Section D

Reproductive and molecular biotechnology

1 Introduction

The development of biotechnologies in the fields of breeding, reproduction and molecular genetics has advanced considerably in recent years. Among reproductive technologies, AI and multiple ovulation followed by embryo transfer (MOET) have already had a major impact on livestock improvement programmes in developed countries. These technologies speed up genetic progress, reduce the risk of disease transmission, and expand the number of animals that can be bred from a superior parent. The field of molecular genetics is also rapidly developing; characterization based on molecular markers, and marker assisted selection offer new opportunities in AnGR management (FAO, 2004). However, the extent to which the technologies are utilized varies greatly from country to country and between regions. The following chapters present an overview of the information presented in the Country Reports on the utilization of biotechnologies.

2 Global overview

Table 86 presents a region-by-region overview of the proportion of countries reporting the use of different classes of biotechnology. It can be seen that AI is by far the most widely used biotechnology. Nonetheless, particularly in the Africa and Southwest Pacific regions, there are many countries where it remains unavailable. In the case of ET and molecular techniques, the gap between the developed and developing regions is even greater. As Table 87 illustrates, the use of biotechnologies tends to be biased towards

TABLE 86
Use of biotechnologies by region

Region	Number of CRs	Artificial Insemination		Embryo Transfer		Molecular Genetic Technologies	
		Number providing information	Reporting use of technology	Number providing information	Reporting use of technology	Number providing information	Reporting use of technology
Europe & the Caucasus	39	39	97%	25	64%	29	83%
Africa	42	42	74%	30	17%	29	14%
Asia	25	22	86%	17	47%	16	50%
Latin America & the Caribbean	22	22	95%	14	86%	15	73%
Southwest Pacific	11	11	55%	10	10%	9	11%
North America	2	2	100%	2	100%	2	100%
Near & Middle East	7	6	100%	3	33%	5	40%

TABLE 87
Use of biotechnologies by species

Region	Artificial Insemination			Embryo Transfer			Molecular Genetic Technologies		
	CRs with information on species	Reporting use of technology:		CRs with information on species	Reporting use of technology:		CRs with information on species	Reporting use of technology:	
		Cattle	Other species		Cattle	Other species		Cattle	Other species
Europe & the Caucasus	38	100%	66%	11	100%	36%	18	89%	100%
Africa	31	100%	10%	4	100%	0%	3	100%	33%
Asia	18	94%	56%	6	100%	50%	7	86%	100%
Latin America & the Caribbean	21	100%	71%	12	100%	33%	9	78%	89%
Southwest Pacific	5	100%	80%	2	100%	0%	0	-	-
North America	2	100%	50%	0	-	-	1	100%	100%
Near & Middle East	6	100%	33%	1	0%	100%	2	0%	100%

cattle. The table shows that this bias is greatest with respect to ET, but it can also be seen that in most regions the use of AI is also dominated by the cattle sector. In the Africa region in particular, few countries have extended the use of AI to other species. The evidence for this species bias is rather less clear in the case of molecular genetic technologies. The number of countries reporting the use of these technologies is quite low. However, among these countries, a relatively high number report studies of molecular characteristics in at least one species other than cattle. Nonetheless, cattle remain the single dominant species in most regions, particularly where commercial applications of the molecular technologies are concerned. Further details of the distribution of biotechnology use, and of the species to which the technologies are applied are included in the following regional descriptions.

3 Africa

The Country Reports indicate that AI is the reproductive biotechnology most commonly used in the management of AnGR in Africa. The reports generally express an aspiration for greater use of the technology, mainly to facilitate breeding programmes and the introduction of exotic germplasm. This aspiration corresponds to the overall objective expressed in most African Country Reports of promoting food security through increased output of livestock products. In many cases, the desire for more widespread use of AI is tempered by concern regarding the implications for genetic diversity of its inappropriate or uncontrolled use. A number of Country Reports from the region also mention the potential use of AI facilities for cryoconservation purposes.

Thirty-one out of 42 countries report the use of AI. A few other countries report that AI has been carried out experimentally in the past, but never applied routinely, or that former AI programmes

have been abandoned through lack of financial resources or other constraints. AI use in Africa is predominantly focused on cattle. All 31 Country Reports indicating the use of AI mentioned that the technology is used in cattle. Two countries report the use of AI in sheep, one in goats, one in horses and one in pigs. The semen used for AI tends to be from exotic breeds rather than local breeds. Nineteen countries indicate that AI is performed using semen from exotic cattle breeds, two report using semen from local breeds, and six report use of both local and exotic semen. Where details of programmes are provided, the objective is often the upgrading of indigenous livestock using semen from exotic breeds, most frequently of dairy cattle. Exotic beef cattle semen is also utilized in a number of countries.

Some Country Reports from West Africa mention the use of exotic semen for cross-breeding with trypanotolerant cattle breeds (CR Guinea, 2003; CR Côte d'Ivoire, 2003). A limited number of AI programmes utilizing semen from indigenous animals are reported, including in one country the use of semen from trypanotolerant cattle (CR Côte d'Ivoire, 2003). CR Madagascar (2003) notes the use of AI in *in situ* conservation programmes for the endangered Renitelo cattle breed. However, even in countries where indigenous breeds are included in AI programmes, the balance appears to favour exotics. CR Botswana (2003) indicates that 94.1 percent of AI services performed during the 1987 to 1995 period were carried out using the semen of exotic breeds. The use of AI by smallholders is largely restricted to dairy producers, and is concentrated in peri-urban areas. A small number of Country Reports mention efforts to promote a wider diffusion of the technology, including in less easily accessible areas. CR Senegal (2003) notes considerable use of AI to introduce exotic germplasm for the breeding of race horses.

There is substantial variation from country to country in terms of the development of facilities and human resources for the implementation of AI programmes, in terms of the availability of services to the farmer, and in terms of the providers involved in service delivery. The public sector is the most frequently reported provider of AI services in the region. Among the 27 Country Reports providing information on service providers, 26 mention the public sector and 12 mention private companies. NGOs are mentioned as providers of AI services in eight Country Reports, while breeders' organizations are mentioned in two Country Reports (CR Burkina Faso, 2003; CR Madagascar, 2003). CR Niger (2003) mentions collaboration between two Italian universities, a local university and a local research station in establishing an AI programme for cattle. CR Zambia (2003) indicates that individual private farmers have imported exotic semen for the purposes of improving their cattle herds. A few countries have quite extensive AI programmes in place. Botswana, for example, in the context of its policy to improve the national herd, has a number of AI camps throughout the country and subsidizes the supply of semen to traditional farmers (CR Botswana, 2003).

Several countries report that problems with the financing of government services are a constraint to the provision of AI. Increased involvement by the private sector is noted as an objective in several Country Reports. A few countries are able to report significant progress in this direction (for example CR Kenya, 2004 and CR Zambia, 2003). CR Zambia (2003) notes that the private sector has taken the lead in providing imported semen, while the government trains and supervises AI technicians. However, as the figures above indicate the role of the private sector appears to be limited or absent in most countries. Few Country Reports discuss constraints to the involvement of the private sector in any detail. However, CR Côte d'Ivoire (2003) mentions that the single private operator in the country had ceased activities as a result of financial difficulties.

Five countries (CR Côte d'Ivoire, 2003; CR Kenya, 2004; CR Madagascar, 2003; CR Zambia, 2003; and CR Zimbabwe, 2004) report

the use of ET technologies. Use of the technology appears to be limited. In one country, the technology is reported only to have been used on Holstein-Friesian cattle on a single private farm (CR Madagascar, 2003). CR Côte d'Ivoire (2003) notes that some individual cattle owners have introduced Brazilian Zebu genetic material through the import of frozen embryos. In Zimbabwe, the technology is reported to be available through two private breeding companies (CR Zimbabwe, 2004). Several Country Reports state that the introduction of ET is an objective. However, the specific role that the technology could be expected to play in the management of AnGR in the local production systems is rarely elucidated. There is a lack of discussion of how it could be integrated within organized breeding programmes. The potential use of the technology for purposes of cryoconservation is, however, noted in several Country Reports. Studies based on the use of molecular markers are mentioned in only four Country Reports from Africa.

4 Asia

Among the Asian Country Reports, 19 out of 22 countries providing information indicate the use of AI. From 18 countries providing details of the species inseminated, 17 mention cattle, eight pigs, five buffaloes, four sheep, three chickens, two goats, two horses, one camels and one ducks. Details of the breeds used as the source of semen are limited. However, in the case of cattle eight Country Reports indicate the use of semen from both local and exotic breeds, four mention only exotic breeds, and two mention only local breeds. Provision of AI services appears to be dominated by the public sector. Of 17 Country Reports giving details of service providers, all 17 mention the public sector, with 6 mentioning the private sector, five breeders' organizations, four NGOs and one universities. There is much variation from country to country in the extent to which AI is used. In an industrialized country such as Japan, almost all cattle breeding (99.4 percent in dairy herds and 97.8 percent in beef herds) is carried out using AI (CR Japan, 2003). In most other Asian countries, services are much more limited and tend to be focused on the dairy sector and peri-urban production systems. Several Country Reports indicate that service coverage is limited by financial and technical constraints. Indeed, a few Country Reports indicate a decline in the use of the technology.

The desire to establish or to increase the availability of AI services is expressed as an objective in many Country Reports. In a number of countries AI has served as a means of introducing exotic germplasm for the purposes of cross-breeding with local breeds. The technology has been used in the development of synthetic breeds incorporating both exotic and indigenous genes – an example being the Jermasia goat (CR Malaysia, 2003). In some cases, AI has also been used to upgrade cross-breeds back to indigenous breeds through back-crossing to promote hardiness. This approach has been applied, for example, using Kedah-Kelantan semen in cattle herds introduced to tree plantations (ibid.). In some cases AI services supply semen from indigenous breeds. CR Pakistan (2003) for example reports the use of semen from Sahiwal cattle. However, the same Country Report indicates that the collection of semen from some other indigenous cattle breeds was discontinued because of a lack of demand.

Eight out of 17 Asian countries providing information on the matter indicate some use of ET technology. Among the six countries providing details of the species in which the technology is implemented, six mention cattle, two buffaloes, one horses and one goats. The breeds involved are rarely detailed, but one Country Report mentions the transfer of embryos from indigenous cattle breeds and one mentions exotic breeds. In most countries, ET is used on a very limited scale and is often largely confined to research. CR Myanmar (2004) notes that an ET project initiated in the country met with some success at first, but soon declined because of a lack of funding. CR Malaysia (2003) mentions that

ET technology was used in the development of the Mafriwal cattle breed. The potential role of the technology in cryoconservation programmes is, again, noted in several Country Reports.

Eight out of 16 Asian countries providing information on the matter report the use of molecular techniques. Among these countries, six specify genetic distancing studies, and two mention marker assisted selection. Among the seven countries providing details of the species involved in molecular characterization studies, six mention cattle, five chickens, four sheep, four goats, four pigs, three buffaloes, two ducks, two horses, one camels, one deer, one quails and one guinea fowl. In the case of distancing studies, among the five countries providing details of the species involved, four mention chickens, three cattle, three sheep, three goats, two pigs, two buffaloes, two horses, one ducks and one deer. With regard to the breeds involved, systemized studies on Asian breeds are being conducted by the Society for Research on Native Livestock in Japan including analysis based of genetic relationships based on mitochondrial DNA polymorphisms and other DNA markers (CR Japan, 2003). Native Japanese breeds covered by the studies include Mishima cattle and Kuchinoshima feral cattle (ibid.).

Other biotechnologies are very largely restricted to the most industrialized countries in the region. The use of *in vitro* fertilization is mentioned in CR Japan (2003) and CR Malaysia (2003). CR Japan (2003) indicates that a number of other reproductive biotechnologies with potential for use in the propagation of rare breeds, as well as commercial applications, have been utilized at an experimental level. The technologies include sperm micro-injection to fertilize eggs – applied in pigs; primordial germ cell (PGC) and chimera germline techniques – applied in chickens; and cloning technologies – used in cattle, pigs and goats (ibid.).

5 Europe and the Caucasus

Thirty-eight of 39 countries in the region report the use of AI. All 38 mention the use of the technology in cattle, 23 in pigs, 16 in sheep, nine in horses, eight in goats, two in rabbits, and one in chickens. Most countries which give details report using semen from both local and imported breeds of cattle, pigs and sheep. While almost all countries are able to report the existence of some AI provision, there is great variation in the extent to which the technology is utilized. In many countries, particularly in western Europe, AI is widely available and used throughout the livestock sector, particularly in dairy cattle. However, a number of Country Reports from the eastern parts of the region, where the livestock sector has often faced substantial problems, indicate that capacity to provide AI services is severely limited as a result of the disintegration of formerly existing infrastructure.

A range of providers are involved in the delivery of AI services. Of the 32 countries giving details of providers, 24 mention the private sector, 20 the public sector, 19 breeders' organizations and three universities. In the countries of the eastern part of the region, services are more likely to be provided by the public sector. Conversely, elsewhere in the region, the private sector and farmers' organizations are the most frequently mentioned service providers, although in many countries there is still considerable involvement or support from the public sector. CR Turkey (2004), for example, mentions the provision of subsidies to private sector providers of AI. Transfer of services to the private sector has not always been without problems. For example, CR Romania (2003) notes that reorganization and greater independence of AI institutes, along with the introduction of service charges, led to a decline in the uptake of the technology.

In some countries, AI using imported semen has been widely used to increase the production levels obtained from local breeds. However, some concerns are raised in the Country Reports.

Attempts to upgrade local livestock using exotic semen have sometimes failed because the resulting cross-bred animals have proved to be poorly adapted to the local conditions. There is also a potential threat to genetic resource diversity. According to CR Greece (2004), inappropriate and unplanned use of AI contributed markedly to the loss of some indigenous breeds.

Sixteen of the 25 countries providing information on the matter report the use of ET. Of the 11 countries providing details of the species involved, all 11 mention cattle, three sheep, two goats, one pigs, one horses and one rabbits. Where specified, ET is carried out using embryos from both imported and local breeds of cattle. Again, it is the dairy industry that is the main user of ET. The technology has contributed significantly to increasing the rate at which selective breeding has contributed to raising the output of livestock products. However, as a result of the costs involved in applying the technology it is less widely used than AI, and in some countries, ET programmes have ceased as a result of the high costs. In the case of ET, out of eight countries providing details of service providers, four mention the private sector, four the public sector, four breeders' organizations and three universities. Other reproductive technologies such as embryo sexing, cloning and transgenetics are mentioned in a very few Country Reports as subjects for research.

Twenty-four out of 29 Country Reports providing information on the matter indicate the use of molecular techniques. Marker assisted selection is used in commercial animal production in a number of European countries. The technology can be applied to eliminate a number of undesirable traits related to health or fertility from livestock populations, and to assist selective breeding for greater productivity.

The importance of ensuring that information on molecular biotechnologies, including their economic benefits, are made available to farmers and breeders' organizations is noted in one Country Report (CR Hungary, 2003). Another Country Report highlights the prospect that molecular biological methods will facilitate the discovery of genes for economically important traits in locally adapted breeds, thereby enhancing their value in breeding programmes (CR Germany, 2003). However, the same Country Report raises the concern that the use of molecular technologies in the context of market-driven attempts to increase production could exacerbate a trend towards inbreeding and loss of genetic diversity within livestock populations. Similar apprehensions are expressed in a small number of other Country Reports. Genetic distancing studies are considered important from the point of view of planning and prioritizing conservation efforts. One Country Report, however, notes that progress to this end has been limited as interest in the subject is largely restricted to universities, and funding is limited (CR Belgium, 2005). Another Country Report puts forward a potential role for such techniques in relation to the niche marketing of livestock breeds on the grounds of their close association with a particular geographical location (CR France, 2004).

Among the Country Reports providing details of the use of molecular technologies, 11 specify the implementation of molecular genetic distancing studies and seven mention the use of marker assisted selection. Out of 17 countries providing information on the species involved in molecular characterization studies, 14 mention cattle, 13 sheep, 11 pigs, eight horses, five goats, three chickens, one donkeys, one turkeys, one deer and one geese. Out of 12 countries providing information on the species involved in distancing studies, 11 mention sheep, nine cattle, five horses, four pigs, three chickens, three goats, two geese, one ducks, one donkeys, one rabbits, and one deer. Out of four countries providing information on the species in which marker assisted selection is practised, four mention cattle, four pigs, one chickens and one horses. Details of the specific breeds to which technologies have been applied are quite limited in the Country Reports. Among the local breeds for which molecular characterization or distancing studies are mentioned in the Country

Reports are the Turoplje and Black Slavonian pigs, Ruda sheep and sheep of the islands of Rab, Pag and KrK (CR Croatia, 2003); Wallachian and Sumava sheep, Brown goats and White goats (CR Czech Republic, 2003); and the Karakachanska sheep (CR The former Yugoslav Republic of Macedonia, 2003).

6 Latin America and the Caribbean

AI is widely practised in the countries of this region. Twenty-one out of 22 Country Reports indicate the use of the technology. All 21 countries report the use of AI in cattle, 13 mention pigs, eight sheep, eight goats, five horses, one rabbits, one buffaloes, one donkeys, one llamas, one alpacas and one turkeys. With regard to the cattle breeds providing the semen used for AI, 13 Country Reports mention only exotic breeds, while four mention both indigenous and exotic. In the cases of sheep, five Country Reports mention exotic breeds and one mentions both exotic and local. In the case of pigs, nine Country Reports mention only exotic breeds while one mentions both local and exotic.

It is clear that the predominant objective is to increase the genetic merit of livestock populations using semen from exotic breeds. In many countries, semen is imported from overseas. Use of the technology is most common in the dairy sector. In some countries it is also quite widely used by commercial producers of beef cattle, pigs and small ruminants. However, there is marked variation between countries and between production systems in terms of the extent to which AI is used. In many small-scale or low external input systems, use of the technology is very limited. A number of countries indicate that improving the provision of AI services is an important objective. A small number of Country Reports, however, mention concerns regarding the decrease of genetic diversity arising as a result of the inappropriate use of AI. With regard to the providers involved in the delivery of AI services, the private sector plays an important role in this region. Of 17 Country Reports giving details of service providers, 11 mention the public sector, nine mention the private sector, and five breeders' organizations. CR Barbados (2005) mentions the provision of subsidies to farmers' organizations for the purchase of semen for AI.

ET technology is increasingly being used by commercial livestock producers in several countries of the region. Twelve Country Reports, out of 14 providing information, report the use of ET. All 12 mention the use of the technology in cattle, three in horses, two in goats, two in sheep, one in llamas, one in alpacas and one in donkeys. Transplanted embryos largely come from exotic breeds – the six countries that provided details of the cattle breeds involved indicate the use of embryos only from exotic breeds. As in the case of AI, though on a more limited scale, use of ET technology is dominated by the dairy industry, with restricted use in other types of commercial livestock production. Some Country Reports indicate the importation of embryos from overseas. Information on the providers of ET services is limited. However, the CR Brazil (2004) and CR Chile (2003) mention private sector organizations involved in the provision of the technology. Additionally, two Country Reports indicate some commercial use of *in vitro* fertilization, while one mentions the development of embryo sexing and cloning technologies.

Eleven countries, out of 15 providing information, indicate some use of molecular techniques. With regard to molecular characterization studies, out of nine countries providing information on the breeds involved, seven mention cattle, three sheep, three pigs, two chickens, two horses, one goats, one buffaloes, one llamas, one alpacas, one vicuñas, one guanacos and two unspecified camelids. Several countries indicate that locally adapted breeds have been included in such studies. CR Peru (2004) mentions molecular investigations of the genetic distances between South American camelid species. Few Country Reports, however, indicate that molecular technologies have been incorporated in breeding programmes. CR

Colombia (2003) notes the potential significance of marker assisted selection programmes utilizing the genes of the Blanco Orejinegro cattle breed, which is reported to show resistance to brucellosis, and which has been the object of molecular characterization studies.

7 Near and Middle East

In this region all six countries providing information on the matter report the use of AI. With regard to the species involved, all six mention cattle, one camels and one rabbits. One Country Report (CR Oman, 2004) mentions the use of ET in camels. The semen used in AI programmes is largely obtained from exotic breeds, either from local populations or imported. A number of Country Reports note that the use of AI has had an adverse effect on genetic diversity and contributed to the decline of local livestock breeds. One Country Report (CR Syrian Arab Republic, 2003) mentions some use of semen from a local cattle breed (Shami). Some Country Reports indicate that the development of AI programmes for local breeds of sheep, goats and/or buffaloes is a priority. CR Syrian Arab Republic (2003), for example, notes that the local Awassi sheep and Shami goats are much sought after in neighbouring countries for breeding, and that plans are in hand to develop AI and ET programmes to meet the demand. Among six countries giving information on service providers, five mention the public sector, four the private sector and two breeders' organizations. Some Country Reports, however, indicate constraints to the provision of AI, such as a lack of trained personnel. Several Country Reports note the potential use of AI and ET technologies in cryoconservation. The use of other biotechnologies is limited. One Country Report (CR Jordan, 2003) indicates molecular characterization and genetic distancing studies in indigenous goats, while another (CR Egypt, 2003) notes that molecular genetic studies of buffalo, sheep and goats have recently been initiated with the aid of regional and international organizations.

8 North America

In the United States of America and Canada reproductive biotechnologies are readily available. AI is widespread in the dairy and pig industries, and is used to a lesser extent in other sectors such as beef cattle and small ruminants. Concern is expressed at the role of AI in contributing to a reduction in the effective population size of some dairy cattle breeds. Details of the utilization of other biotechnologies are limited in the Country Reports from this region. In the United States of America, molecular characterization studies have been carried out, by industry and public sector institutions, for the most widely kept breeds of dairy cattle and pigs, and also in a number of beef cattle breeds (CR United States of America, 2003). Molecular markers are particularly used for the identification of recessive defects in bulls used for AI. Molecular studies, providing measures of within and between-breed genetic diversity are also used by the National Animal Germplasm Program (NAGP) in the planning of conservation programmes for AnGR (ibid.).

9 Southwest Pacific

Biotechnologies are not widely used in this region. Six of the 11 Country Reports indicate the use of AI. Out of five countries indicating the species involved in AI programmes, five mention cattle, four pigs, one sheep and one goats. With regard to AI service providers, two Country Reports mention the public sector, two the private sector, and one mentions an individual volunteer from a developed country. Several Country Reports from small island states note the potential of AI as a means of introducing exotic germplasm, but the use of the technology appears to be limited. In some countries a small number of private livestock producers are involved in the import of semen for the purposes of AI in their herds. Two Country Reports (CR Australia, 2004; CR Vanuatu, 2003) indicate the use of ET technology, both reports referring to cattle. Additionally, CR

Samoa (2004) notes the use of the technology for the introduction of Piedmontese cattle during the 1980s. Capacity for the use of biotechnologies is well developed in Australia, which is the only country from the region reporting the use of molecular techniques to underpin characterization and selection efforts[10].

10 Conclusions

The information provided by the Country Reports unsurprisingly indicates that there is a large gap between developed and developing countries in terms of capacity to utilize biotechnologies in the management and development of AnGR. The focus, particularly in the case of reproductive biotechnologies, is on cattle, and the application of biotechnologies in the use, development or conservation of locally adapted breeds is generally limited. Provision is constrained by a lack of financial, human and technical resources, and problems related to access, affordability and acceptability within diverse local production systems.

In a number of regions, there is increasing diversity in terms of the stakeholders providing services, with greater involvement of the private sector and breeders' organizations. Such developments may have a role in overcoming constraints to the utilization of biotechnologies in developing countries, but it is evident from the Country Reports that progress in this respect is often very limited.

A further concern noted in many Country Reports is the inappropriate use of AI. Concerns largely relate to the unplanned use of the technology to introduce exotic germplasm, which may threaten the existence of indigenous genetic resources. With regard to high-output breeds kept under high external input conditions, there are also some concerns regarding a narrowing of within-breed genetic diversity. The successful application of technologies such as marker assisted selection necessitates high levels of inputs in terms of financial, human and technical resources. As such, the cost-effectiveness of strategies based on the use of such technologies has to be carefully evaluated. Implications for genetic diversity should also be considered. Successful introduction of marker assisted selection will tend favour the utilization of a limited number of breeds at the expense of others, and will also pose a threat to within-breed diversity.

[10] New Zealand, a country with a well-developed biotechnology sector, did not submit a Country Report and is, therefore, not included in the analysis.

References

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