International Journal of Agriculture and Food Science 2026; 8(8): 419-423

ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2026): 4.97
IJAFS 2026; 8(8): 419-423
www.agriculturaljournals.com
Received: 07-06-2026
Accepted: 09-07-2026

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Seasonal Dynamics of Serum Mineral Profiles in Indigenous Nagavali Sheep

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DOI: https://www.doi.org/10.33545/2664844X.2026.v8.i8e.1796

Abstract
Aim: Climatic and ecological variations significantly influence the mineral profile of Nagavali Sheep. Because Nagavali sheep are primarily raised for meat production, establishing a preliminary database of serum mineral parameters across different seasons is essential to evaluate their overall metabolic status and reproduction. This study evaluated the seasonal impact on these parameters across summer, monsoon, and winter using the Temperature-Humidity Index (THI).
Experimental Design: A total of 100 apparently healthy Nagavali sheep (50 Rams, 50 Ewes), aged one year and older and exhibiting similar physiological status, were randomly selected for the study. The present investigation was carried out to study the effect of seasonal change on Serum mineral profile using serum samples.
Results: The mean ± SE values of serum Calcium was significantly (P>0.05) higher during winter in comparison to Summer and monsoon seasons. The serum Phosphorus and Magnesium levels were non-significant (P>0.05) during winter in comparison to summer and monsoon seasons, but the elevated levels were noticed. The reduction in serum calcium concentration observed in hot-humid could be attributed to reduction in the dietary intake which has been reported under heat stress condition.

Keywords: Nagavali sheep, Temperature, Humidity Index, Mineral profile, Season

Introduction
Sheep contribute significantly to India's agriculture, rural employment, and GDP, with Andhra Pradesh ranking second nationally at 17.6 million sheep (20th Livestock Census). The resilient Nagavali breed, reared primarily for meat, constitutes roughly 4.5% of the state's population across the north coastal districts. However, climate change poses a severe threat to livestock productivity. Rising Temperature-humidity Index (THI) levels which peak during summer can adversely effect the health of the animal by increasing the physiological parameters of rectal temperature (RT), respiration rate (RR), and pulse rate (PR) in Munjal sheep reared in a subtropical climate (Kumar S *et al.,* 2025) [2]. Consequently, prolonged heat stress elevates disease incidence and significantly impairs growth, meat production, and reproductive performance (Habeeb, *et al.,* 2018) [4], (Al-Ghareebawi *et al.,* 2026) [3]. Serum biochemical tests are widely utilized to diagnose diseases and evaluate nutritional status in animals. This study aims to establish a baseline mineral profile for Nagavali sheep and evaluate seasonal variations in rams and ewes. Ultimately, these reference parameters will serve to assess the long-term impact of climate change on the mineral status of this breed.

Materials and Methods
The present investigation was carried out on Nagavali sheep of Andhra Pradesh maintained at Livestock Research Station, College of Veterinary Science, Garividi, S.V.V.U, *Viz*ianagaram, Andhra Pradesh. Blood collection was done in the months of May, August and December for the seasons Summer, Monsoon and Winter respectively.

Experimental Design: A total of 100 apparently healthy Nagavali sheep, aged one year and older and exhibiting similar physiological status, were randomly selected for the study. The animals were maintained at the Livestock Research Station, College of Veterinary Science, Garividi (SVVU), located in the *Viz*ianagaram district. For comparative analysis, the sheep were divided based on sex into two equal cohorts (n = 50 each): Group 1 (ewes) and Group 2 (rams).

Chemicals, glassware and equipment

High-grade reagents (HiMedia, Thermo Fisher, Sigma-Aldrich) and standard consumables (Borosil, Tarsons) were used. Centrifugation and spectrophotometry were performed via a REMI RM-12C and a Thermo Scientific Multiskan Sky, respectively.

Temperature-Humidity Index (THI)

Daily microclimatic data—including maximum, minimum, dry-bulb Temperature {db}, and wet-bulb Temperature {wb} alongside relative humidity—were recorded at 1:00 PM using a digital thermohygrometer. The Temperature-Humidity Index (THI) was calculated according to Johnson (1965):

{THI} = 0.72(T_{db} + T_{wb}) + 40.6

Blood Sample Collection

Jugular blood samples (5 mL) were collected seasonally (summer, monsoon, winter) between 07:30 and 08:30 h. Samples were processed into whole blood K3-EDTA and serum (separated at 5,000 rpm for 5 min) before storage at -20°C.

Statistical Analysis

Results are expressed as mean ± Standard error (SE). Data were analyzed using a Student's t-test in Microsoft Excel 2007 following the statistical methods described by Snedecor and Cochran (1989) [1].

Results and Discussion

The average Temperature-Humidity Index (THI)

The mean values of the Temperature-Humidity Index (THI) recorded during the experimental period are presented in Table 1. The mean THI was highest in summer at 80.01, followed by 70.50 during the monsoon, and lowest in winter at 67.89. Among environmental variables, thermal stress is the most critical factor limiting the growth performance of indigenous sheep breeds, particularly in tropical, subtropical, and arid environments. Although indigenous breeds exhibit superior natural adaptation to challenging local climates compared to exotic breeds, prolonged or severe heat stress still significantly impairs their overall growth and productivity.

Parameter	Season		
	Summer	Monsoon	Winter
THI	80.02±0.43	70.51±0.41	67.89±0.27

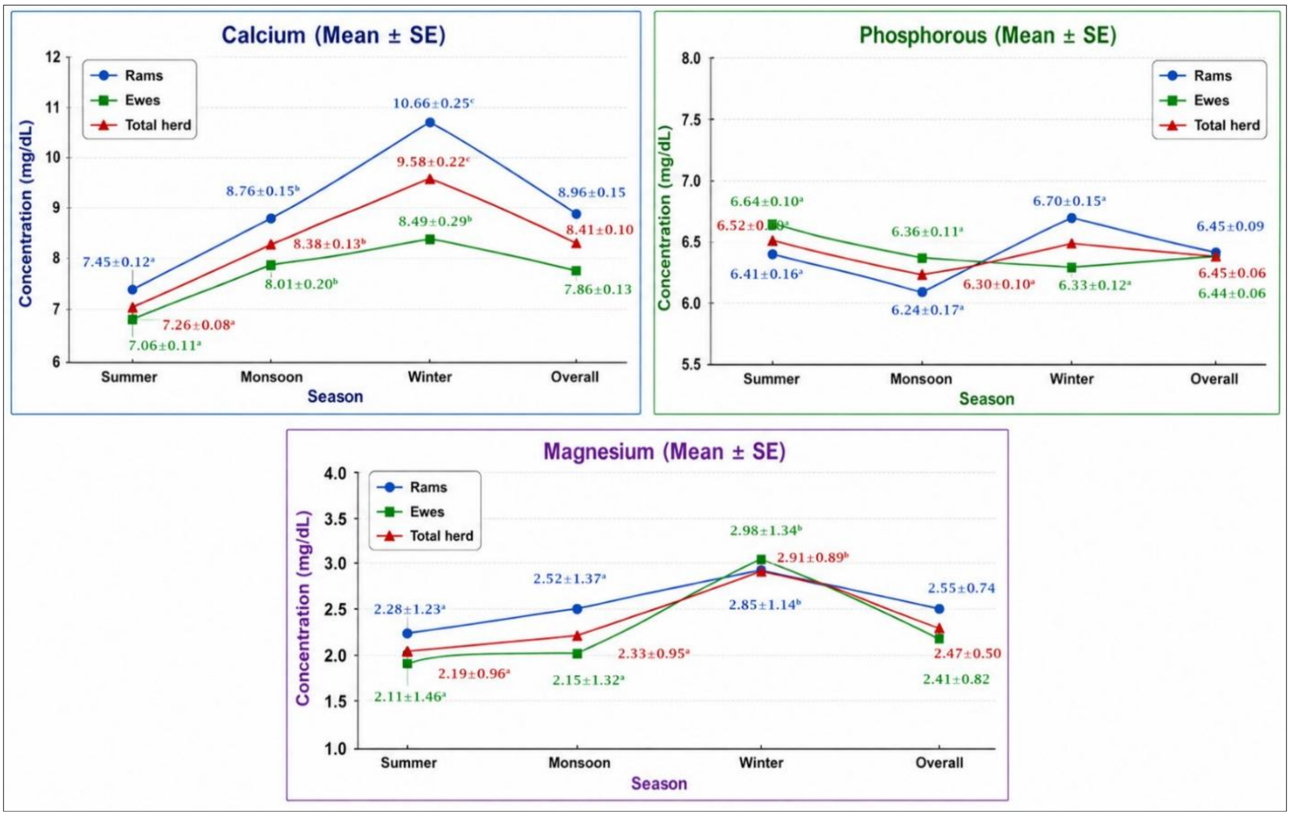
Our results align with those of Abdelatif and Alameen (2012) and Tej *et al.*, (2018), who observed higher Temperature-Humidity Index (THI) values during the summer season. This elevated THI indicates a significant risk of heat stress, particularly for livestock. While sheep and goats are generally believed to cope well with extreme climatic conditions, including high temperatures (Sevi and Caroprese, 2012) [7], Finocchiaro *et al.,* (2005) [8] noted a distinct impact of high THI values on dairy sheep.

One effective approach for studying animal responses to heat stress is evaluating the correlation between bioclimatic indicators such as the THI and production and reproduction traits (Serradilla *et al.,* 2018). According to Srikandakumar *et al*., (2003) [10], a THI value of 72 or below represents a lack of heat stress, 73 to 77 indicates mild heat stress, 78 to 89 denotes moderate heat stress, and values above 90 signify severe heat stress.

Our findings indicate that while the summer season experienced moderate heat stress, the monsoon and winter seasons remained stress-free. This observation is consistent with Silanikove (2000) [11], who confirmed that a THI score of 70 or less constitutes a comfortable thermal zone for animals. Furthermore, Rathwa *et al*., (2017) [6] concluded that the THI is a sensitive indicator in indigenous sheep.

Table 1: The overall mean values of Minerals observed during different seasons in Nagavali sheep

Calcium			
	Rams	Ewes	Total herd
Summer (Mean ± SE)	7.45±0.12a	7.06±0.11a	7.26±0.08a
Monsoon (Mean ± SE)	8.76±0.15b	8.01±0.20b	8.38±0.13b
Winter (Mean ± SE)	10.66±0.25c	8.49±0.29b	9.58±0.22c
Overall (Mean ± SE)	8.96±0.15	7.86±0.13	8.41±0.10
Phosphorous			
Summer (Mean ± SE)	6.41±0.16a	6.64±0.10a	6.52±0.10a
Monsoon (Mean ± SE)	6.24±0.17a	6.36±0.11a	6.30±0.10a
Winter (Mean ± SE)	6.70±0.15 a	6.33±0.12a	6.52±0.10a
Overall (Mean ± SE)	6.45±0.09	6.44±0.06	6.45±0.06
Magnesium			
Summer (Mean ± SE)	2.28±1.23^{a}	2.11±1.46^{a}	2.19±0.96^{a}
Monsoon (Mean ± SE)	2.52±1.37^{a}	2.15±1.32^{a}	2.33±0.95^{a}
Winter (Mean ± SE)	2.85±1.14^{b}	2.98±1.34^{b}	2.91±0.89^{b}
Overall (Mean ± SE)	2.55±0.74	2.41±0.82	2.47±0.50



Graph 1: The overall mean values of Minerals observed during different seasons in Nagavali sheep

Calcium

In the present study, in ewes, significantly lower values of Calcium were noticed in summer (7.06±0.11) when compared to monsoon (8.01±0.20) and winter (8.49±0.29). Similarly, in rams and total herd, significantly lower values were observed in summer (7.45±0.12, 7.26±0.08a) compared to monsoon (8.76±0.15, 8.38±0.13b) and winter (10.66±0.25, 9.58±0.22c). These results are in tandem with the findings of Al-Haidary *et al*., (2012) [12] who studied thermoregulatory and physiological responses of Najdi sheep exposed to environmental heat load prevailing in Saudi Arabia and reported that calcium levels are reduced under heat stress conditions. Similar recordings were observed by Ramana *et al.*, (2013) [13] who examined the productivity and physiological responses of sheep exposed to heat stress and showed lower levels of calcium in heat stress group. The current experiment's results are consistent with those of Nazifi *et al.,* (2003) [14] in Iranian sheep and Srikandakumar *et al*., (2003) [10] in sheep. A decrease in blood calcium concentration in summer might be related to a reduction in food intake, which has been recorded under heat stress conditions (Al Haidary *et al.,* 2012) [12]. Low calcium levels may be caused by hypoproteinemia resulting in reduced calcium transporters which is due to decreased feed intake linked with heat stress (Srikandakumar *et al.,* 2003).

Phosphorus

In the present study, mean values of Phosphorus in ewes, and rams of sheep could not show significant difference but elevated, winter than summer. The results of the present study are in accordance with Al-Eissa *et al.,* (2012) [15] who aimed to investigate the effects of seasonal variations on the composition of blood in Nubian Ibex goats and reported non-significant difference in phosphorus level in summer and winter. Although there was no significant difference, lower levels of phosphorus were noticed in summer in rams. The stidies were incontrast to findings were reported by Nazifi *et al.,* (2003) [14] in Iranian sheep and by Ramana *et al*., (2013) [13] who studied the productivity and physiological responses of sheep exposed to heat stress. The lower level of inorganic phosphorous recorded during the summer season may be attributed to a decrease in feed intake, whereas the greater level of inorganic phosphorous found during the winter season may be related to a higher basal metabolic rate, which leads to increased feed consumption (Vasava, 2017) [16]. Additionally, less availability of green roughage in the summer compared to the winter season may result in decreased serum phosphorous levels in sheep.

Mangnisium

Magnesium is indispensable for numerous enzymatic activities, is important for maintaining the electrolytic balance and is of fundamental importance for normal neuromuscular function as well as for the transport of calcium and potassium. The mean ± SE value of Serum Magnesium was higher during hot-humid in comparison to winter season but the effect was non-significant (p>0.05). The elevated Serum Magnesium levels in present study during hot-humid season were similar to the results of Gottam G.S. (2020) [17] in Pugal Sheep. Stress related changes were observed by Healy and Falk (1974) [18] in the values of magnesium, whereas, stress effect was not observed on the mean value of serum magnesium in Merino sheep by Parker *et al*. (2003). These results were contrary to the findings of Nazifi *et al*. (2003) in Iranian sheep and Al-Eissa *et al*. (2012) in Nubian ibex goat. The researchers observed higher Serum Magnesium during winter than hot humid season. Khan *et al*. (2007) observed interaction effect between season and animal class (p< 0.05).

Conclusion

Climatic and ecological variations significantly influence the physiological and nutritional status of livestock by altering their systemic mineral profiles. For Nagavali sheep an indigenous meat breed in North Coastal Andhra Pradesh, India seasonal forage availability dictates nutritional fulfillment. Establishing baseline serum macro-mineral data across seasons is essential for assessing metabolic health, homeostatic capacity, and productivity. This study systematically evaluated serum mineral profiles in Nagavali sheep to quantify the impact of seasonal transitions.

Serum calcium concentrations demonstrated significant seasonal fluctuations, with markedly higher levels recorded in rams, ewes, and the total herd during winter compared to summer. This increase is primarily attributed to enhanced dry matter intake (DMI) during cooler months and higher dietary calcium concentrations in seasonal vegetation. Conversely, serum phosphorus and magnesium concentrations did not exhibit statistically significant variations across the rainy, winter, and summer seasons. However, both minerals showed a consistent numerical trend toward higher serum levels during winter, aligning with increased pasture biomass availability and superior forage quality that enhance total daily mineral ingestion and absorption.

Author's Contribution Sai Srinivas and Gangu Naidu performed experiments and analysis, K Aswani kumar, A Sampath Ganesh and T Srinivasa rao conceptualized and organized the research.

Funding: This study was funded by Director of Research, S.V.VU, Tirupati, and Department of Biochemistry, India

Ethical Statement: In the present study, saliva samples were collected under the approval of SVVU Institutional Animal Ethics Committee (281/go/ReBi/S/2000/CPCSEA/CVSc/TPTY/010).

Declaration of Competing Interest: The authors declare no competing or financial interests

Acknowledgments: The authors thank Department of Veterinary Physiology and Biochemistry, College of Veterinary Science, Garividi, for providing the infrastructure to conduct the study.

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