



Climate Resilient Animal Husbandry – A Review

Samir Kumar Das

ICAR- Indian Veterinary Research Institute, TEC, Shivajinagar, Pune - 411005, Maharashtra, India

*Corresponding Author: skdashasabad@rediffmail.com

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Abstract

Livestock is vulnerable to different climatic stressors such as high air temperature, relative humidity, solar radiation, high wind speed, flood, drought, desert, heatwave, feed, fodder, and water scarcity, etc. which now seems to be very common in the tropical and subtropical climatic conditions of India. Due to the rapid growth of the human population, demand for milk and meat is increasing day by day. The climate change scenario is assumed to be a major threat to animal production systems under a tropical climate. So, climate-resilient animal husbandry has become the need of the hour for sustainable livestock production which would be one of the remedies for fulfilling the demand of the fast-growing population of India. The objective of this review is to focus on the impact of climate change on livestock production, poultry production, feed and fodder availability, reproduction, disease of livestock, different adaptive and mitigation measures to overcome the adverse impact of climate change on livestock and its production.

Keywords: Adaptation, Climate Change, Impact, Livestock production, Mitigation

Introduction

Livestock is an integral part of agriculture in India, more particularly in this state as most of the people due to multifarious reasons depend on the animal for their economic support. It contributes about 4.11 % to GDP and 25.6 % to total agricultural GDP. It employs more than one billion people and thus creates a livelihood for more than one billion people living in poverty (Steinfeld *et al.* 2006). Climate Change poses a formidable challenge to the development of the livestock sector in India. The rise in temperature between 2 to 3 °C over the entire country resulting from climate change together with increased humidity is likely to aggravate the heat stress in dairy animals affecting the milk yield and growth of animals. India possesses the second largest number of cattle next to Brazil (13 % of the world population), and the largest number of buffaloes (56 % of the world population) in the world (FAO, 2014). It is reported sporadically in different countries of the world including India that climate change has adverse effects on livestock production, particularly on milk production and growth which is reflected in meat production. So, climate-resilient animal husbandry has become the need of the hour for sustainable livestock production.

Impact of Climate Change on Livestock

Impact on Milk Production and Growth

Livestock is homoeothermic which means that they must maintain their body temperature within a relatively narrow zone to remain healthy and productive. The ambient temperature above or below the thermoneutral zone produces stress on the animal which ultimately hampers growth, production, and reproduction. The upper limit of the thermoneutral zone (TNZ) i. e. upper critical temperature is more significant for livestock under tropical and subtropical climates. It is lower in exotic breeds and their crosses than in indigenous breeds. The upper critical temperature for Haryana bulls is 32.0°C, but for its crosses having 50% exotic inheritance of Holstein Friesian, Brown Swiss and Jersey is 26.5°C, 27.5°C, and 29.0°C, respectively (Singh and Bhattacharyya, 1985). Four environmental factors influence effective temperature: 1) air temperature, 2) relative humidity, 3) air movement and 4) solar radiation. The temperature-humidity index (THI) is commonly used to indicate the degree of stress on dairy cattle. It is measured by the formula, $THI = Dbt \text{ in } ^\circ F - (0.55 - 0.55 \times RH \%) (Dbt \text{ in } ^\circ F - 58)$. When the THI exceeds 74, high-producing dairy cows have affected adversely. Livestock Weather Safety Index (LWSI) was developed to classify the combined intensity of temperature and humidity into four categories of THI values: THI less than or equal to 74 is **Normal**, THI 75–78 is **Alert**, THI 79–83 is **Danger** and THI value 84 and above is **Emergency** condition. Experience over time suggested that the THI - based LWSI was a valuable tool for producers, even though it lacked recognition of the effects of thermal radiation and wind speed. Warnings, with respect to these categories, were issued by the United States Weather Bureau to alert producers to potential heat stress conditions (Nienbar and Hann, 1998).

Dairy cows respond to heat stress in several ways: 1) reduced feed intake, 2) increased water intake, 3) changed metabolic rate and maintenance requirements, 4) increased cutaneous evaporated water loss, 5) increased respiratory evaporated water loss, 6) changed blood hormone concentration i.e. decreased concentration of oestradiol, LH, progesterone and 7) increased body temperature. European-type cattle are considered to be comfortable in the temperature range of 5 to 20°C, i. e. within this zone, there is no heat stress problem. Body temperature is maintained with a minimum expenditure of energy, thus leaving a maximum of energy for production processes.

With increasing environmental heat load caused by high temperature, intensive solar radiation, high humidity, low air movement or a combination of several of these factors, defense mechanisms against overheating - sweating and panting come into operation. If cooling derived from these activities is insufficient, body temperature rises. This depresses appetite, which in turn reduces the production of meat and milk. The hot environment negatively affects the appetite center of the hypothalamus causing a reduction in feed intake (Silanikove and Koluman 2015). Berman (2005) determined environmental threshold temperatures for dairy cows based on environmental factors and characteristics of the cows. Environmental factors included temperature, humidity, wind speed, and direction, while cow characteristics included body weight, milk production level, and hair coat colour. The threshold temperatures signaled when environmental intervention should begin in order to limit production loss.

The ability to withstand heat varies considerably. Heat tolerance is low in young animals, in animals that are on a low level of feeding, dehydrated, in high producing, and in non-acclimatized animals. It is also low in European-

type cattle as compared with Indian-type cattle. At a temperature of 29° C and 40 % relative humidity the milk yield of HF, Jersey and Brown Swiss cows was 93, 97 and 98 % of normal, but when relative humidity was increased to 90 %, yield was reduced to 69, 75 and 83 % of normal. So, high relative humidity affected HF breed of cattle maximum. It was reported that when a lactating HF cow was transferred from an air temperature of 18°C to 30°C, milk fat, solids-non-fat and milk protein percentage decreased by 39.7, 18.9 and 16.9 % respectively. So, fat % of milk is affected mostly due to high air temperature. Hahn, 1999 reported the thermal comfort zone for optimum performance of adult cattle is 5 - 15 ° C. However, significant changes in feed intake and physiological processes do not occur even up to 25 ° C. However, it was reported that in the Indian conditions' the temperature limit of the comfort zone for maximum milk yield was 27 ° C, about 2 ° C higher than the same reported in temperate countries. This was due to the adaptation of crossbred cows developed through crossing between an indigenous cow with the exotic bull of Jersey, Brown Swiss, and Holstein Friesian breed. Studies have shown that the milk yield of the crossbred cow was negatively correlated with Temperature Humidity Index (Mandal *et al.*, 2002a). The average daily milk yield of crossbred cows in the hot humid eastern part of the country was significantly reduced by rise in minimum temperature but not maximum temperature as rising in minimum temperature crossed the zone of thermoneutrality in cows. It was observed that dry matter intake in cattle declined with the increase of T max, THI during hot summer, and the hot humid rainy season (Upadhaya *et al.*, 2007). This was due to the adverse negative effect of high temperature on the appetite centre of the hypothalamus. The influence of climatic conditions on milk production was also observed in Haryana cows. The rising temperature decreased dry matter intake and milk yield (Lal *et al.*, 1987). The milk yield of Sahiwal cows also exhibited a declining trend due to an increase in temperature and relative humidity (Mandal *et al.*, 2002b). The hot environment not only affects the quantity of milk, but also the quality of milk. The milk yield and the milk composition (Fat, SNF) of Nili- Ravi buffaloes were affected significantly during hot dry and hot humid conditions in tropical climates (Das *et al.* 2016; Das *et al.* 2014). Upadhyay *et al.* (2009) estimated a 2% loss of milk production due to thermal stress in India. It has also been expected that 3.2 million tons reduction in milk yield by 2020 and more than 15 million tons reduction of milk yield by 2050. Das (2012) in a study at ICAR - ICAR Research Complex for Eastern Region, Patna, observed that air temperature (AT), effective temperature (ET), temperature humidity index (THI) had a highly significant ($P < 0.01$) effect on average daily milk yield, average weekly milk yield, average monthly milk yield, daily total milk yield of crossbred cows. However, relative humidity had a highly significant ($P < 0.01$) effect on the average weekly milk yield and average monthly milk yield of cows. It was found that average daily milk yield, average weekly milk yield, average monthly milk yield, and daily total milk yield of cows were reduced significantly by 0.886, 1.868, 2.471 and 4.375 kg respectively per unit increase of the temperature-humidity index. It was also observed that average weekly milk yield and average monthly milk yield were decreased significantly by 0.062 and 0.069 kg respectively per % rise of relative humidity. Milk yield was significantly decreased by 0.12 (1.2%) kg for each unit increase of THI above 74 in Holstein Friesian cows (Sadek *et al.*, 2015). It was also reported that the growth of crossbred cattle and buffalo was more sensitive to a rise in THI than Zebu cattle. Time to attain puberty was observed to prolong by 5 - 17 days due to a decline in growth rate at high temperatures.

Impact on Different Cardinal Physiological Reactions

It was also revealed that different months had a highly significant ($P < 0.01$) effect on all the cardinal physiological reactions ie rectal temperature, respiration rate, and pulse rate of growing calves in different months due to the change of all the micro climatological components. Regression analysis revealed that AT and RH had a significant ($P < 0.05$) effect but THI and ET had a highly significant ($P < 0.01$) effect on the rectal temperature of calves (Das, 2012). All the micro-climatological components had a highly significant ($P < 0.01$) effect on respiration rate. It was also observed that rectal temperature and respiration rate were increased significantly ($P < 0.05$) with the unit increase of AT, RH, and THI. Similar findings were also observed by several workers (Kamal *et al.*, 2016; Chaudhary *et al.*, 2019). But pulse rate of calves was increased non - significantly with the unit increase of AT, RH, and THI (Das, 2012). A positive correlation between temperature, relative humidity, and rainfall with that of pulse rate, respiration rate, and body temperature was recorded in cattle. The physiological responses are well studied in dairy cattle and buffalo under heat stress. The RR was found to be higher in crossbred cattle than Zebu cattle during hot humid seasons under tropical climatic conditions (Bhan *et al.* 2013; Maibam *et al.* 2014; Mehla *et al.* 2014).

Impact on Animal Reproduction

Reproduction is the backbone of production which might be affected due to elevated temperature in both sexes. It is reported that the length and intensity of the estrous period decrease with the increase of temperature, therefore

less conception rate occurs. The conception rates of dairy cows decreased by 20 – 27 % in summer (Chebel *et al.* 2004). So heat stress may reduce the fertility of dairy cows in summer by poor expression of oestrus due to a reduced estradiol secretion from a dominant follicle. In these situations, the calving interval becomes longer. So, lifetime production of dairy animal comes down. Heat stress during pregnancy slows down the growth of the foetus due to decreased blood supply in the uterus which causes insufficiency of placenta to provide maternal nutrient, so decreased fetal growth and calf size occur. Even there is early embryonic death in heat-stressed cows (Samal, 2013). Heat stress is one of the factors of poor semen quality of crossbred and exotic bulls under tropical climatic conditions (Soren *et al.* 2016). It negatively affects spermatogenesis. Semen production and concentration are reduced. It is reported that semen volume, number of spermatozoa, and motile cells per ejaculate of bulls are lower in summer than in winter and spring. Bhakat *et al.* (2014) also reported a significantly higher percentage of total abnormalities of spermatozoa (head, mid-piece and tail abnormalities) during hot-dry and hot-humid seasons compared to winter. The higher sperm abnormalities, and sperm DNA damage with reduced fertility were observed during the summer season (Valeanu *et al.* 2015).

Impact on Egg and Meat Production in Poultry

The thermoregulation characteristics of poultry differ to some extent from those of mammals due to their high rate of metabolism associated with more intensive heat production and low heat dissipation capacity caused by their feathers and lack of sweat glands. Above 30° C the feed and energy intake decline to such an extent that birds are no more able to compensate for it, production declines rapidly and the rate of mortality increases. Several studies reported that high ambient temperatures decrease the digestibility of nutrients in poultry likely due to a reduced activity of trypsin, chymotrypsin, and amylase (Hai *et al.*, 2000). Consequently, the insufficient nutrient supply limits egg production, egg mass and shell quality of egg in layers, and the growth rate in broilers.

Impact on Feed and Fodder Production

Shortage of feed and fodder to the tune of 40 % dry fodder, 36 % green fodder, and 52 % concentrated on dry matter basis and poor-quality roughage, primarily crop residues, is already one of the major constraints in the expression of the full genetic potentiality of livestock in India. Higher temperatures increase lignin formation in plant tissues and thereby reduce the digestibility and rates of degradation of fodder and crop residues in the rumen of animals. This will lead to reduced nutrient availability for animals and ultimately to a reduction in livestock production. So, in view of this situation of feed and fodder availability, the adverse impact of climate change on crop production will further increase the gap between the availability and requirement of feed and fodder.

Impact on Disease Incidence

It is reported that a high incidence of clinical mastitis and increased milk somatic cell counts in dairy cattle occur during hot summer months. Reduction of thermal stress by air conditioning or shade management resulted in a lower frequency of clinical mastitis than for cows exposed to their natural environments. Singh *et al.* (1996) reported a higher incidence of clinical mastitis in dairy animals during hot and humid weather due to increased heat stress and greater fly population associated with hot–humid conditions. Kumar *et al.* (2004) reported that the hot–humid weather conditions were found to aggravate the infestation of cattle ticks like *Boophilus microplus*, *Haemaphysalis bispinosa* and *Hyalomma anatolicum* which renders a higher incidence of blood protozoan diseases like Trypanosomiasis and Babesiosis in high yielding crossbred cattle. The higher temperature and rainfall increase the prevalence of livestock diseases. If rainfall increases, certain existing parasitic diseases may become more prevalent, or their geographical range may advance (Singh *et al.*, 2018)). The emergence or re-emergence of zoonotic diseases is also likely to be expected due to climate change (Taylor *et al.* 2001).

Adaptation Measures

Adaptation by Housing and Management Intervention

Adaptation with reference to climate change is referred to as the adjustment or preparation of natural, human, or livestock systems to a new or changing environment that moderates harm or uses beneficial opportunities. Adaptation can reduce the current risks of climate change impacts and can be used for addressing emerging risks. Dairy cattle production in hot climates may be improved in two ways: (1) by adapting the animal to the climate

through selection, breeding, and acclimatization; (2) by adapting the climate to the animal by providing protective structures and cooling devices. The first way poses a biological, the second a technical problem. For the solution to both these problems, it is important to know the qualitative and quantitative responses of the animal to various degrees of heat stress.

It was observed that the adverse effect of heat stress i.e. reduction of milk yield was found to be least in indigenous cattle i.e. Sahiwal and Deoni than that of Jersey and Red Sindhi cross. So, promoting indigenous breeds for rearing is one of the adaptation strategies as those are more heat tolerant than cross bred and exotic breeds of animals. Some of the Zebu breeds (Tharparkar, Nagori, and Sahiwal) are well adapted to hot dry desert conditions and are able to reduce their metabolic requirements to a minimum and conserve energy for diversion to production (milk and /or work) without extra energy expenditure. These mechanisms are rarely found in livestock species located in other areas (Singh *et al.* 2014).

The blood flows in the periphery are not only important for nourishment but also for sufficient exchange of heat dissipation from the core to the surface of the body and to the environment. The peripheral blood flow increases to dissipate the heat via conduction and convection. The skin of Zebu cattle is soft, smooth, and clean due to the superior skin blood circulation as compared to crossbred cattle. The blood flow was positively correlated with the temperature of the body parts and it varied in different seasons (Singh *et al.* 2014). Heat stress activates various physiological functions to decrease the heat and enhance the heat release via conduction, convection, radiation, and evaporation. Evaporation involves sweating rate and respiratory rates (Al-Haidary *et al.* 2001). Evaporative cooling by sweating and panting is the most important mechanism for body heat dissipation under elevated hot climates (Collier, 2008). However, heat loss by panting becomes effective, if the excess heat is not dissipated successfully by sweating and its capacity is impacted by the genetic makeup of cattle. It was found that 84 % of heat was lost by evaporation, of which 65 % was lost by sweating and 35 % was lost by panting. Cattle utilize evaporative cooling in the form of both sweating and panting in an effort to get rid themselves of excess body heat when environmental temperatures begin to exceed 35°C and THI of 90 (Collier, 2008). Coat characteristics are associated with heat tolerance and the performance of animals (Dandage *et al.* 2010, Collier and Collier, 2012). Heat stress initiates a complex program of gene expression and biochemical adaptive responses (Fujita, 1999). Heat shock proteins (HSPs) is a highly conserved stress protein reported to have a significant role in heat tolerance and adaptation of livestock breeds. HSPs are activated manyfold during the summer season in cattle and buffaloes. HSPs play an important role in protecting cellular damage under thermal stress. It involves an important physiological role to cope with heat stress (Banerjee *et al.* 2013, Kumar *et al.* 2015).

Livestock management, in reality, is the manipulation of the animal environment to promote the most efficient production of meat, milk, and wool. A better understanding of climatological stress and adaptations will greatly enhance managerial capabilities (Stott, 1981). Several management practices are available to ameliorate heat stress, each with positive and negative properties. Housing provides the most potential control over environmental stressors; however, it comes at a relatively high initial investment cost per head.

Shade for livestock is considered essential to minimize the loss in milk production and improve reproductive efficiency. Shades can improve animal comfort and productivity and should be designed to maximize ventilation and protection from the solar load. It is reported that a well-designed shade would reduce the heat load on animals by around 30 - 40 %. Adequate shade also improved the conception rate. Conception rates were significantly higher for shaded cows (44.4 %) than for no-shade cows (25.3 %). The provision of shade helped in maintaining productive performance (Blackshaw and Blackshaw, 1994). Providing shade to Holstein Frisian during summer showed a significant increase in milk production as compared to cows without any shade. In treated cows, milk production was 3 % higher as compared to control cows. The best height for cattle shades would be 10 to 12 ft. The top of a shelter should be painted white, so as to reflect much of the incident solar radiation; the underside should be painted black, so as to reduce the radiant heat reflected from the ground onto the animals. Kamal *et al.* (2014) reported that whitewashing of the rooftop with the microfine lime powder was able to reduce the mean temperature of the shed by 2–3°C. Crops provide cooler surroundings for a cattle shelter than bare ground. Tree plantation in an animal shed produces a long-term cooling effect on the animal. The design and management of shade for dairy cattle vary in different areas and climates. A shaded space of 60 square feet per animal is considered adequate. The larger space allotments provide a more open area for ventilation, which is a critical factor in a hot, humid climate. Cattle shades should be designed and orientated in such a way that the animals are exposed to a large proportion of the cool sky. Das *et al.* (2015) observed in a study that the orientation of cattle shed had a significant effect on the microclimate

of the shed and milk yield of a crossbred cow in a coastal region. The clear north sky acts as a cold sink. Hence, under an extremely hot, low rainfall (10 to 12 cm) climate, an east-west orientation is preferable as the ground under the shade will remain cooler. Orientation with the long axis north and south will expose the area under the shade to the morning and afternoon sun and assist in keeping it dry. So, this type of orientation of shed is suitable in sub temperate to the temperate climate of hilly regions.

Extensive comparisons of shade materials and the impact of the orientation of the shed on the microclimate of shade were studied by different workers. Hay is proved to be suitable low-cost roofing material for cattle shades. However, corrugated steel sheet is the most popular shade material because of its durability and low maintenance requirements. Elimination of direct solar radiation is essential since the radiated heat load imposed on an animal by the midday sun is several times greater than the metabolic heat generated by the animal. Reduction of indirect radiation would be to a minimum. This is achieved by the absence of objects, such as nearby buildings, heavy wooden fences, etc, which absorb heat and radiate it onto the animals. A false ceiling with low-cost materials in the shed was proved in a study to reduce heat stress in cattle and buffalo (Das *et al.* 2015).

Minimal interference with convective and evaporative heat loss from the animals, ie allowing natural air movement to carry heat and moisture away from the surface of the animals. The ventilation system within livestock housing is a very important factor and greatly affects the initial investment, energy consumption, and cooling capacity. Cross ventilation is highly desirable to reduce heat load in an animal shelter. Increasing air movement with fans, help to increase animal comfort and milk production. The fan should be fitted in a cattle house @ one fan / 25 sq meter of space at a height of 8 - 9 ft from the floor.

Evaporative cooling systems have improved the environment for lactating dairy cows in arid climates. These systems use high pressure, fine mist, and large volumes of air to evaporate moisture and cool the air surrounding the cow. There are questions regarding the effectiveness of evaporative cooling systems in climates with high relative humidity because when relative humidity increases above 70 %, the potential reduction in THI is less than 10 %. The significant impact of evaporative cooling was observed during late gestation in Murrah buffaloes during the summer season under tropical climatic conditions. The milk yield, FCM, fat yield, lactose yield, and total solid yield were recorded higher in cooled buffaloes, indicating the importance of cooling during the summer season (Aarif and Aggarwal, 2015). The physiological response (RR, RT, and PR) and skin temperature at the thorax were lower in cooled Murrah buffalo than in non-cooled buffaloes (Aarif and Aggarwal, 2016). It was reported that evaporative cooling in buffaloes improves the conception rate during the summer season [Verma *et al.* 2016].

Installation of foggers in the shed: Foggers disperse a very fine droplet of water which quickly evaporates, cooling the surrounding air and raising the relative humidity in the process. The design incorporates a ring of fogger nozzles attached to the exhaust side of the fan. As fog droplets are emitted, they are immediately dispersed into the fan's air stream where they soon evaporate. Animals are cooled as the cooled air is blown over their body and as they inspire the cooled air. Fogger systems are most effective in areas of low humidity. They are advantageous in the fact that they use less water (3-5 gallons/cow/day). Water filters must be cleaned or checked daily to prevent clogging of fogger nozzles. High-pressure foggers should be used only in the open-sided, ridge-vented, long shed. A small shed with side walls restricts airflow and evaporation of fog droplets. This reduces cooling and makes for excessively wet conditions in the barn (Bucklin *et al.* 1991).

Mist Cooling System: Mister cools the air by the same principle as a fogger, animals are cooled primarily by inspiration of the cooled air, but a mist droplet is larger than a fog droplet. This system does not work well in windy conditions. In warm humid environments, mist droplets are too large to fully evaporate and set to the ground. The consequence is wet bedding and feeding which is a predisposing factor to respiratory disease.

To achieve greater heat losses from animal surfaces, droplets of water must wet the hide, as it is the drying process from the animal's hide that removes heat from the animal. So, in a study, it was observed that sprinkling cold water on the body surface of an animal followed by air circulation by electric fans for an hour twice daily before milking was found to be very effective for reducing heat stress and increasing milk yield (Bucklin *et al.* 1991). Wolfenson *et al.* (2000) reported an improvement of milk yield by 3.5 kg/day in cows cooled with water spray and fans during the dry period. Cows housed in pens and cooled by water spray and fans showed a great improvement in milk production, milk fat and postpartum reproductive performance (conception rate and days open), calf birth weight compared to non-cooled Holstein Friesian cows in hot and dry conditions during the dry period (Reyes *et al.* 2010).

Seerapu *et al* (2015) reported that the use of fans and foggers reduced the respiration rate of animals.

Modern technology can easily provide fully air-conditioned animal houses thereby completely eliminating any heat stress problem. However, the cost of milk and meat produced in such a way would in most instances is high. It was reported that air conditioning in dairy sheds for 24 h / d improved milk yield by 9.6 % in a subtropical environment. However, a workout on the cost of milk production indicated that air conditioning was not economical. New possibilities for cooling animals should be explored. Examples of this line of approach are the cooling of animals by applying cooled air on their head and neck, a method tried out successfully by American workers. It was reported that zone-cooled cows (cooled air blown over the head and neck) produced on an average 19 % more milk yield than controls, although other scientists reported that it was not also economical (Collier *et al*, 2006). Cooling pond effectively reduces body temperature in dairy cows. The primary mode of heat loss in the cooling pond is conduction with a small amount lost by evaporative cooling after exiting the pond. The water temperature of the pond would be lesser than the skin temperature of the cow, thus a heat transfer gradient between the cow's body and the pond water was operative. This is a common practice of reducing heat stress in buffalo and is called wallowing. Yadav *et al*. (2016) reported that the increase in milk yield was more due to wallowing in the hot humid season than misting in Murrah lactating buffaloes. The availability of drinking water eliminates the need for the animals to move into the sun when obtaining water. Moreover, water should be available round the clock, particularly in the hot summer season. Handling of animals during peak temperature hours *i. e.* midday to late afternoon should be avoided to reduce heat stress. Other species of domestic animals than cattle are faced with similar hot climate problems. They all benefit from an artificially cooled indoor climate. New ways should be sought for providing inexpensive hot climate shelters and for reducing the costs of artificial cooling, thus making environmental control an economically more efficient tool. A Livestock Safety Monitor (LSM) has been developed by Eigenberg *et al*. (2007), to provide an early warning device to producers based on current weather conditions. The LSM uses current weather parameters of temperature, humidity, airspeed, and solar radiation to determine heat stress.

Adaptation by Nutritional Intervention

Take feed to cows, rather than cows to feed in hot weather. Walking to feed increases a cow's heat load, so reduce their walking during the hottest time of the day. Allow cattle grazing at night time in hot weather to reduce heat stress. So, night grazing may be practised for 2-3 hr to fulfil nutrient requirement partially and have sufficient exercise for normal physiological function. Highly digestible high-energy rations are an effective form of summer diet to help animals to control body temperature by reduction of excess heat. Providing cool drinking water and a low fiber diet renders comfort to the animals. Water is the most important nutrient in minimizing heat stress since it acts as a heat sink; therefore, heat is transferred from the cow's body to the ingested water (Mahajan *et al*, 2015).

Bypass fat was proved in a study to reduce heat stress in cattle and buffalo around 18 - 20 % (Terada, 1996). Feeding of dietary rumen bypass fat is an effective source of energy during summer to combat the negative energy balance. An increase in the milk yield was observed by Wang *et al*. (2010) in fat supplemented animals. Melo *et al*. (2016) reported that supplementation of palm oil significantly reduced rectal temperature and respiratory frequency, increased milk yield and feed efficiency in lactating cows.

Heat stress ruminant showed to undergo negative nitrogen balance, so supplementation of bypass protein is beneficial for maintaining energy requirement during heat stress (Kunduet *et al*. 2013). Bypass protein (formaldehyde treated mustard cake) increased 15 % milk production (Walliet *et al*. 2005).

Increase the concentration of minerals and vitamins in the diet to compensate for the reduction in feed intake, particularly sodium, potassium, magnesium and niacin levels in the diet. Supplementing cows ration with 1.5 – 1.6 % of potassium and 0.5 – 0.6 % of sodium will potentially improve milk yield in heat-stressed cows. Include magnesium @ 0.35 – 0.40 % in feed help to avoid metabolic problems (grass tetany) when feeding higher amounts of potassium. Dietary inorganic chromium supplementation in summer-exposed buffalo calves improved heat tolerance, immune status and potency of insulin hormone (Kumar *et al.*, 2015). Supplementation of Zn (120 and 80 ppm) reduces the postpartum estrus interval, days to first insemination, service period, services per conception and increase the conception rate in Karan Fries cows (Patel *et al.*, 2017)

Including niacin @ 6 g / cow / day in feed may also be beneficial. It has been reported to reduce skin temperature and increase milk yield (West, 2003, Zimbelman *et al*. 2013). Mechanism of niacin to counteract heat stress is at

cellular level by stabilizing cellular protein structure by increasing Heat shock protein (Hsp) production. These proteins protect cells against heat stress by refolding proteins in the cytoplasm which have been denatured by high temperatures. It has been observed that expression of Hsp 70 is increased up to 20 fold when subjected to chronic thermal stress (Collier *et al.* 2006). The Hsp 70 helps in conferring the thermo adaptability and high level of thermotolerance. A recent study has shown that intracellular Hsp 70 expression in buffaloes is similar to the other livestock species (Singh *et al.*, 2018).

Improvement in milk yield has also been reported by feeding sodium bicarbonate @ 150 – 200 g / cow / day during hot weather to buffer the rumen. The use of antioxidants such as Vitamin - E, Vitamin - A, selenium helps in reducing the impact of heat stress by oxidant balance, resulting in improved reproductive efficiency and animal health (Sejian *et al.*, 2014). Vitamin-E supplementation to Murrah buffalo calves also improved the growth rate, metabolic and endocrine profile (Singh *et al.* 2012). The studies carried out on heifer and lactating buffaloes during thermal stress demonstrated the ameliorative effect of Vitamin - E against thermal stress (Lallawmkimiet *et al.* 2013). The combination of vitamin E and Zn supplementation showed an improvement in immunity during peripartum period of Sahiwal cows. The higher concentration of total immunoglobulin and interleukin2 were recorded in the plasma of Sahiwal cows after calving as compared to non-supplemented cows (Chandra *et al.*, 2014).

Vitamin C supplementation has been found to ameliorate the heat stress and act as immune-modulator (Ganaie *et al.* 2013). Amlahas strong antioxidant properties and one of the most potent sources of vitamin C. It is rich in amino acids, tannins and flavonoids that are known to protect the body against free radicals. Therefore, use of amla powder as an antioxidant can be of practical importance to ameliorate the adverse effect of heat stress in buffaloes (Singh *et al.* 2018).

Adaptation by the Reproductive Intervention

Progesterone supplementation during early pregnancy has proven beneficial in some studies. Supplementation of exogenous progesterone during summer heat stress has the potential to improve fertility. Friedman *et al.* (2011) reported that heat synchronization with GnRH and PGF2 α also improves fertility. The use of embryo transfer technology (ETT) is considered a potential strategy for minimizing the negative effects of heat stress on bovine reproduction (Baruselliet *al.*, 2011).

Contribution of Livestock to Climate Change

The animal production system, which is vulnerable to climate change, is itself a large contributor to global warming through emission of methane and nitrous oxide. There are two sources of GHG emissions from livestock: (a) From the digestive process: Methane is produced in herbivores as a by-product of 'enteric fermentation,' a digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption in the gut of the animal into the bloodstream. (b) From animal wastes: Animal wastes contain organic compounds such as carbohydrates and proteins. During the decomposition of livestock wastes under moist, oxygen free (anaerobic) environments, the anaerobic bacteria transform the carbon to methane. Animal wastes also contain nitrogen in the form of various complex compounds. The microbial processes of nitrification and de-nitrification form nitrous oxide, which is emitted into the atmosphere. India emerges as the largest contributor to the livestock methane budget, simply because of its enormous livestock population, although the emission rate per animal in the country was much lower than in the developed countries. For instance, the annual methane production per animal was estimated to be 95 kg for the dairy cows in Germany, which is much higher than the Indian cattle which produces around 35 kg (Crutzen *et al.* 1986). The enteric fermentation emission factors for cattle recommended by Inter-Governmental Panel on Climate Change (IPCC, 2001) for national GHG inventories are also much higher for the developed countries compared to the Indian sub-continent.

Methane production in livestock is related to the level of feed intake and digestibility of feed. The differences in per head emissions are due to lower levels and poor quality of feed intake by livestock in India. The livestock characteristics (age, weight, and species), health, and living conditions influence the energy requirement. Higher methane production results from higher energy requirements and feed intake. The energy requirement of Asian cattle species *Bos indicus* is about 10 % lower than European and North American cattle species *Bos taurus* (NRC 1996). In Indian conditions, the animals are mostly fed on poor quality roughages of low digestibility and emit less methane than exotic cattle of developed countries fed with a highly digestible good quality feed. The estimates of

total enteric emissions of methane from Indian livestock vary from 6.17 to 10.40 Tg / year (1 Tg = 1 million tons).

Mitigation Measures

Several mitigation options are available for methane emissions from livestock. In India, the possibility of preventing emissions from animal manure storage is limited as it is extensively used as fuel in the form of dry dung cakes. Hence, the scope of decreasing methane from livestock largely lies in improving rumen fermentation efficiency. There are a number of nutritional technologies for improvement in rumen efficiency like diet manipulation, direct inhibitors, feed additives, propionate enhancers, methane oxidizers, probiotics, and hormones (Sirohi and Michaelowa, 2007). Field experiments in India involving some of these options have shown encouraging results with reduction potential ranging from about 6 to 32%.

Dietary manipulation through increased green fodder decreased methane production by 5.7 %. There is lower methane production when a higher amount of leguminous fodder is included in the diet due to lower crude fiber content, higher digestibility of leguminous fodder, and the faster rate of passage through the digestive system (Indira and Srividya, 2012). Methane emissions may be reduced by feeding more concentrate and reducing the intake of forage. Increasing the concentration in the diet of animals reduced methane production by 15 – 32 % (Singh and Madhu Mohini, 1999). This is because the fraction of feed converted to methane decreases when feed quality enhances (Garnett 2007). Feed conversion efficiency is improved when animals are fed concentrates and the growth rate improves. They reach slaughter weight sooner resulting in fewer emissions. Methane production tends to be lower when forages are ensiled than when they are dried. It means that silage making of fodder enhances digestibility, so reduces methane production. The methane mitigation by urea and molasses supplementation was reported to be 8.7 % (Srivastava and Garg, 2002).

There are a number of feed additives that have been proposed to decrease methanogenesis in the rumen for the reduction of methane emissions (Indira and Srividya, 2012). These are ionophores, antibodies, halogenated compounds (condensed tannins, saponins, or essential oils), and propionate precursors (fumarate and malate). Monensin (an ionophore) is a well-described rumen fermentation modifier that increases the production of propionate, which is a predominate gluconeogenic precursor in ruminants and thus improves the glucose status of heat-stressed cows (Pawer *et al*, 2018). The use of feed additive monensin could reduce methane emission by 21 % (De and Singh, 2001). Stimulation of propionate production could be the best alternative hydrogen sink to methane production in the rumen. Therefore, a strategy for abatement of methane production should be considered with a strategy to enhance propionate production. Vaccines are being developed that contain an antigen derived from methanogenic bacteria and an immunogenic preparation that reduces the activity of rumen protozoa (Sejian *et al*, 2010). Bovine somatotropin (bST) and hormonal growth implants do not specifically suppress methane formation but improve the animals' performance and thereby reduce methane emissions (Garnett, 2007). In IVRI rumen manipulation was developed to improve fibre utilization and to reduce methane emission to the tune of 12 % in CB calves and 25 % in buffalo. Reducing unproductive livestock numbers could be the best possible solution in countries where there are large livestock populations (513 million livestock in India) and who want to reduce their livestock-related greenhouse gas emissions. So, culling unproductive animals as far as possible would reduce methane production. Enteric methane emission/kg dry matter intake has been observed to increase under severe heat. So, the protection of animals from severe heat stress through proper housing and heat ameliorative measures will be effective in reducing methane emissions. In India major amount of dung from cattle and buffalo and all fecal material of all other livestock species is used as manure in agricultural fields which does not undergo much anaerobic fermentation. So, the share of GHG emissions from the manure management system was only 8 % of the global GHG emissions. Improvement in the disposal of farmyard manure *i. e.* its use for biogas production and use of biogas slurry in the field and in the pond as fish feed can reduce methane emission from manure. So, improved manure management *i. e.* biogas production would reduce methane emissions (Suriyasathaporn *et al*, 2006).

Conclusion

- Biometeorology has a key role in rational management to meet the challenges of thermal stress on livestock production systems.
- Animal housing and management is the high priority adaptation measure to minimize the effects of climate and climate change on livestock production. So, climate resilient shed may be constructed at Govt. livestock farm for training and demonstration purpose.

- While the focus is primarily on cattle in hot climates, the importance of dynamic animal responses to climate changes applies to all species and climates.
- Taking advantage of the genetic potentiality of indigenous breeds of animals.
- Risk management, by considering perceived thermal challenges, then assessing the potential consequences and acting accordingly, will reduce the impact of climate changes on sustainable livestock production.

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