

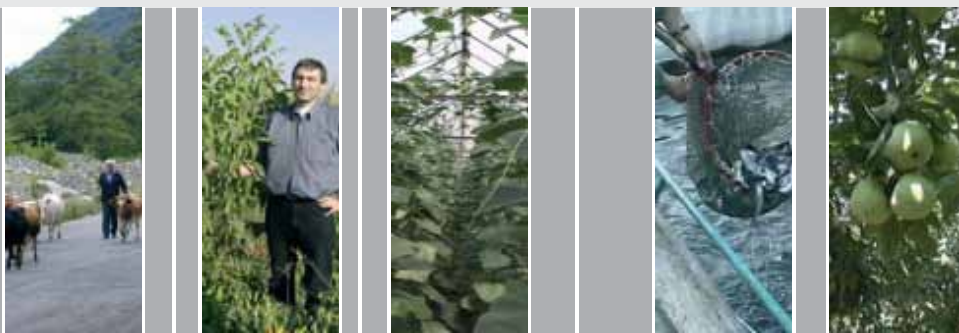


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BUFFALO PRODUCTION AND RESEARCH



FAO REGIONAL OFFICE FOR EUROPE



**FAO REGIONAL OFFICE FOR EUROPE
INTER-REGIONAL COOPERATIVE RESEARCH
NETWORK ON BUFFALO (ESCORENA)**

BUFFALO PRODUCTION AND RESEARCH

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PREFACE

For many years I have had the idea of writing a book about the buffalo: the species that I love and have studied for thirty years. The buffalo is a very quiet and intelligent animal, domestic but rustic, faithful and friendly, rich in history, and can now be found in many countries worldwide. It is employed as a draught animal, but also produces meat, horns, skin and particularly the rich and precious milk that gives creams, butter, yoghurt and many cheeses, including the delicious mozzarella.

The opportunity to write this book was facilitated by the FAO Regional Office for Europe aiming at promoting the diffusion of expertise and technologies among the regions within the framework of the European System of Cooperative Research Networks in Agriculture (ESCORENA). The FAO Regional Office for Europe supported me, as Coordinator of the FAO Inter-Regional Cooperative Research Network on Buffalo for Europe and the Near East, to produce this reference book on buffaloes all over the world with contributions from various buffalo experts and based on the results of my own research and work experience.

This experience was gained thanks to senior researchers devoted to the development and promotion of buffaloes. The first of these was Dr Augusto Romita, my first supervisor at the Istituto Sperimentale per la Zootecnia (the Animal Production Research Institute of the Italian Ministry of Agriculture in Monterotondo, Rome) with whom I conducted many experiments at Tormancina, the farm of the Institute, on buffalo calves and young bulls during the period from 1974 to 1980. He later prepared the first important research project on the buffalo species, financed by the Italian Ministry of Agriculture. This project examined the main aspects of buffalo production: nutrition and requirements, reproduction and physiology, and rumen microbiology, in collaboration with other Italian universities: Naples, Bologna, Perugia, Piacenza.

The second was Professor Giovanni De Franciscis, who shared with me his concept of working towards the realization of the good prospects for buffalo development in Italy and in the world. He promoted the first (1974) and the second (1982) International Buffalo Congress, and organized, in collaboration with the IBF (International Buffalo Federation, founded in 1985) and myself, the Fourth World Buffalo Congress (1997) in the Royal Palace of Caserta.

The third was Mr A. Qureshi, who raised my awareness of the essential role of buffaloes for the livelihood of many rural families in developing countries and encouraged me to establish the FAO Inter-Regional Cooperative Research Network on Buffalo.

I would also like to mention Professor Beniamino Ferrara, the famous university teacher in Animal Production of students of my generation in Naples, and a dear colleague and friend of mine, Tullio Di Lella, Professor of Animal Feeding and Nutrition at the Veterinary Faculty, Federico II University, Naples, Italy, who supported my dedication to buffalo research.

All these five colleagues have unfortunately now passed away and I feel somewhat sad and lonely without them. I would therefore like to dedicate this book to their memory.

Antonio Borghese
Monterotondo (Rome), Italy, 2005

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Chapter I

BUFFALO POPULATION AND STRATEGIES IN THE WORLD

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The buffalo (*Bubalus bubalis*) population in the world is actually about 168 million head: 161 million can be found in Asia (95.83 percent); 3 717 million are in Africa, almost entirely in Egypt (2.24 percent); 3.3 million (1.96 percent) in South America, 40 000 in Australia (0.02 percent); 500 000 in Europe (0.30 percent).

ASIA

Asian buffalo or Water buffalo is classified under the genus *Bubalus*, species *bubalis*. The *Bubalus bubalis* belongs to the class Mammalia, subclass Ungulata, order Artiodactyla, suborder Ruminantia, family Bovidae, subfamily Bovinae, tribe Bovini, which includes the following three groups: Bovina (cattle), Bubalina and Syncerina. Syncerina includes only the species *Syncerus caffer* (the African buffalo). Bubalina (the Asian buffalo) includes three species: *Bubalus depressicornis* or Anoa which lives in Indonesia, *Bubalus mindorensis* which lives in the Philippines and *Bubalus bubalis* deriving from the domestication of the *Bubalus arnee*, the Indian wild buffalo. The domestication of this species occurred relatively recently (5 000 years ago) compared to the domestication of *Bos taurus* and *Bos indicus* (10 000 years ago). Asian buffalo includes two subspecies known as the River and Swamp types, the morphology and purposes of which are different as are the genetics. The River buffalo has 50 chromosomes of which five pairs are submetacentric, while 20 are acrocentric: the Swamp buffalo has 48 chromosomes, of which 19 pairs are metacentric. The difference in the diploid number is only apparent. In fact, the large Swamp buffalo chromosome 1 originated from tandem fusion translocation between the River buffalo chromosome 4 (telomeres of p-arm) and 9 (centromere) (Di Berardino and Iannuzzi, 1981). During this phenomenon, the nucleolus organizer regions (NORs) present in the River buffalo chromosome 4p were lost and the centromere of chromosome 9 inactivated (Di Berardino and Iannuzzi, 1981). The two subspecies are inter-fertile and produce progeny with 49 chromosomes. Male crossbred progeny have sometimes displayed fertility problems while female progeny have manifested longer calving intervals only in the case of further backcross. Morphology of the two types differs considerably. Swamp buffaloes are less heavy, the adult male weight ranging between 325 and 450 kg, while the River type weighs between 450 and 1 000 kg. While the Swamp buffalo is reared mainly for draught purposes, although it also produces a valuable milk yield of up to 600 kg milk per year, the importance of the River buffalo depends on the high quality and quantity of the milk that it produces. River buffaloes are generally large in size, with curled horns and are mainly found in India, Pakistan and in some countries of western Asia. They prefer to enter clear water, and are primarily used for milk production, but are also used for meat production and for draught purposes. Swamp buffaloes are stocky animals with marshy land habitats. They are primarily used for draught power in paddy fields and haulage but are also used for meat and milk production. Swamp buffaloes are mostly found in south east Asian countries. A few animals can also be found in the north eastern states of India (Sethi, 2003). Each subspecies includes many breeds.

The production of milk and meat from buffaloes in Asian countries over the last decades has shown a varying pattern: in countries such as India, Sri Lanka, Pakistan and China, the milk yield per animal has increased by 2.44 percent, 1 percent, 1.45 percent and 1.55 percent,

respectively, while there has been either no change or only a negligible change in milk production in Bangladesh, Myanmar, Nepal and Vietnam. In some regions of east and south-east Asia, there has been a negative growth. Meat production from buffaloes has shown a growth of 1.43 percent only in Pakistan, while in other countries there was no change or a decline. At the Asia level, although buffalo milk production increased by 2.26 percent, meat production marginally declined (Dhanda, 2004).

Buffaloes are known to be better at converting poor-quality roughage into milk and meat. They are reported to have a 5 percent higher digestibility of crude fibre than high-yielding cows; and a 4-5 percent higher efficiency of utilization of metabolic energy for milk production (Mudgal, 1988).

1. INDIA

India has about 95 million animals which represents 56.5 percent of the world buffalo population. India is the first country in the world for number of buffaloes and milk production (about 134 million tons).

India is also the first country in Asia for scientific and technological development in buffalo nutrition, production, reproduction, biotechnologies and genetic improvement. Moreover India has implemented national programmes such as the "green revolution" (to increase crop production for animals), the "white revolution" (to increase milk productivity and satisfy human needs for proteins) and finally the "red revolution" (to increase meat production and strengthen the meat industry), particularly with regard to buffalo.

India possesses the best River milk breeds in Asia e.g. Murrah, Nili-Ravi, Surti and Jaffarabadi, which originated from the north-western states of India and have a high potential for milk and fat production apart from their use as a work animal and as a supplementary stock for use as meat production (Sethi, 2003). Indian Murrah is the most diffuse breed in the world: from Bulgaria to South America and all over Asia (Fig. 1). The production traits of the Indian breeds are reported in Table 1, with more details and figures given in Chapter III.

Table 1. Buffalo Breeds of India and their Production Traits (ICAR, 1997)

Name of the Breed	Average Lactation length (days)	Average Lactation yield (kg)	Milk Composition
Badhawari	272	780	Av.Fat 8.6% Total solid 17%
Jaffarabadi	319	2151	Av.Fat 7.86%
Marathwada	302	900	-
Mehsana	305	1893	Av.Fat 7%
Murrah	305	1675	Av.Fat 7.3%
Nagpuri	286	1055	Av.Fat 7.7%
Nili-Ravi	294	1820	Av.Fat 6.8%
Pandharpuri	305	1142	Av.Fat 7.0% SNF 9.28%
Surti	305	1289	Av. Fat 7.9%
Toda	200	500	Protein 4.45%

Recent statistics concerning buffalo demography show that the buffalo population in some countries like India, Pakistan, China, Vietnam is increasing at a rate of 1.5 percent/per year. Buffaloes are well adapted to a hot and hot humid climate and play a distinct role in the economy of farmers, which is primarily based on agricultural production systems. They provide high quality milk and meat and are a source of draught power for smallholders in countries of this region. In fact these animals are considered a financial asset since they serve as an insurance against the risk of crop failure due to natural calamities (Dhanda, 2004).

Less information is available regarding the production systems of Swamp buffaloes.

However, according to Faruque (2003) the Indian Swamp buffaloes have been mostly evolved for milk production and generally males are used for work in the paddy fields and performing

other agricultural operations.



Figure 1. Murrah buffaloes in the Central Institute for Research on Buffalo, Hisar, India

2. CHINA

China has a huge variety of buffalo genetic resources, unknown to most buffalo experts other than the Chinese. They are all of the Swamp type, with a long history of domestic livestock, and provide many products to the farmers.

In China each region has different types of buffaloes, to the extent that it is possible to say that buffaloes have adapted themselves to a range of climates, altitudes and temperatures as have the different cattle breeds that inhabit the various continents and countries. Therefore, in China there are buffalo breeds that can be found only in the lowlands, and other breeds that live only in the mountains.

The breeds of the lowlands are raised on fertile soils and paddy fields where intensive agricultural activities are carried out. This is the case of the Binhu breed (461 000 head; Fig. 2) in the Hunan province, the Xinyang breed (290 000 head) in the Henan province, the Enshi breed (77 000 head; Fig. 3) in Hubei, the Fuan breed (70 000 head) in the Fujian province, the Yanjin breed (45 000 head) in Yunnan, the Xinglong breed (24 000 head) in Hainan and the Wenzhou breed (10 000 head) in Zhejiang (Zhang Chunxi and Li Zhongquan, 2001).



Figure 2. Binhu buffalo



Figure 3. Enshi buffalo

Two further breeds inhabit the lowlands and can also be found along the saline seaside shores of the east sea: these are the Haizi breed (65 000 head) in Jiangshu and the Shanghai breed (36 000 head; Fig. 4) around the city of Shanghai. A similar adaptability to saline sandy terrain was already mentioned for another buffalo population in Bangladesh, in the bay of Bengal. The

most numerous breed in China is the Guizhou (1.46 million), a mountain breed of the Guizhou province: raised on natural pasture and of varying body size according to environmental conditions.

With regard to the other mountain breeds, there are the Fuling (415 000 head; Fig. 5) in Sichuan, the Dehong (390 000 head) and the Diandong (220 000 head) in Yunnan, the Dechang (190 000 head) in Sichuan, the Xilin (59 000 head) and the Fuzhong (57 000 head; Fig. 6) in Guianxi and the Dongliu (27 000 head; Fig. 7) in the Anhui province.



Figure 4. Shanghai buffalo



Figure 5. Fuling buffalo



Figure 6. Fuzhong buffalo



Figure 7. Dongliu buffalo

Most buffalo breeds tolerate all ranges of temperature, from 0°C in the winter to 30°C and over in the summer.

All buffaloes have long horns, a typical trait of the Swamp buffalo. The colour of the coat is grey, with varying intensities: from deep grey and blackish grey to brown, hoar and light grey. The majority of the breeds also have white spots either in the form of stripes on the breast or in the form of rings on the neck.

As for all Swamp buffaloes, Chinese buffaloes are used for draught, often as their only task. Exceptions are the Wenzhou breed, which is regularly milked and produces 1 020 kg milk in 278 days and the Jiangnan (800 kg milk in 8-12 months). The Fuan breed is also sometimes milked, producing on average 2.6 kg milk/day, in a lactation of extremely variable length: 150 to 300 days (Zhang Chunxi and Li Zhongquan, 2001).

According to statistical data (FAO, 2003), the total number of buffaloes in China in 2003 was 22.759 million, the second largest population of buffalo in the world, representing 17.37 percent of the total bovine population in China. Scientific research on buffaloes began with some delay compared with other breeds.

China imported Murrah buffalo from India in the late 1950s and Nili-Ravi buffalo from Pakistan in the late 1970s. Since China imported two breeds of exotic dairy type buffaloes, experiments such as feeding observation, freezing of buffalo semen, artificial insemination and crossbreeding etc., had already been conducted, and good results were obtained. Over the past

20 years, important developments and breakthroughs in scientific and technological research on buffaloes have been achieved. In the area of breeding improvement, genetics and breeding, physiology and biochemistry, feeding and nutrition, reproductive technology, embryo biotechnology, dairy processing and disease prevention and treatment, many scientific and technological achievements have been acquired, and abundant scientific data has been accumulated (Liang Xian-wei et al., 2004). According to various studies milk performance has been markedly improved in crossbreds through the crossbreeding system applied in upgrading the two breeds such as crossbred Murrah F1, F2 and crossbred Nili-Ravi F1, F2. The average milk yields per lactation in Murrah crossbred F1, F2 are 1 240.5 kg and 1 423.3 kg respectively, which is higher than that of the local buffalo of 1 092.8 kg (this data comes from a selected herd, normally the local Swamp buffalo produces 500 - 800 kg per lactation) by 13.5 percent and 30.2 percent ($p<0.01$). In Nili-Ravi crossbred F1 and F2 milk yields per lactation are 2 041.2 kg and 2 325.6 kg, which are an improvement of 88.6 percent and 115.2 percent respectively ($p<0.01$). Triple-crossbred and their inter se crossing offspring are 2 294.6 kg and 1 994.9 kg respectively, which is an increase of 109.98 percent and 82.55 percent, compared with local buffalo ($p<0.01$) (Yang Bingzhuang et al., 2003), as reported in Table 2.

Table 2. Comparison of milk performance in different buffalo breeds (kg/day)
(Yang Bingzhuang et al., 2003).

Breed	Lactations (n)	Lactation length (days)	Milk yield (kg)	Average milk yield per day (kg)	Highest daily milk yield (kg)
L	70	280.4±20.2	1092.8±207.4	3.79	6.6
M	237	324.7±73.9	2132.9±78.3	6.57	17.40
N	164	316.8±83.6	2262±663.9	7.14	18.40
MLF1	157	313.7±96.7	1240.5±479.8	3.95	7.57
MLF2	118	313.9±90.1	1423.3±534.5	4.53	8.30
NLF1	45	326.7±96.4	2041.2±540.9	6.25	16.65
NLF2	55	321.4±118	2325.6±994.4	7.22	19.35
N.MLF2	168	317.6±78.4	2294.6±772.1	7.22	18.80
N.MLG1	70	329.1±89.8	1994.9±635.0	6.06	18,50

L=local, M=Murrah, N=Nili-Ravi, G=Santa Gertrudis

The body size and body weight in crossbreds are greater than in local buffaloes, therefore meat yield performance in crossbreds is better than in local buffalo.

According to the data supplied by the Guangxi Buffalo Research Institute, a fattening experiment was conducted on triple-crossbreds and half Santa Gertrudis under the same conditions. The results showed that dressing percentage at 18 months was 53.0 percent and 59.9 percent respectively, net meat weight was 43.2 percent and 42.1 percent respectively, bone meat ratio was 1:4.5 and 1:4.4 respectively, and the quality of the buffalo meat was equal to that of bovine meat. The results showed that Murrah F2, had the greatest drawing ability (198.3 kg), next was the Murrah F2 (166.3 kg) and last was the local buffalo (111.8 kg). Meanwhile swamp buffalo can be crossed with River buffalo with high milk yields to create high milk yield cows (Yang Bingzhuang et al., 2003).

3. PAKISTAN

In Pakistan, the buffalo is the main dairy animal in the country. Out of the 22 million head of buffalo in Pakistan, 76 percent are found in the Punjab (24 percent in other provinces of the country: Sind, North West Frontier Provinces (NWFP), and Baluchistan). The Punjab supplies 73 percent of the total national milk production and 71 percent comes from buffaloes which are part of the traditional small mixed farming system which is integrated with crop production. Herd size is very small; 85 percent of buffaloes are raised in herds of one to five animals. There are 0.5 million landless farmers keeping dairy animals and contributing a significant (70 percent) share of the total milk production (Raza et al., 2000).

Table 3. Production performances of buffalo in Pakistan (Mudgal, 1999).

Characteristics	Nili-Ravi		Kundhi	
	Mean	Range	Mean	Range
Body weight at birth (kg)	-	-	-	-
Male	39.8	32-58	35.1	33.4-37
Female	37.7	27-45	32.3	31-34.5
Age at first calving (months)	47	30-54	52.7	48-57
Weight at first calving (kg)	625	544-695	495	407-585
Lactation length (days)	312	200-450	277	244-300
Lactation yield (litres)	2070	1700-2700	1825	1580-2018
Dry period (days)	160	95-240	176	134-214

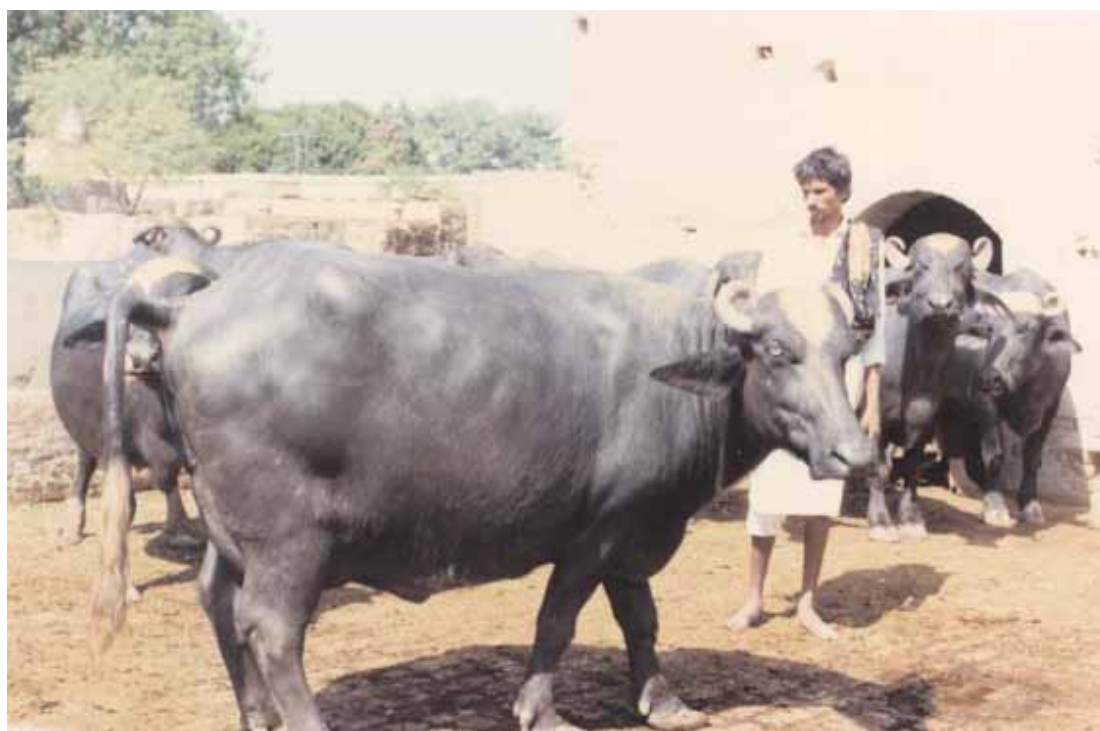


Figure 8. Nili-Ravi buffaloes at the Livestock Research Institute, Bahadurnagar, Okara (Pakistan) (Borghese photo, 1992)

Recording of buffaloes is mainly undertaken in the seven institutional herds and on a few military farms. Apart from this, buffaloes at farm level are recorded under the progeny testing programme which has been operative since 1980. Dairying is still not undertaken on a commercial basis so the level of inputs is very low. Generally, animals are fed on crop residues with some additional forage/fodder grown for this purpose. Hay and silage making does not exist, except to some extent for institutional herds. Concentrates are fed to those animals that

are kept for the sale of milk. The government facilitates vaccination against contagious diseases at nominal costs. About 5-10 percent of breedable females are artificially inseminated while the rest are mated naturally with bulls of a good type. Credit facilities have also been made available to farmers for the purchase of milk yielding animals but on a limited scale (Khan et al., 1999; Khan, 2000).

The most common breeds present in Pakistan are the River Nili-Ravi (Fig. 8) and the Kundhi; their production performances are reported in Table 3.

4. PHILIPPINES

In the Philippines there are 3.2 million Carabao buffaloes, 99 percent belong to small farmers that have limited resources, low income and little access to other economic opportunities.

The Carabao Development Programme is a massive programme started in 1993 to improve the native Swamp buffalo locally known as the Carabao to develop their meat, milk and draught potential. An elite herd of Riverine buffalo has now been established at the Philippine Carabao Center, Science City of Muñoz, by importing about 3 000 Murrah buffaloes with pedigree performance records from Bulgaria. Each female crossbred when raised for milk can produce about 1 350 kg of milk per lactation (Cruz, 2003). The crossbreeding of Bulgarian Murrah (producing 1 800 kg per lactation) with a Swamp population (producing 400 kg per lactation, Fig. 9) obtained F1 (Fig. 10) with 1 100 kg and F2 with 1 350 kg mean production respectively. The Nueva Ecija Federation of Dairy Carabao Cooperatives (NEFDCCO) is a federation that includes 25 cooperatives in the Nueva Ecija area, and specializes in milk collection, in organization of the milk industry and product sales. Since the main purpose of the project is to elaborate a mechanism which will permit the Philippine group to select the parents of future generations of Carabao, it will be necessary for them to develop their livestock and design breeding programmes that will deliver rates of genetic improvement in the range 1.2 - 2.0 percent per year compounding. This appears to be a rather low rate of improvement. For example, if the Carabao population currently produces 700 litres per 305 days lactation then the expectation from genetic improvement alone (i.e. excluding increases due to improvements in nutrition, health, etc.) is an increase to 853 litres. If the milk is valued at 70 cents a litre then the value of the increased production would amount to about US\$110 i.e. the income from one cow rises from US\$490 in the first year to US\$600 in the tenth year of the breeding programme. The difficulty in communicating the value of genetic improvement is that the increase is small per year and will not be attained with precision every year (Phillips, 2004).



Figure 9. Carabao buffalo near Muñoz, Philippines (Barile photo, 2004)



Figure 10. Murrah X Carabao near Muñoz, Philippines (Barile photo, 2004)

5. VIETNAM

Swamp buffaloes in Vietnam are mainly raised by smallholder farmers with small herds (four to eight head) partly used for draught power and partly for meat.

Table 4. Milk production of buffaloes in Vietnam (Nguyen van Thu, 2000a)

	Swamp	(in the South) Swamp	(in the North) Murrah	F1 crossbred
Lactation period (days)	-	210-360	236± 57.31	292±27.5
Milk yield (kg/day)	1.50	1.20-3.45	5.55	3.50

Traditional management dominates the buffalo production systems. Buffaloes play an important role in agriculture and in the life of Vietnamese farmers. They are the main source of draught power for land preparation and transportation in the rural areas, and supply a huge amount of fresh organic manure for cultivation. They are also well adapted to utilizing local feed resources, are economic to maintain, and a source of credit for the farmers. The main crop of Vietnam is rice, and sub-crops are maize, sweet potato, cassava, groundnut, soybean, sugarcane and vegetables. In the highland provinces, cassava is especially popular. Buffaloes are freely grazed on natural grassland, forests, at roadsides, canal banks, rice fields after harvesting, dikes, etc. The local buffaloes are of the Swamp type with a total population of nearly three million. In general, Vietnamese Swamp buffaloes have a small body size, a slow growth rate, late maturity, a long calving interval and a low milk yield, but are very well adapted to local ecological conditions and have good disease resistance. In the 1970s dairy Murrah buffaloes were imported from China, Bulgaria and India to improve the productivity of local buffaloes. These Murrah buffaloes adapted very well to the local conditions and were raised in many parts of the country. The male Murrah buffaloes were used to cross with female Swamp buffaloes. The crossbred F1 have improved body size, growth rate, draught power, milk yield and also reproductive performance, but at present the numbers of crossbred buffaloes are still small (Mai Van Sanh, 2004). Murrah buffaloes and crossbreds (Murrah x Swamp) are mainly reared at the research station in small numbers, consequently their performances are recorded and documented accurately. They are distributed in the northern, central and southern provinces of Vietnam. There are some good examples of breeding Murrah buffaloes for work and milk in village conditions in the northern provinces. Diluted semen and frozen semen from Murrah bulls were successfully produced for artificial inseminations (AI) through financial and technical support obtained from the Indian Government, but this programme was poorly developed (Nguyen van Thu, 2000b). Buffalo milk production in Vietnam is reported in Table 4.

6. SRI LANKA

The estimated number of buffalo owners in Sri Lanka is around 100 000. However, hardly any of them are full time buffalo farmers. About 87 percent are crop producers, who rear buffaloes as an additional source of income. About 64 percent use buffaloes for draught purpose, 34 percent for milk and draught, while only 2 percent keep buffaloes purely for milk. Buffaloes are spread throughout the country, with high concentrations in certain areas due to particular farming systems and market and socio-cultural reasons. The average herd size is around 22.5 animals. However, this figure is heavily dependent on the agro-ecological zone. Larger herds with an average of 40 to 50 animals are found in rice-growing areas of the dry intermediate zone. Smaller herds with an average of six to eight animals are found in mid and low zones (Bandara, 2000).

The present population is unevenly distributed across the major agro-ecological zones of the island which has an area of 65 000 square kilometres. The buffalo population has decreased

from 0.89 million in 1981 to 0.75 million (-15.45 percent) in 1997 with a large reduction in the wet (-20.42 percent) and wet-intermediate zones (-33.26 percent). The reasons for this are the increase in population pressure creating a high demand for land for residential and commercial purposes, especially in the wet zone, urban and peri-urban areas and increased mechanization of paddy cultivation practices and colonization of vast tracts of dry zone resulting in the dwindling of communal grazing grounds for free-ranging cattle and buffaloes. While there has been a decline in the total population, there has been a steady increase in the number of exotic River crosses in the population.



Figure 11. Crossbreds of Murrah and local Sri Lanka (Borghese photo, 2000)



Figure 12. Sri Lanka buffalo bull (Borghese photo, 2000)

The indigenous buffaloes which require many years to reach sexual maturity and are capable of producing only about one to two litres of milk over a very short lactation period of three to five months, have crossbred with the exotic riverine dairy buffaloes since 1950s. As a result a significant shift in the genetic composition of the buffalo population has been recorded. According to more recent reports on a national scale the percentage of herds carrying crossbred buffaloes has increased from 26.5 percent in 1985 to 30.4 percent in 1999 (Figs. 11 and 12).

In the case of Sri Lanka, buffalo milk with high fat and solid non-fat content fetches a higher price at the farm gate and offers the advantage of converting into value-added products, which helps to increase the profit margin several fold. The buffalo has been reported to be a ruminant with a higher potential to utilize marginal resources, a more rugged animal than its counterpart since it possesses the capability to perform well on marginal lands and withstand harsh environmental conditions. In the paddy field the buffalo offers a definite advantage since it possesses more stamina and broader hooves. Lastly, data is emerging in Sri Lanka as well as in other countries favouring the buffalo as a better meat animal than cattle. The above-mentioned advantages certainly highlight the great opportunities for harnessing the potential of water buffalo in order to meet the national needs in many developing Asian countries (Abeygunawarardena and Abeyratne, 2001).

7. BANGLADESH

In 2003 Bangladesh had 772 764 buffalo head owned by 270 228 holdings representing 1.52 percent of the total holdings in the country. The average buffalo head per holding was 2.67 (Faruque, 2003).

Bangladesh now has about 400 000 adult female buffaloes that are being used for draught or dairy purposes. These buffalo are found in the Bramhaputra-Jamuna flood plain of central Bangladesh, the Ganges-Meghna flood plain of southern Bangladesh and in institutional herds. Bangladesh has milk/dairy buffaloes of the Swamp crossbred and River types such as the Murrah and Nili-Ravi. The occurrence of crossbred dairy buffaloes indicates that the genetic improvement programme has been operative and is still running. A brief description of past and present breeding programmes (with relative successes and constraints) is given below (Faruque, 2000).

Recent studies indicate that Bangladesh possesses the following types/breeds of buffaloes (Table 5).

Husbandry and production systems for buffaloes vary depending on the topography and vegetation patterns of the country. Buffaloes are raised under an extensive system in the coastal and hilly areas where large-scale pasture land and enough green forage are available. Buffaloes are raised under a semi-intensive system on plain land and marshy land where there is limited pasture land. An intensive system for buffalo production is not practiced anywhere in Bangladesh even for institutional herds. The husbandry and care of the animals differs somewhat in the two systems. Nevertheless, there are some common practices. These common practices are: no housing system, no artificial insemination system, no routine vaccination programme and no animal identification and record-keeping system. One of the most important characteristics of buffalo production in Bangladesh is that they are raised by medium or large farmers who are generally considered rich in the locality. The staple food for buffaloes in Bangladesh is rice straw, which is an inadequate source of energy and protein. Sugarcane leaves, micro silage of sugarcane leaves, cassava leaves, roadside grass, elephant grass, maize with corn cob and pineapple bran are also used as feeding stuffs (Faruque, 2003).

Table 5. Types/breeds of buffaloes found in Bangladesh (Farouque, 2003)

Type/breed	Location	Population size, Phenotypes and Genotypes
Indigenous River type	Western and Central Part of the country	433 000 head Coat colour- Jet-black to black. Chromosome number = 50. Medium in size
Bangladeshi	Central and South West	4 500 head Light black coat colour, chevron and white stocking present. Chromosome number = 50. Medium in size
Indigenous Swamp type	Eastern part of the country	37 500 head Grey coat colour; chevron, white stocking and crescent horn are present. Chromosome number = 48. Small in size
Crossbred type (Indigenous X Nili Ravi)	Southern part of the country	40 000 head Phenotypes combination of Swamp type and Nili -Ravi. Medium in size
Non-descriptive type - Central part	South west and southern part of the country	207 569 head
Nili Ravi	Buffalo Breeding Farm	60 head

8. THAILAND

In the past Thailand had the second largest number of Swamp buffalo in the world. However this buffalo population drastically declined from 4.7 million in 1990 to 1.9 million in 1998.

The number of buffaloes has decreased yearly and the present number is about 1.7 million and is tending to decrease gradually. In addition in some areas people prefer to consume the buffalo foetuses when the pregnant dames are slaughtered and in this way the buffalo population decreases even more dramatically. As reproductive efficiency is low due to the longer production cycle, the period for reproduction of two calves could be as long as four years. The 1.7 million head of buffaloes belong to 517 941 households. If the situation forces the buffalo population to decrease any further, the national buffalo population would risk disappearing completely (Suthikrai, 2002).

Approximately 83 percent of Thailand's buffaloes live in the northeast where most agricultural production is under rainfed conditions. Thai buffaloes are genetically of the Swamp type. The majority (90-95 percent) are grey to black in colour, while the rest are white. Most buffaloes are raised by small farmers in the rural areas.

Sixty percent of the Thai population belongs to small-scale farmers who raise buffalo in the backyard. It was an integral part of the crop production system. The breeding units of buffalo per family possess on average five to ten head from which no economic profit is made. There are very few farms that possess up to 50 head of buffalo and manage the herd as a commercial undertaking where animals are fed good quality feed and are well supervised. Buffalo breeding under village conditions is generally done by random mating. In fact, during the plantation season the buffaloes are tied up and fed with rice straw for almost four months resulting in a lack of opportunity to be bred during the plantation period. The animals, males and females, are grazed together in the paddy fields after the harvesting season. Consequently, unplanned

breeding occurs during the harvesting time when the villagers allow the buffaloes to graze together. It is obvious that in general, there is no recording system approach at the farmer level as on the government farms (Ancharlie Na-Chiangmai, 2000).

A programme on genetic improvement of Swamp buffaloes for use as a dual purpose animal (meat and draught) is in place. This programme is aimed at solving two basic problems, the decrease in number and the reduction in mature body weight and size of buffaloes under small farm production. Reproduction and growth performance of buffaloes in the matured herd were evaluated as the result of genetic improvement programmes over a 11-year period (1983-1993). With regard to reproductive performance, the age at first calving has been reduced to 3.5 years, the calving interval to 487 days, the conception rate has been increased to 80.5 percent, the calving rate to 76.9 percent and the calf crop to 70 percent (Pakapun Skunmun, 2000).

9. INDONESIA

The number of buffalo holdings in Indonesia in 1993 was 489 000 households; however in 1983 the number had been more than 593 000 households. However, the total population of buffalo in Indonesia during that period did not decline in line with the decline in the number of households with buffalo. In 1985 the total population of buffalo was 3 245 thousand, whereas in 1993, the total population was 3 238 thousand. Therefore according to these statistics in the period 1985 to 1993 the number of households was declining, but there was no significant change in the number of buffaloes. Thus it indicates that the rural buffalo maintained by small farmers in Indonesia can still make a potential contribution to the development of the dairy industry in Indonesia. The most populous province for buffalo in the year 1993 was Jawa Barat with 487 000, followed by DI Aceh with 454 000. The other provinces with relatively large populations of buffalo were Sulawesi Selatan with 342 000 and Sumatra Utara with 265 000. The population of buffalo in Jawa Tengah was also fairly high totalling 232 000, and in Sumatra Barat with 228 000. Moreover, the populations in Nusa Tenggara Barat, Nusa Tenggara Timur, and Sumatra Selatan were 227 000, 167 000, and 152 000, respectively, and the remaining population in each province was less than 100 000.

The buffalo breeds have been classified as Swamp and River subspecies, and most of the Indonesian buffalo are included in the Swamp one that consists of many types and varieties of breeds. There are varieties of the Swamp breeds in many different localities with divergences in size, weight, colour, marking and horn dimension. The Swamp buffalo is generally considered to be a working animal, but it also has a considerable capacity for milk production. Swamp buffalo are used for draught power in most areas and for beef in the Java lowland areas (Figs. 13 and 14) and the Sumatra uplands (Fig. 15).

Spotted buffaloes are highly prized (and therefore they command high prices) to be sacrificed and consumed on special occasions such as marriage ceremonies.

Most of the rural buffaloes maintained by small farmers in Indonesia produce less than 1 000 kg of milk per lactation. However, the production of fresh milk in Indonesia has not increased greatly over recent years and the level of production in the latter part of the 1990s was insufficient to satisfy the fast growing demand for this commodity. Around 90 percent of Indonesia's fresh milk production comes from smallholder dairy farms. Some of the problems these smallholders face are lack of capital, low technology, deficiencies in management of animal health, and insufficient human resources. In addition, in the case of beef cattle and buffalo, it is common practice to tether them by the roadside, and in such cases, feed is cut and carried to them. Alternatively, they may be herded to "waste" areas where they graze on crop residues, and feed supplements are rarely given in sufficient quantities, and during the non-productive period, it is thought that farmers do not give the animals supplementary feed. The age of first calving is late in comparison to temperate animals and the calving interval ranges from 18 to 24 months. Therefore, on the basis of its performance to date, the dairy (cow and buffalo) industry will be unable to meet the growing demand for milk and beef which



Figure 13, 14. Swamp buffaloes in the villages of Banten Province, West Java (Borghese photo, 2004)

Indonesia foresees for the future.

The primary objective of a new pilot programme will be to draw the attention of stakeholders to this situation and increase the availability of animal protein for improving human nutrition. These goals could be achieved by increasing the production of buffalo milk and meat through the improvement of the genetic capacity of buffalo, producing F1 and backcross buffaloes from Swamp and Mediterranean Italian River buffalo, to be used to increase buffalo milk production in Indonesia while maintaining and improving a nucleus of purebred Swamp buffaloes.

Indonesia is also the only country where the *Bubalus depressicornis* (Anoa) still exists (Fig. 16).

This is the smallest bovid in the world with a height at the withers of about 80 cm, with a live weight of 200 kg and with 30 cm long horns. Its colour is black and it is considered to be a wild buffalo.



Figure 15. Swamp buffaloes in Sumatra



Figure 16. *Bubalus depressicornis* (Anoa) typical species of Indonesia (Borghese photo, 2004)

10. MALAYSIA

The domestic water buffalo, commonly found in Malaysia, has been classified into the River and Swamp types. In 1998, the total population of buffaloes in Malaysia was about 170 000. They were mostly concentrated in the rice growing states of Kelantan, Terengganu, Kedah and Pahang in West Malaysia (60 percent). The Swamp buffalo is used for ploughing, harrowing and working in the rice fields. At the end of its working life, the Swamp buffalo is slaughtered and in this way accounts for about 16 percent of the current meat supply in Malaysia. The population of River buffaloes is less than 2 000 head of Murrah buffaloes brought by Indian immigrants at the beginning of the 20th Century.

Over the past two decades, there has been an alarming decline in the buffalo population in Malaysia with an average rate of population decline of 1.2 percent per year. This decline has been attributed to the displacement of buffalo by machinery for draught power in the rice fields, a low reproduction rate and a high extraction rate. Most farmers in rice-growing areas discontinued the rearing of buffaloes due not only to labour shortages, but also to the limited availability of grazing land. Most buffaloes, particularly the Swamp type, produce two calves every three years. Under field conditions, due to biological limitations as well as the seasonality of the feed supply, it is not possible for a buffalo to calve and then conceive immediately during the next few months when feed is still abundant. Thus breeding is delayed until the following year. Nearly all male buffaloes are castrated for draught purposes restricting the opportunities for mating.

Artificial insemination (AI) in the buffalo has not been practised in Malaysia due to poor oestrus detection techniques. Despite the availability of frozen semen and the fixed time insemination technique, there has been no progress in AI.

Formula for the fattening of buffalo calves using local feedstuffs, such as oil palm and rice by-products, have been devised in order to obtain a high average daily weight gain. Swamp buffaloes raised on feedlots using oil palm by-products as the major feed ingredient can reach a normal growth rate of about 0.59 kg per day and age at puberty was significantly lower in bulls on intensive grazing (21.5 months) than in bulls on free grazing (28 months) systems (Jainudeen and Wan Zahari, 2000).

MEDITERRANEAN AREA

The buffalo population in the Mediterranean area, typical for the climatic and cultural conditions, which includes Europe and the countries of the Near East, where the FAO Inter-Regional Cooperative Research Network on buffalo is operating, is about 5.5 million head, 3.4 percent of the world buffalo population, that is now about 168 million head.

A decrease in the number of buffaloes is occurring in some countries in the world and in Europe and the Near East (Bulgaria, Romania, Turkey) associated with three factors: holsteinization i.e. the substitution of low production cows and buffaloes with high production Holstein Friesian cows; mechanization, i.e. the substitution of draught animals with tractors and the poor market demand for buffalo products. On the contrary in Egypt, Iran and particularly in Italy buffalo numbers have increased due to the demand for particular products obtained only from buffalo milk and because the buffalo has changed from a rustic triple-purpose animal to become a dairy purpose animal.

In Italy particularly the increasing demand for buffalo mozzarella cheese both on the national and international markets, the Denomination of Controlled Origin (DOP) as "Mozzarella di Bufala Campana" for this cheese registered in Italy and in Brussels for the European Union (EU), and the milk quotas on surplus bovine milk imposed by the EU, led to an increase in the buffalo population of about 142 percent from 1993 to 2001 (compared with a 7.8 percent increase in the world population in the same period) and to an increase of 1600 percent (16 times) from 1957 to 2002. In Italy this increase in the number of buffaloes is not only remarkable for this percentage increase but also when compared with the trends in other species, which have all decreased over the last 50 years particularly for cattle, dairy cows and horses. The Italian dairy cow crisis was provoked by the milk quotas imposed by the EU, by farm structure inadequacy and lower dimensions in comparison with northern Europe, by BSE and Blue Tongue pathologies and by a reduction in reproductive life that is now no more than 2.5-3 calvings. Ovine livestock is also suffering due to new health regulations in the EU, insufficient pasture availability, Blue Tongue pathology, milk industry problems, and changes in consumer demand that now favours fresh and soft cheeses (such as mozzarella) rather than dry cheese (such as pecorino).

In eastern Europe and Turkey buffaloes were also used for draught. However, with the advent of more and more tractors, buffalo numbers have decreased. In countries of the Near East, where dairy cows give an average milk yield lower or similar to buffaloes, buffalo decline has not been registered and in Egypt they are still useful animals for draught. In Egypt, Iran and Azerbaijan there is a consumer preference for buffalo dairy products rather than for those derived from cow's milk. In Iran and Egypt the increase in buffalo numbers seems to be associated with a global improvement of animal production since the increase affected cattle to the same extent, whereas in Bulgaria and Turkey, alongside the consistent reduction in buffaloes, there has also been a drastic reduction in cattle.

In Table 6, buffalo population, productivity, number and percentage of recorded buffaloes are reported. The importance of animal recording for the process of selection is well recognized all over the world and is demonstrated by the fact that in most countries such activity is at least partially financed by governments, which consider it an important means for improving animal production.

An international non-governmental organization, the International Committee for Animal Recording (ICAR) has been active for over thirty years in the field of promotion and standardization of animal recording. A specific seminar, jointly organized by FAO and ICAR in the year 2000 (Workshop on animal recording for improved breeding and management strategies for buffaloes, Moioli et al., 2000), clearly evidenced the major constraints that have to be faced in order to implement a milk recording activity. These can be briefly summarized as follows: (i) lack of finance; (ii) farmers are reluctant to let other people know the production of

their animals; (iii) identification of the animals is expensive; (iv) recording costs increase proportionally with the distance between herds, and buffaloes are mainly raised by smallholders (two to five animals) scattered over wide country areas. These constraints explain why the percentage of recorded buffaloes in countries where buffalo seems to be more important than cattle is so low. The highest proportion of milk recorded buffaloes, in fact, is found in Italy (27.8 percent), in Iran it is 4.5 percent, while in other countries the recorded buffaloes are about 1 percent of total dairy females (Turkey, Romania) or less. We have high percentages of recorded buffaloes in Bulgaria, Syria and Greece, where the buffalo population is disappearing. All the cows (5 880) are recorded in Bulgaria since they are a small number: 5 640 on private farms and 240 on State and cooperative farms. A small nucleus is recorded in Romania, (0.7 percent total cows), in Egypt (0.2 percent) and in Azerbaijan (0.06 percent). Recently milk recording began in Greece on 41 cows, in Syria on 640 cows and in Turkey on 1 000 cows at the Afion Buffalo Research Institute and in Ilikpinar Village (Hatay). No recording activity has been undertaken in Iraq and Albania. Lactation length varies from 180 to 312 days, while the ideal period was 270 days with an average lactation milk yield of 1 600 kg.

Table 6. Buffalo population and productivity in European and Near East countries (Borghese, 2004)

Countries	Total Number	Adult Female	Lactation Milk Yield (kg)	Days Lactation	Milk Recorded Buffaloes	Recorded %
Italy	265,000	133,000	2,175	270	36,966	27.8
Egypt	3,717,000	1,487,000	1,600	312	3,040	0.2
Iran	400,000	208,200	1,600	220	9,300	4.5
Turkey	110,000	58,806	1,247	230	1,000	1.7
Azerbaijan	290,000	150,000	1,000	266	100	0.06
Romania	100,000	42,300	1,200	270	300	0.7
Iraq	98,000	40,000	1,320	270	NO	0
Bulgaria	9,200	5,880	1,870	278	5,880	100
Syria	4,500	1,800	1,191	254	640	35.5
Greece	1,000	500	1,020	240	41	8.2
Albania	100	70	400	180	NO	0

In Italy the milk production in 36 966 recorded buffaloes (ANASB 2003) was 2 175 kg in 270 days of lactation with 8.10 percent fat and 4.65 percent protein (Table 7) Recorded buffaloes are raised in 287 herds with an average of 128.8 head per farm. The productivity in other countries is lower, due to the fact that only Italy has undertaken a great deal of work on recording, selection and genetic improvement, health, and on improving feeding and livestock systems.

Milk composition improved in Italy in just a few years, with the average protein content moving from 4.4 to 4.73 percent in 2002 and to 4.65 percent in 2003, while the fat content moved from 7.3 to 8.3 percent in 2002 and to 8.1 percent in 2003 without operating any selection for the character of protein and fat content. Moreover the possibilities for genetic improvement for milk quantity and quality will be higher, if the selection pressure is increased reducing the number of bred females. At present there are many females in Italy producing more than

5 000 kg milk for lactation (270 days). Therefore the selection will be directed at the improvement of the yield of mozzarella cheese, not simply for milk production, since the farm income is based firstly on mozzarella cheese, secondly on the sale of pregnant heifers, and lastly on beef sales.

Table 7. Italian Buffaloes (ANASB 2003)

N° Head	265 000
N° Dairy buffaloes	133 000
N° Recorded buffaloes	36 966
% Recorded Buffaloes	27.8
N° Recorded farms	287
N° Head/farm	128.8
Kg Milk production (in 270 d)	2 175
% Fat	8.10
% Protein	4.65

In Europe and countries of the Near East, buffaloes are all of the River type, with similar phenotype but variable size, ranging between a minimum of 280 and 300 kg live weight for the adult female and male respectively in Egypt to a maximum of 900 and 1 000 kg in Iraq, the most frequent size being 600 and 800 kg (Table 8). There has been little exchange of breeding buffaloes among countries, therefore each population has its own phenotypic traits and performances. European buffaloes are all considered to be of the same breed, named the Mediterranean: in Italy the Mediterranean type was particularly selected and it is called Mediterranean Italian breed (figs. 28, 29, 30); in Turkey there is the Anatolian; in Egypt it is called the Egyptian; in Iraq there is the Khuzestani or Iraqi breed; in Azerbaijan it is called the Azeri or Caucasian; in Iran there are Azeri and Khuzestani breeds.

In Bulgaria, crossbreeding with the Murrah breed was undertaken, by importing in 1962 a considerable number of animals from India, and to a lesser extent in Azerbaijan by importing Murrah buffaloes from Bulgaria.

Age at first calving is, on average, 36 months (Table 8), in Italy a good proportion of buffaloes calve at 28 months of age whereas in Egypt and Syria a high number have the first calving after 40 months.

The main factor influencing the age at puberty (after genetics) is the nutrition level. In fact, experimental trials have demonstrated that heifers fed from the age of nine months with a high energy level diet (5.7 MFU/day) had a growth rate of 678 g/d while those fed a low energy level diet (4.4 MFU/day) had a daily gain of only 530 g. Furthermore, buffaloes of the first group reached puberty at 20.5 months while the others only at 23 - 24 months. The possibility of using grazing systems for buffalo heifers, which are less expensive than unifeed mixing or silage, was demonstrated by Borghese et al., (1997); in fact, no delay in the age at puberty was noted even in the grazing buffaloes provided that the average daily gain was not below 600 g/day.

Moreover in most European and Near East countries the puberty age is delayed because the requirements are not satisfied.

Average herd size (considering the number of adult breedable females) is below eight in the whole region, except Italy (90), Syria (35) and Iran (34). The proportion of breedable females to total buffaloes is about 50 percent in all countries. In the countries where the majority of buffaloes are reared in very small herds there are also a few bigger private, cooperative or state herds (Bulgaria, Egypt and Turkey).

Table 8. Type and feeding of buffaloes in Europe and the Near East (Borghese, 2003)

Country	Herd size (n° breedable buffaloes)	adult live weight (kg)		Age at first calving (months)	Housing	Feeding
		female	male			
Italy	90	650	800	28-32	loose in paddock	Common ration: 28% maize silage, 34% concentrates, 25% hay and straw 13% by-products
Romania	2.4	545	665	38-42	tied	Spring: leguminous, gramineous, hay - Winter: concentrates, wheat bran and silo - Sum./Aut.: graze, conc. or wheat bran
Bulgaria	2.5	600	800	34-37	tied	Alfalfa hay, straw, maize silage, green fodder or grazing, concentrates
Egypt	3.5	280	300	34-41	tied and paddock	Grazing + indoor feeding + cut and carry
Syria	35	490	580	36-42	paddock	Grazing, straw and concentrates
Turkey	8	410	510	36	tied and paddock	Summer: grazing and wheat bran - Winter: stems of maize concentrates
Iraq	10	900	1,000	36	paddock	In towns: concentrates, green forage, straw - In marshes: grazing on papyrus, and other plants
Iran	34	550	650	36-39	pasture	Green fodder, concentrates, straw, apple pulp, cotton seeds
Azerbaijan		530	780	36-39	tied	Maize silage, hay straw, hay silage, oilcake, concentrates
Greece				40		Graze all the year, concentrates only in winter
Albania						Grazing, roughage

The most common housing system is the one referred to as traditional, consisting of keeping buffaloes indoors at night and confined in fenced areas during the day (Egypt, Turkey, Iraq, Syria); in the favourable season they are allowed to graze during the day (Romania, Turkey and in some farms in Italy). In the marshes of south-west Iran, buffaloes are kept outdoors on pasture all year long, whereas in the northern areas around the Caspian Sea they are kept in barns only in winter. Lactating buffaloes are kept tied all year long in Bulgaria, Romania and Azerbaijan. In Italy they are housed loose in paddocks all year long, utilizing the same modern systems used for dairy cows, and the buffalo cows normally receive unifeed composed of maize silage, concentrates, hay, straw and sometimes by-products (Table 8). For example, a 600 kg live weight buffalo cow producing 10 kg milk, would be fed 15.3 kg dry matter (33 percent maize silage, 42 percent alfalfa hay, 17 percent concentrate with 38 percent proteins, 8 percent maize grain) with 12.7 Milk Feed Units, 2.1 kg crude proteins and 3.5 kg crude fibre. The same happens in Bulgaria, where the buffaloes receive unifeed composed of maize silage, concentrates, hay, straw, green fodder, and by-products. In other countries where the herds are small and domestic, the buffaloes are fed green forages indoors and outside are left grazing

(Egypt, Iran, Turkey, Syria, Greece). Concentrates are used more in Romania and Azerbaijan. One third of Iraq's buffaloes wallow in marshes all year round, the water reaching up to the middle of their body. They swim far and wide for feeding and when the water is high, they stand on platforms made of papyrus, reeds and mud. Sometimes the farmers build huts on these platforms to house the buffaloes and the platforms can be pushed to different parts of the marshes. Grazing in the favourable seasons is practiced everywhere at least for some of the buffaloes, except in Azerbaijan and Iraq. In any case, green forage "cut-and-carry" in the favourable season composed of legumes, varying from country to country, concentrates and by-products are the basic foodstuff. Green forage and hay are made mainly of alfalfa in Italy, Bulgaria, Romania and Turkey and *Trifolium alexandrinum* in Egypt. The most common by-products given to buffaloes are brewer grain residuals in Italy and Bulgaria, sugar beet-pulp in Italy, Bulgaria and Iran, cotton residuals in Egypt and Azerbaijan, tomato peel in Italy, apple juice residuals in Iran, sugar cane residuals in Egypt and Iran, stalk and cobs in Iran, Egypt and Romania and straw everywhere. In the Iraqi marshes, buffaloes are fed during the night with green forage cut by the farmer during the day. This forage is composed of reeds, papyrus, various water plants, and rice hulls when available.

In the countries examined, all herds have their own bull except in some areas of Romania, Bulgaria, Egypt and Turkey with very small herd sizes (two or three breedable buffaloes), where a group of bulls exists for breeding at the village level.

Artificial insemination is practiced very little: in Italy on 5 percent of buffalo cows, but it is rapidly increasing; in Azerbaijan on 0.7 percent; in Egypt on 0.3 percent and in Romania on 0.1 percent. In Bulgaria, in the large cooperative state farms, it is used on 80 percent of the buffaloes. In Turkey it began in 2002 near Ilikpinar village (Hatay) (Figs. 17 and 18) with Italian semen provided by the FAO Network project. In the other countries it is not used at all. The diffusion of artificial insemination in buffaloes is difficult because of seasonality.

The buffalo cow shows stages of partial anoestrous or even deep anoestrous during the spring and summer. Obviously seasonality depends on many factors, both genetic and environmental, mainly nutritional. In buffalo, as well as in other livestock, melatonin plays a fundamental role in initiating the hypothalamus-pituitary-ovarian axis activity with variations in level between three and ten pg/ml in daytime and between 20 and 90 at night, while levels depend upon daylight hours, and therefore season, as well as upon the age of the buffalo. In Italy the goal of having as many buffaloes as possible to calve before spring is of primary importance because the demand for buffalo milk is especially high in the spring and summer, with variations in the milk price between winter and summer of 50 percent.

For this reason, in Italy many research trials have been carried out to induce buffaloes to calve in the favourable season, in particular regarding oestrus induction which is also helpful for performing artificial insemination. Therefore, methods to induce oestrus are essential to remove anoestrus, to improve artificial insemination, and to increase out of season milk production. The hormonal treatments used to stimulate the hypothalamus-hypophysis axis are varied: 1. hormonal release factors (i.e. GnRh), 2. progesterone (i.e. PRID Progesterone Releasing Intravaginal Device) plus gonadotropine plus prostaglandine (see Chapter IV: "Reproductive efficiency in Female Buffaloes").



Figure 17, 18. Anatolian buffaloes submitted to oestrus induction and artificial insemination techniques (Borghese photo, 2002)

11. TURKEY

The water buffalo is called by different names such as Dombay, Camiz, Camis, and Komus in Turkish. It is recorded that it was introduced into Europe by the crusaders, and Mogul recounted that many buffaloes were raised in Trakya, in BC 3 000. Buffalo figures can be seen on signets made in Mesopotamia.

According to 1974 FAO statistics, at that time there were one million buffalo head in Turkey. From 1984 to 1997, there has been a decrease in the buffalo breeding population of 65 percent and the reason for this decrease in water buffaloes has been the preference for cattle over buffalo in the Ege and Marmara regions, where a large number of buffaloes were found. In Turkey, all the improvement efforts for genotypes were only practiced on cattle.

The buffalo population is about 110 000 head (Borghese, 2004), and only of the Anatolian breed. In 2002 Italian semen was introduced in Ilikpinar village (Hatay), for the local population of buffaloes in order to improve genetic and milk productivity (Sekerden et al, 2003).

In 1988 it was found that the average milk yield of buffaloes raised in controlled herds at first lactation period was 813.12 ± 36.21 kg; it was also reported that at the first, second and third lactation period, the average milk yield was 983.4 ± 58.45 (442-1715) kg respectively. In addition it was noted that the average milk yield of farmers under village conditions was $1,009.89 \pm 21.13$ kg, and the average lactation period was 224.80 ± 6.42 (121-368) days. The dry period was 188.04 ± 11.17 (64 - 552) days. Milking was generally undertaken by hand. Milking by machine was carried out only around Istanbul. The average dairy yield of the buffalo cow was 5.08 ± 1.71 kg.

Composition of the buffaloes' milk was: protein: 4.18 ± 0.07 percent, total solids: 17.71 ± 0.35 percent, and fat: 8.11 ± 0.20 percent. The fat-free solid content of buffalo milk was 11.91 ± 0.17 percent. The water content of the milk was 82.29 ± 0.35 percent.

The milk production of the water buffalo is renowned and favoured particularly for the production of the famous unique Turkish desserts. This was one of the highest motivations for farmers to keep and raise water buffaloes near big cities (Soysal and Kok, 2004).

12. AZERBAIJAN

The most valuable buffalo gene fund of the USSR was in Azerbaijan. During the transition period following the break up of the Soviet Union no research facilities or farm management activities existed to assist buffalo breeders. As a result, the number of buffaloes in many regions of Azerbaijan fell drastically. Valuable breeds of buffaloes were slaughtered for meat. In order to counteract this shortage, the President of Azerbaijan, Heydar Aliyev, issued a decree for the Preservation of the Local Livestock Gene Pools in Azerbaijan. The Azerbaijan Association of Buffalo Breeders, founded in December 2001, played a leading role in passing this law.

There are approximately 300 000 buffaloes in Azerbaijan, including 140 000 female buffaloes with an average milking rate of around 1 200-1 600 kg (eight to ten percent fat content) with 305 days per lactation. On the state-supported buffalo breeding farm, there are 920 buffaloes, including 250 female buffaloes (Farajev and Bashirov, 2002).

The main problem hampering the development of buffalo breeding in Azerbaijan is the absence of high quality reproductive buffaloes and a lack of artificial insemination facilities. Financial assistance, such as that provided by Italy, was useful for the introduction of oestrus induction and artificial insemination techniques (Figs. 19 and 20), to develop milking and cheese industry management (Borghese, 2005) and to improve the local Azeri breed.



Figure 19, 20. Azeri buffaloes submitted to oestrus induction and artificial insemination techniques (Borghese photo, 2003)

13. ARMENIA

Due to the absence of animal recording, it is difficult today to obtain detailed information regarding the potential of buffaloes in Armenia. Scientific research has been conducted in the past in the Republic of Armenia. However, it is important to note that no research or selection has been carried out in Armenia recently. Since 1991, following the collapse of the former USSR, all livestock in Armenia, including buffaloes, became totally privatized. After privatization no precise livestock recording has been undertaken and the data presently available is merely the statistical data which was collected in the past. There are now about 1 000 buffaloes in Armenia (Marmarian, 2000).

14. IRAN

In the 1930s, there were 1 500 000 buffaloes in Iran. By 1995 this number had decreased to 500 000. The buffalo is a native animal of Iran, with over 80 percent of its population concentrated in the north and north-west (Azerbaijan province) and 18 percent in the south of the country. The overall buffalo population is increasing at about 1.3 percent annually, while on the contrary in some countries such as Iraq and Bulgaria, the numbers are dropping. Some of the main reasons for this decline may be industrialization, the increasing demand for buffalo meat but a lack of replacement of the slaughtered animals and farming diversification and income. Official neglect and pro-Holstein propaganda have caused a significant decrease in buffalo numbers in Iran in recent decades (Mohsen pour Azary et al., 2004).

The buffalo farming system in Iran is based on smallholders (99 percent); most of the herds have an average of five animals; a few herds have between 20 and 50 buffaloes and some of them have 300 buffaloes. Smallholders manage their animals according to the opportunities offered by the environment: on pasture, stubble, shrubs and grass. Most of them obtain their feeding by grazing along water sources: streams, rivers; ponds, lakes, integrated with the following products: citrus peels and pulp, sugar cane wastage, etc. In Khuzestan, buffaloes are raised outdoors throughout the year; but in the north-west they are housed in the autumn and winter. Buffalo farming in Iran can be considered to be at a good level since the owned or rented properties are of a large size and the land available for buffalo farming is also extensive. Buffalo farming has been a traditional activity for many decades (Kianzad, 2000).

Milk production in Iran is reported in Table 9 according to data published by Abdulwahid Ghanemi (1998).

Table 9. Milk production of buffaloes in Iran

	Khuzestani	Azeri
Lactation period (days)	210	210
Milk yield (kg/year)	1 865	1 200

15. IRAQ

In Iraq, according to data provided by Borghese (2004), there were 98 000 total River Khuzestani or Iraqi buffaloes, 40 000 adult females with kg 1 320 as medium lactation milk yield, in a 270 day lactation period. Presently it is impossible to estimate the real situation in Iraq because of the war. According to data provided by Magid (1996), buffaloes are bred in the marshes and swim far and wide for feeding on papyrus, reeds, common ash and other plants. When the flood water is high their owners have to go out and collect these plants in order to feed the buffaloes on platforms. Rice hulls are also given when available. Buffaloes in towns rarely graze on natural pasture; they are fed mostly on concentrates, green forage, straw and agricultural by-products.

16. EGYPT

The total number of buffaloes in Egypt reached about 3.717million in 2003, of which 42 percent were dairy cows, 6 percent buffalo bulls, 32 percent heifers less than two years old and 20 percent male calves less than two years old. While the annual growth rate for the buffalo population approached 3 percent over the last two decades, it still only accounts for 1 percent of the cattle population. The aggregate share of buffalo milk, from all types of production systems is about 81 percent of total milk production in Egypt.

The cost of milk production from buffaloes is also less than the cost of reconstituted imported powdered milk at the international market price. The return on one ton of concentrate feed mix generated by milk production confirmed the comparative advantage of buffaloes in Egypt. Recently, in association with the economic reform era and market liberalization, the commercial buffalo system has significantly expanded (Soliman and Sadek, 2004).



Figure 21, 22. Egyptian buffalo cows and calves reared in the Delta Region (Borghese photo, 2000)

There are different research institutes at the Ministry of Agriculture and at the University in Giza (Cairo) involved in developing projects concerning buffaloes and buffalo products. The breed is the River Egyptian (Figs. 21 and 22). The buffaloes are spread along the river Nile, in the Delta Region and at the Fayum Oasis.

Buffalo productivity in Egypt is about 210-280 days/lactation, an average of seven lactations and a milk yielding of 1 600 kg. The age at the first calving is 34-41 months (Fikri El-Kirabi, 1995).

17. ITALY

Buffalo livestock in Italy is a small reality in comparison with the large population numbers of many east Asian countries, but it is an important reality in economic terms, both for workers' occupation and as an example of typical Italian produce in the world. In addition the Italian Buffalo is the first in the world with regard to genetics, applied technologies, the monitoring of pathologies and the hygiene and quality of products.

The selection and genetic improvement is controlled by the ANASB (Italian Buffalo Breeders Association) and at the present time 27.8 percent of the total population of dairy buffaloes (Table 7) is recorded, both in the morning and in the evening, each month. Therefore many buffalo cows, producing more than 5 000 kg/lactation 270 days, have been identified. Many bulls are submitted to performance and progeny tests and many millions of semen doses from bulls of proven high genetic value are available for artificial insemination in Italy and in the world. There are many centres of semen production in the south of Italy, in Campania, where most buffaloes are reared, one (Cooperativa Fecondazione Artificiale, CoFA) is in Cremona, in the north of Italy. The breed is named the Mediterranean Italian to distinguish it from other European breeds which are not at the same genetic level. All data are collected by ANASB which decides on the selection goals, which are presently to increase not only the milk quantity but specifically the mozzarella cheese production according to the mozzarella index:

$$\text{Mozzarella (kg)} = \text{Milk (kg)} \times (3.5 \times \% \text{ proteins} + 1.23 \times \% \text{fat} - 0.88) / 100$$

The "Mozzarella di Bufala Campana D.O.P." is the primary product of buffalo livestock: it is sold for a minimum € 10.00 per kg in the cheese industries, much more in shops and is exported not only within Europe, but all over the world, from the USA to Australia. The demand exceeds the production and mozzarella is particularly sought by restaurants.

Italian buffalo management is exclusively intensive: dairy buffaloes are kept loose in paddocks close to the milking room, where the cows are submitted to udder control and mechanically milked twice a day. Milk production is sustained by diets with a high energy concentration (from 0.85 to 0.95 MFU/kg DM) and a high protein concentration (14-16 percent crude protein on DM), based on maize and other silages, cereal grains, soya, alfalfa or "graminaceae" hay and by-products.

The feeding stuffs movement and distribution is effected by mixing trucks; the movement and stocking of dung is also mechanized; therefore there are no smallholders in Italy, but only farmers with an average herd size of 90 head per herd. Heifers are also fed intensively in order to achieve puberty before 20 months.

The largest proportion of the buffalo population can be found in the Provinces of Caserta and Salerno (Campania region), and the next localities for size of population are the Provinces of Frosinone and Latina (Lazio region), which are in the Denomination of Protected Origin (D.O.P.) area.

The control and monitoring of pathologies is effected by the local veterinary services and by the "Istituto Zooprofilattico Sperimentale" (Animal Prophylaxis Research Institute), one for the Lazio region and another for the Campania region. The hygienic control of the milk production

and of the milk products in the industry is of a particularly high standard.

Research on the buffalo species is carried out by the "Istituto Sperimentale per la Zootecnia" (Animal Production Research Institute, Monterotondo, Rome) and by the Federico II University, Naples.

18. ROMANIA

The buffalo population in Romania was more than 200 000 head in 1996 (Popovici, 1996). Actually it is about 100 000 of Mediterranean breed (Table 6), sometimes crossbred with Bulgarian Murrah.

The average milk production is 1 200 kg per lactation (270 days). Buffaloes are still used today on small private farms for draught and the goal of the selection process is to create a dual-purpose type of animal (milk and meat), realizing good daily gains (600-800 g), in order to slaughter the males at 22 months with 460 kg of live weight. At present the calves are also fattened to be slaughtered at four months (100 kg of live weight).

The animals are housed and tied during the winter due to the unfavourable weather conditions and fed with hay, bran, concentrates, silage (Table 8), grazing on pasture in the warm season.

19. BULGARIA

In Bulgaria a new buffalo population, named Bulgarian Murrah, has been created through the importation of Indian Murrah in 1962 and later in 1975 by crossing them with indigenous Mediterranean. This activity was effected systematically under the scientific management of the Buffalo Research Institute in Shumen and the National Animal Selection Center (Alexiev, 1998). Buffaloes (Figs. 23 and 24) were raised on the State farms, kept tied in closed sheds, machine milked and fed maize silage, alfalfa or grass hay, straw and concentrates.

The animals were managed in separate groups according to physiological conditions: suckling calves, females four to twelve months, heifers, pregnant heifers and dry cows, milking cows.

Milk recording, selection, artificial insemination and progeny testing were coordinated by the Buffalo Research Institute.

After the changes in the political and social-economic system in 1989, buffaloes were transferred to the new private farms, where scientific and genetic activities were limited and the animal numbers have drastically declined.

Actually, there are only 9 200 head, of which 5 880 are cows (Table 6) of Bulgarian Murrah in Bulgaria. All these animals are submitted for milk recording and to artificial insemination.



Figure 23, 24. Bulgarian Murrah herds (Alexiev, 1998)

AMERICA

Today there is great enthusiasm about buffalo in America, particularly among buffalo breeders and livestock associations. Buffalo is considered to be the animal of the future, and there is justification for this. Buffalo numbers have significantly increased and it is felt that breeding policies have led to an all-round improvement in quality, as can be seen from Table 10.

Table 10. The buffalo population in America (Rocha Loures, 2001)

Country	Population
Argentina	50 000
Bolivia	5 000
Brazil	3 000 000
Colombia	30 000
Cuba	30 000
Ecuador	5 000
Paraguay	10 000
Peru	25 000
Venezuela	150 000
Trinidad and Tobago	10 000
Other countries (Belize, USA, Costa Rica, Guatemala, Mexico, Panama, Guyana)	30 000
Total	3 345 000

One of the characteristics that makes buffalo so widely used in these countries is their extraordinary ability to convert fibre into energy. Research trials indicate the superiority of the buffalo in food conversion and in the use of tropical forage and agricultural by-products. Therefore, it is emphasized that the buffalo does not compete with humans, for it does not necessarily use the main production from the crops. It is also an efficient tool in the recycling of nutrients in integrated production.

Other important characteristics of the buffalo are their rusticity, their ability to adapt to different climates and their high fertility rates, always superior to those of bovines. Buffalo breeding is a synonym for low production costs and high levels of productivity (Rocha Loures, 2001). According to recent data (Borghese, 2004) the buffalo population in Venezuela is 200 000 and 70 000 in Argentina. The present population all over America is about 3 415 000.

20. CUBA

In Cuba, buffalo introduction is relatively recent dating from 1983 to 1989. The River buffaloes now present in the country were originally imported from Trinidad, Tobago and Panama. They are the breeds used for upgrading the larger population composed of Swamp buffaloes imported from Australia. As has been well established, the Buffalypso or Trinidadian Buffalo is the result of crossbreeding between the Carabao and other River breeds such as the Murrah, Nili-Ravi, Jaffarabadi, Surti, Nagpauri and Bhadawari, which was undertaken in the sugar cane factories of the Sugar Carone between 1920 and 1930.

In an earlier publication, detailed information was given regarding the comparative

performance during five lactations of both buffalo types in relation to milk and fat production, specifying that the River (Buffalypso) buffalo was superior in milk yield (260 kg), with a 60 day longer lactation period than the Swamp buffalo, without any difference in fat content. In another work, it was indicated that the Buffalypso, when well managed, has a productive potentiality to produce 1 620 kg of milk (802 kg from milking and 817 kg to feed the buffalo calf) (Fraga et al., 2004).

21. TRINIDAD-TOBAGO

Water buffaloes are not indigenous to Trinidad and the River type milk buffaloes were imported into Trinidad from India at the beginning of the last century. Indian contract labourers used the males to haul sugar cane and the cows to provide milk for their families and neighbours. During the mid-19th century, selection and crossbreeding among the original imported milk breeds started with a view to developing a specialized beef animal now commonly referred to as the Buffalypso (Fig. 25). Consequently the milk production potential of these animals was ignored.



Figure 25. Buffalypso from Trinidad

However, since the late 1970s the use of Trinidad water buffaloes for meat as well as for milk production has been encouraged, not only in Trinidad but also throughout the Caribbean. In order to achieve this objective, the Ministry of Agriculture established a small milking herd at the Aripo Livestock Station during the early 1990s.

The average lactation duration was 191.6 days, which is lower than most values reported in literature. The mean total lactation yield, averaged over all lactations, and based on once a day hand milking with the calf suckling the mother was 611.3 kg (range: 767.4-444.2 kg). The average milk yield/day/cow was 3.09 kg (range: 0.50 15.42 kg). The average percentages for fat, protein, lactose, non fat solids, total solids, ash and Ca were 7.15, 4.03, 5.60, 8.84, 16.97, 0.85 and 0.23 respectively (Rastogi and Rastogi, 2004).

22. BRAZIL

At the same time as zebus were imported into Brazil from India, mainly between the 1940s and 1960s, some Murrah and Jaffarabadi buffaloes also arrived. In Brazil, these animals have found ideal conditions, such as thriving pastures, water, grazing space and suitable temperatures. These effects have been enhanced by the buffaloes' hardiness and adaptability.

Today there are approximately three million buffaloes in Brazil, which are found in all States, notably Pará, Maranhão, Ceará, Pernambuco, Rio Grande do Northe, Minas Gerais, Bahia, Rio de Janeiro, São Paulo, Paraná, Santa Catarina, Rio Grande do Sul and Mato Grosso do Sul. In these States, the buffalo population is growing at the rate of ten percent every year, because

breeders slaughter only culled males and females, and all other animals remain for reproduction.

In the 1970s, Brazilian buffalo breeders began using buffaloes professionally for dairy and meat production. At the same time, research on production, reproduction and nutrition began, and several regional associations of buffalo breeders were formed. At the end of the last decade, the associations initiated a programme to evaluate these animals, based on the data that had been gathered over the previous thirty years (Ramos et al., 2004).

In some Brazilian States, buffaloes have become an economic option, mostly for their milk yield and, consequently, for the elaboration of mozzarella cheese, originally produced in Italy. This product is well accepted on the consumer market, and secures high prices due to the substantial demand. For this reason buffaloes have conquered a space in the national cattle husbandry sector and are no longer seen as marginal contributors to the meat and milk yield cycle.

Under Brazilian conditions, the following results were recorded in a study with 659 pure or crossbreds of Murrah buffaloes, from 1979 to 1987, in the county of Pitangueiras (SP): an average milk yield of 725.49 ± 228.91 kg. The data reported, for 1 586 lactation records of the breeds Jafarabadi, Mediterranean, Murrah and their crossbreds (Fig. 26), in several regions of the country was: an average of $1\,517.16 \pm 407.62$ kg milk, in an average lactation period of 248.81 ± 3.86 days. Tonhati and Cerón-Muñoz, after analysing 1 020 lactations, found an average value of $1\,496.20 \pm 605.72$ kg milk, for a 270 day lactation. After taking into account 1 744 lactations of 1 268 females of different genetic groups, observed in six herds from 1996 to 1998, the estimated milk production was found to be $1\,259.47 \pm 523.09$ kg, in 270 days of lactation (Tonhati and Cerón-Muñoz, 2002).

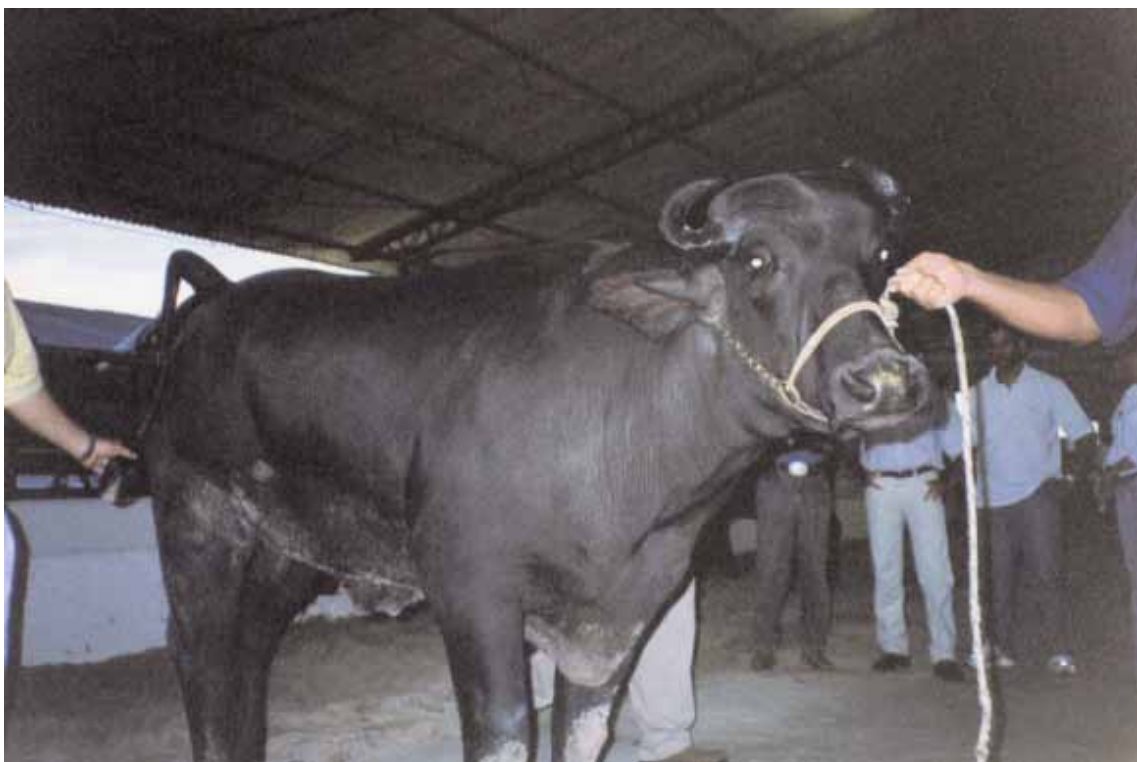


Figure 26. Murrah crossbred in Brazil (Borghese photo, 2002)

This data was based on 5 014 lactations, originating from 1 656 cows, who calved from 1973 to 2003, were sired by 234 bulls and were raised in twelve herds located in seven different Brazilian states (Parà, Rio Grande do Norte, Cearà, Bahia, Minas Gerais, Sao Paulo and Paranà). Only lactations yielding at least 3.0 kg/day and lasting a minimum of 150 days were taken into consideration. The objective was to evaluate the productive and reproductive performances of dairy buffalo cows, whose production was experimentally controlled.

The overall average for monitored milk yield, lactation length and age at calving was

1,589.57±605.14 kg, 265.63±49.00 days and 79.23±47.5 months respectively, which confirmed the data presented by Ramos et al (2001). The maximum yield per lactation was 5 796 kg whereas the minimum yield was only 351 kg of milk. The average milk production in this population was higher than the Brazilian average for cattle (1 265 kg/lactation), which is based on 19 million cows producing approximately 24 billion kilograms of milk (Ramos et al., 2004).

23. VENEZUELA

The buffalo population in Venezuela is about 200 000 heads (Borghese, 2004). There are different breeds: Mediterranean Italian, Bulgarian Murrah, Indian Murrah and others imported from other American countries. The management and feeding systems are almost entirely based on pasture and the primary purpose is for meat production. Therefore generally buffalo cows are not milked but give milk to their calves and the calves, in turn, are sold to the meat market. Each farmer often owns large properties (from 1 000 to 10 000 hectares) with numerous animals. Today there is a development of the milk production potential with the introduction of better genetic lines (Montiel-Urdaneta et al., 1997). Likewise, the technologies for milking cows, storing milk and for cheese production (together with technologies related to other milk products) are also developing. Although the promotion and expansion of buffalo production could solve the problem of the meat and milk deficit, there are many limiting factors such as government inertia regarding the existing sanitary problems and the absence of national development programmes (Reggeti, 2004).

24. ARGENTINA

The buffalo population in Argentina is about 70 000 head, notably Mediterranean, Murrah and Jafarabadi imported from Brazil, (Zava, 2004) and it is rapidly increasing. There are similar conditions to those in Venezuela, but the milk and cheese industry is better developed than in Brazil. In Argentina there is an active Buffalo Breeders Association (Asociacion Argentina de Criadores de Bufalos (AACB)) that works actively towards genetic and production improvement in the buffalo sector, particularly towards increasing meat production for export. The largest concentration of farmers in this regard is in the Corrientes and Formosa Provinces. Buffaloes are reared on an extensive system, on poor pasture on low fertile land, together with bovine herds, on farms with an area of between 750 and 2 000 hectares with about one head/two hectares. The problems in Argentina are: use of low-level technologies, inadequate sanitary conditions, low quality products and insufficient productivity (Vargas, 2004).

AUSTRALIA

Buffaloes were not native to Australia, they arrived with the first British settlements in the Northern Territory. Buffalo numbers are now estimated to be less than 40 000 - 50 000 head, with 20 000 in managed herds confined by fences and the remainder ranging over uncontrolled areas (monitored negative for TB) in southern and south eastern Arnhemland (an Aboriginal reserve), east of Katherine and along the south coast of Darwin. This feral population acts as a source of existent stock or replacement breeders for the controlled herd, while at the same time supplying some of the stock required for the current live export markets. Swamp buffalo are farmed on 30 to 40 properties in the Top End. Over the last 12 years there has been a movement of buffaloes between states with small herds (up to 100 head) scattered over all other states except Queensland (which currently prohibits their farming) (Lemcke, 2001).

From 1994 to 1997, government and private owners imported several River buffaloes (four bulls and four heifers) from the USA. Despite the loss of the two original bulls and one young calf, the purebred herd numbered 21 head in February 2001. Crossbred calves were first produced in 1995 and were involved in performance comparisons with purebred Swamp cows. A grading-up programme has also been carried out with the 3/4 and 7/8 progeny now available. The plan is to keep upgrading in this way in order to increase the number of purebreds available for distribution in Australia. Semen has been imported from milking herds in Italy and the first crossbred calves have been produced *in vitro* (Lemcke, 2001).

The general feed mix used was 2.0-2.5 kg/head/day of sorghum or maize with 0.5 0.75 kg of meat meal plus ad libitum roughage, generally a legume/grass hay plus sodium bicarbonate. During the trials it was found that buffaloes failed to increase their efficiency of utilization of grain above 30 percent of the total diet. Meat meal is no longer used in cattle feeding so an alternative is required; probably cottonseed meal is the most readily adaptable alternative. The most productive properties are those with a mixture of upland and floodplain terrain, and are capable of producing 400 kg Swamp buffalo at 2.0-2.5 years of age.

Significant improvements in these parameters have been achieved, firstly by using improved pastures and fertilizers, and secondly by the use of crossbreeding with the River blood (Lemcke, 2001).

AFRICA

Since Egypt has been considered as part of the Mediterranean area, due to its history, culture and geographical position, there is no tradition of buffalo farming in the African continent. Even if people commonly refer to the African buffalo, the indigenous wild African buffalo, which is very little known to most animal production scientists, this buffalo is a member of another species (*Syncerus caffer*). In the classification of the "Bovini" tribe, three groups have been distinguished: Cattle, Asian buffalo and African buffalo.



Figure 27. Bufalo cafro (*Syncerus caffer*), Zimbabwe (Antinori photo, 1984)

African buffalo therefore belongs not only to a different species with respect to Asian buffalo, but also to a different genus (genus *Syncerus*) with respect to the genus *Bubalus* of Asia and Europe, with a chromosome number of 52 in *Syncerus* in contrast to the 50 chromosomes of *Bubalus bubalis* River and 48 of *Bubalus bubalis* Swamp.

Very few studies have been undertaken on the African buffalo, which is found in the forest and savannah regions of Africa, South of the Sahara: Ethiopia, Sudan, Zaire, Congo, Chad and South Africa. The total population is about two to three million. In view of its tolerance to the tsetse fly and trypanosomiasis and its sustainability to the environment, the possibility to produce fertile hybrids with the Asian River buffalo appear attractive and in fact experiments of crossbreeding with the Indian buffalo have been carried out. Unfortunately these experiments were unsuccessful and therefore interbreeding between *Syncerus* and *Bubalus* appears impossible (Borghese and Moioli, 2000).

Further trials to domesticate the African buffalo have been undertaken in a few countries, with particular success in Zimbabwe (Fig 27), where it was proved that this animal, considered in the past to be wild and ferocious, could be used for draught.

Many trials have been undertaken in the past to introduce River buffaloes into Madagascar, Mozambique, South Africa, Tanzania, Zaire and the Congo (Alexiev, 1998), but these small buffalo colonies died out owing to disease (particularly trypanosoma), nutritional deficiencies, climate, etc., in fact buffaloes are more sensitive than cattle to direct solar radiation and temperature. In hot climates water availability is of high importance for buffaloes, which need

wallows, rivers or splashing water in order to reduce the heat load and thermal stress. Therefore the diffusion of the buffalo population in Africa and in the world depends on the availability of water, hence the fact that the *Bubalus bubalis* is commonly called the "Water buffalo" (Borghese and Moioli, 2000).

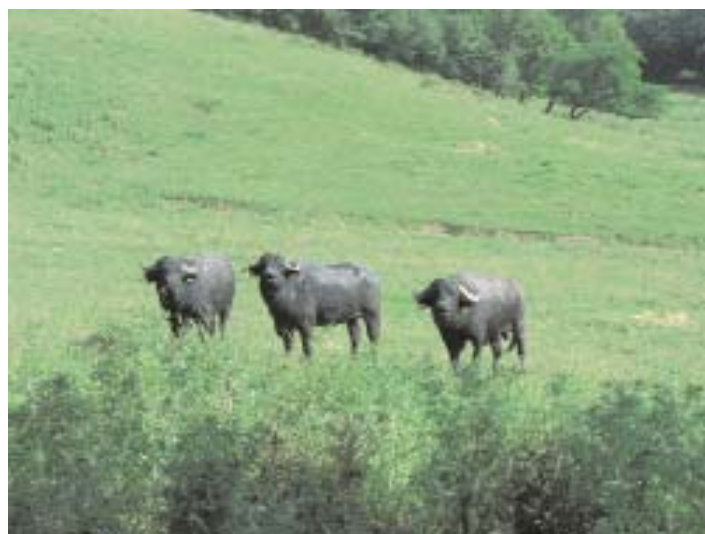


Figure 28, 29, 30 Mediterranean Italian Buffaloes at the Animal Production Research Institute (Barile photo, 2005).



Figure 31, 32 Mediterranean Italian Buffaloes at the Animal Production Research Institute (Barile photo, 2005).

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Chapter II

BREEDING AND SELECTION OF DAIRY BUFFALOES

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Breeding and official selection activity in any country depends on the economic importance of the considered livestock, therefore of the products that can be obtained from it. From Table 1, Column 6, it is evident that in four countries the numbers of buffaloes exceed the numbers of dairy cows, i.e. in Pakistan, Egypt, India and Nepal. Azerbaijan, Italy, Iran and Romania follow with values ranging from 15 to 2.6 percent.

The first step in the breeding and selection activity with regard to any dairy livestock is milk recording of the productivity of each yielding animal, the results of which, when appropriately merged with the genealogy data, allow a definition of the milk genetic merit of each individual, in particular of the bull for which we have no other milk record except the production of his related animals.

The importance of animal recording for the activity of selection is well recognized all over the world and is demonstrated by the fact that in most countries such activity is at least partially financed by governments, which consider it an important means for the improvement of animal production. An international non-governmental organization, the International Committee for Animal Recording (ICAR) has been active for over thirty years in the field of promotion and standardization of animal recording. The ICAR comprises 20 member countries and has obtained excellent results particularly in the dairy cattle sector, where one of its groups, entitled Interbull, regularly produces milk genetic merits of bulls that are comparable among different countries representing the most important dairy breeds: Holstein Friesian and Brown Swiss. What keeps buffaloes far behind the results obtained by dairy cows is the cost of the whole organization of milk recording, genealogy data registration and the selection activity. A specific seminar, jointly organized by FAO and the ICAR in the year 2000 (Workshop on animal recording for improved breeding and management strategies for buffaloes), made clearly evident the major constraints affecting the implementation of the milk recording activity, which can be briefly summarized as follows: 1. Lack of finance; 2. Farmers are reluctant to reveal to other people the levels of production of their animals; 3. Identification of the animals is expensive; 4. Recording costs increase proportionally to the distance between herds, and buffaloes are mostly raised by smallholders (two to five animals) scattered over wide country areas. These constraints illustrate why the percentage of recorded buffaloes (Table 1, Column 5) in countries where buffalo seem to be more important than cattle are so low.

The highest proportion of milk recorded buffaloes, in fact, is found in Italy (28.6 percent), Bulgaria (8.5 percent) and Iran (4.5 percent), countries where the numbers of buffaloes represent below ten percent of dairy animals.

A consistent number of recorded buffaloes (Column 4) is obviously found in countries with the highest presence of buffaloes (India and Egypt) which signifies that these countries have also taken steps towards implementing an organized milk improvement activity, on a solid scientific and technical basis.

The information regarding strategies for buffalo improvement and other associated activities, which are referred to in this document, were obtained through specific questionnaires that the coordination centre of the Buffalo Network, in collaboration with the ICAR Working Group on

Buffalo, regularly sends to reference centres in each country. The activities of each country will be separately examined below, beginning with those countries having the highest number of recorded buffaloes (Column 4).

India

The National Dairy Development Board (NDDB) was the promoter and is the executor of the whole recording and selection activity. The NDDB (organization covering the whole of India) was created to promote, finance and support producer-owned and controlled organizations. The NDDB's programmes and activities seek to strengthen farmer cooperatives and support national policies that are favourable to the growth of such institutions. Fundamental to the NDDB's efforts are cooperative principles; dairy cooperatives account for the major share of processed liquid milk marketed in the whole of India. Milk is processed and marketed by 170 Milk Producers' Cooperative Unions, which are merged into 15 State Cooperative Milk Marketing Federations. NDDB's programmes and activities seek to strengthen the operation of dairy cooperatives, as producer owned and controlled organizations. The NDDB supports the development of dairy cooperatives by providing them with financial assistance and technical expertise.

Table 1. Dairy cows, dairy buffaloes (females), total milk recorded buffaloes, percentage recorded out of total buffalo population, percentage of dairy buffaloes out of total dairy females (cattle + buffaloes). The countries are listed on the basis of total number of recorded cows. Years 2000 to 2003.

1	2	3	4	5	6
Country	Dairy cows	Dairy buffalo (females)	Total milk recorded buffaloes	Percentage recorded out of total buffalo population	Percentage of dairy buffalo out of total dairy females (cattle + buffalo)
India	35 500 000	46 000 000	-	-	56.40
- Gujarat		2 500 000	57 500	2.30	-
Pakistan	4 366 000	10 650 000	-	-	71.00
- Punjab	-	7 900 000	6 000	0.08	-
- North West Frontier Provinces	-	990 000	26 000	2.50	-
Italy	2 169 000	125 000	35 755	28.60	5.40
Egypt	1 253 000	1 487 000	3 034	0.20	54.00
Iran	3 543 000	208 200	13 236	6.30	5.00
Brazil	27 800 000	52 000	500	1.00	0.19
Bulgaria	430 000	4 980	425	8.50	1.10
Nepal	828 000	836 500	400	0.05	50.20
Turkey	5 700 000	58 806	200	0.34	1.00
Azerbaijan	820 000	150 000	100	0.06	15.00
China	53 000 000 (all)	8 500 000	-	-	-
China (only dairy)	4 633 000	2 900	-	-	0.06
Romania	1 600 000	42 300	-	-	2.60

The Dairy Cooperative Network operates in over 285 districts, covers nearly 1 031 281 village-level societies and is collectively owned by nearly 11 million farmer members. The most concrete results of the NDDDB activity in buffalo improvement have been obtained in Gujarat and are outlined below.

Gujarat (India)

Five percent of all Indian buffaloes are raised in the State of Gujarat, in the west of India. In this state, buffalo recording has been carried out since 1987 under the programme entitled "Dairy herd Improvement Programme Actions " (DIPA). The recording systems were introduced with the objective of genetic improvement of buffaloes through a well-planned, field-based progeny testing programme.

In the year 2000, 2.5 million buffaloes were documented by milk recorders employed by the village cooperative society. These recorded buffaloes are all raised on smallholdings of one to five animals, which means over 800 000 recorded herds, and from these herds every year a total of forty young bulls are selected for progeny testing and sent to the artificial insemination (AI) station.

Average lactation production of milk recorded buffaloes is 1 071 kg (300 days) for the Meshana breed and 1 694 kg (292 days) for the Murrah crossbred. Fat content is 7.01 percent in the Meshana and 6.68 percent in the Murrah cross. Protein content is not recorded.

In the region, there are three natural breeding stations controlled by the cooperative and three AI stations. Forty percent of the 2.5 million buffaloes are given AI, while the remaining sixty percent are taken to the breeding station.

The three breeding stations belong to the Dairy Farmers' Cooperative Union, a non-governmental organization; yearly they keep about 260 bulls, of an average age of six years. The milk genetic merit of each bull is estimated on the basis of the milk production of 30 to 50 daughters per bull. An animal model is used for the calculation.

Two of the three AI stations are also owned by the Dairy Farmers' Cooperative Union; they keep 105 bulls which produce 730 000 semen doses a year. Ninety percent of them are progeny tested bulls or bulls born from progeny-tested bulls, while the remaining are new on-test bulls. There is an additional AI station owned by an international non-governmental organization: it keeps 155 bulls, producing altogether 410 000 semen doses a year. Ninety-five of them are progeny-tested bulls or bulls born from progeny-tested bulls, while the remaining are new on-test bulls.

The size of individual smallholdings does not permit the upkeep of their own breeding bull; this is the reason why the AI stations are frequently employed. The majority of farmers is given only one semen dose per buffalo; few of them request two doses. Conception at the first oestrus is 41 percent and the conception rate per year is 2.46 inseminations per conception.

Italy

In the past fifty years, buffalo numbers in Italy have increased 17 fold; it is therefore the livestock that has registered the highest increase in numbers. The reason for this increase lies in the fact that from a rustic triple-purpose animal, buffalo has become a dairy purpose animal. All produced milk is in fact processed into mozzarella cheese, and the increased demand for this cheese, both on the national and international market, together with the milk quotas (i.e. taxes on surplus cow milk production) imposed by the European Union, have favoured the increase of buffalo production. The Italian Ministry of Agriculture is responsible for the milk recording and selection activity through two specific organizations, the Italian Breeders' Association (AIA) and the Buffalo Breeders' Association (ANASB) which provide the technical staff for performing

these activities. The numbers for milk recorded buffaloes (2002) was 35 755, i.e. 28.6 percent of the buffalo population; average lactation milk production was 2 168 kg (270 days); fat content 8.28 percent and protein content 4.73 percent. Fat and protein content analysis is compulsory in the Italian milk recording system because the two results are included in the estimation of the genetic merit of milk, giving the highest importance to protein content, due to the conversion of the milk into mozzarella cheese. Recorded buffaloes are raised in 292 herds in 36 Italian districts (the average herd size is 122).

Selection activity started in the 1980s; five progeny testing cycles were performed from 1987 to 1994, testing comprehensively 43 bulls, and providing 17 positive bulls. Two more progeny testing cycles were performed from 1998 to 2002. In these two last cycles eight bulls were put on-test. 14 477 semen doses were produced from these bulls and 3 718 buffaloes were inseminated. The remaining available doses are 6 350. In 2003-2004 a further cycle was initiated during which four new bulls will be progeny tested.

The keeping of bulls and semen collection is performed in two different AI stations. Bull and cow genetic merit for milk and mozzarella production are published in special catalogues that are produced by ANASB biannually. In the catalogue, the top one percent of Italian buffalo cows with the highest genetic merit for mozzarella and milk production are listed.

Punjab (Pakistan)

The milk recording system and selection activity is implemented by the Livestock and Dairy Development Department of Punjab, through the Livestock Production Research Institute of Bahadurnagar. Six thousand buffaloes are milk recorded in seven very large herds (over 500 buffalo) belonging either to the research institute or to the army, as well as in 27 field recording centres, so including buffaloes in smallholdings of 5 to 20 animals. Average milk production (year 2000) was 1 823 kg (257 days). Fat and protein content are recorded only for the research herds. Breeding of buffalo is mainly through natural mating bulls, however, at the government livestock farms, 100 percent of females are inseminated by frozen semen from proven or on-test bulls. For bull selection a progeny-testing programme began in 1980, where high pedigreed bulls are selected on the basis of the milk production performance of their daughters. Government livestock farms are the principal centres for bull production. In Punjab, semen is produced and stored at Semen Production Units in Qadirabad (Sahiwal), Kalurkot (District Bakhar) and Karaniwala (District Bahawalpur) under the Directorate of Breed Improvement of Punjab, which controls the production and distribution of semen throughout the country.

North West Frontier Provinces - NWFP (Pakistan)

Twenty-five thousand buffaloes are milk recorded in the NWFP; the majority of them (76 percent) are raised in small herds of one to five animals, while 23 percent are raised in medium-size herds (6 to 20 animals). In these herds the owner himself records buffalo milk yield. There are also three public herds, owned by the Animal Husbandry Training Institute of Peshawar, by the Agricultural University and by the Pakistan Army, where the milk recording is performed by technical staff.

Five hundred breeding stations exist in the NWFP, each of them usually keeping one bull of five years of age. The stations are owned by private farmers and the milk genetic merit of the bull is judged according to the performance of his dam. Seventy-three percent of small owners (two to five animals) take their buffaloes to a breeding station, while only thirty percent of medium-size herds (up to 20 animals) take their buffaloes there.

There are three AI stations in the NWFP, two private ones and one run by the Government, keeping a total of 18 on-test bulls. Fifty thousand semen doses are produced annually. One percent of small herds (one to five animals) uses AI while five percent of bigger herds use it. The majority of farmers is given only one semen dose per buffalo; few of them request two doses. Conception at the first oestrus is 50 percent and the conception rate per year is two

inseminations per conception.

Ten percent of small owners raise their own breeding bull, while 20 percent of medium-size herds (up to 20 animals) does the same; 10 percent of medium-size owners buy an adult bull from a different owner. In the bigger herds, which number about 10 000 in the NWFP, breeding bulls are raised from the calves born in the same herd.

The milk genetic value of the bull is judged from the dam's performance. Buffaloes with an average milk yield of above ten litres per day are considered "Elite" buffaloes. Information on buffalo productivity is provided by the extension, research or university veterinarians, NGOs agents, other farmers, postgraduate students, farmers from the province of Punjab or animal dealers, when the breeding bull is purchased from outside the province.

It is estimated that 12 percent of buffaloes are kept grazing all day in village fields and therefore bred there by the grazing bulls.

Egypt

The Cattle Information System/Egypt (CISE) of the Cairo University records about 290 small (one to five animals), 27 medium (six to 20) and six large herds. Due to a lack of financing, fat and protein content cannot be recorded.

The Ministry of Agriculture and Land Reclamation (MALR) through the Animal Production Research Institute (APRI) records four State herds, belonging to APRI, the sizes of which are respectively 50, 70, 75 and 80 and 500 breedable females. The Breeders' Service Unit of APRI provides free complete milk analysis and Somatic Cell Count for the enrolled herds.

CISE is the only institution in Egypt performing data analysis centrally, producing monthly herd summaries and individual milk yield information. Calculation of the genetic merit of recorded buffaloes and breeding bulls is in progress.

The average milk production of milk recorded buffaloes (year 2002) is 2 030 kg (312 days) and the fat content is 8.2 percent. There are six breeding stations with a total of 60 bulls with an average age of five years. These stations belong either to APRI or MALR. All smallholders (one to five animals) take their buffaloes to the breeding stations, as well as 20 percent of the medium size (6 to 20) owners. In bigger herds, breeding bulls are mainly raised from their own male calves although 20 percent of them buy adult buffaloes (two to three years) from different owners. In all cases, breeding bulls are chosen on the basis of pedigree and performance results of the dams, when provided by CISE.

Artificial insemination is used in one percent of the medium to large herds. There are six AI stations owned by the Government and one by the University, possessing a total of 70 bulls.

Artificial insemination is still performed at research level; usually only one semen dose is offered at each oestrus, conception at the first oestrus being 30 percent.

Iran

In Iran milk recording and the selection activity is implemented by the central government through the Animal Breeding Centre of Karaj. The number of recorded buffaloes was 13 236 in 2003. Besides the official recording system provided by government technical staff, there is a semi-private system of recording performed by the farmer himself and by the staff of the local cooperative of farmers. In both cases, executive operations are supervised by the Animal Breeding Centre.

The semi-private system is more popular in the small herds (one to five animals) where 7 100 buffaloes are milk recorded.

There are no breeding stations in Iran, but two performance testing/AI stations, one in West

Azerbaijan (Jabal station), keeping ten bulls and one in Kuhzestan which will be inaugurated in 2004 with a capacity of 50 bulls. Bulls are preselected by provincial experts based on maternal performance and body type and then taken to the station at the age of between 6 and 18 months. Genetic merit of these bulls is estimated against an animal model which includes milk and fat yield, as well as body type parameters. Twenty-thousand semen doses are produced yearly by the Jabal AI station. Artificial insemination is still performed at a low level, since the activity only started in the year 2000; it is estimated that about 200 recorded buffaloes are offered AI yearly; two insemination at each oestrus are always offered, the conception at the first oestrus being 50 percent.

Smallholders (one to five animals) that rear 72 percent of buffaloes in Iran, grow their own calf to become a breeding bull in 50 percent of cases, they borrow a bull from a neighbour during the breeding season in 10 percent of cases, but leave their buffaloes to be bred in village fields by unknown bulls in 40 percent of cases. Medium-size farmers (6 to 20 animals) that rear 23 percent of buffaloes in Iran, grow their own calf to become a breeding bull in 40 percent of cases, they borrow a bull from a neighbour during the breeding season in 10 percent of cases, buy a bull from another farm with proven milk genetic merit provided by the Breeding Centre in 5 percent of cases, but leave their buffaloes to be bred in village fields by unknown bulls in 45 percent of cases. Bigger farmers (over 20 animals), that rear five percent of buffaloes, in 60 percent of cases they borrow a bull from a neighbour during the breeding season, or buy a bull from another farm with proven milk genetic merit provided by the Breeding Centre in 15 percent of cases, but never leave their buffaloes to be bred in village fields.

The milk recorded herds are provided with a wide set of information on the productivity of their buffaloes and breeding values of males that are centrally calculated from the productions of their daughters and related females.

Three breeds of buffalo are reared in the different regions of Iran: Azeri (70 percent); Kuhzestani (22 percent) and Mazandarani (eight percent). Average lactation milk production and lactation duration of the three breeds are as follows (2003): Azeri: 1 500 kg milk in 210-220 days; Kuhzestani: 1 950 kg milk in 210-240 days; Mazandarani: 1 300 kg milk in 220-230 days.

Brazil

Milk recording activity in buffalo of the various imported breeds (Murrah, Mediterranean and crossbred) is performed only in the research herds and in a few private herds for research purposes. About 500 buffaloes are recorded on an annual basis. Average milk production is 1 290 kg (241 days); fat and protein percent are respectively 7.04 and 4.25.

Bulgaria

Milk recording and selection activity in Bulgaria is promoted and executed by the Regional Agency for Selection and Reproduction with scientific and technical support from the Agricultural Institute, Department of Buffalo Breeding, Shumen.

The average milk production of the recorded buffaloes is 1 874 kg (278 days lactation); fat and protein percent are respectively 7.56 and 4.51.

The majority of buffaloes (3 976 i.e. 80 percent of the total population) are reared in small herds (one to five animals); in this herd-size class only 300 buffaloes are milk recorded. Consequently, no information is available to these farmers for improving buffalo productivity: 90 percent of them leave their buffaloes to be bred in village fields; however, five percent of them make use of the governmental breeding station, two percent buy a bull from another owner and three percent take the buffaloes to other herds for mating. Medium-size owners (6 to 20 animals) that rear 8.5 percent of the total population) use AI in five percent of cases, go to the breeding

station in another five percent of cases, and grow their own bull, or buy a different bull in 50 percent of cases; 40 percent of them leave their buffaloes to be bred in village fields. In addition there are ten larger herds (20 to 500 animals). In these herds AI is employed on over 70 percent of buffaloes and a proven genetic merit bull is purchased from other owners in 25 percent of cases.

There is one breeding station in Bulgaria, owned by the government, possessing three to four bulls on an annual basis. The genetic merit of these bulls is estimated using a BLUP Animal Model developed from the records of daughters and related animals. These calculations are performed by the Agricultural Institute, Department of Buffalo Breeding, Shumen.

In addition, there are two AI stations possessing four bulls, which provide 1 320 semen doses every year, of which 1 050 semen doses are from proven bulls. Buffalo are offered two or more inseminations at each oestrus; the conception rate at first oestrus is 45 to 55 percent.

Nepal

There are three institutional herds currently being milk recorded in Nepal. The Department of Livestock Services maintains a breeding herd of about one hundred Murrah cows and five to seven Murrah bulls which provide young bulls for dispersal under the crossbreeding programme throughout the country. The Agricultural Research Stations of the Nepal Agricultural Research Council (NARC) maintain two herds (in Lumle and Tarahara) of hill buffaloes (Lime, Parkote and Tarai breed) with the purpose of assessing the performance of indigenous stock in station production environments. In addition, the Agricultural Research Station, Lumle, has been carrying out milk recording activity in farmer buffaloes for the past 13 years in the western hill area.

Crossbreeding of indigenous buffaloes with Murrah has been the national policy of the genetic improvement programme. Both natural and AI methods are used. In the past, unrestricted grading up with Murrah blood has been the policy throughout the country, but recently, particularly in the central hill area, a limit of 62.5 percent Murrah blood was considered.

Average milk production (305 days lactation) is 1 372 kg; 1 048 kg and 1 031 kg respectively for the Murrah, Lime and Parkote breeds.

There are five breeding stations in Nepal, possessing in total 35 bulls, aged six years. There are a total of 179 AI service centres in 43 accessible districts. The central Animal Breeding and AI Section in Kathmandu valley and the Regional Semen Banks supply frozen semen to these AI centres. Eleven thousand semen doses are produced annually. Each buffalo is offered 1.2 semen doses at each oestrus and the conception rate per year is 35 percent.

Turkey

No milk recording systems for buffalo at the national level are established in Turkey. However, good examples of recording activity are found in two research herds, the first owned by the Mustafa Kemal University of Antakia (Hatay province) and the second at Kocatepe Research Institute. The Department of Animal Production of the Mustafa Kemal University of Antakia performs milk recording activity in buffalo herds of the Hatay province. In total the milk performance of about 200 buffaloes is recorded.

No breeding station for buffalo or AI station exists in the country.

AI was provided to buffalo herds in the Hatay province as part of an FAO development project using semen from proven Italian bulls in the year 2002.

83 percent of buffaloes in Turkey are raised by smallholders (one to five animals); the

remaining 17 percent are raised by medium-size farmers (eight animals on average). All these farmers, except the mentioned recorded ones, leave their buffaloes to be bred in village fields by unknown bulls.

Azerbaijan

Milk recording in Azerbaijan is performed only for buffaloes of the four nationally controlled herds, that raise altogether 240 adult buffalo females.

Fifty-five percent of all buffaloes are raised in small herds (one to five animals); 12 percent in medium-size ones (6 to 20 animals); 21 percent in large herds (21 to 100 animals); there are moreover 101 herds comprising more than 100 buffaloes. All farmers grow their own bull replacements from their calves; small farmers often buy bulls from other owners at the age of three to five years. The practice of leaving buffaloes to be bred in village fields is not used.

China

Although the Chinese buffaloes are Swamp type, therefore not milking buffaloes, the perspectives of the dairy buffalo sector in China cannot be ignored in this context. Contrary to popular opinion, the Chinese are content to consume dairy products. The market for dairy products is growing by 18 percent per annum, the second fastest growth in the world after Brazil. In this context the Ministry of Agriculture, through its Dairy Project Office, has drafted a publication entitled "Dairy and beef buffalo sector investment promotion guide book for domestic and foreign investors (1999)".

The first dairy buffalo herd composed of Indian Murrah was introduced in Guangdong in 1948. Further batches of Murrah were introduced in Guanxi and Hubei in 1957, and in Huizhan City and Zhanjiang in 1960. In 1962 and 1974 further Nili Ravi and Murrah breeding animals were imported. In 1987 the Ministry of Agriculture established a National Buffalo Development Project, and in 1996 a financing agreement for the water buffalo development project was signed with the European Union.

In 1997, 100 paillettes (straws) of Murrah semen were made available to the Buffalo Institute of Nanning. The defined target dairy buffalo provinces are: Guangdong, Guanxi, Yunnan, Jiangxi and Sichuan. The EU-China Water Buffalo Development Project is based on the following assumptions: investment in dairy processing plants; import of 100 000 to 200 000 semen doses from foreign countries for crossbreeding and improvement of milk production of indigenous buffaloes.

Buffalo genome research and applications

DNA technology in buffalo has been principally applied for parentage verification. DNA profiling has become a major tool in paternity verification and forensic medicine in humans, and among the various types of markers, that have been used for creating the profile, microsatellite-based markers overcome many of the difficulties associated with the previously used ones (RFLPs and genetic fingerprints produced by minisatellite probes) (Botstein et al., 1980; Jeffreys et al., 1991), which either suffer from low polymorphic information content or are difficult to interpret. Microsatellite sequences are stretches of tandemly repeated short sequence motifs, one to six nucleotides in length; polymorphisms arise from the difference in number of times the motif is repeated, and they have the advantage that, being 100-300 nucleotide long, they can be amplified by polymerase chain reaction (PCR) (Usha et al., 1995). A set of polymorphic DNA microsatellites useful in Swamp and River buffalo was produced by Moore et al. (1995) and the protocols for two microsatellite multiplex were referred by Blasi et al. (2003). The first multiplex includes: microsatellites INRA006, CSSM42, CSSM47, CSSM19, D5S2, MAF65, RM4, CYP21 and BM1013 and the second multiplex includes: microsatellites CSSM70, CSSM60, INRA026, BM0922, and BM1706. The two multiplex are routinely used for buffalo parentage verification in Italy and give a probability of exclusion of 0.99999.

DNA microsatellites, furthermore, have found widespread application in population genetics. FAO recommended the use of high polymorphic microsatellite markers in the programme strategy for the measurement of domestic animal diversity (FAO, 1998).

Barker et al. (1997) estimated the genetic diversity between and within eight Swamp and three River buffalo breeds based on the variation of 21 microsatellite loci. They found a significant differentiation between the Swamp and the River types, and among population within each buffalo type.

Moioli et al. (2001) analysed the genetic diversity between Italian, Greek and Egyptian buffalo populations, based on 13 microsatellite loci, showing that the differentiation between the Italian and Greek buffaloes was irrelevant, while the differentiation between the Egyptian and the other two is higher than the one found between the river populations in Asia examined by Barker et al. (1997).

The paper by Moioli et al. (2001) indicates also that the genetic analysis undertaken using the 13 microsatellites reflects effectively the isolation by distance of different populations, and that the genetic distances between groups of sampled animals of the same population describe the geography of the country.

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