



Health and productivity of dairy cattle in high altitude cold desert environment of Leh-Ladakh: A review

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ABSTRACT

The environment is usually attributed as the major climatic factor affecting animal health and production system in all agro-climatic zones. There are various environmental components viz. temperature, radiation, snowfall, wind, precipitation, humidity etc. that impact animal health and productivity. Ladakh is a remote and difficult terrain of India for studying the impact of climate change on livestock production. This area is situated at high altitude, which varies from 10,000 to 12,000 feet from mean sea level (MSL) and temperature range is 35° to –35°C. The atmospheric oxygen pressure is 30% short of MSL. Therefore, this region exhibits hypobaric-hypoxia, extreme cold and dry-arid climate for most of the year, which restrict the growth and productivity of the different livestock populations, including dairy cattle. However, demands are very high for milk and milk products by local people, Indian troops deployed in this region and tourists. Availability of fodder and high altitude stress-induced maladies, mountain sickness (brisket edema), stunted growth, infertility, mastitis pneumonia, etc. severely limits the dairy development, which has increased the gap between supply and demand of dairy products in this region. The impact of climate change on livestock production in Ladakh is a relatively ignored research area. Since the literature on the effect of climate change on dairy cattle productivity in Leh-Ladakh is scarce, therefore, the present article reviewed the available reports and presents authors' own observations on how this climate change impacted on health, production and reproduction of dairy cattle in high altitude cold desert.

Key words: Animal health, Cattle, Climate change, Cold desert, Environment, High altitude

The basic purpose of rearing food animals is to convert feedstuffs into meat and milk for human consumption. The rate and efficiency of this conversion is affected by ambient environment and animal's genetic potential, which are economically important to both producers and consumers of animal origin products (Gaughan 2012). In the event of climate change, the adverse and abrupt changes in temperature, solar radiation, wind velocity, precipitation and humidity pose severe challenges to not only animal population but also to crop production system (Salak-Johnson 2011). Thus, climate change represents a critical challenge to society in present days.

The adverse effect of climate change is mostly seen as global warming, hence a relevant increase of drought is expected across the world affecting forage and crop production (Nardone *et al.* 2010). Reports indicated that developing countries are more vulnerable to climate change as compared to the developed ones due to their high dependence on agro-animal based economy with limited capacity to adapt institutionally and financially (Singh *et al.* 2011). Despite the importance of livestock in livelihood

of poor people and the magnitude of the climate change that is likely to affect livestock systems, the intersection of climate change and livestock in developing countries is a relatively neglected research area (Thornton *et al.* 2009). At high altitude also, climate change will affect animal health and production adversely by affecting micro-environment, vector/insect population and crop production (Meena *et al.* 2008, Singh *et al.* 2012). This paper, therefore, discusses various aspects of high altitude environment and their effect on animal health and production.

Climate change impact on environment at high altitude

Ladakh is situated in the upper Himalayas at altitudes ranging from 3,000 m, PO₂: 15.123 kPa to 5,000 m, 11.76 kPa above mean sea level (msl). There are 4 important factors that affect high altitude climate, namely altitude, latitude, topography and continentality. These factors are responsible for changes in diurnal/annual temperature, air density, vapour content, snowfall, rainfall, wind velocity, evaporation, solar radiation and day length. Environment of Leh-Ladakh is characterized by hypobaric hypoxia coupled with extreme temperature variation (–35° to 35°C), high UV (ultra-violet) exposure (intensive radiation level up to 6–7 kWh/mm), low precipitation (less than 100 mm, mostly snowfall and frozen ice), low humidity (25–39%),

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longer photoperiod and sunny days (Bharti *et al.* 2011a, Charan *et al.* 2012).

Changes in climate are responsible for reducing the depth of snowpacks of the mountains and glaciers, increasing freshwater runoff or shifting of runoff in Leh-Ladakh. Therefore, it poses a number of potential risks to high altitude habitans including human, domestic animals and wildlife. We observed the migration of native yak to a higher altitude to protect themselves from warm sunny days. Reduced pashmina fibre productions in goat, grazing of cattle at higher altitude etc. are the other observations. Hence, global warming is causing a shift in the habitat from lower altitude to the higher alpine zone and such shift would encroach the rare flora and fauna of alpine region or other high-altitude habitats (Nogues-Bravo *et al.* 2007).

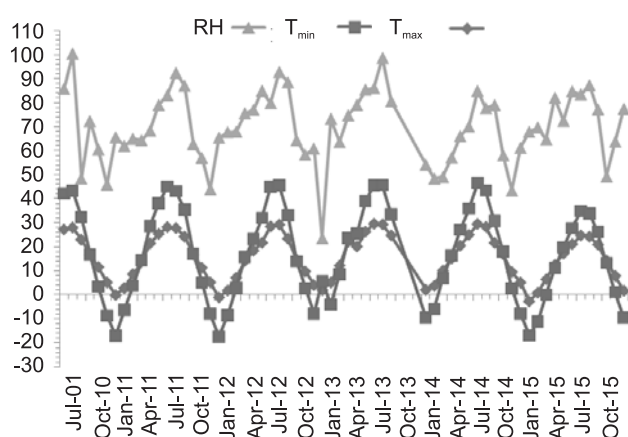


Fig. 1. Variation in relative humidity (RH), maximum temperature (T_{max}), and minimum temperature (T_{min}) of six consecutive years (2010–2015) in Leh-Ladakh, Kashmir.

Some of the climatic factors indicated significant variation in maximum-minimum temperature, relative humidity and rainfall across the years and month-wise (Fig. 1). The study indicated a rise in maximum temperature, while a decline in minimum temperature by 3–4°C during winter (October–April). Interestingly, rainfall (mm) showed a decreasing trend during the study periods, viz. 265.6 (2010), 102 (2011), 46.43 (2012), 28.93 (2013), 47.05 (2014), 52.45 (2015). However, only 20–30% of villages depend on Indus river water for irrigation and rest rely on

glacier melting waters. Hence, climate changing patterns are posing a serious problem to farmers.

Moreover, this terrain responds very quickly to any weather change. Recently Ladakh witnessed the climatic events such as drought, untimely rainfall, cloudburst and flash floods in August 2010 and 2015, which caused soil erosion rendering agricultural fields unsuitable for crop cultivation. Since the weather forecast is very limited due to line of sight problem owing to obstruction of radar's view by the high mountains, the satellite is not able to send the farsighted images. Therefore, it is very difficult to predict the weather accurately over the region. Hence, climate change in Ladakh is more likely to affect agriculture leading to food insecurity and also the risk of disease outbreak resulting health insecurity.

Feed and fodder management for dairy cattle

At high altitude, agricultural practices are badly affected due to the hostile environment that lead to low fodder production. The district has 10,196 ha land under cultivation. Average holding size is about 1.377 ha. Holdings are mostly of small size, 46.36% are less than 1 ha, 38.44% between 1 and 3 ha, and 15.2% are above 3 ha. However, land under fodder cultivation is 2,095 ha, which is approximately 20% of net cultivable land (District Land Department 2010–11). Hence, limited cultivable land for



Fig. 2. Barren lands covered with unknown grasses, lucerne, and grain crops (left to right) during summer.



Fig. 3. Stall feeding of dairy cattle.

Table 1. Chemical composition of concentrate feed ingredients found in Ladakh*

Parameter	Local pea	Wheat grains	Barley grains
Dry matter (%)	93.33	89.09	92.05
Crude protein (%)	21.60	7.22	8.09
Crude fibre (%)	6.33	1.69	4.14
Ether extract (%)	1.35	1.45	2.07
Sand and silica (%)	3.33	0.13	0.70
Total ash (%)	6.69	1.42	2.97
Calcium (%)	0.35	0.25	0.30
Phosphorus (%)	0.34	0.27	0.34

*All the values are expressed on DM (dry matter) basis except for dry matter.

and alpine pasture for grazing. Untimely snow fall restricts the fodder production in Ladakh especially the lucerne. During the last 5–8 years, lucerne production decreased due to focus on cereal crop cultivation. Since the economics of milk production largely depend upon the availability of quality fodder at affordable prices, it is essential to develop low cost balanced feed using locally available feed ingredients. Attention should also be given to identification of new cold tolerant fodder crops for augmenting the fodder availability in the region.

Micro-environment management and housing of dairy cattle

Modification in the existing micro-environment is important to reduce the magnitude of cold stress and to improve energy efficiency of cattle (Ames 1980, Hahn 1981,

Table 2. Chemical composition of different tree leaves found in Ladakh*

Parameter	Willow (<i>Salix</i> sp.)	Poplar (<i>Populus</i> sp.)	Apricot (<i>Prunus</i> sp.)	Sarsing (<i>Elaeagnus</i> sp.)	Seabuckthorn (<i>Hippophae</i> sp.)
Organic matter (%)	92.07	91.55	91.76	92.35	93.00
Crude protein (%)	20.19	19.88	16.52	21.17	13.53
Crude fiber (%)	21.81	18.52	17.45	12.00	9.67
Ether extract (%)	3.75	3.60	2.69	4.66	4.02
Total ash (%)	7.93	8.45	8.14	7.65	7.12
Nitrogen free extract (%)	46.32	49.55	55.20	54.52	58.66

*All the values are expressed on dry matter (DM) basis.

fodder crops and unfavourable soil quality limit the availability of green and dry fodder (Bharti *et al.* 2011a, Charan *et al.* 2012). Moreover, the limited agricultural land resources available are utilized for grain production (wheat and barley) for human consumption rather than fodder production. Further, the crop yield including the fodder production declines due to climate change which affects the availability of food and fodder for animals. Under such conditions, animals are reared on a low plane of nutrition, which affects their health and productivity.

In Ladakh, agro-pastoral and pastoralist systems are prevailing to a larger extent. Lucerne hay, local grasses, wheat straw, and dried tree leaves are the only option as feed and fodder resources, especially for winter-feeding provided these are properly preserved (Fig. 2). Cattle are stall fed during winter (Fig. 3) on crop residues (local pea, wheat and barley), alfalfa (lucerne), tree leaves (willow and poplar plant), and other plant residues (apricot cake, apricot pomace).

Studies of Charan *et al.* (2011) indicated that the cereal crop residues and lucerne have good nutrient value, however, the tree leaves are rich in antioxidants (Tables 1, 2).

Lucerne is the only green fodders grown in Leh-Ladakh for feeding dry cattle during entire year. Different varieties of lucerne are grown in Leh-Ladakh, however, popular variety is *M. sativa*. Proximate nutrients of different varieties of lucerne are presented in Table 3.

In summer, the animals are let loose in uncultivated land

Cook *et al.* 2005, Salak-Johnson 2011). Villagers in general live in a traditionally compact housing system with their animals and build semi-underground or on ground animal houses of mud wall, roof covered with dry grasses, minimal ventilated room so that the house becomes thermally insulating and maintains warmth (Fig. 4). There is no concept of drainage system in animal sheds, which makes

Table 3. Chemical composition of different varieties of Lucerne grown in Ladakh*

Parameter	<i>Medicago sativa</i>	<i>Medicago media</i>	<i>Medicago falcata</i>
Organic matter (%)	94.86	94.36	92.74
Crude protein (%)	18.22	17.50	15.85
Crude fibre (%)	20.65	20.58	20.86
Ether extract (%)	1.57	1.23	1.14
Total ash (%)	5.14	5.64	7.26
Nitrogen free extract (%)	54.42	55.05	54.89

*All the values are expressed on dry matter basis.



Fig. 4. Housing system in Ladakh for dairy cattle and other livestock.

Table 4. Haematological indices of milking native and exotic (Jersey crossbred) cattle at high altitude

Parameter	Native cow	Exotic (Jersey crossbred)
WBC ($\times 10^3/\mu\text{l}$)	8.56 \pm 1.75	9.12 \pm 1.15
RBC ($\times 10^6/\mu\text{l}$)	6.96 \pm 1.01	8.05 \pm 1.40
Hb (g/dl)	11.44 \pm 1.65	9.26 \pm 1.27
HCT (%)	35.64 \pm 4.83	38.11 \pm 3.65
MCV (fl)	58.38* \pm 1.75	47.31 \pm 2.10
MCH (pg)	16.18* \pm 0.76	11.30 \pm 1.17
MCHC (g/dl)	31.89* \pm 0.97	24.23 \pm 1.24
PLT ($\times 10^3/\mu\text{l}$)	406.28 \pm 16.05	643.13* \pm 18.10
MPV (fl)	6.12 \pm 0.53	8.03* \pm 0.67
PCT (%)	0.23 \pm 0.05	0.36* \pm 0.04

*Values bearing superscript differ significantly ($P < 0.05$) between the rows.

housing quite unhygienic making these animals susceptible to respiratory tract infection due to high ammonia concentration.

Cleaning of the sheds is practiced once in 5–6 days for dung/urine disposal. During snowfall and extreme winter, farmers provide fumigation and artificial heating (Bukhari) to the animals.

Patho-physiological changes in cattle at high altitude

The variation in barometric pressure, which occurs with latitude, influences enormously the inhaled oxygen concentration at extreme altitudes that significantly affect adaptability, productivity and draughtability of animals (Bharti *et al.* 2011b, Singh *et al.* 2012). The efficiency of oxygen usage and energy metabolism is important for high altitude adaptation and optimum performance of animals (Bencowitz *et al.* 1982, Gautier 1996). The most significant factor determining the inspired O_2 at any given altitude is the barometric pressure since percentage of oxygen in atmospheric gases remains constant at 21%. With regards to adaptation and productivity of high yielding animals, high altitude stress (hypobaric-hypoxia, cold stress) is of primary concern, which induces various high mountain problems. The important cardio-respiratory changes which take place at high altitude are increased ventilation, constriction of the pulmonary artery, increased pulmonary vascular resistance and pulmonary arterial pressure, changes in the oxygen-haemoglobin dissociation curve, increase cardiac output, high heart and pulse rate, high systolic pressure, increased pulmonary circulation, increased erythropoiesis etc. (West 1984, Gautier 1996, Bharti *et al.* 2011b). These physiological mechanisms attempt to compensate body metabolism under high altitude stress. However, in susceptible animals, cardio-pulmonary changes may cause increase in pulmonary arterial pressure, cerebral edema, hypertrophy of arterioles and right ventricle. This hypertrophic cardiomyopathy leads to a dilated cardiomyopathy that causes hydrothorax (brisket disease) and finally the congestive heart failure (Cueva 1967).

Animals try to compensate for hypoxia by modifying their red blood cell characteristics (Bharti *et al.* 2011c), with significant differences in blood components, viz. Hb (haemoglobin), WBC (white blood cell count), RBC (red blood cell count), PLT (platelets count), HCT (haematocrit), MCV, MCH (mean corpuscular haemoglobin), MPV (mean platelet volume), MCHC (mean corpuscular haemoglobin concentration), and PCT (plateletcrit) between exotic cattle (susceptible) and healthy native cattle at high elevation (Table 4) (*unpublished data*).

In addition to haemogram, blood biochemicals also undergo a change in cattle at high altitude which further help in adaptation to high altitude stress. Our study revealed increase in serum lactate dehydrogenase, alkaline phosphatase, catalase, superoxide dismutase, SGPT (ALT) activity (serum glutamic-pyruvic transaminase or alanine transaminase), lower body antioxidant defense, increased level of pro-inflammatory cytokines, abnormal hormonal profile of cattle at high altitude (Bharti *et al.* 2011b, *Unpublished data*). Therefore, estimation of these biomarkers would help in understanding physio-pathology of high altitude stress which may help in better understanding of animal performance, health status and thus form the bases for their selection and breeding at high altitude.

Reproductive health and productivity of dairy cattle

In the recent years, climate change has further aggravated the problems for livestock productivity at high altitude. We have observed extension of the summer period, early or late change of winter or summer, higher UV radiation, increased rainfall, low snowfall during winter or summer snowfall, melting of glaciers, etc that are severely affecting the agricultural practices, livestock rearing and their health. Evidence from the Intergovernmental Panel on Climate change (IPCC 2007) is now overwhelmingly convincing that climate change is real and most vulnerable to agriculture and animal husbandry practices. Further, due to climate change, high environmental temperature impairs production and reproductive performance, body homeostasis, and metabolic and immune status of dairy cattle (Broucek *et*



Fig. 5. Local Ladakhi cow.

Table 5. Dairy cattle population in Leh district

Name of the block	Exotic cattle		Indigenous cattle		Yak/demo		Total	
	2007	2012	2007	2012	2007	2012	2007	2012
Khaltse	574	1108	3242	7768	2252	2060	6068	10936
Kharu	816	1588	3825	3768	881	864	5522	6220
Nyoma	92	138	2569	2531	5150	9103	7811	11772
Leh	9268	8613	3377	5384	175	227	12820	14224
Durbuk	0	164	2605	2702	3438	4272	6043	7138
Nubra	668	1366	9295	12021	1524	2351	11487	15738
Total	11418	12977	24813	34174	13420	18877	49751	66028

Source: 18th Livestock Census, Leh 2007; 19th Livestock Census, Leh 2012.

al. 1991). Therefore, there is a tremendous loss of metabolic energy in coping with stress that result in lesser energy available for production and reproduction. Hence, the native as well as exotic cattle do not perform well at high altitude.

Ladakhi cattle is the only native cattle residing in this region, which is non-descript breed of *Indicus* species (Fig. 5). Animals were well built and compact with strong legs. Body colour varied in different colours and shades i.e. black, brown and black with white patches. Muzzle and eyelids were mostly black. Body had long hairs with glossy sheen. Colours of skin, muzzle eyelids and hoof were black while horns were black in colour. Horns were curved with upward, outward then forward orientation with pointed tips. Hump and dewlap were mostly absent or small. The average body length, height at wither, horn length, ear length, face length, face width, tail length without switch and with switch in cows were 86.70 ± 0.62 cm, 93.12 ± 0.55 cm, 13.14 ± 0.54 cm, 14.23 ± 0.19 cm, 36.40 ± 0.45 cm, 14.31 ± 0.23 cm, 61.20 ± 1.42 cm and 88.10 ± 1.47 cm, respectively.

These cattle have poor genetic potential for milk production, however, their milk is rich in fat (4.9–5.2%), protein (3.8–4.0%), lactose (4.7–5.0%) and ash (0.82%). Spatial distribution of cows in different blocks of Leh is presented in Table 5.

Indigenous cattle (Ladakhi cow) population is gradually upgraded through cross-breeding with Holstein Frieswal and Jersey (Table 5). Adaptability traits are important than productive traits for cattle at high altitude. Therefore, dual-purpose crossbred having better resistant to hypobaric-hypoxia are more relevant to this region for milk production. The native people are also crossing female native cow with male yak. The female of the crossbred progeny is called Dzomo, while male is called Dzoe. Now, this became more domesticated animal than yak due to versatile nature and farm utility as dual-purpose animals in this hilly Ladakh region (Rizvi 1980). The Dzoe ploughs the field, transports luggage, while Dzomo supplies rich milk with a good percentage of fat. Dzoe and Dzomo are domesticated in most of the houses. The data revealed that the majority of the milk comes from Dzomo. The Dzomo can survive within cold of high altitudes, but is unable to tolerate the summer heat at lower altitude (Bharti *et al.* 2011).

Anoestrus and still birth are the foremost reproductive problems experienced in plain areas (Dong *et al.* 2009, Singh *et al.* 2011); owing to cold stress, hypobaric hypoxia, poor nutrients supply including mineral deficiency. Farmers in general practice natural service method of breeding, because artificial insemination (AI) does not insure to get good quality semen and also due to the non-availability of AI facility at times in many villages. Natural service also requires multiple attempts to conceive due to poor quality of semen as a result of high altitude stress (Bharti *et al.* 2011a). At high altitude, a very long calving interval (2–4 years) was observed in crossbred and native cattle due to anoestrus condition, poor fertility and an early embryonic death. Selective breeding, cross-breeding, and up-gradation of local cows with small size Sahiwal, Jersey and Red Sindhi are the important strategies for improvement of genetic potential of native cattle. Regular monitoring of estrus, estrous induction using low doses of PGF2 α (prostaglandin F2 α) through intra-vaginal sub-mucosal route, and administering mineral-vitamin-antioxidant mix (vitamin A, E, C; selenium, copper, cobalt, and zinc) is important aspect for better reproductive health.

Excessive cold may breakdown thermoregulation leading to fertility impairments and lower milk production. Cows develop thick hair coat to maintain thermoregulation mechanism. We recorded a wide variation in daily milk yield among different breeds of crossbred at government farm and village level, ranging from 1.5–4.5 litre in crossbred native cattle, 1.5–2.0 litre in cattle \times yak cross, 6–15 litre in HF cross, and 4–9 litre in Jersey cross. Average herd size is 2–8 cattle and 1–4 calf, whereas cattle holding size is 2–3/household. There are more than 10 small cooperative societies involved in milk collection and distribution. Approximately, 10–11 lakh litre of milk is marketed annually through these cooperative societies and individual farmers. With this milk production, Leh feeds its own population and part of the production goes to the security forces deployed in the region. During a survey carried out in 2011, 2014 and 2015, the milk production scenario in Leh district indicated that milk production was higher in rural areas in spite of traditional dairy practices, low yielding local cows, lack of green fodders and poor health. The milk

yield data from different villages indicated increasing trend in progressive years, which is associated with increase in population of crossbred cattle through crossbreeding and up-gradation programme (Table 5). However, with increasing population the yield per cow did not increase. Hence, higher culling rate is prevalent at 9–12 years age, as their productivity and health are severely affected due to high altitude stress and fodder scarcity. Among these villages, milk production at Shey village was maximum i.e. approximately 33% of total milk production of Leh district.

After reviewing several reports on dairy production and personal interactions with dairy farmers, it was experienced that high altitude stress and scarcity of fodder are the two important limiting factors for poor milk production and reproductive health (Bharti *et al.* 2011a). Some of the bottlenecks, especially on technology front can be minimized by providing modern technology on the feeding of mineral and energy rich concentrate feed (feed block, antioxidant-vitamins-minerals mix, non-conventional feed technology), proper housing, quality germplasm, veterinary care, farmers training etc. DIHAR (DRDO) has taken a long stride in the development of a herbal feed additive (DB-Lactomax), a patented feed for dairy cattle to boost milk production.

Metabolic and production diseases

It is well known fact that livestock health and production is at risk in regime of climate change in the region (Singh *et al.* 2011). In order to adapt to the harsh environment coupled with hypobaric-hypoxia, domestic mammals have evolved special physiological adaptation mechanism, nutrient metabolism and cellular energy kinetics (Shao *et al.* 2010, Bharti *et al.* 2011b). The energy expenditure of animals is profoundly influenced by characteristics of the physical environment such as altitude, ambient temperature (T_a), solar radiation and wind speed (National Research Council 1981, Brosh *et al.* 1998, Linn 2014). Also, the atmospheric O_2 concentration and cold stress play a significant role in determining the body basal metabolic rate (Gautier 1996, West 2003). At high altitude, most of the times animals live outside of the comfort zone, effective feed intake and activity to generate the energy required for keeping animal body warm and for milk production.

A high incidence of parturient paresis (milk fever) is observed in crossbred cattle. Since cows are metabolically challenged, especially during post-partum period, energy demands exceed then the inputs, animals enter into a state of negative energy balance. This triggers mainly catabolic pathways and changes in oxidative phosphorylation, which at the cellular level increases the production of free radicals (Castillo *et al.* 2006). There is evidence that calcium level and oxidative stress are affected by body condition at calving and milk yield (Gabai *et al.* 2004, Lohrke *et al.* 2004, Bernabucci *et al.* 2005). Cows with a body condition score of greater than 3 before calving, mobilize more body reserves in the post-partum period and experience more

oxidative stress than animals with lower scores (Bernabucci *et al.* 2005).

Studies determined the effect of direct solar radiation on thermoregulatory responses in a hot environment in cattle (Yamamoto *et al.* 1994, Brosh *et al.* 1998, Wall *et al.* 2010). High solar radiation as experienced at high altitude causes an additional heat load on animals especially in summer and may, therefore, have an important influence on their thermoregulatory mechanism and heat balance in grazing cattle (West 2003). However, no systematic study has so far been conducted on the influence of solar radiation on heat energy at high altitude. As observed, many crossbred were found panting heavily, and developed intense solar radiation and heat.

Brisket disease and congestive heart failure, parturient paresis, hypocalcaemia, hypomagnesium tetany, ketosis are some of the common metabolic diseases of cattle at high altitude (Bharti *et al.* 2011a, b). Pre-calving administration of vitamin E, selenium, ascorbic acid, antioxidants, and calcium-magnesium fluid may be practiced to improve reproductive health and to minimize incidence of metabolic diseases. Exotic animals may be given dexamethasone, acetazolamide and aspirin to treat mountain sickness and brisket disease when introduced to this region for acclimatization to high altitude.

Parasitic infestation

Parasitism is a global problem, especially in low-elevation regions with a humid and tropical climate where temperature favours hatching and larval development of parasites (Bishop *et al.* 2000, Patz *et al.* 2000). High elevations provide natural buffers against some livestock parasites, but not for all (Blodgett and Lanier 2006). At high altitude, it is presumed that the harsh climate will limit parasitic infestation, but this presumption is not always true across all the parasite species. Furthermore, because of global warming, infestations of some parasites have shown high episodic due to weather variation. Infestation of ectoparasites and gastrointestinal helminths (liver fluke, ascariasis and strongyloids) has now become quite common despite severe dry cold climate (Bharti *et al.* 2011a). Recently in August-September 2015, babesiosis and theileriosis were also reported in recently inducted 16 Jersey cattle from plains to DIHAR, Leh (*Unpublished data*). Further deworming is not practiced regularly, merely 20–30% of dairy cattle were covered under deworming across village and near city areas. Therefore, areas that were considerably virgin for many disease pathogens, have now become home for many pathogens and vectors.

There always exists a possibility for cattle-sheep-goat mixed grazing and housing, which has raised the concern for several parasite and disease transmission issues. Therefore, there is a need that farmers should be advised for regular monitoring of parasitic infestation (tick, lice, mites, strongyloids, amphistomes and ascaris), adoption of deworming schedule and isolation of affected animals to restrict transmission of diseases.

Microbial diseases

Monitoring the incidence of microbial disease in high altitude cold desert regions is a complicated issue due to non-availability of disease surveillance mechanism. Poor vaccination coverage (60%), meager access to field diagnostics and veterinary supports are some other related animal health issues. The majority of the farmers are unaware about the proper time of the vaccination, deworming schedule, and other health practices, which make livestock population vulnerable to different kinds of pathogens. Incidence of certain viral and bacterial diseases, viz. FMD (foot and mouth disease), BQ (black quarter), HS (haemorrhagic septicemia), TB (tuberculosis), brucellosis, acute pneumonia, etc. has increased gradually and led to poor health and by-products. One of our studies indicated 100% seropositive animal population (N=100) for different FMD serotypes (O serotype: 60%, A serotype: 70% and Asia-1 serotype: 69%) (Bharti *et al.* 2012). Hence, vaccination for prevention of these diseases needs to be strictly followed in this region.

Mastitis is another common problem in high producing crossbred and exotic breed animals at high altitude. Field veterinarians have reported immunosuppression and bacterial resistance to common antibiotics. In mastitis prevention, antioxidant, vitamins and minerals supplementation plays an important role due to their role in mammary resistance to mastitis (Scaletti *et al.* 2003, Ranjan *et al.* 2005). Therefore, supplementations with zinc, ascorbic acid, and antibiotic in combination were quite effective for controlling mastitis.

Climate change escalates infestation of insects and microbial population. As a result, incidence of vector borne and infectious diseases has increased globally (Baylis and Githeko 2006, Singh *et al.* 2012). In Leh-Ladakh, flies, ticks, mites, mosquitoes, reptiles, rodents, etc. are commonly seen which otherwise were not present 4–5 years ago. Considering these changes in vectors population, preparedness for effective vector identification and control, disease surveillance and prevention and control programme is needed.

CONCLUSION

Native cattle are well adapted to the high altitude stress, however, they have poor genetic potential for milk production. There is an urgent need to undertake the identification of important biomarkers of adaptation, forecasting of diseases and performance besides selective breeding, balanced feeding and proper housing. Hence, proper breed improvement, quality fodder production, disease surveillance programme are essential for augmenting milk production in Leh-Ladakh. Effective extension setup is another important strategy to bridge gap between the research institutions/government departments and the farmers on modern technologies and practices in the changing seen due to global warming. There is also a need to support funding for modern dairy farm establishment, insurance coverage, proper housing, value

addition to the produce. This will help in dairy product development and remunerative prices for their produce so that dairy husbandry becomes a profitable venture in Leh-Ladakh.

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