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Introduction

Long ago the term was used for the Asian buffaloes (*Bubalus* spp.), African wild buffalo (*Syncerus* spp.), *Bison* (*Bison* spp.) and Asian pseudo (*Pseudonovibos spiralis*). Out of these only main Asian buffalo (*Bubalus bubalis*) has been domesticated and developed as one of the important farm animal of economic importance for the farming community. Now, domesticated Asian buffalo has acquired almost cosmopolitan status distributed in almost all the continents. However, uptil now it has not succeeded in making consiberable presence in the north America. The main inhabited regions of domestic buffaloes are the tropical countries in both the hemispheres but due to high adaptability, it has been successfully bred and established in the subtemperate regions. The domesticated Asian (water) buffalo has established itself as a multipurpose farm animal capable of thriving in dominated natural herbage cover. The Indian subcontinent is the home-land of dairy type Indian (River) buffalo, globally famous for fat rich thick milk of high nutritive value. The other type of domestic Asian buffalo is the 'draught swamp buffalo' capable of working in knee deep muddy water fields of paddy crop. The home tract of swamp buffalo extends from Indian to Philippines, and other Indo-Pacific island region via Nepal, Bangaladesh, Bhutan, Mayanmar, Thialand, Combodia, Laos, SR Vietnam, China, Taiwan, and Korea, etc. The high adaptation capacity of domesticated water buffalo has fovoured it for finding newer homes. During ancient time domestic buffalo was almost an integral part of the nomadic families of Asia-Europe an region and in European countries. Domestic buffalo farming was introduced by Asian nomads and others. In Indian Murrah breed of dairy buffalo is a highly valuable dairy animal which has been taken to many countries for farming. In Egypt there is a 'Al Murrah' tribe and Murrah breed of buffalo has been found the needs of anthropological studies.

▶ CONTRIBUTION OF DOMESTIC WATER BUFFALO (*BUBALUS BUBALIS*)

The economic contributions of domestic water buffaloes are both direct and indirect.

The Direct Economic Contributions of Domestic Water Buffaloes

1. **Production of highly nutritious foods:** Milk and meat are the main foods produced by the buffaloes. Both foods are highly rich sources of dietary energy and balanced proteins rich on essential amino acids besides adequate supply of minerals and vitamins. Since there is no need of sacrificing animals for milk production

and sufficient milk is spared by the animals after nursing their calves, the milk of buffalo is extensively consumed even by the strict vegetarian population of India. Buffen (Buffalo meat) is the another nutritious food rich in energy and balanced complete protein. Earlier fattening of buffaloes for good quality meat production was practiced in Egytp, near east, Europe, Australia, and Latin American countries but during the last few decades buffalo fattening for good quality buffen production has also gained momentum in the Asian countries. This happened due to sparing of large number of draught buffaloes due to increasing mechanization of paddy and sugarcane farming. In these regions only spent animals were disposed for meat production about half a century ago. Even the surviving male calves of dairy buffaloes were also reared for draught purpose.

2. **Draught power:** The buffaloes are sturdy, agile, and hard working animals of high endurance. Although animal is slow in movement but preferred due to its high traction power, hardiness, ability of ploughing the water logged mudy paddy fields, longer daily working capacity, easy handling, and less expensive maintenance than the other draught animals. Preferably males of dairy breeds and both sexes of swamp buffaloes are used for working. However, female buffaloes are put to light work like ploughing and puddling the paddy fields. Only infertile and sterile females of dairy breeds are used for draught purpose in some of the countries.
3. **Manure production:** The buffaloes are continuous source of organic manure. Both dung and urine along with soiled bedding of straw, dry leaves or dry grass are used for preparation of organic manure by composting. Manure prepared from the buffalo excreta is a good source of nitrogen, carbon, calcium, phosphorus, and many minerals required for optimum crop production. Use of organic manure in the field improves soil health and water holding capacity necessary for optimum crop production. It also stimulates the movement and multiplication of earthworms in the field which increases aeration and turnover of the soil considered to improve the fertility of soil.
4. **Use of fallen buffaloes:** The carcasses of dead animals provide hide, horns, hooves and switch hairs of industrial uses. The flesh and bones are largely used in cottage industry for the manufacture of meat meal, meat cum-bone meal, bone meal, and bone ash used for supplementing the diets of poultry and pig for the supply of essential amino acids and minerals. Bone meal and bone ash are also used as fertilizers for the crops. The hide and horns are used in cottage industry as well as large scale leather manufacturing industries.
5. **Use of slaughter house by-products:** The edible carcass is the primary product of abattoir but in big industrial cities glands, blood, sex organs, and empty gastro-intestinal tracts are mostly used for the manufacture of pharmaceuticals, industrial oil, casings for stuffed meat products, and others. The residue available after the extraction of enzyme, hormones, and the other pharmaceutical products is further processed for the manufacture of animal protein supplements or manure, if not fit for animal consumption.

Indirect Economic Contribution of Domestic Buffaloes

1. **Source of power for agricultural and industrial works:** Buffalo is a most suitable draft animal for puddling the paddy field and traction of carts loaded with agricultural produce. Buffaloes are also used for haulage of industrial goods for short distance. Although slow in pace the high load pulling capacity and endurance

had made it a draft animal of choice for the transportation of grains and straw to market, and sugarcane to crushers and sugar mills. Due to low heat tolerance and heavy traffic on roads during daytime the haulage of goods form villages to mandi and other markets is done during the relatively comfortable hours of night. In most parts of northern India, it is a common seen to see the carvan of loaded carts moving in almost a constant pace and disciplined line. One, two or more lighted lanterns hang from the wheel beam of the cart. Normally, one lantern is used for 5–6 carts and maximum number may not be more than three even for 25 loaded carts. The main objective of placing lighted lentern is to give signals to other vehicles for preventing collision.

2. **Food grain production:** Buffaloes supply traction power and organic manure for crop production. The food grains and vegetables produced from the exclusive application of organic manure are considered healthy foods and fetch higher price. Increasing demand of organic foods are simultaneously increasing the price of dung manure and higher return from buffalo keeping.
3. **Buffalo as source of employment:** In large commercial farming system buffalo production needs only few persons but in small holder buffalo keeping system a large number of part-time and full time employments are generated. Various jobs generated from buffalo rearing in rural and urban areas are:
   a. Buffalo management
   b. Grazing of buffaloes
   c. Milking of buffaloes
   d. Preparation of milk products at home
   e. Marketing of raw (liquid) milk and milk products
   f. Use of milk for the preparation of khoa, chenna, paneer, srikhand, and a variety of sweets provide employment for owner, halwais, and salesman
   g. Marketing of animals on foot
   h. Fattening and meat industry provides employment for rearing, processing and marketing
   i. Hide provides jobs in leather making, leather goods manufacture, and marketing
   j. Horns provide employment to artisans in cottage industry for the making of decoration items and daily use articles
   k. Dead animal carcass and abattoir rejects are used for the manufacture of pharmaceuticals, vaccines, and diagnostics, etc.
   l. Employment in pharmaceutical industry for the manufacture of pharmaceuticals, storage, transportation, marketing, and accounting are the integral part of almost all the production system for commercial purpose.
4. **Miscellaneous contributions:** The buffalo are used for joy riding during grazing, and wallowing in running water source, and johads (Ponds for wallowing of buffaloes). In some countries buffalo bull fighting is organized at specific festivals. Sacrifice of entire buffalo, specially the yearling is practised to please specific deities. Ritual sacrifice of buffaloes was quite common in India, Nepal, and Indonesia but now it is decreasing.

▶ INDUSTRIAL DEVELOPMENT AROUND BUFFALOES

A large number of industries of various dimension ranging from small scale cottage industries in rural areas to big manufacturing houses of industrial areas are dependent

on the growth and production of buffaloes. Some of the common industries around buffalo production are listed as follows:

1. **Buffalo handling articles and gears:** These include ropes, halters, whips, pegs, plough, carts and their harness, nose ring and nose string, etc. All these works required the services of artisans like carpenter, blacksmith and cobbler, etc. Greater proportion of raw materials are produced locally. Greater quantity of products is also marketed locally.
2. **Feed stuff cultivation and processing equipments:** Almost all equipments required for the cultivation of grains are also used for the cultivation of fodder. These are ploughs, harrows, leveling plank (henga or patella), tractor, trolly, dibler, sickle, and harvesting machine.
3. **Fodder and feed processing equipments:** These are chaff cutter, drier, grinder, feed mixer, pelleting machine, extruder, and feed block making machines.
4. **Feeding articles:** These include baskets, troughs, trench, etc. for offering and feeding of the buffaloes. For watering buckets, trough or trench are used in the stall feeding system.
5. **Milking and milk handling equipments:** These are milking pail, earthen milking pot (ghooncha), and metallic bucket for milking. Earthen pot (Kahantari or Nadi) and metallic can or pan for heating, boiling, evaporation, curd making, churning, freezing, and sweets making.
6. Abattoir construction and abattoir machine manufacturing industry.
7. Buffalo meat and meat products manufacturing, handling, packaging, storage, transporation, and marketing industries.
8. Hide processing industries for the manufacture of leather.
9. Leather goods manufacturing industries.
10. Horns and hooves utilization industries.
11. Hide flaying and fallen animal utilization industries.
12. Pharmaceutical and cosmetics industries.
13. **Miscellaneous cottage and household industries:** There are utilization of long and coarse hairs of tail switch for making ropes and mats; dung for making dung cake for fuel and abattoir wastes for making manure.

The long list depicts the dimension of employment generation around buffalo farming. In the land holding pattern of India dominated by small and marginal farmers and landless farming families Animal Husbandry, specially the buffalo keeping has been found to be a reasonably satisfactory source of livelihood through part-time and full time employment.

▶ DOMESTICATION OF WATER BUFFALO (*BUBALUS BUBALIS*)

Domestication of water buffalo for the production of foods and working animals was taken up much later than the domestication of cattle. This was probably due to high affinity of Asian buffaloes for water and swamp. These buffaloes spend longer part of day time in wallowing in water bodies or lying deep in mud holes. During free living wild state making gathered sufficient knowledge regarding the hostile conditions on the earth. They gradually learnt to meet their necessary requirement for survival. In the process of evolution they frequently encountered dangerous and furious wild animals and learnt protection with the use of twigs, bamboo, and pavels, etc. Initially they started living in groups beneath the natural shelters and caves and for a very long period lead nomadic life in search of food, water, and shelter. During the course of

settlement some wild animals sought the proximity of humans and some of the useful species were initially lured by offering foods. These selected species were gradually tamed and then domesticated for controlled management. Among the tamed species dogs and horses are considered to be domesticated first. These were subsequently followed by cattle, sheep, and goats. Probably buffaloes were domesticated much later but hunted for food and hide in most parts of their homelands. The taming and herding of buffaloes on marshes was started so that they may be made available for food on a short notice as evident from the incidence of 'Ramayan epic' (more than 3000 BC or about 5000 years ago). It has been mentioned in couplet (doha) of Ram Charit Manas (By Shri Goswami Tulasi Das ji) that when despondent Lankapati Ravan went to awake his brother Kumbhakaran, before the lapse of his six months sleeping period, for fighting with the army of Lord Ram. On awaking Kumbhakaran came to know the rivalary of Ravan with Ram, he was shunned. He started praising Lord Ram for his kinderness, generosity and other goodness of lord Ram, Ravan was also absorbed for a moment but immediately omen time prevailed. In order to divert the attention of Kumbhakaran and to prepare him for fighting Ravan ordered for the immediate supply of thousands of pitchers of wine and enumerable fattened buffaloes for the feast of Kumbhakaran as mentioned in the following couplet of Ram Charit Manas (Pathak, 2003).

'Ram roop gun sumirat magan bhayou chhan ek
Raven mangeu koti ghat mud aru Mahish anek'

After eating buffaloes and drinking wine the Kumbhakaran roared like thunder, and drunk he marched to battlefield alone from his fort as depicted in the following couplet of Ram Charit Manas:

'Mahish khai kari madira pana,
Garja bajra ghat samana
Kumbhakaran durmad run ranga
Chala durg taji, sen na sanga'

During the period of Mahabharat epic buffalo was wild beast like wild animals such as lion, tiger, boar, bear, elephant, and apes. The domesticated animals of the era were cattle, sheep, goats, horses, ass, and mule.

There is also reference to taming boars, buffaloes and elephant for food supply and other works like extensive use of domesticated elephants in war and also for the ride of royals and rich. Domestication of several species of animals was perfected before the Mahabharat period. The advancement in Animal Husbandry can be visualize by the evidence of well cattle by Nakul and Shadev, respectively. In post epic period, Emperor Ashoka the great is credited for the systematic education and training of the veterinarians. During this period specialized Veterinary education was imparted and Veterinary hospitals were established before the start of Christian calendar for the livestock of public. Organized farming of cattle, buffaloes, goats, and sheep for milk, work, meat, and fiber production was developed. The hides and skins were used for the manufacture of leather goods, fiber for fabrics and oxen for power has been distributed in detail in the 'Kuatiliya Arthashastra' (321–186 BC). Almost all domesticated animal were grazed on the well-managed pastures. The management of heards, flocks, and pasture lands was carried by different level of workers, supervisors, and superintendents for high production and maintenance of good health of livestock.

More informations on the rearing of buffaloes are available from the medieval period. Vast area from Mesopotamia to Indo-Gangatic plains intercepted by several rives and

covered by dense forest and swamps provided suitable environment for the growth of riverine buffaloes during the third millennium BC (Bats, 1937). Almost similar conditions were present along the perennial rivers and lakes, and large swamps in most parts of the tropical Asian countries and island countries of the Asia-Pacific region. These favourable conditions provided optimum environment for the inhabitation of swamp buffaloes during the pre-historic period. Several modern historians believe that the buffaloes were first tamed and then domesticated for working in agricultural operations before 2500 BC in the Mesopotamia during the period of Akkadian dynasty and in the Indus valley civilization of the Indian subcontinent extending to Harrappa, Mohenjodaro, some parts of Rajasthan, Gujarat, Maharastra, Haryana, Madhya Pradesh, and Uttar Pradesh. The evidences are available in the seals and small sculptors depicting mostly male buffaloes. On one of the seal of Indus valley excavation, now present in Lahore museum, depiction of male buffaloes on feeding through may be considered sample evidence of domestication of buffaloes. Some multi-coloured ceramics of the 'Nal Culture' of the south Balochistan depict buffaloes (Brentijes, 1969) and it is contemporary with the Indus valley civilization. A picture of holding of growing buffalo by its fore legs and a horn probably depict a fight or an attempt to control the beast. Another, scene showing watering of buffaloes in a stream by two God heroes, and the buffaloes being charged by the lions. These are considered reasonable evidences of domestication of water buffalo during 2350–2150 BC; and in the ancient Mesopotamia it was restricted to two periods, i.e. the late third millennium BC to Sasonian period during 224–651 AD (Boehmer, 1974). It has also been suggested that during both period buffaloes were introduced from the domesticated herds of the Indus valley areas (Cockraill, 1977). It means buffaloes were already domesticated in the Indus valley before 2350 BC.

Another almost contemporary river civilization existed along the Yangtze and the yellow rivers in the China during the Shang dynasty (about 1766–1123 BC). Evidences of tamed buffaloes during the second millennium BC are present (White, 1974). The importance of buffaloes in the socioeconomic and cultural life is evident from the depictions on the clay vessels, pillars, and paintings of the Shang dynasty period (Bentjes, 1969). In the north-east region of Thailand the bone remains of buffaloes stored during ploughing for paddy cultivation around 1600 BC suggested the taming of buffaloes in the south-east Asian countries during the second millennium BC (Higham and Kijugam, 1979).

Despite economic importance of the buffaloes through direct and indirect contribution of foods and work power supply since the beginning of river valley civilization in the Asian countries and Egypt, there appears to be lack of serious attempts in finding the correct period of domestication of water buffaloes and linkages among the different buffalo breeding tracts.

Till further evidences are collected, it may be suggested that pre-historic wild water buffalo (*Bubalus arnee*) was domesticated in the region of Indus valley and thereafter it extended to Mesopotamia in the west, and China in the east. Had domestication initiated in the Mesopotamia during the third millennium BC, it could have spread at least west to Mesopotamia during the said period (Epstein, 1969).

Clear genetic difference in two broad groups of water buffalo, i.e. river or dairy buffalo with $2n = 50$ chromosomes and another swamp buffalo with $2n = 48$ number of chromosomes shows the existence of two distinct ancestral strains of wild ancestor of domesticated Indian river buffalo, if the wild group in the reserved forest area near Kolhapur in Maharasthra does not contain $2n = 50$ number of chromosomes. The present

Asian wild buffalo in the forests of eastern states of India, Nepal Tarai, Mayanmar, Thailand, Combodia, Laos, Vietnam and probably in China is the ancestor of modern domesticated, tamed and ferel swamp buffaloes with $2n = 48$ number of chromosomes.

Development of several good breeds of the dairy type river buffalo (*Bubalus bubalis*, better to use trinomical name (*Bubalus bubalis ...*) in the Indian subcontinent suggests that it was the seat of domestication of riverine / dairy type water buffalo. Development of good number of well-defined breeds of dairy type buffalo, before the use of modern breeding system, shows that interest, deep involvement, and scientific approach of breeding through intensive selection to meet their area specific requirements. Some of the important breeds of riverine buffalo are the Murrah, Mehsana, Nili-Ravi, Kundi, Banni, Jaffarabadi, Surti, Nagpuri, Pandharpuri, Bhadawari, and Tarai. On the other hand, in case of swamp buffalo (*Bubalus bubalis carabaosis*) less serious efforts have been made in the past for the development of specific breeds. The swamp buffaloes are very low milk producers but some selection practice in some areas of the north-east states of India has considerably improved milk production capacity (Singh, 1978 and Tamuli, 1978).

Reasons for the Domestication of Water Buffalo (*Bubalus Bubalis*)

Buffaloes were initially domesticated for the assured regular supply of nutritious foods like milk and meat. Later on with the start of food grain farming buffaloes particularly that in swamp areas were found more useful for pudding the paddy fields than the cattle. Subsequently the main use of riverine and swamp buffaloes precipitated as dairy animal and draught animal respectively. In practice both types of buffaloes are used for milk, meat, and draught. The reasons for the domestication of water buffalo may be listed as follows:

1. Proximity of wild water buffalo with human inhabitation along the running rivers, and other perennial water sources and marshy lands for wallowing. This behaviour provided opportunity for taming and capture of docile buffaloes and young stock.
2. Water buffaloes are generally docile and easy to handle. Capture of female buffaloes in terminal stage of pregnancy and lactating buffaloes nursing the calves is quite easy. Although, nursing buffaloes normally do not allow strangers to handle their calves and turn highly offensive to the extent that in lack of adequate precaution their charging may be highly injurious or even fatal. But once her calf is restrained she will not go away.
3. Buffaloes are capable of thriving on large variety of herbages including the coarse grasses of low feeding value. Water logging and mud do not create problem for buffaloes rather they prefer wallowing for several hours.
4. Buffaloes continue grazing even during the rains and enjoy rain bath.
5. Production of highly nutritious foods such as milk and meat. These foods are rich sources of essential amino acids besides high energy value and good amount of dietary essential minerals and vitamins.
6. Buffalo is a powerful beast of high traction ability. It is preferred over oxen for paddy cultivation and sugarcane haulage.

Reasons for the Growth of Domesticated Water Buffaloes

The buffalo population is continuously growing in most countries of home tract and also in many of the other countries where buffaloes were introduced for good production. However, as diminishing trend in buffalo population has been observed in

some of the European countries. The growth in buffalo population reflects the economic contribution and sustainability of the animal under the diversified agroclimatic of the tropical and subtropical countries. Some of the important reasons for the steady growth of buffaloes particularly that of dairy type riverine buffaloes are listed as follows:

1. **Requirement of local people:** In the Indian subcontinent buffalo is the main dairy animal and contributes more than half of the total milk production by different dairy animals.
2. **Temperament of the animal:** Domestic buffaloes are slow, docile, and harmless. Handling is very easy and any familiar person can handle buffaloes fearlessly. Buffaloes do not accept strangers easily and acquaintance need longer time and kind approach.
3. **Management case:** Docile nature, slow pace, and quite disposition make the management of buffaloes easier. They eat poor quality crop residues and dry roughages with equal interest. Although wheat straw feeding alone is non-sustainable but buffalo can consume up to 2% of body weight (John *et al*., 1982).
4. **Ability of energy conservation:** Due to slow movement on grazing lands the buffaloes spend more time in eating and also loose less energy in movement for feeding. One can easily differentiate in the thriftness of cattle and buffaloes grazing the same pasture. The buffaloes on poor pasture maintain significantly better health than the cattle (Pathak, 1988).
5. **Consumer's choice:** In dairy buffalo dominant countries people have developed taste for the high fat containing buffalo milk. Recovery of ghee (clarified butter oil), Khoa (dehydrated milk), Chenna (coagulated milk clot), paneer, and curd from the buffalo milk is much higher than from the cow milk. Therefore, sweets and milk products are more popular. Mozrella cheese is the most popular buffalo milk product of west. Buffalo veal is quite popular in near east and European countries.
6. **Relative price of buffalo and cattle:** The buffaloes for milk, meat, and draught were much cheaper than the cattle of respective class. Although the difference in price between the two species is gradually decreasing, indeed buffalo for meat and working buffaloes are much cheaper in most of the buffalo breeding countries.
   In most of the countries buffen in much cheaper than most of the edible meats. In recent years, fattening of buffalo has shown an increasing trend due to increasing demand of good quality meat and sparing of sizable number of buffaloes for works. Despite extensive mechanization of agriculture, the use of buffaloes in paddy cultivation will continue as the buffaloes are more suitable for pudding paddy fields than the oxen.
7. **Utilization ability of course roughages:** The buffaloes consume wide variety of herbages and thrive better than cattle on coarse fodder. They eat fibrous crop residues like straws, stovers, and tops of sugarcane and root crops with great appetite. However, almost all dry cereal crop residues are highly deficient in most of the essential nutrients and energy, and need supplemental feeding of more nutritious feeds for survival (Johri *et al*., 1982).
8. **Gainful utilization of by-products of buffaloes:** Different kinds of by-products are available from the live, slaughtered and dead animals and all are utilized for the benefits of mankind. The excreta and soiled wastes of slaughter house and eviscerated dead buffaloes are composed for manure making. The gastrointestinal tract is utilized for the preparation of casings and other products. Blood, glands, reproductive organs, and joint oil are used for pharmaceuticals and industrial

purpose. Hide is used for the manufacture of valuable leather and leather goods. Horns are used for the preparation of trophies, decoration pieces, fancy items, and ornaments, etc. Dressed carcass of fallen animals is used for the manufacture of meat meal, meat-cum-bone meal or bone meal, and autolized carcass is converted into manure. The long hairs of tail switch is used for ropes and mat making.

▶ GLOBAL DISTRIBUTION OF RIVER BUFFALOES

Although by origin water buffaloes are the animals of humid-hot tropics of Asia but due to high adaptability they have spread beyond 45°C latitude in the temperature zone. From Asia buffaloes spread to island countries of Asia-Pacific region, near east and Europe long back. Later on it was taken to south Africa and Americas for the utilization of natural pastures of wet regions for the production of meat and milk. Now river buffaloes can be seen in almost all the continents including the United States of America. The population of water buffalo is increasing at a very high rate of 12–13% per year. The buffaloes were first introduced in Brazil followed by Venezuela and Columbia for milk and meat production. Buffaloes are quite popular in Trinidad and Cuba and now they also paved into Canada, Mexico, Panama, Costa Rica, Guatemala, Honduras, and Belice (Zava, 2007).

In the home tract of swamp buffaloes, milch breeds of river buffalo (Murrah and Nili-Ravi) have been introduced for developing triple purpose (milk, meat, and work) breeds. The countries using Murrah and Nili-Ravi for crossing with swamp buffaloes are the China, Combodia, Laos, Philippines, Thailand, Vietnam, Indonesia, Malaysia and many other contries.

▶ ADAPTABILITY IN RIVER BUFFALOES

Buffaloes are normally under stress in hot climatic condition and undergo wallowing in cool water and mud hole for several hours to alleviate the heat stress. Despite this limitation largest number of buffaloes are found in the tropical countries of Asia and India houses about 70% percent of the domesticated water buffaloes on the earth (FAO, 2007). The dairy type river buffaloes are mostly congregated in the dry hot zone of India, i.e., Punjab, Haryana, Delhi, Rajasthan, Uttar Pradesh, Madhya Pradesh, and Maharashtra. Greater proportion of draught type swamp buffaloes is distributed in the east and north-east states of India, Nepal, Bangladesh, Mayanmar, Thailand, Combodia, Lao, Vietnam, China, Taiwan, Philipines, and other countries of Asia-Pacific region. Water buffaloes prefer grazing in the cool hours of morning and late in the evening to avoid heat of the sun. During hot hours grazing buffaloes cluster beneath the shady trees, or wallow in water and mud. Planting of trees with large canopy and housing in well-ventilated sheds provide protection from direct exposure to sun rays. The evaporative effect of blowing air produces cooling effect. Showers, rains, and wallowing provide comfortable environment by conduction (Minett, 1947).

Plastering of body with mud provides protection form direct solar radiation and produce cooling effect through the heat loss in the evaporation of moisture of mud on the body. The heat tolerance coefficient of buffaloes varies from 76 in adult animals to 85.15 in young calves below 1 year of age (Asker et al., 1952; Bhatnagar and Choudhary, 1960). The heat tolerance coefficient of Egyptian buffaloes is much less than 91, 85, 83, and 89 for the Egyptian native cattle, pure shorthorn cattle, pure jersey cattle, half bred shorthorn and three-fourths shorthorn cattle respectively. The average rise in body

temperature on the exposure to direct sun had been much higher in buffaloes than the cattle. The buffaloes tethered in open during the daytime of summer season became restless in a short-time. Heat stress causes excessive salivation, cessation of rumination and exhaustion. The rise in body temperature and respiration rate of the buffaloes due to exposure in sunlight is much higher than the zebu and humpless European cattle (Minett, 1947; Badreldin et al., 1951; Askar et al., 1952). In the conventional management of collecting the grazing buffaloes beneath the tree or housed in airy sheds provides satisfactory protection from heat stress. There is no abnormal rise in body temperature (rectal), respiration rate and pulse rate. Significant rise in the body temperature and pulse rate indicates the higher susceptibility of buffaloes to direct solar radiation. The high haemoglobin content during summer has been considered as an index of good adaption ability of the river buffaloes are more hyperthermic on exposure to direct solar radiation due to black pigmentation of skin and scanty hairs on the body. The increase in body temperature is quite sharp and ranges from 0.3°C to 2.4°C depending on the atmospheric temperature and duration of exposure occurs on shifting the animals in sheds, sprinkling cold water, and wallowing (Villoz and Nguyen, 1939; Minette, 1947; Misra et al., 1963).

▶ HEAT PRODUCTION

Metabolic heat production for the maintenance of optimum body temperature is a normal physiological function of the living animals. Average rate of heat production in adult buffaloes is about 485 ±31 kcal per hour, which is equivalent to about 107 kcal per hour per square metre body surface area. The heat production rate in almost similar in buffaloes to that of crossbred cattle (Bos indicus x Bos Taurus) but significantly higher than the zebu cattle of India (Mullick and Kehar, 1952). The heat production rate in buffaloes is significantly influenced by the seasons and it is higher in winter season (524 kcal per hour) in comparison to summer season (462 kcal per hour). The change in body heat production is associated with changes in pulse and respiration rates (Mullick, 1964).

▶ BODY HEAT DISSIPATION ROUTES AND THERMOREGULATION

For the maintenance of normal physiological functions, the body produces heat by metabolism activities and also external heat enters into the body by radiation, conduction and convection systems. The body also looses heat through similar processes added by evaporation of moisture from the skin, respiratory exhalation and also through excretion (dung and urine). Like many homoeotherms, the loss of excess heat from the body of buffalo takes place by circulatory adjustments, cutaneous evaporation and increased respiration rate.

Circulatory Adjustment for the Maintenance of Homoeostasis in Buffaloes

In the warm weather vaso dilation of the skin takes place. This causes a steep change in the heat exchange gradient for the atmospheric below skin temperature. This steep change between the two temperature zones decreases heat loss form the body. Considerable increase in the blood and plasma volume of the buffalo occurs on rise in the atmospheric temperature (Table 1.1). This increase provides more space for the adjustment of absorbed heat in the summer season (Murti and Mullick, 1961).

TABLE 1.1: Mean volume of blood and plasma of various groups of buffaloes in different seasons of northern India at Izatnagar

Physiological stage/ age of buffalo	*Blood volume (ml/kg body weight)*			*Plasma volume (ml/kg body weight)*		
	Summer	*Rains*	*Winter*	*Summer*	*Rain*	*Winter*
Young buffaloes						
Below 12 months	67.2	59.3	59.9	45.0	43.3	40.7
13–24 months	57.1	56.5	54.2	41.3	39.2	36.6
Buffalo bulls	51.5	51.9	50.9	34.7	35.7	33.9
She buffaloes,						
Dry	56.0	48.5	51.0	38.2	35.1	33.6
Lactation	58.7	55.9	54.2	41.1	38.1	36.4
Pregnant	59.7	55.4	55.6	39.9	37.4	35.1
Overall	58.4	54.6	54.3	39.9	38.1	36.0
Relative (%)	107.6	100.6	100.0	110.8	105.8	100.0

Cutaneous Evaporation

The adaption mechanism of buffaloes to hot climatic conditions is limited by the black pigmentation of skin, which favours the absorption of infrared rays of solar radiation (Badreldin and Ghay, 1952). Therefore, direct exposure of buffaloes to sun should be avoided in the summer season. On poor pastures the frequency of mud plastering on the body increases because hungry buffaloes need longer time for grazing to fill their belly. Mud plastering also prevents the absorption of heat from the hot air and ground and helps in dissipation of heat from the body during the process of moisture evaporation of mud plaster on the body. Taking the advantage of this behaviour of buffaloes the owners of draught buffaloes use mud plastering or wet gunny bag for covering the head and body of buffaloes used for the traction of loaded cart during daytime in the summer season.

The buffalo possesses two types of sweat glands, i.e. the apocirne and accrino glands. The accrino glands are scanty in number (Hafez and shafei, 1954). Great variation has been reported in the density of sweat glands in different buffaloes. It ranges from 135 to 142 per cm^2 in the adult swamp buffaloes (Yamano and Ono, 1936). The average in calves of Egyption buffalo at birth is 124.8 per cm^2, which increases to 394 per cm^2 in the adult buffaloes (Hafez et al., 1955). Average 124 sweat glands per cm^2 has been recorded in buffalo bullock (Prusty, 1965) and 160 ±11 per cm^2 in the adult non-descript and Murrah buffaloes (Nair and Benjamin, 1963). Highly significant difference has been reported in the density of sweat glands of Murrah buffalo heifers of different age group (Table 1.2), which showed fluctuating pattern with the increase in age of the Murrah buffalo heifers (Sachdeva and Nagarcenker, 1981). The density of sweat glands in the buffaloes is only 6–7% of that recorded in the cattle of same area (Govindaiah and Nagarcenker, 1978). In the Egyptian buffaloes these glands are about one-third of the Egyptain cattle of same area (Hafez et al., 1955).

Mean heritability of the density of sweat glands has been estimated to be 0.67 0.37, which shows the scope of selection at young age among the progeny of selected sires for better homeothermy (Sachdeva and Nagarcenker, 1981).

The muzzle glands of buffaloes are the compound tubuloacinar and multilobular seromucous modified sweat glands. The glandular acini are made of myoepithelial

cells and a basement membrane (Quasem et al., 1976). The presence of sweat drops on the muzzle does not require justification regarding the sweating of muzzle glands but there is doubt about the function of sweat glands on the body and their role in heat regulation (Prusty, 1973). This doubt was removed in subsequent studies. Although body surface evaporation through sweating is apparently insensible but has shown the functional characters of sweat glands in the skin of buffaloes (Joshi et al., 1968; Agarwal et al., 1983). Average sweating rate is lower in winter and highest in summer. The sweat excretion rate increases considerably with the increase in environmental temperature (Joshi et al., 1968). Average sweating rate between 37–45°C has been about 21.7 ± 2.2 g per square metre per hour in the adult Murrah buffalo bulls (Agarwal et al., 1983). Sweating is though limited but contributes in the amelioration of heat stress through the loss of heat in the evaporation of sweat. Approximately 0.58 kcal heat is lost in the evaporation of 1 g water.

Respiratory Heat Dissipation

It is observed that panting and parotid salivation increase during high environmental temperature by about 2 to 2.5 times. The buffalo has a relatively lower level of respiration rate, body temperature, and pulse rate than the cattle and shows noticeable distress in hot climate (Badreldin et al., 1951; Pandey and Roy, 1969b; Chikamune and Shimizu, 1983). The reaction of buffaloes is more vigorous in their increased rate of respiration and higher body temperature at air temperature about 74.4 8°F or 23.55°C (Goswmai and Narain, 1962). During summer months the buffaloes exhibit an increased respiration rate associated with rise in body temperature and pulse rate on direct exposure to sun light. Sudden decline in respiration rate occurs when buffaloes are removed from the sun, but fall in body temperature takes place after a latent period of about 10 minutes and pulse rate falls after about 40 minutes (Table 1.2). Respiration evaporation is more important in buffaloes than the other mechanism for the regulation of body heat balance. The rise in respiration rate during hot climate is necessary and effective in maintaining the body temperature with in the physiological limits (Kamal and Ibrahim, 1969; Pandey and Roy, 1969).

TABLE 1.2: Effect of direct exposure to sunlight and then return to shade on some physiological reactions in buffaloes

Treatments	*Body temperature*	*Respiration rate per minute*	*Pulse rate per minute*
Normal housing at 10 AM	38.3	36	54
Exposure to direct			
Sunlight	10 AM		
	11 AM		
	12 AM		
On return back to shade, 12 NOON			
1 PM	38.6	40	53
2 PM	38.2	32	51

▶ EFFECT OF LATITUDE AND ALTITUDE ON THE ADAPTABILITY OF WATER BUFFALOES

Both dairy type river buffalo and draught type swamp buffaloes are distributed from equatorial zone to beyond 45°C latitude in both the hemispheres.

The performance of local Mediterranean buffalo and exotic Murrah buffaloes are quite satisfactory in the European countries like Bulgaria, Italy, Romania, etc. though Murrah is a native of hot-humid tropics of India. The Murrah and other breeds of Indian dairy buffaloes are performing satisfactorily in the hot and humid –hot climate of Indonesia, Srilanka, Malayasia, Thailand, China, Combodia, Loas, S.R. Vietnam, Singapore, Philippines, etc. These buffaloes have adapted well to the high altitude of Uttrakhand, Himachal Pradesh, Nepal, Sikkim, and Bhutan. The increase in migration rate domestic buffaloes specially the dairy breeds of the Indian subcontinent to Brazil, Venezuella, and other countries of Americas show their high ability of adapting in diversified agroclimatic conditions provided they are protected from the fatal diseases and water supply is assured. Protection from extreme climatic conditions like direct solar heat higher than 35°C for longer period and chilling frost for several days. Rains and running water are the highly desirable situations for the dairy type river buffaloes of Indian origin.

▶ BUFFALOES IN MYTHOLOGY, RELIGION, AND SPORTS

Some information about the use of buffaloes in mythology, religion, and sports, etc. are presented in brief to show the closeness of this multipurpose beast with mankind since prehistorical period. India is the home land of riverine buffalo while major part of east and south aisa is the homeland of swamp buffaloes, this animal had been closely associated with the socioeconomic activities of the besides the main contribution of milk and draught power.

1. In India and Nepal, ritual sacrifice of entire male buffaloes had been quite common at the festive occasion of ' Dusshera or Durgapooja'. Goddess Durga incarnated as 'Chamunda' and killed 'Mahishasur' (means demon buffalo) at Mysore. The word Mysore is actually a distorted form of the original word '*Mahish oor*' means the 'chest of buffalo'. It is believed that goddess 'Chamunda' after killing 'Mahishasur' constructed a town on his chest and named it 'Mahishoor' which in use subsequently became the present day 'Mysore'.
2. During Mahabharat period 'Pandavas' charged with the sin of homicide for murdering cousins 'Kauravas' in war. To get pardoned they required the blessings of Lord 'Shiva' but thou went in hide. In search of 'Shiva' the Pandavas reached 'Kedarnath'. The 'Shiva' took the form of a buffalo bull and mixed with the buffaloes. Some how one of the Pandavas, Bhim suspected that robust buffalo bull in the herd is Shiva. He then moved to catch him. The moment Shiva saw Bhim running to him Shiva started entering into the earth but Bhim succeeded in catching him by tail. At Kedarnath in high Himalaya the Lord Shiva is worshiped in the form of Buffalo bull with front buried in the earth and hind part on the ground.
3. Lord Shiva created 'Yamraj' the god of death from eight strong buffaloes for infusing great strength in him necessary for performing the hard job of managing the death of creatures on the earth.
4. The gesture shown by a gatekeeper of lord Shiva palace named 'Nontakara' by throwing flower on a nymph of palace angered the Shiva and he was made a buffalo 'Tarap'. The gesture was regarded misbehaviour. Later on his request for relief was considered for release from buffalo life. For this he was to be killed by his own male progeny. He was provided 5000 breedable buffaloes. One of these female buffaloes conceived but she was knowing that if she delivers a male calf, that may kill 'Tarap'. Thus, she ran away to hide herself in a cave where she delivered a male calf and

named it 'Tarapee'. The calf grew as a strong buffalo bull matching his father. The mother of 'Tarapeer' made all possible efforts for preventing encounter between father and son but failed. Subsequently, in a fierce fighting 'Tarapee' killed 'Tarap' to revent back to original 'Nantakara'.

Further survival of 'Tarapee' was dangerous for others and he was killed by the great warrier monkey king 'Bali' on the dictate of the God.

5. In the China, the founder of 'Taoism', the great philosopher monk 'Lao Tzu' left China after completing his jog on the back of a male water buffalo to west not to return again. The period of 'Laotz' is about sixth century BC (Cu-I, Tai, 1959). This shows the domestication of buffalo during the period of Taoism.
6. The albinioid specimen of carabao (swamp buffalo) is regarded as a notional symbol in the Philippines.
7. In Indonesia, Torajan community, is believed to come from Combodia in boats and settled in isolation on hills. This was a community of illiterate people of fierce nature and inaccessible for the native Indonesia. Later on this community was gradually brought into mainstream by the efforts of the European missionaries during the beginning of the twentieth century. Torajan people practice many rituals which are performed at different occasions by the specific priests. Sacrifice of buffaloes is quite common at such occasions.

   The buffalo is also considered a symbol of fertility and worshiped for the maintenance of fertility in humans and worshiped. A famous 'Mabua' ceremony is organized every 12 years and the priests wearing dress decorated with buffalo horns in head dress and dance around a sacred tree.
8. Ritual sacrifice of buffalo is practiced in Laos and number slaughtered depends on the size of community for feast.
9. In Vietnam water buffalo is the symbol of prosperity and these are more precious than the common member of the family. In ancient time the name of west lake Ha Noi was *Kim Nguu* means the 'golden buffalo'. Probably due to this reason the mascot of the 22nd southeast Asian Games organized in Vietnam was a 'golden water buffalo'. The water buffalo is a symbol of power and strength of the martial race the native of Vietnam.
10. In Malaysia buffaloes are sacrificed at major sociocultural occasions for the community feast. Some of the such occasions are the laying of foundation for the construction of house. At this occasion head and legs of the sacrified buffalo are buried deep beneath the central pillar. The remaining flesh is served in community feast. However, albinoid buffaloes are considered inauspicious and they are not used for ritual sacrifices.
11. In Combodia buffaloes are used in religious functions and processions. The decorated buffalo bulls and calves suckling the dams are carved on the walls of the world famous 'Ankore batt temple' constructed during 9th to 10 century AD.

▶ BUFFALO FIGHT FESTIVALS OF DIFFERENT COUNTRIES

Buffalo fight festivals are quite common in one or the other form in most of the Asian countries in the home tract of water buffalo.

1. Organization of buffalo bullfight is quite common in Assam (India) at the festival of 'Bhogali Bihoo'. It is called 'Moh Yuddha' (fight between buffaloes). For this purpose buffalo bulls are specially reared and trained. The buffalo bulls participating in the fight festival may be from the different groups of same village or from different

villages. The 'Ahotguri' village in Naogaon district in upper Assam is famous for organizing 'Moh Yuddha' competition.

2. **Mud race of buffaloes in southern India:** This is a festival of Palakkad district of Keral and Mangalore district of Karnataka in India. The male buffaloes are yoked in pairs and driven to run in mud by the person standing on the wooden plank pulled by the racing buffaloes. This is known as 'Kambala' race. The race is competition and each participant wants to wean the race.
3. **Bullfight show at the occacion of Goberdhan pooja in India:** In greater part of India workship of mount Goberdhan is celebrated on the next day of Dipawali festival. Both cow and buffalo bulls may be used for the show. It is a nonfatal fight between the two bulls of comparable power. In the region of Rohilkhand in the northern part of India generally buffalo bulls are used for the friendly fight show. The bulls may be from the same village or different villages. Competition is also organized and prizes are distributed. A red or orange scarf is tied around the horns of winner bull. The show is witnessed by large number of villagers and necessary arrangements are kept ready for stopping the fierce fight, if occurs due to excitement during the show.
4. The buffalo fight festival of Thailand is known as 'Ko Samui' and generally organized at the occasion of New Year Day in January and 'Songkaran' in April. For this purpose buffalo bulls are raised and trained for head-on fight. It is a prize winning competition. The buffalo that turns away and run away is the looser. The fight is mostly nonfatal. The market value of winner buffalo increases many fold.
5. The annual water buffalo race festival of Thailand or Chon Buri water buffalo race. Chon Buri is a town situated about 70 km away from the Bangkok in south. It is an annual festival celebrated in the month of October before harvesting the paddy crop. This is a newer festival evolved over hundred years ago from the casual argument between the two buffalo owners of Chon Buri claiming fast racing ability and agility of their buffalo. This has now become the annual festival attracting large number of tourists from different countries to witness buffalo race. The participant join the race in group of 5 to 6 jokies riding bare back buffaloes. The total number of buffaloes may be more than 300.
6. **Water buffalo race festival of Vihear Gour village in Combodia**: It is an annual festival of Vihear Guor village of Combodia to honour the pledge made to a spirit for protecting the farm animals from dreaded diseases organize a buffalo race on the last day of the "Pchum ben" festival. This village is situated about 30 km north east from the capital city 'Phnom Penh'. It is said that more than thousand years ago large number of draught cattle used in various agricultural operations were killed by an unknown disease. Thereafter they shot the help of a sprit for soving their animals. Since then people of this village arrange buffalo race annually on a fixed date to please the spirit as per pledge made at that time. At this occasion the horns of the buffaloes are decorated by wrapping a coloured cloth. The jocky rides on bare back and excite the racing buffalo by bouncing for high speed.
7. **'Karapan Sapi' buffalo race festival of Madura, Indonesia:** The Community of Madura island in east Java of Indonesia organize buffalo race events at least three times every year particularly in the month of August, September and October. People are generally free from the agricultural works. For this purpose selected buffalo calves are raised for strength and trained for high speed for winning the race. The

owner of winner receives prize and the market value of winner buffalo increases many folds. The high caloric nutritious diets of these racing buffaloes may be made of several raw eggs and honey fortified with different kinds of medicinal herbs. Some of the towns famous for attractive buffalo race are Bangkalan, Pamekasan and Sampang.

8. **Water buffalo race on the occasion of 'Babulang' ceremony at Sarawak in Malaysia:** The 'Babulang' is the grand festival of Borneo island inhabited by the 'Bisaya' community inhabiting in Limbang of Sarawak province. At this occasion water buffaloes are put to racing competition known as 'Ratu babulang'.
9. **Buffalo fight festival of 'Do Son' in Hiphong city:** It is an annual festival celebrated on the 9th day of the eight month of the Lunar calendar of Vietnam. The race is complete in three rounds. Greater proportion of the participating buffaloes are eliminated from the final race during first and second races organized in the middle of the 5th and 8th month of the lunar calendar of Vietnam.

   For this fighting festival male buffaloes calves are selected young and raised on highly nutritious diets during growth. The animals are given rigorous training for fighting. For this purpose an experienced fighter buffalo is put against the novice. The buffaloes are used for competition at 4 to 5 years of age. The animal must appear masculine with robust disposition, broad and deep chest with well-sprung ribs, long groin, a long and strong neck and bow shaped massive horns. The feeding, management and training of these buffaloes are arranged separated and kept away from the common buffaloes.

   It is an elaborate festival. The worship ceremony is performed up to mid day or lunch time. The ceremony begins with a great procession chair carried by six strong youth followed by a team of eight singers. In the procession finally selected six buffaloes covered with red drape and reddish horn band are lead in the procession. On the fighting ground the two opposite teams stand near their flag known as 'Ngu phung' holding their buffalo opposite each other. Now a signal is given to begin. The buffaloes of both sides are brought against each other within 20 m distance. The buffaloes of either side is left free at them same time by releasing the rope tied with nose peg or nose ring. At this time a group excite their buffalo by shouting. At the end of fight time the winner buffalo is received with applause and rewarded by the leader of community.

   This buffalo fighting festival is organized annually for worshiping a water god and also for showing gratitude to martial spirit of the local people, the 'Hien Sinh' custom.
10. **Makepung buffalo race in Negara of Bali island of Indonesia:** It is an annual event of Bali island organized on every Sunday from July to October. The buffalo bulls are specially reared and trained for winning the race. For this race a pair of buffalo bulls is yoked in a chariot. Two pairs participate in each round of race on a dusty tract of about 1.5 km. The sport ground is situated in the interior part about 150 km away from the Kuta, Negara. It is a traditional race organized by Bali people (Nick, 2006).
11. **Water buffalo in folk lore of Indonesia:** In a popular folklore of Java in Indonesia the victory of Javanese queen over the king of Sumatra is nawated. The queen won with the help of an unfair fight between the buffalo bulls of the two kingdoms. To commemorate the occasion the ladies decorate the head covering part of special dress to depict the horns of buffalo. The male folk of Java also wear a head dress

decorated with the pair of buffalo horns and several varieties of medicinal herbs. These are considered to infuse power and increase the lifespan of the person.

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