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CLIMATE CHANGE: IMPACTS ON REPRODUCTIVE PATTERN OF CATTLE AND BUFFALOES : REVIEW

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About 70 per cent of the India's human population is dependent on agriculture for their livelihood. Livestock sector is the integral part of Indian agriculture. Livestock sector provides sustainability and stability to the national economy by contributing to farm energy and food security. During the last decade, the annual growth rate of livestock has maintained a steady growth of 4.8 to 6.6%. In contrast, the crop production remained either stagnant or increased marginally. An estimated 440 million livestock heads distributed over 100 million households in approximately 600,000 villages in the country provides livelihood and food security. India has approximately 182 million cattle, 98 million buffaloes, 126 million goats, 68 million sheep and 18 million other animals. The rain fed areas face great instability in crop production due to erratic and inadequate rainfall. Due to uncertainties in the crop yields, livestock production has been found to provide economic stability to farmers. The rain fed land can sustain livestock better than crop production.

Heat stress affects the reproductive functions of dairy animals mainly by two general mechanisms (i) increase in body temperature which can compromise reproductive function mainly due to redistribution of blood flow from the body core to the periphery and thereby increasing sensible heat loss. (ii) reduced feed intake which reduces metabolic heat production, affects energy balance and availability of nutrients for productive functions such as cyclicity, establishment of pregnancy and fetal development, functions of germ cells, the early developing embryo and other cells involved in reproduction.

Climate Change Scenario

One of the environmental threats that our earth faces today is the potential changes in earth's climate and temperature patterns. An estimate indicated that the earth's average temperature has increased between 0.3°C-0.6°C, the sea level between 10-25 cm, atmospheric carbon dioxide concentration by more than 20 percent and methane by 145 percent over pre-industrial levels.

The report of Intergovernmental Panel on Climate Change (IPCC, 2007a) projected that, without further action to reduce greenhouse gas emissions, the global average surface temperature is likely to rise by 1.8-4.0°C and in the worst case scenario 6.4°C by the end of this century. Even the lower end of this rise in temperature would take the increase in temperature above 2°C of the threshold of pre-industrial times beyond which irreversible and possibly catastrophic changes become far more likely. With the increase in global average temperature by 1.5–2.5°C, approximately 20-30 percent of plant and animal species are expected to be at risk of extinction (FAO, 2007). The IPCC further indicated that many of the developing countries tend to be especially vulnerable to extreme climatic events as they largely depend on climate sensitive sectors like agriculture and forestry. Therefore, climate change is one of the most serious long-term challenges facing farmers and livestock owners around the world. Climate change is widely considered to be one of the most potentially serious environmental problems ever confronting the global community. Rise in temperature due to climate change is likely to have impact on livestock production and health. The temperate cattle breeds and their crossbred will be affected more compared to zebu cattle because Indian breeds have more capacity to withstand the stress of thermal stress, feed and water scarcity, diseases and parasite load.

Assessment of heat stress levels

A simple and most practical method to measure the heat stress in cattle and buffaloes is temperature–humidity index (THI). The test is based on atmospheric temperature and relative humidity (RH %). Equations for calculation of THI and their interpretation are as follows:

A. When ambient temperature is measured in °F (LPHSI, 1990):

$$THI = db\ °F - \{(0.55 - 0.55\ RH)(db\ °F - 58)\}$$

Where db = dry bulb temperature (°F) and RH = relative humidity (%) / 100.

Interpretation: If the calculated value is < 72 = indicates absence of heat stress, 72 to < 74 = moderate heat stress, 74 to < 78 = severe heat stress and 78 and more = very severe heat stress. The THI in a range of 72–81 reduces milk yield and TDN intake in dairy cattle and buffaloes (Kumar et al. 2009). Upadhyay et al. (2009) also reported a significant depression in milk production and in reproduction at an average daily THI of above 76. However, some depression may also occur between 68 and 76 in high milk producing animals, acclimated to a lower THI.

B. When temperature is expressed in °C (Marai et al. (2001):

$$THI = dbt°C - \{(0.31 - 0.31\ RH)(dbt°C - 14.4)\}$$

Where dbt = dry bulb temperature (°C) and RH = relative humidity % / 100.

Interpretation: If the calculated value is < 22.2 = absence of heat stress, 22.2 to < 23.3 = moderate heat stress, 23.3 to < 25.6 = severe heat stress and 25.6 and more = extreme severe heat stress.

C. Body temperature and respiratory frequency can also be used to determine heat stress in cattle and buffaloes Pramod , 2008).

Livestock Strain index (LSI)

$$LSI = 5\ (RT_{obs} - RT_{min})\ (RT_{max} - RT_{min})^{-1} + 5\ (RR_{obs} - RR_{min})\ (RR_{max} - RR_{min})^{-1}$$

Where RT_{obs} and RR_{obs} are simultaneoys measurement taken at any time

RT_{min} was 37°C for cattle

RT_{max} was 41.5 °C

RR_{min} was 10for cattle

RR_{max} was 120 for Sahiwal and 150 for KF

Physiological reasons for poor adaptability of buffaloes and crossbred cattle:

Effect of temperature and humidity on cattle and buffaloes has been investigated with emphasis on their thermal stability and adaptability. Metabolism of animals has been affected by increased environmental temperature and magnitude of the response depended upon species, breed and physiological stage of the animal. Heat production study on adult cattle and buffaloes indicated that the heat produced by Zebu cattle was 62.0 Kcal/hr/100 Kg body weight against 96.3 Kcal/hr/ 100Kg for buffaloes during summer season. The heat production was more during hot-humid and winter season than summer season in both cattle (80 Kcal/hr/ 100Kg) and buffaloes (107 Kcal/hr/100 Kg). This study clearly indicates higher energy needs during winter and rainy season than summer due to extra energy expenditure during rainy season and winter season (Rao et al, 1979).

The rectal temperature of animal has been considered as an index of thermal balance and studies carried out on cattle, crossbreds and buffaloes showed differing responses in relation to climatic conditions (Singh and Upadhyay,2009). The Hariana cattle maintained a low body temperature than crossbreds indicating that their metabolism is set at lower level than crossbreds (Singh and Bhattacharyya, 1991). In maintaining body temperature heat dissipation by radiation, conduction, convection and evaporation plays significant role. The distribution of sweat gland (Macfarlane, 1981), the capacity of skin vascular blood dispersion (Hales, 1973) and the effective adrenergic governing the sweating rate (Taneja, 1956) are the mechanism responsible for efficient distribution of heat from animals surface. As the environmental temperature increases heat loss by conduction, convection and radiation decreases and heat loss by evaporation increases. Macfarlane (1981) reported that Zebu cattle have higher number of sweat glands and produce more sweat than Taurus cattle and the crossbred. This mechanism helps the Zebu cattle to maintain low body temperature compared to Taurus cattle (Upadhyay et al; 1987). The necessity of heat dissipation to maintain thermal balance particularly during hot humid conditions force animals to employ open mouth panting mechanism with protruding tongue to complement heat elimination process (Upadhyay and Madan, 1985).

Effect of Climate on Reproductive functions

Reproductive functions of livestock are vulnerable to climate changes and both female and males are affected adversely. The livestock species which are more vulnerable to climatic changes are cattle and buffaloes. Sheep and Goats can withstand the stress to some extent. In most agro-climatic zones of India, the average temperature throughout the year is in the range of mild to moderate stress. A map of India has been prepared on the basis of THI values. The THI map developed at NDRI, Karnal using all India data for 230 locations indicated that animals are under constant stress from March to October at about 200 locations spread all over India. Generally animals maintained by small, marginal and landless farmers remain under open housing conditions and exhibit rhythmicity in breeding. During hot dry (March- June) and hot humid (July- September) season, the THI values exceeds 80 in most parts of India. The pattern of estrus varies among cattle and buffaloes. Most of the buffaloes exhibit sexual activity during cooler parts of the year (October- Feb), when the THI generally remains < 72 (Upadhyay et al. 2009).

A study on Holstein- Friesian cattle (847estrus) revealed seasonal influence on the estrus frequency in this temperate breed, under tropical climate of India (reference? (Verma et al, 1985). The highest activity of estrus symptoms are shown by these animals during winter and the lowest during rainy season. The thermal stress depressed estrus activity from April to June in temperate cattle. The heat stress (>32 °C) was aggravated by high humidity (vapour pressure >24 mmHg) from July to September and it had harmful effects on the ovarian activity, resulting in depressed estrus frequency during rainy season (Verma et al, 1985). The dairy cows that become pregnant during the warm months and cool month of the year were 22.1 and 43.1 per cent respectively (Lo´pez-Gatius 2003).

Animals maintained under open housing system in rural conditions exhibit seasonality in breeding and reproductive rhythm. Frequencies of estrus are pronounced during cooler months around equinox (March to July) in Hariana and their exotic crossbred cattle. The period from March to July is hot dry or hot-humid period when THI value throughout India exceeds 80. The pattern of estrus in buffalo is different from that of cattle since majority of buffaloes exhibits estrus from October to March when ambient temperature is low and THI value is less than 70. In addition to ambient temperature, humidity and solar radiation profoundly affect expression of reproductive rhythm in buffaloes and cattle (Upadhyay et al. 2009). The incidence of calving is also predominant from October to March, facilitating upbringing of offsprings due to availability of good quality fodders during this period. The climate change scenario due to rise in temperature and higher intensity of radiant heat load will affect reproductive rhythm via hypothalamo- hypophyseal–ovarian axis. The main factor regulating ovarian activity is GnRH from hypothalamus and the gonadotropins i.e. FSH and LH from anterior pituitary gland (Madan and Prakash, 2007). Gilad et al. (1993) and Wise et al. (1988) reported the decrease in LH pulse amplitude and frequency in heat stressed cattle. Plasma inhibin content was lower in heat stress cows (Wolfenson et al; 1995) and cyclic buffaloes (Palta et al. 1997). The effects are more pronounced in buffaloes than cattle which may be due to high thermal load in this species as a result of difficulty in heat dissipation due to unavailability of place for wallowing and lesser number of sweat glands (Vaidya et al. 2010 and Shashikant et al. 2010). The higher thermal loads, if persisted for longer periods due to either non dissipation of heat or uncomfortable environment conditions, will affect production, reproduction and health on long term basis. Therefore, heat mitigation measures and strategies need to be adopted not only to reduce thermal stress but also to curtail fertility losses and other health consequences on animals.

Seasonal trends in reproductive functions

Heat stress has adverse effects on reproductive functions i.e. gamete formation and function, embryonic development, fetal growth and development. The potential impact of heat stress on a mammalian population can be seen by examining seasonal trends in reproductive functions of livestock species. Indeed, the effects of summer in lowering fertility is much less in non-lactating heifers and low producing cow compared with high yielding cows as reported by Badinga et al. (1985) and Al-Katanani et al. (1999). It is likely that the direct impact of global warming on mammalian reproduction will be more severe for domestic animals with high yielding genetic potential. In addition, the existence of allelic variation in genes regulating body temperature and cellular resistance to heat shock will be responsible and may be tool to manipulate genetic adaptation to increasing global temperature in various species of domestic animals.

Diurnal pattern of estrus behaviour has been observed in majority of Murrah buffaloes. About 60 % of Murrah buffalo exhibited estrus between 10 PM and 6 AM. Out of a total 460 observation recorded during the year, the maximum occurrence of estrus was seen during winter months (November to February) and the lowest during summer months (March to August Prakash, 2002. Due to high incidence of silent heat, large numbers of buffaloes are left un-bred during summer. The overall mean service period was 139 days in buffaloes. Season of calving had a profound influence on the service period in this species. The mean service period were 140 and110 days in animals calved from December to June and July to November respectively The longer service period of buffaloes in summer may be due to the high incidence of silent estrus (Prakash, 2002). The analysis of climatic data showed that temperature humidity index started increasing from February onwards in the afternoon and exceeds 75 for 2 to 3 hr in the afternoon of March. For more than 1500h during the year temperature humidity Index ranges between 76 and 80 and for other 1500h it ranges between 81 and 85. Severe heat stress days with temperature humidity index > 85 were from May to August. After onset of monsoon in June /July difference between morning and evening THI is reduced and buffaloes got some opportunity for relief from thermal stress. From May to June, THI with a value of > 80 increased by approximately 450% than March (65 hrs vs. 295 hrs). Low temperature and THI during nights in summer (April and May) provide an opportunity to buffaloes to dissipate heat during night hours compared to day hours. This may be the reason that buffaloes experienced less stress during hot dry season compared with hot humid season (Upadhyay et al. 2009).

Analysis of reproductive data for 10 years showed that cows and buffaloes have typical rhythmic patterns with 1 or 2 peaks during the year (Upadhyay et al. 2009 ?). The peak of reproductive activity in Zebu and crossbred cows was observed in March (near equinox) which coincided with the start of increase in sun shine days and subsequently through in reproductive behaviour was observed during peak solar radiation and hot days. Reproductive activity in buffaloes started increasing from July and reached at the peak during October. The expression of estrus and conception rate was recorded low during summer in crossbred cattle and buffaloes. The levels of estradiol 17ß on the day of estrus was significantly low during this period in both species. Low estradiol level on the day of estrus during summer period in buffaloes may be the likely factor for poor expression of estrus in this species (Upadhyay et al. 2009).

During heat stress, motor activity and other manifestations of estrus reduced (Nobel et al; 1997) and the incidence of anestrus and silent ovulation are increased (Gwazdauskas et al; 1981). Due to these effects a reduction in the number of mounts during heat stress compared to cold weather, leading to poor detection of estrus (Pennington et al; 1985).

Al-Katanani et al. (1999) examined 90-day return rates throughout the calendar year and found that summer infertility was greatest in the highest milk producing dairy cattle. Therefore, there is an additive effect of heat stress and greater milk production for decreasing conception rate in dairy cattle. The effects of heat stress can be directly related to the increase in rectal temperature of heat-stressed cows/ buffaloes during summer/ hot humid season . Ulberg and Burfening (1967) showed that small increases in maternal rectal temperature would cause decreased pregnancy rates in cattle. The increase in body temperature affects the reproductive tract and the early embryonic development. These changes in the reproductive tract influence the ability of a cattle to become pregnant during heat stress.

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Climate/ season and reproductive disorders

Study on 2289 calving records it has been observed that the overall incidences of reproductive disorders (dystocia, retained placenta and uterine prolapse) were 10.18 percent (Verma et al. 1982 reference?). The frequency of reproductive disorders in tropical (Hariana), temperate (Holstein Friesian) and crossbred breeds of cattle were 8.12, 20.31 and 9.36%, respectively. The incidences of reproductive disorders (based on 2434 calving) were higher from April-September, when ambient temperature and humidity were higher. The prevalence of retained placenta was highest during July-September. The overall reproductive disorders were maximum in September (16.26%) and minimum in November (6.22%). The magnitude of dystocia, retained placenta and uterine prolapse during the months of March were (3.47%), September (13.01%) and May (3.36%), respectively as reported by Verma et al. (1982).

Seasonal effects on reproductive disorder associated with calving in cattle have been observed by Verma et al. (1986). The author observed that the reproductive problems were highest during rainy season (14.87%) and lowest during winter-season (7.44%). Occurrence of retained placenta, dystocia and urethra prolapse was 11.27, 2.38 and 1.88%, respectively in unfavourable summer/rainy season (It may be interesting to discuss some possible reasons for the seasonal effects on these reproductive disorders). The increased intervention of man in regulating behavior and environment of livestock so as to exploit the best of their genetic potentials has led to an increase in the incidence of the reproductive disorders. This scenario is further aggravating due to more emphasis on selection and rearing of animal for specific commercial purposes, which compromises livestock reproduction and creates fertility problems. Underfeeding coupled with high environmental temperature stress was also incriminated for long anestrous and anovulatory periods. Inadequate nutrient intake has been found to deplete body energy reserves resulting in extended interval from calving to first estrus. Season of calving had influence on the reproductive performance (Khan et al.,2009).

Projected climate change impact (2100 AD) on reproductive functions:

A rise in temperature by >4°C due to global warming is likely to impact cattle and buffaloes negatively. The rise in stressful days (THI< 80) from 40 at present to 104 days for A2 scenario and 89 days for B2 scenario for time slice 2079-2099 will further delay the sexual maturity and puberty in cattle and buffaloes. The increase in thermal stress days by 260% will negatively impact estrus expression/ ovarian activity and conception rate in cattle and buffaloes (Upadhyay et al. 2009). The effect may be much more pronounced in buffaloes, temperate and crossbred breeds compared to indigenous breed of cattle due to poor adaptability of these species to tropical climatic conditions. Shortage of feeds/ fodders and scarcity of water will further impact milk production, reproduction and health of animals negatively on a long term basis (Upadhyay et al; 2009).

Studies based on projected global climate change models, showed that changes in climate would lead to decrease in milk yield and conception rate in dairy cows (Hahn et al., 1992 and Klinedinst et al., 1993). Hahn (1995) further reported that conception rates in dairy cows were reduced 4.6% for each unit change in THI, when the THI reaches above 70. Amundson et al. (2005) reported decrease in pregnancy rates of Bos Taurus cattle of 3.2% for each unit increase in average THI 70, and a decrease of 3.5% for each increase in average temperature above 23.4° C. Amundson et al (2006) further reported that the environmental variable i.e. minimum temperature of the day had the greatest influence on the percent of cows getting pregnant. Clearly, increase in temperature and/or humidity have the potential to affect the conception rates of domestic animals which were not adapted to these conditions. The number of changes in reproductive performance due to further global warming will include:

- Decreased duration and intensity of the estrus period.
- Decreased conception (fertility) rate.
- Decreased size and development of ovarian follicles.
- Decreased fetal growth and calf weight at calving.
- Increased risk of early embryonic losses.
- Increased number of artificial insemination per conception.
- Increased incidence of silent heat in buffaloes.

Projected economic losses due to heat stress/ climate change

A decline in milk yield of lactating cows and buffaloes is observed during summer and rainy seasons due to high temperature and humidity. Studies on crossbred cows and buffaloes have revealed that high THI negatively impacts milk yield that occur due to increase in body temperature and other related reasons (Upadhyay et al, 2009). Therefore, a major challenge for high producing crossbred cows and buffalo under tropical environment is thermal stress. The loss in productivity on account of thermal stress is higher in crossbreds (about 100 lit/ cow/ year) than Indigenous cattle and buffaloes (about 20 lit/ animal/ year). The annual loss of milk due to thermal stress on livestock is about 1.8 million tonnes, which is about 2 percent of the total milk production in India. This amounts to Rs. 2661.62 crores (at current prices). The annual loss in milk production of cattle and buffaloes due to thermal stress by 2020 will likely be about 3.4 million tonnes which will cost more than Rs.5000 crores at current prices (Upadhyay et al, 2009). The heat in terms of thermal stress on account of global warming will increase number to 104 stress days by 2100 due to rise of more than 4 °C. It will accentuate the magnitude of economic losses attributable to heat stress. The loss in milk production due to climate change of dairy animals will be about 15 million tonnes by 2050. High milk producing crossbred cows and buffaloes will be impacted more than indigenous cattle. Northern India is likely to experience greater impact of global warming on milk production of both cattle and buffaloes in future. The improved understanding of the impact of temperature will help in developing management techniques to alleviate thermal stress (Upadhyay et al, 2009).

CONCLUSION

The studies indicated that high temperature adversely affected production and reproduction in buffaloes and cattle. The reproductive efficiency in these species decreased considerably. The frequency, intensity and duration of estrus decreased due to adverse climatic conditions in the summer season. Conception rate falls between 20-30% in summer compared to winter. Reproductive disorders viz. Dystocia, retained placenta and uterine prolapsed were higher in crossbreds compared to native breeds of cattle and their incidences were higher in September compared to November. Incidences of anestrus, silent estrus were more in buffaloes during summer period. Increase in temperature due to global warming is likely to further reduce the reproductive efficiency and milk production of livestock species. Earth's temperature has increased between 0.3-0.6°C over the pre industrial time and likely to rise by 1.8-4.0 °C by the end of this century. This will increase the stress level on livestock species, since the stressful days will increase by 260% during this period over the present time. Therefore, it will be imperative to modify the managemental practices of cattle and buffaloes as per the climatic conditions. It requires development of suitable breeds by selection of cattle and buffaloes species which are more tolerant to heat stress and can sustain the productivity in the changing climatic scenario. Dairying in tropical countries like India will change as the conditions change, even at farmer's field, but climatic conditions will ultimately be the limiting factors for livestock production system. Modification of micro environmental conditions in the tropics is very important particularly for high producing European and crossbred breeds of cattle and buffaloes compared to heat tolerant breeds (Zebu).

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