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The Feasibility and Potential Payoff for Research on Water Buffaloes

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Importance of Buffaloes in World Agriculture

Cockrill (1976) reported that water buffaloes were first domesticated in Mesopotamia about 2500 - 2100 B.C. India is considered to be the home of the river of milking-type buffalo and Southeast Asia for the swamp or work-type buffalo. Water buffaloes are now widely distributed throughout the tropical countries of the world and even into the warmer regions of temperate countries including the Middle East, Southern Europe, South America, the Caribbean area, and Australia.

Distribution and Use

The distribution of buffaloes is shown in table 1. The total number of buffaloes appears to be almost 15% lower than Cockrill's (1974) estimate of 150 million. Over 97% of the world's buffaloes are found in Asia, with some 47% in India, 23% in China, 9% in Pakistan, 5% in Thailand, and 2% in the Philippines. Most of the buffaloes in Africa are in Egypt, with almost as many as in the Philippines. Numbers are still small in South America and the Caribbean, but they are increasing there as well as in Brazil, Venezuela, and Trinidad and they have been introduced into Colombia, Bolivia, Guyana, Costa Rica, Ecuador, Panama, Suriname, Cayenne and in Tanzania, Uganda, and Nigeria in Africa. The NRC Report (1981) lists 400,000 buffaloes in Brazil, more than 100,000 in Italy, and about 500,000 in the U.S.S.R. All of these are considerably larger than shown in table 1. There is considerable difficulty in obtaining accurate data on animal numbers. On the basis of FAO data, world buffalo numbers have increased at the rate of about 0.7% per year compared to cattle at 1.1% during recent years.

Numbers have been decreasing in Thailand, the Philippines, and some other countries because of the demand for meat and the replacement of working buffaloes in the rice paddies by small motorized machines. The high price and potential shortage of fuel is starting to change this trend. Expanded research efforts are needed to increase the productivity of buffaloes as a source of farm traction and especially for meat and milk production.

Most of the domestic buffaloes in the world are owned and used by small farmers. In the Philippines, more than 70% of the buffaloes are used for farm operations and over 90% are owned on small farms. In the Philippines, Thailand, and some other Asian countries, there are more buffaloes than cattle and they provide a major source of farm power and a good source of meat or milk. They are sometimes more productive than local cattle. For example, in India and Pakistan, buffaloes are fewer in numbers than cattle, but they contribute more to the economy. India has only one third as many buffaloes as cattle, yet buffaloes produce 55% of the milk and 60% of the meat from cattle and buffaloes. Some 95% of the milk available in the cities comes from buffaloes. There has been a 13% increase in buffalo numbers in the last decade in India compared to 2% for cattle. About 70% of the milk in Pakistan is produced by buffaloes although cattle numbers are some 30% higher. Products from buffaloes contribute more than from cattle, sheep, and goats combined. In Thailand, buffaloes are the main source of capital for 85% of the Thai people of working age, 88% of whom are rice farmers.

Table 1. WORLD DISTRIBUTION OF BUFFALOES (1980)

Location	Population (thousands)	Location	Population (thousands)
Asia		Africa	2379
Bangladesh	1550	North and Central America	8
Burma	1803	South America	
China	30080	Brazil	360
India	61300	Oceania	1
Indonesia	2353	Europe	
Iran	220	Bulgaria	52
Kampuchea	400	Italy	83
Lao	756	Romania	228
Nepal	4200	Yugoslavia	87
Pakistan	11547	others	3
Philippines	2760	USSR	350
Thailand	6250		
Turkey	1040		
others	3588	WORLD TOTAL	131398

Source: FAO Monthly Bull. Stat. May 1981.

In the late 1950's the U.S. Government international assistance program recognized the importance of the water buffalo in many developing countries. The governmental agency (International Cooperation Administration) sponsored several studies on buffaloes (The Water Buffalo, Bradford Knapp, 1957; Water Buffaloes in Egypt; and The Water Buffalo of India and Pakistan, Rife, 1959). These reports reviewed the available data on numbers of animals in 25 countries. Nine other countries were reported to have buffaloes but the numbers were not known and Brazil was not listed.

Knapp's (1957) report estimated that there were some 80 million buffaloes world-wide compared to 170 million cattle. Of a population of 750 million in these countries, 250 million people depended on the buffalo for work, meat, milk, and milk products. Knapp's brief summary of the importance of buffaloes applies equally well today. He stated, "As a work animal, the water buffalo has some outstanding traits. Its large feet make possible work in rice paddies and fields where smaller footed cattle could not work as well. Their gait is slow but the water buffalo is powerful and on farm roads it can move loads of one ton or more. During extreme heat of the summer, the water buffalo cannot work during the heat of the day because of its poor temperature regulating mechanism. Aside from this, it is considered a fine draft animal. In general, although the water buffalo lacks much to be desired as an economical producer of milk and meat, it has been and will be an important part of the agricultural economy of the Near and Far East. The water buffalo is not likely to be replaced by other species in the foreseeable future." Until the past ten years (mid 1970's) little attention has been paid to the water buffalo by research organizations. This is partly due to limited research facilities in these areas as much as lack of interest on the part of the animal husbandman.

Research

Knapp (1957) reviewed the published research and cited 80 publications. Data were available for some types of buffaloes on growth, body measurements, blood analyses, reproductive traits, mortality rates, longevity, milk and meat production, and heat tolerance. Good data were available to show that reproductive rates were very low, death loss of calves was high, growth rates were low, and many mature animals were very small. The variations among animals were very large suggesting that there was potential for much genetic improvement by selection. The great need was stressed for research to better characterize the potential performance of animals of different types of breeds and to determine the effects of improved feeding, management, and disease control productivity.

Castillo (1967) reviewed the research on areas of origin and economic importance, anatomy and breeds, genetics of some characters, reproductive physiology of the female and male, and hematology, citing over 800 references from technical journals starting from the 1920's. He pointed out that water buffaloes and cattle are parts of the stream of life for rural people in many tropical countries. Buffaloes are triple-purpose animals - work, meat, and milk. In addition, they provide leather for clothing and other uses, fertilizer for crops, fuel for cooking, and many items for the sustenance and pleasure of humans.

Some applied research with buffaloes was started in the Philippines in the 1930's (Villegas, 1932). Considerable research has been done with buffaloes in India going back to the 1940's. During the 1960's in particular, PL -480 projects financed much of the research. There has also been active research with buffaloes in Egypt for several decades and a considerable amount of this has been published in Indian scientific journals (Ichhponani et al, 1977; Ranjhan and Pathak, 1979). Only recently has there been increasing interest in extensive coordinated research to improve the productivity of buffaloes in the Philippines, Thailand, and other Southeast Asian countries.

Financial support for research on buffaloes is still very limited, except perhaps in India, where a number of universities and research institutes have active programs.

A brief summary of selected research papers and reviews is presented to illustrate the type of research that has been done in recent years. Trained research personnel and research facilities are presently available in several countries and some good quality research has been carried out the past decade or two. Progress will be relatively slow and limited in scope unless additional financial support can be obtained for coordinated research programs.

The NRC (1981, p. 88) report states, "research on the animal (buffalo) is scanty and limited to only a few situations and sites." The amount of research as well as the quality of this research with buffaloes has increased greatly in the last decade. In his review, Castillo (1967) cited 767 publications. The DCWB (1978) listed 1,469 abstracts of research on water buffalo published between 1971 and 1975 by no less than 1,350 different researchers in various countries. Many of these researchers have had graduate studies in universities in the U.S.A., Europe or Australia or from those who received these graduate degrees. The books by Cockrill (1974) and Ranjhan and Pathak (1979) cite numerous references to published research. Much of this research is limited in scope and the need exists for more critical and extensive studies of many of the major problems which limit the productivity of buffaloes.

Reproductive Performance

Age at Puberty/Sexual Maturity

Puberty is defined as that time when an animal attains breeding capability, while sexual maturity is the time of maximum breeding potential. Camoens (1976) observed male calves attempting to mate as early as four months of age with attempts increasing in frequency as they approached twelve months of age. Dutt and Bhattacharya (1952) reported meiotic division in the seminiferous tubules of a one year old buffalo bull. These reports indicate that puberty in male buffaloes occurs at about one year of age. However, sexual maturity occurs at two to three years of age. Camoens (1976) reported that the use of well-fed two year old bulls has met with great success. However he recommends that males raised under poor conditions should not be used for breeding purposes before they attain a body weight of approximately 340 kg or an age of 36 months.

The reproted age of puberty of the female buffalo varies greatly. Camoens (1976) reported that puberty in females ranged from 12 to 18 months. Cockrill (1976) reported that the average age at first estrus was 35.7 months for 12 animals in China. In the review by Chantalakhana (1979) the age at puberty ranged from 19 to 36 months. This variation in the age of puberty may be due in part to the difficulty in estrus detection and the effects of a wide range of environmental factors. McDowell (1972) stated that buffalo heifers bred at puberty had a higher incidence of abortion or calf mortality. He reported that conception was possible as early as 21.5 months but the full reproductive potential, sexual maturity, was not reached until about six months later. These values are in agreement with those of Camoens (1976).

Estrous Cycle

Estrus is not generally accompanied by many observable signs. Estrus may involve: 1) a slight edema of the vulva, but this is masked by the general thickness of this area; 2) redness of the vulvar lips when they are parted since the normal external color of the vulva is black; and 3) a scanty amount of mucous (sometimes opaque) discharge. Some females have been known to mount other females or to allow other females to mount them. There may also be a change in the receptivity of the female to the male. The best indication of estrus is the increased attention of the male toward the female (Camoens, 1976).

There are many reports on the length of the estrous cycle and the duration of estrus, (Butchaian et al., DCWB, 1978 No. 826; Chantalakhana, 1979; Cockrill, 1974, 1976; McDowell, 1972; PRCP, 1978). The length of the estrous cycle in buffaloes varies from a reported 21 days to as high as 34 days. While the duration of estrus has been reported to vary fro 5 hours to 5 days, the average appears to be 36 to 40 hours. These wide variations may be due to the difficulty in detecting estrus. The majority of cattle exhibit estrus during the daytime, while for buffaloes estrus begins in the night more frequently (84% from 6 p.m. to 6 a.m.).

Breeding Season

Dessouky and Juma (1973) compared the maximum conception rates and time of conception for the cattle and buffaloes of Iraq. The majority of cattle were artificially inseminated, while the buffalo cows were under a natural pasture mating system. These authors reported that season had an effect on the maximum conception of cattle with the higher rates occuring in the spring and summer and the lower rates occuring in the fall and winter. Buffalo females showed the highest conception rates in the winter followed by spring and fall while summer was the lowest. These authors indicated that the higher air temperature in the summer influenced the lower conception rate. The signs of estrus were supressed and the duration of estrus was reduced at higher environmental temperatures according to Pandey and Raizada (1979). Bhat (1979) reviewed several articles that reported 70 to 80% of the conceptions in buffaloes were between July and February in India. He indicated that a lower number of services per conception were needed during the breeding season than between March and June.

Bhat and Kumar (1979), as cited by Bhat (1979), observed that buffalo cows continue to come into heat regularly throughout the year. Therefore, there is no seasonal anestrus in water buffaloes. However, there is a definite bi-modality in conception rate. This distribution of conception rate was thought to correspond to a seasonal anestrus in the female. Since buffaloes have been observed in estrus throughout the year, breeding seasons can be attributed to environmental and nutritional factors.

Breeding Ratios

The age and condition of the bull are important factors to consider when determining the ratio of buffalo males to females during the breeding season. In the Philippines, a young bull, 2.5 to 3.5 years of age, can be handmated to 20 heifers. The number of females can be increased to 30 heifers for bulls 3.5 to 4.5 years of age. For bulls 4.5 years of age and over, the ratio can be increased to 40 females per bull (PRCP, 1978).

Conception Rates

There is a large variation in conception rates reported in the literature. These variations are due in part to environmental and management factors. Bhat (1979) reported conception rates for Murrah females ranged from 16.2% to 28.3% over one year. Similar results were reported by Dessoky and Juma (1973), 18.7% to 29.4% for buffaloes and 18.7% to 32.2% for domestic cattle. In the last study the buffaloes were pasture mated and the cattle were artificially inseminated. McDowell (1972) reported that in Egyptian buffalo conception rates varied from 36% to 46% for first service. Whereas these values are higher than those reported by Bhat (1979) and Dessoky and Juma (1973), they were not as high as the following values. McDowell (1972) compared conception rates from natural service and artificial insemination and found a slightly higher conception rate for those buffaloes that were artificially inseminated, 63% vs. 66.2% respectively. Cockrill (1976) reported an overall conception rate of 60% in China, while Chantalakhana (1979) reviewed papers that listed common conception rates of 50 to 65% for buffalo (based on calving rates).

Gestation Length

The gestation length in buffaloes is longer than in cattle. The Ravi/Nili buffaloes of Pakistan have an average gestation length of 308 days compared to 285 days for Sahiwal, Red Sindhi, and Thari breeds of cattle (Pakistan Rep., 1974). Within the two types of buffalo, the swamp type buffalo appears to have a slightly longer gestation period. In the Philippines, Murrah buffalo are reported to have gestation lengths ranging from 314 to 317 days with the Carabao having a gestation length of 320 to 325 days. The crossbred females have a gestation length of the same range as the Murrah, 314 to 317 days (PRCP, 1978). Cockrill (1976) reported slightly lower values in gestation length for the Murrah and swamp buffaloes found in China, 305 vs. 312, respectively. The average gestation length of the river buffaloes was 310 days according to Bhat (1979). Research by Nambiar and Raja (1967, as cited by Bhat, 1979) showed a positive correlation between the length of gestation and the weight of the calf at birth. McDowell (1972) stated that gestation length is influenced by sex of the calf. He also indicated that

the sire, age of dam, size of dam, parity number, and season influenced the gestation length. In contrast, Kerur and Kodagali (DCWB, 1978 No. 0886) reported that sex of calf and season of calving had no effect on gestation length of river buffaloes.

Age at First Calving

Camoens (1976) stated that 2.7% of firstborn calves were from dams less than 36 months of age with the majority (51.1%) of firstborn calves from females 36 to 54 months of age. The remaining 46.2% of first calves were born to females over 54 months of age. In Pakistan, the Ravi/Nili buffalo had an average age at first calving of 45 months which was slightly higher than the Thari breed of cattle (44 months) and considerably higher than Red Sindhi cattle (35 months) (Pakistan Rep., 1974). Kanaujia et al. (DCWB, 1978 No. 0880) reported an age at first calving of 42.7 months in Indian buffaloes. Age at first calving was significantly affected by farm, year, and season of calving. The age at first calving values reported by McDowell (1972) were similar to those reported above. He also reported that season of the year significantly affected the age of first calving. Other factors that influence the age at first calving are the plane of nutrition, management, and male to female ratio (Camoens, 1976; McDowell, 1972). In the Philippines, the Murrah x Carabao crossbred females have a lower age at first calving, 39 months, than the Murrah, 52 months, and Carabao, 43 months, purebreds (PRCP, 1978).

Calving Interval

The calving interval is defined as the time elapsed between successive calvings. This interval includes the days prior to postpartum estrus, the days until conception, and the length of gestation. The optimum calving interval should be 450 days or less (Camoens, 1976). Approximately 20% of the population in Malaysia falls within this range. While another 20% had a calving interval between 450 and 550 days. The remaining 60% of the population had a calving interval greater than 550 days (Camoens, 1976). McDowell (1972) reported that the average calving interval from 37 studies was 495 days with herd averages ranging from 403 to 730 days. Liang et al., (1980) reported an overall average of 436 days for calving interval. Calving intervals of approximately 550 days have been reported in the Philippines (PRCP, 1978) and Pakistan. In Pakistan, a reduction in the average calving interval from 550 to 467 days over a five year period was achieved by improving herd management (Pakistan Rep., 1974).

Calving interval is influenced by the plane of nutrition, the level of milk yield, the month of calving, the season of calving, and the sequence of calving (McDowell, 1972). The interval between first and second calvings was longest while the interval between second and third calves declined with the later intervals shorter still, 530, 495, and 460 days respectively, (Desai and Kumar, 1964, as cited by McDowell, 1972). Similar results were reported by Camoens (1976) and Liang et al., (1980). McDowell (1972) found no distinct relationship between calving interval and breed. However, Bhat (1979) reported a variation in calving interval between four breeds of buffaloes.

Katyega (1981) in Tanzania reported a 438 day interval from first to second calving for Egyptian buffaloes as compared to 436 days for Mpwapwa cattle. The mean values from second to sixth calvings were 374 days for buffaloes and 396 days for cattle. The calving interval decreased further for the sixth to seventh calvings (349 days vs. 391 days) for the buffaloes and cattle, respectively. The maximum breeding potential for buffaloes could be the production of one calf per year.

Average Calf Crop

The highest calf crop observed by Camoens (1976) was 46.3% per year. However, the overall yearly calf crop was 29.5% for all herds. Only 20% of the herds in Malaysia exceeded a 25% calf crop annually. In the review by Chantalakhana (1979), he recorded calf crops of 56% in the Philippines, 65% in Taiwan, and from 23 to 66% in Thailand. Thamotharam (1981) observed a 65% calf crop in Sri Lanka.

In Northern Australia (Ford 1981, personal communication), comparisons were started in 1970 between cattle and swamp buffalo grazing the same pastures. Calving percentages for buffaloes were 81% vs. 68% for cattle. Cattle remained anestrus when suckling a calf, while a calf did not affect the ability of buffaloes to conceive. They conceived an average of 5 months after calving. Buffalo cows held their condition better than cattle on poor quality forage and weighed ±100 kg more than Brahman x Shorthorn cows. Many Brahman x Shorthorn cows did not survive the dry season, particularly when suckling a calf, while buffalo cows did much better. Under year-around breeding, cattle tended to calve evenly throughout the year while 90% of the buffalo calves were born in the mid to late wet season. Growth rates of young cattle and buffaloes were similar both before and after weaning over a range of pasture types and they both calved first about 3 years of age.

Season of Calving

McDowell (1972) observed that calvings were more frequent during certain times of the year. In India, 70% of the buffalo cows and heifers calve between August and November and less than 5% during the summer months, April to July. In Italy, the majority of calvings occur between July and October. Camoens (1976) reported a significantly higher rate of calving between February and August than during any other months. Nagarcenkar (1976; unpublished data) stated that calvings were highest for: Murrah buffalo between July and September; Bulgarian buffalo between June and September; and Murrah x Bulgarian crossbreds between May and September. Kerur and Kodagali (DCWB, 1978 No. 0886) reported that 56% of calvings occurred in the wet season with 24% in the cold season and 20% in the hot season. There was no seasonal calving pattern reported by Thamotharam (1981). The season of calving can influence the onset of first postpartum estrus either directly, through climatic stress or indirectly through feed supplies (McDowell, 1972).

Birth Weight

At birth the weight of swamp buffalo calves averaged from 26.6 kg to 38.4 kg (Chantalakhana, 1979). Male calves averaged heavier than the females 38.4 kg vs. 32.7 kg (Camoens, 1976). Liang et al. (1980) reported mean birth weights of 31.4 kg for males vs. 30.7 kg for females. McDowell (1972) reported that male calves were 0.4 to 4.0 kg heavier than female calves at birth. In contrast to these findings, Thamotharam (1981) observed that the average birth weights of male and female calves were the same, 20.5 kg.

Other factors that influence the birth weight of buffalo calves are parity, breed, nutrition of the dam and season (McDowell, 1972). Liang et al. (1980) showed that calves from first calving dams were significantly lighter ($P<.01$) than calves born to multiparous dams. The Beheri breed of Egypt appeared to have the largest birth weights, 30.0 to 42.2 kg , the breeds of Southeast Asia were intermediate, and the Carabao, the smallest, 25 kg (McDowell, 1972).

In Pakistan, the birth weights of Ravi/Nili buffalo calves were about 40% heavier than the local breeds of cattle, Red Sindhi, Sahiwal, or Thari calves (Pakistan Rep., 1974).

Calf Mortality

The observed range of calf mortality in 25 herds was 0 to 48% (Camoens, 1976). In 60% of the herds, mortality averaged 11.8%, while in the other 40% the average calf mortality was 26.3%. The overall population average was 18.3% for calf mortality. The average mortality was computed as 2.5% per year.

The causes of calf mortality were determined for 307 dead calves by postmortem examinations. Specific diseases accounted for 10.7% of the deaths. Calf scours accounted for 6.5% of the deaths while pneumonia accounted for 1.6% of the deaths. Accidents such as strangulation, lightning, etc. accounted for 8.8% of the total deaths. Deaths that could be prevented by improved management were responsible for 76.9% of the calf mortality. Insufficiency of milk was the major problem accounting for 35.2% of the deaths followed by 23.1% caused by helminthic infestations. Undiagnosed death accounted for 3.6% of the total calf mortality (Camoens, 1976).

Sharma et al. (1975a), reported the mortality of Murrah buffaloes to one year of age was 24% compared to 20% for Tharparker, 15% for Sahiwal, 16% for Red Sindhi, and 19% for Brown Swiss crossbred cattle. There was no sex difference, (males, 19%; females, 18%). Causes of mortality were: 34% pneumonia, 36% scours/enteritis, bloat 2%, foot and mouth disease 2%, and all others 26%. McDowell (1972) compared calf mortality between buffaloes and cattle. Losses from gastrointestinal disorders were 67.8% in buffalo calves vs. 19.7% in cattle calves. This may be due in part to the high fat content of buffalo milk increasing the occurrence of digestive disturbances. The death rate of calves weaned at birth is 50% due to digestive disturbances compared to 15% mortality when the calves are allowed to suckle for 3 days after birth. Pathological studies conducted on 65 calves (39 buffalo and 26 cattle) under one year of age resulted in the

following causes of calf mortality: pneumoenteritis, 40%; pneumonia, 12.6%; meningo-encephalitis, 12.6%; calf scours, 15.4%; foot and mouth disease, 7.6%; joint and naval pathologies, 7.6%; pulmonary tuberculosis, 1.5%; and adenomatosis, 1.5% (Singh and Singh, DCWB, 1978 No. 1358). Pneumonia (33.8 to 41.3%) and gastro-enteritis (32.1 to 35.5%) have been found to be serious causes of calf mortality in India (Ranjhan and Pathak, 1979).

Calf mortality appears to be highest from birth to 6 months of age. Within this time period, approximately 70 to 80% of the deaths occur (Camoens 1976; McDowell, 1972).

Reproductive Longevity

Cockrill (1976) reported that buffaloes can reproduce to 28 years of age and that one calving at 29 years of age was recorded in China. However, he stated that generally animals were not bred after 12 years of age. Alim (1953) estimated that the average productive life of buffaloes in Egypt was approximately 5 calvings. However, McDowell (1972) found the productive life was as low as 3.5 lactations.

Female Reproductive Performance

Estrus Detection

The onset of estrus in buffaloes is not generally accompanied by many outward signs. Camoens (1976) stated that estrus might be accompanied by a slight edema of the vulva and scanty mucus discharge. Occasionally, females in estrus will mount other females or stand to be mounted. However, the best indication of a female in estrus is the attention of the male toward a particular female. Janakiraman (1979) measured several signs of estrus throughout the year and concluded that frequent urination was the most reliable symptom of estrus. The incidence of silent estrus is high in water buffaloes. In the Philippines, it was estimated that 30% to 40% of females have silent estrus (PRCP, 1978), while McDowell (1972) reported that 35.3% of females examined had silent estrus. Since the occurrence of a silent or missed estrus prolongs the reproductive cycle length, the reproductive potential of buffalo females is not being attained. In order to maximize the reproductive performance of water buffaloes, an accurate and reliable means of estrus detection is required.

Janakiraman (1979) stated that animals could be detected in estrus by observations for frequent urinations. In this study, small quantities of urine were expelled 5 to 6 times in a 30 minute interval. Kamonpatana et al. (1979) described a method of estrus detection based on the fact that progesterone levels are high in the blood and milk during the luteal phase of the estrous cycle and low during estrus. This proposed method uses the enzymeimmunoassay in place of the standard radioimmunoassay for progesterone. Using this method, these authors stated that conception would occur if the progesterone level was below 0.5 ng/ml at the time of insemination. Pandey and Raizada (1979) suggested that a vasectomized bull

be used to check females 2 or 3 times a day and that females should be checked for mucous discharge at 3 hour intervals. Any mucous collected should be placed on a microscope slide and allowed to dry. Under microscopic examination a typical fern pattern would be indicative of estrus.

Estrus Synchronization

Wagelie et al. (1981) induced estrus in Carabao females with luteinizing hormone. The average estrus length and length of the estrous cycle was comparable to those of control females. However, the time of ovulation after the cessation of estrus was 13.3 hours in induced females vs. 7.2 hours for control females.

Glotra (DCWB, 1978 No. 0861) reported that 90% of the prepubertal females treated with a combination of pregnant mare serum and chorionic gonadotropic hormone came into estrus. Rajamahendran et al. (1981) used a progesterone vaginal device on a herd of non-lactating, difficult breeders and reported a 62% conception rate with natural service following removal of the device. When this method of synchronization was used on post-partum females, only 25% conceived after natural mating and artificial insemination.

The use of prostaglandin $F_2\alpha$ ($PGF_2\alpha$) or its analogue, Estrumate, for estrus synchronization has been reported for water buffalo. Wongsrikeao et al. (1981) used one injection of 30 mg $PGF_2\alpha$ on day 12 of the estrous cycle vs. a control group (no $PGF_2\alpha$) and reported pregnancy rates of 50% and 33.3%, respectively. When these authors compared control animals (no $PGF_2\alpha$) to animals given two 30 mg injections of $PGF_2\alpha$ twelve days apart, the pregnancy rates were 66.7% for control females and 50% for induced females. Pandey (1979) used two injections of either $PGF_2\alpha$ or Estrumate at 12-day intervals and reported that heifers receiving $PGF_2\alpha$ had a 50% conception rate while heifers receiving Estrumate had a 57% conception rate. These values reported by Wongsrikeao et al. (1981) and Pandey (1979) are similar for the treated females. In contrast to these results, lower conception rates were reported by Perera (1979, 1980) for animals treated with $PGF_2\alpha$ or its analogue. Perera (1979) injected 0.5 mg Estrumate 11 days apart and found that the control and treated animals had a 33.3% conception rate following natural service, whereas, the treated females bred with fresh semen had a conception rate of 30%. Perera (1980) reported first service conception rates of 30% and 39% for treated animals in two separate trials using artificial insemination and only 33% with females bred naturally. He stated that these conception rates were not significantly different.

Pregnancy diagnosis

The most reliable and widely used method of pregnancy diagnosis is rectal palpation. Other methods of pregnancy diagnosis are being studied. One such method of pregnancy diagnosis uses the high level of progesterone in the blood of the female during pregnancy. Perera (1980) took blood samples 21 days after artificial insemination. Using high progesterone concentrations, 67% of the animals were found to be pregnant on the basis of rectal palpation. Whereas 97% of the animals predicted to be non-pregnant were confirmed by rectal palpation. Perera (1979) used 700 pg/ml as the discrimination level

of progesterone for pregnant and non-pregnant animals. Values over 700 pg/ml were considered to be from pregnant females and those values under 700 pg/ml were from non-pregnant females. The prediction accuracy was 64% for pregnant females and 95% for non-pregnant females. A higher percentage of females, 95%, were diagnosed pregnant based on the blood progesterone level when samples were taken on day 22 post-insemination (Pandey, 1979). Kamonpatana et al. (1979) suggested that the blood samples for pregnancy diagnosis be taken on day 27 post-insemination to minimize the number of false positive results due to the longer estrous cycle of the buffalo.

Aly (DCWB, 1978 No. 0814) described two methods of pregnancy diagnosis. The specific gravity of the cervical mucous was <1.008 if the animal was non-pregnant, in 94% of the females, and >1.008 in 92% of the pregnant females. The fern pattern found in dry smears of cervical mucous were present in 70% of the non-pregnant females and a fibrous structure was present in the cervical mucous in 96% of the pregnant females.

Infertility Problems

Dessouky and Juma (1973) found the causes of infertility between cattle and buffalo cows were: inactive ovaries (39% cattle, 37% buffaloes), Pathological uterine changes (30% cattle, 45% buffaloes), persistent corpus luteum (6% cattle, 2% buffaloes), cystic ovaries (9% cattle, 2% buffaloes), free martinism (8% cattle, 0% buffaloes), and miscellaneous (4% cattle, 4% buffaloes). Buffalo cows were found to have a higher incidence of pathological uterine changes due to poor sanitation and hygiene than cattle resulting in a higher rate of infection. A contributing factor to the higher infection is the management practice in Iraq of inserting the hand into the vagina during milking to quiet the animal. The incidence of repeat breeders did not differ (11% cattle, 11% buffaloes).

Male Reproductive Performance

Semen Characteristics

Kerur (DCWB, 1978 No. 0885) compared the semen characteristics between two cattle breeds, Gir and Kankrej, and three breeds of buffaloes; Jaffi, Surti, and Murrah. The average ejaculate volume was higher for the cattle bulls, 6.6 and 6.2 ml, respectively, than for the buffalo bulls, 5.3, 4.4, and 4.6 ml, respectively. A lower ejaculate volume, 3.0 ± .2 ml, for the Surti breed was reported by Kodagali et al. (DCWB, 1978 No. 0895). Cockrill (1976) observed that the Murrah buffaloes in China had an average ejaculate volume of 1.8 ml and that the volume was less for the native swamp buffaloes. El-Wishy et al. (DCWB, 1978 No. 0850) observed that ejaculate volume increased with increasing age of the buffalo bull up to 5 to 8 years of age.

The progressive forward motility of spermatozoa was rated on a scale of 0 to 5, with 5 being the the best. Using this rating system, Kerur (DCWB, 1978 No. 0885) found that the motility of cattle spermatozoa was slightly higher or equal to the motility found in buffalo spermatozoa (3.8 for both cattle breeds and 3.5, 3.5, and 3.8 for the buffalo breeds, respectively). The motility estimate made by Kodagali et al. (DCWB, 1978 No. 0895) for the Surti breed was slightly lower (3.2 ± .4).

The average concentration of spermatozoa per ml of ejaculate was highest for the Kankrej and Gir cattle (1940 and 1250 $x10^6$/ml, respectively) while the Murrah, Jaffi, and Surti buffalo were lower (1240, 1170, and 1140 $x10^6$/ml, respectively) (Kerur, DCWB, 1978 No. 0885). The Surti buffaloes in the study by Kodagali et al. (DCWB, 1978 No. 0895) had a lower concentration (847 ± 39 $x10^6$/ml) than the Surti bulls in the study by Kerur (DCWB, 1978 No. 0885). El-Wishy et al. (DCWB, 1978 No. 0850) observed that sperm concentration was greater in the first ejaculate than in the second or third ejaculates of Egyptian buffaloes. Since the total spermatozoa in an ejaculate is a function of the ejaculate volume and concentration, the trend observed above applied for total spermatozoa/ejaculate.

Kerur (DCWB, 1978 No. 0885) determined the pH of semen for the breeds studied and found that semen from the buffalo breeds, Jaffi, Surti, and Murrah was slightly higher (6.6, 6.4, and 6.5, respectively) than that of the Gir and Kankrej, 6.4 and 6.2, respectively.

Two of the better estimates for the evaluation of an ejaculate is the percentage of live sperm cells and the percentage of abnormal sperm cells. Kerur (DCWB, 1978 No. 0885) reported that the percentages of live spermatozoa/ejaculate were 80 and 82% for the Gir and Kankrej breeds of cattle and 77, 74, and 76% for the Jaffi, Surti, and Murrah buffalo breeds, respectively. Kodagali et al. (DCWB, 1978 No. 0895) estimated that the percentage of live spermatozoa/ejaculate was 84.2 ± 2.2 for the Surti breed.

The percentage of abnormal spermatozoa was 9.8 ± 1.4 for Surti bulls (Kodagali et al., DCWB, 1978 No. 0895). Reddy et al. (DCWB, 1978 No. 0941) reported 17.0 ± 1.4% abnormal spermatozoa in the semen of Murrah bulls. This author also found that bulls differed ($P<.01$) in the percentage of abnormal spermatozoa. Therefore, the selection against bulls with high sperm abnormalities is possible.

Ganguli (1979) reported several biochemical differences when he compared cattle semen to buffalo semen. The level of several components, fructose, sialic acid, ascorbic acid, citric acid, and plasma proteins were higher in the semen of cattle than buffaloes. While the calcium and phosphorous levels were higher in buffalo semen than in cattle semen, there was a higher level of motility inhibitory factor in the semen of buffaloes than in cattle. The release of acrosomal enzymes such as acrosin and hyaluronidase was higher from frozen buffalo spermatozoa than from frozen cattle spermatozoa. This increased release is indicative of greater cell damage due to freezing and thawing. The level of acrosomal hyaluronidase is 2.5 times as great in cattle spermatozoa compared to buffalo spermatozoa.

Sexual Preparation and Semen Collection

Semen is collected from buffalo bulls by means of an artificial vagina. Cockrill (1976) stated that in China the equipment used for semen collection was adapted for use with water buffaloes. The example given was the shortening of the artificial vagina. The standard artificial vagina used for cattle was associated with reduced conception rates when it was used to collect semen from buffalo bulls. The reduced conception rates could be explained if the bull ejaculates in or near the artificial vagina and not in the collection cone because of the higher temperature inside the artificial vagina. Therefore, shortening of the artificial vagina would force the bull to ejaculate closer to the collection tube.

Badawy et al. (1973) evaluated the effect of sexual preparation on the semen characteristics of both buffalo and cattle bulls. The treatments consisted of no false mounts before collection (control) 1, 2, or 3 false mounts before collection, 10 minutes restraint before collection, and a combination of 3 false mounts and 10 minutes restraint. The volume of the ejaculate, number of motile sperm, and the total spermatozoa output increased with an increase in the number of false mounts for both buffalo and cattle bulls. The greatest increase in ejaculate volume, number of motile sperm, and total spermatozoa output occurred when both buffalo and cattle bulls underwent 3 false mounts and 10 minutes restraint. Since both males respond well to sexual preparation, the incorporation of sexual preparation into the collection schemes of artificial insemination studs will increase the harvest of spermatozoa.

Artificial Insemination

The techniques for the artificial insemination (AI) of buffalo females are the same as the AI techniques used for cattle.

The time of insemination varies widely in the literature. Wagelie et al. (1981) recommended the optimum time of insemination in carabaos was within 19 to 25 hr. after the onset of estrus. However, the time of insemination recommended by the Philippine Council for Agriculture and Resources Research was between 24 and 36 hr. after the onset of estrus (PRCP, 1978). Cockrill (1976) reported that in China the recommended time of insemination was 48 hr. for the native swamp buffaloes and Murrah x native buffalo crosses and 52 hr. for the Murrah buffaloes after the onset of estrus.

The number of services per conception for Nili/Ravi heifers was 1.5 and 2.4 for cows (Chandhary and Ahmed, 1979). The average for all buffalo females was 2.2 services per conception. These values are similar to those reported by McDowell (1972) where the services per conception ranged from 1.4 to 2.1 in Egypt.

Liquid Semen

Abhi and Grewal (DCWB, 1978 No. 0809) compared the effects of extender type and dilution rate on the storage of buffalo spermatozoa. When semen was stored at 4 to 6C° for 3 days, the preservation of spermatozoa was superior when extended in either Cornell University Extender or egg yolk-glycine as compared to egg yolk-citrate extender. The dilution rates of 1:10 and 1:20 (semen:extender) were not significantly different for sperm motility but the motility was significantly lower when semen was extended at the 1:50 ratio. Using citric acid whey extender, sperm motility was maintained at 50% or less for 96 hr. at refrigerator temperatures (Ganguli et al., DCWB, 1978 No. 0858). Rajamahendran et al. (1981) stated that sperm motility was maintained at 50% or better during storage at 4 C for 7, 6, 4, and 1 day for semen extended with Tris, citric acid whey, milk egg yolk, and egg yolk citrate, respectively. According to Gautam et al. (DCWB, 1978 No. 0859) the optimum storage temperature for cattle and buffalo semen was 20 to 25 C for extended semen. However, Rajamahendran et al. (1981) reported that the maintanance of motility was of shorter duration for semen stored at room temperature than for semen stored at the 4 C temperature. Similar results were reported by Ganguli et al. (DCWB, 1978 No. 0858).

Frozen Semen

Buffalo semen has been frozen into pellets on dry ice or in straws or ampules using liquid nitrogen. Saito and de Fierro (1981) compared the post-thaw motility of buffalo semen frozen in straws and ampules. They reported a slightly higher motility (31% vs 29%) percentage for semen frozen in straws than semen frozen in ampules. Pavrithran et al. (DCWB, 1978 No. 0926) reported a loss of approximately 50% motility due to freezing and thawing. El-Kafrawi and Barrada (DCWB, 1978 No. 0845) compared semen from Friesian and buffalo bulls to determine the effects of extender and method of freezing. Wagelie et al. (1981) compared the conception rates for refrigerated and frozen semen. The conception rate of refrigerated semen was 61% vs. 54% for frozen semen. The first trial used semen frozen by the pellet method and compared the post-thaw motility in egg yolk lactose glycerol and egg yolk fructose glycerol extenders for the Friesian and buffalo bulls. Semen extended in egg yolk lactose glycerol extender had higher motility than semen extended in egg yolk fructose glycerol extender for both the Friesian (41.2% vs 25.4%) and buffalo bulls (37% vs 21%). The second trial used semen frozen in straws and extended with either egg yolk, skim milk, glycerol or egg yolk citrate glycerol. The post-thaw motility was higher for semen extended with the egg yolk, skim milk, glycerol extender than in the egg yolk citrate glycerol extender for both the Friesian (52% vs 49%) and the buffalo bulls (46% vs 38%). For both cattle and buffalo bulls, the post-thaw motility was higher when semen was frozen in straws than in pellets. Within each treatment, Friesian semen had higher post-thaw motility than buffalo semen.

Jainudeen and Dass (1980) reported that the interaction between the level of glycerol and the rate of freezing and the interaction between level of glycerol and the thaw rate was significant ($P<.01$) for the percentage of intact acrosomes but not significant for post-thaw motility. The interaction

between freeze rate and thaw rate was significant ($P<.01$) for both intact acrosomes and post-thaw motility.

Varying conception rates have been reported in the literature for frozen buffalo semen. Pei-Chien (1979) reported conception rates of 85% on well managed research farms and of approximately 30% in rural communes. Pavrithran et al. (DCWB, 1978 No. 0926) reported conception rates of 79 to 80% for frozen semen. Lower conception rates were reported by Wagelie et al. (1981) and Shafi and Wierzbowski (1979) (54% and 48 to 50%, respectively).

Work Production

The water buffalo is probably the most adaptable and versatile of all work animals. Even with the advent of mechanized farming the water buffalo still plays an important role in agriculture in much of the tropical world. Water buffaloes provide 20 to 30% of the farm power in South China, Thailand, Indonesia, Malaysia, Philippines, and Indochina (NRC, 1981). Buffaloes are widely used as a source of power to: plow; harrow; plant crops; puddle rice fields; cultivate field crops; thresh grain; press sugar cane; pump water, haul logs, carts, sleds, boats and even snow plows; carry people; and for sport (Cockrill, 1974, and NRC, 1981). For many small farmers, the working buffalo often represents their major investment and greatest amount of capital. The use of tractors usually requires a minimum of four hectares for economical operation, which excludes the use of tractors on many of the farms in these regions (NRC, 1981).

Work Capacity

The anatomical structure of the water buffalo make it well suited as a draft animal. A major advantage is the animal's large forequarters and smaller hindquarters. This distribution of weight over the feet and legs allows for more efficient use of it's body weight for power (Garner, 1957). The large cloven hooves of the buffalo allow it to walk in the soft mud of rice paddies. The pastern and fetlock joints of buffaloes are very flexible and allow the hooves to bend back and step over obstacles more easily than cattle (NRC, 1981). Continued work under wet conditions does not have an adverse effect on the legs and hooves of buffaloes (Garner, 1957).

The capacity for work varies widely with the size, age, and sex of the animal. The system of management, length of the working day, duration of rest intervals and type of equipment also influence the buffalo's capacity for work.

The length of the working day for buffaloes in Thailand ranged from 4.8 to 5.2 hours (Cockrill, 1974). In China, the usual number of hours worked per day ranged from 6 to 10 depending on the region. Animals that were worked for 10 hours were rested at five intervals during the day (Cockrill, 1976). Several estimates of working time, expressed as days or months per year are presented in table 2.

Table 2 . Working Periods of Water Buffaloes

Location	Days/Year		Months/Year	
	Mean	Range	Mean	Range
Thailand[a]	66.1	---	3.3	2-8
	136.9	---	5.6	4-12
	138.3	---	5.3	1-12
	146.1	---	7.9	3-10
China[b]	---	130-140	---	----
Taiwan[b]	---	60-70	---	----
Taiwan[c]	53	20-78	---	----

[a] Cockrill (1974)

[b] Cockrill (1976)

[c] Chantalakhana (1981a)

Due to the poor regulation of body temperature in hot, humid weather, it is necessary to allow the working buffalo to cool off in a wallow or by sprinkling approximately every two hours (NRC, 1981). Without this cooling-off period their body temperature could rise to dangerous levels.

Buffaloes are efficient work animals when speed is not the major consideration. Several authors have reported working speeds ranging from 3.0 to 3.6 km/hr (Cockrill, 1976; Goe and McDowell, 1980; McDowell, 1972; NRC, 1981). Because of the buffaloes slower speeds and inability to withstand dry heat and exposure to the sun, mules, oxen, and horses are preferred in the more arid areas (NRC, 1981).

The normal draft power of various animals is presented in table 3 (Chantalakhana 1975, as cited by PRCP, 1978). In Taiwan, Cockrill (1976) observed that the maximum loading power of an adult buffalo female was 869 kg or 240% of the body weight and the maximum traction power of 370 kg or 113% of the body weight. Goe and McDowell (1980) reported that under normal conditions a working buffalo could develop a tractive effort of 10 to 14% of its weight. The plowing power of water buffaloes ranged from .05 acres/hr in Thailand to .08 acres/hr in Taiwan and China (Chantalakhana, 1981 a). The estimated draft power equivalent values of cattle and buffaloes, in the Philippines, were calculated and are presented in table 4 (PRCP, 1978). A wide variety of carts and drays are used in many countries where buffaloes are used as traction animals. As an example of the buffaloes ability, two intact male buffaloes can haul a 2 ton load over 25 to 32 km per day (Cockrill, 1974). When buffaloes are working on rough land or on paved or asphalt roads, their hooves require protection. Protection can come in several ways. Shoes which are tied on to the foot are made out of old automobile tires or tightly woven straw pads (Goe and McDowell 1980; Cockrill, 1974) or cold shod with metal plates, one on each claw (Cockrill 1974; Goe and McDowell, 1980; NRC, 1981).

Water buffaloes are generally trained at 3 or 4 years of age, however, training may begin as early as 2 years or as late as 8 years (Goe and McDowell, 1980). Once an animal is trained, the average working lifespan is between 10 and 20 years (Cockrill, 1974; NRC, 1981). Cockrill (1974) observed two buffaloes that continued to work at the age of 40 years. He also stated that it was not uncommon to find buffaloes 25 to 30 years old still capable of doing a good days work. Male buffaloes are generally preferred for work because of their larger size (Chantalakhana, 1981 a). However, female buffaloes are used and according to McDowell (1972) there is no adverse effect on milk yield if females are not worked over 3.0 to 3.5 hours per day.

Draft buffaloes require proper nutrition to work up to their potential. In the Philippines, it is recommended that animals be supplemented with concentrates at a rate of 1 to 2% of their body weight. Also, a mineral mixture should be given at a rate of 1 to 1.5% of the concentrate mixture. The concentrate and mineral mixture are in addition to the fresh forage and crop residues provided by the farmer (PRCP, 1978).

Table 3. Normal Draft Power of Various Animals

Animal	Average Weight (kg)	Approx. Draft (kg)	Average Speed at Work (meter/sec)	Power Developed (kg/sec)	Power Developed Horse Power
Light Horse	400-700	60-80	1.0	75	1.00
Cattle, Steer	500-900	60-80	0.6-0.85	56	0.75
Buffalo	400-900	50-80	0.8-0.9	55	0.75
Cattle, Female	400-600	50-60	0.7	35	0.45
Mule	350-500	50-60	0.9-1.0	52	0.70
Donkey	200-300	30-40	0.7	25	0.35

PRCP (1978).

Table 4. Estimated Draft Power Equivalent Values of Cattle and Buffaloes

Type of Animal	Age (yr)	Sex	Male Buffalo Power Equivalents[a]
Buffaloes	4-6	Female	0.43
	4-6	Male	0.50
	7-15	Female	0.71
	7-15	Male	1.00
Native Cattle	4-11	Female	0.39
	4-11	Male	0.58
Crossbred Cattle	4-11	Female	0.50
	4-11	Male	0.74

[a] Power equivalents are assumed to be directly proportional to the body weight, except for buffaloes 4-6 yrs. old which have been adjusted slightly downward to account for their inexperience.

PRCP (1978).

Harness Usage

The only study conducted on the use and improvement of harnesses for working buffaloes was done in 1957 by Garner. The yoke used on working buffalo in Asia is made of wood or bamboo. This yoke has undergone little change in the last 1500 years (NRC, 1981). There are two major disadvantages to the design of this tradition yoke: 1) the design of the yolk causes a rope to pull tight against the animal's neck, when pulling a load and thereby restricts the flow of air resulting in a rapid onset of fatigue, 2) the yoke contacts a very small area of the animal's neck and shoulders causing discomfort and pain when the buffalo is pulling a load. These two disadvantages reduce the animal's potential for work. Garner (1957) designed and tested two new harnesses for water buffaloes, the collar and the breast strap, against the traditional yoke. When the yoke was used as a base value, he observed a 25% increase in plowing and harrowing ability for buffalo which used the collar or the breast strap. The increased production was due to longer work periods with fewer rest breaks; less restriction of air exchange; and the improvement of the animal's overall appearance.

Maximum load tests and endurance tests were done using all three types of harness and the results are presented in table 5 (Garner, 1957). The collar harness showed a 24% increase in maximum load tests over the traditional yoke harness. The total time required to pull a 550 lb stone boat was 41.3% faster when the breast strap was used as compared to the traditional yoke harness.

Using the yoke harness, buffalo developed 0.52 units of horse power (table 5). The horse power developed when the collar was used was 0.77 and 0.88 units when the breast strap was used. The collar harness accounted for a 48% increase in horse power over the yoke and the breast strap increased horse power 69.5% over the yoke (Garner, 1957).

Meat Production

In most countries where water buffaloes are produced, the meat has generally been considered as a by-product to their usefulness for draft or milk production except in Egypt, the Middle East and Southern Europe. Most buffalo meat was, and still is, derived from old animals slaughtered at the end of their productive life. The water buffalo offers promise as a source of meat and the production of these animals solely for meat is now expanding.

Growth and Development

Insufficient data have been reported in the literature to obtain definitive statements about the genetic growth potentials of various types of water buffaloes. However, many observations have been made under various nutritional and management conditions concerning the growth of buffaloes.

Table 5. Maximum Load and Endurance Tests for Three Types of Water Buffalo Harness

Test	Harness Type		
	Yoke	Collar	Breast Strap
Maximum load test			
Maximum load moved (lb)	1250	1550	1405
Net increase (%)	0	24	12.3
Endurance test[a]			
Time required (min)	31.5	21	18.5
Time required (%)	0	33.3	41.3
Horsepower test			
Horsepower developed	0.52	0.77	0.88
Net increase (%)	0	48	69.5

[a] A course of 550 yd pulling a stone boat of 750 pounds. (Garner, 1957)

The mature weights of the river type buffaloes are generally higher than those of the swamp buffaloes with the possible exception of the buffaloes in Thailand. Cockrill (1976) reported that Chinese buffaloes averaged 330 kg vs. the >600 kg weight of Thai buffaloes. In the review by Chantalakhana (1979), he estimated that the mature weight of swamp buffalo ranged from 350 to 650 kg. Chaudhary and Ahmed (1979) stated that the Nili/Ravi buffaloes ranged from 500 to 800 kg for mature live weight. When water buffaloes were compared to local cattle, the mature weight of buffaloes was generally higher. The average weight of 30 female buffaloes in New Guinea was 375 kg vs. 320 kg for the Brahman x Shorthorn females of the same age. Similar results were reported in Venezuela where 100 buffalo steers averaged 508 kg at 30 months of age as compared to 320 kg for Zebu steers of the same age (NRC, 1981). In Australia, buffalo steers grew as fast or faster than Brahman crossbred steers on improved pastures and had higher mature weights. However, on one very poor pasture, the mature buffaloes weighed 400 kg while the Brahman crossbred steers on the same pasture weighed 500 kg. Chantalakhana (1979) reported weaning weights ranging from 66.3 kg to 125.3 kg for swamp buffalo calves.

The average daily gain (ADG) values reported for water buffaloes varies widely due to environmental and nutritional differences as well as differences in animal age (table 6). The 12 month overall ADG for the 10 best male and female buffalo calves were 0.81 kg (range, 0.63 to 1.06 kg) and 0.66 (range, 0.50 to 0.77), respectively, (Pakistan Rep. 1974). Thamotharam (1981) reported an ADG of approximately 0.34 kg for buffalo calves in Sri Lanka. A similar range (0.28 to 0.43 kg) was observed by Camcens (1976) for buffaloes in Malaysia. Ragab (1979) observed that the ADG from birth to 50 days of age, 50 days of age to 6 months, 6 months to 12 months, 12 months to 18 months, and 18 months to 24 months were: 0.67, 0.64, 0.40, 0.72, and 0.50, respectively. Cockrill (1974) cited research that found ADG of fattening buffaloes ranged from .93 to 1.14 kg with a high value of 1.54 kg ADG. It appears that individual variations are wide enough to allow for selection of animals for rapid daily gain.

Several reports have compared the average daily gains of buffaloes and cattle. When buffaloes were compared to a native breed of cattle (Cockrill, 1974) the ADG for buffalo steers was 1.12 kg and 0.68 kg for the beef bulls on a fattening ration. Ichhponani et al. (1977) and NRC (1981) reported that the ADG of buffaloes was the same or higher than that observed for native cattle in those studies. The effect of pasture quality on ADG of buffaloes, Jamaica Red, and Brahman cattle was reported (Cockrill, 1974). All animals were grouped together for 10 weeks on poor pastures and then 10 weeks on moderate (abundant but inferior) pastures. The ADG on poor pastures was 0.21 kg for the buffaloes compared to 0 for either group of cattle. When all animals were transferred to the moderate pasture, the ADG was 0.62, 0.43, and 0.30 for the buffaloes, Jamaica Red, and Brahman cattle, respectively. According to Tillman (1981), when a high concentrate ration was fed to Bali, Madura, Grati, Ongole cattle, and swamp buffalo bulls, Moran found that Grati cattle had the highest ADG (0.90 kg); followed by Ongole cattle and swamp buffalo (0.75 and 0.73 kg, respectively). The Bali and Madura cattle were the slowest growing with 0.66 and 0.60 kg ADG, respectively (table 6).

Table 6. Average Daily Gain (kg) Values for Buffaloes and Cattle

Reference	Buffalo		Cattle	
	Mean	Range	Mean	Range
Pakistan Rep. (1974)	0.81 (male)	0.63-1.06	--	--
	0.66 (female)	0.50-0.77	--	--
Thamotharam (1981)	0.34	--	--	--
Camoens (1976)	--	0.28-0.43	--	--
Ragab (1979)	--	0.40-0.72	--	--
NRC (1981)	0.80	--	--	--
Cockrill (1974)	--	0.93-1.14	--	--
	1.02	--	--	--
	0.95	--	--	--
NRC (1981)	0.50	--	0.28	--
Ichhponani et al. (1977)	0.70	--	0.49	--
Cockrill (1974)	1.12	--	0.68	--
	0.21	--	0.0	--
	0.62	--	0.48	--
	0.62	--	0.30	--
Moran	0.73	--	0.90	--
(see Tillman, 1981)	0.73	--	0.75	--
	0.73	--	0.66	--
	0.73	--	0.60	--

Selected reports of comparative growth studies with buffaloes and cattle fed different types of rations in different countries are shown in table 7. River type buffaloes in Pakistan gained 0.8 to 1.0 kg per day on a ration of 28% wheat straw plus 72% of a concentrate mixture, and 0.73 to 1.2 kg/day on 45% wheat straw, 55% concentrate. In Italy buffaloes gained 0.7 to 0.9 kg daily on alfalfa hay plus a concentrate. On a high concentrate ration, 18 month old buffaloes in U.S.S.R. gained 1.0 kg per day. Swamp buffaloes in Australia gained 0.53 to 0.56 kg per day on alfalfa hay alone compared to 0.6 to 0.93 kg daily on alfalfa hay plus concentrates from 25 to 80% of the total ration. In Bulgaria, cattle gained 0.87 kg per day vs. 0.71 kg per day for buffalo on good quality meadow hay as the only feed. Swamp buffaloes gained slightly less rapidly than improved cattle on a ration of 15% roughage and 85% concentrate in Australian tests. Murrah buffaloes performed a little better than Hariana cattle when fed wheat straw and a concentrate in Indian studies.

A review of buffalo feed conversion values is presented in table 8. Cockrill (1974) reported feed conversion values of 7.24 and 7.77 kg of feed per kg of weight gain for the Bulgarians and Murrah buffaloes, respectively. When the Murrah x Bulgarian F_1 crosses were evaluated their feed conversion value was 7.25 kg for the 130-day feeding period. The feed conversion values for water buffaloes were 8.22, 7.5, and 12.8 kg for animals from 6 to 12 months, 12 to 18 months, and 18 to 24 months, respectively (Ragab, 1979).

When the feed conversion values were compared between buffaloes and cattle, the buffaloes needed less feed per unit of gain than did the native cattle, 1.70 kg vs. 3.12 kg, respectively (Ichhponani et al., 1977). In the report by Moran (as cited by Tillman, 1981) buffaloes had a feed conversion of 7.95 kg of feed per kg of gain vs. 8.56, 8.85, 9.12, and 9.22 kg for the Ongole, Grati, Bali, and Madura cattle breeds (table 9). In contrast to these results, El Naggar et al. (1972) found that buffaloes had a higher feed conversion than did either the 3/4 native cattle or the 3/4 Friesian cattle.

Carcass Characteristics

A review of buffalo dressing percentage is presented in table 10. In Australia, buffaloes had a 53% dressing percent while cattle had a 53 to 56% dressing percentage. In Brazil, the difference in dressing percent was approximately 1%, 55.5 vs. 56.6% for mediterranean-type buffaloes and Zebu cattle, respectively (NRC, 1981). Cockrill (1974) reported a 48.4% dressing percent for buffaloes and 51.2% dressing percent for cattle. The dressing percentage of Brahman crossbreds and Thailand buffaloes averaged 52.7% and 43.5%, respectively (Intaramongkul et al.,1979). Moran (cited by Tillman, 1981) reported that dressing percent of the buffaloes was 51.8% as compared to the five cattle breeds which ranged from 56.6 to 63.2% (table 9). The buffaloes were approximately 6 to 12% below the cattle breeds for dressing percentage. Knapp (1957) reported that Italian buffaloes had dressing percentages of 49% at 1.5 years of age and 48% as mature females. Camoens

Table 7. Growth Studies with Buffaloes and Cattle

Ration	Daily gain kg	Country	Reference
Wheat straw 28%, conc.	0.8 - 1.0	Pakistan	Akram et al., 1962
Wheat straw 35%, conc.	0.98 - 1.3	Pakistan	
Wheat straw 45%, conc.	0.73 - 1.2	Pakistan	
Wheat straw 46%, conc.	0.73 - 0.95	Pakistan	Athar et al., 1966
Alfalfa hay, conc.	0.7 - 0.9	Italy	Proto & Landi, 1966
Barley,conc.	1.0	U.S.S.R.	Mamedov, 1963
Alfalfa hay only	0.53 - 0.56	Australia	Charles & Johnson, 1975
Alfalfa hay 20% conc. 80%	0.60 - 0.93	Australia	
Alfalfa hay 75% conc. 25%	0.54 - 0.69	Australia	
Alfalfa hay 25% conc. 75%	0.60 - 0.81	Australia	
Roughage 15%, conc. 85			
Angus	0.70 - 0.75	Australia	Johnson et al., 1969
Friesian	0.61 - 0.99	Australia	
Hereford	1.05 - 1.10	Australia	
Swamp Buffaloes	0.67	Australia	
Wheat straw, conc.			
Murrah Buffalo	0.49 - 0.53	India	Ichhponani & Sidhu, 1965
Hariana Cattle	0.43 - 0.50	India	
Meadow hay			
Buffalo	0.71	Bulgaria	Kadiiski & Zaharier, 1956
Cattle	0.87	Bulgaria	

Table 8. Feed Conversion Values (kg/kg gain) for Buffaloes and Cattle

Reference	Buffalo		Cattle	
	Mean	Range	Mean	Range
Cockrill (1974)	7.24	--	--	--
	7.77	--	--	--
Ragab (1979)	--	7.5-12.8	--	--
Ichhponani et al. (1979) [a]	1.70	--	3.12	--
Moran	7.95	--	9.22	--
(see Tillman, 1981)	7.95	--	9.12	--
	7.95	--	8.85	--
	7.95	--	8.56	--

[a] Sum of digestible protein, carbohydrates, and fat.

Table 9. Production Performance of Breeds of Indigenous Cattle Fed a High Concentrate Diet

Item	Breed of Cattle				
	Madura	Ongole	Bali	Grati	Buffalo
Average daily gain, kg	0.60	0.75	0.66	0.90	0.73
Dry matter intake,					
kg/day	5.33	6.42	6.02	7.97	5.80
g/kg 0.75/day	72.6	72.3	76.8	84.9	76.6
Feed conversion					
kg feed/kg gain	9.22	8.56	9.12	8.85	7.95
Organic matter					
digestibility, %	70.6	72.6	68.6	73.7	68.3
Dressing percentage	63.2	57.9	56.6	57.3	51.8
Rib eye area, cm^2	63.4	54.5	63.7	61.0	46.2
Muscle:bone ratio	5.34	4.23	4.44	3.89	3.34
Relative rates of					
fat deposition	0.49	0.34	0.52	0.33	0.57

Source: Moran, see Tillman, 1981.

(1976) observed 65% of buffaloes slaughtered had an average dressing percentage of 47.1% (range 21.7 to 59.0%). His data follow:

Age (yr)	Live Weight (kg)	Dressing Percent (%)
2-3	145-387	43.9-52.7
3-5	253-505	44.3-56.2
>5	252-525	43.9-59.0

In each age group the heavier animals had higher dressing percentages. Cockrill (1976) found the average dressing percent to be approximately 45% in China. He also reported differences in the dressing percentage for different types. The Wuchü type had a dressing percent ranging from 38 to 40% while the Tangyang type varied from 30% for old animals to nearly 50% for young animals. Chantalakhana (1979) reported a range of 42 to 49% for the dressing percent of water buffaloes. McDowell (1972) reported that for Egyptian buffaloes the dressing percentage ranged from 57.2 to 59.9% for calves up to 6 months of age (table 11). The dressing percentages for bulls were 53.7 and 52.7 and steers 53.3 and 54.3 at 12 and 24 months of age, respectively. Similar results were observed by Ragab (1979) for buffaloes of similar age. Slightly lower dressing percentages were reported by Liang et al. (1980) for bulls 18, 24, and 30 months of age.

The main reason that buffaloes have lower dressing percentages than cattle of similar age and nutritional status is because buffaloes have heavier hides, heads, and digestive contents. Australian studies (Cockrill, 1974, p. 391) showed that the hide was 11.6% of live weight compared to 8.7% for cattle and the heads of buffaloes were 5.8% of live weight vs. 4.9% for cattle. In unpublished tests in Florida, the digestive tract and its contents amounted to 16.6% of the live weight of buffalo vs. 12.3% of cattle. The animals had been fed in a feedlot on the same feed for several months before slaughter.

Data from Venezuela (Jusepin, 1981 personal communication) show that mature buffaloes weighing 559 to 636 kg at slaughter had dressing percentages of 45.9 to 53.5% depending on body condition, and averaged 50.6%.

Carcass Composition

McDowell (1972) presented data on the meat, bone, and fat content of Egyptian buffaloes. Selected data are shown in table 11. Young animals have a lower percentage of fat and more bone than more mature animals. Cockrill (1974) summarized more of the information on the composition of buffalo carcasses. Data from Southern Europe and Australia are shown in table 12. Carcasses of buffaloes vary considerably in the amounts of meat, fat, and bone depending upon age and nutritional status. Mature buffaloes appear to have less fat than cattle, but the difference may not be very

Table 10. Dressing Percentages for Buffaloes and Cattle

Reference	Buffalo		Cattle	
	Mean	Range	Mean	Range
Camoens (1976)	47.1	21.7-59	--	--
Cockrill (1976)	45.0	--	--	--
	--	38-40	--	--
	--	30-50	--	--
Chantalakhana (1979)	--	42-49	--	--
McDowell (1972)	--	57.2-59.9	--	--
	--	52.7-57.6	--	--
	--	53.3-54.4	--	--
NRC (1981)	53	--	--	53-56
	55.5	--	56.5	--
Cockrill (1974)	48.4	--	51.2	--
Intaramongkul et al. (1980)	43.5	--	52.7	--
Moran (1979; see Tillman, 1981)	51.8	--	58.8	56.6-63.2
		--		--

Table 11. Dressing Percentage and Carcasses Composition of Buffalo.

Aniaml	Age	Dressing Percent	Carcass Composition		
			Lean	Fat	Bone
	(mo)		(%)	(%)	(%)
Calves	1.5	59.9	59.4	8.2	32.4
	6	57.2	65.8	6.6	27.6
Bulls	12	53.7	66.4	12.3	21.3
	24	52.7	65.6	12.9	21.5
Steers	12	53.3	64.8	15.7	19.5
	24	54.3	63.5	16.8	19.7

Source: McDowell (1972).

great if they were fed under similar conditions and at the same stage of maturity. In Egypt the buffaloes were stall fed from birth until slaughter. The Bulgarian buffaloes had been fattened for four months before slaughter, while the Australian animals were taken direct from pasture. Camoens(1976) reported carcass studies of swamp buffaloes in Malaysia. The amount of bone in their carcasses varied from 23.8 to 41.8%. Heavier carcasses in each of the age groups included had relatively less bone to edible meat and age alone had little influence on the percentage of bone. However, no animals under two years of age were tested.

The average rib-eye area of Thai buffaloes ranged from 33 to 43 sq cm (Chantalakhana, 1970). Cockrill (1974) reported rib-eye areas of 64.3 and 60.6 sq cm for Bulgarian and Murrah buffalo bulls. Moran (cited by Tillman, 1981) found the rib-eye area of Indonesian buffaloes was 46.2 sq cm, which was lower than the values for the five breeds of cattle (table 9). A significantly lower rib-eye area of 40.7 sq cm was reported for carabao than for cattle (50.9 sq cm) by Calub et al. (DCWB, 1978 No. 413). Generally, the buffalo carcass has a higher proportion of muscle and bone and a lower proportion of fat than beef carcasses. Australian research has shown that buffaloes seldom have more than 25% fat. whereas average choice-grade beef carcasses can have 35% fat (NRC, 1981). Camoens (1976) reported that muscle accounts for approximately 70% of the carcass while bone accounts for approximately 25% of the carcass. This author stated that for 94% of the animals measured, the meat accounted for 61 to 75% of the carcass. Liang et al. (1980) reported average meat:bone ratios of 3.2, 3.7, and 3.5 for buffaloes slaughtered at 18, 24, and 30 months of age, respectively. Moran (cited by Tillman, 1981) reported a similar meat:bone ratio of 3.34 for buffaloes. The four cattle breeds had higher meat:bone ratios than did the buffaloes (table 9).

Meat Quality and Palatability

In the Philippines and most Asian countries, buffaloes are slaughtered for beef when they are too old to be useful for work or reproduction. Meat from old animals is stringy and tough. Meat from young animals that have been adequately fed is similar to beef from cattle in quality and flavor. The composition of beef and carabeef (water buffalo meat) are similar as shown in table 13. Buffalo fat is always white and the meat is darker in color than beef due to greater pigmentation or less intramuscular fat. Buffalo meat contains only 2 to 3% of intramuscular fat as compared to 3 to 4% in cattle beef (NRC, 1981). DCWB, (1978 No. 0406, 0407) reported that carabeef had higher protein, cholesterol, total pigmentation, and myoglobin than cattle meat but was less tender and juicy. Calub et al. (DCWB, 1978 No. 0413) observed that carabeef was slightly superior to beef in juiciness but beef was superior in tenderness and flavor, according to an untrained taste panel. In a study conducted at the University of Florida, a water buffalo and a Charolais bull were fed a concentrate ration, slaughtered and the meat evaluated. One half of each carcass was subjected to electrical stimulation. Loin steaks from the non-stimulated buffalo carcass, when evaluated by a trained panel, were rated approximately the same as the Charolais steaks in tenderness. However, steaks from the electrically stimulated buffalo carcass

Table 12. Carcass Composition of Buffaloes and Cattle

	Live Weight	Carcass Weight	Composition		
			Lean	Fat	Bone
	kg	kg	%	%	%
Bulgarian Buffaloes	362.2	194.6	71.9	9.9	16.8
Australian Animals Buffaloes		129.4	71.3	4.9	19.6
Cattle		180.9	68.5	8.1	20.7

Table 13. Composition of Beef and Carabeef

Item	Beef	Carabeef
Moisture (%)	76.62	76.63
Protein (%)	19.93	19.39
Ash (%)	1.10	1.08
Ether Extract	1.07	0.84

PRCP (1978).

was considerably more tender than the Charolais carcass. Steaks from the buffalo were more tender, as determined by the Warner-Bratzler shear values, in both the stimulated and non-stimulated sides than were steaks from the Charolais bull. When lean trimmings from both carcasses were processed into wieners no detectable difference was found between the two sources of trimmings (unpublished).

When a 28 member trained taste panel compared steaks from a Trinadad buffalo, a Jamaica-Red/Sahiwal steer, and European beef steer, 14 judges rated buffalo highest; 7 rated the European steer highest; and 5 rated the crossbred steer the highest. Two judges stated that the buffalo and crossbred were equal and superior to the European steer. The buffalo received the highest rating for color of fat and lean, taste and general acceptability (NRC, 1981). McDowell (1972) reported that in Italy, Bulgaria, and Yugoslavia, buffalo meat is good and cannot be distinguished from beef. Buffalo steaks have rated higher than beef in some taste tests in Australia, Malaysia, Venezuela, and Trinadad (NRC, 1981). Hoefer and Tsuchitani (1980) stated that in China the dressing percent for buffaloes was approximately 48% and that the meat was tough and stringy. However, they also stated that the majority of the buffaloes slaughtered were aged which could account for the quality being poor.

Milk Production

More than 5% of the world's milk supply comes from water buffaloes (NRC, 1981). Buffaloes are the main milk producers in India, China, Pakistan, Nepal, Philippines, and Thailand, and important milk sources in Egypt, Turkey, Italy, and several other countries. The estimated world production of buffalo milk is shown in table 14.

In India, where half of the world's buffaloes are found, they are increasing more rapidly than cattle numbers. From 1961 to 1972, the cattle population increased 1.9% compared to buffaloes increased 13.1% (Ichhponani et al., 1977). The 26.6 million milk buffaloes contributed more milk than 48.6 million milk cows. The average annual milk yield of the buffalo in India is 491 kg compared to 172 kg for cows. The higher total solids and fat of buffalo milk magnifies this difference even further. In Pakistan, approximately 70% of that country's milk is produced by buffaloes even though the population of cattle is approximately 30% higher than for buffaloes (Mahadevan, 1977). In Egypt, the populations of cattle and buffaloes are approximately equal, yet 65% of the milk is produced by buffaloes.

Milk Yield

The Murrah breed has been studied extensively for milk yield. Various average lactation yields have been reported for the Murrah breed: 1388 to 1855 kg (Bhat, 1979); 1980 to 2355 kg in a 300 day period (Cockrill, 1976); 1800 kg (NRC, 1981); and 2052 kg (McDowell, 1972). The Nili/Ravi buffalo from Pakistan is also of the dairy type. The reported average lactation

Table 14. WORLD PRODUCTION OF BUFFALO MILK (1980)
(1,000 metric tons)

Location	Production	Location	Production
Asia		Syria	1
Bangladesh	44	Turkey	289
Burma	53	Viet Nam	48
China	1390	others	18
India	17000	Africa	
Iran	39	Egypt	1267
Iraq	31	Europe	
Nepal	480	Bulgaria	33
Pakistan	6383	Greece	1
Philippines	18	Italy	62
Sri Lanka	53	WORLD TOTAL	27209

Source: FAO Monthly Bull. Stat. May 1981.

yields for the Nili/Ravi were: 1858 kg (McDowell, 1972); 1925 kg (NRC, 1981); 2000 to 2700 (Chaudhary and Ahmed, 1979); and 2300 kg (Pakistan Rep., 1974). Bhat (1979) reported an average lactation yield of 1772 kg for the Surti and 1111 kg for the Bhadwari breeds of buffaloes. The Kundi breed of Pakistan averages 1350 to 2000 kg of milk per lactation (Chaudhary and Ahmed, 1979). McDowell (1972) reported that Egyptian village buffaloes averaged 800 kg of milk while buffaloes on government farms averaged 1700 kg of milk. A similar milk yield of 1639.4 kg was reported by Mathur and Roychoudhury (DCWB, 1978 No. 0233) for Italian buffaloes. The native buffalo of China had a 751 kg average milk yield. However, when the native buffalo were crossed on Murrah buffalo, the crossbred females had a 1658 kg average milk yield (Cockrill, 1976). The Carabao of the Philippines had the smallest reported milk yields; 528 kg in a 240-day period (P.R.C.P., 1978) and values ranging from 100 to 400 kg (McDowell, 1972). There is considerable variation in milk yield both within a breed and across breeds. The large variation in yields within a breed suggest that there is ample genetic variability for selection for higher milk production.

The milk yield of buffaloes is generally higher (680-800 kg) than the milk yield for local cattle (360-500 kg) (NRC, 1981). Raut and Singh (DCWB, 1978 No. 0302) reported 1710 kg for Murrah buffalo as compared to 784 kg for Haryana cattle. In contrast to the preceeding reports, Fahmy et al. (DCWB, 1978 No. 0127) reported that Friesian cows had an average milk yield of 2718 kg compared to 1745 kg for buffalo cows in Egypt.

As with cattle, the higher the milk production during the first lactation the higher the lifetime production (Mathur and Raychoudhury, DCWB, 1978 No. 0233; Fahmy et al., DCWB, 1978 No. 0126). Fahmy et al. (DCWB, 1978 No. 0126) and de Franciscis (1979), found buffalo cows produced approximately the same milk yield per lactation during 6 to 10 years of age, the third to the sixth lactations.

In a review, Ragab (1979) cited papers showing that age of the dam affected the total milk yield, and others showing the lack of an age effect.

The effect of season on milk yield is uncertain. Ragab (1978) and Raizada et al., (DCWB, 1979 No. 0296) found no significant effect on milk yield due to season. Dash and Basu (DCWB, 1978 No. 0091) reported that there was a diurnal effect on daily milk production with the morning milk yields being higher than the evening yields taken at 12-hour intervals. Other factors reported to effect the milk yield were: year and farm (Ragab, 1979), lactation length, and calving interval (Bhat, 1979), time of suckling (Liang et al., 1980).

Composition of Milk

Many studies have been made of the composition of milk from various types of buffaloes and cattle. PRCP (1978) reported a summary of data on the Carabao (swamp water buffalo). The values are shown in table 15. Fat is the most variable constituent of milk. For swamp buffaloes the fat in milk varies from about 7 to 12% with a mean value of 9.6%. The river type

buffalo is generally about 2 percentage units lower in fat content than the swamp type. Breeds of cattle vary from about 3% to over 6% in milk fat. Other constituents are less variable. The fat content of buffalo's milk is generally higher than that of cow's milk. Ishaq and Shah (DCWB, 1978 No. 0170) compared Nili/Ravi buffaloes and Sahiwal cattle. The percent fat for the buffaloes was 6.7% vs. 4.3% for the Sahiwal cows. In the Philippines, Carabao milk contained 9.6% fat compared to 3.8% fat in cows milk (PRCP, 1978). Alim (DCWB, 1978 No. 0040) found 8.9% of milk fat for buffaloes as compared to 4.3% fat for native cattle milk. Due to the higher fat content of buffalo milk, its energy value is higher than that of cows milk. Shah et al. (1982) reported that the fat percentage in Nili/Ravi buffalo milk was significantly ($P<.01$) effected by year but not by season, age, parity, or milk yield. The year effect was due to differences in the level of nutrition.

Alim (DCWB, 1978 No. 0040) observed that buffalo milk was higher in solids-not-fat (SNF) than milk from the native cattle (10.2% vs. 8.6%, respectively). In a study conducted by Ishaq and Shah (DCWB, 1978 No. 0170), the SNF value for the Nili/Ravi buffaloes was 9.1% vs. 4.3% for the Sahiwal cattle. The protein values for buffalo milk is higher than for cows milk (McDowell, 1972; NRC, 1981; P.R.C.P., 1978).

The vitamin A content of buffalo milk is at least as high as that found in cow's milk with similar feeds. The two milks are similar in the B complex vitamins and vitamin C, however, buffalo milk is lower in riboflavin than cow's milk (NRC, 1981). The mineral content of milk is generally the same for both cattle and buffaloes, except for the phosphorus content which is higher in buffalo milk. Buffalo milk and butter is white rather than yellow because carotenoids are not present (Balcita, et al., 1954).

Most of the data on the productivity of buffaloes show that they grow slowly, reach sexual maturity late, and calve the first time at 3 to 4 years of age. The reproductive rate is not more than 50% and calving intervals vary from about 500 to 700 days. Milk yields are usually very low, especially for swamp buffaloes, 300 to 800 kg in a lactation. Because of slow growth rates, surplus animals are not slaughtered for meat until they are three years of age or older and most of the meat supply comes from old worn-out animals. Death losses of calves are often high, up to 50% before they are six months of age. There are a few exceptions. Some animals with improved conditions perform almost as well as improved well managed cattle. What are the main factors that cause the low productivity of buffaloes?

In an attempt to identify the key factors the available information has been reviewed on a) heat tolerance and climatic stress, b) diseases and parasites, c) genetic improvement, d) feeding and nutrition, and e) care and management.

Table 15. Mean Composition of Milk of Buffaloes and Cattle

Animal	Moisture	Protein	Lactose	Fat	Ash	Ref
Carabao	78.8	5.3	5.3	9.6	0.95	PRCP, 1978
Murrah	81.2	5.7	4.	7.3	0.81	PRCP, 1978
Friesian	87.2	3.4	4.8	3.8	0.75	PRCP, 1978
Native Cattle	86.6	3.2	4.6	5.0	--	NRC, 1981

Heat Tolerance and Climatic Adaptability

While only a limited number of papers have been published on the heat tolerance of buffaloes it has been known since earliest times that buffaloes refuse to continue working when they become overheated in the midday tropical sun. Spraying them with water or letting them rest in the shade or in a wallow or stream quickly corrects the problem. This helps to explain the work habits of rice farmers in the tropics who begin field work at the dawn of morning light and have a 4 to 6 hour midday break before starting to work again in the late afternoon. To avoid extended physical work in the midday heat of the tropical sun is good advice for man and animal alike. In India, Zebu cattle are used in preference to buffaloes for farm cultivation, except in rice paddies, and for hauling products on the highways. Bos Indicus cattle are more heat tolerant than bufflaoes, especially in dry areas.

Harvey (see Cockrill, 1974) compared the physiology of thermoregulation between buffaloes and cattle. He concluded that the buffalo is more sensitive than cattle to exposure to heat and that they are less adaptable to long exposure to direct sunlight. Ranjahan and Pathak (1979) presented a brief summary to show that the climatic environment has an effect on reproduction and nutrition similar to the effect on cattle, but even more extreme in some instances.

Hentges et al.(1978) found that, in Florida, buffaloes exposed to the sun in the summer exhibited larger and more rapid increases in skin and body (rectal) temperature than Angus cattle. When they are sprinkled with water, these measures returned to normal faster in buffaloes than in the cattle. When resting in the shade, buffaloes had lower body temperatures and respiration rates than Angus cattle. From Hentges' observations, it appears that buffaloes generally showed less heat stress under normal grazing in the summer in Florida than Angus cattle and they suffered less from the cold winter nights than Brahman cattle. In Southern Europe, buffaloes appear to adapt well to the winter climate, but they are protected during the most severe storms.

Buffaloes are uniquely adapted to the humid tropics. Ranawana et al. (1982) found that buffaloes had a higher water turnover than either Sahiwal or Holstein cattle. The Holsteins were unable to prevent body temperature rise in spite of heavy respiratory cooling and could not lower skin temperature by evaporative cooling (sweating). Their water turnover increased at higher temperatures causing dehydration and weight loss, while Bos indicus cattle gained weight. The buffaloes were between the Sahiwals and the Holsteins in ability to maintain skin temperature under heat stress with minimum increase in respiration rate. Other research by these workers in Sri Lanka showed that water turnover increased 25% in buffaloes not allowed to wallow. Water turnover was greater of Murrah buffaloes than in Bos indicus cattle but there was no difference in water content of the body.

The NRC (1981a) summarized the effects of heat stress on the nutrient requirements of domestic animals. Apparently no research has been done with buffaloes.

Diseases and Parasites

The most common infectious and parasitic diseases of water buffaloes are presented in tabular form by P.R.C.P. (1978). These tables also contain the causes, mode of transmission, symptoms, and prevention/control data available. Cockrill (1974) presented an extensive discussion of the diseases and parasites of water buffaloes.

Major Diseases

Mapa (DCWB, 1978 No. 1282 and P.R.C.P., 1978) stated that the important diseases of buffaloes in the Philippines were antrax, blackleg, hemorrhagic septicemia, tetanus, foot and mouth disease, brucellosis, leptospirosis, and pneumonia. In areas of the world that have dairy buffaloes, mastitis also appears to be an important and costly disease.

Bain (1963) reported that the overall death loss of buffaloes to hemorrhagic septicemia is slight compared to the total population. However, in certain areas where hemorrhagic septicemia outbreaks occur, the death losses can be quite high. Generally, losses vary from 1 to 10% but can be as high as 70%.

Brucellosis in cattle vs. buffaloes was found to be 2.8 vs. 3.9%, respectively (Kapur and Grewal, DCWB, 1978 No. 1260). Mamatelashvili (DCWB, 1978 No. 1278) reported that 10 to 64% of abortions in buffaloes were caused by brucellosis. Beyond the advantages of brucellosis control of buffaloes, the control of this disease is a prerequisite for the control of brucellosis (undulent fever) in the human population.

Leptospirosis causes an economic loss through abortion, emaciation, and death to water buffaloes. This infestation is also transmissible to humans in contact with carriers of this disease (Cockrill, 1974).

In areas where milk production is of economic importance, mastitis can reduce the production. Cady et al. (1982) reported that in animals that had mastitis the overall milk production was decreased by 430 kg and the lactation period was shortened by 57 days per lactation. The incidence of mastitis in buffaloes was lower than in cattle. Afifi and Barrada (DCWB, 1978 No. 1167) reported that the percentage of infected Friesian cattle ranged from 0 to 28% while the buffaloes ranged from 0 to 20%. Tsonev et al. (DCWB, 1978 No. 1385) found that the incidence of subclinical mastitis was 0.5% for buffalo cows while mastitis ranged from 12 to 28% for the cattle breeds.

Major Parasites

In the Philippines, the most common endoparasites affecting water buffaloes are liver flukes, gastrointestinal parasites, brucellosis, leptaspirosis, sarcosporidiosis, and surra (Mapa, DCWB, 1978 No. 1282). Other ectoparasites or parasitic infections of importance are: black flies, ticks, pediculosis, and mange.

The buffalo is subject to heavy infestations of Fasciola ssp. (liver fluke). The natural habitat of the water buffalo is also the habitat of the Fasciola ssp. vector, the snail causing the heavy rate of infestation. Due to the nature of Fasciola ssp., it is difficult to estimate the cost in reduced work, or decreased milk and meat production (Cockrill, 1974). Schillhorn van Veen (1982, personal communications) has shown an interest in research dealing with control of liver flukes by management.

Sarcosporidiosis is a condition caused by infection from parasites of the genus Sarcocystis. This infection results in cysts being formed in the musculature. These cysts seldom reduce the capability of the buffalo but can cause rejection of parts of the carcass. The rejection of meat for human consumption results in a subsequent loss in potential protein and an economic loss to the producer (Cockrill, 1974).

The ectoparasites which feed on the blood of water buffaloes include the buffalo flies, black flies, lice, mites, and to a lesser degree, ticks. The population of buffalo flies on buffaloes is usually very large, however, the buffalo seldom appear to suffer from these large populations. However, due to the severity of the bite, large populations of black flies can cause serious damage to buffaloes (Cockrill, 1974).

Only one species of louse infests water buffaloes, the sucking louse Haematopinus tuberculatus. Buffaloes in poor condition are generally more heavily infested with lice than buffaloes in moderate to good condition. The overall unthriftiness of these animals may not be solely due to lice infestation but lice are a contributing factor. A consideration in lice infestation is the possible introduction of secondary infection due to the scratching associated with lice (Cockrill, 1974).

Mites are the causes of three types of mange in buffaloes, sarcoptic, psoroptic, and to a lesser extent, demodectic (Cockrill, 1974). The most common form of mange is the sarcoptic mange. Mange can cause unthriftiness and even death in the more severe cases (Cockrill, 1974).

Buffaloes rarely suffer severe tick infestations except during periods of confinement (Cockrill, 1974). In a tick infested area of northern Australia, only 2 ticks were found on 13 adult buffaloes during a 2 year period (NRC, 1981). The difficulty in penetration of the buffalo's hide may account for the reduced infestations.

Resistance to Disease

A good review of the buffalo's estimated resistance to diseases is presented in the NRC report (1981). This report compared the buffalo's susceptibility to diseases of cattle. Buffaloes generally had greater susceptibility to buffalo pox, sarcosporidiosis, and fascioliasis than cattle, whereas buffaloes were less susceptible to contagious pleuropneumonia, anaplasmosis, and babesiosis than cattle. The susceptibility of buffaloes was reported as equal for 9 diseases, equal or greater for 5 diseases, and

equal or less for 2 diseases than cattle. The susceptibility comparison with cattle was not known for 4 diseases.

McDowell (1972) suggested that buffalo were less susceptible to rinderpest than cattle but this may not hold true for all areas. In India and Indochina, the buffalo appears to be less susceptible to foot and mouth disease. However, the occurence of foot and mouth disease appears to be equal to cattle in southeast Asia. The incidence of tuberculosis in buffaloes varies with location. Egyptian buffaloes may have a resistance to tuberculosis but in India the occurence of tuberculosis is much higher in buffaloes than in cattle (McDowell, 1972).

Much less research has been done on diseases of buffaloes than on cattle. It is clear that research on the control of certain diseases is critical for improving the productivity of buffaloes. Consideration of diseases should be an important component of a research program with buffaloes.

Genetic Improvement

The genetic quality of many breeds of cattle is being upgraded by the use of selected and tested bulls or by crossbreeding with superior sires, but very little consistent selection and upgrading is being done with buffaloes. Some selection has been practiced on a herd basis in India to develop the milking breeds, such as the Murrah and Nili-Ravi in Pakistan, and also some in Egypt and southern Europe. However, most buffalo breeding is done at random without selection of either the cows or bulls. There does not appear to be any progeny selection and testing programs except within single herds aimed at locating superior sires and dams, and certainly there is little concerted effort to bring about the improvement of the buffalo population in general.

Knapp (1957) pointed out that the growth rate of Egyptian and Italian buffaloes were similar up to 6 months of age, but from 6 to 24 months, growth was much slower in Egyptian buffaloes, probably, he suggested, due to poor feeding. Thus their genetic potential was not being realized. Poor feeding and management would be an even greater limitation to the selection of animals for milking potential. It seems likely that most of the world's buffaloes are not being well enough fed throughout the year to allow effective selection for growth, milk production or working ability. It is critically important that some effective selection be started in a few places for animals are properly managed to bring about eventual improvement. The NRC (1981) report stresses the importance of research on genetic improvement.

As selection is made for growth, meat production, milk production, and workability under conditions of improved feeding and management, it is important to recognize that there are regions in the warm climate zones of the world where buffaloes and cattle have become adapted to survival under difficult conditions with periods of stress from high humidity and temperature, periods of poor quality and shortage of feeds, and diseases and parasites. These animals have the ability to utilize the limited resources in these areas and

produce some meat and milk where no other food production is possible. It is often not feasible to improve the environment. Selection among these animals may improve their ability to survive and produce if the selection is done properly. The gene pool of these hardy animals should be preserved.

Feeding and Nutrition

There have been many reports that buffaloes grow faster and produce more meat and milk than native cattle in the warm climate zones of the world, especially under poor conditions, but there are few controlled studies to confirm or deny these reports. Most buffaloes exist during the dry seasons on straws and other crop residues, weeds, and anything else they can graze. It is generally believed that buffaloes will eat a wider variety of crop residues, weeds, bushes, etc. than cattle. Too few controlled studies have been made to measure the true abilities of buffaloes and the ways they may differ from cattle.

Pant and Roy (see McDowell, 1972) reviewed the earlier research on digestibility and utilization of feeds. Some studies show that buffaloes digest fibrous feeds better than cattle, but other studies show the opposite or that there are no species differences. They conclude that buffaloes thrive better than cattle on low-protein, high-fiber feeds because they recycle nitrogen in the saliva or directly into the rumen more efficiently than cattle. Buffaloes have similar bacterial and protozoal population to cattle, but they may have a higher concentration of acetic and total fatty acids in the rumen ingesta than cattle. Studies of feeding habits suggest that buffaloes will consume poor quality forage and crop residues refused by cattle.

The chapter by Chambers on nutrition in Cockrill's (1974) book reviews the earlier studies on growth, digestibility of feeds, physiology of the rumen, meat and milk production, and the effects of climatic conditions on productive responses. The need is stressed for more extensive and better controlled studies on all aspects of nutritional physiology using modern techniques.

Ranjhan and Pathak (1979) summarize the status of knowledge in India on the chemical composition and digestibility of feeds and feed utilization for productive pruposes. DCWB (1978) cites several abstracts of research on nutrition of buffaloes. A few examples of more recent research are cited.

Many studies have measured the effects of adding protein-rich supplements to improve the growth or milk production of buffaloes fed wheat or rice straw, corn, sorghum or millet stalks. These low quality roughages are inadequate for maintenance when fed alone, but they are useful sources of fiber and energy when supplemented with high-protein fresh forage or by-products (Ahuja, DCWB, 1978 No. 1039; Cockrill, 1974). Some research has been done on milk replacers for buffalo calves (Cockrill, 1974; Arora et al., DCWB, 1978 No. 1046). More research is needed to develop more satisfactory and less expensive replacers using locally available feeds.

The FAO Technical Report (1981) cited a study in the Philippines in which rice straw supplemented with salt, bone meal, and limestone was not adequate to maintain body weight. The buffaloes gained weight when the rice straw was supplemented with a concentrate mixture fed at 1.0% of body weight. The dry matter intake of rice straw was 2.3 to 2.9% of body weight.

Ludri and Razdan (1980) reported that in India Murrah buffaloes consumed more of experimental diets per unit of metabolic size than Zebu cattle, but digested less of the protein. Variable protein intakes of 40% to 100% of the recommended level did not affect intake or digestibility. On the lowest protein intake buffaloes remained in positive nitrogen balance while the cattle were in negative balance, suggesting that nitrogen utilization is more efficient in buffaloes.

Sebastian et al. (1970) reported that there was no difference in the efficiency of milk production between Murrah buffaloes and Sahiwal cattle. The good quality forage was alfalfa and greed corn supplemented with a concentrate related to milk yield. Buffaloes had a higher water intake per unit of body weight but the intake of dry matter was lower. Digestibility of protein was similar, but the cattle retained less nitrogen.

Nutrient Requirements

Ranjhan and Pathak (1979 has summarized the available information on the nutrient requirements of buffaloes and their utilization of feeds. Feeding standards used in India for buffaloes are largely based on U.S. NRC data for dairy cattle. Pant and Roy (McDowell, 1972) list the following requirements for buffaloes in India.

Daily Requirements for Maintenance and Lactation

Body Weight kg	Dry Matter kg	Digestible Protein kg	TDN kg
400 - 500	6.0 - 9.0	0.37	4.24
Change in body weight			
±50	±0.5	±0.03	±0.32
Per kg of milk	(7.0% fat)	0.03	0.20

Very few published data are available on the requirements of minerals by buffaloes. Agorwala et al. (DCWB, 1978 No. 986) reported that mature buffaloes required between 12 and 17g of phosphorus per day for maintenance. Ranawana et al. (1981) reported that in India, Murrah buffalo calves supplemented with phosphorus, sulfur, iron, manganese, zinc, copper, and cobalt gained 0.39 kg

compared with 0.19 kg per day for unsupplemented calves. Research on the mineral composition of available feeds and animal requirements is critically needed. Research should be carried out to define the nutrient requirements of buffaloes and to determine how much they differ from cattle.

Several studies have been designed to develop milk replacers for early weaned buffalo calves and some have been moderately successful. Calves grow more slowly on the replacers than on whole milk, but the cost is considerably lower (Arora, S.P., et al. DCWB No. 1046). More tests are needed to formulate more satisfactory and less expensive feeds that will save more of the fresh buffalo milk for human food.

Comparative Digestibility of Feeds by Buffaloes and Cattle

Johnson (1967) and Grant et al. (1974) reviewed the previous research and reported their own comparisons of the digestibility of Guinea grass and Napier grass by swamp buffalo bulls and Holstein x Red Sindhi steers. The earlier research showed that in most studies buffaloes digest 2% to 5% more dry matter, protein, and fibrous fractions of forages than cattle. In their own studies, buffaloes digested 2% to 4% more than cattle of most nutrients of the grass during the wet season, but there was no difference in the dry season grass. Buffaloes consumed significantly less dry matter than cattle, which may explain the higher digestibility. There are other studies which show that buffaloes digest poor quality feeds slightly better than cattle, but some show no difference between them.

There are several references which claim that buffaloes utilize poor quality roughages better than cattle. Cockrill (1976) states, "A highly satisfactory yield of top quality meat can be obtained at a lower production cost than with cattle, due in part to the ability of buffaloes to thrive on inferior fodders and a minimum of concentrates." The NRC (1981) report cited observations of producers that buffaloes thrive better than local cattle on poor quality grazing lands. The differences in digestibility are too small to explain the difference in performance. In the few cases when careful tests were made, it was found that cattle consumed more feed than buffaloes per unit of body weight. Tests have not been made using unsupplemented poor quality forage alone.

Achacoso (1956) compared the digestive ability of the Murrah buffalo, Murrah x Carabao, native steer, and Holstein bull when fed rice straw plus salt alone, or supplemented with copra meal, molasses or urea. There were important differences between rations, as expected. Across all rations, the buffaloes digested 57.4% of the organic matter, 51.2% of the protein, 58.6% of the crude fiber, and 55.2% of the nitrogen-free extract compared to 52.8%, 47.4%, 52.2%, and 50.8%, respectively by the cattle.

Razdan et al. (1971) compared mature Zebu and Murrah buffalo cows on rations of wheat straw supplemented with a concentrate containing urea or true protein to supply 9.3% or 6.6% crude protein in the ration. There was no difference in feed intakes but the buffaloes digested more of the dry

matter (53 vs. 48%) crude protein (50 vs. 43%) and crude fiber (69 vs. 65%) and they retained more nitrogen. The buffaloes consumed more water per unit of body weight.

An attempt has been made to tabulate the limited data on digestibility of various feeds and typical rations by buffaloes and cattle (table 16). Other studies have undoubtedly been carried out that were not available to us. In eight of the studies listed, buffaloes digested more of the dry matter than cattle. In five comparisons, cattle were highest in two and they were similar in three comparisons. There were more digestion studies in which buffaloes alone were used than those in which the two species were compared and these should be greatly expanded.

Many more studies are needed using newer methods of analyzing the fiber component of forages and roughages. All available feeds and by-products need to be studied.

The single study on rice straw by Achacosa showed that buffaloes digested the straw better than cattle. In a more extensive study, Pate and Castillo (DCWB, 1978 No. 1112) found there was no difference in the utilization of rice straw by these animals. They observed TDN values for cattle of 46.6 ± 1.51% and for buffaloes 49.0 ± 1.27. The digestible protein content of the rice straw was 1.15 ± 0.15% for cattle and 1.11 ± 0.10% for buffaloes, and digestibility energy value was 1972 ± 65 for cattle and 1963 ± 44 kcal per kg of dry matter for buffaloes. Castillo (DCWB, 1978 No. 1050) also reported that carabaoes digested high moisture corn grain and fresh forage better than cattle.

Care and Management

Water buffaloes are highly adaptable and intelligent animals. Young buffaloes learn patterns quickly and feral animals tame down within a couple of weeks when placed in an enclosure (NRC, 1981). The overall docile nature of buffaloes is an important consideration in their care and management. When buffaloes are used for draft or milk production, their docile nature is a great asset in the ease in which they are trained. Cockrill (1974) stated that training often begins when the calf is still very young. Often times the training begins by simply following the dam as she does her daily work. This placid disposition also effects the management of buffaloes under range conditions. Rough handling and loud shouting makes them more difficult to handle and is unnecessary (NRC, 1981).

Buffaloes and cattle can be maintained on the same pastures satisfactorily Generally, they tend to segregate into two groups and do not interfere with each other (NRC, 1981). Buffaloes will not interbreed with cattle. Buffalo bulls may service cattle cows and vice versa, however, these occurences do not result in a fertile mating. There is no reliable evidence of such a mating resulting in a hybrid progeny (Cockrill, 1974).

Table 16. Digestion Coefficients of Rations by Buffalo and Cattle

Ration	Species	Dry Matter	Crude Protein	Crude Fiber	Reference
Spear grass + ground nut cake (8% body wt.)	Buffalo	54.1	47.5	62.0	Jang and Majumdar, 1962
	Cattle	53.5	49.5	61.6	
Guinea grass	Buffalo	59.4	65.7	66.5	Johnson, 1967
	Cattle	55.3	62.3	62.5	
Wheat straw, 2 kg conc.	Buffalo	50.5	60.2	46.8	Ichhponani and Sidhu, 1965
	Cattle	46.9	58.3	44.4	
Wheat straw, 2 kg 2% urea conc.	Buffalo	57.3	66.7	55.2	
	Cattle	49.5	63.5	57.3	
Rice straw, salt	Buffalo	45.9[a]	11.4	60.9	Achacoso, 1956
	Cattle	47.3[a]	8.2	60.3	
Rice straw, concentrate	Buffalo	61.2[a]	64.4	57.9	
	Cattle	54.7[a]	60.5	47.8	
Alfalfa hay	Buffalo	61.3	61.4	62.7	Singh and Mudgal, 1967
	Cattle	61.9	63.4	51.5	
Berseem hay	Buffalo	70.4	78.7	57.5	Taparia and Jhanway, 1974
Napier grass	Buffalo	54.7	63.9	----	Robles and Ordoveza, 1971
	Cattle	54.0	61.7	----	
Wheat straw, conc.	Buffalo	54.3	70.0	----	Sharma et al., 1975
	Cattle	55.6	67.0	----	
Wheat straw, conc.	Buffalo	57.4	62.5	----	
	Cattle	57.2	54.0	----	
Berseem	Buffalo	75.3	75.3	68.3	Kishan and Singh, 1978

Table 16. Digestion Coefficients of Rations by Buffalo and Cattle (continued)

Ration	Species	Dry Matter	Crude Protein	Crude Fiber	Reference
Green oat	Buffalo	66.5	66.1	67.7	
Cow pea	Buffalo	59.9	71.3	65.2	
Maize	Buffalo	60.9	63.6	70.2	
Oat hay	Buffalo	54.2	30.3	61.8	
Wheat straw, conc.	Buffalo	56.4	74.5	47.8	Varma *et al.*, 1975
	Buffalo	60.1	65.4	50.2	
Wheat bran	Buffalo	73.8	72.2	79.0	Gill *et al.*, 1977
Rice bran	Buffalo	50.6	57.4	27.0	
Deoiled rice bran	Buffalo	48.6	57.4	48.7	
Wheat straw, 2 kg conc,	Buffalo	61.9	57.9	66.2	Gill *et al.*, 1976
1.5 kg	Buffalo	59.5	55.3	60.5	
1.0 kg	Buffalo	59.9	51.5	64.3	
0.5 kg	Buffalo	56.4	48.9	52.5	
0.0 kg	Buffalo	58.6	46.7	62.7	
Maize & Salt	Buffalo	61.5	43.4	62.1	Chauhan *et al.*, 1976
Pearl-millet & Salt	Buffalo	70.6	72.2	69.8	
Sorghum & Salt	Buffalo	65.0	59.3	60.8	
Hybrid Napier & Salt	Buffalo	58.5	54.9	57.2	
Wheat straw, conc.	Buffalo	69.0	60.3	71.9	Malik *et al.*, 1977
Concentrate	Buffalo	68.3	65.7	71.9	
Concentrate	Buffalo	71.5	71.4	73.9	

Table 16. Digestion Coefficients of Rations by Buffalo and Cattle (continued)

Ration	Species	Dry Matter	Crude Protein	Crude Fiber	Reference
Wheat straw, conc.	Buffalo	45.4	36.2	53.8[b]	Pandit and Singh, 1967
2 lb molasses	Buffalo	51.6	37.6	54.2	
4 lb molasses	Buffalo	55.0	38.0	47.0	
Wheat straw, conc.	Buffalo	51.2	55.5	53.8[c]	
2 lb molasses	Buffalo	54.1	53.1	55.0	
4 lb molasses	Buffalo	58.8	56.6	55.8	
Wheat straw, conc.	Buffalo	----	53.4	58.5	Sawhney et al., 1974
.5% urea	Buffalo	----	56.0	61.3	
1.0% urea	Buffalo	----	56.0	57.5	
1.5% urea	Buffalo	----	56.0	51.6	
Wheat straw, conc.	Buffalo	49.9	59.0	66.9	Sharma and Mudgal, 1975
	Cattle	48.1	55.0	59.0	
1% urea	Buffalo	50.5	55.0	53.7	
	Cattle	48.9	54.1	60.0	
2% urea	Buffalo	53.2	51.5	63.2	
	Cattle	51.5	47.6	58.7	
3% urea	Buffalo	48.8	50.0	58.6	
	Cattle	48.6	48.2	54.7	
Wheat straw, conc., 2 lb. molasses	Buffalo	49.4	53.0	46.0	Pandit and Singh, 1970
2 lb maize	Buffalo	48.3	53.8	50.6	
urea, 2 lb molasses	Buffalo	47.9	56.9	49.8	
urea, 2 lb maize	Buffalo	37.8	64.7	58.8	
urea, 2 lb molasses	Buffalo	46.6	62.0	47.7	
urea, 2 lb maize	Buffalo	46.3	55.7	54.5	

[a] Organic matter.

[b] 0.4 kg digestible protein/1000 kg body weight/day.

[c] 0.8 kg digestible protein/1000 kg body weight/day.

The need for proper fencing is a management problem for buffalo. Fences must be of stronger construction than those used for cattle (NRC, 1981). Buffaloes respond well to electric fencing (Cockrill, 1974; NRC, 1981). In NRC (1981) the development of a suspension fence designed in Brazil was reported to be successful in the management of buffaloes. Another consideration in buffalo management is the design and construction of larger chutes to accomodate the wider bodies and horn spread of the buffaloes (NRC, 1981).

In many areas, small farmers have problems in obtaining the feed supplements and other supplies needed for optimal management of their buffaloes. Oftentimes prompt veterinary service is not available in rural areas for treatment of prevention of disease problems.

Garner (1957) reported that through the use of improved harness, the efficiency of buffaloes for draft production could be increased (for more information see "Work Production"). This improvement is an important management consideration for water buffaloes.

The NRC (1981) reported several management areas that require research to determine their effect on all aspects of buffalo production. Some of these areas include methods of: castration, dehorning, forage preservation, grazing management, milking, breeding, artificial insemination, and disease prevention.

Centers for Research on Buffaloes

Some of the early research with buffaloes appears to have been published in the 1920's by Villegas in the Philippines. Since then, more research has been done with buffaloes in India than in any other country. Since the 1940's research has been published in India from several research centers, but the most meaningful data collection has occurred since the 1950's.

Recently, several countries have coordinated the research on buffaloes. The All India Coordinated Research Project on Buffaloes has headquarters at the National Dairy Research Institute, Karnal, Haryana, India.

In Egypt buffalo research in the areas of milk and meat production and feed utilization has been conducted since the early 1950's. Active research is now being conducted at the universities in Cairo and Alexandria. The Food and Fertilizer Technology Center in Taipei City, Taiwan, has served as the central office to plan seminars and release publications on buffaloes for Southeast Asia for a number of years.

The Philippine Council for Agriculture and Resources Research sponsored the Documentation Center on Water Buffalo at the University of the Philippines at Los Baños, College, Laguna 3720, Philippines. The Documentation Center on Water Buffalo (DCWB, 1978) in the Philippines published 1469 abstracts of research on water buffaloes world-wide carried out between 1971 and 1975. A similar summary for more recent research has not appeared. These papers were concerned with general production of milk and meat and their use, physiology, genetics, reproduction and artificial insemination, nutrition, feeds, and health.

In Brazil buffalo research has been in progress for many years at the Agricultural Research Center for the Humid Tropics (CPATU), Belem, Brazil. This research center is a part of the National Brazilian Agricultural Research Corporation (EMBRAPA). The director of the station was in charge of the buffalo research for more than ten years prior to his current appointment. During the past four years, 16 research abstracts have been published in the Proceedings of the Brazilian Society of Animal Science (SBZ) on crossbreeding, feeding, management, comparative production with Zebu and production systems. A bibliography containing 240 references to buffalo research and articles about buffaloes in Brazil was published by EMBRAPA (Bibliografia Brasilina de Bufalo, 1981).

A herd of swamp buffaloes was established in 1973 at the University Pertanian Malaysia (UPM) for teaching and to do research on the potential of the buffalo for meat production. Research in the areas of reproduction, genetics, and nutrition is now in progress at UPM and facilities and trained personnel are available for effective research in these areas.

In Thailand, a Cooperative Buffalo Research Project was established in 1975. This project has now become the National Buffalo Research and Development Project, a multi-agency, multi-disciplinary project whose goal is to improve the small farm buffalo production. The National Buffalo Research and Development Project Center publishes the Buffalo Bulletin and an annual report on buffalo research. The Annual Report for 1980 contained 24 articles on all aspects of buffalo production.

In January 1981, an FAO supported research program with buffaloes was started in the Philippines. The main research center is at the University of the Philippines at Los Baños. Other cooperating sites are Central Luzon State University (CLSU), Nueva Ecija; Cagayan in Northern Luzon, the Bureau of Animal Industry (BAI) in La Carlote, Negros Occidental; and Central Mindenao University (CMU) in Bukidnon, Mindenao. These FAO supported studies are just being started. They will include growth studies on different feeds, digestion and metabolism tests, measurement of protein and energy requirements at different stages of the life cycle and methods of supplementing rice straw and other crop residues for best utilization. Breeding and physiological studies are also being aimed at improving buffalo production on small farms.

Potential Payoff for Buffalo Research

The potential payoff of buffalo research can be considered under the three areas of buffalo production; milk, meat, and draft. These estimates are based on the research and development needs discussed later and require that the research be conducted and that the information be adopted by producers.

The potential for increasing the milk production of buffaloes appears to be from two to three fold. A doubling of the growth rate of buffaloes could be possible for increased meat production. Draft production could be increased from 30 to 50% by incorporation of the improved harness described by Garner (1957) and probably it could be increased considerably more by improving the genetic merit of many of the buffaloes and by improving feeding

practices. The production of animals for draft purposes would also benefit from the doubling of the growth rate causing an increase in the mature weight. All three areas of buffalo production would benefit from the potential doubling of the reproductive rate of water buffaloes. Overall, the potential payoff of water buffalo research appears to be very large for small farmers as well as for large producers.

Research and Development Needs

The world population of buffaloes can be divided into two groups, swamp and river types. The major goal for buffaloes in Asia is for an animal adapted for work. The buffaloes of Egypt, Europe, the Caribbean, and the Americas are used for meat and milk production and not so much for draft. Research should be designed to compare buffaloes and cattle to determine if data can be extrapolated from cattle to buffaloes. The introduction of buffaloes into areas where they are not now found could increase the productivity of some of the world's underutilized humid areas.

Feeding and Nutrition

The area most likely to yield rapid payoff is research in feeding and nutrition. Proper nutrition is essential for all other aspects of research with buffaloes. Specific areas of nutrition research are presented below in order of relevance and potential payoff.

1) Methods of improving the nutrititive value of rations consisting of crop residues.

2) Improved use of the native forages.

3) Improved use of high concentrate by-product rations.

4) Establishment of the mineral requirements for buffaloes and the degree of supplementation required.

5) Development and use of milk replacers.

6) Establishment of the nutrient requirements for buffaloes by breed, age, sex, and weight for maintenance, growth, reproduction, lactation, and work.

7) Investigations into the rumen microbiology and digestive physiology of the buffalo.

Genetic Improvement

A high priority with greatest potential for the long-term improvement of water buffaloes is the initiation of a selection program for each important type or breed to identify the high milk, meat, or draft producers. This program would bring about genetic progress and improve production. The initiation of a crossbreeding program would also improve productivity. The

crossing of swamp and river buffaloes should result in progeny that benefit from heterosis and create a triple-purpose animal (meat-milk-work).

Reproduction

The use of artificial insemination (AI) would increase the genetic progress discussed earlier. To maximize the potential of AI, research interests need to focus on: 1) improving the freezability of buffalo semen; 2) characterizing the desirable semen traits; and 3) relating those semen traits to fertility. Other areas of interest are: the effect of season and environment on semen quality, improved methods of semen collection to maximize semen yield, and to identify sources of variation in semen quality among males. Methods for wide use of artificial insemination should be developed in each area.

Research priorities for female reproduction include: 1) an easy method of estrus detection; 2) a regimen for estrus synchronization; and 3) a reliable means of early pregnancy diagnosis.

Milk Production

Establish progeny testing and recording systems to identify outstanding milk producing cows and herd sires for A.I. Other research could include the: 1) environmental effects on production; 2) development of new or improved milk products; and 3) adaptation of milking machines to milking buffaloes.

Meat Production

Selection of outstanding animals for carcass characteristics needs highest priority. Other critical areas for meat production are the effect of environment on meat production; the performance of buffaloes in a feedlot system; the growth characteristics of buffaloes; and the carcass composition of buffalo breeds and crossbreds.

Work Production

Selection of the best animals for work in terms of size, conformation, and traction power needs to be done for upgrading of farmers buffaloes for working ability. The most rapid payoff of research in this area involves the development and use of improved harnesses in place of the traditional yoke.

Health

The health of water buffaloes requires research in the prevention and/or control of major diseases of buffaloes. This should allow for the development of herd health programs and specific disease control programs for the different management or production systems. One special area of herd health needing attention is the factors involved in calf mortality.

Management

The development of new or improved management techniques is an area where rapid advances could be made. Research areas that could increase or improve the production of buffaloes are: 1) preservation of forages; 2) comparision of young bulls vs. steers for beef; 3) method of dehorning; 4) method of milking; and 5) proper fencing. There are many other areas of management that require research which can be investigated in conjunction with the previously mentioned areas of interest.

Dissemination of Information

Due to the increased interest in water buffaloes world-wide, it is essential that a central clearinghouse for the reporting of these data be organized. The NRC (1981) panel recommends a water buffalo newsletter and a scientific water buffalo journal. This recommendation will consolidate results and allow more efficient use of research time and resources.

Interrelationship of Research Areas

This study has attempted to set certain research priorities in areas of interest. However, the relationships between areas is not as definate as it appears in print. There should be considerable overlap in research projects and an efficient use of animals and facilities.

Critical Research Priorities

Research priorities are ranked as follows: 1) nutrition and management, 2) reproduction, including reduction of calf mortality, 3) disease prevention and control, and 4) genetic improvement and selection for milk, meat, and draft. The priorities listed are closely related and there should be considerable overlap in research projects. Emphasis should be on applied research and the results should be applicable to the solution of problems of the small producer.

Nutrition and Management

Improvement of nutrition and feeding management is clearly necessary as a priority for any improvement in livability, growth rate, reproduction, milk production or workability. Underfed, half starved animals cannot perform as they should and the damage may be severe if they suffer from specific deficiencies in addition to a lack of energy and protein. Comparative studies need to be conducted with buffaloes, *Bos indicus* (Zebu), *Bos taurus* (European), and *Bos banteng* cattle with emphasis on nitrogen, energy, and phosphorus metabolism. It is believed that buffaloes can utilize dietary nitrogen and poor quality forages most efficiently; however, this is controversial. If true, buffaloes would have a major advantage which would have far reaching impact on the under utilized land and crop residue roughage resources. In addition, feeding systems utilizing locally available agriculture and industrial by-product feed resources for optimum production of milk, meat, and work need to be investigated in a number of different geographical areas.

Reproduction and Reduced Calf Mortality

Annual reproductive rates of 30 to 50% appear to be the rule among buffaloes on small farms in tropical countries. Limited research in selected, well managed herds suggest that buffaloes are able to achieve a calving interval of about 12 to 13 months. Proper nutrition, management, and disease control are necessary to obtain this level of reproductive efficiency. More research should be done on semen collection, preservation, and utilization in widely adapted artificial insemination (A.I.) programs.

A marked reduction in calf mortality is a problem area where dramatic results could be achieved rapidly. The discovery of methods of reducing calf mortality would involve research in the areas of feeding, management, disease control, and prevention.

Disease Prevention and Control

The prevention of disease is an improtant priority for buffalo research. Several diseases are of economic importance as well as being important to human health. Research on hemorrhagic septicemia is a major need because calf losses from this disease have been reported to vary from 2 to 10%, but they can be as high as 70%. This disease, as well as others, contribute to the high calf mortality rate. Brucellosis and leptospirosis cause abortions in buffaloes thereby contributing to low reproductive rates. Some buffalo diseases are also transmissible to the human population. Mastitis is a disease of economic importance which causes a reduction in milk production and in milk quality. In Pakistan, cows that had mastitis produced an average of 430 kg less milk in a lactation than buffalo cows without mastitis. Research on both disease control and prevention is necessary if the potential production of buffaloes is to be realized.

Genetic Improvement and Selection

Only in a few research herds is consistant selection and upgrading being done with buffaloes. The identification of superior sires and dams for the production of meat, milk, and work is a critical need if the future usefulness of buffaloes are to reach their potential.

At least a doubling of the growth rate and milk production can be achieved in the first cross of a superior sire with typical, small buffalo cows. Long-term progeny and performance testing of cows and bulls using modern research methods need to be initiated to realize maximum advances in production and efficiency. Because long-term efforts are necessary to make the most progress, it is critical that testing and recording programs be started as soon as possible in countries with large numbers of buffaloes to educate owners of the need for selection. These programs along with the use of artificial insemination, improved feeding, management, and disease control are necessary for continuing progress.

Communication

Due to the increased interest in buffaloes world-wide, it is essential that a central clearing house for the reporting of research data be organized. The NRC panel (1981) recommended an international buffalo newsletter and a scientific journal to report research with buffaloes. This would help inform people of the progress and would provide more efficient use of research time and resources.

WATER BUFFALO RESEARCH - INTERNATIONAL COOPERATORS

Country	Address	Research Interest
Brazil	Dr. Cristo Nascimento Director CPATU CAIXA Postal, 48 Belém, PA, 66.000 Brazil	Increased productivity of dairy buffaloes.
Egypt	Dr. M.A. El-Ashry Department of Animal Production Faculty of Agriculture AIN Shams University Shoubra El-Khiema Cairo, Egypt	Development of milk replacers for buffalo calves. Selection for increased milk and meat production.
Malaysia	Dr. M.R. Jainudeen Professor, Department of Animal Science University Pertanian Malaysia Serdang, Selangor, Malaysia	Increased production for draft, meat, and milk.
Pakistan	Dr. S.K. Shah Livestock Production Research Institute Bahadurnagar (O Kara) Distt, Sahiwal (Punjab) Pakistan	Reproduction and nutritional requirements of buffaloes.
Philippines	Dr. S.K. Ranjahn, Project Manager Philippine Council for Agriculture and Resources Research 3732, Los Baños, Laguna, Philippines	Applied aspects of reproduction, nutrition, and breeding for draft, meat, and milk production
Thailand	Dr. C. Chantalakhana Department of Animal Science Kasetsart University Bangkok, Thailand	All aspects of productivity.
Trinidad	Dr. F.G. Youssef Department of Livestock Science University of the West Indies St. Augustine Trinidad, W.I.	Increase productivity for meat and work. Comparative growth and metabolism trials with cattle and buffaloes

BUFFALO RESEARCH - U.S.A. COOPERATORS

Address	Countries	Research Interest
Cornell University Ithaca, NY 14853 Dr. R.E. McDowell Animal Science Department Morrison Hall	Pakistan	Applied general production of milk, meat, and work.
Louisiana State University Baton Rouge, LA 70803 Dr. D.E. Franke Center for Agricultural Sciences Animal Science Department		Breeding and selection.
Michigan State University East Lansing, MI 48824 Dr. G.H. Axinn Asst. Dean and Professor of Agricultural Economics		Small farm systems. Rural Sociology.
Dr. T.W. Schillhorn van Veen Veterinary Clinical Center		Epidemiology of liver fluke disease.
University of California Davis, CA 95616 Dr. W.R. Pritchard, Dean School of Veterinary Medicine		Buffalo diseases and production.
University of Florida Gainesville, FL 32611 McCarty Hall	All Countries	
Dr. Hugh Popenoe Department of Animal Science		International agriculture
Dr. C.B. Ammerman		Nutrition
Dr. J.W. Carpenter		Meats
Dr. J.H. Conrad		Nutrition
Dr. G.L. Ellis		Nutrition
Dr. M.J. Fields		Reproductive physiology
Dr. D.D. Hargrove		Breeding, genetics, and management
Dr. J.F. Hentges	Egypt	Nutrition and production
Dr. J.K. Loosli		Nutrition and production
Dr. L.R. McDowell		Nutrition
Dr. J.E. Moore		Nutrition
Dr. T.A. Olson		Genetics and breeding
Dr. H.D. Wallace		Nutrition
Dr. A.C. Warnick		Reproductive physiology

Address	Countries	Research Interest
College of Veterinary Medicine Dr. E. Bliss Dr. M. Burridge Dr. W. Cripe Dr. M. Drost Dr. P. Gibbs Dr. E. Greiner Dr. P. Nicoletti		Preventative medicine Epidemiology Hematology-blood chemistry Reproduction Virology Parasitology Brucellosis
University of Illinois Urbana, IL 61801 Dr. W.C. Wagner 269 Veterinary Medicine Building 1101 West Peabody Drive		Diseases and reproduction.
Dr. Upson Garrigus Animal Science Department 332 Mumford Hall	Several Asian countries	Nutrition and production
University of Minnesota St. Paul, MN 55108 Dr. B.G. Crabo Dr. R.B. Goodrich Department of Animal Science 1988 Fitch Avenue		Reproduction Production
Dr. Delane Welsch 316 Classroom Office Building 1994 Buford Avenue		Economics
Virginia Tech Blacksburg, VA 24061 Virginia - Maryland Regional College of Veterinary Medicine Dr. R.G. Carter	Brazil, Sri Lanka, and Malaysia	Diseases of buffalo particularly hemorrhagic septicemia.

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