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Global warming: Impact, adaptation and amelioration strategies for bovine under tropical climatic conditions

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ABSTRACT

Livestock are exposed to different climatic extreme events such as high air temperature, humidity, flood, drought, desert, heat wave, feed, fodder and water scarcity etc. Which are now seems to be very common in the tropical and sub-tropical climatic conditions. The climate change scenario assumed to be a major threat to animal production systems under tropical climate. The demand of food or the food security issue compel us to a holistic approach to sustainable livestock production system that may be one of the remedies for fulfilling the demand of fast growing population. The objective of this review is to focus the major effect on dairy production system and different strategies to overcome the adverse effect of heat stress under tropical climatic conditions. The identification of unique adaptive traits between and within breeds and their propagation seem to be essential in near future in respect of climate change scenario. The management and feeding strategies revealed to be beneficial for relieving adverse effects of heat stress for maintaining the productivity of dairy animals. Nevertheless, decision makers, extension services and research institutions have to support and encourage livestock activities to enhance the animal productivity under changed climate scenario.

Key words: Adaptation, Global warming, Production, Reproduction, Strategies, THI

The livestock sector is a crucial component of India's economy in terms of income, employment, equity and foreign exchange. 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 (Steinfold *et al.* 2006). Nutritionally, it contributes (globally) approximately 30% of the protein in human diets. In countries like India and other developing countries, livestock is the backbone of agriculture as it offers milk, meat, wool, as well as draught power, farmyard manure etc. Therefore, food security is considered the highest priority in developing countries giving more importance to the livestock production systems for the enhancement and sustainability. Global plea for foods of animal origin is budding and it is obvious that the livestock sector will need to expand. On the other hand, livestock stratum is adversely affected by the detrimental effects of extreme weather. According to the IPCC (2008), climate change is any "shift in climate over time either due to natural variations or as a result of human activity". The increasing earth surface temperature, erratic changes in seasonal patterns and increase in the frequency of extreme climatic events like heat waves, droughts, floods and precipitation are emerging as the new challenges for crop and livestock production. In the year 2050, the world population will reach 9.3 billion; it is predicted that global meat consumption will be double that of the present-day. How can we keep pace with animal production to animal consumption in the coming decades? Perhaps the challenge will be how to equally balance either the boost in the number of stocks or the productivity per head, at the same time remodelling the sustainability of the livestock sector. Total anthropogenic greenhouse gas (GHG) emissions have continued to upsurge over 1970 to 2016 with a considerable absolute increase between 2000 and 2016, despite a growing number of climate change mitigation policies. Numerous climate model projections recommend that by the year 2100, the mean global temperature may be 1.1–6.4 °C warmer than in 2010 (Nardone *et al.* 2010). Majority of animals reared in tropical environments are generally subjected to more than one stress at a time, which alters animal production, reproduction, immune status etc. Animals can adapt to hot climates, nonetheless, the response mechanisms that are supportive of survival may be detrimental to performance. It has been estimated that about 85% places in India experience moderate to high heat stress during April, May and June. The comfortable ambient temperature for better performance varies from 15 to 25°C for crossbred

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cattle and 15–28°C for indigenous cattle (Singh and Upadhyay 2009). The upper limit of thermo-neutral zone (TNZ) i.e. upper critical temperature has more significance for livestock under tropical and subtropical climate. The information on upper critical temperature for most of the species and breeds of farm animals in India is scanty. However, the upper critical temperature is lower in exotic breeds and their crosses than indigenous breeds. The upper critical temperature for Haryana bulls is 32.0°C, but for its crosses having 50 percent 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).

Climate change is one of the most potentially serious environmental problems confronting the global community in respect of food security. If managemental practices of livestock are not changed, huge economic loss is likely to be expected. Therefore, the emphasis should be given to understand the mechanism of adapting livestock for their performance during stressful conditions (heat, cold stress, drought, flood etc.) in tropical climatic conditions. The productivity of livestock is disturbed, when it moves away from its comfort zone. Even small upward shifts in core temperature have profound effects on tissues and neuro-endocrine functions, which in turn reduce fertility, growth, lactation, and ability to work. Suitable strategies should be taken in animals housing, reproduction, nutrition, and health care. Requirement of a significant research commitments and selection of tolerant breeds to climate change are mandatory without compromising production performance.

Projections of Climate Change over India for the 21st Century

Based on modelling and other studies, the following changes due to increase in atmospheric GHG concentrations may arise from increased global anthropogenic emissions (Harris and Roach, 2016):

- As per IPCC, annual mean surface temperature will rise by 3 to 5° C (A2 scenario) and 2.5 to 4° C (B2 scenario) by end of this century. The warming will be more pronounced in the northern parts of India as per the simulation studies carried by Indian Institute of Tropical Meteorology (IITM), Pune.
- Indian summer monsoon (ISM) is a manifestation of complex interactions between land, ocean and atmosphere. The simulation of ISM's means pattern as well as variability on inter -annual and intra-seasonal scales has been a challenging ongoing problem. Some simulations by IITM, Pune, have indicated that summer monsoon intensity may increase beginning from 2040 and by 10% by 2100 under A2 scenario of IPCC.
- Changes in frequency and/ or magnitude of extreme temperature and precipitation events.

Ruminant are the contributor and sufferer of global warming

Ruminant are the contributor of greenhouse gases, mainly methane, which has 21-folds higher global warming potential than that of carbon dioxide. The greenhouse-effect is the absorption of solar infrared (IR) radiation, which maintains the earth's surface temperature. Due to more and more accumulation of greenhouse gases (GHGs) viz. CO_2, CH_4, CFCs, N_2O from different sources mainly anthropogenic and naturally. The higher concentration of GHGs entrap more solar infra-radiation results in global warming (increase earth's surface temperature). The emission of total GHGs from Indian livestock estimated to be 247.2 Mt aggregate CO_2 equivalents, which included 99.8% CH_4 and 0.2% N_2O emissions (Chhabra *et al.* 2013). Cattle and buffalo respectively contributes approximately 54.7 and 30.4% in methane pool among the livestock population in India (Cattle, Buffalo, Sheep and Goat) (Karim and Sejian, 2010). Methane is produced during the anaerobic digestion in the rumen of ruminant animals, who chew the cud. Ruminants have a distinctive digestive system that enables them to eat fibrous plants and in the process of digestion, they produce methane. As a result of anaerobic fermentation volatile fatty acids, ammonia, carbon dioxide, methane, cell material and heat are produced. Methane is released into the atmosphere from ruminants routinely as a by-product of the microbial digestion process. The methanogenesis (production of methane by methanogens bacteria) is occurring by utilization of hydrogen and carbon dioxide, which produced during carbohydrate fermentation (Hungate *et al.* 1970). Removal of hydrogen from ruminal environment is important to maintain the metabolism of rumen micro-organisms; otherwise, present of hydrogen inhibit the metabolism (Sharp *et al.* 1998). The levels of methane production in the rumen are also affected by the quantity and quality of the feed. As the feed digestibility increases, the portion of energy that is converted to methane decreases. More than 90% of the total emission from enteric fermentation is contributed by the large ruminants and rest are from small ruminants (Swamy and Bhattacharya 2006), this amount also depends upon the amount of feed consumed and its digestibility.

Impact of Heat Stress

The most compelling direct influence of climate change on livestock comes primarily from heat stress, which further results in a significant financial burden to livestock producers through a decrease in milk production, meat production, reproductive efficiency, animal health and much more. Thus, a difference in a micro environment around animal could directly affect its performance significantly.

Milk production

High yielder dairy cows/ buffaloes are the choices of commercial dairy farmers, which play an important economic contribution in the country. Livestock farming plays important role in eradicating poverty in the country like India and other developing countries. It is well known fact that the high yielder dairy animals have higher metabolism for milk synthesis and its sustenance. The internal heat production is more in lactating dairy cattle than in non-lactating animals and is more susceptible to heat stress. The milk production is generally declined in cattle or buffaloes under heat stress (Singh and Upadhyay 2008, 2009). Roenfeldt (1998) estimated the range of comfortable temperature for milk production is around 5 to 25 °C. Mid-lactating cattle found to suffer more under heat stress than early lactating cattle. Nevertheless, cow's performances are also affected by climatic conditions during early lactation (Sharma *et al.* 1983). Animals have to reduce the internal heat production and utilization of energy for maintaining body temperature under heat stress. Reduction of feed intake is one of the mechanisms for reducing internal heat production resulted in significant impact on milk yield. The hot environment negatively affects the appetite center of hypothalamus causing reduction in feed intake (Silanikove and Koluman 2015). The feed intake of animals negatively correlated with the ambient temperature; it declines more rapidly at 40°C by 40% in lactating dairy cattle (breeds) and 8–10% in buffalo heifers (Baumgard and Rhoads 2013). Reduction in feed intake is one of the ways to decrease internal heat production under warm environments as the heat increment of feeding is an important source of heat production in ruminants (Kumar *et al.* 2014). About 35 and 14% reduction of milk was observed by Nardone *et al.* (1992) and Lacetera *et al.* (1996) during mid lactating cattle, respectively under heat stress. 10–14% reduction in milk yield was reported in Argentina due to heat wave (Voltorta *et al.* 2002). Drastic reduction of milk yield was observed in high yielder than low yield dairy animals (Berry *et al.* 1964). This might be one of the reason of Zebu cattle whose productivity is least affected by heat stress compared to crossbred or European breeds. 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 climate (Das *et al.* 2014). The hot environment not only affects the quantity of milk, but also the quality of milk (Das *et al.* 2016; Das *et al.* 2014; Bernabucci and Calamari 1998; Calamari and Mariani 1998). Reduction in the percentage of casein was reported in dairy cattle during summer (Bernabucci *et al.* 2002). However, they did not observe significant difference in alpha-lactoalbumin and beta-lactoglobulin concentration. Short term heat exposure also showed a significant decrease in milk yield of lactating cows (Blackshaw and Blackshaw 1994; Kadzere *et al.* 2002). Multiparous cows generally yield more milk than primiparous cows and are more sensitive to heat stress (Holter *et al.* 1997). Higher accumulation of fat in multiparous dairy animals might be one of the reasons of preventing heat loss from internal body to the environment (Broucek *et al.* 2009). Heat stress showed a negative correlation with lactation length, dry period, calving interval, milk constituents and milk yield in Murrah buffaloes (Singh *et al.* 2013). Upadhyay *et al.* (2009) estimated 2% loss of milk production due to thermal stress in India. It has also been expected that 3.2 million tons reduction by 2020 and more than 15 million tons by 2050. The decline in milk production reported to be higher in crossbreds (0.63%) followed by buffaloes (0.5%) and indigenous cattle (0.4%) (Upadhyay *et al.* 2009). The higher ambient temperature with higher relative humidity in crossbred cattle (Holstein Friesian x Deoni) showed a detrimental effect on milk yield (Kumar *et al.* 2014). Elevated temperature is one of the major threats to dairy animal's performance under tropical climatic conditions.

Temperature humidity index (THI) is commonly considered as an indicator for measuring the level of heat stress on dairy animals. THI can be calculated using the formula $THI = 0.72(W + D) + 40.6$, where "W" is wet bulb temperature and "D" is dry bulb temperature in °C (McDowell, 1972). Mild, medium, and severe stress was classified on the basis of THI range, i.e. 72–80 (mild), 80–90 (medium), and 90–98 (severe). Livestock species are comfortable at THI values between 65 and 72 (Upadhyay *et al.* 2009). Milk yield was significantly decreased by 0.12 (1.2%) kg for each unit of THI above 74 in Holstein Friesian cows from four herds (Sadek *et al.* 2015). The threshold level of THI varies among the breeds; it also depends on the productive level and adaptability of the animals in different agro-climatic conditions. When the THI shifted from 68 to 78, 21% reduction of milk yield was recorded in Tunisia (Bouraoui *et al.* 2002). A decrease in milk yield of 0.2 kg/day was recorded per unit increase in THI above 70 (Johnson *et al.* 1962). Therefore, the threshold of THI may vary depending upon the region and the breeds of livestock and their adaptability. The THI value between70–72 is considered by majority of the researchers to be warning signals to make the lactating animal cool by modification of micro-climate.

Growth

Thermal Stress is one of the chief concerns in respect to growing animals in the hot regions of the world, since there will be considerable decrease in growth performance, immunity and increased mortality rate (Hansen 2004). A decrease of 7% in circulating glucose concentrations analogue with an increase in insulin concentration was reported by Wheelock *et al.* (2010) and Rhoads *et al.* (2013). Animals under heat-stress divert blood flow to the periphery in an effort to squander heat, leading to hypoxia and subsequently GI tract damage (Hall *et al.* 1999; Lambert 2002). Heat Stress on productivity or growth is spectacled by reduced intestinal integrity (Pearce *et al.* 2013; Baumgard and Rhoads 2013), probably due to decreased intestinal blood flow (Lambert *et al.* 2002). Abridged blood flow leads to hypoxia at the intestinal epithelium, which can modify intestinal cytology, and may upsurge the permeability of tight junctions (Yan *et al.* 2006; Pearce *et al.* 2013). Enhanced intestinal permeability can upsurge the risk of bacterial translocation (Baumgart and Dignass 2002), and may shrinkage nutrient digestibility and absorption in heat-stressed animals. The rise in temperature due to global warming will negatively impact growth and time to attain puberty of livestock species. The negative impact of THI rise on animals growing at higher rates (500g/day or more) will be more than slow growing (300–400g/day) cattle (Upadhyay *et al.* 2009). The crossbreds have been observed to be more sensitive to rise in THI than either Zebu cattle or buffaloes (Upadhyay *et al.* 2009).

Reproduction

Reproduction is the back bone of production which might be affected due to elevated temperature in both sexes. Artificial insemination (AI) is one of the reproductive biotechnological tools, which is successfully transferred at grassroots level. Still the success rate of AI is around 45–50%. There are different causes of failure in the conception rate. The semen quality of crossbred bulls is also affected by different climatic consequences. Heat stress is one of the factors of poor semen quality of crossbred and exotic bulls under tropical climatic conditions (Soren *et al.* 2016). A change in temperature and humidity with changes in photoperiodicity can affect the reproductive performance of buffaloes significantly. The longer photoperiodicity affects the secretion of melatonin from pineal gland, which might have significant role on reproduction of buffalo under heat stress (Ghuman *et al.* 2010). Heat stress affect the secretion of GnRH which might changes in ovarian function that the oocytes maturation and embryonic growth which leads to reproductive incompetence (Naqvi *et al.* 2012). The conception rates of dairy cows decreased by 20–27% in summer (Chebel *et al*. 2004), which is also associated with poor expression of oestrus due to reduced oestradiol secretion from the dominant follicle. It has been reported that the herdsmen can detect only 18–24% estrus in summer and 45–56% in cool months (Thatcher and Collier, 1986). The cows calved during summer months had longest service period of 159±3 days, whereas autumn calved female had the shortest service period of 148±4 days (Kumar and Gandhi 2011). The service period of Murrah buffaloes was prolong (180 days) in the month of summer (THI=80.27) (Dash *et al.* 2016).

Follicular growth and embryo development

Heat stress reduces the length and intensity of estrus along with increase in incidences of anestrous and silent heat in farm animals (Kadokawa *et al.* 2012). About 80% of estrus is undetectable during summer season, which further reduces fertility (Rutledge 2001). It increases adrenocorticotropic hormone and cortisol secretion (Singh *et al*. 2013). The aromatase activity found to reduces under heat stress resulted reduce in estradiol levels and poor expression of oestrus symptoms (Ozawa *et al.* 2005). Higher prolactin level under heat stress may reduce the frequency of luteinizing hormone resulted poor follicle maturation, decrease oestradiol production (Wolfenson *et al.* 2000). Heat stress delays follicle selection and reduces the degree of dominance of the dominant follicles, which causes decrease blood progesterone concentration, which is one of the major causes of implantation failure and early embryonic death in dairy cattle (Khodaei-Motlagh *et al.* 2011). The blood flow to the uterus under heat stress might be chances of early embryonic loss and suppress embryonic development (De Rensis and Scaramuzzi 2003). The *acyclicity* or infertility in buffaloes during heat stress is attributed by significantly higher mean plasma prolactin concentration in summer as compared to winter season (Roy and Prakash 2007).

It has been reported that the embryo quality decrease due to heat stress resulting in negative impact on reproduction. Yadav *et al.* (2013) investigated the effects of physiologically relevant heat shock on buffalo oocytes/embryos cultured at 38.5°C (control) or exposed to 39.5°C or 40.5°C for 2 h once every day throughout *in vitro* maturation (IVM), fertilization (IVF) and culture (IVC). The percentage of oocytes that developed to 8-cell, 16-cell or blastocyst stage was lowered in the heat-exposed oocytes. The relative mRNA abundance of stress-related genes HSP 70.1 and HSP 70.2 and pro-apoptotic genes CASPASE-3, BID and BAX was higher ($p<0.05$) in heat-exposed embryos. The development of oocytes to blastocyst was severally affected at 40.5 and 41.5 °C (Ashraf *et al.* 2014). Similarly, the mean cell number was markedly decreased at cleavage and blastocyst. The relative mRNA expression of heat shock protein (Hsp 70.1, 70.2, 70.8, 60, 10 and HSF1), pro-apoptotic (caspases 3, 7, 8, Bid and Bax) and oxidative stress (iNOS) related genes was significantly higher ($p<0.05$) in all the developmental cells under heat stress (Ashraf *et al.* 2014). It is clearly established that the heat stress causes oxidative stress to buffalo oocytes indicated by higher production of reactive oxygen species (ROS), lipid peroxidation and nitric oxide. Similarly, the antioxidant defence mechanism is triggered for scavenging ROS, the higher antioxidant enzymatic activities of superoxide dismutase, catalase, glutathione peroxidase and glutathione reductase was estimated in heat stress oocytes during maturation (Waiz *et al.* 2015). When buffalo oocytes were given heat treatment (40.5 and 41.5°C) during in-vitro maturation for 12 hours and 24 hours, compared with control (38.5°C for 24 hours) showed significant decrease in anti-apoptotic (Bcl-2, Mcl-1, Bcl-xl), glucose transport (Glut1, Glut3 and IGF1R), developmental competence (ZAR1 and BMP15) and oxidative stress (MnSOD) related genes under heat stress (Ashraf *et al.* 2014). Exposure to heat stress (40 & 42°C) during in vitro maturation also revealed significant effect on cleavage and quality of blastocyst (Singh, 2015). The most vulnerable stage was observed during mid maturation phase between 8–12 hours of in vitro maturation. Similarly, embryo at earliest stage between 1–4 hours after in vitro fertilization was observed very sensitive to heat stress than other stages (Singh 2015). The most likely cause of oocytes deterioration under heat stress was the oxidative stress and the starvation of ATP leading apoptosis (Singh 2015).

Effect on Semen quality

Sperm membrane is rich in phospholipid content, necessary for sperm motility. Due to high phospholipid content, the sperm membrane is vulnerable to free radical attack and ROS is enhanced by thermal stresses. Decrease in the percentage of live spermatozoa, acrosome integrity, hypo-osmotic swelling and a higher percentage of major abnormalities were observed in Karan Fries bulls during the summer as compared to winter season (Soren *et al.* 2016a). Higher concentration of glutathione peroxidase also observed during the summer as compared to winter (Soren and Singh 2016b). The concentration of malondialdehyde, total antioxidant capacity and other antioxidant enzymes were higher ($p<0.05$) during the summer as compared to winter and spring seasons (Soren *et al.* 2016c) which indicates the over production of reactive oxygen species (ROS), which affects sperm membrane resulted in poor motility. Bhakat *et al*. (2014) also reported the similar observations in crossbred bulls, i.e. significantly higher percentage of total abnormalities (head, mid-piece and tail abnormalities) during hot-dry and hot-humid season compared to winter. The rise in temperature and humidity may have a negative consequence on sperm quality and subsequently to fertilization and conception rate through A.I. (Mieusset *et al.* 1992). Cattle living in discomfort zone might also be one of the causes of sub-fertility (Barros *et al.* 2011). The elevated temperature activates degenerative process in the testes (Rahman *et al.* 2011; Blanchard *et al.* 1996). Lower sperm concentration, poor motility, poor post thaw motility and lower volume were reported in Holstein Friesian bulls during summer season (Shrivastava *et al.* 2013). The higher sperm abnormalities, sperm DNA damage with reduced fertility were observed during summer season (Valeanu *et al.* 2015; Nichi *et al.* 2006). The higher ambient temperature and humidity have an adverse effect on spermatogenesis and negative effect on LH secretion (Gilad *et al.* 1993), which might be one of the reason for poor semen quality in crossbred or un-adapted breed under heat stress.

Animal health

Climate change, coupled with general anthropogenic factors, alters farming and the natural landscapes and in the process, health of animals will be affected in multiple ways. Deviations in temperature and rainfall are the most compelling climatic variables affecting livestock disease outbreaks. Some of the viral diseases may reappear and affect both small and large ruminant populations. Warmer and humid weather (especially warmer winters) will up burst the risk and occurrence of animal diseases, as certain species that serve as disease vectors, such as ticks and biting flies, are more likely to subsist year round. The migration of disease vectors into new areas, e.g. malaria and livestock tick borne diseases (theileriosis, anaplasmosis), Bluetongue diseases and Rift Valley fever in Europe have been documented (Singh *et al.* 2017). Incidence of protozoan diseases like Trypanosomiasis and Babesiosis are likely to increase in high producing crossbred cattle. If rainfall increases, certain existing parasitic diseases may become more prevalent, or their geographical range may advance. The higher temperature and rainfall increases the prevalence of livestock diseases. Changes in wind could also affect the spread of certain pathogens and vectors. The higher incidence of chlamydiosis, caprine arthritis (CAE), equine infectious anaemia (EIA), equine influenza, Marek's disease (MD), and bovine viral diarrhoea is likely to be expected. The incidence of flood, drought and other disaster might also enhance the parasitic, bacterial, viral disease and vector borne diseases. The emergence or re-emergence of zoonotic diseases is also likely to be expected due to climate change (Taylor *et al.* 2001). Fascioliasis (F. gigantic) can prevail in warmer climatic condition due to adaptability of Lymnaeids (vector for transmission) and can be hyper endemic (Boko *et al.* 2007). Schistosomiasis also expected to increase due to global warming (Berguist 2001).

The evaporative cooling showed a beneficial effect to the health of animals and incidence of reproductive disorders were reduced. The retention of placenta, metritis and endometritis occurring rate was 37.25%, 25% and 12.25%, respectively in non-cooled animals whereas only retention of placenta was observed in cooled (12.5%) Murrah buffaloes (Aarif and Aggarwal 2015). Strengthening the diagnostic laboratories, veterinary dispensaries, hospital, veterinary institute including the awareness camps against climate change, vaccination, preventive measures and extension camps among the farmers should be carried out time to time. Strengthening the animal health infrastructure and ensuring surveillance for diseases is essential since the diseases occurrences most likely to be influenced by climate. This difficulty could be overcome by establishing a coordinated circumpolar infectious disease surveillance system. If coordinated with appropriate climate data, such a network could also be used to monitor the emergence of climate-sensitive infectious diseases providing both early detection opportunities and precautions for livestock health intervention. Early warning systems should be developed to generate preventive health messages. Timely vaccination of livestock is advisable as a preventive measure. Spread of disease vectors can be reduced by using flies or insect repellents. There should be provision of clean water supply to livestock as water is a good medium for the spread of infectious diseases.

Adaptive mechanisms

Morphological mechanism

Most of the breeds have been named on the basis of their habitat or location to which they have adapted well. Zebu breeds have small size and low body weight with small barrel shaped body and slender legs. They have a hump and a dewlap. The head is held high in most zebu breeds. Since most of these breeds have been developed for draught purposes having long legs with articulate joints, they provide ample capacity to run and swiftly move even under moist soils. The balanced fore and hind body quarters help them in propelling body and moving forward with loads at moderate speeds. Balanced body is mainly due to small size and low volume of internal organs. Small sized rumen, reticulum, omasum and abomasum, do not distend down belly of these Zebu draught breeds contrary to their heavy bodied counterparts. 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.* 2013).

Physiological and biochemical mechanism

The physiological responses are important to cope the animals under adverse climatic conditions. The respiration rate (RR), heart rate (HR), pulse rate (PR) rectal temperature (RT) and skin temperature are recorded higher in crossbred cattle as compared to Zebu cattle. The relationship between behavioural and physiological indicators can be used to evaluate the adaptive capacity and consequently the "welfare" of animals in relation to different conditions (Broom and Johnson 1993). Stressors of some systems are detectable as modifications of respiration or heart rates, which are the valid index of social stress (Guyton, 1995). The positive correlation between temperature, relative humidity and rainfall with that of pulse rate, respiration rate and body temperature were recorded in cattle. This increase in respiration rate may be used as an index of discomfort in large animals. Singh and Upadhyay (2009) observed higher respiration rate and rectal temperature in Karan Fries (Tharparkar x Holstein Friesian) than Sahiwal cattle during heat stress. McDowell (1972) and Gaughan *et al.* (1999) reported a low respiratory rate under hot weather identifies animals with lesser discomfort. The physiological responses are well studied in dairy cattle and buffalo under heat stress (Das *et al.* 2014; Maibam *et al.* 2014; Mehla *et al.* 2014; Bhan *et al.* 2013, 2012). The RR was found to be higher in crossbred cattle than Zebu cattle during hot humid season under tropical climatic conditions (Naidu 2016; Maibam *et al.* 2014). Higher RR, RT, PR and skin temperature (ST) were recorded in Tharparkar and Karan Fries cattle during heat stress (44 °C) in climatic chamber (Indu *et al.* 2016). However, the magnitude of physiological response, RBC, haematocrit, haemoglobin was recorded higher in Karan Fries than Tharparkar cattle. Similarly, the cortisol and prolactin levels were also higher in Karan Fries cattle than Tharparkar, which indicates the higher distress level in Karan Fries at higher temperature. The highest antioxidant enzymes (glutathione peroxidase, glutathione reductase, superoxide dismutase and catalase) were estimated in crossbred cattle than zebu cattle during heat stress (Singh *et al.* 2014; Bhan *et al.* 2013). The highest antioxidant enzyme and lipid peroxidation also estimated in semen of crossbred bulls during the summer season than other seasons of the year (Soren *et al.* 2016). The deviation in physiological, haematological and biochemical profile during the summer compared with baseline data (spring) directs the significant impact of thermal stress on cattle and buffalo under tropical climate, which needs to be protected for sustainable productivity (Bhan *et al.* 2013; Maibam *et al.* 2014; Hooda and Upadhyay, 2015; Vaidya *et al.* 2015; Lallawmkimi *et al.* 2013).

Metabolic profile

The quality and quantity of feed are affected during extreme climatic stress. Zebu cattle can survive, gives some milk and reproduce due to their low metabolic rate and adaptation to such stressful conditions. However, the crossbred cattle cannot able to maintain their production performance, which reduced drastically during extreme heat stress. The adapted animals recycle the nutrients more efficiently than temperate breeds (Bayer and Feldmann 2003). The performance of the Bos Taurus breeds is better than zebu cattle under comfortable conditions, however, loss of weight and fail to survive when fed poor quality grasses or straw. These changes are not seen in adapting breeds. The mRNA expression of metabolism related genes (Dio2, TRIP11) was lower in Tharparkar cattle than Karan Fries cattle during hot humid season (Naidu, 2016). The thyroid hormone, skin temperature and rectal temperature were positively correlated with the expression level of deiodinase type2 (Dio2) gene in peripheral blood mononuclear cells (PBMC) (Naidu 2016). The magnitude of TRIP11 gene expression was higher in Karan Fries heifers than Tharparkar heifers (Naidu, 2016). Thyroid Hormone Receptor Interacting Protein 11 (TRIP11) was positively correlated with cortisol, rectal temperature, pulse rate, respiration and skin temperature (Naidu 2016).

Peripheral blood flow

The nourishment of the skin is received from the blood (peripheral circulation) carrying essential nutrients. The blood flows in the periphery are not only important for nourishment, but also sufficient exchange of heat dissipation from 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. During summer, the mean blood flow was 4.71±0.49, 14.85±1.63 and 16.72±1.47 PU; whereas, during winter, it was low i.e., 1.10±0.16, 8.96±0.58 and 12.16±0.95 PU at dorsal, abdomen and middle ear, respectively in buffaloes (Singh *et al.* 2014). The blood flow was positively correlated with the temperature of the body parts and it varied in different seasons.

Sweating

Cattle indigenous to tropical regions had a relatively thin hair follicle depth and very often a simple sac-like sweat gland (Jenkinson and Nay 1975). These cattle have looser and thicker skin, larger ears, and prominent hump and live in the hot and humid climates. Bos taurus, on the other hand, lack all of these characteristics (except for the thick hide) and are more adapted to cooler and drier climates. Heat stress activates various physiological functions to decrease the heat and enhance the heat release via conduction, convection, radiation and evaporation. Evaporation involves in sweating rate and respiratory minute volume (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 (Robertshaw 1985). McLean and Calvert (1972) 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 rid themselves of excess body heat when environmental temperatures begin to exceed 35°C and THI of 90 (Collier 2008). The ability of cattle to maintain body temperature depends on their capacity of thermoregulation based on the balance of heat gain and heat loss through: conduction, convection, radiation, and evaporation (Kadzere *et al.* 2002). The evaporative heat loss through alveolar ventilation were increased by two-fold in cattle exposed to solar radiation and the dead space ventilation was recorded higher in crossbred than in zebu cattle (Aggarwal and Upadhyay 1997).

Coat colour

It is a familiar observation that different ecotypes of cattle, whether they are distinguished as species, breeds, or strains, show marked contrasts in coat cover. These differences follow the principle, dignified by Wright (1954) as "Wilson's Rule", of a gradient from thick, woolly coats in cold climates to short coats with bristly hairs lying sleekly against the skin in hot climates. The contrasts between European cattle and Zebus of India clearly represent adaptations to cold and to heat. Individual animals also grow shorter coats when transferred from a cold to a hot environment (Berman and Volcani 1961). The fact that coat genotype seems to have changed fairly rapidly in breeds introduced to the tropics confirms the importance of this trait to adaptation. Verissimo (2002) reported that the tropical breed cattle had shorter hair length compared to the crossbred animals. He found that hair length increased as the Holstein fraction increased. Dowling (1956) associated the heat tolerance and performance of different strains of cattle with their coat characters. Turner and Schleger (1958, 1960) measured the degree of variability of coat type within herds, and assessed the proportion of the variation in growth rate that is accounted for by variation in coat type. Coat characteristics are associated with heat tolerance and performance of animals (Dandage *et al.* 2010; Collier and Collier 2012). Skin color is also associated with the health condition of the individual (Stephen *et al.* 2011). In animals, hair and skin pigmentation is a highly visible trait. Under tropical conditions with high levels of solar radiation, animals with a light color hair coat and darkly pigmented skin are better adapted (Finch and Western 1977; Finch, 1984). The light colour cows showed lesser alterations in physiological variables than did cows with less white. The basis of coat color in mammals including cattle is the presence or the absence of melanin pigment (eumelanin and pheomelanin). Eumelanin is responsible for black and brown colours and pheomelanin for reddish brown (Simon and Peles 2010). Melanocortin 1 receptor (MC1R) gene is responsible for pigmentation differences in mammals (McRobie *et al.* 2014). Acquisition of a highly stable MC1R allele promotes black pigmentation, which helps in protection from UV damage (Greave 2014). Another gene, premelanosome (PMEL), encodes a trans-membrane protein called pre-melanosomal protein. PMEL is a melanocyte protein necessary for eumelanin deposition (McGlinchey 2009). Therefore, the above-mentioned genes (MC1R and PMEL) divert the pathway of melanin synthesis towards eumelanin (true melanin) rather than pheomelanin. The rate limiting enzyme for melanin synthesis is tyrosinase (Zhang *et al.* 2010). Eumelanin intensifies skin pigmentation and thus helps in photo-protection because of its efficiency in blocking ultraviolet rays (UV) and scavenging reactive oxygen species (Klungland *et al.* 1995). The expression of skin color related genes (MC1R and PMEL) in lymphocytes and plasma tyrosinase activity were found to be significantly higher in Tharparkar than Karan Fries cattle. It shows that the ability of Karan Fries cattle to protect themselves from the harmful UV radiation by melanisation was significantly less compared to Tharparkar and it was found to be declined with heat stress (Maibam *et al.* 2014a, b).

Adrenocorticotropic hormone (ACTH)

Activation of hypothalamo-pituitary adrenal axis and the consequent increase of plasma cortisol level are the most prominent responses to stressful conditions. This increase in cortisol level stimulates physiological adjustments that enable the animal to tolerate the stress caused by a thermal stress (Christison and Johnson 1972). Bhan *et al.* (2013) reported higher plasma cortisol levels in Karan Fries compared to Zebu cattle during different seasons, but the peak levels of cortisol were observed when animal were exposed to higher temperature.

Insulin and prolactin: role in heat stress

The higher concentration of glucose and insulin were estimated in lactating cattle, whereas the adipose tissue mobilization did not occur (Rhoads *et al.* 2009; Schwartz *et al.* 2009; Wheelock *et al.* 2010). The tissues of heat stress lactating animals showed partial resistance to insulin (Achmadi *et al.* 1993). Higher concentration of insulin is still un-known and suggested to have role in adaptation under heat stress (Achmadi *et al.* 1993). Higher concentration of prolactin level was also recorded in heat stressed mammals, which might modulate the sweat gland functions and regulates water and electrolyte balance

(Alamer 2011; Collier *et al.* 1982; Faichney and Barry 1986). Prolactin also influences the pancreatic functions by increasing the insulin secretion and activate carbohydrate metabolism (Bole-Feysot *et al.* 1998). Prolactin might reduce the receptors of insulin in adipose tissues which might be the reason of not mobilizing the adipose tissue under heat stress (McNamara 1991). Therefore, it has been suggested that there is a scope to make the tissue insulin sensitivity, which might help in alleviating heat stress in lactating dairy cattle.

Heat shock proteins

Heat stress initiates a complex program of gene expression and biochemical adaptive responses (Fujita 1999). It is a highly conserved stress protein reported to have significant role in heat tolerance and adaptation of livestock breeds (Kumar *et al.* 2015; Banerjee *et al.* 2014). Heat shock proteins (HSPs), which is activated many fold during summer season in cattle and buffaloes. HSPs play important role in protecting the cellular damage under thermal stress. Heat shock proteins (HSPs) involves in important physiological roles to cope with heat stress (Parsell and Lindquist 1993). HSPs function as molecular chaperones in restoring cellular homeostasis and promoting cell survival (Collier *et al.* 2008). Several studies in bovine, mice and human cells give evidence that constitutive elevation of the inducible HSPs levels in gene and protein provides cyto-protection upon thermal stress (Collier *et al.* 2006). HSPA1A and HSPA1B genes increases suddenly under thermal stress followed by HSP60 and HSP10 genes in cattle and buffaloes (Kumar *et al.* 2015). However, continuous temperature rise does not protect cellular damage due to an imbalance between various physiological and cellular functions (Patir and Upadhyay 2010). Among the members of HSP family, HSP70i (HSPA1A & HSPA2) is the most temperature sensitive and induced by various physiological and environmental stressors (Beckham *et al.* 2004). HSPA1A and HSPA2 play a crucial role in guiding conformational status of the proteins during folding and translocation (Arya *et al.* 2007). In the hot environmental niche, a greater amount of constitutive HSP70.8 (HSPA8) was found during non-stress condition (Singh *et al.* 2014), suggesting significant role in adaptation to hot environment (Gething 1997). The higher expression of HSP72 and positive correlation of antioxidant enzyme concentration in Murrah buffalo suggesting an importance of HSP72 in heat stress (Lallawmkimi *et al.* 2012). Similarly, higher expression of HSP70 in different tissues under heat stress further gives evidence about the importance of HSPs and can be used as biomarker for assessing heat stress in livestock (Maibam *et al.* 2017; Sheikh *et al.* 2016; Banerjee *et al.* 2014; Singh *et al.* 2014; Dangi *et al.* 2014; Mohanarao *et al.* 2013; Patir and Upadhyay 2010). Microarray analysis revealed that a total 460 transcripts were differentially expressed with a fold change of P2 in peripheral blood leukocytes of heat exposed (42°C) Tharparkar (Bos indicus) cattle, it revealed the number of genes involves in alleviating thermal stress, further analysis is required to understand their functional role in livestock (Kolli *et al.* 2014). The mRNA expression profile of CASP-3, BCL-2, BAK, P53 and ratio of BAX/BCL-2 in PBMC of peri-partum Sahiwal cows (Somal *et al.* 2015) increased during summer as compared to thermo-neutral conditions suggesting the susceptibility of these cells to apoptosis.

Strategies for amelioration of adverse effect of climate change

Dietary manipulation:

Vitamins and minerals: Supplementation of vitamins, minerals and amino acids play significant role in reducing the adverse effects of heat stress. Supplementation of Zn (120 and 80 ppm) found to reduce 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). In vitro studies revealed that the zinc supplementation (0.01mM) to heat stressed PBMCs down regulate the HSPs and reduce the IL–10 concentration (Sheikh *et al.* 2016). The down regulation of HSP in zinc treated PBMCs might be due to decrease in free radical production in the cellular level, which might protect the cellular damage. The Zn supplementation also reduces the concentration of superoxide dismutase (SOD), catalase (CAT) in heat stress (42°C) PBMC cells of Karan Fries and Sahiwal cows suggesting an ameliorative measures of heat stress and immune-modulator in peri-parturient cows (Sheikh *et al.* 2016).

The lower level of HSP70 was reported in plasma of á-tocopherol acetate supplemented cows during transition period (Aggarwal *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 immunoglobin and interleukin-2 were recorded in the plasma of Sahiwal cows after calving as compared to non-supplemented cows (Chandra *et al.* 2014). Vitamin-E supplementation alone also improves the condition of liver during late pregnancy and early lactation indicated by lower concentration of alanine aminotransferase, alkaline phosphatase and aspartate aminotransferase (Chandra *et al.* 2013). This might be due to neutralizing the reactive oxygen species generated during transition period. Vitamin-E supplementation to Murrah buffalo calves also improved the growth rate (higher average daily gain compared to control), metabolic and endocrine profile (Singh *et al.* 2012). The studies carried out on heifer and lactating buffaloes during thermal stress (heat and cold) demonstrated the ameliorative effect of vitamin-E against thermal stress (Lallawmkimi *et al.* 2013). It reduced the mRNA expression of HSP72 and antioxidant (SOD and CAT) concentration in both heifer and lactating buffaloes. The performance of lactating buffalo improved. The combination of Zn and vitamin-E supplemented combat the lipid peroxidation, non-esterified fatty acid and improved the milk yield in Sahiwal cows (Chandra *et al.* 2013). Vitamin C supplementation has been found to ameliorate the heat stress and as immune-modulator (Ganaie *et al.* 2013).

Betaine: Administration of betaine (a trimethyl form of glycine) reduces the adverse effect of heat stress (Digicomo *et al.* 2015). The lower expression of HSPs was observed in treated goat (Dangi *et al.* 2015). Betaine can be utilized as methyl donor by mammals and it participates in protein and lipid metabolism. It can also be used as an organic cellular osmo-protectant.

Amla: Its strong antioxidant properties are due to its small molecular weight tannoid complexes. Apart from being one of the most potent sources of vitamin C, amla 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 (Lakhani *et al.* 2016).

Bicarbonate and direct fed microbes: Elevated environmental temperature negatively affects the physiological mechanism of rumen that might increase the metabolic disorder in ruminants (Soriani *et al.* 2013). Feeding of more fermentable carbohydrate during heat stress may lead to acidosis and laminitis (Lettat *et al.* 2012). The less intake of roughages and more production of propionate and butyrate may alter the rumen pH resulted decrease in rumen motility. Lower production of saliva affect the buffering capacity in the rumen, therefore, supplementation of bicarbonate stimulates saliva production and feeding of direct fed microbes or yeast also helpful for maintaining rumen pH in heat stress cattle and buffalos.

Dietary Fat: Feeding of dietary rumen bypass fat is an effective source of energy during summer to combat the negative energy balance. The heat increment of fat is minimum i.e. around 50% less than typical forages. An increase in the milk yield was observed by Wang *et al.* (2010) in fat supplemented animals. Supplemental fat at 5% found to enhance lactation performance under thermo-neutral and heat stress conditions (Knapp and Grummer 1991).

Glucose: Higher production of glucose precursors i.e. propionate in the rumen could be effective for maintaining production. But it alters the rumen pH and motility. Therefore, safe and effective way is advisable for maintaining the milk production. Supplementation of monensin found to stabilize the rumen pH during stress (Schelling 1984). Propylene glycol is typically fed in early lactation, but may also be an effective method of increasing propionate production during heat stress. With the increasing demand for biofuels and subsequent supply of glycerol, it will be of interest to evaluate glycerols efficacy and safety in ruminant diets during the summer months.

Protein: Heat stress ruminant showed to undergo negative nitrogen balance (Kundu *et al.* 2013). Bypass protein (formaldehyde treated mustard cake) showed to increase 15% milk production (Walli *et al.* 2005). Supplementation of bypass protein is beneficial for maintaining energy requirement during heat stress (Kundu *et al.* 2013).

Insulin sensitivity

The higher concentration of prolactin was estimated in mild heat stress animals as compared to thermo-neutral conditions (19-24°C) (DiGiacomo 2011). Improvement in insulin sensitivity may be one of the possible ways of reducing the impact of heat stress on lactating dairy cows (Dunshea *et al.* 2013). Insulin resistance in pregnancy and lactating animals is one of the physiological means of diverting the nutrients towards the priority tissue like the foetus and lactating mammary gland. The resistance of insulin is associated with the impaired ability to regulate body temperature; therefore, insulin resistance may make the animal less ability to cope with heat stress (Dunshea *et al.* 2008). Insulin resistance is one of the reasons of reducing milk yield under heat stress lactating cows. Interestingly, significantly lower concentration of glucose was noticed in cooled Holstein Friesian lactating cattle than control (Reyes *et al.* 2010). However, complete mechanism of insulin in heat stress lactating cows in not known. It is suggested that improvement of insulin sensitivity under heat stress cows help alleviating heat stress.

Effect of cooling during summer

The significant impact of evaporative cooling was observed during late gestation in Murrah buffaloes during summer season under tropical climatic conditions. The physiological response (RR, RT, and PR) and skin temperature at thorax were lower in cooled Murrah buffalo than non-cooled buffaloes (Aarif and Aggarwal 2016). Blood pCO_2, pO_2, PCV, Hb were found to be higher in cool buffalo, similarly, the dry matter intake (DMI) also increased. The milk yield, FCM, fat yield, lactose yield and total solid yield were recorded higher in cooled buffaloes, indicates the importance of cooling during summer season. The mRNA expression of prolactin receptor gene (PRL-R) was higher, whereas cytokine signalling gene 1(SOCS-1) and interleukin-6 was lower in cooled parturition buffaloes (Aarif and Aggarwal 2015). The level of interferon gamma was significantly higher at –20 and +20 days of parturition in cooled animals than non-cooled animals. Verma *et al.* (2016) also found the improvement in conception rate in cooled buffaloes during summer season. The cooling effects using fans with mist showed significant improvement in milk yield of Holstein Friesian cows as compared to control groups. The milk yield of cooled cows for 3 h AM and 3 h PM increased the milk yield by 2 kg per day as compared control (providing only one-hour cooling) (Reyes *et al.* 2008). The output of milk energy also shown to increase in treatment groups and the milk yield was recorded 21.12 kg/day in cooled group (3h AM+ 3h PM) as compared to control i.e. 19.1 Kg/ day (Reyes *et al.* 2008). There are many method of cooling system during hot and dry conditions, but water spray and fans are often used. Evaporative cooling is the effective method which includes mist, fog and sprinkling (Armstrong 1994). 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 condition during dry period (Reyes *et al.* 2007). Reyes *et al.* (2007) reported increase of milk yield by 2.61kg/day in cooled cows compared to non-cooled cows. Similarly, Wolfenson *et al.* (1998) reported improvement of milk yield by 3.5 kg/day in cows cooled with water spray and fans during dry period.

Shade

Shade provides protection from direct sunlight and allows cooling effect of wind. Availability of shade affects the production of animals. Providing shade to Holstein Frisian during summer showed significant increase in milk production as compare to cows providing no shade. In treated cows milk production was 3% higher as compared to control cows. When lactating cows were provided adequate shade, their milk production and reproductive performance increases. Milk yield of shade cows was recorded 16.6 kg/day than non-shade cows who yielded 15.0 kg/day (Roman-Ponce 1977). Adequate shade also improved the conception rate. Conception rate were significantly higher for shaded cows (44.4%) than no shade cows (25.3%) (Roman–Ponce, 1977). Provision of shade helped in maintaining the productive performance and reduces the radiant heat load upto 30% (Blackshaw *et al.* 1994).

Supplementation in one package

Supplementation of micro molecules, oil and modification of micro-climate helped in alleviation of the heat stress. Supplementation of niacin, yeast, edible oil and provided with curtains, additional ceiling fans, and mist showed improvement in milk production, total fat and SNF with lower physiological response (RR, RT) in treatment group compared to control of Niliravi buffaloes (Das *et al.* 2014). This study indicated that the nutrient supplementations, microclimate modifications, and management alterations together in the form of one package helpful in reducing heat stress in buffaloes.

Selection and breeding strategies

Single nucleotide polymorphisms (SNPs)

Propagation of heat tolerant breeds is one of the strategies for combating the climate change. The single nucleotide polymorphisms (SNPs) of HSP90ab1 gene was studies in Sahiwal and Karan Fries cows and their association with thermo-physiological parameters (Sailo *et al.* 2016). The AA genotype showed significantly (p<0.01) lower RR than AC genotype, similarly, CT genotype showed lower rectal temperature than CC genotype during summer. The propagation of AA and CT genotype may be an aid for breeding programmes to enhance thermo-tolerance in dairy cattle (Sailo *et al.* 2016). The two SNPs i.e., g.507G>A in exon 1 and g.88>C in intron 1 of HSPB8 gene were identified by comparative sequence analysis. The results showed lower (p<0.01) RR, RT and HTC in GA genotype compared to GG genotype of g.507G>A SNP of HSPB8 gene (Verma *et al.* 2016). Whereas the SNP i.e., g.881T>C, located on intron 1, did not find any significant association with the different genotypes (TT and TC) of Sahiwal cattle (Verma *et al.* 2016). The SNPs of HSP90AA1 in Karan Fries cattle showed that the GG (homozygous) genotype had lower RR, RT and HTC than AA (homozygous) and AG (heterozygous) genotypes suggesting GG genotype can be an aid for selection of thermo-tolerance of Karan Fries cows in sub-tropical and tropical climate (Kumar *et al.* 2016). ATP1A1 gene encodes for á subunit of Na+ K+ ATPase enzyme which is necessary for Na+ coupled transport of metabolites, nutrients, ions and a candidate for heat tolerant trait. The analysis of five SNPs (A27008223G, T27008097A, C27008016T, G27008015A and C27007790A) of ATP1A1 gene and their association with RR, RT and HTC revealed that the AA genotype at 27007790 nucleotide position in Jersey crossbred cows are suitable during summer under tropical climatic conditions (Das *et al.* 2015). Genetic polymorphisms analysis is one of the acceptable tools for selection of breeding of thermo-tolerance breeds for near future.

CONCLUSION

Intensification in the ambient conditions causes severe impairment in the physiology, the metabolism and to the health of the animals. Considerable research evidence showed a significant waning in animal performance portraying heavy economic losses when laying open to the heat stress. With the advancement of molecular biotechnologies, efforts in selecting animals till now have been primarily preoccupied toward productive traits. From now, it should essentially be oriented toward suitability and fitness, above all adaptability to heat stress. In this way, molecular biology allows to directly achieve genotypes with the necessary phenotypic characteristics. These tools will enable an improved accuracy and efficiency of selection for heat tolerant animals. Livestock is an important foundation of livelihood. It is essential to find appropriate solutions not only to maintain this industry as an economically feasible enterprise, but also to boost up the profitability and decrease environmental pollutants by reducing the ill-effects of climate change. Animal sector and agriculture will eyewitness more harsh challenges in countless fields in the 21st century. Decision makers, extension services and research institutions have to support and encourage livestock activities to handle as best as possible with less loss in production, abating of animal products, expansion of land desertification and the worsening of animal health under the effects of the climate change we expect in the coming decades.

Future perspectives

Acknowledging the challenges of global warming, there should be an urge in shift of the practice in agriculture and in the role of livestock within farming systems. Science and technology are lacking on fundamental issues, including those related to climatic adaptation, dissemination of new understandings in rangeland ecology (matching stocking rates with pasture production, adjusting herd, managing diet quality, more effective use of silage, pasture seeding and rotation, using more suitable livestock breeds or species). Mixing grain crops with pasture plants and livestock could result in a more branch out system that will be more resilient to higher temperatures, elevated carbon dioxide levels, uncertain precipitation changes, and other dramatic effects resulting from the global climate change. The key issues for effectively managing environment stress and livestock production include

- Development of early warning system;
- Advances in the tactics to improve water use proficiency and upkeep towards diversified production system
- Taking advantage of genetic potential of native breeds
- Research on development of suitable breeding programmes and nutritional interventions.

Epigenetic regulation of gene expression and thermal imprinting of the genome could also be a knowledgeable method to improve thermal tolerance. In the future we can be benefited, more than in the past decades, from the years of experience and by applying our scientiûc knowledge to useful traditional practices.

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