Chapter III

BUFFALO BREEDS AND MANAGEMENT SYSTEMS

Bianca Moioli and Antonio Borghese

Istituto Sperimentale per la Zootecnia
(Animal Production Research Institute)
Via Salaria 31, 00016 Monterotondo (Rome), Italy

BUFFALO BREEDS

Breeds (only for the River subspecies) are listed in alphabetical order. Breed names are those given in Mason (1996). A World Dictionary of Livestock Breeds, Types and Varieties, Fourth Edition. Wallington, UK. Population size is given for years 1999-2004, according to the different sources.

1. Anatolian

The Anatolian buffalo has been raised in Turkey for centuries, originating from Indian migration (7th Century), together with the expansion of Islam.
Population size: 110 000
Description: Black in colour, long hair, with variation in tail length and frequent white switch. Height at withers of adult male is 138 cm, body weight is 200-500 kg.
Height at withers of adult female is 138 cm, body weight is 200-500 kg.
Distribution: Concentrated in the Black Sea region, North of Middle Anatolia, Thrace, Hatay, Mus, Kars, Dyarbakir, Afyon, Sivas.
Husbandry: In dairy farms, housing differs from region to region. If grazing is available, the three to five buffaloes owned by the family are taken to graze together with the other buffaloes from the village. Mating and calving occur at the pasture. Generally on the ground floor of each house there are barns to keep the buffaloes in winter. The barns have no windows and the doors are tightly closed. Young animals are never taken outdoors in winter in the cold climates. Buffaloes are slaughtered together with cattle. Milking is done by hand except at the two existing research stations. Average slaughter weight is 300-350 kg, at the age of 18-20 months. Carcass yield is 53-55 percent. Overall growth rate is 400 g/day.

Dairy performance:

Lactation duration	220-270 days
Milk yield	700-1 000 kg
Milk fat	6.6-8.1 percent
Milk protein	4.2-4.6 percent

Products: a semi-hard cheese called "peyaz peyneri" is made from buffalo milk.
Ayran is a drink with water and buffalo yoghurt. Buffaloes are raised for milk production only as source of income that does not require any expenditure, i.e. in the areas that have natural feeding conditions. The price of buffalo milk is only slightly higher than the price for cows' milk. Meat production is all converted into sausages. The price of buffalo meat is 10 percent less than the price for beef.
Sources: Sekerden et al., 1996a,b; Sekerden et al., 2000, Borghese, 2005.

2. Azeri or Caucasian

This breed originates from the Indo valley (Indian buffalo). There is some evidence that buffalo were raised in Lorestan (Iran) in the 9th Century B.C. since six engraved buffalo heads have been found on a bronze stick from this period.
Population size: 600 000
Description: Black in colour, short horns growing backwards.
Height at withers of adult male is 137 cm, body weight is 400-600 kg.
Height at withers of adult female is 133 cm, body weight is 400-600 kg.
Distribution: In Iran, they are found in West Azerbaijan, East Azerbaijan and the Caspian Sea. In Azerbaijan, everywhere. In Georgia and Armenia, they were widespread until 1940, but then declined.
Husbandry: Housing differs from region to region. They are generally untethered in summer and tied up in winter. In some areas, milking females are tethered all year round.
Average slaughter weight is 300 kg, at the age of 15 months. Carcass yield is 50 percent. Overall growth rate is 420 g/day.

Dairy performance:

Lactation duration	200-220 days
Milk yield	1 200-1 300 kg
Milk fat	6.6 percent

Products: Milk, yoghurt, fresh cream, fresh cheese, butter, ice-cream, rice pudding, churned yoghurt, dried whey, ghee.
In Iran, the price of buffalo milk is twice that of cows' milk. Buffalo skin is used in the leather industry. Buffalo manure is used for fuel in rural areas.
Sources: Latifova, 2000; Turabov, 1991; Turabov, 1997a,b; Naderfard and Qanemi, 1997; Marmarian, 2000; Qanemi 1998; Borghese, 2005.

3. Bangladeshi

Population size: 5 000
Description: Black in colour, white spot on the forehead and tail-switch in some cases. Curled and short horns.
Indigenous Bangladeshi buffaloes of the River type are found in the South-West. In the remaining parts of the country they are either Swamp or crosses of exotic breeds: Nili-Ravi and Murrah type.
Sources: Faruque, 2000.

Figure 1, 2. Anatolian buffaloes in Ilikpinar village (Hatay, Borghese photo, 2002)

Figure 3, 4. Azeri buffaloes (Borghese photo, 2003)

Figure 5. Azeri buffalo, Iran, Mazandaran (Naderfard H. photo, Iran)

Figure 6. Bangladeshi buffaloes in coastal area (Faruque O. photo)

4. Bhadawari

This is an improved local breed. It is the result of selection of Indian breeds of buffalo. It is considered the best breed of buffalo in Uttar Pradesh.

Population size: 30 000.
Description: Copper coloured coat, scanty hair which is black at the roots and reddish brown at the tip. Sometimes it is completely brown. The neck presents the typical white colour ring. Tail switch is white or black and white. Horns are short and grow backwards.
Height at withers of adult male is 128 cm, body weight is 475 kg.
Height at withers of adult female is 124 cm, body weight is 425 kg.
Distribution: It is raised in the Agra and Etawa districts of Uttar Pradesh and in Bhind and Morena districts of Madhya Pradesh.
Husbandry: Buffaloes are traditionally managed under domestic conditions together with the calf. They are hand-milked twice a day. They are fed different kinds of roughages (barley and wheat straw, cornstalks, sugar cane residuals). In addition, they are given concentrate mixtures. If grazing is available, they graze all day long. They are naturally mated. Some villages also provide artificial insemination.

The performance characteristics of the Bhadawari breed maintained at the Indian Grassland and Fodder Research Institute (IGFRI), Jhansi Centre (India) of the Network Project on Buffalo are presented below (Sethi, 2003):

Average body weight (kg)	385.5
Age at first calving (months)	48.6±0.58
First lactation 305 days or less yield (kg)	711±25
All lactation 305 days or less yield (kg)	812±23
All lactation total yield (kg)	781±29
All lactation length (days)	272±4
Average fat (percent)	7.2±0.4 to 13
Average dry period (days)	297±24
Service period (days)	179±10
Calving interval (days)	478±11
Average calf mortality (0-3 months)	12.15 percent

Sources: Alexiev, 1998; FAO, 2003; Sethi, 2003.

Figure 7. Bhadawari cow (Sethi, 2003)

Figure 8. Bhadawari bull with the typical ring on lower side of neck

5. Bulgarian Murrah

From 1962 to 1990, Murrah buffaloes from India were imported into Bulgaria and a new population of buffalo was created by upgrading the local buffalo.

Population size: 14 000
The buffalo population in Bulgaria has dramatically declined since the Second World War, with the advent of Holstein and mechanization. Furthermore, after 1989, privatization forced the cooperative buffalo farms to close down. The private sector is composed of small units which has made selection and recording more difficult.
Description: Black or black and brown or dark grey in colour.
Body weight of adult male is 700 kg.
Body weight of adult female is 600 kg.
Distribution: All over Bulgaria, Romania and South America.
Husbandry: Buffaloes are traditionally managed under domestic conditions together with the calf. They are hand-milked twice a day. Some milking machines are now available. During winter, they are kept in sheds and are fed different kinds of roughages: barley and wheat straw, cornstalks. In addition, they are given concentrate mixtures, sometimes mixed with beet pulp. During the summer, they graze all day long in the marshy areas and in the evening they return to their sheds. They are mated mainly through natural mating. Some villages provide artificial insemination. In state buffalo farms (200-400 buffaloes) they are managed according to their condition: heifers, lactating, pregnant, dry. Milking buffaloes are kept in closed sheds and tied up. During winter, they are allowed outside in paddocks for part of the day, in summer they are allowed to graze. They are always given concentrate mixture in addition to roughage. AI is used on all buffaloes.
Average slaughter weight is 400 kg, at the age of 16 months. Carcass yield is 50.4 percent. Overall growth rate is 750 g/day.

Dairy performance:

Lactation duration	270-305 days
Milk yield	1 800 kg
Milk fat	7.04 percent

Products: Yoghurt and milk by-products. Processed meat products are very important: all kinds of salami and sausages, Pastarma, lukanska and flat sausages.
Sources: Peeva et al, 1991; Peeva, 1996; Alexiev, 1998.

Figure 9, 10. Bulgarian Murrah bull and herd (Alexiev, 1998)

6. Egyptian

Buffaloes were introduced into Egypt from India, Iran and Iraq approximately during the middle of the 7th Century.

The distinction between the different types of Egyptian buffaloes is only environmental. It is the most important and popular livestock for milk production in Egypt.

Population size: 3 717 000
Description: Blackish grey in colour, horn form varies from lyre to sword-shaped. The head is long and narrow, the jaws are long and strong. Ears are long and dropping. The neck is rather long, thin and straight. The forelegs are rather short and heavy boned. Ribs are wide, deep and well sprung. The rump is sloping and the tail setting is low.
Height at withers of adult male is 178 cm, body weight is 600 kg.
Height at withers of adult female is 144 cm, body weight is 500 kg.
Distribution: All over the country, mainly in peri-urban areas and the Nile delta.
Husbandry: The farmer keeps manure in a solid state inside the animal enclosure. The solid manure is taken twice a year and spread in the fields before planting. The animals are slaughtered only in slaughterhouses, following the Islamic practice of cutting the jugular vein. Milking is done by hand, twice a day, mainly by women.
Average slaughter weight is 500 kg, at the age of 18-24 months. Carcass yield is 51 percent. Overall growth rate is 700 g/day.

Dairy performance:

Lactation duration	210-280 days
Milk yield	1 200-2 100 kg
Milk fat	6.5-7.0 percent

Products: The following cheeses are produced with the addition of cow milk: Domiati, Karish, Mish, Rahss.
Sources: El Kirabi, 1995; Nigm, 1996; Ragab and Abdel Salam, 1963; Mokhtar, 1971; Askar et al., 1973; Borghese, 2005.

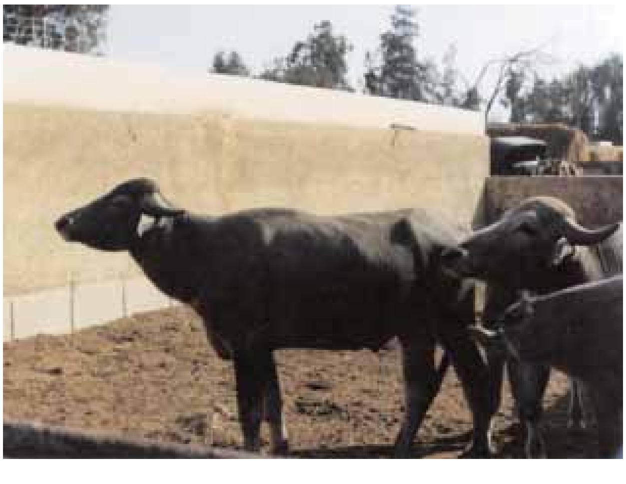



Figure 11, 12. Egyptian buffaloes from Fayum oasis (Borghese photo, 1996)

7. Jafarabadi

The existence of the Jafarabadi breed in Gujarat (India) is referred to in 1938.
Population size: 600 000
Description: Black coloured coat. Massive and long-barreled conformation. Horns are long, heavy and broad and sometimes they cover the eyes.
Height at withers of adult male is 142 cm, body weight varies from 600 to 1 500 kg.
Height at withers of adult female is 140 cm, body weight is about 550 kg, some individuals may weigh as much as 700-800 kg.
Distribution: It is one of the most important breeds in Gujarat. This breed is located principally between the Mahi and Sabarmati rivers in north Gujarat. Some breeding stock has been exported to Brazil.
Husbandry: Buffaloes are traditionally managed in domestic conditions together with the calf. They are hand-milked twice a day. They are fed different kinds of roughages: barley and wheat straw, cornstalks, sugar cane residuals. In addition, they are given concentrate mixtures. If grazing is available, they graze all day long. They are naturally mated. Some villages also provide artificial insemination.

Dairy performance:

Lactation duration	350 days
Milk yield	1 800-2 700 kg
Milk fat	8.5 percent

The performance characteristics of the Jafarabadi breed maintained at the Junagarh Centre (India) of the Network Project on Buffalo are presented below (Sethi, 2003):

Average body weight (kg)	529±13
Age at first calving (days)	1 925±196
First lactation 305 days or less yield (kg)	1 642±283
First lactation total yield (kg)	1 642±283
All lactation 305 days or less yield (kg)	1 950±79
All lactation total yield (kg)	2 097±110
All lactation length (days)	320.1±11.6
Average fat (percent)	7.7±1.0
Average dry period (days)	159.8±10.9
Service period (days)	161.5±14.0
Calving interval (days)	509.8±20.1
Number of services per conception	1.4±0.1
Average calf mortality (0-3 months)	10.75 percent

Sources: Alexiev, 1998; Trivedi, 2000; Sethi, 2003.

Figure 13. Buffalo cows of Jafarabadi breed in Brazil (Alexiev, 1998)

8. Jerangi

Description: Black in colour, with small horns running backwards. It is a small animal.
Distribution: It is localized along the border of Orissa with Andhra Pradesh.
Husbandry: Buffaloes are traditionally managed in domestic conditions together with the calf. If grazing is available, they graze all day long. They are naturally mated.
It is a draught animal with a rapid pace.
Sources: Cockrill, 1974; FAO, 2003.

9. Kuhzestani or Iraqi buffalo

Population size: 200 000
Description: Horns are short and grow upward forming a ring at the end. In size, it is very likely the biggest buffalo breed in the world.
Height at withers of adult male is 148 cm, body weight is 800 kg.
Height at withers of adult female is 141 cm, body weight is 600 kg.
Distribution: In Iran, they are located in Kuhzestan and Lorestan. In Iraq, mainly in the South, in the peri-urban areas of Baghdad and Mosul.
Husbandry: Buffaloes are raised outdoors all through the year. They are housed in paddocks made of local plants (reeds, brushes, palm leaves) with a wall on one side, and three open sides. They are hand fed at the time of milking, morning and evening, with available green forage. They are also fed any type of by-products: waste of sugar cane, reeds from marshy land, home baked wastes. Those that swim in ponds and rivers are also fed aquatic plants.
Milking is done by hand in 95 percent of cases and in a few cases with movable milking machines, there are no milking establishments. Male buffaloes are very hazardous, strong and difficult to handle and always aggressive to humans. In a few cases, for tilling operations, they are castrated. Females are very sensitive to non-familiar persons and reduce milk yield with non-familiar milkers. Generally females are also not docile. Average slaughter weight is 400 kg, at the age of 12 months. Carcass yield is 50 percent. Overall growth rate is 580 g/day.

Dairy performance:

Lactation duration	200-270 days
Milk yield	1 300-1 400 kg
Milk fat	6.6 percent

Products: Milk, yoghurt, fresh cream, fresh cheese, butter.
Sources: National Buffalo Project, 1988; Magid, 1996; Saadat, 1997; Borghese, 2005.

Figure 14, 15. Iraqi buffalo near Mosul (Iraq) on the Tigris river
(Al-Jamass R. photo)

10. Kundi

Domestication of draught animals in the Indus valley civilization is referred to about 4 500 years ago.
It is the second most important breed in Pakistan.
Population size: 5 500 000.
Description: Black in colour, short horns.
Height at withers of adult male is 135 cm, body weight is 700 kg.
Height at withers of adult female is 125 cm, body weight is 600 kg.
Distribution: Widespread in South Pakistan Sindh region.
Husbandry: Buffaloes are traditionally managed under domestic conditions together with the calf. They are hand milked twice a day. They are fed different kinds of roughages: barley and wheat straw, cornstalk, sugar cane residuals. In addition, they are given concentrate mixtures. If grazing is available, they graze all day long. They are mated mainly through natural mating. Some villages also provide artificial insemination.
There are a few state buffalo farms with 500 to 1 000 milking buffaloes.

Dairy performance:

Lactation duration	320 days
Milk yield	2 000 kg
Milk fat	7.0 percent
Milk protein	6.0 percent

Sources: Alexiev, 1998; Tunio A.N., 1999.

11. Lime

The pure Lime breed is believed to have originated from the wild Arna and has been domesticated throughout the known history of Nepal.
The Lime buffalo is estimated to constitute 35 percent of the total indigenous buffalo population in the hills and mountains of the country.
Population size: 700 000
Description: Light brown colour, small body size, characteristic chevrons of grey or white hair below the jaws and around the brisket, small sickle-shaped horns, curved towards the neck.
Height at withers of adult female is 115 cm, body weight is 399 kg.
Distribution: The breed is found in the mountains, high hills and hill river valleys in Nepal. It is not found in the Terai plane.
Husbandry: Mainly raised under migratory conditions or semi-stall systems. The breed is a voracious eater and is fed only low quality feedstuff such as rice, wheat and millet straw. Small farmers exchange breeding animals within and between villages. Among the migratory herds, male and females are grazed together and mate freely during the breeding season from June to November.
Females are legally banned from slaughter; only culled animals are slaughtered for meat.

Dairy performance:

Lactation duration	351 days
Milk yield	875 kg
Milk fat	7.0 percent

Products: milk, ghee, meat, swiss-cheese, yoghurt, leather.
Sources: Rasali, 1997; Rasali, 1998a,b.

Figure 16, 17. Typical Lime buffalo (Rasali D. Photo, Nepal)

12. Manda

This is an improved local breed, resulting from the selection of Indian breeds of buffaloes.
Population size: 100 000
Description: Uni colour: grey, brown.
Distribution: It is raised along the border of Orissa with Andhra Pradesh.
It is a hardy breed, able to work under the hot sun. It is not very demanding in terms of feeding and acclimatizes very easily to various conditions.

Dairy performance:
Milk yield 4 kg/day
Products: Milk, ghee, cream, meat.
Sources: Cockrill, 1974; FAO, 2003.

13. Mediterranean or European

The Mediterranean buffalo originates from the Indian buffalo. It was introduced into Europe with the advent of Islam and the Arab occupation as well as through other central European conquerors in the 6th and 7th Centuries.
The buffalo population in Europe has been dramatically declining since the Second World War, with the advent of Holstein and mechanization.
Population size: 400 000
Description: Black, black and brown, dark grey coat. Horns are flat at the bottom, backwards and slightly outwards pointed, and backwards straightened; the top is pointed inwards. They have a compact conformation with a deep and wide chest as well as a developed pectoral. The back is short. The rump is short. The udder is medium size with squarely placed quarters and halves; the teats are cylindrical. Where machine milking is popular (only in Italy) udders are more regular and better shaped. Size, weight and productivity vary a lot according to the environment and management. Average herd size is below five breedable buffaloes in most countries, except in Italy where it is 90. The proportion of breedable females to total buffaloes is about 45 percent except in Italy where it is 62 percent, since males have little market potential.
The body weight of the adult female is 450-650 kg.
Distribution: Italy: 265 000 (Mediterranean Italian breed); Romania: 100 000; Brazil: 10 000; a few thousand in Greece, Albania and TFYR Macedonia; a few hundred in the United Kingdom, Germany, The Netherlands, Switzerland and Hungary.

Husbandry: 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. In the favourable season they are allowed to graze during the day. In Italy, they are housed loose in paddocks all year long, with the same modern systems used for dairy cows. One third of Italian buffaloes are also put out on pasture in the favourable seasons, or green forage "cut-and-carry" such as alfalfa can also be used. Maize silage, concentrates and by-products are the basic foodstuffs in Italy.

Performance varies very much depending on the area. There is no common practice to wean buffalo calves. When milking is done by hand, both male and female calves suckle from the dam. In some cases they suckle from a dairy cow. This results in a wide difference in daily gain up to weaning, as well as weaning weight and age. Males are now in greater demand as meat producers, therefore increased attention is being paid to their feeding and health.

Average daily milk yield reveals a huge variability, mainly depending on the feeding system. It can range from 3 to 4 kg milk/day for poorly fed animals to 15 kg/day in intensive management systems. In Bulgaria, Romania, TFYR Macedonia, Greece and Albania, extensive management systems are employed.
Average slaughter weight is 250-400 kg, at the age of 12-15 months.

Dairy performance:

Lactation duration	270 days
Milk yield	900-4 000 kg
Milk fat	8.0 percent
Milk protein	4.2-4.6 percent

Products: Mozzarella, treccia, scamorza and other cheeses, ricotta (Italy); Vladaesa cheese, Braila cheese (Romania); White brine cheese (Bulgaria, Romania); yoghurt, meat and meat industry products: bresaola, salami, sausages, cacciatorini (little salami), etc.,
Sources: Borghese and Moioli, 1999; Borghese et al., 2000; Borghese, 2005; Stravaridou, 1998; Bikocu, 1995; Popovici, 1996; Bunewski, 2000.

Figure 18, 19. Mediterranean Italian buffalo cow and herd in intensive system, Tor Mancina (Rome). (Borghese photo, 2004)

14. Meshana

The existence of the Meshana breed in north Gujarat, India, is referred to in 1940. This breed is the result of selection of Indian breeds of buffalo.
Population size: 400 000
Description: Characteristics are intermediate between Surti and Murrah. Jet black skin and hair are preferred. Horns are sickle-shaped but with more curve than the Surti. The udder is well developed and well set. Milk veins are prominent.
Body weight of adult male is 570 kg.
Body weight of adult female is 430 kg.
Distribution: Concentrated between the Mahi and Sabarmati rivers in Gujarat (India).
Husbandry: Buffaloes are traditionally managed under domestic conditions together with the calf. They are hand-milked twice a day. They are fed different kinds of roughages: barley and wheat straw, cornstalks, sugar cane residuals. In addition, they are given concentrate mixtures. If grazing is available, they graze all day long. They are naturally mated. Some villages also provide artificial insemination.

Dairy performance:

Lactation duration	305 days
Milk yield	1 800-2 700 kg
Milk fat	6.6-8.1 percent
Milk protein	4.2-4.6 percent

Products: milk, ghee, cream, meat.

According to Sethi (2003), the average milk yield per animal per day in Mehsana buffaloes ranges from 4.37 to 4.81 kg. However, a systematic Mehsana breed improvement programme through field progeny testing was launched in 1985 in the milk shed area of the Mehsana district. 107 bulls were tested in eight batches. Average 305 day first lactation milk yield of 50 daughters of the top proven bulls of the first four batches in these buffaloes ranged from 2 085 to 2 312 kg.
Sources: Trivedi, 2000; Sethi, 2003.

Figure 20. Meshana heifers (Gujarat, India)
(Early Bulletin of National Dairy Development Board)

15. Murrah

In the north-west of the sub-Indian continent, buffaloes have long been selected for milk yield and curled horn. It is the most important and well-known buffalo breed in the world.
Population size: 2 000 000
Description: Black in colour. Massive and stocky animals, heavy bones, horns are short and tightly curled. Placid.
Height at withers of adult male is 142 cm, body weight is 750 kg.
Height at withers of adult female is 133 cm, body weight is 650 kg.
Distribution: From its origins in the centre of Haryana, it has spread to the Punjab, Ravi and Sutley valleys, north Sind and Uttar Pradesh. It has been exported to Brazil, Bulgaria and many countries of eastern Asia.
Husbandry: Buffaloes are traditionally managed in domestic conditions together with the calf. They are hand-milked twice a day. They are fed different kinds of roughages (barley and wheat straw, cornstalks, sugar cane residuals). In addition, they are given concentrate mixtures. If grazing is available, they graze all day long. They are naturally mated. Some villages also provide artificial insemination.

Dairy performance:

Lactation duration	305 days
Milk yield	1 800 kg
Milk fat	7.2 percent

Products: Milk, ghee, cream, meat.

Sethi (2003) reported the performance characteristics at the Haryana Agricultural University (HAU) Centre, India.

Average body weight (kg)	495
Age at first calving (months)	50.6±2.0
First lactation 305 days or less yield (kg)	1 894±44
All lactation 305 days or less yield (kg)	2 183±136
All lactation total yield (kg)	2 226±152
All lactation length (days)	305±16
Average fat (percent)	6.70
Average dry period (days)	144±26
Service period (days)	146±27
Calving interval (days)	479±33

Sources: Reddy and Taneja, 1982; Pal et al., 1971; Cockrill, 1974; FAO, 2003, Sethi, 2003.

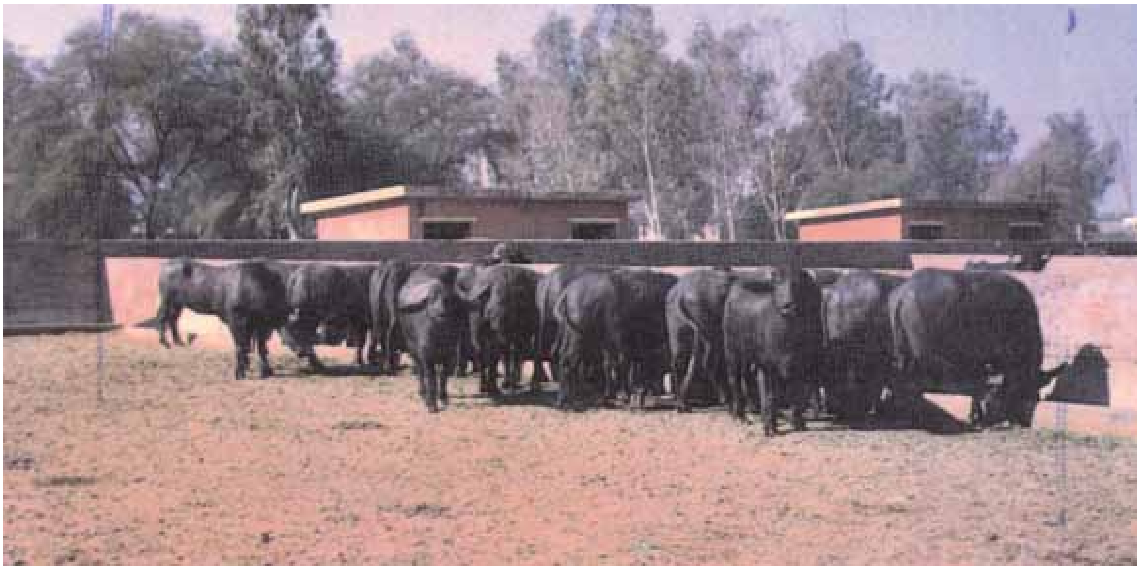
16. Nagpuri

It is an improved local breed, the result of a selection of Indian breeds of buffaloes.
Population size: 360 000
Description: Black in colour, sometimes there are white markings on the face, legs and switch. Horns are 50-65 cm long, flat-curved and carried back near to the shoulders. Nasal flap is mostly absent and even if present is very short.
Height at withers of adult male is 140 cm, body weight is 522 kg.
Height at withers of adult female is 130 cm, body weight is 408 kg.
Distribution: This breed is raised in the Nagpur, Wardha and Berar districts of Madhya Pradesh.

Husbandry: Buffaloes are traditionally managed under domestic conditions together with the calf. They are hand-milked twice a day. They are fed different kinds of roughages: barley and wheat straw, cornstalks, sugar cane residuals. In addition, they are given concentrate mixtures. If grazing is available, they graze all day long. They are naturally mated.

Dairy performance:

Lactation duration 243 days
Milk yield 825 kg
Milk fat 7.0 percent
Products: Milk, ghee, cream, meat.
Sources: Cockrill, 1974; FAO, 2003; Sethi, 2003.



Figures 21, 22. Murrah bull and herd at the Buffalo Research Institute (Hisar, Haryana, India)

17. Nili-Ravi

Domestication of draught animals in the Indus valley civilization is referred to about 4 500 years ago. Nili and Ravi were two different breeds until 1950, but after this period it was difficult to distinguish between the two breeds probably due to an overlapping selection criteria of breeders. Thus, the common name Nili Ravi became popular. It is the most important livestock in Pakistan. It is also present in India and in the Punjab. This breed is similar to the Murrah in almost all characteristics except for the white markings on extremities and walled eyes; horns are less curled than in the Murrah; the udder is well shaped and extends well forward up to the naval flaps.
Population size: 6 500 000
Description: Black in colour, short horns.
Height at withers of adult male is 135 cm, body weight is 700 kg.
Height at withers of adult female is 125 cm, body weight is 600 kg.
Distribution: All over Pakistan but mainly in the Punjab.
Husbandry: Buffaloes are traditionally managed under domestic conditions together with the calf. They are hand-milked twice a day. They are fed different kinds of roughages: barley and wheat straw, cornstalks, sugar cane residuals. In addition, they are given concentrate mixtures. If grazing is available, they graze all day long. They are naturally mated. Artificial insemination is available at the state farms and in some villages.

Dairy performance:

Lactation duration	305 days
Milk yield	2 000 kg
Milk fat	6.5 percent

Products: Milk, ghee, cream, meat.

The highest milk yielder at the Institute at Bahadurnagar produced over 4 000 kg while the breed champion produced as high as 6 535 kg in 378 days (Alexiev, 1988).
The performance characteristics of the Nili Ravi breed maintained at the Central Institute for Research on Buffaloes (CIRB) Sub-campus Centre (India) of the Network Project on Buffalo are presented below (Sethi, 2003):

Average body weight (kg)	546
Age at first calving (months)	39.97
First lactation 305 days or less yield (kg)	1 565
First lactation total yield (kg)	1 571
All lactation 305 days or less yield (kg)	1 946
All lactation total yield (kg)	1 969
All lactation length (days)	299
Average fat (percent)	7.1
Average dry period (days)	131
Service period (days)	151
Calving interval (days)	443
Number of services per conception	1.6
Average calf mortality (0-3 months)	7

Sources: Alexiev, 1998; Cockrill, 1974; FAO, 2003; Sethi, 2003.

Figure 23. Nili-Ravi bull at Livestock Research Institute, Bahadurnagar, Okara, Pakistan (Borghese photo, 1992)

Figure 24. Nili-Ravi bull cow at Livestock Research Institute, Bahadurnagar, Okara, Pakistan (Borghese photo, 1992)

18. Parkote

The hill buffalo of Nepal, named Parkote buffaloes, are the typical buffalo of the mid-hills and river valleys. However, due to the traditional practice of crossbreeding with Lime buffalo as well as recent crossbreeding with Indian Murrah, their population in pure form is now declining. At present the pure bred population is estimated at only 25 percent of the indigenous population in the hills and mountains of Nepal.

Population size: 500 000

Description: The Parkote are dark in coat colour and of medium-built body size, with sword-shaped horns directed laterally or towards the back. Black skin, black muzzle, black eyebrows. Usually they have no markings on the legs.

Distribution: The breed is raised in the mountains, high hills and hill river valleys of Nepal.

Height at withers of adult female is 114 cm, body weight is 410 kg.

Husbandry: Mainly raised under migratory conditions or semi-stall systems. The breed is a voracious eater and is fed only low quality feedstuff such as rice, wheat and millet straw. Small farmers exchange breeding animals within and between villages. Among the migratory herds, male and females are grazed together and mated freely during the breeding season from June to November.

Females are legally banned from slaughter; only culled animals are slaughtered for meat.

Figure 25. Typical Parkote buffalo (Rasali D. photo, Nepal)

Dairy performance:

Lactation duration	351 days
Milk yield	875 kg
Milk fat	7.0 percent

Products: milk, ghee, meat, swiss-cheese, yoghurt, leather.
Sources: Rasali, 1997; Rasali, 1998a,b.

19. Sambalpuri

Description: Black in colour, with white switch on tail, with narrow and short horns, curved in a semi-circle, running backward, then forward at the tip.
Distribution: This breed is raised around Bilaspur in Madhya Pradesh (India).
Husbandry: Buffaloes are traditionally managed under domestic conditions together with their calf. They are hand-milked twice a day. They are fed different kinds of roughages: barley and wheat straw, cornstalks, sugar cane residuals. In addition, they are given concentrate mixtures. If grazing is available, they graze all day long. They are naturally mated. It is a good healthy draught animal with a rapid pace and it is comparatively the most productive breed of the region. Some exceptional buffaloes may yield as high as 2 300 to 2 700 kg in about 340 days.

Dairy performance:

Lactation duration	350 days
Milk yield	2 400 kg

Products: Milk, ghee, cream, meat.
Sources: Sethi, 2003

20. Surti

The existence of the Surti breed in north Gujarat (India) is referred to in 1940. It is the result of a selection of Indian breeds of buffalo. It is one of the most important breeds in Gujarat and in Rajasthan.

Population size: 500 000
Description: Black colour coat, skin is black or reddish. They have two white chevrons on the chest. Animals with white markings on forehead, legs and tail tips are preferred. Horns are flat, of medium length, sickle shaped and are directed downward and backward, and then turn upward at the tip to form a hook. The udder is well developed, finely shaped and squarely placed between the hind legs. The tail is fairly long, thin and flexible ending in a white tuft.
Height at withers of adult male is 131 cm; body weight is 700 kg.
Height at withers of adult female is 124 cm; body weight is 550-650 kg.
Distribution: Concentrated between the Mahi and Sabarmati rivers in Gujarat (India).

Husbandry: Buffaloes are traditionally managed under domestic conditions together with the calf. They are hand-milked twice a day. They are fed different kinds of roughages (barley and wheat straw, cornstalks, sugar cane residuals). In addition, they are given concentrate mixtures. If grazing is available, they graze all day long. They are naturally mated. Some villages also provide artificial insemination.

Dairy performance:

Lactation duration	350 days
Milk yield	2 090 kg
Milk fat	6.6-8.1 percent
Milk protein	4.2-4.6 percent

Products: Milk, ghee, cream, meat.

Sethi (2003) reported the following performance characteristics of the Surti breed maintained at the Maharana Pratap University of Agriculture and Technology (MPUAT) (India) Vallabhnagar Centre of the Network Project on Buffalo:

Average body weight (kg)	462±7.0
Age at first calving (months)	53.2±1.7
First lactation 305 days or less yield (kg)	1 295±57
All lactation 305 days or less yield (kg)	1 477±42
All lactation total yield (kg)	1 547±50
All lactation length (days)	311±7
Average fat (percent)	8.10
Average dry period (days)	234±21
Service period (days)	207±17
Calving interval (days)	510±16
Number of services per conception	2.55
Average percentage calf mortality (0-3 months)	7.0

21. Tarai

Population size: 940 000
Description: Black to brown colour coat; sometimes there is a white blaze on the forehead, tail switch is white. Horns are long and flat with coils bending backwards and upwards.
Height at withers of adult male is 127 cm; body weight is 375 kg.
Height at withers of adult female is 120 cm; body weight is 325 kg.
Distribution: This breed is raised in the Agra and Etawa districts of Uttar Pradesh and in the Bhind and Morena districts of Madhya Pradesh (India).
Husbandry: Buffaloes are traditionally managed under domestic conditions together with the calf. They are hand-milked twice a day. They are fed different kinds of roughages: barley and wheat straw, cornstalks, sugarcane residuals. If grazing is available, they graze all day long. The breed is well adapted to the difficult climatic and feeding conditions of the Tarai region. Sometimes it is crossbred with the Murrah.

Dairy performance:

Lactation duration	250 days
Milk yield	450 kg
Milk fat	6.6-8.1 percent
Milk protein	4.2-4.6 percent

Products: Milk, ghee, cream, meat.

Sources: Cockrill, 1974; FAO, 2003.

22. Toda

Population size: 6 000
Description: Unicolour, light or dark grey. Horns are set wide apart with recurved tip inwards, outward and forward. They are large and powerful animals.
Height at withers of adult male is 160 cm; body weight is 380 kg.
Height at withers of adult female is 150 cm; body weight is 380 kg.
Distribution: This breed is raised in the Nilgiris hills of Madras.
Husbandry: The breed is semi-wild and raised under semi-nomadic conditions, with total grazing.

Dairy performance:

Lactation duration:	200 days
Milk yield	500 kg

Products: Milk, ghee, cream, meat.

Sethi (2003) reported the following performance:

Average birth weight	27.9±0.43 kg
Average 305 days lactation yield	501±10.6 kg
Average lactation length	198.6±2.8 days
Average daily milk yield	2.53±0.44 kg
Average fat (percent)	8.22±0.08
Average carcass weight in adults	142.1±10.1 kg
Average calving interval	15.74±0.4 months

Sources: Cockrill, 1974; FAO, 2003; Sethi, 2003.

Figure 26. Surti cow (Sethi, 2003)
Sources: Trivedi, 2000; Sethi, 2003.

Figure 27. Toda buffalo in its natural habitat (ICAR Ad hoc Scheme, Breeding Research Station, Sandynallah)

References

Alexiev, A. 1998. The Water Buffalo. St. Kliment Ohridski University Press, Sofia.

Askar, A.A., Ragab, M.T. and Ghazy, M.S. 1973. Repeatability and heredity of some charcteristics in Egyptian buffalo. Ind. J. Dairy Sci., 6: 61-65.

Bikocu, Y. 1995. Buffalo population and production in Albania. Buffalo Newsletter, 4: 8.

Borghese, A. and Moioli, B. 1999. Buffalo population and products in Europe and the Middle Eastern countries. International Conference on Sustainable Animal Production. Hisar, India, 24 to 30 Nov.: 245-257.

Borghese, A., Moioli, B. and Tripaldi, C. 2000. Buffalo milk: processing and product development in the Mediterranean countries. Third Asian Buffalo Congress, Kandy, Sri Lanka, 27 to 31 Mar.: 37-46.

Borghese, A. 2005. Personal information.

Bunewski, G. 2000. Buffalo breeding in TFYR of Macedonia. Proc. Workshop on Animal Recording and Management Strategies for Buffaloes. ICAR Technical Series, 4: 77-78.

Cockrill, W.R. 1974. The husbandry and health of the domestic buffalo, FAO, Rome.

El-Kirabi, F. 1995. Buffalo population and production in Egypt. Buffalo Newsletter, 3: 8-9.

FAO. 2003. www.FAO.org/DAD-IS.

Faruque, O. 2000. Buffalo breeding in Bangladesh. Proc. Workshop on Animal Recording and Management Strategies for Buffaloes. ICAR Technical Series, 4: 51-54.

Latifova, E. 2000. Case study on buffalo recording. Breeding and management strategies of buffalo in Azerbaijan. Proc. Workshop on Animal Recording and Management Strategies for Buffaloes. ICAR Technical Series, 4: 45-50.

Magid, S. 1996. Buffalo population and production in Iraq. Buffalo Newsletter, 6: 6-7.

Marmarian, Y. 2000. Buffalo breeding in Armenia. Proc. Workshop on Animal Recording and Management Strategies for Buffalo. ICAR Technical Series, 4: 73 76.

Mason, I.L. 1996. A World Dictionary of Livestock Breeds, Types and Varieties, 4th Edition, Wallington, UK.

Mokhtar, S.A. 1971. Study on some economic traits of Holstein Friesian cattle in U.A.R. M.Sc.Thesis, Fac. Agriculture, Ain Shams Univ., Cairo, Egypt.

Naderfard, H.R. and Qanami, A. 1997. Buffalo breeding in Iran. Proc. Fifth Buffalo Congress, Caserta, 13 to 16 Oct.: 942-943.

National Buffalo Project, 1988. Ministry of Jihad, Teheran, Iran.

Nigm, A.A. 1996. Characterization of Egyptian buffalo. Proceedings of International Symposium on Buffalo Resources and Production Systems. Giza, Egypt, 17 Oct.

Pal, S., Basu, S.B. and Sengar, O.P.S. 1971. Heredity and genetic correlations for milk constituents in Murrah buffaloes. Ind. J. Animal Sci., 41: 1019-1021.

Peeva, T., Vankov, K. and Vasilev, M. 1991. Persistency index of lactation milk production in buffalo cows. Proc. of the Third World Buffalo Congress, Agricultural Academy, Varna, Sofia, 13 to 18 May: 61.

Peeva, T. 1996. Buffalo population and production in Bulgaria. Buffalo Newsletter, 4: 6-7.

Popovici, I. 1996. Buffalo population and production in Romania. Buffalo Newsletter, 5: 9-10.

Qanemi, A. 1998. Buffalo population and production in Iran. Buffalo Newsletter, 10: 12-14.

Ragab, M.T. and Abdel-Salam, M.F. 1963. Heredity and repeatability of bodyweight and growth rate in Egyptian buffalo and cattle. Egypt. J. Anim. Prod., 3: 15-26.

Rasali, D.P. 1997. Present status of indigenous buffalo genetic resources in the western hills of Nepal. Proceedings of the Fourth Global Conference on Conservation of Domestic Animal Genetic Resources. Rare Breeds International: 168-170.

Rasali, D.P., Joshi, H.D., Shrestha, H. and Gautam, D.C. 1998a. Assessment of the infertility situation in cows and buffaloes in the western hills of Nepal. Lumle Agricultural Research Centre. Working Paper, 98/40: 16.

Rasali, D.P., Joshi, H.D., Patel, R.K and Harding, A.H. 1998b. Phenotipic clusters and karyotypes of indigenous buffaloes in the western hills of Nepal. Lumle Agricultural Research Centre. Technical Paper, 98/2: 24.

Reddy, C.E and Taneja, V.K. 1982. Genetic trends for 300 day first lactation milk yield in Murrah buffaloes. Second World Congress on Genetics Applied to Livestock Production, Madrid, 4 to 8 October 1982: 152-156.

Saadat, M.N. 1997. In "Dairy goats and buffalo production". University of Teheran.

Sekerden, O., Kebapci, M. and Kopar, A. 1996a. Buffalo population and production in Turkey. Buffalo Newsletter, 5: 7-8.

Sekerden, O., Kebapci, M. and Kopar, A. 1996b. Blood transferrin types and genetic structure for transferrin types of buffalo population in Samsun province. Buffalo Newsletter, 5: 11-12.

Sekerden, O., Dogrul, F. and Erdem, H. 2000. Blood serumtransferrin types and genetic structure for transferrin types and growth performance of Anatolian buffalo. Kocatepe Enstitutu manda surusu sut ve dol verim ozellikleri. Ataturk University.

Sethi, R.K. 2003. Buffalo Breeds of India. Proc. of Fourth Asian Buffalo Congress, New Delhi, India, 25 to 28 Feb.

Stravaridou, S. 1998. Buffalo population and production in Greece. Buffalo Newsletter, 9: 7.

Trivedi, K. 2000. Buffalo recording systems in India. Proc. Workshop on Animal Recording and Management Strategies for Buffalo. ICAR Technical Series, 4: 5 12.

Tunio, A.N. 1999. Personal communication.

Turabov, T. 1991. Selection of Caucasian breed of buffalo. PhD Thesis. Academy of Agriculture, Baku, Azerbaijan.

Turabov, T. 1997a. The modern condition of buffalo production in Azerbaijan and the ways for further improvement. Proc. of the Fifth Buffalo Congress, Caserta, 13 to 16 Oct.: 884-888.

Turabov, T. 1997b. Buffalo population and production in Azerbaijan. Buffalo Newsletter, 8: 9-10.

Chapter IV

REPRODUCTIVE EFFICIENCY IN FEMALE BUFFALOES

Vittoria Lucia Barile

Istituto Sperimentale per la Zootecnia
(Animal Production Research Institute)
Via Salaria 31, 00016 Monterotondo (Rome), Italy

Introduction

The world buffalo population is continuously increasing and was estimated to be more than 170 million in 2003 as reported by FAO (2004). More than 95 percent of the world population is found in Asia where buffalo play a leading role in rural livestock production. Over the last decades buffalo farming has widely expanded in Mediterranean areas and in Latin American countries and several herds have also been introduced in Central and Northern Europe.

Buffalo farming is increasing in Italy too due to the growing market demand for buffalo milk that is utilized exclusively for the production of "mozzarella cheese". Another economic benefit deriving from buffalo milk production is that buffalo milk is not restricted by the specific European Union (EU) directive called "milk quotas", introduced to stop the increase of cow milk production. In fact, this regulation induced some farmers, in areas where Friesian cattle are traditionally reared, to consider the option of breeding milking buffaloes for the production of "mozzarella" cheese. This led to an expansion of buffalo breeding in the north of Italy too, away from the customary area, traditionally situated in southern Italy (Campania, Lazio and Puglia regions) where 95 percent of the Italian buffalo population is reared.

In spite of this expansion in buffalo breeding, there was no improvement in milk and meat production due to slow genetic progress. The productivity increase obtained over the last years is due mainly to an improvement in management techniques rather than to genetic selection. Reproductive efficiency is the primary factor affecting productivity and is hampered in the female buffalo by a delayed attainment of puberty, seasonality, long post-partum anoestrus and subsequent calving interval, and poor oestrus expression. Regarding the latter, artificial insemination (AI) which is the normal practice in cattle breeding, is limited in buffaloes due to the weakness of oestrus symptoms and variability of oestrus length that makes oestrus detection very difficult.

Studies have been undertaken in order to better understand the reproductive physiology of the buffalo and the factors affecting its behaviour. Considerable attention has been paid to reproductive endocrinology over the last two decades, with the aim of developing models to improve reproductive efficiency, particularly when controlled breeding techniques are utilized.

Puberty

Puberty in buffalo is delayed compared with cattle (Jainudeen and Hafez, 1993). The age at puberty is difficult to establish because of difficulties in oestrus detection in this species and most estimations appear to have been extrapolated from the age at first calving. According to Jainudeen and Hafez (1993), the River type exhibit first oestrus earlier (15 to 18 months) than the Swamp type (21 to 24 months). First conception occurs at an average body weight of 250 to 275 kg, which is usually attained at 24 to 36 months of age.
There is a large variation in age at puberty in different countries (Table 1).

In one of the first investigations to study the phenomenon of puberty and first conception in buffalo heifers Hafez (1955) reports that in Egyptian buffalo, on the basis of mating behaviour

Table 1. Puberty in buffalo heifers as reported by various authors.

Author	**Type or Breed**	**Age at puberty**	**BW (kg)**	**Age at first conception**	**BW (kg)**	**Age at first calving**
Hafez (1955)	Egyptian	406 d (13.5 m)	198	647d (21.5 m)	319	
Mohamed et al. (1980)	Egyptian	9.9 m				
Barkawi et al. (1989)	Egyptian	24.7 m	310			
Salama et al. (1994)	Egyptian	15.4 m	271			
Madan (1988)	Indian	16-40 m				
Saini et al. (1998)	Murrah	36.5 m 33.1 m	355.8 322.3			
Pathodiya et al. (1999)	Surti					1683 d (56.1 m)
Sule et al. (2001)	Surti	1365 d (45.5 m)		1418 d (47.3 m)		
Gogoi et al. (2002)	Murrah Surti					53.8 m 51.5 m
Ishaq (1972)	Nili-Ravi	30-33 m	450-519			
Naqvi and Shami (1999)	Nili-Ravi	976 d (32.5 m)				
Le Xuan Cuong (1983)	Vietnamese Swamp	30-36 m				
Kamonpatana et al. (1987)	Asian Swamp	24-25 m	300			
Tulloc and Grassia (1981)	Australian Swamp	14-19 m				
McCool et al. (1988)	Australian Swamp	30.3 m	318			
Okuda et al. (1999)	Brasilian	540 d (18 m)				850 d (28 m)
Ferrara (1964)	Italian					36 m
Salerno (1974)	Italian			27 m		39 m
Zicarelli et al. (1977)	Italian			26-35 m		44.7 m
Borghese et al. (1994a)	Italian	575.4 d (19.1 m) 623.1 d (20.7 m)	359.1 390.1			

d: days; m: months.

and rectal examination of uterus and ovaries, the average age at first oestrus and at first conception was 406 and 647 days respectively, with a body weight at first oestrus and first conception of 198 and 319 kg respectively. The period elapsing from first oestrus to first conception ranged from 52 to 438 days. More recently, Mohamed et al. (1980) kept calves with good feeding levels and sprayed them with water during the hot months and reported the youngest age at puberty for the Egyptian buffalo (9.9 months); while Barkawi et al. (1989), under the common practices in the state farms, reported the oldest age (24.7 months at 310 kg body weight). Salama et al. (1994) with an improved feeding system and managerial practices, and taking into account progesterone value to define more accurately the onset of puberty, obtained the average age at puberty of 15.4 months with an average body weight of 271 kg.

For the Indian buffalo, Madan (1988) reports a large variation in age at puberty ranging from 16 to 40 months depending on the breed, with an earlier age in the Surti and a later age in the Nagpuri. In contrast, Sule et al. (2001) reports in Surti buffalo an average first heat and first conception of 1365.06±12.85 and 1418.6±13.16 days (about 45.5 and 47.3 months) respectively. According to Saini et al. (1998), Murrah buffalo kept under normal management at the University farm, reach puberty at 36.5 months and 355.8 kg body weight, while improving management and splashing buffaloes with water during the hot period, shorten the age at first oestrus to 33.1 months and to 322.3 kg body weight. Gogoi et al. (2002) studying the age at first calving of Murrah and Surti buffaloes from some government farms, found that Murrah buffaloes had a higher age than Surti buffaloes (53.88±0.48 *vs* 51.51±1.18 months), while Pathodiya et al. (1999) found an average age at first calving for the Surti buffaloes of 1683.48±34.86 days (about 56.1 months).

In Pakistan, Naqvi and Shami (1999) studied the age at sexual maturity in the Nili-Ravi buffaloes and report a mean age of 976.49±9.2 days (about 32.5 months) ranging from 957.93±10.68 to 1015.26±17.39 days depending on farms. Similarly, Ishaq (1972) found for the Nili-Ravi an age at puberty of 30 - 33 months and at 450-519 kg body weight.

Kamonpatana et al. (1987) in the Swamp buffalo report a mean age of 24 to 25 months and a body weight of 300 kg at sexual maturity. In the Vietnamese Swamp buffalo, Le Xuan Cuong (1983) states that puberty is achieved between 30 and 36 months.

According to Tulloch and Grassia (1981), puberty in the Australian Swamp buffalo occurs between 14 and 19 months of age, while McCool et al. (1988), on the basis of progesterone profiles, reports a mean age at puberty of 30.3±6.1 months at a body weight of 318±54 kg.
For buffalo bred in Brazil, Okuda et al. (1999) report that the age at sexual maturity and the age at first calving averaged 540.9±146.88 days (about 18 months) and 850.0±169.13 days (about 28 months) respectively.

For the Italian buffalo data refer more to the age at first calving rather than the age at puberty. Ferrara (1964) reported an age at first calving of 36±4.7 months; likewise Salerno (1974) reported 27 months as the age at first conception and 39 months as the age at first calving. According to Zicarelli et al. (1977) Italian buffalo heifers on average have first conception at 26-35 months and first calving at 44.7 months. Later De Franciscis (1988) reported 32-33 months as the age at first calving. Borghese et al.(1994a), on the basis of progesterone levels and rectal examination of uterus and ovaries, stated that Italian buffalo heifers on average showed the first high value of progesterone at 575.4±84.5 days (about 19.1 months) and 359.1±51.8 kg of body weight, while they showed ovarian cyclic activity at 623.1±81.2 days (about 20.7 months) and 390.1±50.9 kg. Age and weight at puberty such as ovarian cyclic activity were affected by different farm conditions especially by feeding levels that improved growth and sexual maturity.

The delay in puberty and the consequent delay in conception is one of the problems that lead to the low reproductive efficiency of the buffalo species, thus lengthening the non-productive life. Many factors influence age at puberty, such as breed, season, climate, nutrition and growth rate, and several experiments have been carried out at our institute aimed at advancing the age at first calving (Borghese et al., 1993a, 1994a, 1994b, 1996; Terzano et al., 1996; Borghese et al., 1997; Terzano et al.,1997). The pre- weaning and weaning systems are important in promoting growth and achieving puberty, therefore attention must be given to heifer management needs beginning from birth to ensure a correct weight increase. In fact, the animals that showed a higher daily gain before the trials reached puberty in a shorter time. The age at puberty is affected by the dietary energy level. The heifers fed with a high level diet (5.56 MFU/d) had a daily gain of 562 g *vs* 465 g of the heifers fed with a low level diet (4.42 MFU/d), and reached puberty 30 days earlier. However, it is possible to rear heifers on pasture obtaining the same performance of those reared with intensive feeding on condition that the daily gain is nearly 600 g/day. Heifers on pasture realized their reproductive performances with less energy consumption, the best feed efficiency and the lowest cost in terms of feeding stuff and management. Campanile et al. (2001), in a study on the effects of long-term and short-term nutritional management on growth and conception in buffalo heifers, concluded that nutritional management and growth from the time of weaning and during the pre-pubertal period has a considerable influence on age and body weight at first conception in buffalo heifers. In fact heifers bred with a good early management system conceived at a younger age compared with the others (543±16 and 844±11 days respectively). They also observed that the negative effects of early nutritional deficiency on reproductive function are not surmounted by a relatively short-term period of dietary supplementation.

Simulating the hormonal changes occurring around puberty may induce sexual maturity in heifers. Trials to induce and synchronize oestrus in buffalo heifers have been undertaken, although to a lesser extent than in cattle (Saini et al., 1988; Honnapagol and Patil, 1991; Andurkar and Kadu, 1995; Zicarelli et al., 1997a). Saini et al. (1988), using PRID (progesterone-releasing intravaginal device) plus PMSG (Pregnant Mare Serum Gonadotrophin) to induce oestrus in non-cycling buffalo heifers, reported that all animals in the treated group expressed oestrus while none expressed oestrus in the control group. Those authors reported that more intense oestrus symptoms and a better conception rate were obtained when PMSG was used with PRID, as PRID treatment alone failed to induce a fertile oestrus. Andurkar and Kadu (1995), using a progesterone intravaginal pessary (CIDR) with prostaglandin F2α and PMSG, induced oestrus in non-cycling buffalo (either cows or heifers) and found better fertility with a long-term (12 days) than a short-term (8 days) treatment.

Our work has also shown that the use of PRID together with PMSG treatment is able to induce fertile oestrus in non-cycling heifers (Barile et al., 2001a; Pacelli et al., 2001). This has an economic impact on buffalo production as a greater proportion of heifers can be bred early. In fact, the PRID treatment increased ($P \leq 0.01$) the proportion of heifers that became cyclic within 60 days from the start of the trial (Table 2). Moreover, treated animals had a higher conception rate (CR) compared with controls (65,0 *vs* 28,2 percent, Barile et al., 2001a; 66.6 *vs* 33.3 percent, Pacelli et al., 2001). A marked difference in conception rate (CR) was

Table 2. Rate of heifers becoming cyclic within 60 day after PRID + PMSG treatment.

Trial 1: PRID + 1000 IU ≤PMSG.
Trial 2: PRID + 1000 IU PMSG (Group A), PRID + 750 IU PMSG (Group B)

Trial	Treated (%)		Control (%)
1	Farm TM Farm IM	70.0a 71.4a	11.1b 18.6b
2	Group A Group B	66.6a 73.3a	33.3b

a,b $P \leq 0.01$ within row
TM: Tormancina; IM: Iemma
Trial 1 (Barile et al. 2001a); Trial 2 (Pacelli et al. 2001)

Table 3. Conception rate (CR; March-June) in treated (PRID+PMSG) and control heifers in relation to their cyclicity before the treatment in two farms (TM and IM).

Farm	Cyclicity	Treated		Control	
		No. of animals	CR No. (%)	No. of animals	CR No. (%)
TM	cycling	10	8 (80.0)	10	6 (60.0)
	non-cycling	10	5 (50.0)a	9	0 (0.0)b
IM	cycling	2	2 (100.0)	2	1 (50.0)
	non-cycling	18	11 (61.1)a	18	4 (22.2)b

a,b P≤0.01 within row.
TM: Tormancina; IM: Iemma
(Barile et al., 2001a).

Table 4. Conception rate (CR; March - August) in treated (Group A: PRID + 1000 IU PMSG; Group B: PRID + 750 IU PMSG) and control heifers (Group C)

Groups	Cyclicity	No. of animals	CR No. (%)
A	Non cycling	15	(66.6)A
B	Non cycling	15	10 (66.6)A
C	Non cycling	15	5 (33.3)B

A,B P≤0.05
(Pacelli et al., 2001)

found between treated and control heifers that were non cycling at the beginning of the trial (Tables 3 and 4). In relation to the dose of PMSG utilized, no difference was found either in the number of animals becoming cyclic or in the CR using 1 000 IU *vs* 750 IU of PMSG (Pacelli et al., 2001), although Khan et al. (1995) using 1 400 IU *vs* 700 IU of PMSG showed that the low dose of PMSG was better than the high dose for oestrus induction and subsequent CR in non-cycling buffalo heifers.

Using the PRID regime, it is possible to synchronize oestrus in cycling heifers, overcoming the problem of oestrus detection and increasing the effectiveness of AI programmes in buffalo heifers. The CR to AI obtained in our work, utilizing either cycling or non-cycling animals,

Table 5. Conception rate (CR) in buffalo heifers at artificial insemination as reported by various authors

Reference	Treatment	CR (%)
Honnappagol and Patil (1991)	PGFα	12.5-62.5
Zicarelli et al. (1997a)	PRID or norgestomet + PMSG	20.20
Neglia et al. (2001)	PGF2α PGF2α + GnRH	55.00 44.40
Kumaresan and Ansari (2001)	Spontaneous oestrus: 6-12h 12-18h 18-24h	 16.67 28.99 33.33
Barile et al. (2001a)	PRID + PMSG	37.50
Pacelli et al. (2001)	PRID + PMSG	36.50

(37.5 percent, Barile et al., 2001a; 36.7 percent, Pacelli et al., 2001) was a good result relative to the small amount of data reported in literature (Table 5). Honnappagol and Patil (1991), using an analogue of prostaglandin F2*a* to synchronize oestrus in cycling Surti buffalo heifers, had a CR to AI ranging from 12.5 to 62.5 percent. Zicarelli et al. (1997a), using PRID in Italian cycling buffalo heifers, reported a CR to AI of only 20.2 percent; the same group of researchers, using prostaglandin or prostaglandin +GnRH had a CR of 55.0 percent and 44.4 percent respectively (Neglia et al., 2001). Indian authors (Kumaresan and Ansari, 2001), utilizing AI on spontaneous oestrus, reported a CR ranging from 16.67 to 33.33 percent in relation to the stage of oestrus; the highest CR was obtained when the heifers were inseminated at 18 - 24 hours after oestrus.

Seasonality

Although buffaloes are polyoestrus, their reproductive efficiency shows wide variation throughout the year. As reported by different authors (Shah et al., 1989; Singh and Lal, 1994; Zicarelli, 1997; Srivastava and Sahni, 1999), buffalo cows exhibit a distinct seasonal change in displaying oestrus, conception rate and calving rate. This may be the cause of the prolonged intercalving period since buffalo calving during the unfavourable season may not resume their ovarian activity until the following favourable season, decreasing their reproductive efficiency.

In a study undertaken over five years on Indian Murrah buffaloes, the maximum percentage of heats were observed in November and the minimum in June; the conception rates ranged from 41.85 percent to 44.85 percent during August to November, with the highest rate in September, and from 29.45 percent to 32.92 percent during the months of February to April, with the lowest rate in April (Reddy et al.,1999). Data collected on Surti buffaloes reared in Rajasthan confirm a distinct seasonality in breeding behaviour. The monthly and seasonal calving pattern recorded at the research station and in the field indicated that buffaloes calved all the year round but have a tendency to calve more during the rainy season (July to September) followed by the winter season (October to January). The breeding season started in the rainy period and the winter appeared the most favourable season while the summer appeared the most unfavourable season for buffalo reproduction (Sule et al., 2001). Also for buffaloes bred in Pakistan, Shah (1988) reported that the breeding frequency was highest during the winter, decreased in autumn and spring, and was lowest in the summer. According to Shah et al. (1989), it may be possible that during the summer season, farmers are unable to fulfil the fodder requirements of buffalo because of less fodder availability at this period. High environmental stress together with under-nutrition might therefore be responsible for the long periods of seasonal anoestrus in buffaloes. Similar effects of these factors on oestrus activity in Australian Swamp buffaloes were described by McCool et al. (1987). These authors find in an area subject to a monsoon rainfall pattern, the highest number of cyclic buffaloes during the late wet and early dry seasons (wet season being December to March; dry season being April to November). During the late dry season (August to November) fodder availability is low, ambient temperatures are highest and body condition deteriorates, therefore the authors hypothesized that the combined effects of these factors could be the cause of depressed oestrus activity in this season. In fact, few buffalo cows conceived in this period, as reported previously by Tulloch and Grassia (1981). Similarly, Vale et al. (1990) in a study on buffalo reproduction in the Amazon Basin, were of the opinion that the seasonality in buffalo could be due more to management factors and unavailability of green fodder rather than to the inability of the species to reproduce throughout the year. However, in Italy, where buffaloes are fed with a constant balanced diet in place of free grazing, a distinct seasonal reproductive pattern is also found (Zicarelli, 1992). With regard to this aspect, Zicarelli (1997), in his review on buffalo seasonality, emphasizes how the need of a species, mainly in wildlife, to coincide calving and weaning with favourable environmental conditions represents one of the causes of reproductive seasonality; therefore the tendency of buffalo to seasonality depends upon the environmental characteristics of their place of origin which are the subtropical zones of North of the equator, which condition the forage availability and thus the state of animal nutrition throughout the year.

Therefore, the reproductive seasonality in the buffalo does not seem to depend on diet, food availability or metabolic status, while climate and particularly photoperiod, depending on melatonin secretion, play a pivotal role (Parmeggiani et al.,1993; Borghese et al.,1995; Di Palo et al., 1997; Zicarelli, 1997). Melatonin is a hormone secreted by the pineal gland during the night and represents the endocrinal signal of the light-dark rhythm in the environment. The role of melatonin in the regulation of the circadian and annual rhythm is well known in the control of ovarian cyclicity in seasonal species such as sheep, goats and mares, while few investigations have been made to clarify the role of this hormone in buffalo reproduction. Parmeggiani et al. (1993, 1994) investigated whether melatonin could act as a transductional signal of photoperiod in buffalo. The investigations were carried out on Mediterranean buffalo cows reared in Italy. In this country, calving occurs mainly between July and December with the highest calving frequency in August-September; the intercalving interval is longer for deliveries occurring between February and June, indicating a decrease in the conception rate during the spring - summer seasons (De Franciscis, 1988; Borghese et al., 1993b) (Figures 1 and 2).

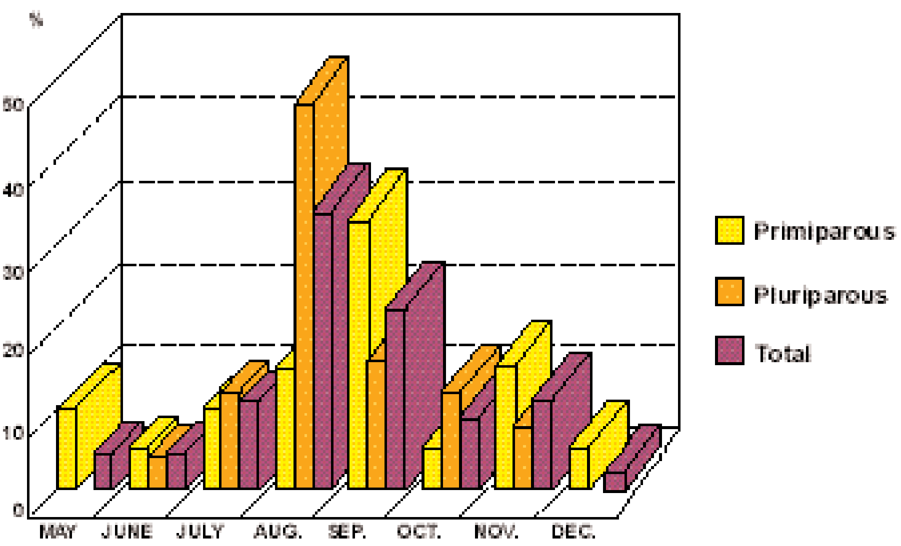


Figure 1. Trend of calving frequency in buffalo in Italy.
(data from Borghese et al., 1993b)

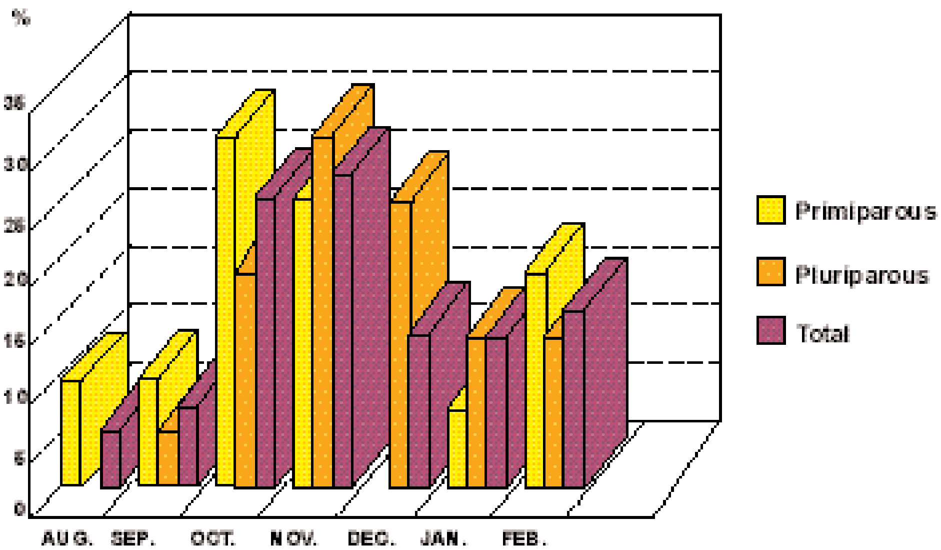


Figure 2. Trend of conception frequency in buffalo in Italy.
(data from Borghese et al., 1993b)

The proportion of buffaloes exhibiting oestrus during the period of short day length is significantly higher than during the period of long day length, indicating that decreasing daylight is a strong determinant of the resumption of ovarian activity. In fact Parmeggiani et al. (1993,1994), in a study of buffaloes reared in farms with a clear seasonal reproductive trend, found high levels of melatonin during the night and the persistence of these levels was clearly related to the photoperiod: they were the highest in December (35.22±2.07 pg/ml) and decreased progressively from March-April (35.0±2.07 pg/ml) to June (23.13±2.30 pg/ml). These secretory

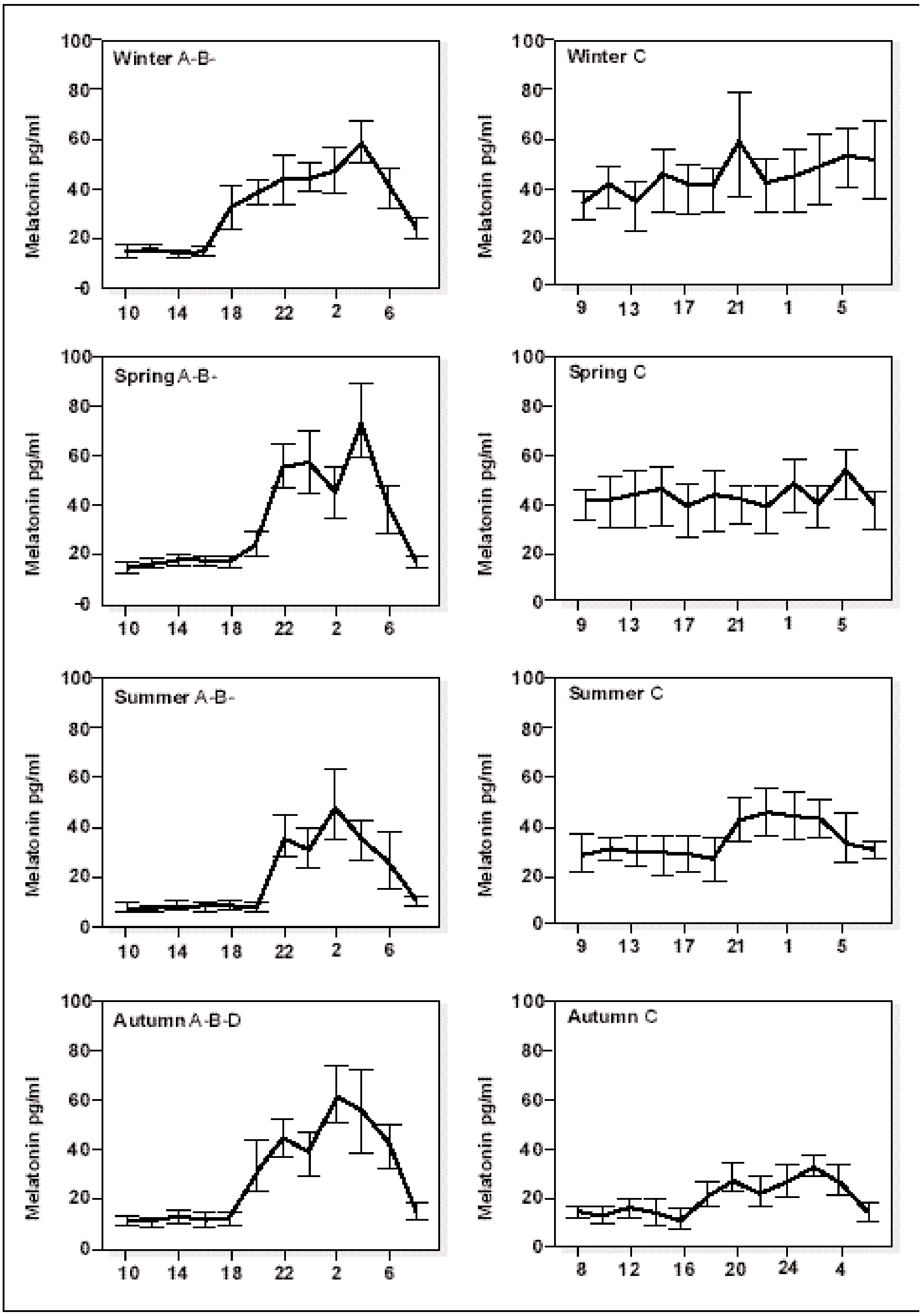


Figure 3. Circadian trend of melatonin in buffalo cows in different seasons.
On the left, farms A-B-D characterized by a higher trend of seasonal reproduction activity; on the right, farm C characterized by a lower trend of seasonal reproduction activity. (Parmeggiani et al., 1994)

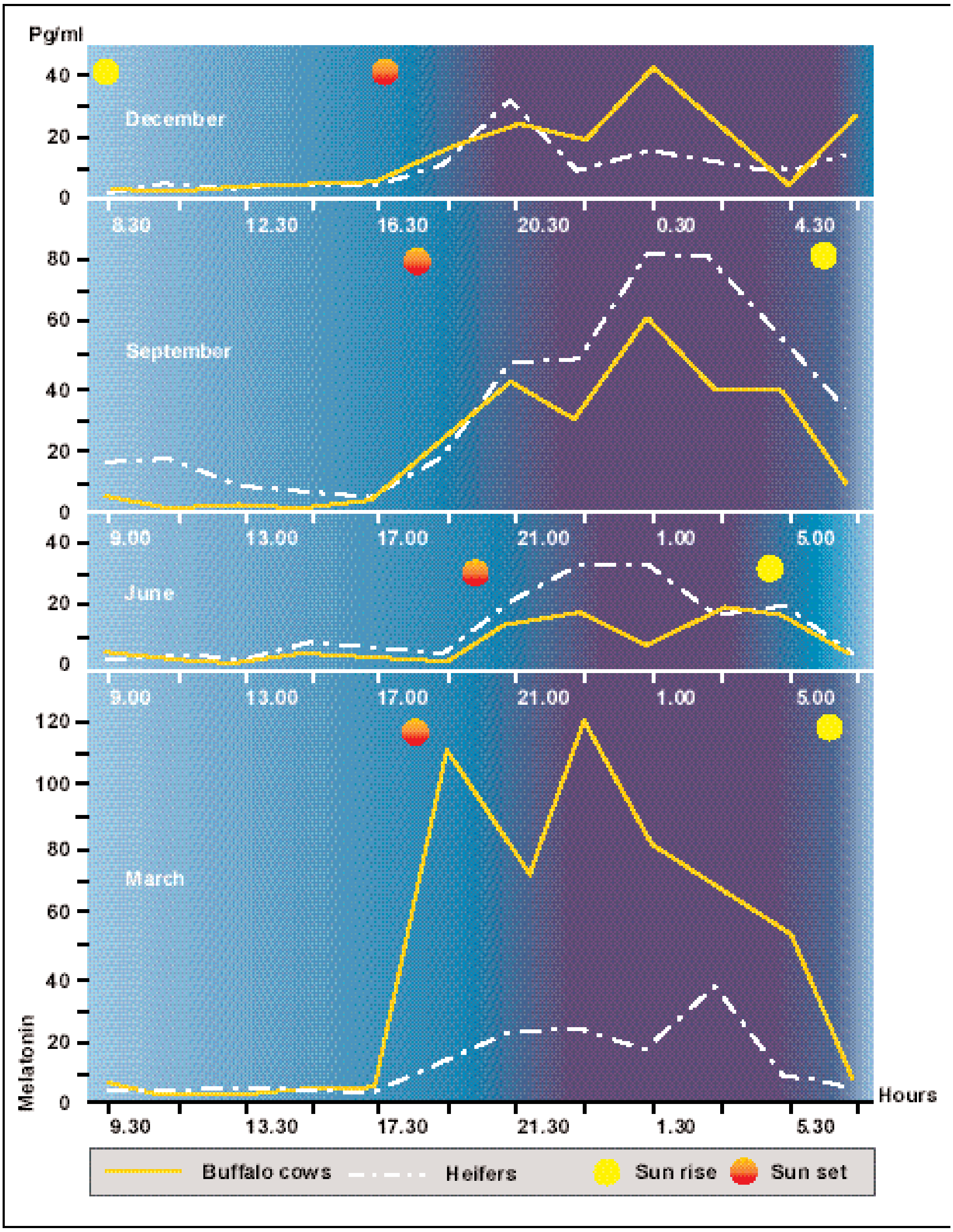


Figure 4. Circadian trend of melatonin in buffalo heifers and cows at equinoxes and solstices. (Borghese et al., 1995)

patterns were not observed in all the animals; in a farm where parturition frequency tended to be more uniformly distributed around the year, melatonin concentration was persistently high during the day (30-40 pg/ml), with a lack of evident melatonin increase during the night. According to the authors, the absence of strong seasonality in this particular farm was probably due to an extensive selection carried out with the aim of eliminating any seasonal breeder. However nutrition does not seem to be the cause of this difference since in all the farms a fairly similar diet was used. Borghese et al. (1995), also report, in a study carried out on buffalo heifers and cows in Italy, that the melatonin trend shows remarkable differences between seasons (Figure 4). In June at the summer solstice, the lowest values and less persistence of melatonin peak were found because of the shortest night, while the highest values were noted at the equinoxes, particularly in September, the month corresponding to the start of hypothalamus-pituitary-ovarian axis activity.

The heifers showed significantly higher values during the day than in cows and in September also during the night, probably because they were close to the onset of puberty.

Therefore these data suggest a relationship between photosensitivity and the seasonal reproductive trend in this species.

The strong influence of photoperiod seems to be further demonstrated by the findings that the period of higher reproductive efficiency is reversed in the two opposite hemispheres (Zicarelli, 1997). In Brazilian buffaloes, Pires et al. (2002), in a study lasting 13 years, report that most of the births (86.73 percent) occurred during the first six months of the year, with 57.93 percent during February, March and April and only 0.65 percent during October and November. The reproductive period, moreover, is longer near the equator where the light/dark ratio is constant throughout the year. Da Silva and Grodzki (1991) have reported 95.4 percent of calving between December and May in the Parana State (Southern Brazil) that is characterized by a reverse light/dark ratio compared to the Northern hemisphere, and a calving concentration between April and September in the Para State (Northern Brazil) characterized by a constant length of the light/dark ratio during the year. In the zones near the equator, the satisfaction of nutritional requirements seems to prevail over light stimulus as a factor influencing reproductive activity.

In Italy, the reproductive seasonality of the species implies economic implications, since the milk production is totally utilized to produce fresh white "mozzarella" cheese. The demand for "mozzarella" cheese is mainly concentrated in the spring / summer period, while the higher milk production is during the autumn/winter months due to calving seasonality. In Italy under natural conditions, 70 to 80 percent of calving occurs in the last six months of the year (July to December) involving a higher production of milk in the period between the end of August and the middle of February, when the milk is not in great demand. In order to meet the market demands many Italian breeders (at present over 60 percent), over the last 20 years have managed to modify the natural calving calendar by keeping females without males from October to February, the period during which conception is undesired (out of breeding season mating) (Figures 5 and 6). The use of this reproductive strategy is spreading among Italian buffalo breeders also due to the higher price paid for buffalo milk produced during the spring and summer than that produced during the autumn and winter. This strategy is also attracting interest in other countries in order to cope with the need to guarantee a constant milk production for the market.

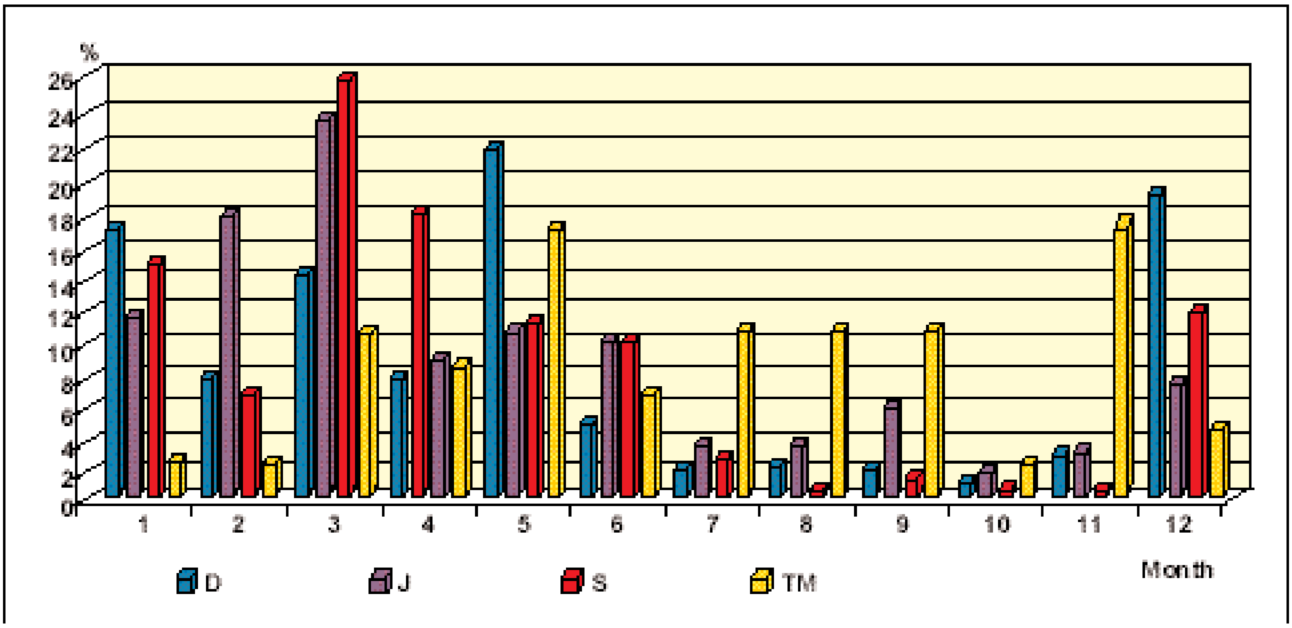


Figure 5. Calving frequency in pluriparous buffalo cows. Farms D-J-S utilized "out of breeding season mating"; in farm TM mating occurred during the natural breeding season period. (Zicarelli et al., 1994)

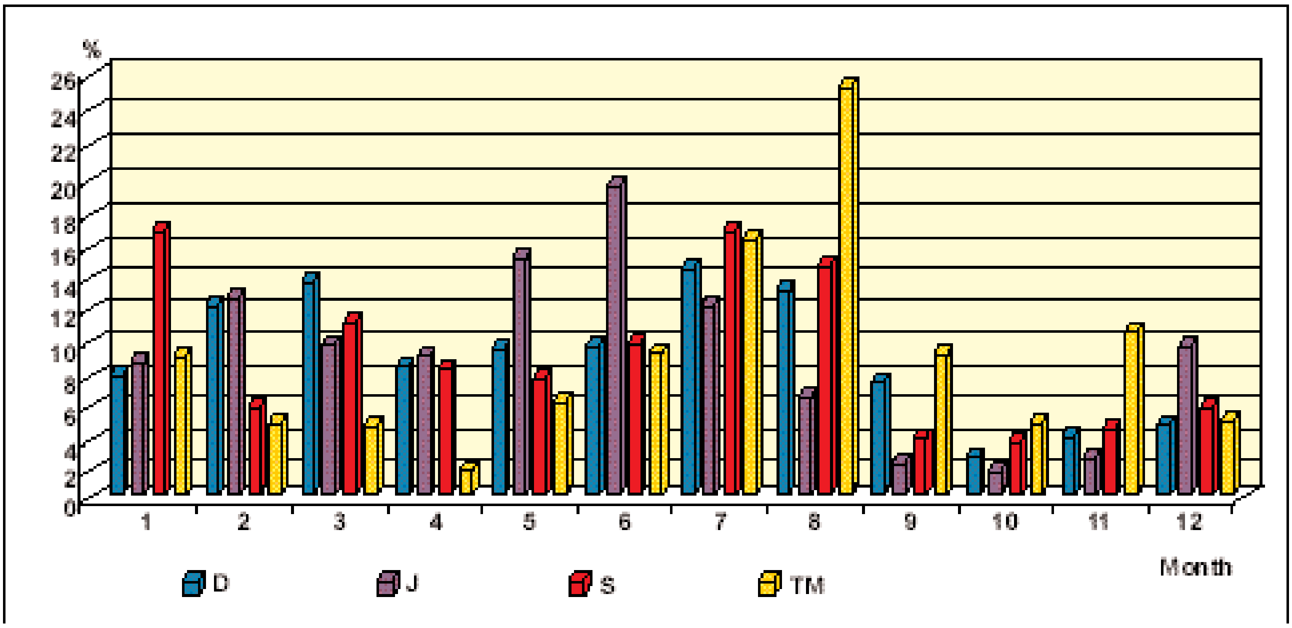


Figure 6. Calving frequency in primiparous buffalo cows. Farms D-J-S utilized "out of breeding season mating"; in farm TM mating occurred during the natural breeding season period.
(Zicarelli et al., 1994)

Anoestrus and Oestrus Induction

The long intercalving period is one of the major problems in buffalo breeding. The interval from calving to resumption of ovarian function is longer in buffalo when compared with cattle. Post-partum ovarian activity resumption, and subsequent conception, may be affected by several factors such as breed, nutrition plan, milk yield, suckling, uterine involution, season of calving (Ahmad et al.,1981; Jainudeen et al., 1983; McCool et al., 1987; Usmani et al., 1990; Borghese et al., 1993b; Qureshi et al., 1999b; Arya and Madan, 2001; Baruselli et al., 2001; Campo et al., 2002).

A large variability is reported in the literature for the intercalving period depending on the region where buffalo are raised and the calving season (Table 6). In India, Gill and Ruki (1985) referred to an intercalving period of 459 to 478 days for buffaloes calving from February to June and 369 to 391 days for those calving from July to January. In Pakistan, Ahmad et al. (1981) reported an average calving interval of 531.5 days with highly significant differences in length of calving interval due to the season of calving: 569.1 and 570.6 days in spring and winter *vs* 506.6 and 515.7 days in summer and autumn respectively. In Italy, Maymone and Pilla (1960) referred to an average intercalving interval of 447.5 days for the buffaloes kept mostly in stables and 411.7 days for those kept in semi-range conditions; they found that the intercalving period was shorter during the months in which parturitions were more numerous (August, September and October).

In Brazil, Pires et al. (2002) report that the mean interpartum interval was of 453.1± 127.26 days. In Cuba, Campo et al. (2002) have found an intercalving period of 384.0±2.3 days in buffaloes calved in the rainy season (June to September) and 361.0±2.5 days in those calved in the dry season (November to February). In Egypt, Barkawi et al. (1998) report an intercalving interval of 363.5±16.0 and 400.3±14.3 days in the cool season (November through April) and an interval of 387.0±15.3 and 441.5±14.3 days in the hot season (May through October), depending on different frequency in oestrus detection checking; thus buffaloes calving in the cool season had better reproductive performance than those calving in the hot season.

Body condition score (BCS) plays an important role in the reproductive performance of post-partum buffalo cows. Baruselli et al. (2001), in South-eastern Brazil, report that first post-partum oestrus was influenced by BCS at calving; cows with high BCS had an earlier first post-partum oestrus and a shorter service period than cows with lower BCS.

Suckling significantly increases the interval from parturition to first oestrus in buffalo. Jainudeen et al. (1983) found that in Malaysian Swamp buffaloes that suckled their calves the interval from parturition to first ovulation was 96±22 days in 32 percent of buffaloes, while over 68 percent were in anoestrus within 150 days post-partum. An earlier resumption of ovarian activity in milked rather than suckled buffaloes was found by El-Fouly et al. (1976). These authors report that only 38 percent of suckled buffaloes restored ovarian activity within 90 days from parturition in concurrence with the data of Janudeen et al.(1983). The extension of anoestrus period due to calf suckling is also reported by Usmani et al.(1990). They found a post-partum oestrus cyclicity resumption delayed by three to four weeks due to the practice of let buffaloes be suckled by their calves, before each milking, to stimulate milk let down. Arya and Madan (2001) also found a longer interval from parturition to first observed oestrus and a longer service period in suckled than weaned buffaloes (71.67±11.13 and 98.00±17.53 *vs* 44.17±8.58 and 70.33±9.56 days respectively). Therefore, suckling regulates the resumption of post-partum ovarian activity, but there is evidence to indicate that the season of calving may be more important than suckling.

The sensitivity of the species to the photoperiod, together with environmental factors, plays an important role in the regularity of oestrous cycle. Buffaloes calving in the autumn show shorter postpartum anoestrus than those calving in the spring and summer, since their ovarian activity

Table 6. Post-partum reproductive features in the buffalo cow as reported by various authors

Author	Country	Calving interval	Anoestrus length	Service period
Maymone and Pilla (1960)	Italy	411.7 - 447.5 d		
Ahmad et al. (1981)	Pakistan	506.6 - 570.6 d		
Gill and Ruki (1985)	India	369 - 478 d		
McCool et al. (1987)	Australia		5.8 m	
Borghese et al. (1993b)	Italy		25.2 d autumn 58.2 d summer	
Barkawi et al. (1998)	Egypt	400.3 - 441.5 d		
Qureshi et al. (1999a)	Pakistan		55.9 d breeding season 91.1 d low breeding season	
Qureshi et al. (1999b)	Pakistan		48.4 d autumn 185.9 d summer	67.2 d autumn 220.5 d summer
Naqvi (2000)	Pakistan			237.5 d
Arya and Madan (2001)	India		71.6 d suckled 44.1 d weaned	98.0 d suckled 70.3 d weaned
Pires et al. (2002)	Brazil	453.1 d		
Campo et al. (2002)	Cuba	361.0 - 384.0 d	39.0 d dry season 58.3 d rainy season	

d: days; m: months

resumption corresponds to the beginning of the short day-length period.
In the Australian Swamp buffalo cow, McCool et al.(1987), found a mean post partum anoestrus interval of 5.8±3.3 months with a variation depending on the season of calving: buffaloes calving in the late dry season (August to November) exhibited a longer interval than those calving earlier. Moreover, heavier cows had a shorter post-partum anoestrus. The late dry season is characterized by high temperatures and low fodder availability that lead to a deterioration in the buffalo's body condition and thus could be, according to the authors, the cause of delayed ovarian activity resumption. Qureshi et al. (1999a), in the Nili-ravi buffalo raised in Pakistan, found a shorter postpartum anoestrus interval in buffaloes calved during the normal breeding season (August to January) than those calved during the low breeding one (February to July) (55.95±4.90 *vs* 91.15±11.61 days). In another work, the same authors (Qureshi et al., 1999b) confirm the influence of season on the post-partum anoestrus length (185.95 days in summer *vs* 48.42 days in autumn) and on the service period (220.53 days in summer and 67.29 in autumn); the number of services per conception was also higher in the

summer with respect to that recorded in the winter. Likewise, Naqvi (2000) in a study in Pakistan, registered a service period of 237.57±4.5 days with a trend of reduction in the length of service period with an increase of parity (287.54±6.89 days in the 1st parity *vs* 107.95±19.72 days in the 8th parity); a shorter service period was recorded in buffaloes calving in the spring and winter compared with those calving in the summer and autumn. Campo et al. (2002) investigated the seasonal effect on uterine involution and post-partum ovarian activity in buffaloes raised in Cuba. These authors found no significant differences in the uterine involution between buffaloes calved in the rainy season (June to September) and those calved in the dry season (November to February), but seasonal influence was found in the resumption of ovarian activity: the first formation of corpus luteum after calving was found at 58.3±3.4 days in the rainy season and at 39.0±2.3 days in the dry one. In the Italian buffaloes, Borghese et al. (1993b) reported a post-partum anoestrus of 49.5±38.8 days in the primiparous and 51.3±26.0 days in the pluriparous. The early resumption of ovarian activity occurred mainly in October - November in the decreasing photoperiod. In fact, the buffaloes calved in the autumn showed a shorter post-partum anoestrus (19.9±10.9 days in primiparous and 25.2±12.7 days in pluriparous) than those calved in summer (50.8±24.3 days in primiparous and 58.2±24.3 in pluriparous). Sometimes the anoestrus is prolonged due to sudden climatic variation such as a fall in temperature, exposure to cold wind, heavy rain associated with low temperature or hot weather without any possibility of bathing or sheltering from the sun (Zicarelli, 1997).

In Italy another reason for prolonged anoestrus is the practice of "out of breeding season mating". In this case, buffaloes which calve in the first months of the year and do not become pregnant within 70 days from calving, will prolong anoestrus until the beginning of the short day-length period (autumn) (Zicarelli, 1997). The need to employ the strategy of "out of breeding season mating" with the aim of conciliating the production with the higher milk market demand in the spring / summer period, is in contrast with the condition of the greatest fertility of the herd that corresponds to the autumn season, period in which females are separated from males.
To increase fertility in the low breeding season and reduce the post-partum anoestrus and subsequent intercalving period, different hormonal treatments are utilized.

Prostaglandins have been used to induce oestrus in buffalo, but they work if a corpus luteum is present and therefore they can be useful in suboestrus animals, having a synchronizing more than an inducing effect (Dhalival et al., 1988; Sahasrabudhe and Pandit, 1997; Awasthi et al., 1998; Chohan, 1998; Kharche and Srivastava, 2001). The use of gonadorelin (GnRH), given by multiple injections or in microencapsulated form, did not appear efficacious and moreover their administration times are not of practical use (Minoia et al., 1984; Chantaraprateep et al.,1988; Shah et al., 1990; Fateh Mohammed et al., 1999; Takkar et al., 1999). More useful and efficacious have been the treatments using progesterone associated with gonadotrophin or gonadorelin (Zicarelli and Boiti, 1982; Rao and Sreemannarayana, 1983; Singh et al., 1983, 1984, 1988; Borghese et al., 1993c; Uma Shanker et al., 1999; Hattab and Osman, 2000).

Trials to remove anoestrus have been carried out on the Italian buffalo (Borghese et al., 1993c; Zicarelli et al., 1994). Buffalo cows found non-cycling at 150 days from calving, were submitted to the following treatments in the January-May period: a) subcutaneous implants of Norgestomet (synthetic Progesterone) + PMSG; b) Buserelin (GnRH-analogue) released by subcutaneous osmotic pump; c) Progesterone + Buserelin i.m. Buffaloes which began cycling were 81.3 percent, with no differences between treatments, while none of the control animals were found cycling in the same period (Table 7) (Borghese et al., 1993c). At the end of the breeding period, the fertility for all the treated animals was 73.8 percent *vs* 54 percent for the controls; nevertheless hormonal treatment was inefficacious on farms where buffaloes had serious infertility problems, and less efficient when utilized in the winter / spring period in respect to the summer period which is nearest to the reproductive season. In treated buffaloes the calving conception interval was reduced to about 40 days on average and the number of culled animals, because of infertility, was lower (18.1 percent *vs* 31.2 percent respectively in treated and controls) (Zicarelli et al.,1994). Therefore these hormonal treatments have been able to reduce the intercalving interval and to increase the fertility of the herd out of the breeding season.

Better results have been obtained using a progesterone - releasing intravaginal device (PRID) associated with PMSG and prostaglandin. In a group of buffaloes on the experimental farm of our Institute which did not get pregnant in the autumn, PRID was used during the following spring and summer seasons in order to ascertain whether the treatment would improve the pregnancy rate in the low breeding season (Barile et al., 1996a; 1997).

Table 7. Rate of buffaloes becoming cyclic after different hormonal treatments (Borghese et al., 1993c)

Treatments	**No. of animals**	**Non Cyclic No. (%)**	**Cyclic No. (%)**
a) Norgestomet	14	2 (14.2)	12 (85.8)
b) Buserelin	17	5 (29.4)	12 (70.6)
c) Progesterone	33	5 (15.2)	28 (84.8)
Treated (a+b+c)	64	12 (18.7)	52 (81.3)
Control	52	52 (100)	0

The conception rate after PRID treatment (Table 8) was 21 percent at the induced oestrus while the total conception rate (up to the third oestrus) was 56.5 percent. This result is very satisfactory if compared to the conception rate ranging from 12.2 percent to 44.4 percent obtained on the same farm and during the same period (June-August) in the previous years without oestrus induction (Figure 7).

A significant difference was found between the lactating group and the non-lactating one (Table 8). The very low conception rate obtained for non-lactating buffaloes at first oestrus (4 percent) was probably due to the fact that they were animals which had fertility problems, as they had not become pregnant during the whole previous lactation period. For these buffaloes however PRID was helpful in improving cyclic activity so that a 50 percent conception rate was finally achieved.

Table 8. Conception rate in buffalo cows after PRID treatment

Group	**No. of animals**	**Conception rate**		
		1st oestrus No. (%)	**Following oestrus (2nd+3rd) No. (%)**	**Total No. (%)**
Lactating buffaloes (AI at first oestrus + natural mating at subsequent oestrus)	23	8 (34.8) a	8 (34.8)	16 (69.6)
Lactating buffaloes (natural mating)	17	4 (23.5) a	4 (23.5)	8 (47.1)
Non-lactating buffaloes (natural mating)	22	1 (4.0) b	10 (45.5)	11 (50.0)
Total	62	13 (21.0)	22 (35.5)	35 (56.5)

a,b P≤0.001
(Barile et al., 1997)

Similar results using PRID during the spring season were obtained by Zicarelli and Boiti (1982). They reported a conception rate of 50 percent for the cycling animals and 33 percent for the non cycling animals after the treatment.

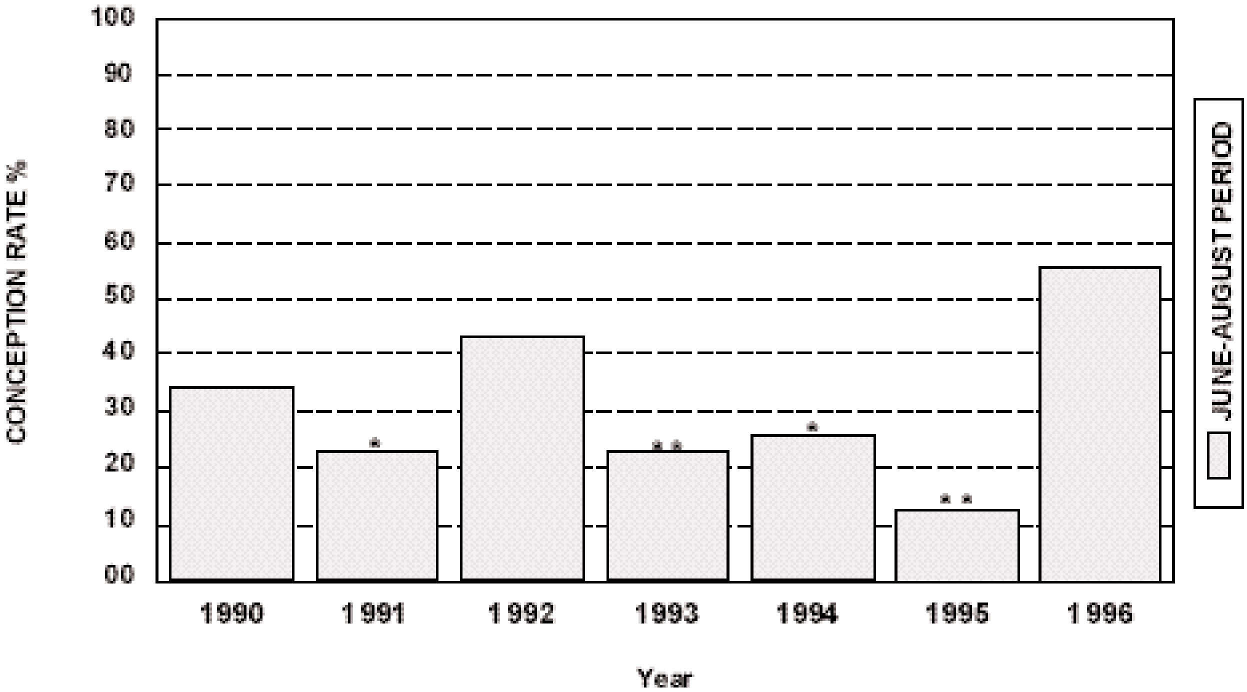


Figure 7. Conception rate in buffalo cows during the non breeding season (June August) using PRID (1996) or not (previous years).
(Barile et al., 1996a)

Oestrous Cycle

An accurate knowledge of the regulatory mechanisms associated with the oestrous cycle is necessary to increase the reproductive efficiency of the buffalo. Current knowledge of the basic pattern of changes in the hormone profile during the oestrous cycle and the basic pattern of follicle development, are important to develop models for improving reproductive efficiency, particularly when controlled breeding techniques using synchronization and superovulation protocols are utilized.

Up-to-date studies on the oestrous cycle, oestrous behaviour and the endocrinology of the oestrous cycle in the buffalo, have been recently reviewed by Beg and Totey (1999), Singh et al. (2000) and Malfatti (2003). Considerable variations in the reproductive traits of the different breeds have been observed. The average length of the oestrous cycle has been reported to be 21 days in the riverine type. Several factors such as climate, temperature, photoperiod, nutrition, have been shown to affect the length of oestrous cycle and the degree of heat expression. Oestrous behaviour in buffalo has a lower intensity than in cows and is therefore much more difficult to detect. Acceptance of the male is considered as the most reliable indication of oestrus in the buffalo. Salient signs of oestrus in River buffalo are reported to be frequent urination, bellowing, vulva swelling, mucous discharge, but they cannot be considered reliable indicators of oestrus because of their weak expression. The average duration of oestrus is 20 hours and appears to be slightly longer in the River buffalo than in the Swamp buffalo. Durations ranging from a short period of 9 hours to a long period of 56 hours have been reported.

In the Italian buffalo cow, a wide variability in the length of oestrous behaviour has been verified, depending on the month in which it was recorded and also according to some climatic factors (Campanile et al., 1988; Zicarelli et al.,1988). In relation to oestrous cycle length, Zicarelli (1992) distinguishes these categories: short (<12 hours), medium (13-24 hours), long (24-48 hours) and very long (>48 hours) oestrus. In the short and medium oestrus the ovulation occurs after the end of oestrus (6-72 hours and 24-60 hours from oestrus beginning respectively). Depending on the ovulation time, the short oestrus often continues as silent oestrus. On the contrary, in the long and very long oestrus, ovulation can occur before the end of oestrous behaviour. Sometimes in these cases a second ovulation can be recorded after the end of oestrus and pregnancy occurs in the uterine horn on the same side as the last ovulation.

To better understand the endocrine factors involved in the control of ovarian activity in the buffalo, a research was elaborated to evaluate the secretory patterns of gonadotrophin (Luteinizing hormone (LH) and follicle stimulating hormone (FSH)), prolactin, ovarian steroids (progesterone and oestradiol-17β), and PGFM (a prostaglandin metabolite) through the oestrous cycle. The trials were carried out on buffalo cows of our Institute, in different seasons, and the results have been reported by Seren et al. (1994). Only 37.5 percent of the animals showed signs of heat. Oestrous behaviour lasted on average 32.7 hours, with a large individual variation (from 5 to 57 hours) as previously reported by Zicarelli (1992). In 16.6 percent of buffaloes showing oestrus, symptoms were present during the luteal phase and therefore recorded as false heats. The remaining 62.5 percent of buffaloes had a normal endocrine activity without external signs of oestrus (silent heat); the only sign in these animals was the mucous discharge. Regarding the interval between the beginning of oestrous behaviour and ovulation time, which is important for the application of artificial insemination, the value was 54.6 hours. Double ovulations were recorded in 33.3 percent of buffaloes; in this case the mean intervals between the beginning of oestrous behaviour and ovulation time was 40.4 hours for the first and 112 hours for the second ovulation. The perioestrous endocrine changes observed did not show clear difference between the seasons and are entirely similar to those recorded in cows (Figure 8). The progesterone concentration dropped two to four days before oestrus and ovulation. At the same time peak levels of PGFM were recorded; high pulses of PGFM were then found until luteolysis was completed. After the progesterone drop, oestradiol progressively increased triggering FSH and LH ovulatory peak. The mean interval between the LH peak and the ovulation time was 35.5 hours. Sometimes a second peak of LH occurred that preceded the following ovulation by 47.7 hours. No correlations were found between hormonal profile and oestrous behaviour in buffaloes with silent oestrus, anovulatory heat or double ovulations (Zicarelli et al.,1993).

In a recent study on buffalo oestrous behaviour in the presence of a teaser bull (Moioli et al., 1998), the average duration of interest shown by the bull towards a buffalo cow (from the very first to the last sign of interest) was 68 hours. Within this period, the phase of continuous courtship was longer and lasted on average 32 hours; this phase was considered the best variable to refer to for visual assessment of oestrus, because it is easy to detect even if the herd is observed only three or four times a day. In this study the interval between the LH peak and ovulation was found to be on average 25 hours for those animals which became pregnant after artificial insemination and 46 hours for those which did not become pregnant. It has been hypothesized that in this case an insufficient LH peak and a delayed luteinization are contributing causes to unsuccessful inseminations.

These studies indicate that the oestrus length and the ovulation time in the Italian buffalo manifest a wide variability with respect to buffalo raised in tropical conditions. Ovulation cannot be predicted from oestrous behaviour signs such as bellowing, frequent urination and mucous discharge, because they are not often displayed or when they are present they are very variable in relation to ovulation time and sometimes do not coincide with oestrus. For these reasons the application of artificial insemination is limited in the buffalo, taking into account the fact that a high conception rate depends mainly on insemination at a correct time relative to ovulation.

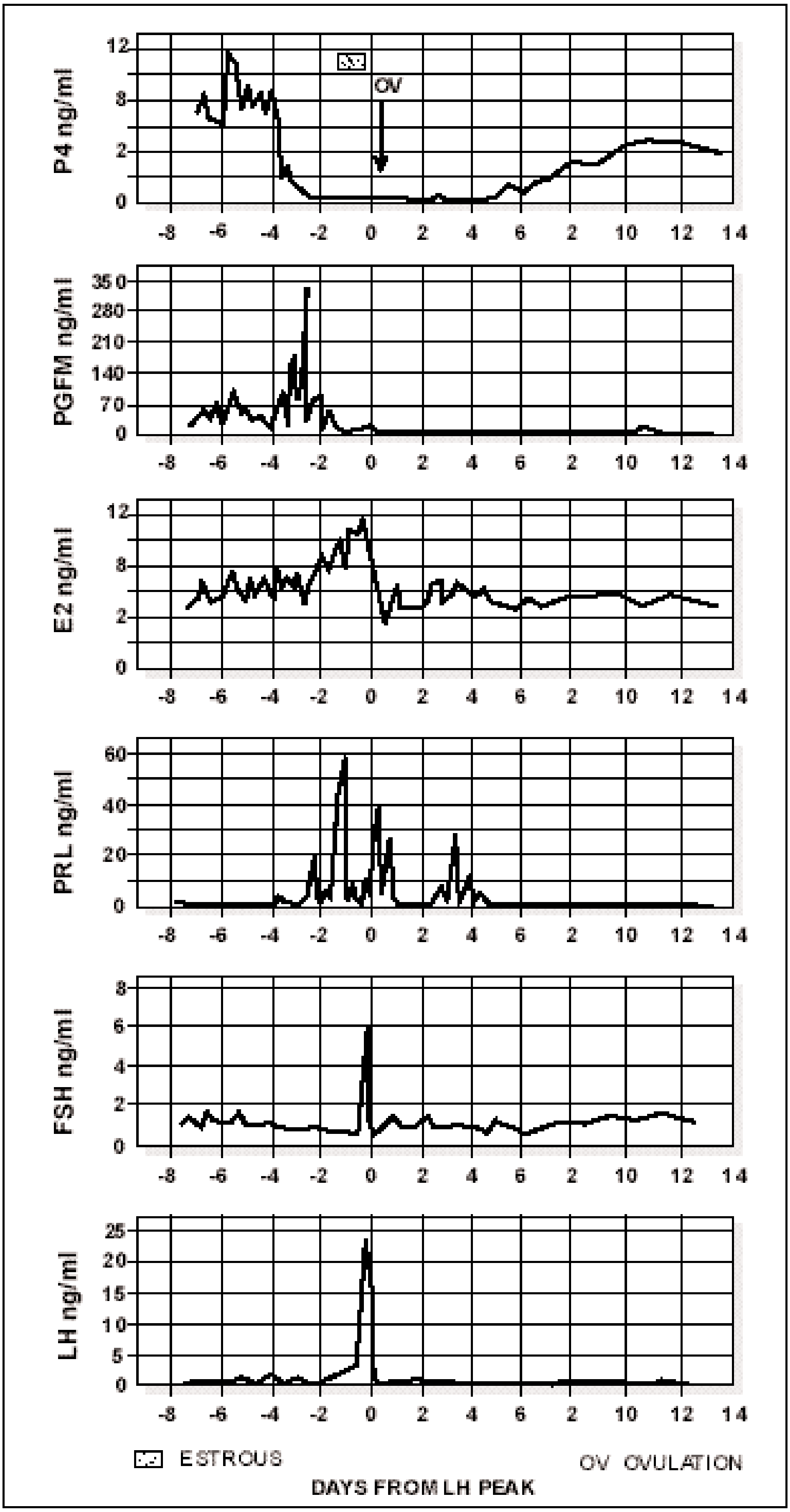


Figure 8. Perioestrus endocrine changes in the buffalo cow. (Seren et al., 1994)

Oestrus Control in order to apply Artificial Insemination

The presence of a teaser bull is helpful to identify buffaloes on heat (Figure 9); in this case the standing oestrus is the most reliable sign referable to a next ovulation, although a wide variability has been observed in the interval between the start of standing oestrus and LH peak (from 124 hours before the LH peak to 6 hours after the peak) (Barile et al., 1996b). The end of bull courtship and the end of bull acceptance by the female are reliable signs that indicate the end of heat and the occurrence of ovulation. Utilizing a teaser bull and inseminating the animals after the end of heat, Baruselli (1996) had a conception rate ranging from 40.44 percent to 60.68 percent depending on farms. Zicarelli et al. (1997b) have studied the effects of the presence or absence of a vasectomised buffalo bull on the reproductive efficiency of buffalo cows undergoing artificial insemination. They reported that exposure to a vasectomised bull increases the pregnancy rate in buffaloes inseminated at spontaneous (42.5 *vs* 18.9 percent) or induced oestrus (51.1 *vs* 33.3 percent). In the absence of the bull, pregnancy rate at AI was higher in cows inseminated at induced oestrus than at spontaneous oestrus (33.3 *vs* 18.9 percent). Similar results were found from our group in buffaloes inseminated at spontaneous oestrus in the presence of a vasectomised bull: pregnant cow rate was 56 percent in total and 40 percent at first oestrus (Moioli et al., 1998).

New approaches are being developed to provide automated systems of detection of oestrus using electronic technology in cattle such as pedometry and pressure sensing radiotelemetric HeatWatch® system (Nebel et al., 2000). Recently, studies on the efficiency of pedometers in buffalo oestrus detection have been carried out in Italy by Di Palo et al. (1999, 2001). They report that the pedometer has been found to be very useful for AI when visual observation of oestrus can be carried out only for a short time, providing a greater number of alerts for spontaneous oestrus to be inseminated; the conception rate at AI was 40 percent. A study on oestrous detection using radiotelemetry has been carried out in Brazil by Baruselli (2001). The author reports that the distribution of mountings during the day did not present significant differences showing that buffalo present a homogeneous distribution of oestrus during the 24 hours of the day. The use of a vaginal electrical resistance (VER) probe to predict oestrus and ovarian activity has been studied by Gupta and Purohit (2001) on Indian buffaloes. They proved that VER can be used successfully to predict the stage of oestrous cycle, ovarian status and ovulation; insemination at a low VER distinctly improves the conception rate in buffaloes (81.48 *vs* 16.66 percent with 26 and 40 ohms respectively).

The use of management schemes that do not require the identification of oestrus, contribute to the increase in the use of AI in buffalo herds, mainly because it is easy to perform. In order to apply a fixed time AI, thereby surmounting the problem of oestrus detection, different hormonal treatment schedules have been proposed (Tables 9 and 10). Various authors have recorded the use of PGF2*a* or one of its analogues in oestrus control in buffalo, often using an 11 day interval between two consecutive doses. The endocrine change after PGF2*a* induced luteolysis appears similar to that occurring at natural oestrus (Kamonpatana et al., 1979). Chohan et al., (1993) reported a fertility rate at AI of 22.8 percent in the low breeding season and 53.3 percent in the peak breeding season, in buffaloes synchronized with PGF2*a*, concluding that the use of PGF2*a* to synchronize oestrus should be undertaken in animals having a functional corpus luteum and preferably during the peak breeding season. Nevertheless, Sahasrabudhe and Pandit (1997) reported that a high percentage of suboestrus buffaloes expressed oestrus after PGF2*a* treatment during the hot season. The detection of oestrus after prostaglandin treatment, however, had posed problems because external signs of oestrus were found by some workers to be less apparent than at spontaneous oestrus. Baruselli (2001) detected a greater variation in the duration of oestrous manifestation after the administration of prostaglandin; moreover he found that the phase in which prostaglandin was administered interfered with the interval from administration and the beginning of oestrous manifestation and ovulation. Therefore protocols using fixed time insemination and only prostaglandin treatment have not produced good results. In order to decrease the variation in the ovulation time after prostaglandin treatment, the use of GnRH has been associated with

Figure 9. Use of teaser bull for oestrus detection: phase of courtship (a and b); standing oestrus (c). (Moioli photo, 1994)

that of prostaglandin. Some trials have demonstrated that oestrus synchronization and in particular ovulation synchronization can be obtained using GnRH + prostaglandin after seven days + GnRH after 36 to 48 hours (Ovsynch protocol). This second administration of GnRH improves the efficiency of fixed time insemination because it synchronizes the ovulation in a short period of time. Baruselli et al. (1999) using this protocol had a CR of 48.8 percent in buffaloes inseminated during the breeding season (autumn / winter) and 6.9 percent in those inseminated during the non-breeding season. Neglia et al. (2001) utilizing a synchronization treatment with prostaglandin have reported a CR of 43.4 percent; by adding an injection of GnRH to this treatment, at the time of the first insemination, they found a similar CR (45.8 percent).

Table 9. Hormonal treatments to control oestrus in order to apply AI in buffaloes. Use of PGFα and GnRH

Reference	Treatment	Period	Conception rate
Chohan et al. (1993)	PGF2α	Peak breeding season Low breeding season	53.3 22.8
Baruselli et al. (1999)	GnRH+PGF2α+GnRH	Breeding season Non-breeding season	48.8 6.9
Neglia et al. (2001)	PGF2α PGF2α +GnRH	Low breeding season	43.4 45.8
Baruselli et al. (2002)	GnRH+PGF2α+GnRH	Non-breeding season	28.2
de Araujo et al. (2002)	GnRH+PGF2α+GnRH GnRH+ PGF2α+LH	Breeding season	56.5 64.2
Neglia et al. (2003)	GnRH+PGF2α+GnRH	Low breeding season	36.0
Barile et al. (2004)	GnRH+PGF2α+GnRH	Low breeding season	42.5

Table 10. Hormonal treatments to control oestrus in order to apply AI in buffaloes. Use of progesterone intravaginal device.

Reference	Treatment	Period	Conception rate
Rao and Rao (1983)	PRID	Peak breeding season Rest of the year	40.7 25.3
Sing et al. (1988)	PRID PRID+PMSG	Summer	8-28 50.0
Barile et al. (2001c)	PRID PRID+500 IU PMSG	Low breeding season	17.5 26.0
Barile et al. (2001b)	PRID+1000 IU PMSG	Low breeding season	56.7
Baruselli et al. (2002)	CIDR+eCG+hCG	Low breeding season	53.5
Neglia et al. (2003)	PRID+1000 IU PMSG	Low breeding season	28.2
Barile et al. (2003)	PRID+ 1000 IU PMSG PRID+1000 IU PMSG+GnRH	Low breeding season	64.5 45.2
Barile et al., (2004)	PRID+1000 IU PMSG	Low breeding season	47.8

Other authors using the Ovsynch protocol reported a CR at AI ranging from 56.5 percent (de Araujo Berber et al., 2002), if used during the breeding season, to 36.0 percent (Neglia et al., 2003), and 42.5 percent (Barile et al., 2004) if used in the period of transition to seasonal anoestrus.

Natural or synthetic progesterone containing devices (injections, intravaginal pessary, ear implants along with estradiol, PMSG and prostaglandin) have been used successfully to improve synchrony of oestrus and conception in buffaloes. Baruselli (2001) used progesterone intravaginal pessary (CIDR-B) or progestagen ear implant (CRESTAR) along with estradiol to study the follicular dynamic during the retaining of implants in order to evaluate the appropriate moment for fixed time insemination in buffalo cows. The author found that the CRESTAR protocol was not efficient in synchronizing oestrus and ovulation, while animals treated with CIDR-B protocol ovulated, although the percentage of ovulated animals (66.6 percent) and synchronization of ovulation (varying from 32 to 96 hours) was not particularly efficient.

The synchronization protocols, however, are efficient if buffaloes are cyclic and therefore these protocols can be used during the breeding season (autumn). In the spring season there is a higher variability between the beginning of oestrus and the ovulation time and it is more difficult to establish the correct time for AI.

Our previous work showed that the use of a progesterone pessary (PRID) improves pregnancy rate in the low breeding season and, moreover, is able to induce synchronization so that insemination can be effected at fixed times, overcoming the problem of the difficult oestrus detection (Barile et al., 1996a, 1997). The protocol foresees the use of a progesterone releasing intravaginal device (PRID), containing 1.55 g natural progesterone and a gelatine capsule with 10 mg oestradiol benzoate, kept in place for ten days. On the seventh day after PRID insertion, an injection of 1000 IU PMSG and one of 0.15 mg cloprostenol, a prostaglandin F2*a* analogue, are given. At PRID removal buffaloes are artificially inseminated at fixed times from withdrawal. In the first trial, in order to deal with ovulation time variability animals were inseminated three times: at 48, 72 and 96 hours from withdrawal and, in addition the same synchronization treatment schedule was used in the peak breeding season (autumn) and the low breeding one (spring), to evaluate if there was any difference in the conception rate at AI (Barile et al., 1999). The fertility rate did not differ between the two seasons considered. In fact, in autumn and in spring, respectively the peak and the low breeding seasons for Italian buffalo, the CR was 46.2 percent and 44.3 percent. Rao and Rao (1983) investigating the PRID treatment both during the peak and the low breeding season found that fertility was much higher during October to January (peak breeding season) than during the rest of the year (40.7 percent *vs* 25.3 percent). Singh et al. (1988) found that the use of gonadotrophin in addition to the PRID treatment ensures a good ovulatory response in the low breeding season. In fact, during the summer months, they observed a pregnancy rate of 50 percent in Indian buffaloes synchronized with PRID + PMSG, which was higher than that observed in their previous work using treatment with PRID alone (8 percent to 28 percent; Singh et al., 1983; 1984). We also found that the use of PMSG increases the fertility that is related to the doses utilized; in fact CR was 26 percent in buffaloes in which PRID + 500 IU PMSG were used and 17.5 percent in buffaloes in which PRID was used without gonadotrophin (Barile et al. 2001c). In our treatment schedule the addition of PGF2*a* to PRID + PMSG was useful to avoid any presence of a functional corpus luteum at the device removal which could delay the synchronization as reported in cattle by Mialot et al. (1996) and in buffaloes by Subramanian and Devarajan (1991).

Therefore PRID associated with PMSG and prostaglandin can be successfully employed in the low breeding season to increase the effectiveness of AI programmes in improving the fertility rate. The lack of difference in the CR between autumn and spring allows the use of AI for application in breeding schemes during the low breeding season, thus resolving the need of Italian farmers to have conceptions between March and September in order to satisfy the higher market demand for buffalo milk in the summer.

To better define the proper time for AI following the PRID synchronization treatment we have evaluated the time of LH peak after pessary removal (Barile et al., 1998; Borghese et al., 1999). In buffaloes synchronized in spring (Barile et al., 1998) the interval from PRID removal to LH peak was 54.7±12.3 hours ranging from 40 to 76 hours. Considering ovulation as the time at which a ruptured follicle was palpated, the interval from PRID removal to ovulation was 84±13.1 hours whilst the one from LH peak to ovulation was 31.0±8.9 hours, similar to the one found in previous work (Seren et al.,1994) in non treated buffaloes which was 36 hours on average. Evaluating the time of LH peak in oestrus synchronized buffaloes in two different seasons (Borghese et al.,1999), it was found that the interval from PRID removal to LH peak was 46.87±21.53 hours in November and 61.00±12.05 hours in March. The ovulation (checked daily by rectal palpation) occurred within 72 hours from PRID removal in November and within 96 hours in March. On the basis of these results it has been suggested that 72 and 96 hours after PRID removal are more appropriate times for AI in synchronized buffalo cows in the low breeding season while 48 and 72 hours could be better in the autumn. In fact, utilizing PRID+1000 IU PMSG and two AI schedules at 72 and 96 hours during the spring season we have obtained a CR ranging from 47.8 to 64.5 percent in different years (Barile et al, 2001b, 2003, 2004). These are good results considering that animals are treated in a period in which their reproductive efficiency is lower and that the treatment increases the fertility so that buffaloes that do not conceive at AI will become pregnant later during the natural breeding period.

In order to decrease the variation in ovulation time and increase the effectiveness of fixed time AI, GnRH was used in association with PRID treatment, but the conception rate did not improve with respect to that found using the PRID protocol alone (45.2 percent and 64.5 percent with PRID+GnRH or PRID respectively) (Barile et al., 2003). Satisfactory results (53.5 percent of CR) during the non-breeding season have been obtained by Baruselli et al. (2002) using a progesterone intravaginal device (CIDR) associated with eCG and hCG (equine and human Chorionic Gonadotrophin), since the animals received only one insemination (62 hours from CIDR withdrawal). Recently, we have compared the efficiency of PRID and Ovsynch protocols for the application of fixed time AI in buffalo cows in the Spring. The two different hormonal schedules utilized showed the same efficiency in obtaining oestrus synchronization and a good conception rate at AI, in the Spring. Although the fertility rate did not differ significantly between the PRID and Ovsynch protocols (47.8 percent and 42.5 percent respectively), a higher conception rate was found in buffaloes synchronized with PRID compared with Ovsynch, as PRID treatment was efficient in removing the anoestrus status in non-cycling animals (Barile et al., 2004). This conclusion is supported by the work of Baruselli et al. (1999) that using an Ovsynch protocol resulted in a CR of 48.8 percent in buffaloes inseminated during the breeding season (autumn-winter) and 6.9 percent in those inseminated during the non-breeding season. In fact, the same researchers, comparing CIDR+eCG+hCG treatment to GnRH+PGF2*a*+GnRH (Ovsynch protocol) in the non-breeding season, resulted in a higher CR at AI in animals treated with CIDR (53.5 percent *vs* 28.2 percent) (Baruselli et al., 2002).

Conclusion

Improvement of reproductive efficiency in the buffalo can be obtained by directing attention to management systems and utilizing controlled breeding techniques.

The application of oestrus induction techniques permits the possibility of inducing fertile oestrus in non cycling heifers, in order to increase fertility in the low breeding season and reduce the intercalving period. Different treatments are utilized to induce oestrus, such as prostaglandin, gonadorelin, progestagen, however improved results have been obtained using PRID plus PMSG and prostaglandin. To identify buffaloes in heat, in order to apply AI, the presence of a teaser bull can be helpful. New approaches are being developed to provide automated systems of detection of oestrus using electronic technology such as pedometry and radiotelemetry. To apply a fixed time AI, thereby overcoming the problem of oestrus detection, different hormonal treatment schedules have been proposed. Protocols using fixed time insemination and only prostaglandin treatment have not provided good results. The use of GnRH, in association with that of prostaglandin, improves the efficiency of fixed time insemination because it synchronizes the ovulation in a short period of time but this treatment is efficient when buffaloes are cyclic. The use of PRID associated with PMSG and prostaglandin can be successfully employed in the low breeding season thereby proving to be the preferred treatment when oestrus synchronization and AI are programmed out of the breeding season.

References

Ahmad, N., Chaudhry, R.A. and Khan, B.B. 1981. Effect of months and season of calving on the length of subsequent calving interval on Nili Ravi buffaloes. Anim. Reprod. Sci., 3: 301-306.

Andurkar, S.B. and Kadu, M.S. 1995. Induction of oestrus and fertility with CIDR device and combination in non cycling buffaloes. Indian J. Anim. Reprod., 16 (2): 81-84.

Arya, J.S. and Madan, M.L. 2001. Post partum reproductive cyclicity based on ovarian steroids in suckled and weaned buffaloes. Buffalo J., 17 (3): 361-369.

Awasthi, M.K., Tiwari, R.P. and Pangaonkar, G.R. 1998. Induction of oestrus and fertility with low dose of prostaglandin F2 alpha in suboestrus buffaloes. Indian J. Anim. Sci., 68 (10): 1049-1050.

Barile, V.L., Galasso, A. and Carretta, A. 1999. Preliminary results on conception rates in Italian buffaloes after the use of intravaginal progesterone device and artificial insemination. Buffalo Newsletter (FAO Bulletin, Rome), 6: 3-4.

Barile, V.L., Moioli, B., Terzano, G.M., Napolitano, F., Puppo, S., Debenedetti, A., Malfatti, A., Catalano, A. and Borghese, A. 1996b. Ovulation prediction to improve artificial insemination in buffalo cows. Bulgarian J. Agric. Sci., 2: 103 107.

Barile V.L., Galasso A., Marchiori E. and Borghese A., 1997. Effect of PRID treatment on oestrus synchronization and progesterone levels in Italian buffaloes. In: Proc. Fifth World Buffalo Congress, Caserta, Italy, 13-16 October: 738-743.

Barile, V.L., Galasso, A., Terzano, G.M., Malfatti, A. e Barbato, O. 1998. Valutazione del picco di LH in bufale (Bubalus bubalis) sottoposte a sincronizzazione dell'estro ai fini della inseminazione artificiale [Evaluation of LH peak in oestrus synchronized buffaloes (Bubalus bubalis) to perform artificial insemination]. In: Atti LII Convegno Nazionale S.I.S.Vet., Silvi Marina, Italy; 17 - 19 Settembre: 85-86.

Barile, V.L., Galasso, A., Pacelli, C., Francillo, M., Cigliano, A., Penna, L., Panfili, M., Fiorini, M. and Borghese, A. 1999. Conception rate in synchronized and artificially inseminated buffalo cows in two different seasons under field conditions. In: Recent Progress in Animal Production Science.1. Proc. XIII A.S.P.A. Congress, Piacenza, Italy. 21-24 June: 262-264.

Barile, V.L., Galasso, A., Marchiori, E., Pacelli, C., Montemurro, N. and Borghese, A. 2001a. Effect of PRID treatment on conception rate in Mediterranean buffalo heifers. Livest. Prod. Sci., 68: 283-287.

Barile, V.L., Galasso, A., Carretta, A., Marchiori, E. and Borghese, A. 2001b. Evaluation of different timed inseminations on conception rate in synchronized Italian buffaloes. In: Proc. Sixth World Buffalo Congress, Maracaibo, Venezuela, 20-30 May : 172-178.

Barile, V.L., Pacelli, C., Galasso, A., De Mauro, G.J., Francillo, M., Cigliano, A., Penna, L., Panfili, M., Terzano, G.M. e Borghese, A. 2001c. Inseminazione artificiale nella bufala. - Risultati di prove condotte nel Lazio. [Artificial insemination in buffaloes. - Results of trials carried out in the Lazio region]. In: Atti 1° Congresso Nazionale sull'Allevamento del Bufalo, Eboli, Italy, 3-5 Ottobre: 354-358.

Barile, V.L., De Santis, G., Malfatti, A., Barbato, O. and Borghese, A. 2003. Use of GnRH in association with PRID treatment in oestrus synchronization protocol for fixed timed insemination in buffalo cow. In: Atti 2° Congresso Nazionale sull'Allevamento del Bufalo, Monterotondo, Italy, 28-30 Agosto: 285-289.

Barile, V.L., Pacelli, C., De Santis, G., Penna, L., Veloccia, C., Allegrini, S., Lomolino, R., Barbato, O. and Borghese, A. 2004. Fixed time artificial insemination in buffalo using two different hormonal schedule for oestrus synchronization. Preliminary results. In: Proc. 7th

World Buffalo Congress, Manila, Philippine, October 20-23, vol.II: 585-587.

Barkawi, A.H., Mokhless, E.M. and Bedeir, L.H. 1989. Environmental factors affecting age at puberty in Egyptian buffaloes. Buffalo J., 5 (1): 71-78.

Barkawi, A.H., Khattab, R.M. and El-Wardani, M.A. 1998. Reproductive efficiency of Egyptian buffaloes in relation to oestrus detection systems. Anim. Reprod. Sci., 51: 225-231.

Baruselli, P.S. 1996. Reprodução de bubalinos. In: I Simposio Brasileiro de Bubalinocultura, Cruz das Almas, Brasil: 29.

Baruselli, P.S., Madureira, E.H., Visintin, J.A., Barnabe, V.H, Barnabe, R.C. and Amaral, R. 1999. Timed insemination using synchronization of ovulation in buffalo. Rev. Bras. Reprod. Anim., 23: 360-362.

Baruselli, P.S. 2001. Control of follicular development applied to reproduction biotechnologies in buffalo. Atti 1° Congresso Nazionale sull'Allevamento del Bufalo, Eboli, Italy, 3-5 Ottobre: 128-146.

Baruselli, P.S., Barnabe, V.H., Barnabe, R.C., Visintin, J.A., Molero-Filho, J.R. and Porto R. 2001. Effect of body condition score at calving on postpartum reproductive performance in buffalo. Buffalo J., 17 (1): 53-65.

Baruselli, P.S., Carvalho, N.A.T., Henriquez, C.E.P., Amaral, R., and Nichi, M. 2002. Synchronization of ovulation for timed artificial insemination during the off breeding season in the buffalo. In: Proc. First Buffalo Symposium of Americas, Belém, Brasil: 418-420.

Beg, M.A. and Totey, S.M. 1999. The oestrous cycle, oestrous behaviour and the endocrinology of the oestrous cycle in the buffalo (Bubalus bubalis). Anim. Breed. Abs., 67 (5): 329-337.

Borghese, A., Terzano, G.M., Barile, V.L., Annicchiarico, G. and Parmeggiani, A. 1993a. Onset of puberty in Italian buffalo heifers: Note II-Influence of bull exposure on age at puberty. In: Proc. International Symposium "Prospects of Buffalo Production in the Mediterranean and the Middle East", Cairo, Egypt, 9-12 November 1992, EAAP Publication, Pudoc, Wageningen, n. 62: 370-373.

Borghese, A., Barile, V.L., Terzano, M.G., Annichiarico, G., De Benedetti, A. and Malfatti, A. 1993b. Anoestrous length in Italian buffalo cows. Note I. In: Proc. International Symposium "Prospect of Buffalo Production in the Mediterranean and in the Middle East", Cairo, Egypt, 9-12 November 1992. EAAP Publication, Pudoc, Wageningen, n. 62: 389-392.

Borghese, A., Barile, V.L., Campanile, G., Esposito, L. e Pacelli, C. 1993c. Induzione dell'estro in bufale acicliche. Nota I. Percentuale di ciclicità. [Oestrus induction in acyclic water buffaloes. Note I. Cyclicity rate]. In: Atti 5° Meeting Nazionale "Studio della Efficienza Riproduttiva degli Animali di Interesse Zootecnico", Bergamo, Italy, 30 Aprile:125-129.

Borghese, A., Terzano, G.M., Barile, V.L., Annicchiarico, G., Allegrini, S., Zicarelli, L., Montemurro, N., Pacelli, C., Campanile, G., Esposito, L., Di Palo, R., Boni, R., Seren, E. e Parmeggiani, A. 1994a. Pubertà e mantenimento dell'attività ciclica ovarica nella bufala. [Puberty and maintenance of ovarian cyclic activity in buffalo] Agricoltura Ricerca, 153: 5-16.

Borghese, A., Terzano, G.M., Barile, V.L. and Parmeggiani, A. 1994b. Season and feeding level effects on onset of puberty in buffalo heifers. In: Proc. Fourth World Buffalo Congress, Sao Paulo, Brazil, 27-30 June: 525-527.

Borghese, A., Barile, V.L., Terzano, G.M., Pilla, A.M. and Parmeggiani, A. 1995. Melatonin trend during season in heifers and buffalo cows. Bubalus bubalis, 1: 61 64.

Borghese, A., Terzano, M.G., Barile, V.L., Catalano, A. and Malfatti, A. 1996. Onset of puberty in buffalo heifers in different feeding and management systems. In: Proc. International

Symposium on Buffalo Resources and Production Systems, Cairo, Egypt, 14 -17 October: 41-46.

Borghese, A., Barile, V.L., Ficco, G., Galasso, A., Marchiori, E. and Terzano, G.M. 1997. Feeding system effect on reproduction performances in buffalo heifers. In: Proc. Fifth World Buffalo Congress, Caserta, Italy, 13 - 16 October: 697-701.

Borghese, A., Barile, V.L., Terzano, G.M., Galasso, A., Malfatti, A. and Barbato, O. 1999. Time of LH peak in oestrus synchronized buffaloes in two different seasons. In: Book of Abstracts of the 50th EAAP Annual Meeting, Zurich, Switzerland, 22-26 August: 166.

Campanile, G., Di Palo, R., Ferrari, G., Intrieri, F. and Zicarelli, L. 1988. Influence of farm and climatic elements on the alfaprostol-induced heats in Mediterranean buffalo cows. In: Proc. Second World Buffalo Congress, New Delhi, India, 12 - 16 December, vol. III: 40-48.

Campanile, G., Di Palo, R., Gasparrini, B., D'Occhio, M.J. and Zicarelli, L. 2001. Effects of early management system and subsequent diet on growth and conception in buffalo heifers. Livest. Prod. Sci., 71 (2/3): 183-191.

Campo, E., Alons,o J.C., Hincapie, J.J., García, L., Faure, O. and Fernández, O. 2002. Seasonal influence on uterine involution and postpartum ovarian activity in river buffaloes. Bubalus bubalis, 8 (3): 59-63.

Chantaraprateep, P., Loachit, C., Kobayashi, G., Techakumphu, M., Virakul, P., Kunavongkrit, A. and Prateep, P. 1988. Ovarian responses to gonadotrophin stimulation in swamp buffalo. Buffalo Bull., 7 (4): 82-86.

Chohan, K.R., Iqbal, J. and Asghar, A.A. 1993. Influence of season on fertility of oestrus synchronized buffalo. Buffalo J., 9 (1): 65-67.

Chohan, K.R. 1998. Oestrus synchronization with lower doses of PGF2*a* and subsequent fertility in suboestrus buffalo. Theriogenology, 50 (7): 1101-1108.

Da Silva, M.E.T. and Grodzki, L. 1991. Study of correlations between climatic factors and seasonal fertility of female buffaloes in the Northeast of the State of Parana - Brazil. In: Proc. Third World Buffalo Congress, Varna, Bulgaria, 13 - 18 May: 689-700.

de Araujo Berber, R.C., Madureira, F.H. and Baruselli, P.S. 2002. Comparison of two Ovsynch protocols (GnRH versus LH) for fixed timed insemination in buffalo (Bubalus bubalis). Theriogenology, 57 (5): 1421-1430.

De Franciscis, G. 1988. Buffalo production system in Europe. In: Proc. Second World Buffalo Congress, New Delhi, India, 12-16 December, vol.II: 21-42.

Dhalival, G.S., Sharma, R.D. and Singh, G. 1988. Efficacy of prostaglandin F2 alpha administration for inducing oestrus in buffalo. Theriogenology, 29 (6): 1401-1406.

Di Palo, R., Parmeggiani, A., Spadetta, M., Campanile, G., Esposito, L., Seren, E. and Zicarelli, L. 1997. Influence of changing farm on repeatability of melatonin plasma level in Italian Mediterranean buffalo. In: Proc. Fifth World Buffalo Congress, Caserta, Italy, 13-16 October: 758-761.

Di Palo, R., Campanile, G., Prandi, A., Ciaramella, R. and Zicarelli, L. 1999. Preliminary results on the use of pedometers to detect oestrus in dairy buffaloes. In: Recent Progress in Animal Production Science.1. Proc. XIII A.S.P.A. Congress, Piacenza, Italy 21-24 June: 265-267.

Di Palo, R., Campanile, G. e Zicarelli, L. 2001. Tecnologie utilizzate per la rilevazione dei calori e inseminazione strumentale nella specie bufalina. [Use of new technologies for heat detection and artificial insemination in the buffalo] In: Atti 1° Congresso Nazionale sull'Allevamento del Bufalo, Eboli, Italy, 3 - 5 Ottobre: 100-113.

El-Fouly, M.A., Kotby, E.A. and El-Soubhy, H.E. 1976. Post partum ovarian activity in suckled and milked buffaloes. Theriogenology, 5: 69-79.

FAO (Food and Agriculture Organization of the United Nations), FAOSTAT Agriculture Data, 2004. http:\\apps.fao.org/default.htm.

Fateh, Mohammed, Dhaliwal, G.S. and Sharma, R.K. 1999. Clinical efficacy of GnRH analogue (buserelin) and oestradiol benzoate treatments in anoestrus buffaloes. Indian J. Anim. Sci., 69 (5): 310-312.

Ferrara, B. 1964. Su alcuni aspetti dell'allevamento del bufalo in Italia. [About some aspects of buffalo breeding in Italy]. Rivista di Zootecnia, 37: 304 319.

Gill, S.S. and Rurki, G.S. 1985. Effect of season of calving on the reproductive behaviour of water buffalo (Bubalus bubalis). In: Proc. First World Buffalo Congress, Cairo, Egypt: 604-612.

Gogoi, P.K., Das, D., Goswami, R.N., Nahardeka, N. and Das, G.C. 2002. Studies on age at first calving in Murrah and Surti buffaloes maintained in Assam. Indian Vet. J., 79 (8): 854-855.

Gupta, K.A. and Purohit, G.N. 2001. Use of vaginal electrical resistance (VER) to predict oestrus and ovarian activity, its relationship with plasma progesterone and its use for insemination in buffaloes. Theriogenology, 56 (2): 235-245.

Hafez, E.S.E. 1955. Puberty in the buffalo cow. J. Agr. Sci., 46: 137-142.

Hattab, S.A. and Osman, R.A. 2000. Use of Norgestomet and oestradiol valerate injection with norgestomet implant and/or PMSG for induction of oestrus in anoestrous buffaloes. Vet. Med. J., Giza, 48 (1): 135-143.

Honnappagol, S.S. and Patil, R.V. 1991. Oestrus synchronization and fertility in buffalo heifers using Carboprost Tromethanine. Indian J. Anim. Reprod., 12 (2): 177-179.

Ishaq, S.M. 1972. Ninth Annual Report. Directorate of Livestock Farms, Punjab, Lahore.

Jainudeen, M.R., Bongso, T.A. and Tan, H.S. 1983. Postpartum ovarian activity and uterine involution in the suckled swamp buffalo (Bubalus bubalis). Anim. Reprod. Sci., 5: 181-190.

Jainudeen, M.R. and Hafez, E.S.E. 1993. Cattle and Buffalo. In: Hafez E.S.E. (Ed.), Reproduction in Farm Animals, 6th ed., Lea and Febiger, Philadelphia: 315-329.

Kamonpatana, M., Kunawongkrit, A., Bodhipaksha, P. and Luvira, Y. 1979. Effect of PGF2*a* on serum progesterone levels in the Swamp buffalo (Bubalus bubalis). J. Reprod. Fertil., 56: 445-449.

Kamonpatana, M., Pansin, C., Timsard, V., Limsakul, A., Vechabusakorn, A., Savasri, S., Parnpai, R. and Pikultong, P. 1987. Indication of puberty as related to fertility based on body weight, age and profiles of reproductive hormones in swamp buffaloes. Buffalo J., 3 (2): 181-194.

Khan, A.H., Chohan, K.R., Chaudhry, R.A. and Naz, N.A. 1995. Comparison of two different doses of PMSG for oestrus induction in non cycling buffalo heifers. Pakistan Vet. J., 15 (1): 34-37.

Kharche, S.D. and Srivastava, S.K. 2001. Fertility following treatment of suboestrus buffaloes with prostaglandin F2*a*. Indian J. Anim. Reprod., 22 (2): 170 - 171.

Kumaresan, A. and Ansari, M.R. 2001. Evaluation of conception rate in buffaloes (Bubalus bubalis) with reference to semen quality, stage of oestrus and inseminator. Indian J. Anim. Sci.,71 (2): 144-145.

Le Xuan Cong, 1983. Performances in Vietnamese Swamp buffalo. Buffalo Bulletin, 2 (2): 12-13.

Madan, N.L. 1988. Status of Reproduction in female buffalo. In: Proc. Second World Buffalo Congress, New Delhi, India, 12-16 December, vol. III: 89-90.

Malfatti, A. 2003. Recent advances in buffalo endocrinology. In: Atti 2° Congresso Nazionale sull'Allevamento del Bufalo, Monterotondo, Italy, 28 - 30 Agosto: 161-176.

Maymone, B. e Pilla, A.M. 1961. L'intervallo interpartum della bufala in rapporto alla stagionalità dei parti ed all'effetto di altri fattori extragenetici. [Intercalving interval in the buffalo cow related to calving seasonality and other extragenetic factors]. Ann. Istituto Sperimentale Zootecnico, Roma, 15: 15-60.

McCool, C.J., Townsend, M.P., Wolfe, S.G. and Entwistle, K.W. 1987. Endocrinological studies on pregnancy, post partum anoestrus and seasonal variation of ovarian activity in the Australian Swamp buffalo cow. Buffalo J.,1: 67-72.

McCool, C.J., Townsend, M.P., Entwistle, K.W., Wolfe, S.G. and Ridd, C.A.J. 1988. Puberty in the Australian Swamp Buffalo Heifer. Buffalo J., 2: 237-241.

Mialot, J.P., Gipoulou, Ch., Bihoreau, J.L., Roux, M.E., Ponsart, C., Pobel, T. et Deletang, F. 1996. Synchronisation des chaleurs chez les vaches allaitantes lors de vêlage d'automne avec l'association PRID+Hormo P2*a*. [Oestrus synchronization after autumn calving period with PRID+Hormo P2? in suckled beef cows]. Renc. Rech. Ruminants, 3: 192.

Minoia, P., Zicarelli, L., Lacalandra, G. and Mastronardi, M. 1984. Follicular development in anoestrus water buffalo by means of pulsatile doses of GnRH. In: Proc. 10th International Congress on Animal Reproduction and Artificial Insemination, Urbana-Champaign, USA, 10-14 June, vol. II: 13-14.

Mohamed, A.A., El-Ashry, M.A. and El-Serafy, A.M. 1980. Reproductive performance of buffalo heifers bred at a young age. Indian J. Anim. Sci., 50: 8.

Moioli, B.M., Napolitano, F., Puppo, S., Barile, V.L., Terzano, G.M., Borghese, A., Malfatti, A., Catalano, A. and Pilla, A.M. 1998. Pattern of oestrus, time of LH release and ovulation and effects of time of artificial insemination in Mediterranean buffalo cows. Anim. Sci., 66: 87-91.

Naqvi, A.N. and Shami, S.A. 1999. Comparative performance of early and late maturing Nili Ravi buffalo heifers. Asian-Australasia J. Anim. Sci., 12 (3): 336 - 340.

Naqvi, A.N. 2000. Effect of parity and season of calving on service period in Nili-Ravi buffalo in Pakistan. Asian-Australasian J. Anim. Sci., 13 (3): 287-291.

Nebel, R.L., Dransfield, M.G., Jobst, S.M. and Bame, J.H. 2000. Automated electronic systems for the detection of oestrus and timing of AI in cattle. Anim. Reprod. Sci., 60-61: 713-723.

Neglia, G., Midea, D., Caracciolo di Brienza, V., Rossi, N. e Zicarelli, L. 2001. Associazione del GnRH alle prostaglandine nella inseminazione artificiale della bufala Mediterranea Italiana. [GnRH associated with prostaglandin in artificial insemination of the Mediterranean Italian buffalo cow]. In: Atti 1° Congresso Nazionale sull'Allevamento del Bufalo, Eboli, Italy, 3-5 Ottobre: 337-340.

Neglia, G., Gasparrini, B., Di Palo, R., De Rosa, C., Zicarelli, L. and Campanile, G. 2003. Comparison of pregnancy rates with two oestrus synchronization protocols in Italian Mediterranean Buffalo cows. Theriogenology, 60 (1): 125-133.

Okuda, H.T., Starke Buzetti, W.A., Fagliari, J.J., Passipiéri, M., Zocoller Seno, M.C. and Bergamaschine, A.F. 1999. Idade a pubertade, idade a primeira cria e intervalo entre partos de búfalos.[Observations of puberty, age at first calving and calving interval in buffalo cows].

Veterinária Notícias, 5 (1): 91-96.

Pacelli, C., Barile, V.L., Lenza, R., Terzano, M.G., Montemurro, N. and Borghese, A. 2001. Comparison of two different doses of PMSG on conception rate in Mediterranean buffalo heifers treated with PRID. In: Proc. Sixth World Buffalo Congress, Maracaibo, Venezuela, 20-30 May: 160-165.

Parmeggiani, A., Seren, E., Esposito, L., Borghese, A., Di Palo, R. and Terzano, M.G. 1993. Plasma levels of melatonin in buffalo cows. In: Proc. International Symposium "Prospect of Buffalo Production in the Mediterranean and in the Middle East", Cairo, Egypt, 9-12 November 1992. EAAP Publication, Pudoc, Wageningen, n. 62: 401-403.

Parmeggiani, A., Di Palo, R., Zicarelli, L., Campanile, G., Esposito, L., Seren, E., Accorsi, P.A. e Soflai, S.M. 1994. Melatonina e stagionalità riproduttiva nella bufala. [Melatonin and reproductive seasonality in the buffalo cow]. Agricoltura Ricerca, 153: 41-48.

Phathodiya, O.P., Jain, L.S. and Tailor, S.P. 1999. Age at first calving and its correlation with economic traits in Surti buffalo. Indian Vet. J., 76 (10): 902-905.

Pires, R.M.L., Reichert, R.H., Martinez, A.C. and Baruselli, P. 2002. Índices reprodutivos de búfalos da raça Murrah. [Some reproductive traits in a Murrah buffalo herd]. Revista Brasileira de Reprodução Animal, 26 (2): 119-120.

Qureshi, M.S., Habib, G., Samad, H.A., Lodhi, L.A. and Usmani, R.H. 1999a. Study of factors leading to seasonality of reproduction in dairy buffaloes. II. Non nutritional factors. Asian-Australasian J. Anim. Sci., 12 (7): 1025-1030.

Qureshi, M.S., Safi, G.M., Dhanani, J. and Kaka, I. 1999b. Reproductive performance of dairy buffaloes in the northern hilly areas of Pakistan. Buffalo J., 15 (3): 391-396.

Rao, A.R. and Rao, Ch.C. 1983. Synchronization of oestrus and fertility in buffaloes with a progesterone releasing intravaginal device. Vet. Rec., 113: 623 624.

Rao, A.V.N. and Sreemannarayana, O. 1983. Induction of ovulatory oestrus and fertility in non cycling buffaloes with norgestomet during low breeding season. Therigenology, 19 (3): 305-309.

Reddy, A.O., Ramesha, K.P. and Rao, M.K. 1999. Effect of climate on the incidence of oestrus, conception and cycle length in Murrah buffaloes. Indian J. Anim. Sci., 69 (7): 485-489.

Sahasrabudhe, S.A. and Pandit, R.K. 1997. PGF2*a* induced oestrus in suboestrus Murrah buffaloes during the summer. Indian J. Anim. Sci., 67: 513-514.

Saini, M.S., Galhotra, M.M., Sangwan, M.L. and Razdan, M.M. 1988. Use of PRID in inducing oestrus and its effect on the sexual behaviour of Murrah buffalo heifers. Indian J. Dairy Sci., 41 (1): 40-42.

Saini, M.S., Dhanda, O.P., Singh, N. and Georgie, G.C. 1998. The effect of improved management on the reproductive performance of pubertal buffalo heifers during the summer. Indian J. Dairy Sci., 51 (4): 250-253.

Salama, M.A.M., Mokhless, E.M. and Barkawi, A.H. 1994. Pubertal performance of Egyptian buffalo heifers. Buffalo J., 10 (1): 61-66.

Salerno, A. 1974. Statistiche vitali nei bufali. [Performances in buffalo]. In: Atti I Convegno Internazionale sull'Allevamento Bufalino nel Mondo, Caserta, Italia, 7-9 Novembre: 115-140.

Seren, E., Parmeggiani, A., Mongiorgi, S., Zicarelli, L., Montemurro, N., Pacelli, C., Campanile, G., Esposito, L., Di Palo, R., Borghese, A., Barile, V.L., Terzano, M.G., Annicchiarico, G. e Allegrini, S. 1994. Modificazioni endocrine durante il ciclo estrale nella bufala. [Periestrous endocrine changes in Italian buffaloes]. Agricoltura Ricerca, 153: 17-24.

Shah, S.N.H. 1988. Comparative studies of seasonal influence on breeding behaviour and conception rate of dairy buffaloes and zebu cattle. In:Proc. Eleventh Int. Congr. on Anim. Reprod. Dublin (Ireland), III: 538.

Shah, S.N.H., Willemse, A.H. and Van de Wiel, D.F.M. 1989. Influence of season and parity on several reproductive parameters of Nili-Ravi buffaloes in Pakistan. Anim. Reprod. Sci. 21, 177-190.

Shah, S.N.H., Willemse, A.H. and Van De Wiel, D.F.M. 1990. Reproductive performance of Nili-Ravi buffaloes after a single injection of GnRH early post partum. Tropic. Anim. Health and Prod., 22 (4): 239-246.

Singh, B. and Lal, K. 1994. Effect of seasons on the incidence of breeding and conception rate in buffaloes. Indian J. Anim. Sci., 64: 314-316.

Singh, G., Singh, G.B., Sharma, R.D. and Nanda, A.S. 1983. Experimental treatment of summer anoestrus buffaloes with norgestomet and PRID. Theriogenology, 19 (3): 323-329.

Singh, G., Singh, G.B., Sharma, R.D. and Nanda, A.S. 1984. Ovulation and fertility after PRID, PRID+GnRH and GnRH in anestrous buffaloes. Theriogenology, 21 (6): 859-867.

Singh, G., Dhaliwal, G.S., Sharma, R.D. and Biswas, R.K. 1988. Treatment of summer anestrous buffalo (Bubalus bubalis) with progesterone releasing intravaginal device plus pregnant mare serum gonadotropin. Theriogenology, 29 (5): 1201-1206.

Singh, J., Nanda, A.S. and Adams, G.P. 2000. The reproductive pattern and efficiency of female buffaloes. Anim. Reprod. Sci., 60-61: 593-604.

Srivastava, S.K. and Sahni, K.L. 1999. Effect of season on oestrus and conception in village cows and buffaloes. Indian Vet. J. 76 (5): 385-387.

Subramaniam, A. and Devarajan, K.P. 1991. Oestrus synchronization in nondescript Indian buffaloes with a new intravaginal progesterone pessary and PGF2*a*. Buffalo J., 7 (1): 101-105.

Sule, S.R., Taparia, A.L., Jain, L.S. and Tailor, S.P. 2001. Reproductive status of Surti buffaloes maintained under sub-humid conditions of Rajasthan. Indian Vet. J., 78 (11): 1049-1051.

Takkar, O.P., Narinder Singh, Jaght Kaur, and Chaudhary, K.C. 1999. Augmentation of post-partum reproductive efficiency by use of GnRH in buffaloes, Indian J. Anim. Reprod., 20 (1): 9-11.

Terzano, G.M., Barile, V.L., Francia, U., Malfatti, A., Todini, L. and Borghese, A. 1996. Onset of puberty in buffalo heifers bred on pasture or in intensive feeding systems. Bulgarian J. Agric. Sci., 2: 89-92.

Terzano, G.M., Galasso, A., Barile, V.L., Pacelli, C., Montemurro, N. and Borghese, A. 1997. Effect of feeding system and puberty on blood metabolites trends in buffalo heifers. In: Proc. Fifth World Buffalo Congress, Caserta, Italy, 13 - 16 October: 951-956.

Tulloch, D.G. and Grassia, A.A. 1981. A study of reproduction in the Water Buffalo in the Northern Territory of Australia. Australian Wildlife Res., 8: 335-348.

Uma Shanker, Agarwal, S.K., Satish Kumar and Greesh Mohan, 1999. Oestrus response and fertility using progestagen ear implant in noncyclic buffalo (Bubalus bubalis). Indian J.Vet. Res., 8 (1): 54-58.

Usmani, R.H., Dailey, R.A. and Inskeep, E.K. 1990. Effects of limited suckling and varying prepartum nutrition on postpartum reproductive traits of milked buffaloes. J. Dairy Sci.,73: 1564-1570.

Vale, W.G., Ohashi, O.M., Sousay, J.S. and Ribeiro, H.F.L. 1990. Studies on the reproduction of Water buffalo in the Amazon Basin. In: Livestock Reproduction in Latin America. Proceedings of the final research coordination meeting. Bogotà, Colombia, 19-23 September 1988. IAEA, Vienna: 201-210.

Zicarelli, L., Di Lella, T. e De Franciscis, G. 1977. Osservazione e rilievi sui parametri riproduttivi e produttivi di bufale in allevamento presso un'azienda della valle del Sele. [Observations on the reproductive and productive parameters of buffalo bred on a Sele valley farm]. Acta Medica Veterinaria, 23: 183-206.

Zicarelli, L. e Boiti, C. 1982. Risultati preliminari sull'impiego in primavera di spirali vaginali con progesterone nella bufala. [Preliminary results on the use of a progesterone intravaginal device in Italian buffalo cows during the spring season]. In: Atti II Convegno Internazionale sull'Allevamento Bufalino nel Mondo, Caserta, Italia, 29 Settembre - 2 Ottobre: 412-419.

Zicarelli, L., Infascelli, F., Esposito, L., Consalvo, F. and De Franciscis, G. 1988. Influence of climate on spontaneous and alfaprostol induced heats in Mediterranean buffalo cows bred in Italy. In: Proc. Second World Buffalo Congress, New Delhi, India, 12-16 December 1988, vol. III: 49-56.

Zicarelli, L. 1992. Recenti acquisizioni sull'attività riproduttiva nella bufala. [Advances in buffalo cow reproduction]. In: Atti 4° Meeting Nazionale "Studio della Efficienza Riproduttiva degli Animali di Interesse Zootecnico", Bergamo, Italy, 10 Aprile: 9-39.

Zicarelli, L., Campanile, G., Seren, E., Borghese, A., Parmeggiani, A. and Barile, V.L. 1993. Periestrus endocrine changes in Italian buffaloes with silent oestrus or ovarian disorders. In: Proc. International Symposium "Prospects of Buffalo Production in the Mediterranean and the Middle East", Cairo, Egypt, 9-12 November 1992, EAAP Publication, Pudoc, Wageningen, n. 62: 397-400.

Zicarelli, L., Campanile, G., Esposito, L., Di Palo, R., Boni, R., Spadetta, M., Montemurro, N., Pacelli, C., Borghese, A., Barile, V.L., Terzano, G.M., Annicchiarico, G., Allegrini, S., De Benedetti, A., Malfatti, A., Lucaroni, A. e Todini, L. 1994. Anaestro e induzione dell'estro in bufale acicliche. [Anoestrus and oestrus induction in acyclic buffaloes]. Agricoltura Ricerca, 153: 25-40.

Zicarelli, L. 1997. Reproductive seasonality in buffalo. Bubalus bubalis, 4, Suppl.: 29 - 52.

Zicarelli, L., De Filippo, C., Francillo, M., Pacelli, C. and Villa, E. 1997a. Influence of insemination technique and ovulation time on fertility percentage in synchronized buffaloes. Proc. Fifth World Buffalo Congress, Caserta, Italy, 13-16 October: 732-737.

Zicarelli, L., Esposito, L., Campanile, G., Di Palo, R. and Armstrong, D.T. 1997b. Effect of using vasectomized bulls in artificial insemination practice on the reproductive efficiency of Italian buffalo cows. Anim. Sci., 47: 171-180.