Climate Change Impacts in Livestock Sector

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Abstract

Global warming is real. Sea surface temperature is increasing. Polar ice is melting. Sea level rise is likely. Increase in sea surface temperature across the Indian Ocean may be having significant influence on summer monsoon over India. Global CC is expected to alter temperature, precipitation, atmospheric carbon dioxide levels, and water availability in ways that will affect the productivity of crop and livestock systems. For livestock systems, CC could affect the costs and returns of production by altering the thermal environment of animals thereby affecting animal health, reproduction, and the efficiency by which livestock convert feed into retained products (especially meat and milk). Further, it is predicted that global warming is likely to increase temperature levels and the frequency of extreme temperatures – hotter daily maximums and more frequent or longer heat waves – which could adversely affect livestock production in the warm season. In the present changing climate scenario, there are numerous stresses other than the heat stress which constrain the livestock and have severe consequences on their production. The projected climate change seriously hampers the pasture availability especially during the period of frequent drought in summer. Thus, livestock suffer from drastic nutrition deficiency. Both the quantity and the quality of the available pastures are affected during extreme environmental conditions.

Keywords: Climate change, live stock, global warming

1. Introduction

Global warming is real. Sea surface temperature is increasing. Polar ice is melting. Sea level rise is likely. Increase in sea surface temperature across the Indian Ocean may be having significant influence on summer monsoon over India. For example, the onset of monsoon was on 6th June during 2014 and the monsoon rainfall was unusually deficit (more than 30−50% in some districts across the Peninsular India) till the first week of July and picked up later, finally ended with a deficit of 12% across the country while several regions in south experienced unusually deficit monsoon rainfall. In contrast, heavy floods were noticed in Orissa, Jammu & Kashmir and several other meteorological sub-divisions across the Country in 2014. The unprecedented cyclone 'Hudhud' in the second week of October, 2014 devastated the three northern districts of Andhra Pradesh. Such monsoon aberrations and intensity of cyclones are expected frequently due to global warming and climate change. Another important aspect of monsoon in India is that whether the monsoon is normal, excess or deficit as noticed in 2012, 2013 and 2014, one region or other experiences floods or droughts and the agriculture sector including animal agriculture is adversely affected. Considerable extent of mortality is likely during the occurrence of cyclones, floods and droughts. Lack of fodder and drinking water are the constraints to feed the animals during prolonged drought periods and thereby mortality is noticed. Cold and heat waves are not uncommon in India and they adversely affect poultry and dairy production to a considerable extent. The classical examples were the cold wave in 2002−03 and 2005-06 and the heat wave in 2003−04. The poultry farming was adversely affected due to heat wave in May 2003 across the State of Andhra Pradesh. Therefore, suitable housing and other management techniques are essential to minimize the adverse impact of heat and cold waves in poultry and dairy farming. The year 2010 was the warmest year in India, followed by 2009 and the very first decade of this century recorded as the warmest since eight out of 10 years were identified as the warm years. Increase in mean annual surface air temperature across India was 0.54 °C during the last 110 years while the rate of increase was high in post monsoon and winter seasons (Attri and Tyagi, 2010; Rathore et al., 2013). Rate of increase in temperature was high across the West Coast, North East and the Western Himalayas of India when compared to that of other zones within the Country. Reports on global warming projections indicate that increase in temperature will be restricted to be around 2–3 °C by 2080 A.D. through concerted efforts globally. Decline in rainfall was also noticed during the monsoon season in many parts of the country since last 50–60 years and availability of water is a constraint in ensuing decades under the projected climate change scenario. To meet the requirement of egg, milk, meat, fish and foodgrains' production by 2020 in tune with the growing population in warming India, there is urgent need to climate change adaptation and mitigation strategies in animal agriculture for sustenance of rural livelihoods.

2. Impact of heat stress on livestock production and reproduction

Global CC is expected to alter temperature, precipitation, atmospheric carbon dioxide levels, and water availability in ways that will affect the productivity of crop and livestock systems. For livestock systems, CC could affect the costs and returns of production by altering the thermal environment of animals thereby affecting animal health, reproduction, and the efficiency by which livestock convert feed into retained products (especially meat and milk). Further, it is predicted that global warming is likely to increase temperature levels and the frequency of extreme temperatures – hotter daily maximums and more frequent or longer heat waves – which could adversely affect livestock production in the warm season (Figure 1).

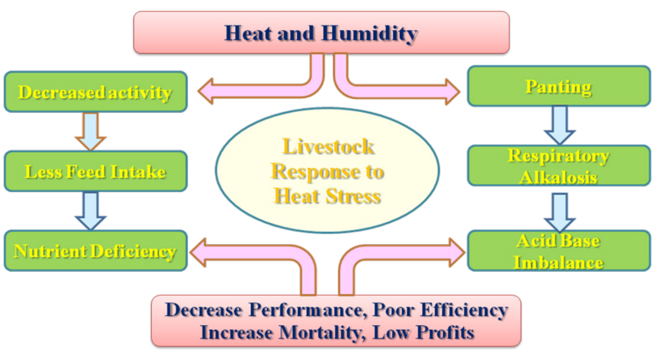

Figure 1: Livestock response to heat stress

High ambient temperatures, solar radiation, and humidity are environmental stressing factors that affect animals.

Reproductive axis is one plane where stress effects are the most pronounced and have gross economic impact. Stress activates systems which influence reproduction at hypothalamus, pituitary or gonads levels. The reproductive axis is inhibited at all levels; steroidogenesis is directly inhibited at both ovaries and testes. The principle target is the GnRH neuron activity thus affecting the GnRH secretion into the hypophyseal portal blood. Stress can also affect the gonadotrophic cell responsiveness to GnRH. Glucocorticoids are critical to mediating inhibitory effect on reproduction. Environmental stresses affect the estrous behaviour, embryo production, birth weights of lambs, placental size, and function and foetal growth rate. Several factors affect the reproductive performance of farm animals, among which the physical environment and nutrition play a significant role.

Most reproductive responses to environmental factors are coordinated at the brain level, where all external and internal inputs ultimately converge into a final common pathway that controls the secretion of gonadotrophin-releasing hormone (GnRH). In turn, this neurohormone controls the secretion of gonadotrophins, the pituitary hormones that determine the activity of the reproductive axis (Figure 2).

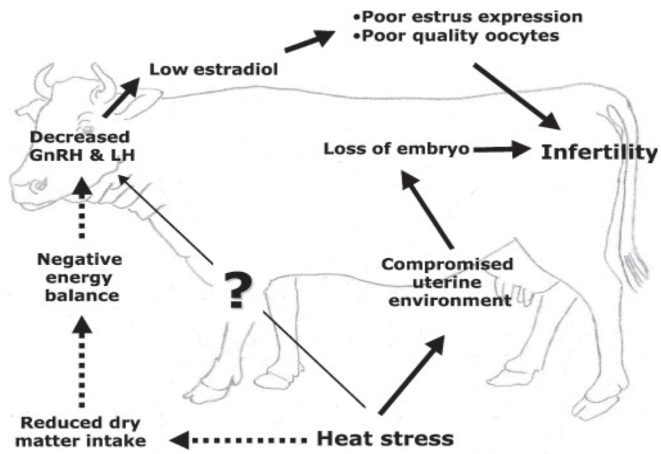

Figure 2: Effect of heat stress on livestock

3. Climate Change and concept of multiple stresses

In the present changing climate scenario, there are numerous stresses other than the heat stress which constrain the livestock and have severe consequences on their production. The projected climate change seriously hampers the pasture availability especially during the period of frequent drought in summer. Thus, livestock suffer from drastic nutrition deficiency. Both the quantity and the quality of the available pastures are affected during extreme environmental conditions. Further, with the changing climate, animals have to walk a long distances in search of pastures. This locomotory activity also put the livestock species under enormous stress (Sejian et al., 2012). Hence it's not only the heat stress that need to be counteracted but the nutrition and walking stress are also of great concern. Though the animals live in a complex world, researchers most often study the influence of only one stress factor at a time as comprehensive, balanced, and multifactorial experiments are technically difficult to manage, analyze and interpret. When exposed to one stress at a time, animals can effectively counter it based on their stored body reserves and without altering the productive functions. However, if they are exposed to more than one stress at a time, the summated effects of the different stressors might prove detrimental to these animals. Such a response is attributed to animal's inability to cope with the combined effects of different stressors simultaneously. In such a case, the animal's body reserves are not sufficient to effectively counter multiple environmental stressors (Sejian et al., 2012). As a result their adaptive capabilities are hampered and the animals struggle to maintain normal homeothermy. Table 1 describes the impact of individual, combined and multiple stresses on sheep production and reproduction.

Table 1: Effect of thermal, nutritional, combined and multiple stresses on growth and reproductive parameters of Malpura ewes

Parameters	Control	Thermal stress	Nutritional stress	Combined stresses	Multiple stresses
Initial body weight	33.75±2.56[a]	33.52±1.85[a]	34.68±1.70[a]	34.87±1.46[a]	32.63±0.98[a]
Final body weight	39.67±2.65[a]	35.19±1.46a[b]	30.39±1.50[b]	30.04±1.35[b]	29.55±1.22[b]
ADG	169.14±0.01[a]	47.71±0.07[b]	-122.57±0.06[c]	-138.00±0.07[c]	-88.00
Ewes in heat (%)	85.71[a]	57.14[b]	85.71[a]	71.43[ab]	41.7[c]
Estrus duration (hrs)	38.00±2.41[a]	23.40±3.34[b]	28.50±5.68[bc]	18.75±3.75[bd]	14.4±2.78[c]
Estrus cycle length (days)	18.17±0.31[b]	20.28±0.74a[b]	18.00±0.27[b]	22.25±1.67[a]	23.56±1.45[a]
Conception rate (%)	71.43[a]	42.86a[b]	57.14[ab]	28.57[b]	-
Lambing rate (%)	71.43[a]	42.86a[b]	57.14[ab]	28.57[b]	-
Estradiol (pg mL^{-1})	14.58±0.96[a]	12.06±0.73[b]	12.80±0.91[b]	10.04±0.74[c]	7.19±0.23[d]
Progesterone (ng ml^{-1})	3.31±0.56[c]	4.48±0.32[ab]	3.98±0.26[bc]	5.19±0.27[a]	7.34±0.28[d]

Combined stresses-thermal and nutritional stress; Multiple stresses- thermal, nutritional and walking stress. Means and SEM within a row having different superscripts differ significantly (P<0.05). (Source: Sejian et al., 2010; Sejian et al., 2011 ; Sejian et al., 2012; Sejian et al., 2013).

4. Environmental stress and livestock adaptation

4.1. Behavioral and Morphological adaptability

An adaptation is referred to means by which an animal makes it possible for it to live in a particular place and in a particular way. It may be a phenotype adaptation, like the size or shape of the animal's body, or the way in which its body works i.e. physiological adaptation. Or it may be the way the animal behaves. Each adaptation has been produced by evolution. A novel study by a team of scientists in Britain reported that average body size of a wild Soay sheep of Hirta (Scottish island) in the St Kilda archipelago has decreased by approximately 5% over the last 24 years. This is in contradiction to evolutionary theory which suggests that average size of wild sheep increases during process of evolution in colder environment and tend to be more likely to survive and reproduce than smaller ones. The reason for bringing down the size of Soay sheep was attributed to shorter and milder winters caused by global climate change. In the changing climate conditions, the weight gain by the lambs during early months of life was diminished as compared to few decades back when winters were colder. The lambs had to put more weight to survive under extreme cold for survival. The advantage of dark coloured coat of animals over lighter counterparts in colder environment is linked to conservation of solar energy and saving food energy for maintenance of homeothermy. The change in climate (warmer cold season) has been associated with the change in the proportion of light colored Soay sheep in total population. A study has revealed that dark colored Soay sheep have decreased over the past 20 years as the ambient temperature was increased.

4.2. Physiological adaptability

Normal fluctuations in physiological responses, i.e. respiration rate, pulse rate, rectal temperature and sweating rate vary with the changes in season in an effort to maintain normal body temperature independent of the fluctuation in environmental temperature. Hence these are considered important indices for comparative adaptability of different genotypes. Increased respiration rate is the first reaction when animals are exposed to environmental temperatures above the thermoneutral zone (Sejian et al., 2010). This response ensures direct heat stimulation of the peripheral receptors, which transmit nervous impulses to the heat centre in the hypothalamus. The magnitude of physiological responses evoked by thermal stress and time required for their subsequent return to normalcy after removing the stress were considered useful indices for assessing the thermal ability of animals. Sweating in livestock is considered to be important in heat dissipation than respiratory evaporative cooling. The native animals were found to utilize cutaneous evaporative cooling relatively more than exotic animals during thermal stress at high ambient temperature. The environmental variables viz; ambient temperature relative humidity and wind velocity have been found to influence sweat gland structural dimensions and coat characteristics in sheep.

4.3. Neuro-endocrine mechanism of adaptation

Homeostasis is referred to as the relative physiological activity in an organism critical to survival. Regardless of the changes in the environmental conditions, living species attempt to maintain constant core body temperature within a range through a definite set of regulatory behavioral and physiological mechanisms. The stress response in general is influenced by a number of factors including: species, breed, previous exposure, health status, level of performance, body condition, mental state and age. Neuroendocrine responses to stress play an integral role in the maintenance of homeostasis in livestock. There are substantial evidences which suggests that neuroendocrine responses varies with the type of stressor and are specific and graded, rather than 'all or none'. While acute responses bring about survival; chronic responses may result in morbidity and mortality. Both of these responses are integrated via a network of mutual interplay between central nervous system, endocrine system and the immune system. Infact, it's a network that exist between nervous and endocrine system which coordinate this stress response. An important component of this network is the hypothalamo-pituitary- adrenal (HPA) axis and it consists of 3 components: corticotrophin releasing hormone (CRH) neurons in the hypothalamus, corticotrophs in the anterior pituitary and the adrenal cortex. The HPA axis is a critical part of this mesh which is activated by the release of several neurotransmitters and hormones. Further, understanding the cellular dynamics behind the short and long term adaptation in the tropical animals is useful in developing mitigatory measures for improving the productivity.

4.4. Molecular and cellular mechanism of livestock adaptation

Genetic selection has been a traditional method to reduce effects of environment on livestock by development of animals that are genetically adapted to hot climates. Despite the strong knowledge base about the physiological aspects, the effects of heat stress at the cellular and genetic level are not clearly understood. It is the cellular or molecular level at which stress also has its deleterious effects. Thus, the adaptive response is observed at cellular level as well and an insight into the molecular or cellular mechanism of stress relieve is important. As a result of stress, there are an increased number of non-native conformational proteins with anomalous folding. Heat shock proteins, as we know, are evolutionary conserved and many of them act as regulator of protein folding and structural functions of proteins. There is presence of common environment specific response genes, making 18-38% of the genome. These genes induce expression of classical heat shock proteins, osmotic stress protectants, protein degradation enzyme etc.

Functional genomics research is providing new knowledge about the impact of heat stress on livestock production and reproduction. Using functional genomics to identify genes that are regulated up- or down during a stressful event can lead to the identification of animals that are genetically superior for coping with stress and toward the creation of therapeutic drugs and treatments that target affected genes. Given the complexity of the traits related to adaptation to tropical environments, the discovery of genes controlling these traits is a very difficult task. One obvious approach of identifying genes associated with acclimation to thermal stress is to utilize gene expression microarrays in models of thermal acclimation to identify changes in gene expression during acute and chronic thermal stress. Further, gene knockout models in single cells also allows for better delineation of the cellular metabolic machinery required to acclimate to thermal stress. With the development of molecular biotechnologies, new opportunities are available to characterize gene expression and identify key cellular responses to heat stress. These new tools enable to improve the accuracy and the efficiency of selection for heat tolerance. Epigenetic regulation of gene expression and thermal imprinting of the genome could also be an efficient method to improve thermal tolerance.

5. Conclusion

Among the environmental variables, heat stress seems to be the most detrimental factor affecting livestock production. Heat stress can cause a significant financial burden to livestock producers by decreasing milk and milk component production, meat production, decreasing reproductive efficiency, and adversely affecting livestock health. In addition, CC is seen as a major threat to the survival of many species, ecosystems and the sustainability of livestock production systems in many parts of the world.

6. Future Research

Responding to the challenges of global warming necessitate a paradigm shift in the practice of agriculture and in the role of livestock within the farming system. Science and technology are lacking in thematic issues, including those related to climatic adaptation, dissemination of new understandings in rangeland ecology, and a holistic understanding of pastoral resource management. The key thematic issues on environment stress and livestock production includes: early warning system, multiple stress research, simultaneously, simulation models, water experiments, exploitation of genetic potential of native breeds, suitable breeding programme and nutritional intervention research. Livestock farmers should have key roles in determining what adaptation and mitigation strategies they support if these have to sustain livestock production in changing climate. The integration of new technologies into the research and technology transfer systems potentially offers many opportunities to further the development of CC adaptation strategies.

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