Effects of environment on buffalo reproduction

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ABSTRACT: It has been long recognized that the environment has an important role to play in the regulation of the mammalian reproductive function. Environmental cues, such as changing day-light or increase temperature, are know to trigger off growth or regression of the reproductive organs in a whole variety of species and nutrition and stress can influence the onset of breeding and affect the fertility. Although the domestic buffalo (Bubalus bubalis) has been since long time considered as a short-day-breeder polyestral seasonal animal, indeed in the tropical areas near of equator line they are polyestral continuous. It would seem that photoperiod has a marked influence in buffalo reproduction in determinate areas of the world, however in some tropical areas like in Brazil, mainly in the Amazon valley and areas nearest of the equator the light seems to have a minimal effect or no effect on the reproductive cues however the nutrition and heat stress measured throughout temperature/humidity indexes (THI) play an important role in the reproductive functions of buffaloes and it is suggested that THI >75 has a negative effect on reproductive performances of buffaloes. The calving season is regulated by the availability of native pasture in the floodplain or in areas of artificial pasture. On the other hand when buffaloes are raised in the southwest and southern regions (parallels 14 to 33 South) they show a typical seasonal pattern when the calving season are concentrated between de February to July. The body condition score (BCS) seems to affect directly the fertility of female buffaloes since females that calve with a BCS < 2.5 show delayed postpartum ovulation, weak estrus symptoms and more service per conception rate. Seasonal anestrus is a normal phenomenon in the out breeding season that occur in areas near, upon or down of the Cancer and Capricorn lines, respectively, however the anoestrus can be overcame by the use of hormone to synchronize heat and ovulation. Buffaloes are quite resistant to the cold weather but protection must also be provided as well as in the tropical areas where shade, water access and good management increase the fertility rates.

Key words: Buffaloes, Breeding, Environment, Reproduction

INTRODUCTION - Apparently domesticated around 5000 years ago in the Indus valley in the Indian subcontinent the domestic buffalo is widely distributed in Asia and has also been introduced into every continents. Actually is used for milk and meat production as well as the swamp type used for work in southeast of Asia and China but becoming important also for milk and meet production as well. The rate of geographical dispersion of the domestic buffalo, both river type and swamp type has been slow until recently and distinct gene-
tic populations of buffaloes have arisen that are adapted to specific environment. Although the dispersion of buffaloes have occurred more frequently in the middle of 20th century they were introduced in different environment which involved geographical change in location of specific breeds, management practices that confer environment stress and diseases impact causing alterations in the genetics and physiology of buffaloes and other domestic species as result of an adverse environment causing a decrease in the physiological and productive functions due a non optimal environmental local condition reducing the full capacity for economic production. If we look to the buffalo husbandry around the world there is a population estimated in ~170 millions of herds, Table 1. The situation is quite different when we compare for instance, the development of the bovine species. Thus buffaloes differently of other domestic mammals species are higher adaptable animals and possess many homeokinetic mechanisms to maintain critical body functions at the expense of changes in other physiological functions which allowed buffaloes being economic productive in rush areas

Table 1. Population of water buffaloes in different geographical regions and countries.

| Region/Country     | Population (million) | Region/Country                        | Population (million) |
|--------------------|----------------------|---------------------------------------|----------------------|
| South Asia         | 123                  | Central and West Asia, North Africa    | 4.0                  |
|                    |                      | and Europe                            |                      |
| Bangladesh         | 0.83                 | Azerbaijan                            | 0.30                 |
| Bhutan             | 0.01                 | Bulgaria                              | 0.02                 |
| India              | 95.10                | Egypt                                 | 3.55                 |
| Nepal              | 3.70                 | Iran                                  | 0.52                 |
| Pakistan           | 24.00                | Iraq                                  | 0.09                 |
| Sri Lanka          | 0.72                 | Italy                                 | 0.17                 |
|                    |                      | Kazakhstan                            | 0.10                 |
|                    |                      | Romania                               | 0.20                 |
|                    |                      | Turkey                                | 0.14                 |
| South-East Asia    | 38                   | Latin America and the Caribbean       | 4.0                  |
| Cambodia           | 0.62                 | Argentina                             | 0.12                 |
| China              | 22.24                | Brazil                                | 3.50                 |
| Indonesia          | 2.30                 | Colombia                              | 0.08                 |
| Laos               | 1.06                 | Cuba                                  | 0.02                 |
| Malaysia           | 0.15                 | Peru                                  | 0.03                 |
| Myanmar            | 2.55                 | Trinidad-Tobago                       | 0.01                 |
| Philippines        | 3.12                 | Venezuela                             | 0.20                 |
| Thailand           | 2.10                 |                                       |                      |
| Vietnam            | 2.80                 |                                       |                      |

Total world population ~ 170 million

Adapted from: FAOSTAT and Perera et al. (2005).
of tropical countries where the other domestic species can not survive. For these reasons buffalo has demonstrated its superiority as a productive element in the environment, to the benefit of human welfare in sustainable agriculture (Cockrill, 1994). The same author figured out that with the advent of new systems of management, incorporating improved reproduction efficiency and better nutrition, are emerging as the constrains on productivity of genetic default, malnutrition, disease and neglect are mitigated. Applied research and practical development are influencing the establishment of production systems more favorable mainly in the tropical developing countries (Wiepkema & van Adrichem, 1989).

The effects of environment on reproduction

According to Jöchle and Lammond (1980) environment factors which influence or interfere with reproduction are consisting of inanimate and animate factors as listed below:

A. Inanimate factors:
   1. Biometereological factors:
      a. Climate and seasonal changes in photoperiod, temperature, humidity and precipitation;
      b. Significant short-term changes in climate = weather;
      c. Microclimate imposed by man.
   2. Nutrition

B. Animate factors:
   1. Other forms of life interacting in an undesirable or fatal manner; infections, endoparasites, ectoparasites;
   2. Interaction with members of the same species: social factors;
   3. Interaction with the man.

C. These and other factors affecting the “milieu interno”, the homeostatic capability of the organism having repercussions on the reproductive function.

In order to consider the effect of environment factors on techniques which may be imposed on animals to control reproduction, it is appropriate to divide these factors in classes:
   a. external factors acting through stereoeceptive pathways which modify hypothalamic-pituitary functions (photoperiod, temperature, odors, sight and noise);
   b. factors which may act on the organism as a whole (nutrition, diseases, changes in climate, seasons and weather);
   c. combinations of the above, plus social factors and encounters with man and his actions, and how they interact with the body’s homeostatic capabilities, effecting reproduction.

The photoperiod

Photoperiodism can be defined as the physiologic response of animals and plants to the variations of light and darkness (Dorland’s Illustrated Medical Dictionary, 1995). It is a product of and a necessity derived from species evolution. The relation between the breeding season and gestation length is such as to allow parturition in a particular species at a time of the year when nutrition and temperature are favorable to survival of both the
mother and her offspring. Seasonal changes in the photoperiod are a major determinant of reproductive activity, since these changes have been, are, and will be the most precise cue involved in the shift of the behavior in the animals.

Table 2. Domestic animal species in which the photoperiod is determinant of reproductive activity.

| Short-days breeders | Long-days breeders |
|---------------------|--------------------|
| Domestic buffalo    | Cat                |
| Goat                | Dromedary          |
| Sheep               | Horse              |
| Small camelideos (alpaca, llama, vicuña, guanaco) | Mink |

Such indicator of seasonal change is known as “Zeitgeber” and act in seasonally breeding species such as the buffalo cow, ewe, goat, mare, mink and other wild mammals. That being so, the domestic species which are in control of Zeitgeber phenomenon can be divided in long days breeders and short days breeders (Table 2).

Figure 1. Schematic diagram summarizing the photoperiod-pineal-hypotalamic relay in the short day breeding domestic species, in the case from the sheep. Adapted from Maeda and Lincoln (1990).

The seasonal danoestrus

The postpartum anoestrus is more concerned to multifactorial causes then isolated one. Sousa (2000) in the Ribeira Valley, in the Southern region of Brazil, state of São Paulo (Latitude 14° to 33° South) found that 86 % of female buffaloes did not expressed any seasonal anoestrus in a long photoperiod season. Furthermore the same author used melatonin implants in a group of animals in the same environmental conditions and could not observe any improve in the animals cycle activity and the fertility did not show any statistic significant difference (p<0.05). Moreover the duration of the seasonal fertile period in 71% of female treated were extended for a long period and the P₄ blood profiles which were lower between November and Mar-
ch – out-season period and returned for the normal pattern after April - autumn and winter season in the south hemisphere. Furthermore, the ovarian follicular dynamic was present in the open female buffaloes although they showed anoestrus. Therefore the diameter of the dominant follicle did not showed any statistical significant difference among the group that received melatonin implant and the group without treatment (p<0.05).

In the Table 3 it can be observed the average calving distribution along the year when it was observed two different peaks of more calving occurrence which corresponding two different management systems in the floodplain and a normal farming system using artificial pasture belonged a private and governmental farms. In addition it can be observed that the average calving distribution along the year showed two distinct peaks for both management systems, respectively. The lowest calving values found were between January-March corresponding the flooding season of the Amazon river and its tributaries and the second peak in September when there were a low availability of fodder, high temperature, sunstroke, low relative humidity and low rainy precipitation >34º C, 12.5 hours, < 75 per cent and <100 mm, respectively (Ribeiro, 2002).

Indeed, the calving distribution in the Amazon valley is completely different of the other Brazilians regions and do not have any influence of the photoperiod as stated Vale et al. (1990), Zicarelli and Vale (2002). Similar results were found by Baruselli et al. (2002) e Ribeiro (1996; 2002) which found the yearly calving distribution in the buffalo production system near of the Equator line. The same results were also observed by Vale et al. (1996) and Vale (1994; 1996) with a few difference concerning the peak of calving which has occurred between November and December. Female buffaloes submitted to artificial insemination

### Table 3. Calving distribution number and per cent through the year according to the production system in Amazon basin, Brazil.

| System          | Floodplain | Normal artificial pasture | Average |
|-----------------|------------|---------------------------|---------|
| Month           | 1-Private farm | 2-Gov. farm | 3-Gov. farm | 4-Private farm |
| Jan             | 2.7 (33)   | 1.6 (03)      | 4.9 (42)  | 8.5 (17)  | 3.9 (95) |
| Feb             | 1.1 (14)   | 7.9 (15)      | 6.5 (55)  | 10.5 (21) | 4.3 (105) |
| Mar             | 0.5 (06)   | 5.8 (11)      | 12.6 (107) | 5.5 (11)  | 5.0 (124) |
| April           | 0.7 (09)   | 13.1 (25)     | 13.4 (114) | 7.5 (15)  | 6.6 (163) |
| May             | 5.0 (61)   | 11.6 (22)     | 13.7 (116) | 4.5 (09)  | 8.4 (208) |
| Jun             | 10.8 (132) | 19.5 (37)     | 9.9 (84)  | 7.5 (15)  | 10.9 (268) |
| Jul             | 15.1 (184) | 12.1 (23)     | 10.5 (89) | 7.0 (14)  | 12.6 (310) |
| Aug             | 17.8 (217) | 7.9 (15)      | 10.2 (87) | 5.0 (10)  | 13.4 (329) |
| Sep             | 8.9 (109)  | 6.3 (12)      | 4.7 (40)  | 6.0 (12)  | 7.0 (173) |
| Oct             | 10.4 (127) | 7.9 (15)      | 6.5 (55)  | 10.5 (21) | 8.7 (218) |
| Nov             | 17.3 (211) | 4.7 (09)      | 3.5 (30)  | 8.5 (17)  | 10.8 (267) |
| Dec             | 9.7 (118)  | 1.6 (03)      | 3.5 (30)  | 19 (38)   | 7.7 (189) |
| Total           | 100 (1221) | 100 (190)     | 100 (849) | 100 (200) | 100 (2460) |

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also showed reproductive activity throughout year around and the fertility was considered normal. The use of Ovsynch methods is also a good alternative for enhance conception rates, mainly in animals raised in floodplain areas and when compared with animal raised in other regions were seasonal pattern play a role in the sexual activity the results are similar, (Baruselli & Carvalho, 2005; Vale et al., 2005).

**Are buffaloes a seasonal species?**

Buffaloes are polyestrous continuous species and shows estrous all year around, however a seasonal pattern has been reported from different countries of the world (Gangwar, 1980). Such characteristic related as a seasonal polyestrous is more related to the ambient temperature, photoperiod and feed supply. In addition with the possibility of the use of hormonal control of the estrous cycle, seasonal pattern can be overcome and they can bred through the synchronization of the estrous cycle in the year around (Vale et al., 2005).

**Effects of heat stress on reproduction function**

According to the United Nations Development Program through the Global Environment Facility UNDP/GEF the recent environment changes due to the global warming is affecting the domestic animals causing an increase in the heat stress. In Thailand Somparn et al., (2004) reported the use of temperature/humidity indexes (THI) to study the thermal stress in cattle and buffalo is an important tool to determine the welfare of this species. According to the authors, livestock managers recognize four livestock welfare categories for environmental management decisions. A THI ≤ 74 generally does not cause safety problems for healthy animals. Under alert conditions (THI = 75–78), producers can expect some decrease in the rate of weight gain. A danger conditions (THI = 79–83), animals show noticeable decreases in weight gain and, when handled, transported or overcrowded, may be severely affected. Under emergency conditions (THI ≥ 84) without management intervention, animal mortality can occur, especially when such conditions are prolonged. Furthermore, the authors concluded that in the southern part of Thailand there is a great risk of heat stress and lost of production for bovine and buffalo production systems.

For Bhat (1999) while the buffalo is remarkably versatile, it seems that it has less physiological adaptation to extremes of heat and cold than the various breeds of cattle. Body temperatures of buffaloes are actually slightly lower than those of cattle, but buffalo skin is usually black and heat absorbent and is only sparsely protected by hair. Also, buffalo skin has one-sixth the density of sweat glands that cattle skin has, so buffaloes dissipate heat poorly by sweating.

Although buffalo has a superior ability to adapt to the hot, humid areas of muddy and swampy lands they are also frequently affected by the heat stress which affects directly its reproduction. Moreover, buffalo skin is covered with thick epidermis, the basal cells of which contain many melanin particles that give the skin surface its characteristics black color, that forms a natural protection and attenuate the harmful effect of the environment in the tropical areas of the world where they area raised. According to Shafie (1993-1994), the melanin particles that exist in its skin trap the ultraviolet rays and prevent them to penetrating through the dermis of the skin to the lowest tissues. These rays are abundant in solar radiation in tropics and sub-tropics, and excessive exposure of animal tissues could be detrimental, perhaps even resulting in skin tumors. Moreover, buffalo skin is almost
devoid of hair, particularly in older animals, because of its exposure to water and mud. This beneficial characteristic is reinforced by its well-developed sebaceous glands which have a great secretory activity when compared to bovine (Shafie and El-Khair, 1970). These glands secrete a fatty substance called sebum, which emerges on the skin’s surface and covers it with a lubricant, making slippery for water and mud. This greasy sebum, along with the thick cornified top layer of skin, prevents water and solutes in it from being absorbed into the skin. In this way, the animal is protected from the harmful effects of any deleterious chemical compounds in the water. Moreover the sebum layer melts during hot weather and becomes glossier to reflect many of the heat rays, thus relieving the animals from the excessive external heat load (Shafie and El-Khair, 1970; Shafie, 1985).

Thus, with this outstanding capacity for physical adaptation to the tropical and subtropical hot humid conditions, the water buffalo has acquired a reproductive-productive pattern that conforms to the sequential seasonal changes in climate, terrain and vegetation conditions (Shafie, 1993-1994).

Vieira (1995) reported in a study involving 24 Mediterranean buffalo heifers with a 773 days age average and 393 kg body weight average were divided into three different groups. The animals in the 3 groups were injected with 2 intra muscle doses of PGF₂α 11 days a part during the adjustment period and after 48 hours of the injection of second prostaglandin dose the thermal stress began. Blood samples were collected immediately before the beginning of the thermal stress and every 4 days throughout 24 days of the experiment. The Respiratory Frequency (RF), Rectal Temperature and sweating rate (SR) were higher (P<0.01). The author concluded that buffalo heifers were considerably sensible to solar irradiation, the animals stressed suffered an thermal discomfort which was considered a moderate stress. The food consumption and consequently the body weight gain in the group subjected to thermal stress was significant lower and that water was extremely used to minimize the effect of thermal load. Furthermore, after 8 hours of thermal stress, the night period was sufficient to bring the animals for the thermo neutrality conditions without any harmful effect on the red blood cells, hemoglobin and volume globular medium, however after 24 days of experimental period it was observed alterations in the leukogram and level of total protein as well as the progesterone and cortisol levels were not affected in the thermal stress group but occurred a inhibition of the follicular growth which was correlated with alteration at the estradiol level and the radiation and environmental temperature showed to play a big role on the physiological answer. Finally the RF was high correlated with the RT and SR and, RT also with the SR and the cardiac frequency positively correlated to SR but high negative correlated to the body weight.

For Garcia (2007) the impact of the heat stress on the female can be observed on the sexual behavior, with less estrous cycle identification, low conception rate, high embryonic dead rates and reduction in the reproductive efficiency. The author figure out that as the most of Brazilian territorial area and Amazon region were localized in hot tropical climate conditions it is necessary the introduction of management practices suitable for a better sustainability of the buffalo production systems. The incorporation of trees together the grazing pasture areas (Integration of livestock within agro-forest systems), including planting of new forage species is high recommended. Finally he claimed that such system increase the local biodiversity providing multiply areas of shading, protection and resting for the animals, reducing the direct incidence of solar radiation on the buffaloes, increasing the
comfort and well being of the herd, and consequently positive impacts on the productive and reproductive efficiency of the buffalo herds.

**Effects of heat stress on oestrus**

It is well known that in buffalo species, the ability to detect oestrus declines during the warmest hours of the day and in animals with heat stress (Vale, 1983). In Egypt the reproductive behavior of female buffaloes, in particularly oestrus is feeble during the hot season. A herd of buffaloes had almost equal incidences of ovulation in hot (May-October) and the colder (November-April) seasons. However, oestrous detection is more frequent and stronger in the colder season which is accomplished by changes in the seasonal patterns of P4 and estradiol and the number and amplitude of the LH pulses were greater in the colder season (Shafie et al., 1982; Barkawi et al., 1989; Shafie, 1993-1994). However, Raizada and Pandey, 1981) studying two group of females, one protected (shaded shed, allow wallowing and sprinkled) and another unprotected, without such management. They found the fertility was a little higher for the protected group, but not significant difference could be observed between groups in the number of animals coming in heat, conception rate, services per conception, estrous cycle length, birth weight of the calf and gestation. On the other hands, the expected natural coincidences between climatic condition in northern Brazil, where the temperature has a minimal variation throughout the year, the flooding of the Amazon River modulate different patterns for the establishment of breeding season according to the Amazon river and its tributaries overflowing and ebb (Vale et al., 1999).

Such phenomenon is observed alongside the floodplain areas of Amazon basin, where the calving season occur in a variable pattern though no light variation occur among different micro-regions. When occur the Amazon reflux, the rich floodplain areas is characterized by a favorable environment with abundance of nutrition green pasture fodder for the lactating buffalo and her offspring. Also in the Low Amazon region, Brazil, Ribeiro et al., (2003) found a evident importance of the environmental effect on the ovarian postpartum activity in buffaloes since the highest incidence of estrous occurred after two months of the beginning of the rainy season, that means a pleasant temperature and abundant green fodder. The authors concluded that in this region the rainy season showed to be favorable to the reduction of calving interval and resumption of ovarian activity and estrous behavior through the postpartum period.

**Effects of heat stress on pregnancy**

The heat stress can affect the pregnancy in three different ways: i. in the establishment of pregnancy. ii. associated to pregnancy failure; iii. on the late pregnancy or postpartum period. Vale et al. (1989) reported problems of embryonic absorption and abortion in female buffaloes raised in the Brazilian Amazon valley, related with heat stress causing a hyperthermia as part of inadequate management. For Grunert, Birgel and Vale (2005) the blood flow in the heat stressed female animals increased in the proximity of the superficial vessels in detriment of the deep vessels whereas such change in the deep circulatory flow affect the circulation and nutritive supply at the uterus and ovaries level causing an impairment in its normal physiology. Such problem has been well documented in either milk and beef cows managed at tropical and sub-tropical areas of southern USA where the magnitude of the depression in the conception rate is proportional to the degree of hyperthermia. The
disruption in establishment of pregnancy is severe if heat stress occurs around the time of ovulation or early pregnancy. Rather, heat stress altered the oocyte or the reproductive tract so that normal embryonic development was compromised (Hansen, 2003).

**Effects of heat stress on the bull**

It is known that in many mammals male gametogenesis is unable to occur at temperatures characteristic of the body core – heat stress as little as 12 hours disrupts spermatogenesis in the bull. Vale (2004) reported that the male buffalo is also hard affected for local thermoregulation of the testis which involve intricate anatomical and physiological system from the surface area of the scrotal sac, muscular control of the placement of the testis and the countercurrent mechanism of the pampiniform plexus which regulates the blood temperature that enters in the testis.

Ohashi, Sousa, Vale (1988) reported that the main cause for the disruption in sperm production of male buffalo raised in the Amazon basin is the heat stress which lead to a testicular degeneration which affect the semen patter which includes a decrease in the sperm number, decreased sperm motility and increased number of abnormal sperm in the ejaculated semen and also affect the sexual libido.

**Environmental effects of nutrition on the reproduction of buffaloes**

Perhaps one of the most striking deleterious effects of the environment on the buffalo reproduction raised in the tropics is the seasonal shortage of fodder and nutritional imbalances. Although the superiority of the buffaloes in the utilization of coarse feed into milk and meat as compared with the other domestic species is mainly due to the specific nature of its physiological characteristics in regarding its adaptation to the different ecological systems. It is well known that buffaloes submitted to an under-nutrition management acquired a low body score condition (BSC). Female buffaloes which calved with a. BSC 2 a 2,5 (in a scale of 1-5) presented delayed ovulation and service period and more service per conception rate compared with buffaloes with a BSC between 3 -4 (Vale et al. 2004). As in the Amazon region and other parts of Brazil and Latin America most of the production system use extensive management it could be predict that the nutrition play a big role inside the buffalo production systems. With rare exceptions there are few production systems that use a management as it is used in the advanced production systems used in the developed countries in Europe and North America. Over large parts of the tropics and sub-tropics the average nutrition of buffalo is very poor. However, although the bulk of world’s buffalo population is to be found in the tropics and sub-tropics, the greatest advances in animal nutrition have taken place in the temperate region where animal production is based in scientific feeding standards. The offering of fodder for buffalo has a great importance in the puberty, calving interval, service period and fertility in general. In the Amazon basin, Brazil, usually, buffalo farmers follow their own feeding practices which largely depend upon the seasonal availability of feed and grazing including the ingredients of concentrates and mixtures. Taking in account the example of Latin America, Argentina, Brazil, Colombia and Venezuela, the technicians and farmers with few exceptions look for the dry as well as animals in milk not individually, but in groups. In general, no consideration is given to their weight and level of production. Such situation is largely due to general shortage of feed and grazing and lack of knowledge concerning proper feeding of buffaloes according to a scientific feeding standard.
A good example has happened recently in Brazil, where by the enforcement of the Brazilian buffalo Breeders Association, the University of Naples, Italy and the Italian NGO Buffalotec, set up a project “Internationalization process for the productive system in the buffalo chain production system”. On the other hand, there is a general idea that to overcome the problem of underfeeding, seasonal shortage of fodder and nutritional imbalances the use of high dry matter and protein contain fodder usually based in feeding standards of European or American countries will solve the problem. Notwithstanding high rate of feeding usually results in a definitive increase of rectal temperature, respiratory rate and rate of water loss in buffaloes. there is also a widespread belief that high protein diets are disadvantageous to buffalo exposed to heat stress, because of the specific dynamic effects of proteins (McDonald et al., 1999; Rahjhan, 1992).

Thus, all these aspects of buffalo nutrition in the tropics and the specific characteristics of each tropical environment region demand an intensive research on the buffalo nutritional requirements and the formulation of sound feeding standards for the buffalo as the example of the project attempt above mentioned.

Schemes to prevent effects of environment stress on reproduction

Housing

In order to protect buffaloes from heat stress in the tropics and sub-tropics the use of adequate housing, artificial shade, water ponds, showers seems to be the right way. Stables, barns, corrals and milk parlous must allow good ventilation. Those facilities may therefore be different in different areas of the world, due to differences in climate. It should be taken in account considerations and solutions when planning housing in hot and cold climates respectively. One common aspect for every housing is that enough space should be allowed for each category in the herd. The outdoor facilities like corral and pen should preferably be covered with straw or tile clay, and the floor covered by concrete or cement in order to prevent it from becoming an unhygienic mud hole in rainy periods.

Hot climate

Buffaloes may appear to be misplaced in a hot and humid environment. They have a dark skin and few sweat glands and are more or less dependent on water for their cooling. This is not entirely true, buffaloes protected from direct sunlight do very well even during hot and humid days, partly because their ability to loose heat through the respiratory tract. High milk production requires a high feed intake which leads to higher metabolic heat production. High yielding buffaloes thus have a disadvantage over lower yielding animals, and need more cooling facilities. The following points are guidelines to have in mind when giving advice on management.

1. The feeding, watering and milking place should always give shade and protection from heavy rains, either by trees or by a roof;
2. Cool water either from a clean river or served in an earthen pit, helps the animals to maintain temperature. Water trough should always be placed in the shade;
3. A paddock with trees gives a very cheap and effective protection from sun. However, the trees may need to be protected from the buffaloes also;
4. A shelter of a simple construction with only a roof. In hot humid climates it is better not to have walls. Walls may lead to inadequate ventilation and thereby favoring bacteria and mold growth, thus making the stable unhygienic. To protect the inside from sunshine (or heavy rain), curtains made from straw, textile or other suitable material, can be used;

5. Providing the animals with a wallow. However, the wallow should be one with clean water and not far from the farm. Spending time walking in the sun to and from the wallowing costs more than it saves;

6. Showering of the buffaloes with cool water for 3 minutes twice a day has proven to be an efficient way for them to get rid of excess heat.

**Cold tolerance**

Although generally associated with humid tropics, buffaloes have been reared for centuries in temperate countries such as Italy, Greece, Yugoslavia, Bulgaria, Hungary, Romania, and in the Azerbaijan and Georgian republics of the FSU (Former Soviet Union). Buffaloes are also maintained on the high, snowy plateaus of Turkey and Iran as well as in Afghanistan and the northern mountains of Pakistan. The buffalo has greater tolerance of cold weather than is commonly supposed. The current range of the buffalo extends as far north as 45°C degrees latitude in Romania and the sizable herds in Italy and the FSU range over 40° C degrees N latitude. Cold winds and rapid drops in temperature, however, appear to have caused illness, pneumonia, and sometimes death. Most of the animals in Europe are the Mediterranean breed, but other River type buffaloes (mainly Murrahs from India) have been introduced to Bulgaria and the FSU, which indicates that the River breeds, at least, have some cold tolerance.

1. A shelter should protect the animals from rain, snow and strong wind. It may be a simple construction with a roof and three walls. This system will allow the buffaloes to go outside to graze when the weather allows it. There should be a feeding area inside the shelter in case of several days with bad weather. A separate heated milking area is advisable in this case.

2. A dry and clean bedding is important in cold weathers to maintain animal health.

3. In case of extremely cold climate, (Caucasian and Balkan) with several months with a temperature below 0 °C, a heated barn may be necessary.

**Altitude**

Although water buffaloes are generally reared at low lands a herd of Swamp buffaloes is thriving in Kandep in Papua New Guinea, 2,500 m above sea level. In Nepal, River buffaloes are routinely found at or above 2, 800 m altitude.

**Wetlands**

Water buffaloes are well adapted to swamps and to areas subject to flooding. They are at home in the marshes India and the Near and Far East, in the floodplain areas of Amazon Valley and Orinoco Basin of Venezuela, the tidal plains near Darwin Australia, the Pontine marshes in south central Italy. In the Amazon the buffaloes (River type and Swamp breeds) are demonstrating their exceptional adaptability to flood areas. Buffalo productivity outstrips that of cattle, with males reaching 450 kg in 30 months on a diet of native grasses.
The advantage of water buffaloes over European breeds and Criollo cattle was demonstrated in Argentinean Chaco, Delta Amacuro and Maracaibo lake in Venezuela, when the cattle developed serious foot rot and are tick born diseases as well as low production level. In the Low Amazon area which is flooded 6 months of the year and creates constant problems for cattle, yet the buffalo seems to adapt well. Furthermore high humidity seems to affect buffaloes less than cattle. If shade, wallows or showers are available, buffaloes may be superior to bovine in humid areas (Vale, 1996).

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