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Effects of climate change on yak production at high altitude

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ABSTRACT

Yak is considered the life-line of highland pastoral nomads who raise them on high altitude ranges under transhumance. Yak production at high-altitude alpine ranges may be affected due to the gradual increase of environmental temperature as a result of impending climate change. The mean environmental temperature of yak habitat at 3,000 m above mean sea level in Northeastern Indian Himalaya, varying from 1.2 to 11.1°C and 7.9 to 19.7°C during winter and summer seasons, respectively, evidencing the heat stress to the yaks in summer with THI more than 52. When environmental temperature exceeds 13°C, adaptive mechanisms of body accelerate respiration rate and heart rate to cope with heat stress in yaks. It was reported that the climate change is already witnessed at high altitude with average rise of environmental temperature 0.01 to 0.04°C/year and the expected increase of 2–3°C have potentially catastrophic for high-altitude animals and ecosystem. The alpine pasture decreased in vegetative above ground biomass and composition which results in starvation or loss of body condition appeared to be manifested as reduced fertility in yak with low milk yield. Further, climate change may result in increase of pests and diseases at the lower permanent settlements of sub-alpine region thereby making these areas incompatible for yaks. Mitigation of heat stress in yak possibly can be done through three means by physical modification of the environment, improved nutritional management and genetic development of strains that would be less sensitive to heat stress.

Key words: Climate change, Heat stress, High altitude, Yak production

Yak (*Poephagus grunniens*) is the most remarkable and multipurpose domestic animal living at high altitudes of 3,000–6,000 m above mean sea level (msl), where the alpine pastures are found without frost-free period during any part of the year. Many of the characteristics of the yak can be regarded as adaptations to the high altitude conditions, in which other livestock species have difficulty in surviving (Wiener *et al*. 2003). Yak husbandry is one of the important and indispensable aspects of the of highlanders, where other livestock species can hardly live but yaks can survive, reproduce and produce milk, meat, wool and other byproducts (Haynes *et al*. 2014). Hence, yaks are considered as lifeline of the highlanders in remote terrain and yak is the only sustainable livelihood due to non-availability of arable land for major agriculture (Haynes and Yang 2013). As the effect of global warming, the atmospheric temperature of earth has increased by 0.74 ± 0.18°C in 20th century and is predicted to be increased by 1.8 to 4°C by the end 21st century (IPCC 2007b). The gradual increase of environmental temperature in yak tracts may affect the themoneutral zone of yak which ranges from 5° to 13°C (Wiener *et al*. 2003) with an average of 10°C (Zhang 2000, Krishnan *et al*. 2009). Therefore, the increasing trend of ambient temperature may absolutely cause heat stress to the yaks at high altitudes (Krishnan *et al*. 2014).

Traditional system of yak rearing: The strategies practiced by the yak rearers to adjust and adapt to their natural surroundings have resulted in unique systems of natural resource management (Dong *et al*. 2012). The transhumance pastoralism is the most common and popular adaptive method at the high altitudes to utilize the seasonal pastures. Traditionally, yak farmers used to migrate to higher altitudes during summer and return to lower altitudes called winter pastures at around 3,000 m above msl during winter (Maiti *et al*. 2015). This transhumance pastoralism provides almost same ambient temperature round year which is also one of the important practice to minimize the heat stress in yak (Krishnan *et al*. 2009). The climate change may significantly alter the normal schedule of transhumance pastoralism due to fodder scarcity and increasing trend of environmental temperature which may force the herds to move further higher altitudes.

Effect of climate change at high altitude: Global warming may cause a variety of risks to mountain habitats by affecting the distribution of plant and animal (Beckage *et al*. 2008), under the expected climate scenarios in which the final perspective may result in loss of rare species of alpine habitats (Dirnbock *et al*. 2011) and dearth of pasture lands. Parmesan and Yohe (2003) reported that a significant range shifts of many organism toward the poles or toward higher altitudes as a consequence of increased global

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temperatures. The impact of climate change on high altitude animals and their habitats has become big challenge in the 21st century to sustain their production. The climate change is already witnessed in the high altitudes with average rise of temperature 0.01° to 0.04°C/year; the highest rates of warming are in winter with the lowest or even cooling in summer and increase with altitudinal rise (Haynes *et al*. 2014). The Annual mean temperatures are projected to increase an average of 2.9°C by the middle of the century with range (places/seasons) of 2.9° to 4.3°C by the end of the century (Sharma *et al*. 2009). The expected current trend of increase in temperature of 2–3°C due to climate change have potentially catastrophic for greater Himalayan animals and ecosystems (Xu *et al*. 2009). The data available on temperature in Himalayas indicated that the warming trend of last 3–4 decades was more than the global average of 0.74°C over last century (Du *et al*. 2004).

Change on rise of temperature with altitude: The seasonal temperature fluctuations are also changing in both timing and extent and the rate of change of temperature with altitude is becoming less that is higher altitude areas are warming faster than lower altitude areas (Li *et al*. 2010). Hence, the difference in temperature between different altitudes is becoming less and gradually more increase in temperature with elevation or altitude, with areas above 4,000 m experiencing the greatest warming rates up to 0.06°C (Shrestha *et al*. 1999, Sharma *et al*. 2009). Whereas, Liu and Chen (2000) and Gautam *et al*. (2014) reported that the decadal temperature rise remains 0.2°C up to 2,000 m above msl and it often exceeds 0.3°C when the altitude is above 2,000 m.

Climate change and its effect on alpine pasture: The primary habitat types of high altitude are alpine meadow and shrub vegetation, vegetation in this region provides relatively favourable forage for yak, the pastoralists' primary livestock. The high altitude pasturelands may be affected by warming and drying trend as result of climate change (Wangchuk *et al*. 2013). Direct field measurements (French and Wang 1994), ice core data (Thompson *et al*. 2003) and interviews with pastoralists over 25 years in the Himalayas, provided evidence of a warming trend on alpine pasture (Yao *et al*. 1997, Haynes *et al*. 2014). The altitude at which the alpine habitat is found decreases with increasing latitude and studies have shown that the mean temperatures in the Himalayan alpine zones have increased by 0.6 to 1.3°C between 1975 and 2006 (Dimri and Dash 2011). The species composition and structure and functioning of alpine meadows are going to change both, because of increased temperatures and loss of glacier. The shift of alpine pasture to higher elevations may affect the high altitude animal rearing and also cause fodder scarcity (Singh *et al*. 2010). However, alpine pasture has little scope to march upward as the temperature rises. Because, species that depend on snow cover for protection would be exposed to frost, and others that require winter chilling for bud break may not get sufficiently low temperatures over a long enough period to survive (Cannone *et al*. 2007). The effects of climate change and grazing pattern have decreased the vegetative above ground biomass in total and composition at high altitude (Klein *et al*. 2004).

Effects of climate change on distribution of yak: The temperature is one of the most important environmental variables that can affect the health, welfare and the production efficiency of animals (Kuczynski *et al*. 2011). The mean environmental temperature of yak habitat at the altitude of 3,000 m above msl varies from -1.16 to 11.06°C and 7.88 to 19.69°C during winter and summer, respectively, which absolutely cause thermal stress to the yak during summer (Krishnan *et al*. 2014). The physiological and metabolic adjustment resulting from the climate change may have negative consequences on yak production. The climate change has complicated impacts on animals affecting distribution, growth, incidence of diseases, availability of fodder, productivity and even extinction of species in extreme cases due to habitat loss (Nardone *et al*. 2010). Climate change has an adverse effect on yak production at high altitudes, since the rising temperature is disturbing their natural habit and creating conditions that they may not live in (Wangchuk *et al*. 2013). Consequently, the stocking density of yaks decline in their native regions with the increased mean annual temperature. As a result, the yaks are moving upwards through the Himalayas and a quickly running out of comfortable living conditions. As the global warming continues, changing climatic patterns could possibly affect high altitude indigenous species like yak by creating shortage of water, fodder and increase in pests and diseases (Zhang 2000).

Factors disposing yak to heat stress: The yak's body is compact with short neck, short limbs, no dewlap, small ears and a short tail. The scrotum of the male is small, compact and hairy, and the udder of the female is small and also hairy. The skin has few wrinkles and the surface area of the yak is relatively small per unit of body weight (0.016 sq m/kg) (Wiener *et al*. 2003). Sweat glands are distributed in the skin over the whole body which is non-functional and sweating is restricted to muzzle region. The absence of sweating in the yak assists in cold tolerance by minimizing dissipation of body heat (Li Shihong 1984) but the same enforces the yak to intolerant to heat stress (Ouyang 1984).

Heat stress and prediction in yak: As the environmental temperature increases, certain thermoregulatory responses are initiated, including reduced feed intake, decreased activity and increased water intake, shade or wind seeking, increased peripheral blood flow, sweating and panting (West 2003, Haynes *et al*. 2014). However, these thermoregulatory activities may not be sufficient to maintain a normal body temperature during periods when ambient air temperature and humidity are particularly high. The temperature humidity index (THI) is one of most commonly used tool to assess the impact of heat stress on dairy animals, which combines the effects of both the temperature and humidity into one value (Dikmen and Hansen 2009). Mader *et al*. (2004) reported that the upper comfortable limit of cattle is THI 72 and when it exceeds 72 cattle start experiencing the heat stress. Whereas, the modified temperature humidity index for yak indicates that the THI 52 is comfortable and when it exceeds 52 the yaks started to experience the heat stress at higher altitudes (Krishnan *et al*. 2009).

Responses of yak to heat stress: The various adaptation characteristics of yak to cold harsh environmental conditions are more accountable to heat stress. As the ambient temperature increases above 13°C, the respiration rate of the yak starts to rise (Wiener *et al*. 2003, Haynes *et al*. 2014) and it was also reported that the respiration rate increased when the ambient temperature exceeded 10°C at the altitude of 3,000 m above msl (Krishnan *et al*. 2010). It has been suggested that yaks alter their respiration rate not only in response to a changing need for oxygen, but also to regulate the body temperature (Wiener *et al*. 2003). Since, the yak has thick skin with few functional sweat glands and a heavy coat, has few means for heat dissipation, other than respiratory system (Haynes *et al*. 2014). The heart rate and body temperature start to rise when the ambient temperature reaches 16°C, and at 20°C, yak start panting, stand nearby water sources or wading into streams and ponds, laying in the shade of trees without moving and ruminating (Li Shihong 1984).

Impact of climate change on yak production

Effect of heat stress on body weight gain: Air temperature were reported as the most important environmental factor influencing the growth and body size of yak (Chen 2000). Generally, yaks gain their body weight during summer and lose 25–30% of their body weight during winter (Pourouchottamane *et al*. 2011). Due to cyclic nutrient deficiency or unbalanced nutrient supply within short growing seasons for herbage, annual cycle of weight loss in cold season and weight gain or compensatory growth in warm season in yak is a common phenomenon (Yongqiang *et al*. 2000, Xue *et al*. 2005). The yaks are able to gain their body weight during summer inspite of thermal stress, if scientific interventions were adapted more production can be achieved.

Effect of heat stress on milk yield: The important factor that influencing milk yield is pasture production, which includes the quantity and quality of the herbage or alpine pastures (Li *et al*. 2011). It is clear that the climate change has already affected the quantity and quality of alpine pasture which in turn reduces the milk production (Li *et al*. 2010). The temperature affects the milk yield of yak grazing on pastures, where yak produces less milk at high temperature with strong solar radiation on clear days and high yield within short periods of cloudy or rainy (Dong *et al*. 2007). Even, day-to-day fluctuations of weather is tend to affect the milk yield of the yak (Xu Guilin 1983) and the optimum temperature for high production of yak is around 5°–13°C (Zeng and Chen 1980).

Effect of climate change on reproduction: Yaks are considered to be seasonal breeders with mating and conception restricted to the warm part of the year (Krishnan *et al*. 2010). The onset and end of the breeding season are affected by climatic factors such as ambient temperature, relative humidity, availability of feed and fodder and latitude and altitude (Shrestha *et al*. 1999). The estrus is most common in the cool morning or evening and bred during overcast days in the breeding season. The duration of estrus is difficult to quantify because signs of estrus may be weak or vague during summer (Krishnan *et al*. 2014). However, the duration of estrus is longer during cool weather compare to warm weather and age of the animal (Wiener *et al*. 2003). The quality and quantity of fodder is decreasing as a result of global warming at high altitude which results in starvation or loss of body condition appear to be manifested as reduced fertility and pregnancy rate in yak (Zhang 2000).

Effects of climate change on yak diseases: The heavy coat and other specialized thermoregulatory mechanism of yak keep them alive in extreme conditions of high altitude but are responsible for heat load in warm climatic condition (Wiener *et al*. 2003). Moreover, the absence of immunity to lowland cattle diseases dispose them to parasitic and vector borne diseases. The occurrence of diseases has become more prominent along with the changing climate (Sherpa and Kayastha 2009). Some diseases like foot and mouth, brucellosis, infectious bovine rhinotracheitis, hemorrhagic septicaemia, chlamydiosis, salmonellosis, gid, and tick-borne diseases are causing death of yaks which in turn minimize yak productivity (Gyamtsho 2000). Yaks can survive in the summer pasture in high altitude even during the severe winter provided that there is sufficient feed and fodder but they cannot withstand the warmer climate of the lower settlement in the sub-alpine region with more ticks and flies, which force the yaks to migrate upslope or higher altitudes (Wangchuk *et al*. 2013). The rising ambient temperature due to climate change will result in increase in pests as well as diseases (Philip *et al*. 2014) especially in the lower permanent settlements in the sub-alpine region thereby making these areas unsuitable for yaks (Wangchuk *et al*. 2013).

Strategies to ameliorate heat stress in yak

The high altitude climate, the ecosystems are very fragile and sensitive to global climate change (Wangchuk *et al*. 2013). As the global warming continues, changing climatic patterns could possibly affect high altitude indigenous animals like yak by creating shortage of water, fodder and increase in pests and diseases (Haynes *et al*. 2014). Therefore, different strategies have to be developed to mitigate heat stress in yaks and to augment the productivity. Yaks are more susceptible to heat stress. Hence, it is extremely necessary to minimize the heat stress to obtain optimum productive and reproductive performance (Krishnan *et al*. 2008). Mitigation of the effect of climate change on yak possibly can be done by three means, physical modification of the environment, improved nutritional management and genetic development of strains that would be less sensitive to heat stress (West 2003, Collier *et al*. 2006).

Physical modification of the environment: Yaks are reared in free range system without any shelter at alpine pasture. It is necessary to construct suitable temporary shed in the grazing areas for free-range yaks to protect them from adverse climatic conditions. Moreover, at organized farms, suitable housing with necessary air circulation and cooling facilities may be provided for the animals maintained under semi-intensive system (Krishnan *et al*. 2008). Housing of milking yaks during hot days improves the milk production than the free range. The perspective of yak milk production is bright if all or most of these options are adopted timely and properly (Dong *et al*. 2007).

Improved nutritional management: The yaks must be maintained on quality feed with low fibre, optimum protein and energy during the period of heat stress (West 1999). However, yaks are not fed with any supplementary feed where they are solely depending on the alpine pastures. Hence, grazing management remains an important consideration to improve the fodder quality at high altitude (Paul *et al*. 2010). Energy requirements of yaks may be standardized by scientific approach to determine the optimum time for supplemental feeding to prevent loss of body weight in the winter season as well as to augment the production during summer.

Genetic development of strains with less sensitive to heat stress: Systematic crossing of yak with local cattle is popular in traditional herd farming system of yak husbandry (Robinson 1993). These hybrids find a special niche with herdsmen, usually at lower altitude than typical yak. Hybrid females are an important source of milk and males are used as draught or meat animal since they are infertile. These hybrids are very suitable for work as they are easily tamed and have better heat tolerance than pure yak (Joshi *et al*. 1994). The cross breeding/hybridization can benefit from the higher performance of hybrid vigor and the crosses are better adapted than the parents to various range of altitudes/ ecological zones (Dong *et al*. 2009).

Yak husbandry is declining at an alarming rate due to lower economic benefits derived from yak husbandry in addition to global warming. Many aspects of the environment cannot be altered, although their worst effects can be lessened by provision of shelter and feeding management. However, the cost effectiveness of such measures is always an over-riding consideration. Developing genetically superior animals through selective breeding / hybridization that would be less sensitive to heat stress is another possible option to minimize the heat stress. Approach should be made to develop animals that would maintain desired productive and reproductive performance specific to high altitude environmental conditions. Creating suitable temporary sheds in the grazing areas for free-range yaks are necessary to protect them from adverse climatic conditions. Climate change is one of possible cause of rangeland degradation and of desertification of some areas. Therefore, alpine pasture restoration programme, sustainable yak stocking rate along with control grazing scheme based on people's participation may be adopted in the yak rearing areas. Research and development on yak husbandry should be accomplished in the light of highlander's perspective so that conservation of yak as well as heat ameliorative measures could be achieved in the near future to obtain optimum productivity.

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