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Research Article

Climate Resilient Goat Farming-A Review

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Abstract

About 70 per cent of the landless agricultural labourers, marginal and small farmers in the country are associated with goat husbandry. It is not only an important source of income and employment for them, but also a vital source of animal protein for their family. So, it indicates that goat is potential animal for nutritional security, employment generation, economic growth and livelihood improvement. Recent research efforts have ascertained that goat is the ideal climate animal model due to better thermo tolerance, drought tolerance, and ability to survive on limited pastures as well as their disease resistance capacity. In the context of indirect effects of changing climate pertaining to feed and fodder availability, rearing goats is considered more economical than large ruminants. So this review article will give an idea about different stressors affecting productive, reproductive performances, diseases occurrence of goat and different adaption and mitigation measures to overcome the impact of climate change particularly heat stress so that goat farming would be climate smart and economically viable enterprise for the employment of rural population.

Keywords: Effect; Heat Stress; Growth; Milk Yield; Reproduction; Immunity; Adaptation; Mitigation

Introduction

Goats occupy unique place among domestic livestock in India because of their high population ie 148.88 m as per 20 th livestock census (2019) [1] which indicates 10.14 % increase over the previous census of 2012. Goat has ability to survive and produce under unfavorable climatic and managemental condition. Goats play an important role in the food and nutritional security of the rural poor especially in the rain fed regions where crop production is uncertain, and rearing large ruminants is difficult due to acute shortage of feed and fodder. In Maharashtra goat population is 10.60 million as per 20th livestock census (2019) [1], which is 7.12 % of National population. In Maharashtra goat population increased by 25 % over last census. Maharashtra ranks sixth position in goat population after Rajasthan, WB, UP, Bihar and MP. Goat farming has several advantages over the husbandry of other livestock species.

Principal Scientist

Those are as followings

- Initial investment for starting goatary is lesser than dairy, piggery, poultry.
- Goats possess superior efficiency for transforming poor quality feed into high quality products ie milk, meat and capable of selective browsing on undesirable vegetation.
- It does not compete with human beings for grains like pig and fowl. So, feed cost is lesser.
- Goat is prolific animal, which usually produces twin and some breeds even produce triplet.
- Goat being hardy animal, disease incidence is very less in comparison to cattle, pig and fowl. Hence health management cost is lesser.

- National milk yield from goat was to 6.1 million tones as per FAO (2020) [18] which is 2.7 % of total milk production in India. Goat milk is rich in certain amino acids (Aspartic acid, Histidine, Phenylalanine, Threonine); minerals (Copper, Iron, Sodium) and vitamins (Vitamin A, Nicotinic acid and Choline).
- g) Goat is known as poor man's cow, because its milk is wholesome and nourishing. It is considered especially for infants and aged persons due to easy digestibility. Goat milk is being used to produce different products such as cheese, curd etc.
- h) Goat meat is very rich in protein, energy and fat. There is no prejudice about the consumption of goat meat. Best quality meat is obtained from a goat of age group 8 - 9 months. At this time dressing per cent of goat is observed to be 50 - 55 %. In India meat production from goat was 1.08 million tones as per 20 th livestock census (2019) [1] which is 13.35 % of total meat production of India.
- Goat skin is of high values e.g. skin form Bengal goat is of best quality in the world.
- Besides meat, milk, skin, hair is another product obtained from goat, e.g. Pashmina and Mohair is valued high in international market due to its several uses.
- On an average each adult goat produces manure @ 500g/head/day. The manural value of goat droppings is also very high. Nitrogen (N), phosphorous (P) and potassium (K) content of fresh goat manure is 2.50 - 3.50 %, 1.25 - 1.50 % and 1.00 - 1.25 % respectively and used in field for improving soil fertility and to increase productivity of crop.

About 70 per cent of the landless agricultural labourers, marginal and small farmers in the country are associated with goat husbandry. It is not only an important source of income and employment for them, but also a vital source of animal protein for their family. So, it indicates that goat is potential animal for nutritional security, employment generation, economic growth and livelihood improvement.

Impact of climate change on goats

- Livestock are homoeothermic which means that they must maintain their body temperature within a relatively narrow zone to remain healthy and productive. The ambient temperature above or below thermo neutral zone produces stress to the animal which ultimately hampers growth, production and reproduction.
- The upper limit of thermo-neutral zone (TNZ) i.e. upper critical temperature has more significance for livestock under tropical and subtropical climate. It is lower in exotic breeds and their crosses than indigenous breeds. The thermo neutral zone for goats is about 12 - 24 °C in the hot regions of the world [32].
- Four environmental factors influence effective temperature: 1) air temperature, 2) relative humidity, 3) air movement and 4) solar radiation.
- The temperature-humidity index (THI) commonly is used to indicate the degree of stress on livestock. It is measured by the formula, THI = Dbt in °F – (0.55 - 0.55 x RH %) (Dbt in °F - 58). When the THI exceeds 80, goats are affected adversely.
- Livestock Weather Safety Index (LWSI) was developed to classify the combined intensity of temperature and humidity into four categories of THI values: In goat THI less than or equal to 80 is Normal, THI 81 – 85 is Alert, THI 86 - 90 is Danger and THI value above 90 is Emergency condition.
- Experience over time suggested that the THI - based LWSI was a valuable tool for producers, even though it lacked recognition of the effects of solar radiation and wind speed. Warnings, with respect to these categories, were issued by the United States Weather Bureau to alert producers to potential heat stress conditions [35].
- With increasing environmental heat load caused by high temperature, intensive solar radiation, high humidity, low air movement or a combination of several of these factors, defense mechanisms against overheating - sweating and panting come into operation. If cooling derived from these activities is insufficient, body temperature rises. This depresses appetite, which in turn reduces the production of meat and milk.
- The ability to withstand heat varies considerably. Heat tolerance is low in young animals, in animals that are on a low level of feeding, in dehydrated, in high producing, and in non-acclimatized animals.

- Recent research efforts have ascertained goats as the ideal climate animal model due to their better thermo tolerance, drought tolerance, ability to survive on limited pastures as well as their disease resistance capacity. In the context of indirect effects of changing climate pertaining to feed and fodder availability, rearing goats is considered more economical than large ruminants [49]
- The thermo neutral zone of goat is of goat is 12 - 24 °C. During heat stress conditions, goats exhibit both behavioral and physiological changes to maintain their body temperature. Reduced feed intake, increased water intake and drinking frequency, changes in urinating frequency, defecation, standing time, lying time, and seeking shed behavior are the major behavioral changes in goat exposed to heat stress [49].
- Shed-seeking behavior is one of the foremost behavioral responses exhibited by heat-stressed animals. However, indigenous animals in tropical regions are considered more heat tolerant, spending more time grazing than resting in the shed.
- Reduced feed intake is another important behavioral indicator exhibited by heat-stressed animals to reduce metabolic heat production during hot conditions [60]. It is an adaptive mechanism exhibited by the animals during heat exposure since digestion of feed is an important source of heat production. Increased water intake and drinking frequency are essential for heat dissipation and maintaining milk secretion.
- In hot environment, goats spend more time standing to reorient themselves in different directions to avoid the impact of direct solar radiation and ground radiation. A standing posture also facilitates heat loss from animal bodies to the surroundings by exposing the body surface to the wind flow [60].
- Rumination time and urinating frequency are also get reduced in goats exposed to heat stress, and this was considered an adaptive mechanism to cope with heat stress [31]. The reduction in defecating frequency could be an adaptive mechanism of these animals to conserve body water [51].
- Although goats are considered well adapted to the tropical climate, some studies established the impact of elevated ambient temperature on growth [41], milk production [46], meat production [6,20] and immune responses [13] in goats. Sejian *et al.*, (2021) [49] observed a reduction of 3–10 % milk yield and 4 % meat production respectively.
- Goats start experiencing heat stress when they were exposed to 38 °C and above with the THI of above 75. Once the goats are exposed to high temperature, they activate their physiological adaptability in terms of alterations in behavior, physiological responses, blood biochemical and endocrinological responses to regulate their body temperature to maintain homeothermy.
- These adaptive processes are of energy demanding, and the animals channelize their energy from the productive pathway towards the adaptive pathway. Such behavior of reducing the production to support the life-sustaining activities is the typical characteristic of adapted goat breeds [3,47].

Effect of heat stress on growth and meat production

- The adverse impact of heat stress on growth performance can be attributed to the reduction in feed intake, digestibility and utilization efficiency [25,42]. Though goats have the capacity for adaptation to convert poor quality feeds to high quality products, still if the heat stress prolongs for a longer duration, it can affect their growth performance.
- Pragna., *et al*. (2018) [41] observed a reduction of 11.0 %, 8.0 % and 6.0 % of growth for Osmanabadi, Malabari and Salem Black breeds, respectively due to heat stress. This reduction in heat stress associated growth variables could be due to the outcome of activation of hypothalamus–pituitary–adrenal axis (HPA) in response to heat stress.
- The activation of the HPA axis during heat stress directly influences the release of growth hormone, negatively influences growth [42]. However, breed variations were observed for these mechanisms of HPA-axis oriented impact of heat stress on growth.
- Heat stress has as an aberrant effect on meat production and the goat's carcass characteristics. Hashem *et al*. (2013) [20] conducted a study to illustrate the effects of heat stress on Black Bengal goats. They reported a reduction in preferred meat quality characteristics, such as pH, cooking loss, water holding capacity, shear force and color.
- Further, Archana *et al*. (2018) [6] attributed the increased meat pH in heat-stressed goats to glycogen depletion. She also noted an increased shear force in the meat of heat-stressed Osmanabadi goats, which significantly hampered the tenderness and juiciness of meat.

- Further, heat stress also reduces the plasticity of muscle fibers, which in turn could contribute to the alteration in the quality of goat meat. Negative impact of heat stress on meat quantity and quality was attributed to depleted energy reserves in the animals as a result of partitioning energy towards life-sustaining activities during the adaptation process, especially when the heat stress is prolonged for a long period [6,20].

Effect of heat stress on milk production and milk quality

- Several studies were conducted to find the influence of heat stress on milk production where it was ascertained that milk production was reduced considerably in response to reduced feed intake during exposure of heat stress in goats [46].
- In addition, keeping milk production a major concern, extensive experiments were conducted to determine the effect of heat stress on milk quality and it was reported a reduction in milk fat, protein, lactose and total solids content, thereby reducing the ultimate milk quality [19].
- Such an effect could be due to insufficient energy levels, as in heat-stressed animals predominantly, the energy is deviated to maintain life-sustaining activities. However, the effect of such impacts varied accordingly with the genetic potential, lactation stage and nutritional availability of goats during their exposure to heat stress.
- Heat stress reduces milk production by 9 % in early lactating dairy goats with greater reductions in milk fat and protein percentage with a higher level of somatic cells [21]. Milk yield in dairy goats decreased as THI value increased, and for each 1 unit increment of THI there is a decrease of 1 % in milk yield [46].
- The goat produces milk normally up to the THI level of 80, and the yield moderately decreases when THI reaches between 80 to 85 [12,16]. The milk yield of goat is severely affected by heat stress as soon as the THI reaches 85 to 90. The decrease in milk yield in goats during heat stress may be due to reduced feed intake and the process of metabolic adaptations [54].

Effect of heat stress on reproduction

- Goats are extremely good in reproductive performance with higher fertility and short generation intervals. However, heat stress affects the goats' reproductive efficiency when the THI reaches above 70 in the mountain regions [54].
- Further, Amitha *et al.* (2019) [5] reported that heat stress adversely affects the reproductive efficiency in goats by down regulating most of the reproduction-related genes' expression patterns.
- The elevated environmental temperature affects reproductive performance by decreasing estrous expression and altered follicular growth with impaired embryonic development [22].
- In males, heat stress (HS) seriously affects fertility and reduces sexual desire by reducing testosterone level, sperm production and motility, and increasing proportion of morphologically abnormal spermatozoa, thus affecting semen quality [24]. Semen characteristics (ejaculate volume, semen pH, spermatic concentration, spermatic motility, sperm abnormalities) of bucks are affected within days of exposure to HS.
- In females, HS reduces expression of estrus, ovulation, conception rate, fertility, embryonic survival and fetal development [24]. HS impairs follicular and oocyte development by altering progesterone, luteinizing hormone (LH) and follicle stimulating hormones (FSH) secretion and dynamics during the estrous cycle [40] .

Effect of heat stress on immunity

- Apart from their effects on production traits, heat stress also influences the goats' immune responses, reduces natural immunity, making animal more vulnerable to diseases. Sophia *et al.* (2016) [57] noted that innate immune response, which was considered the first line of defense, was compromised in goats after exposure to heat stress.
- However, various reports show the inefficiency of goats' primary innate immunity in response to heat stress. With the decline in immunoglobulin release, the adaptive immune system becomes impaired, leading to likely parasitic infestation [2]. In agreement with this, Hirakawa *et al.* (2020) [26] noted that extreme temperatures resulted in a limited synthesis of lymphocytes along with suppression in phagocytic activities of leukocytes in goats.
- In addition, Yadav *et al*. (2016) [63] reported that heat stress depressed the production of antibodies in goats, particularly the production of IgM and IgG. The TLR2, TLR8, IL10, IL18, TNF, and IFN are considered important inflammatory markers for quantifying the impact of heat stress on the immune system of goats.

Impact of heat stress on physiological responses

- Dangi *et al.* (2015) [13], in their study with Barbari goats, identified respiration rate (RR) as a practical and reliable measure of heat load. The animals utilize the respiratory evaporating cooling mechanism to expel the excess heat, which culminates with the increase in RR. When compared to a basal respiration rate of 15–30 breaths/min, goats exhibiting a respiratory rate of 40–60, 60–80, 80–120 and more than 200 breaths/min are considered to be exposed to low, medium, high and severe heat stress, respectively.
- Several studies were conducted on various breeds to validate the utilization of evaporative cooling mechanisms in heat-stressed goats. One such study, conducted on Murciano-Granadina dairy goats [21], witnessed an increase in RR up to 150 breaths/min with the prevailing THI value of 77. Similar heat-stress-associated increases in RR occurred in several other indigenous goat breeds [3,38].
- Nevertheless, the respiratory evaporating cooling mechanism fails when the ambient temperature increases beyond the threshold level. This failure subsequently results in increased body temperature to aid the release of excess heat load. The increase in rectal temperature (RT) is an alternate used by goats to bring down their body temperature to keep themselves under comfort environment.
- As homeotherms, goats try to constantly maintain their core body temperature around 39 0 C with small variations. The increase in the body temperature is a normal phenomenon by which animals can transfer the heat load from the core body to the periphery during heat stress [10].
- It is reported that indigenous goats exposed to zero, four and eight hours of heat stress showed a significant difference in their rectal temperatures. Further, similar findings occurred in Osmanabadi, Malabari and Salem Black goat breeds of Southern India and Barbari goats of Northern India [3,13].
- Adaptation to prolonged heat stress may also be incurred through the cutaneous evaporative cooling mechanism by increasing the peripheral blood flow and thereby increasing the pulse rate (PR). With an increase in the circadian rhythm of heart rate, heat exchange occurs both via sensible (conduction, convention and radiation) as well as insensible (cutaneous evaporation) means to the immediate surroundings of the animals, thereby making their internal environment more comfortable [3].
- Shilja *et al*. (2016) [51] reported that PR of Osmanabadi goats increased towards exposure to heat stress than their counterparts kept in the shed in more comfortable conditions. Similar findings occurred in Boer, Anglo-Nubiana, Savana, Saanen, and Garfagnina goat breeds [44,59].
- Skin being the intermediate between the animal body and the surrounding environment, plays a major role in aiding the adaptation of animals to heat stress. With the increased flow of blood towards the periphery of the skin through cutaneous vasodilation, the exchange of heat occurs from the core body to the surroundings. Al-Tamimi (2007) [4] found that Damascus male goat kids had higher skin temperature, and they attributed this abrupt increase to heat stress.
- Many investigations have been conducted to reveal the thermoregulatory mechanism behind sweating. One such notable study by Baker (1989) [9] with Alpine Toggenbergs and Nubian goats claimed that the cutaneous moisture loss was less in dehydrated goats. Later, Niliand and Baker (1992) [36] found a decline in skin temperature in heat-stressed goats, and they attributed this to the evaporative heat loss through sweating

Effect of heat stress on cellular, hematological and biochemical responses:

- Expression of many heat shock proteins (i.e. 32, 40, 60, 70, 90 and 110) is increased during heat stress [50]. Heat shock protein 70 (Hsp 70) is used as a biomarker of cellular stress [43].
- Heat Stress (HS) affects biochemical parameters, i.e. alkaline phosphatase, alanine aminotransferase, aspartate transaminase, lactate dehydrogenase, total protein, albumin, globulin, glucose, cholesterol, blood urea nitrogen, non-ester fatty acids, beta-hydroxybutyrate, creatinine, triiodothyroxine, thyroxine, cortisol, prolactin, sodium, potassium, chloride, calcium, magnesium, iron, manganese, copper, zinc and oxidative stress parameters (glutathione peroxidase, glutathione reductase, superoxide dismutase and lipid peroxides).

Adaptation by housing and managemental intervention

- Adaptation with reference to climate change is referred to as adjustment or preparation of livestock to new or changing environment which moderates harm or uses beneficial opportunities. Adaptation can reduce the current risks of climate change impacts and can be used for addressing emerging risks.
- Most important environmental variables influencing goat production are temperature and humidity. These are vital components that can have deleterious impacts on goat production. Therefore, the housing pattern can protect the animals from these deleterious impacts by providing the optimal microenvironment. Animal housing is one of the prime aspects to be looked at from an animal welfare and production point of view.
- Several management practices are available to ameliorate heat stress, each with positive and negative properties. Housing provides the most potential control over environmental stressors; however, it comes at a relatively high initial investment cost per head.
- **Shed** for livestock is considered essential to minimize loss in weight gain, milk production, milk quality, meat quality and improve reproductive efficiency. Sheds can improve animal comfort and productivity and should be designed to maximize ventilation and protection from the solar load.
- A well-designed shed structure reduces heat load by 30-50 % [34]. Accessibility of animals to shed during summer is simple, easy, cheap and an efficient tool to minimize heat stress (4, 52). Providing goats to shed leads to improvements in weight gain, milk production and reproductive performance [11], and allows a reduction in rectal temperature and respiration rate in goats [23]. Sheds providing sufficient spacing and ventilation maintain a hygienic environment within the shed and provide the ultimate comfort to the animals. Goats tend to rest against a wall rather than lying in the center of a pen, which could be an anti-predator strategy adopted by them.
- Proper selection of the shed site to emphasize factors for enhancing heat dissipation (minimal radiation, air temperature, relative humidity, and maximal air velocity) will have long-term protection benefits [48].
- In addition to sufficient floor space, the type of floor is also essential as goats prefer solid and dry surfaces. Therefore, it is essential to ensure a clean, dry and adequately ventilated housing environment for the goats, keeping them comfortable and protecting them from disease risk [37].
- Orientation of goat shed is also very important, as under an extremely hot, low rainfall (10 to 12 cm) climate, an east-west orientation is preferable as the ground under the shed will remain cooler. An orientation with the long axis north and south will expose the area under the shed to the morning and afternoon sun and assist in keeping it dry. So, this type of orientation of shed is suitable in sub temperate to temperate climate of hilly region.
- Extensive comparisons of shed materials and the impact of orientation of shed on the micro - climate of shade was studied by different workers. Hay is proved to be suitable low cost roofing material for animal sheds. However, corrugated steel sheet is the most popular shed material because of durability and low maintenance requirements.
- Elimination of direct solar radiation is essential, since the radiated heat load imposed on an animal by the midday sun is several times greater than the metabolic heat generated by the animal. Reduction of indirect radiation is very important. This is achieved by the absence of objects, such as nearby buildings, heavy wooden fences etc, which absorb heat and radiate it on the animals.
- Daily monitoring of temperature, relative humidity and air quality are crucial aspects in goat shed [27]. In addition, fully enclosed shelters are not recommended for hot climates because of the decreased air movement, therefore, it is preferred to use partially enclosed/semi open shelters [48].
- Alteration of air temperature and velocity must be considered to alter the microclimate of an animal effectively [15]. It may be necessary to install fans or other cooling systems in the shed [7]. Cooling goats by spraying could reduce heat stress symptoms and improve animal welfare [45].
- Direct wetting of animals is often used as an emergency measure and can be an effective protective method [39]. Sprayed and ventilated heat-stressed goats for 1h/day consumed more feed (18 %) and water (7 %) and produced more milk (21 %) [14].

Adaptation by nutritional intervention

- Ration modifications can greatly help in reducing the negative effect of heat stress, and these adjustments may include changes in feeding schedules (feeding at cool hours, feeding intervals), grazing time, and ration composition such as dietary fiber adjustment, the use of high-quality fiber forage, increased energy density (supplementation of bypass fat) and use of feed additives (buffers ie sodium bicarbonate, niacin, antioxidants and yeast culture).
- During summer, the feeding behavior for most of the animals changes and they tend to consume more feed during the cooler periods of the day [62]. Therefore, feeding animals during the cooler periods of the day encourages them to maintain their normal feed intake and prevents the metabolic disorder and heat load [30].
- Also, feeding animals at more frequent intervals helps to minimize the diurnal fluctuation in ruminal metabolites and increase feed utilization efficiency in the rumen [58].
- Another point to be taken into account to alleviate heat stress is to reduce the grazing time. In extreme heat, animals decrease their grazing time and spend more time in the shed, especially during the hot part of the day. Thus grazing would be practiced during the milder weather of the day, i.e. before sunrise, at dawn or after sunset ie during the night [17].
- Careful ration modifications during heat stress are important in achieving the optimum animal performance. Decreasing the forage to concentrate ratio can result in more digestible rations that may be consumed in greater amounts [2]
- Feed containing low fiber rations during hot weather is logical since heat production is highly associated with metabolism of acetate compared with propionate [7].
- More nutrient-dense diets are usually preferred during the heat stressed period [62]. Dairy goats supplemented with 4 % fat during summer had lower rectal temperature. Soybean oil fed to goats under heat stress increased milk fat content [45].
- Feed additives have been proposed to offset the consequence of heat stress. For example, antioxidants such as vitamin C and E protect the body defense system against excessive production of free radicals (antioxidants are free radical scavengers) during heat stress and stabilize the health status of the animal [53].
- Ayo *et al*. (2006) [8] found that vitamin C supplementations to goats are effective in alleviating heat stress. Vitamin E and C supplementations decreased rectal temperature and respiration rate [55], and alleviated heat stress in goats [28].
- One of the best practices to reduce heat stress is to provide adequate fresh and cool drinking water [52]. The water requirements of goats increase under heat stress conditions, thus, it is essential that animals have a continuous access to adequate, clean, cool and fresh water. This is done by having adequate watering devices (making sure pressure is adequate to refill waterers), and providing more water sources in the pasture [7].
- In addition, handling animals should be kept at minimum. Goats can be handled (i.e. milking, transportation) in the early morning or late evening time (Morrison, 1983), and the afternoon work should be avoided when body temperature is already high. One of the effective methods for prevention of heat stress is to delay afternoon milking for 1-2 hours [7].
- Increase the concentration of minerals and vitamins in the diet to compensate for the reduction in feed intake, particularly sodium, potassium, magnesium and niacin levels in the diet.

Approach for Mitigation

- Several mitigation options are available for methane emissions from livestock. In India, the possibility of preventing emissions from animal manure storage is limited as it is extensively used as fuel in the form of dry dung cakes. Hence, the scope of decreasing methane from livestock largely lies in improving rumen fermentation efficiency**.**
- There are a number of nutritional technologies for improvement in rumen efficiency like, diet manipulation, direct inhibitors, feed additives, propionate enhancers, methane oxidisers, probiotics and hormones [56].
- Field experiments in India involving some of these options have shown encouraging results with reduction potential ranging from about 6 to 32%.
- Culling of unproductive goats as far as possible would reduce methane production.

- Enteric methane emission/kg dry matter intake has been observed to increase under severe heat. So, protection of animals from severe heat stress through proper housing and heat ameliorative measures will be effective in reducing methane emission
- Improvement in disposal of farm yard manure ie its use for biogas production and use of biogas slurry in the field and in the pond as fish feed can reduce methane emission from manure. So, improved manure management ie biogas production would reduce methane emission [60].
- Kumar., *et al.* (2018) [29] reported that incorporation of dried tree leaves such as *L. leucocephala* and *Ficus infectoria* leaves in the complete pellet feed can reduce the methane production in growing Barbari goats upto 9.89 and 18.93 % without adverse effect on fermentation and digestibility of feeds

Conclusion

- Although goat is hardy animal and adaptable to wide range of agro climatic condition, climate change particularly heat stress have adverse negative impact on milk and meat production, meat and milk quality, reproductive performance, physiological response, immunity and health of goat.
- Housing (sufficient floor space, cross ventilation etc.) and cooling arrangement (provision of ceiling fan, spraying of water etc.) in the shed could reduce heat stress significantly.
- Scheduling most of the activities in early morning, late afternoon, practice of night grazing is advisable.
- Provision of low fiber, energy rich diet and cold clean drinking water to goats.
- Use of anti-oxidants, feed additive, ensiling of fodder, manure management, reducing unproductive animals and use of indigenous breeds of goat are some of the mitigation measures.
- Linkage between scientists, farmers, state Govt officials, extension officials, NGOs are to be strengthened for awareness of climate change impact, effective implementation of adaptive and mitigation measures.

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