Long-Term Breeding Strategies for Genetic Improvement of Buffaloes in Developing Countries[a] - Review -

C. Chantalakhana* and P. Skunmun
Kasetsart University, Bangkok 10900, Thailand

ABSTRACT : Buffalo raising to produce milk, meat, and draught power as well as other products continues to be important in Asia and other parts of the world in the next century due to an increase in the demand for such products and the unique roles of buffaloes in rural economy. Long-term breeding strategies with special relevance to present and future farming systems prevailing in developing countries are proposed. Some important considerations in the choice of certain breeding strategies for long-term genetic improvement in buffaloes are discussed. Some recent research results in genetic selection and crossbreeding of buffaloes are highlighted. A review of genetic inheritance of buffalo traits is presented as well as a discussion of certain quality traits of buffaloes which deserve future research for improvement. (***Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 7 : 1152-1161***)

Key Words : Breeding Strategies, Buffalo Improvement, Crossbreeding, Milk, Meat-and-Draught

INTRODUCTION

There were approximately 148.9 million water buffaloes in the world in 1993, while there were only 90 million in 1961. Almost 96% (142.6 million) of them were found in Asia and Pacific, while they were distributed in more than 50 countries around the world, from China and India to Brazil, from USA and Europe to Australia. The number of buffaloes by continent is shown in table 1. Most buffaloes are raised by small farmers in developing countries.

The water buffaloes (*Bubalus bubalis*) can be classified into two breed types, the river and the swamp type.

A. River breeds consist of (a) Asian breeds such as those in India and Pakistan, and (b) Mediterranean breeds such as those in Italy, Romania and Middle East.

B. Swamp type such as those in China and Southeast Asia (SEA).

More than 70% of the total buffaloes in the world belong to the river type while almost 30% are of the swamp type.

During the past three decades the number of buffaloes in the world steadily and consistently increased at about 1% to 2% per year, except in some Eastern European countries, where buffalo numbers decreased during 1981-1990, as indicated in table 1. The most obvious increase in the number of buffaloes took place in Brazil and some other Latin American countries.

In the year 2025 it is expected that there will be a human population of more than 8.2 billion in the world with about 3.3 billion people living in rural area. Clearly, more meat and milk will be required for urban consumption, while rural farmers will continue to depend on buffaloes for draught power, manure, cash income as well as other non-cash values. The water buffaloes will remain an important component contributing to sustainable farming systems and rural development in developing countries for many decades to come (Chantalakhana, 1996).

BUFFALO PRODUCTION AND RURAL FARMING

In 1990, out of 136 million buffaloes in Asia more than 95% (129.5 million) of them were found in India (75 m), China (21.4 m), Pakistan (15 m) and Southeast Asian countries including Myanmar, Bangladesh and Sri Lanka. Most buffaloes in these countries are concentrated in the following crop/animal agro-ecosystems (Devendra, 1995): Irrigated lowland farming systems, rainfed lowland farming systems, and upland farming systems.

In India most milk production in India is obtained from dairy buffaloes while the use of buffalo for draught power is also important. In Pakistan and China buffaloes are used as draught animals as well as for meat and milk. In Southeast Asia the water buffaloes provide meat and draught power, while manure and other by-products such as hide, horn, etc are also important.

* Address reprint request to C. Chantalakhana.

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Table 1. Number of buffaloes by continent (Chantalakhana, 1991)

Continents		Decades		
		1961/70	1971/80 (In millions)	1981/90
Asia	N	88.04/107.00	108.39/120.31	122.73/136.27
	GI[1]	2.5	1.1	1.0
Africa[2]	N	1.05/2.01	2.06/2.35	2.37/2.55
	GI	3.5	1.8	0.9
S. America[3]	N	0.063/0.118	0.129/0.495	0.542/1.234
	GI	7.7	17.7	9.7
Europe	N	0.528/0.369	0.392/0.437	0.440/0.376
	GI	-4.0	1.2	-2.0
World[4]	N	90.52/109.97	111.43/123.95	126.43/140.86
	GI	2.5	1.1	1.1

[1] GI = Growth Index, average annual percentage change.
[2] Only for Egypt and Mauritius, some numbers of buffaloes can be found also in Madagascar, Mozambique, S. Africa, Uganda, Zaire and Congo.
[3] Only for Brazil, but some numbers of buffaloes can be found also in Venezuela, Trinidad, Peru, Paraguay, Argentina, Ecaudor, Colombia, Surinam, Hondurus, Costa Rica, Bolivia, and Uruguay.
[4] Australia is not included, where about 200,000 buffaloes could be found.

BUFFALO FARMING IN DEVELOPING COUNTRIES

1) South Asia

Buffaloes in this region mostly belong to the river breeds. More than 67% of the world buffalo population can be found in Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka. Water buffaloes are a source of milk, meat, and draught power i.e. a triple purpose animal. In India 25.5 million tons of milk is produced by buffaloes annually, while only 23 million tons from cattle (Soni, 1991). In Pakistan, buffaloes produce three times as much milk (9.9 m tons) as do by cattle (3.1 m tons).

According to Soni (1991), buffalo production in South Asia is mainly by small farmers who are engaged in traditional integrated small-farm systems in which crop is commonly a major component. Farmers maintain buffaloes mainly because they depend on these animals to carry out agricultural operations. Most of the farmers are subsistence farmers with limited land area for cultivation. The number of livestock, especially bovine animals, kept per farmholding are rather low. Most of the farmers keep around one or two buffaloes for crop cultivation or for milk production. Meat and manure are generally considered as by-products.

In India and Pakistan, buffalo production systems can be generally classified into 3 types, i.e. (1) extensive, (2) semi-intensive, and (3) intensive (Soni, 1991). The extensive system of buffalo raising is commonly practiced by small farmers who keep one or two buffaloes and maintain them by grazing on common village land, roadside grass, and on stubble. Natural grazing is supplemented with straw and other crop residues. The semi-intensive system of buffalo raising is generally associated with intensive systems of crop production. Buffaloes are raised mainly for milk production and are stall fed. Some farmers may raise 10 to 50 buffaloes. The intensive system is usually characterized by large-scale buffalo production or colony to provide milk for large city consumption. This kind of buffalo operation involves a relatively large number of dairy buffaloes, usually being located near metropolitan areas.

2) East and Southeast Asia

According to Bunyavejchewin and Chantalakhana (1991), 95 to 99% of the buffalo production in China and most SEA countries can be classified as smallholder or small farm systems, in which buffalo raising is regarded as an integral part of a crop production system. Swamp buffaloes primarily provide a source of farm power for tillage and transportation, and a source of manure for use as fertilizer for crop, while meat is a secondary product and milk is generally unimportant. The most common areas where buffaloes play prominent roles are in rainfed lowland or upland rice production.

Raising swamp buffalo for beef production is becoming more common in East and SEA, however, the number of commercial buffalo farms in most countries are still relatively few. Raising buffaloes for dual-purpose, i.e. for meat and milk, has also become an important area of buffalo development in certain countries such as the Philippines, Malaysia and Thailand.

It is very important that breeding strategies for long-term genetic improvement of buffaloes should serve the requirements of present and future farming systems and at the same time well comply with the socio-economic conditions of the farmers in developing countries. This paper aims to discuss some buffalo breeding strategies and approaches with special emphasis on farming systems which are expected to prevail in developing countries for a long period of time.

GENETIC ASPECTS OF SOME CHARACTERISTICS

The degree of genetic inheritance of animal traits is expressed in terms of heritability (h^2), the value which can theoretically range from zero to 1 or zero to 100 percent ; when $h^2 = 0$ means that the observed variation (P) of such trait is completely controlled by the environmental factors (E), and $h^2=1$ is the opposite i.e. all the observed variation (P) of the trait is controlled by the genetic factors (G). In general, the observed variation of a trait is controlled partly by both G and E, i.e. P=G+E. Hence, the value of heritability estimate of a trait indicates the effectiveness of its improvement by genetic methods.

It is very important to have information on the heritability estimates of buffalo traits before implementing a long-term genetic improvement program. The following section is to present a summary of the heritability estimates of some characteristics in the buffaloes.

1) Milk production

Figures in table 2 were the h^2 estimates of different milk production traits of the river buffaloes obtained by various researchers as reviewed by Chantalakhana (1992). In general it can be said that most milk yield characteristics in the river buffaloes ranged from low (<0.2) to high (>0.5). Genetic selection to improve milk production in buffaloes should be able to achieve a medium rate of success. There has been no research report on the genetics of milk production in swamp buffalo since milk yield is not important in such type of buffalo.

2) Meat production

Genetic studies concerning traits related to meat production in buffaloes have been very limited, especially in swamp buffalo, since there have been very few long-term genetic studies.

Table 3 shows the estimates of heritabities of various body weights of the river buffaloes (Bhat, 1979; Bhat, 1992), which generally ranged from medium to high (0.2 to 0.5). This estimates indicate that genetic selection for body weights in buffaloes can be successful at medium to high rates. The genetic data from swamp buffalo breeding program in Thailand showed that the heritability estimates for body weights and daily gains ranged from low to high as shown in table 4. Body weight at 2-years of age and postweaning (8 m. to 2 yr.) daily gain were highly heritable, with the heritabilities of 0.60 and 0.75, respectively (Topanurak, 1992). In general, it is believed that animal's draught ability is related to its body weight, hence, selection for larger or heavier buffaloes will automatically improve working capacity of the animals.

Table 2. Estimates of heritability (h^2) of milk production traits in river buffaloes

Trait	Heritability estimates
Milk yield	0.16-0.47
First lactation yield	0.08-0.42
Second lactation yield	0.14
Butterfat percentage	0.48
Percent protein	0.74
Total solids	0.35
Length of lactation	
First	0.13
Second	0.59
Length of dry period	
First	0.11-0.13
Second	0.59

Table 3. Estimates of heritability (h^2) for body weight in river buffaloes at various ages

Weight	h^2 Estimates	
	Bhat (1979)	Bhat (1992)
Birth	0.74	0.56
At 3 months	0.49	0.49
At 6 months	0.43	0.42
At 9 months	0.33	
At 1 year	0.74	0.39
At 2 year	0.43	0.40
At 1st calving	0.23	0.15
1st year weight gain	0.56	

Table 4. Heritability estimates of body weights in swamp buffalo (Topanurak, 1992)

Trait	No. of observations	h^2	Standard error
Birth weight	1,429	0.23	0.10
240-day weight	1,126	0.09	0.05
Weight at 2 yrs	437	0.60	0.25
Preweaning daily gain	1,126	0.06	0.05
Postweaning daily gain	437	0.75	0.10

3) Reproductive traits

It is well known in other livestock such as cattle and pig that most reproductive traits are lowly heritable, which means that these traits are mainly influenced by feeding, management, and cares. In water buffaloes, so far there has been very few genetic studies on reproductive traits. The heritability estimates obtained by some studies in river buffaloes as reviewed by Acharya (1991) and Chantalakhana (1992) are presented in Table 5. The estimates were generally low except that for age at first calving. It is therefore recommended that most reproductive traits should be improved through feeding and herd management, as well as culling of animals with low reproductive efficiencies.

Table 5. Estimates of heritability (h^2) of some reproductive traits in river buffaloes

Traits	h^2 Estimates as reviewed by	
	Chantalakhana (1992)	Acharya (1991)
Age at first calving	0.78	0.23
Calving interval		0.14
First	0.01-0.64	
Second	0.11	
Breeding efficiency	0.02	
Service period		0.09

SOME CONSIDERATIONS FOR CERTAIN BREEDING STRATEGIES

Breeding buffaloes for draught purpose

Recognizing that the working capacity of an animal is directly related to body size and weight, rural farmers generally select larger buffaloes for work. In many countries farmers prefer to use male animal for work due to its larger body size, however, during recent years more and more female buffaloes are used for work as well as for reproduction due to the shortage of draught animals. The measurement of draught ability of an animal is rather complicated since it depends on age, sex, size, health and nutritional conditions, training, harness and working equipment, time of day, soil types and conditions, etc. Since the conditions under which the animals are put to use vary from one location to another, standard engineering or laboratory measurement might not be useful or meaningful to all farm situations.

Draught buffaloes are generally used to work during early morning hours, usually from 5 o'clock in the morning until 10 or 11 o'clock. It has been well recognized that buffaloes are generally less heat tolerant than cattle due to fewer sweat glands in body skin. No breeding work has been done to imporve heat tolerance in buffaloes. It is probrably quicker and more effective to improve animal working efficiency by reducing heat stress through management or other body cooling methods.

Animal draught efficiency can also be significantly increased through the use of improved harness systems (Garner, 1957; Starkey 1989), or improved farm tools and implements (Starkey and Sims, 1989). However, most of these improved harness systems and tools have not been widely adopted by rural farmers due to various reasons. Many of these problems were due to a lack of farmer participation in the development of these tools and equipment. Other socio-economic factors and government policies, for instance, lack of credit for small farms, lack of farmer training, or low price for farm commodities, have had negative effect on the ability of rural farmers to adopt new technologies. Indeed, it will be very useful and helpful to find ways and means to extend existing improved farm tools and harness systems to farmers in rural areas. If this effort becomes successful, animal draught capacity will be much improved.

Breeding improvement of buffaloes for draught purpose through genetic selection within population is expensive and slow as compared to improvement by other methods such as feeding and management, health care, and use of improved farm tools and harness systems. From breeding aspects, it appeared to be generally agreed that the draught ability of buffaloes could be improved as a secondary purpose within the improvement programs for meat or milk production (Chantalakhana, 1992; Gunawan and Vercoe, 1989) by simultaneously selecting for animal body weight and height.

Crossbreeding of swamp buffalo with Murrah and Nili-Ravi in order to improve draught ability as well as milk and meat has been conducted in some countries such as the Philippines and China. Some crossbreds were found to have higher body weights than the swamp (local) buffalo at the same age, while the working ability of crossbreds having the same body weight and heat resistance were comparable to the local (Momongan et al., 1989). It was reported that crossbred bufffaloes in China were superior to local swamp buffalo in working ability, i.e. draught power, area ploughed per unit time, ploughing speed, and duration of work. This could be attributed to the higher body weight of the crossbreds (Xiao Yongzuo, 1989a).

In some Asian countries, male buffaloes are usually castrated by farmer at about 2-3 years of age before training for work. Castrated animals are believed to be more tame and not distracted by female while working. However, castration of larger males in effect has resulted in negative selection against superior breeding stock as evident by the decline in the average body size of buffalo in Thailand and some other SEA countries. Therefore, it is very important to provide superior buffalo bulls for breeding at village level. Artificial insemination of buffalo cows with semen from superior bulls has had limited impact at farm level as far as draught buffaloes on small farms are concerned. This is due to various socio-economic, technical as well as institutional constraints facing village farmers.

Breeding buffaloes for meat or meat-and-draught purpose

Meat production from buffalo has provided an important part of total national beef supply in many Asian countries. In China and SEA countries, many buffaloes are sold for slaughter immediately after the planting season in order to obtain cash for purchase of fertilizer and other farm inputs. In some Asian countries, such as the Philippines, China, and Thailand, more and more farmers raise buffaloes for sale while buffalo draught power becomes a complementary source of farm power to two-wheel tractor (Chantalakhana, 1996). As the beef demand rises with increasing number of people and their educational and income levels in Asian countries, it is anticipated that meat production from buffalo will become more economically important because cattle beef supply do not grow at sufficient rate to meet fast expanding demand. In a country like Thailand with approximately 60 million people it was estimated that each year up to one million cattle and buffaloes were imported (smuggled) for slaughter from neighboring countries, while according to official statistics only about half a million cattle and buffaloes were slaughtered in various municipal slaughter houses annually. It was estimated that illegal slaughtering in some areas could be up to 3 to 5 times of the official records. Therefore, it is anticipated that buffalo raising for meat purpose at small farm level will increase in the future, while feeding and management will continue to rely on the use of low quality roughages such as rice straw, natural grasses and tree leaves. However, buffalo fattening or finishing operation utilizing supplementary energy feeds such as cassava chips or molasses could become profitable as beef demand rises. Hence. breeding strategies to improve buffalo for meat or meat-and-draught can be quite useful for many Asian countries.

The traits related to meat production in buffaloes such as weights at different ages and growth rates are expected to be medium to highly heritable, as mentioned in previous section. There has been no genetic study on buffalo carcass traits so far but judging from experiences in beef cattle breeding they can be expected to be highly heritable, which means that breeding improvement can be effective.

Selection of swamp buffalo for beef and draught. Superior male and female buffaloes can be selected based on their own performance such as weights at 6 or 8 months and at one year to 18 months of age and growth rates before and after weaning at 6 or 8 months of age. Body height at wither and conformation score can also be used as supplementary criteria, while some reproductive traits such as size of scrotum or udder should also be observed. Performance testing of animals from known or pedigree parents selected from breeding herds after weaning needs to be conducted at a central location where buffaloes can be fed and managed under uniform and well-planned herd management. Since buffaloes will be used for breeding by village farmers after the test it is important to provide them similar feeding and management background while being on the test. The testing period is relatively longer (up to 10 months or a year) if the animals are tested for their growth performances on grass. During the test buffaloes are allowed to graze in pasture during the day and return to the barn in the evening where rice straw or other crop residues are fed *ad libitum*. Mineral licks are also provided in the barn as well as clean drinking water. In the early morning hour before buffaloes are let out to graze, they are fed with feed supplements at about 2-3 kg per head. Feed supplements are composed of low priced and locally available ingredients such as cassava chips, leucaena leaf meal, etc. Feed supplements are provided to tested buffaloes in order to allow optimum genetic expression as far as growth rates and body weights and size are concerned. Selection and breeding scheme of buffaloes is shown in the following diagram (figure 1).

An example of buffalo selection scheme for meat and draught purpose in Thailand was reported by Konanta and Intaramongkol (1994) with satisfactory progress. This selection scheme implemented by the Thai government has been going on for more than 15 years. It started as a small scale project and has been expanded in scale during a five-year period (1996-2001) as the demand for meat and draught buffalo increases.

Crossbreeding for beef and draught. Crossbreeding of swamp buffalo with river breeds such as Murrah has been carried out in various countries in Asia in order to improve meat production and draught ability. F1 crossbreds of swamp × Murrah are fertile and perform well under rural conditions. Their working ability is comparable to the swamp parent, while body size and growth rates in some cases equal or are slightly better as reported by Momongan et al. (1994), as shown in tables 6 and 7.

One major concern relating to crossbreeding of the swamp buffalo (diploid chromosome number or $2n=48$) with river buffalo ($2n=50$) is the unequal number of chromosomes, which result in unbalanced chromosome numbers ($2n=49$) in the F_1 crossbreds. So far no breeding work in the field has been reported to indicate that the fertility of F_1 crossbreds is negatively affected by this cytogenetical phenomenon

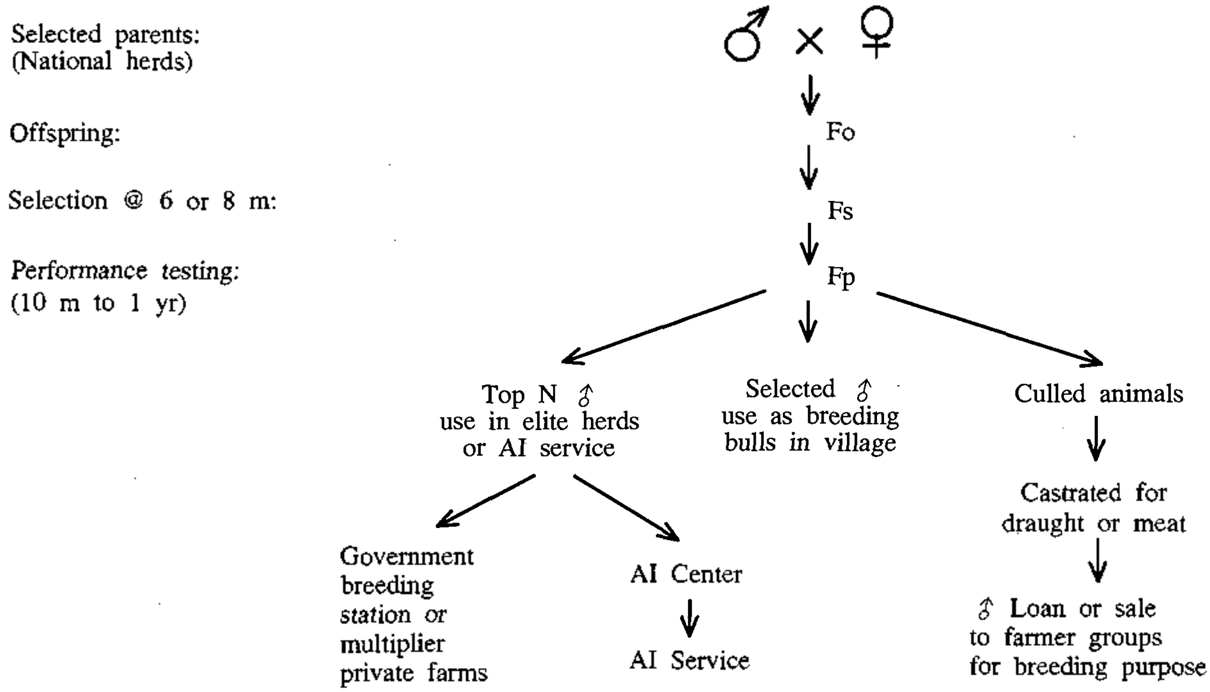

Figure 1. Selection and breeding scheme

Table 6. Least-square means (LSM in kg) for body weights of Philippine carabao and crossbreds

Age (months)	Philippine carabao		Phil-Murrah F_1		Phil-Ravi F_1	
	n	LSM	n	LSM	n	LSM
0	102	26 ± 1^{a}	182	35 ± 1^{b}	38	35 ± 1^{b}
6	95	111 ± 5^{a}	172	127 ± 6^{b}	37	133 ± 6^{b}
12	85	160 ± 6^{a}	160	210 ± 9^{b}	31	215 ± 9^{b}
18	75	204 ± 7^{a}	125	281 ± 15^{b}	27	283 ± 11^{b}
24	58	239 ± 9^{a}	105	318 ± 17^{b}	24	332 ± 19^{b}
36	48	305 ± 10^{a}	98	462 ± 24^{b}	21	460 ± 25^{b}

Note : Significant difference ($p<0.01$) only between Philippine carabao and crossbreds.

Table 7. Work performance of Philippine carabao (PC) and Phil-Murrah F_1 (CB) steers

Parameters	Wet land condition		Dry land condition	
	PC	CB	PC	CB
Depth of ploughing (cm)	12.25	12.23	11.92	11.14
Width of ploughing (cm)	17.61	17.69	18.94	18.57
Soil moisture (%)	42.96	43.74	22.92	22.55
Hardness of soil (kg/cm^2)	1.66	1.66	1.91	1.92
Ploughing velocity (m/sec)	0.50	0.54	0.60	0.50
Ploughing time (hour) for 2500 m^2	8.89	8.29	7.14	8.72
Average draught force (kg)	54.14	49.42	50.14	50.60
Drawbar horsepower (PS)	0.36	0.35	0.40	0.34

(Na-Chiangmai and Chavananikul, 1998). However, Chavananikul (1994) reported that some recent investigations showed the occurrence of a meiotic impairment which affected the semen quality in the crossbred buffalo male carrying unbalanced karyotype of 49 chromosomes. No report on the effect of unbalanced chromosomes on the fertility of crossbred buffalo cows is available so far. F_2 and F_3 upgraded (backcross to river breeds buffaloes have been produced in different countries but the long-term ultimate breeding goal is often unclear while sufficient and good data are lacking to carry out comparisions of production and reproductive performance of crossbreds and their parental breeds.

Breeding buffaloes for meat-milk-and -draught

Crossbreeding between the swamp buffalo and the river breeds is often aimed at producing milk in addition to meat and draught in the crossbreds, as reported in China and the Philippines (Xiao Yongzuo, 1989a; Momongan et al., 1994). In many developing countries, though UHT milk is available and can be kept without refrigeration, drinking milk is not always available to rural people, and furthermore drinking milk is still expensive and not affordable by farmers. Crossbred buffaloes can produce 3 to 5 kg of milk per day which can be used for household consumption, where only 1 or 2 buffalo cows are kept. Hence, buffalo crossbreeding in this case is aimed at improving nutritional status and human health as well, especially for children and the elder.

Only moderate levels of milk and meat production is expected from crossbred buffaloes since most dairy and beef characteristics in bovine animals are genetically negatively correlated. Under village conditions where feed resources and feed quality are commonly limited, milk production by an animal could mean that less nutritional supply available for meat production. Similarly, to use crossbred buffaloes for farm works resulted in decrease of milk production by 12 to 17% (Xiao Yongzuo, 1989b). However, Zerbini et al. (1995) who worked on dairy cow traction in Ethiopia concluded that with appropriate feeding levels dairy cows could be used for draught purpose without any detrimental effects on fertility, except for extended calving interval and small reduction in milk (see table 8). Further feed supplementation to dairy cows used for work could result in a satisfactory level of milk production, but socio-economic considerations at small farm level may render feed supplementation of the multi-purpose animals impractical and uneconomical.

Table 8. Cumulative milk yield (kg) of F_1 crossbred cows over a period of two years

Treatment	0-365 d	0-730 d
Non working/non supplemented	849	1,226
Non working/supplemented	1,792	3,186
Working/non supplemented	802	927
Working/supplemented	1,770	3,044
Standard error	152	219

Rural people in some countries are not natural milk drinker and milk drinking could be problematic; marketing milk is also a complicated process. In such cases promoting milk production from buffalo might not be too useful. However, improved milk production of buffalo cows will definitely increase growth rate and body weight of the offspring at weaning age.

Table 9 shows the levels of milk yield from different buffalo genotypes in China (Xiao Yongzuo, 1989b). It should be noted, however, that these buffaloes were raised on experimental farms and they were expected to be well managed for milk production.

Breeding buffaloes for milk production

The use of buffaloes as dairy animals by rural farmers has been well known in many countries such as India and Pakistan. River buffaloes of at least 15 breeds had been described by various authors (Mudgal and Sethi, 1989; Bhat, 1992). Some river breeds such as Murrah and Nili-Ravi have been introduced to some other countries such as China and the Philippines to cross with local buffaloes in order to use the crossbreds as dairy or multi-purpose buffaloes. Different types of crosses such as that shown in the following breeding scheme (figure 2) are commonly carried out in various countries, especially in SEA and China where only swamp buffaloes exist locally.

Mudgal and Sethi (1989) did a comprehensive review of performance for both meat and milk of different breeds of river buffaloes and some types of crossbreds between river and swamp buffaloes, mainly

Table 9. Milk yield of different buffalo breeds in China

Breed	Number of animals	Average lactation (days)	Average lactation milk yield (kg)	Average daily milk (kg)	Highest daily milk yield (kg)
Local (L, Swamps)	10	235	441±212	1.9	5.5
M×L	12	276	1096±261	3.7	9.5
M×L (F_1)	60	270	1153±397	4.3	11.0
M×(M×L) (F_2)	12	291	1540±687	5.2	13.0
Triple-Cross	10	288	1981±470	6.9	5.3
Murrah (M)	81	237	1573±524	6.6	7.0
Nili-Ravi	25	261	1873±690	7.2	9.9

in China and the Philippines as further reported by Xiao Yongzuo (1989a and 1989b) and Momongan et al. (1994). Only the Murrah and the Nili-Ravi have been used more extensively so far in crossbreeding programs with the swamp buffalo in Asia. The milk yield and lactation period of dairy buffaloes of different genotypes appeared to be at satisfactory levels as shown in table 10 (Xiao Yongzuo, 1989b).

Judging from existing reports, it is not possible to state clearly what breeds or genotypes are best suited for milk production. Variation due to feeding, management and environmental conditions apparently presented difficulty in genetic evaluation of various crosses conducted in different studies, while the numbers of animals in each study were usually not sufficiently large.

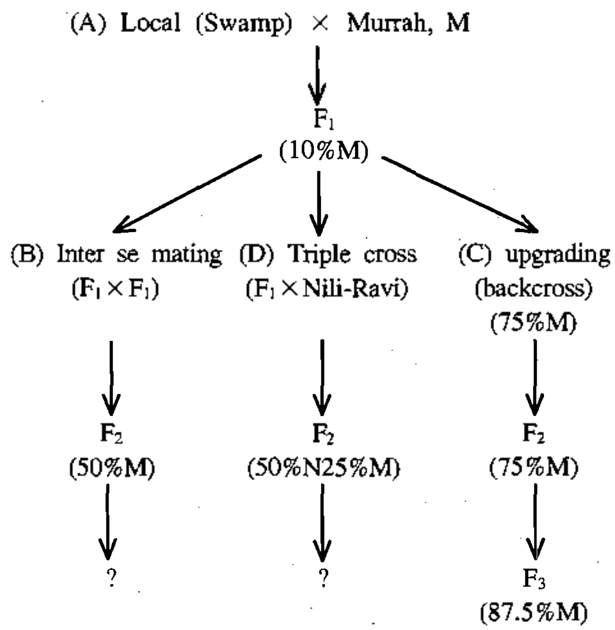

Figure 2. Some crossbreeding schemes of swamp × river buffaloes

Cattle vs. buffalo crossbreds for dairy production

In countries where buffalo milk, which is exceptionally high in percent butterfat (7-8%), is not traditional food for local people there is a question whether cattle crossbreds such as Holstein crosses or buffaloes are more suitable for dairy production. In many Asian countries, Holstein crossbreds of 50% or higher can easily produce 15 kg milk per day or higher, while buffaloes of river breeds or crosses usually average lower (6-8 kg). It appears that dairy farmers can earn more income from raising crossbred dairy cattle than crossbred buffaloes in SEA countries, such as Thailand, where the benefit of high butterfat in buffalo milk cannot compensate for lower milk yield. However, crossbred buffaloes become more superior to crossbred cattle when they are considered as the multipurpose animal in integrated farming systems to utilize farm wastes and by-products, natural grasses and tree leaves, as well as marginal lands such as highway shoulders and scrub forest, since they are able to produce moderate milk yield under poor management and feeding conditions.

SOME OBSERVATIONS ON BUFFALO TRAITS FOR FUTURE IMPROVEMENT

Tick resistance

It is well recognized that on smallholder farms in villages where cattle and buffaloes are raised together by small farmers in tropical Asia, buffaloes generally have no problem with tick infestation while cattle either *Bos indicus* or *Bos taurus* breeds have problem with ticks and some tick-borne diseases such as anaplasmosis. Some may argue that swamp buffaloes are free of ticks because they like to lie down in mud hole and as a result prevent themself from ticks. This observation needs to be investigated in order to prove whether buffaloes' resistance to tick is due to genetic or environmental factors. If tick resistance in buffaloes was due to genetic influence then, with available

Table 10. Milk production of different buffalo genotypes in China

Breed	Lactation sequence	Lactation period	Lactation milk yield (kg)	Highest milk yield (kg)	Average milk yield (kg)
Triple	1	311.5	2100.7	12.5	6.7
crossbred	2	312.2	2574.2	15.7	8.2
	3	317.9	2704.9	17.0	8.5
Nili-Ravi	1	297.0	1500.0	7.4	5.0
× Local	2	351.8	2370.1	11.5	6.7
	3	324.3	2287.0	11.5	7.0
Murrah	1	269.6	711.9	16.7	6.3
	2	269.5	1921.8	17.5	7.1
	3	284.7	2073.6	14.8	7.2
Nili-Ravi	1	274.3	1825.4	19.9	6.6
	2	265.7	2087.2	19.9	7.8
	3	279.2	2096.5	18.7	7.5

genetic engineering techniques, buffaloes can be a very valuable genetic resource for future animal improvement.

Ability to use low-quality roughages

It has been well recognized that during dry seasons when sources of roughages become very limited on smallholder farms cattle would lose much body weight and become rather thin while the buffaloes on the same farm maintain their body conditions at rather satisfactory level. This could be partly due to their less selective grazing behavior, but currently many researchers believe that buffaloes may have different kinds of rumen microbes as compared with cattle, which enable them to utilize low quality roughages such as rice stubles or high-fibrous residues more efficiently. Furthermore, some research reports indicated that swamp buffaloes have a total nitrogen balance either equal to or higher than that of Zubu cattle due to a reduced nitrogen output in the urine (Moran, 1983; Devendra, 1992). It will be very useful to study in further details concerning these superior traits of buffaloes, especially their genetic information.

Milk and meat

Buffaloes are known to produce milk with high butterfat percentage (7-8%). Buffalo meat has been reported to contain cholesterol half as much as compared to that in cattle beef. This special characteristics in buffaloes deserve further investigation in order to utilize this superior genetic resources for human use in the long term. Genetic studies utilizing modern biotechnological tools available at molecular or DNA level will be very useful in the future.

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