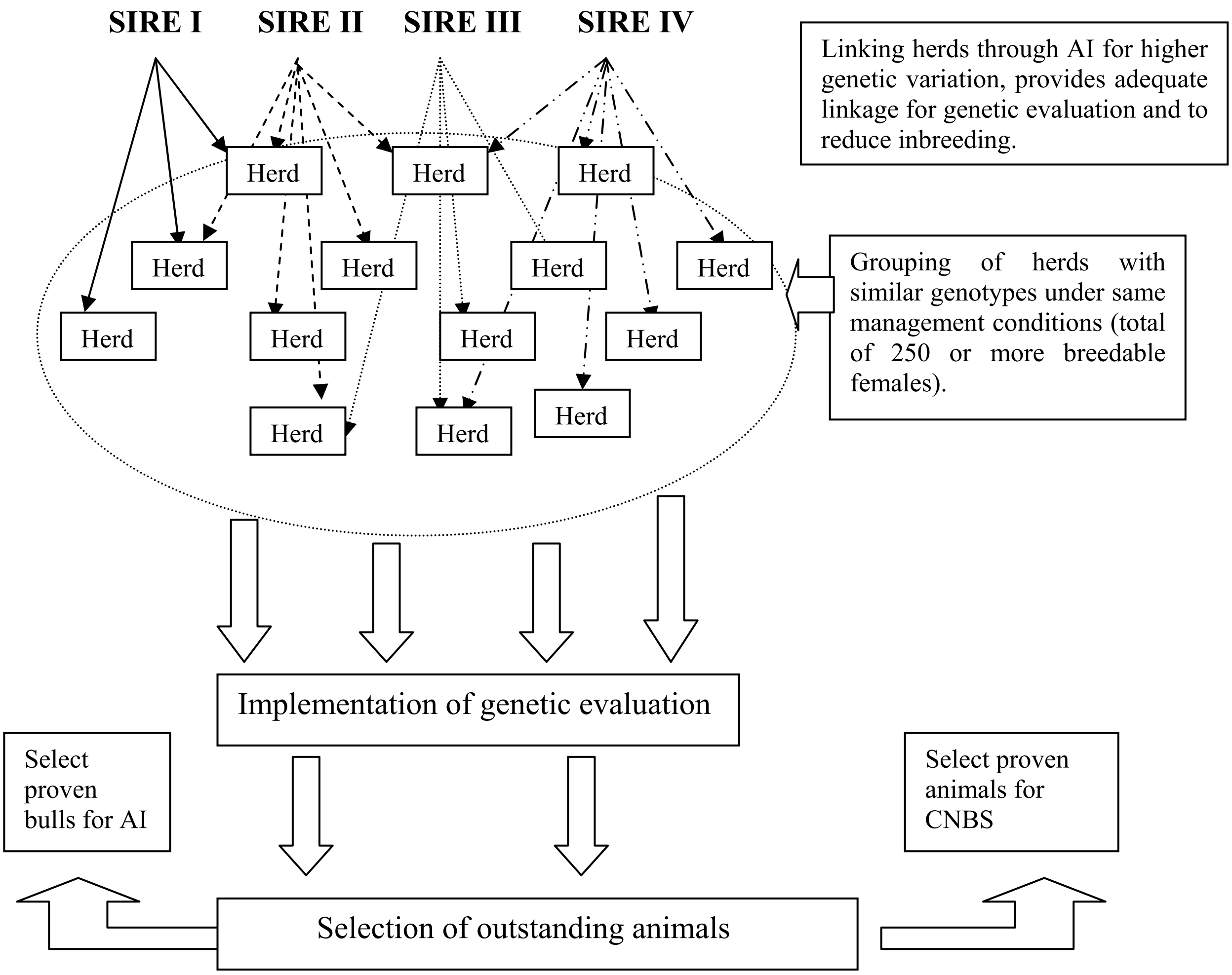

FIG. 2. Structure and flow of genetic materials in a Group Nucleus Breeding Structure in the proposed genetic improvement programme for cattle development in the South Asia Pacific region.

Group Nucleus Breeding Structures can be established with minimal infrastructure and capital investment. This system could be used in conjunction with a CNBS, and improve its operation, by providing performance recorded animals for the elite nucleus. Otherwise, establishing GNBS could be a first step in countries that do not have organized nucleus breeding system in place to eventually develop into a CNBS. Farmers with proper management and practicing proper herd recording system could be grouped to form GNBS for selection and breeding of replacement animals. Furthermore, animals from farms or villages that have the same general genotype and similar cattle management conditions to produce improved germplasm for genetic improvement in the vicinity, would reduce a potential genotype interaction due to variation in management and climatic conditions. Moreover, by grouping animals from different farmers, inbreeding among the animals in the GNBS may also be decreased, relative to a CNBS.

Farmer participation in the implementation of genetic improvement programmes will help to ensure the ownership and maintenance of the nucleus by various farmer groups. This integration of farmers in organizing the breeding structure can help to foster the formation of farmer groups and farmer associations and this in turn will further strengthen the GNBS breeding programme and increase chances of long term sustainability. Benefits to farmers through sale of breeding stocks can be a crucial factor in sustaining the GNBS and ensuring the required commitment by the farmers to keep pedigree and production information.

Recognition of possible benefits from preferential treatment of candidates for the GNBS and competition between farms may lead to less accurate records for genetic evaluation. This type of problem regularly occurs in the modern breeding and animal marketing programmes operating in industrialized countries and methods have been developed to detect and account for such possible sources of bias [22]. The benefits of organizing a formal selection programme and creating a market that gives an economic premium to superior breeding stock are surely greater than the difficulties encountered in estimating breeding values. The GNBS provides risk aversion while reducing the maintenance cost in relation to the CNBS. Nevertheless, proper terms of agreement are essential in relation to the ownership of animals and progeny, transfer of genetic materials, location and management of the group for efficient implementation of the structure.

An essential feature of modern quantitative techniques is the use of estimated breeding values (EBV) or estimated progeny difference (EPD) instead of individual performance. These are obtained by the BLUP technique, which uses information on the relatives of the animal being assessed as well as its own performance. The BLUP approach differentiates genetic effects from influences of management and feeding and produces unbiased estimates of genetic merit for animals. Obtaining a sufficient number of farms and animals in each GNBS is essential to have adequate contemporary groups and the accuracy required for proper between-herd genetic evaluations. A minimum of 250 breeding cows, from herds having 10 or more cows that are mated to 2 or more sires, could be grouped to form a sustainable GNBS. Furthermore, the herds should be genetically linked or connected to achieve unbiased prediction with BLUP across herds. Genetic links can be created across the herds by using AI bulls on a portion of the females in each flock or by sharing bulls for natural breeding (Fig. 2). Eight to ten proven AI bulls or natural bulls could be used to create the required genetic linkage in the nucleus.

One limiting factor to GNBS in the SAP is that average herd size in many countries is small and may vary from 3 to 10 animals. Smaller herd size and management variation between farms may reduce the detectable genetic variability and in turn the effective heritabilities for traits that are under consideration for genetic evaluation in the nucleus. The greater environmental variation leads to less accurately evaluated breeding values for animals in the GNBS. Moreover, a lack of proper identification and recording of pedigree information of all animals in a herd may also be a limiting factor for the implementation of efficient genetic selection programme.

If interest from outside investors exists, the GNBS could be maintained and owned by private breeding farmers for which high monetary return will be the prime objective of the GNBS. Therefore, animals with greater genetic potential may be sold at a higher price than that which could be affordable by private farmers, private breeding companies and AI organizations. A proper memorandum of understanding should be developed to ensure the supply of breedable animals at reasonable prices to cooperative AI organizations or to any other breeding organization.

4. CROSSBREEDING FOR EXTENSIVE MANAGEMENT

Crossbreeding, which uses complementary breed differences, avoids antagonistic genetic relationships and uses heterosis, is recommended for genetic improvement of farm animals [23–26]. Because of these benefits, and for the reason that the exotic breeds from industrialized countries had been intensively selected for increased productivity, many of the countries in the SAP have historically resorted to crossbreeding to upgrade their national cattle populations.

Despite the crossbreeding programmes, 50 to 75% of the cattle in the region are still unimproved, non-descript cattle. Upgrading the production potential of the large proportion of these lowly productive non-descript cattle is seemingly necessary to improve the overall cattle productivity in the region, incomes of farmers and diets of citizens. A significant proportion of the non-descript cattle are being grazed under extensive management conditions with very minimal input. Application of AI or other reproductive technologies within these populations of cattle for genetic improvement would be expected to have very limited positive impact under these management conditions. Genetic improvement is mainly achievable by introducing improved males and females from other populations into this system. These improved animals may be indigenous × exotic crossbred or improved indigenous breeds. Crossbreeding with improved *Bos indicus* or *Bos indicus* × *Bos taurus* genotypes from GBNS or CNBS is recommended for areas where information about production performance and genotypic constituents are not accessible. Controlled crossbreeding to produce 50% *Bos taurus* or 100% *Bos indicus* can be implemented based on the availability of nutritional resources in the area. Although achieving genetic improvement may be a slow process, a well-planned crossbreeding programme can be a valuable tool in helping to obtain genetic improvement as long as the compatibility of the genotypes of the incoming breed with local farming objectives and the production system are considered.

For this reason, specifying the production system and the breeding objectives [11] before resorting to a crossbreeding programme is essential. Basic performance traits (Table 1) should be assessed to evaluate the adaptation of the crossbred genotype to the existing production system. Controlled mating and assessment in a grazing system is most important in appraising the crossbreeding system in grazing ruminants [27]. The impact of fitness, especially survival, should be monitored at regular intervals to assess the impact of crossbreeding on the grazing population. Uncontrolled crossbreeding by borrowing animals from neighbouring commercial farms, and sale of unsuitable males for breeding purposes should be discouraged.

5. SUMMARY

Livestock development in the SAP is essential to fulfil the increasing demand for livestock products in the region. Strategies that incorporate the genetic resources existing locally and active farmer participation are essential to achieve sustainable livestock development and genetic improvement in the region. A three-stage genetic improvement programme is a feasible approach and logical medium to the long term goal for striking a balance between genetic progress and breed adaptation. A combination of CNBS and/or GNBS with good links to the crossbreeding programmes are essential to achieve consistent genetic gain and to produce genetically superior animals for upgrading the commercial herd.

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TECHNOLOGIES TO ASSIST IN SELECTING REPLACEMENT FEMALES

H.T. BLAIR
Institute of Veterinary, Animal and Biomedical Sciences
Massey University
Palmerston North, New Zealand

1. INTRODUCTION

A number of technologies are required in taking the various steps needed to identify the genetically most superior animals to keep as parents or to bring into a herd. These technologies are not always new, and due to changing circumstances, some previously uneconomic technologies may become cost-effective. Therefore, there is need to reconsider the use of previously ignored technologies on a regular basis. In some situations, new technologies are being developed for quite different intended purposes, so it is important that those persons involved in genetic improvement of livestock maintain an awareness of developments in fields other than their own discipline. It is paradoxical that some new technologies may be more readily applicable in developing countries than in developed countries, due to the more limited application of existing technologies in developing countries. A good example of this is the rapid uptake of cellular networks for telephone communication in developing countries, where landline networks have typically been in limited use or in poor condition.

2. ANIMAL IDENTIFICATION

The estimation of an animal's genetic merit requires the accurate identification of two groups of animals within the population:

- those animals that will contribute to genetic gain;
- those animals that will be measured (including their contemporaries) to provide data from which genetic evaluations will be generated.

Consequently, it is not required to have all animals in a population identified.

There are many forms of animal identification [1], including:

- Physical attributes — colour, horns, size, shape, eye patterns (e.g. with retinal scanning).
- Ear notches.
- Branding — this may be an animal welfare issue in some countries, especially if hot branding is employed.
- Temporary identification — colour markings (paint or crayon), temporary tags attached by various means.
- Visual tags — typically applied to the ear.
- Electronic tags — e.g. radio frequency identification (RFID) chips may be contained within or on a visual tag or implanted under the skin. There are several forms of electronic tags, and the purpose of use must be clearly known before committing to the use of a particular type.
- DNA — while the nuclear-related technique of DNA fingerprinting is currently too expensive for the routine identification of animals, it is likely that the costs (and time taken to obtain a result) will decline with time. Fingerprinting may be efficacious

immediately for high value animals such as bulls and bull mothers to ensure their identity. If fingerprinting is used for another purpose (for example, proof of ownership or movement control), the marginal cost for each use may make the implementation of a DNA based system attractive at an earlier opportunity.

Links to a number of manufacturers of animal identification systems are given at the following web site: http://www.drovers.com/directories.asp?pgID=712 (accessed 02/2008).

Most forms of animal identification are not completely infallible or tamperproof. For example, physical attributes may be modified, DNA is dependent on several steps allowing the opportunity for errors, tags may fall out, brands fade or become distorted with age and microchips migrate from their place of insertion.

Some electronic tags also provide the opportunity for more complex operations, such as the use of GPS to automatically locate an animal at a particular time or the automatic reading of the tag by a computer (see above web site). Such abilities may give the opportunity to collect information for other purposes such as traceability and control over animal movement.

Some forms of identification may be expensive relative to the value of the animal or the intended purpose. Therefore, it is important to choose a form of identification that is fit for purpose and provides unique identification within the population being considered.

3. TRAIT MEASUREMENT

A significant challenge for most developing countries is the difficulty of measuring (directly or indirectly) traits of economic importance in a repeatable and reliable manner for inclusion in a genetic evaluation. Limitations include: absence of the necessary equipment, absence of or variability in supply of electricity, cost of data collection, difficulty in transferring data from the point of collection to the point of analysis, disinterest by the animal owner/handler in taking the measurements and untrained people taking the measurements. Trait measurement must be consistently implemented across animals, herds and regions to be of optimal use in selection; this requires the education and training of either all animal handlers or a smaller number of animal technicians who then assess animals from many herds. The training of a smaller number of animal technicians has the associated advantage of requiring less equipment, providing the equipment is sufficiently robust and small to be portable.

3.1. Size and growth

Measurement options include scoring, weighing or taking linear measures (girth, height, length). There seems to be little demand for new technology for these traits, as the accurate scoring of size and growth is straightforward and the trait is sufficiently heritable. Furthermore, if it is desirable to have more accurate measurement, scales are readily available, albeit at a greater cost. A more likely obstruction is convincing the farmer of the need to accurately weigh their animals.

3.2. Milk yield

Milk yield, as assessed by weight or volume, is another straightforward trait to measure and is typically collected for an entire herd, as it is the basis for assigning payment to farmers. However, to be useful for genetic evaluation purposes, accurate records need to be assigned to individuals, and this is again not a priority for many farmers. Another particular problem in some communities is that calves may suckle their dams immediately before or during milking, in which case the milk yield measured will clearly not be a true indication of the cow's yield, resulting in less accurate data. Furthermore, individual farmers may not have the necessary equipment for measuring yield. An alternative to measuring the individual milk yield is for the milker to provide a subjective scale score (say 1 to 5) for each cow. A flow meter placed in a funnel as the milk is accumulated into the herd container may also give records of sufficient accuracy. It is not necessary to measure the milk yield of every cow every day. As few as 2 measurements spread throughout the lactation can provide a sufficiently accurate prediction of total lactation yield of a cow for management purposes, however, a minimum of 5 is recommended when assessing cows to progeny test a bull [2]. It may also be possible to focus attention on those farms with above average milk production (total yield divided by total cows) and good management systems. Attention would then be directed at these herds to identify the top cows who would become bull mothers. This approach would allow limited resources to be concentrated on herds where there is a good chance of accurately identifying the best cows.

3.3. Milk composition

While most farmers in developing countries are paid on the basis of milk volume or weight, there may be specific products and markets that require milk of a particular composition. However, it is unlikely that many developing countries will have sufficient resources to support two genetic improvement programmes (one for milk yield and one for milk composition), at least in the early stages of adoption. It is probably more realistic to screen a number of herds to identify cows with the desired milk composition and relocate the desirable cows into herds to allow for separate collection and processing of the milk [3].

3.4. Milk hygiene

Milk hygiene can be a problem for both the producer (limited markets and low prices) and for the consumer (poor quality and hygiene). Milking and cooling plants that are easily transported by 1–2 individuals would assist in the improvement of milk quality and hygiene. Mobile plants would enable training and education to be focused on the individuals using the milking and cooling machines, resulting in better milk hygiene. More importantly from a genetic improvement perspective, this would allow the collection of individual cow records by a trained technician, thereby providing accurate records for a genetic evaluation scheme.

3.5. Meat quality

While some meat quality traits are highly desired by the consumer, these traits are receiving minimal attention via payment schemes to the farmer; hence there is little incentive for the farmer to modify his behaviour. While meat remains in short supply, this situation is likely to continue. If it does become desirable to change meat quality traits, there are currently a number of nuclear and related scanning technologies that can accurately measure these traits either pre- or post-slaughter, such as ultrasound, video-imaging, CT scanning and DEXA scanning [4]. Most of these technologies are expensive and require trained operators. Most developed countries are relying on DNA/RNA-based tools (see below) to meet this need, however, few are currently available. In the short term, crossbreeding local breeds with temperate breeds may provide an immediate solution.

3.6. Reproduction

Given the importance of reproduction to generate both milk and meat for sale, it is deserving of attention in any genetic improvement programme [5]. However, reproductive traits are difficult to measure and typically have low heritabilities. The use of artificial insemination assists with the collection of useful information. The use of tail-painting [6] is not costly and can provide useful data for genetic evaluation (onset of estrus, return to service) as well as improve the rate of estrus detection, but as has been repeatedly mentioned, the farmer may not see any reward for the additional work and expense of recording the data for breeding purposes. Monitoring the female reproductive status can also be achieved by measuring the level of progesterone in milk samples by the use of radioimmunoassy (RIA) or ELISA [7], and if samples are already collected for another purpose (i.e. improved on-farm reproductive management), this approach may be practical. In the future, a cow's reproductive status may be monitored through remote sensing devices (see below).

3.7. Animal health

Animal health can be a major direct and indirect cost to animal production. However, most health traits are difficult to measure and may exhibit low heritability [8]. Currently, the resolution of most health problems is achieved through management intervention with drugs or traditional animal medicines. Once again, hope is being placed on the successful development of nuclear and nuclear-related molecular DNA/RNA-based tools (see below) to genetically improve animal health [9, 10]. DNA/RNA-based tools may also be used to accurately diagnose disease-causing agents, which will give more accurate phenotypes, which in turn will assist with animal selection. Remote sensing devices may also play a role in trait measurement [11].

3.8. Feed efficiency

In most ruminant production systems, feed costs account for about 70% of production costs. However, there are few simple and accurate means of determining feed intake of individual animals. A technological advance is required in this area before on-farm application will be achieved for this trait. One such example is the use of naturally occurring isotopes and doubly-labeled water [12], however, this approach is currently too expensive for routine application. In many countries, mature weight is used as an indirect indicator of feed consumption. However, caution is needed when using this in meat-animal genetic improvement, as selecting for lower mature size will result in a correlated decline in growth rate in young stock.

4. MOLECULAR TECHNOLOGIES

There is currently a large international investment in sequencing farm animal genomes and searching for genes controlling economically relevant traits [13]. In many cases, genetic markers that are linked to the gene of interest are discovered before the gene itself is discovered; the unknown gene may be referred to as a Quantitative Trait Locus (QTL), and the use of genetic markers to enable selection of the QTL is referred to as Marker Assisted Selection (MAS). To date, there are few examples of animal traits being genetically improved through the application of DNA technologies, although some examples may be confidential information and trade secrets held by breeding companies [14]. Exceptions are the removal of some undesirable genes such as BLAD (Bovine Leukocyte Adhesion Deficiency) and DUMPS (Deficiency of Uridine Monophosphate Synthase) [15].

The use of DNA technologies for genetic improvement provides the advantage that once the gene or QTL is described, there is no need to measure animals to allow the estimation of genetic merit. In these situations, a blood or tissue sample is obtained from the animals and the DNA examined for the presence or absence of the superior form of the gene or QTL of interest. This approach will be attractive where animal identification and trait measurement is difficult. However, a large investment is required to locate genes of interest and may be beyond the resources of many countries. In addition, many genes known to control traits of economic relevance have been patented, requiring those who wish to use this knowledge to pay a royalty. Caution is necessary when applying knowledge of QTL that was estimated based on data from well-managed animals in temperate environments to animal populations in tropical environments. The QTL may be absent from tropical breeds or the effect may differ in the environments cattle experience in the South Asia Pacific (SAP) region. Furthermore, where the economically relevant trait is identified via a QTL, the linkage relationship will only be relevant to the population in which the relationship was defined. This requires the relationship to be re-derived in each different population. Once again, this is an expensive exercise that is unlikely to be attractive to many countries.

Apart from the resources required to locate and identify genes/QTL, caution must be applied when using MAS to ensure that long term response to selection is not compromised [16]. However, as mentioned above, if genetic improvement is challenged by poor animal identification or poor phenotyping, the use of DNA technologies might provide a solution.

Technologies for the analysis of DNA are continually advancing. Microarray chips are now available for cattle that allow for the simultaneous analysis of tens of thousands genetic markers at a cost of less than US $300 per chip. This technology has opened the door to genomic selection [17]. With genomic selection, a single experiment could be performed on a few 1 000 animals to establish the statistical relationship between the genetic markers on the chip and the trait or set of traits of economic importance. The number of animals required to establish the marker-trait relationships is dependent on the number of markers used and the accuracy with which the animals' BVs are estimated. It is also important to recognize that the animals used to establish the marker-trait relationships must be relevant to the farming system in which offspring will be utilized. Consequently, caution must be applied when using relationships derived in another country from an unrelated breed. Once the marker-trait relationships are established, the cost of estimating breeding values of new animals would be the cost of purchasing new chips. New data would not be necessary and, in most cases, only the most valuable animals would need to be analyzed. Because the marker-trait relationships will most likely be due to linkage, it will be necessary to re-estimate the relationships every few generations, otherwise the accuracy of selection will decline. Genomic selection has the potential to revolutionize animal selection in developing countries in the same way that cellular telephones have revolutionized communication. Specifically, it could reduce the need for nationwide systems for on-farm data collection and progeny testing. Nevertheless, this method would require both collection of data for the initial test and a significant financial investment for the first round of genotyping. Many countries in the SAP lack both the initial phenotypic data required for such an experiment, as well as the free capital required for acquisition of the chips that would be necessary. They also lack much of the infrastructure required to exploit the results of such an experiment to the fullest extent.

DNA-based technologies can also be used to genetically characterize populations of interest, such as those that are at risk from extinction [18].

Research and development of tools to measure/assess DNA, RNA and proteins will continue at a rapid rate. As mentioned earlier, these new tools should be assessed on a regular basis to ascertain as to whether they can provide benefit to genetic improvement.

5. DATA MANAGEMENT SYSTEMS

The recording, storage and archiving of data are important issues deserving of significant attention at the initiation of any programme for breeding, selection and genetic evaluation [19, 20]. Inaccurately recorded data and the accidental or purposeful loss of data due to a variety of reasons will incur significant costs to the enterprise concerned.

6. GENETIC EVALUATION

Once the appropriate data are recorded and genetic and phenotypic parameters are known, it is a relatively trivial task to generate breeding values and selection indices. Publicly available software is available for this purpose [21], although it should be applied by a person with postgraduate education in animal breeding and genetics. Several companies/institutions around the world will produce genetic evaluations for a fee.

There will be ongoing advances in the statistical techniques used to produce genetic evaluations, however, these advances will likely be of only minor improvement over currently available techniques and will largely be for traits with non-standard statistical distributions.

7. REPRODUCTIVE TECHNOLOGIES

Assisted reproductive techniques may assist with either increasing the rate of genetic gain or decreasing the time it takes to deliver genetically improved animals from genetically superior herds to genetically inferior herds (reduced genetic lag). There are a number of relevant reviews of both the technologies [22] and also the theoretical genetic advantage that they might provide [23].

An extremely important point to consider is that the genetic benefits associated with use of these technologies is predicated on the knowledge that the genetic worth of the animals being used in the scheme are of superior genetic quality. This has not always been true in schemes implemented to date. Indeed, there may be the belief that the use of reproductive technologies somehow imposes superior genetic qualities of the animals being used! If the animals being subject to the advanced reproductive technologies are not truly superior, then these technologies will potentially have a negative consequence by decreasing the genetic biodiversity of the population in which they are applied.

Apart from the potential of assisted reproductive techniques to improve the rate of genetic gain in a population, these techniques may also be used in the conservation of at-risk populations [24]. In fact, for countries in the SAP that lack well-organized systems of genetic evaluation, genetic conservation may be the most logical use for advanced reproductive technologies, especially those that involve increasing the reproductive capacity of females.

Some assisted reproductive techniques are technically demanding and may require advanced laboratory facilities. Accordingly, the anticipated costs and financial benefit must be seriously considered in advance of embarking on a programme to utilize assisted reproduction.

If it is not necessary to produce a calf for replacement or sale (or to stimulate milk let-down), there may be an opportunity to develop a hormonal programme for the induction of lactation [25]. Such a programme may provide advantages for the collection of milking records for genetic evaluation, and would certainly provide significant management advantages, allowing farmers to rapidly react to changing nutritional and/or market circumstances.

7.1. Artificial insemination (AI)

AI has been widely applied around the world and high conception rates can be achieved providing the cow is inseminated at the correct time by a competent technician using viable semen. A manual covering the requirements for a successful AI scheme was the subject of a previous publication by the IAEA [26]. If replacement offspring are to be retained from the mating, bulls providing semen for AI must be of high genetic merit.

7.2. Sexed semen

Mendel's laws of segregation dictate that sperm carrying X (female) and Y (male) chromosomes should be produced in equal quantities, thereby resulting in 50% male and 50% female offspring. Under some circumstances there will be either genetic, commercial or religious reasons for producing only female or only male offspring.

There are a small number of techniques available to produce semen which contains either predominantly male or female sperm. These techniques are typically expensive and may result in sperm with reduced fertility.

Van Vleck and Everett [27] demonstrated that the use of sexed semen on the cow to breed cow and cow to breed bull pathways [28] might increase the annual rate of genetic gain by up to 15%. This benefit is unlikely to be sufficiently great to offset the current costs of producing sexed semen. This is especially true in systems such as those common in the SAP where record-keeping is not commonplace and female genetic evaluations have limited precision. However, reduced wastage of male offspring could help make the technology more economically justified in countries where religious beliefs preclude the consumption of meat from cattle.

7.3. Embryo transfer (ET)

Embryo transfer is the female equivalent of AI, whereby many offspring can be obtained from one cow. The magnitude of this increase is much less for ET (tens of offspring) than for AI (hundreds of thousands of offspring). Embryo transfer typically requires the use of several technologies, such as the application of reproductive hormones to stimulate the release of many eggs, recovery of eggs, in-vitro incubation, synchronization of surrogate dams and application of the fertilized egg to the surrogate dam. For most uses of ET, it is assumed that the female is of high genetic merit, which limits its value in many developing countries. Where the primary purpose of the ET is to achieve lactation and the offspring are not retained for breeding purposes but possibly retained for meat production [29], the genetic merit of the egg (or indeed the fertilized egg) for milking traits may be unimportant.

Multiple ovulation, followed by AI (or natural mating), embryo recovery and embryo transfer into surrogate dams who have undergone oestrous synchronisation is typically known by the acronym MOET. A variation of MOET is to use ovum pickup directly from the ovary, which is followed by in vitro fertilization, incubation and embryo transfer into surrogate dams.

Another alternative to obtain eggs for fertilization is to recover ovaries from slaughterhouses, recover eggs from the ovaries and to fertilize them under in vitro conditions before incubation and transfer into surrogate dams. With this approach, the genetic merit of the donating female may be unknown. However, if ovaries can be sourced from a population of high genetic merit cows, the individual cow genetic merit may not be of concern. Thus, some developing countries may wish to consider sourcing ovaries from cows slaughtered in developed countries. These cows are likely to be of a different breed to those in the developing country, giving the opportunity to generate a first-cross (F1) calf by using semen of local breeds. F1 females calves would be retained as replacements, while F1 male calves would be used for beef production in most countries. This system provides the opportunity to overcome the problem of how to maintain a population of F1 animals in the long term and obviates the need to resort to a composite breed, or more complicated mating plans such as rotational crossing. Because the eggs will be fertilized in an in vitro system, the opportunity exists to modify the expected sex ratio using sexed semen. In some systems, it may be desirable to produce only female F1 calves, allowing for the sale of excess females as replacements in herds that are not producing genetically superior females. Other systems may prefer to modify the ratio in favour of males to generate animals for beef production. Generating replacements in such a manner will import the rate of genetic gain from the source population of cows (most likely in a developed country). This will be merged with the genetic gain made in the local breed that provides the semen. Individual hybrid vigour will be superimposed on this genetic gain, and if the F1 animal is used as a dam, it will express maternal hybrid vigour. A possible deficiency of this system is that if the F1 cows become extremely popular, the majority of cows in the population will become F1 and there will be insufficient local cows to maintain a genetic improvement programme for the local breed(s). However, such a decline in the local breed population should be obvious and steps can be taken to intervene to ameliorate the problem such as the implementation of a breed conservation plan. Finally, ET using this approach is relatively inexpensive, requires limited technical expertise (except for a laboratory for the in vitro fertilization) and has negligible animal welfare implications. A pilot trial using this set of reproductive technologies is deserving of immediate support.

MOET has been the subject of several theoretical studies that suggest genetic gain can be enhanced by its use. However, caution must be taken to avoid the excessive accumulation of inbreeding [30].

7.4. Cloning

Cloning is the creation of multiple genetically identical copies of the same individual. Cloning techniques can be broadly classified as either embryo cloning or nuclear transfer.

7.4.1. Embryo cloning

Embryo cloning is achieved by physically splitting a multi-cell fertilized egg into several constituent cell masses. Each of these cell masses is then transferred into surrogate dams. Each of the offspring derived from the one fertilized egg should have identical nuclear DNA, but it is quite possible that they will have different mitochondrial DNA and different patterns of imprinting [31], meaning that the performance of offspring may be more variable than would be expected. Embryo cloning can only produce a limited number of offspring and has not received wide application in industry, although it has been used as a research tool.

7.4.2. Nuclear transfer

Adult somatic cell nuclear transfer (adult cloning) received wide publicity upon the birth of Dolly [32]. Since then, adult cloning has been achieved in many animal species, including cattle. Currently, this technique has only been used for research purposes, and significant improvements are needed in these technologies before elite females can be multiplied on a large scale. Adult cloning may provide a significant opportunity for developing countries, whereby high producing cows (possibly from government-owned herds) would be used to provide donor DNA for the large-scale multiplication. The clones would then be sold or gifted to commercial farmers. Providing that the superior performance of the elite cows has a nuclear DNA basis, the cloned offspring may express the same high performance. However, if the high level of performance is due to other reasons (most likely the environment, imprinting and/or programming), the cloned offspring may not exhibit superior performance.

7.5. Genetic modification

The genetic modification (GM) of farm animals using DNA technologies can now be regularly achieved. GM of farm animals may be undertaken to improve traits that are difficult to change by traditional means or to produce high-value novel proteins. To date, the use of GM to improve traits of economic relevance has received little emphasis due to consumer resistance and also the costs associated with generating GM animals. GM has received more attention for producing animals that will produce high value proteins for human use such as α1-antitrypsin [33]. However, this research and development is typically the domain of pharmaceutical companies due to the significant costs in producing the GM animals and the associated costs of shepherding the protein through the regulatory system prior to human usage.

8. COMMUNICATION (INCLUDING ELECTRICITY SUPPLY, GIS AND REMOTE SENSING)

Because of the recent explosion of cellular communications in developing countries, the opportunity exists to consider the use of this tool in animal genetic improvement. In the immediate future, there will be limited opportunity for exploitation due to there being no measuring devices that can be co-located with animals of interest. However, several research groups have a vision of miniature devices that can be placed on or in the animal to measure traits of interest [11, 34]. In the immediate future the traits measured will be macro-level such as body temperature, but in time the measurement of hormone or immune traits might be feasible. Initially these devices may need to be recovered from the animal to access data, but in time some form of remote communication should be feasible, leading to the phrase remote biosensing.

New communication methods may also be used in imaginative ways to deliver education and training to professionals, technicians and farmers that will assist in the usefulness of genetic improvement programmes.

9. BIOETHICAL CONSIDERATIONS

Over the last several decades there has been increasing concern by some sectors of society regarding the ethical treatment of animals. There are some interventions used during genetic improvement programmes that may attract the attention of those concerned about animal welfare issues. Awareness and consultation about these issues during the development of an animal improvement scheme will likely be worthwhile.

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LIST OF PARTICIPANTS

Blair, H.T.	Institute of Veterinary, Animal & Biomedical Sciences Massey University Palmerston North 5320 Private Bag 11-222 Palmerston North, New Zealand Tel.: 0064 6 3505122 Fax: 0064 6 3505699 EMail: h.blair@massey.ac.nz
Boettcher, P.	International Atomic Energy Agency Department of Nuclear Sciences and Applications Wagramerstrasse 5, P.O. Box 100 A-1400 Vienna, Austria Telephone: 0043 1 2600-26048 Fax: 0043 1 26007 Email: p.j.boettcher@iaea.org
Herath, H.M.S.P.	15/4 Sudharmarama Mawatha Bowala Kandy, Sri Lanka Tel.: 0094 81 2388031 Fax: 0094 81 2388031 EMail: hmspherath@yahoo.com
Jain, A.K.	Punjab Agricultural University Ludhiana, Punjab 141 004, India Tel.: 0091 161 2401961 280 Fax: 0091 161 2400822 EMail: jain4ashok@rediffmail.com
Jeyaruban, G.	Animal Genetics and Breeding Unit The University of New England Armidale, NSW 2351, Australia Tel.: 0061 2 67733979 Fax: 0061 2 67733266 EMail: gjeyarub@une.edu.au
Mohammad, S.	Malaysian Agricultural Research and Development Institute(MARDI) Pejabat Pos Besar P.O. Box 12301, GPO 50774 Kuala Lumpur, Wilayah Persekutuan, Malaysia Tel.: 0060 3 89437348 Fax: 0060 3 89485053 EMail: mshapii@mardi.my

Muladno, M.	Fakultas Peternakan Institut Pertanian Bogor (IPB) Kampus Darmaga Jalan Agatis Bogor, Indonesia Tel.: 0062 0251 624774 Fax: 0062 0251 628774 EMail: muladno@indo.net.id
Rahman, M. H.	Artificial Insemination and Fodder Cultivation Department of Livestock Services Krishi Khamar Sarak Farmgate Dhaka, Bangladesh Tel.: 00880 2 9132015 Fax: 00880 2 9132015
Shamsuddin, M.	Department of Surgery and Obstetrics Faculty of Veterinary Science Bangladesh Agricultural University (BAU) Mymensingh 2202, Bangladesh Tel.: 00880 91 556957 2374 Fax: 00880 91 55810 EMail: m.shamsuddin@gmail.com

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