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Nutritional and Mineral Analysis of Selected Fodder Plants from Northwestern Himalaya

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ABSTRACT: This study evaluates the nutritional and mineral profiles of the leaf parts of five fodder plant species with the highest use reports (UR): *Acer pictum* (34 UR), *Berberis lycium* (30 UR), *Bromus japonicus* (31 UR), *Cynodon dactylon* (34 UR), and *Rosa webbiana* (36 UR). These plants were collected from the high-altitude Batseri village in the Kinnaur district of the Western Himalaya. Nutritional characteristics were analysed using standard methods, and mineral content was determined through ICP-MS. The findings revealed a significant decline in traditional knowledge of fodder plants among younger generations, driven by societal modernization. This highlights the urgency of documenting traditional knowledge along with the nutritional and mineral profiles of fodder plants in the region. The study highlights the dependence of rural communities in the Western Himalaya on these plants and the pressing need for conservation strategies to safeguard them from extinction in the fragile cold desert ecosystem. The analysis showed that the leaves of these plants are rich in essential minerals, including N, P, K, Na, Mg, Ca, Mn, Fe, Cu and Zn. These findings suggest that the evaluated fodder plants not only serve as vital forage but also hold potential as nutritional supplements for livestock, contributing to sustainable livestock management in the region.

Keywords: Nutrition, Minerals, Forage, Batseri, Tribal community, Use report.

INTRODUCTION

Forage plants are important for providing ecosystem services to humans. Globally, forage supports approximately 1 billion goats, 0.2 billion buffalo, 1.5 billion cattle, and 1.2 billion sheep, contributing to the production of meat, milk, and other essential products (FAOSTAT, 2016). Traditionally, tribal peoples have relied extensively on a wide variety of wild plants for diverse purposes, including medicine, food, fodder, fuel, and cultural practices etc. (Nath and Khatri 2010; Kumar and Duggal 2019). Wild herbivores depend on forage plants, which are essential for conserving biodiversity, supporting complex interactions among species, and affecting the scale and direction of ecosystem processes and services (MEA, 2005). These plants exhibit considerable variation in the nutritional components with different concentrations of fats, proteins, carbohydrates, fiber, and micronutrients found in their tissues (Capstaff and Miller 2018). Fodder trees and shrubs hold significant potential as a protein source for ruminants in tropical regions. However, their presence in ruminant feeding systems has been largely overlooked until recent years, primarily due to limited knowledge about their potential applications and the lack of initiatives to develop more innovative feeding systems (Khan *et al*., 2014). The prevailing animal protein deficiency in the developing world is largely attributed to a shortage of forage. Fodder trees and shrubs have historically contributed to livestock feeding and are increasingly acknowledged as vital components of animal nutrition, particularly as sources of protein (Khan *et al*., 2014). Livestock diets can be made up entirely of forage or mostly forage with added concentrates to improve nutrition. Concentrate supplementation is active to address nutritional deficiencies in forage, enhance animal performance—such as increased milk production—or support critical developmental stages like calving (Erb *et al*., 2012). Minerals are essential for the growth, production, and reproduction of both plants and animals. As structural components and constituents of body fluids and tissues, minerals function as electrolytes and act as catalysts in enzyme and hormone systems (Sharma *et al*., 2007). However, minerals constitute approximately 3% of an animal's body weight (Reddy, 2001). Deficiency, imbalance, or toxicity of minerals can severely hinder both production and reproduction in living organisms (Kumar *et al*., 2011). In many regions, large numbers of livestock consume mineral-deficient diets, leading to nutritional disorders. Addressing these deficiencies by recommending a fixed-composition mineral mixture for dairy animals across diverse agro-geological conditions in the country has been questioned (Panda *et al*., 2015). In forage crops, 50–80% of dry matter consists of

carbohydrates. It is reported that when carbohydrate levels are insufficient, then grain supplements should be added to the diet. However, variations in carbohydrate ratios within forage crops influence downstream digestibility in animals, particularly if the structural composition of the cell wall obstructs digestion by microbial populations or limits cell wall penetration (Capstaff and Miller 2018). The decreasing availability of grazing areas and fodder has become a pressing challenge in many regions. Indigenous tree and shrub species offer significant potential to sustain pastoral systems by providing viable alternatives to dwindling grazing lands (Maselli *et al*., 2011). Integrating fodder trees and shrubs into farming systems can enhance the nutritional resource base, thereby maintaining or improving livestock productivity (Chakeredza *et al*., 2007). Tender shoots, twigs, leaves, fruits, and pods from these trees and shrubs can be browsed by livestock commonly found in pastoral and agro-pastoral areas. These feed resources play a crucial role in mitigating the adverse effects of harsh climatic conditions prevalent in such areas (Derero and Kitaw 2018). The composition of plant species has a significant impact on the nutritional quality of alpine grasslands, semi-natural grasslands and pastures (Chapman *et al*., 2014; Komac *et al*., 2014; French, 2017). However, the differences in nutritive value and palatability among forage plants from various functional groups have not been thoroughly studied on a global level. A previous study by Lee *et al*. (2017), focused on grasses and found that fiber content of forage grasses, analysed across 55 species from 16 countries, ranged from 34% to 90%, while the protein content ranged from 5% to 36%. Limited data coverage has hindered comprehensive comparisons of the nutritive values of forage plants across regions. Nonetheless, evidence suggests that forage grasses in warmer regions tend to be of lower quality, characterized by higher fiber content, which makes them more difficult to digest (Lee *et al*., 2017). Increasing temperatures can induce phenological changes in plants, such as earlier flowering, as well as physiological changes, including thicker cell walls and elevated lignin concentrations (Kering *et al*., 2011). The decline in biodiversity and the rising global temperatures are interconnected challenges that significantly impact ecosystem stability and functionality. As biodiversity decreases, ecosystems become less resilient to climate-induced changes, such as species turnover. Elevated temperatures further degrade these changes by favouring taller, slow-growing plant species that prioritize energy allocation towards structural support and defence mechanisms rather than leaf growth, altering plant community dynamics and ecosystem productivity (Waghorn and Clark 2004; Jego *et al*., 2013; Verma and Kapoor 2019). Therefore, the objective of this study was to assess the nutritive value of five high-priority fodder plants. The selected foliage species were chosen due to their abundant availability, high preference by ruminants in their natural habitats, and the strong belief among tribal communities that these species are highly nutritious.

METHODOLOGY

Use report (UR). The UR was determined by using the formula: UR = [category of use] × [route of administration] (Prakash *et al.,* 2022).

Statistical analysis. The proximate analysis of the plants was performed in triplicate, and the results for each parameter were expressed as Mean ± Standard Error. Statistical analysis was carried out using one-way Analysis of Variance (ANOVA), followed by Duncan's Multiple Range Test (DMRT) to identify significant differences among plant samples from various study sites. Data processing and analysis were conducted using IBM SPSS Statistics, version 20.

To determine the forage quality of plants used by tribal peoples of Kinnaur district.

Nutritional analysis: The leaf samples of 5 commonly used forage plants from Batseri village were collected during 2022 and 2023. The leaves were shade dried, pulverized and stored in air tight container. Samples were labelled, packed in bags and taken to the laboratory of Shoolini University for the determination of physiochemical and quantitative analysis as well as minerals in the leaves. The leaves were rinsed with deionized water, gently blotted with a paper towel, and chopped into small pieces. They were then oven-dried at 55°C for 72 hours until a constant weight was reached and subsequently ground into a fine powder. Nutritional analysis was conducted to assess the presence of key components influencing the nutritional properties of the fodder plants. The parameters analysed included moisture, ash, crude fat, crude fiber, crude protein, carbohydrates, NDF, and ADF. The methods for determining these were based on Unuofin *et al*. (2017) for the first set of parameters, and Van Soest and Wine (1967) for NDF and ADF content.

Quantitative analysis of minerals in forage plants. The nitrogen content in the different leaf samples was determined using the Kjeldahl method, as described by Dhyan *et al*. (2005). This method allowed for accurate measurement of nitrogen levels, which are essential for assessing the nutritional value of the forage plants (Table 1).

Table 1: Mineral analysis of leaf samples.

Sr. No.	Parameters	Methods and References
1.	Nitrogen	Kjeldahl method (Dhyan *et al*., 2005)
2.	P, K, Ca, Cu, Fe, Zn, Na, Mn and Mg	ICP-MS (Inductively coupled plasma mass spectrometry) (Thermo Scientific AN 43446)

Nutrient Analysis in Dried Leaf Samples Using ICP-MS Digestion Method. The analysis was performed using ICP-MS (Thermo Scientific AN 43446). For nutrient analysis, approximately 0.3 g of leaf samples were digested with a mixture of 5 mL HNO_3 and 1 mL HCl in a closed-vessel microwave digestion system.

The samples were heated to 200°C and maintained at this temperature for 15 minutes. After digestion, the samples were diluted to a final volume of 10 mL using ultrapure water.

RESULTS AND DISCUSSION

Forage plants play a critical role in providing essential nutrients for livestock, influencing their growth, reproduction, and overall health (Chand *et al*., 2022). In this study, we evaluated various nutritional and mineral parameters of selected fodder species from the Northwestern Himalaya. The highest NDF content was found highest in *Bromus japonicus* (59.40%) ad lowest in *Cynodon dactylon* (55.49%). The highest ADF content was found in *Rosa webbiana* (56.55%) and lowest in *Bromus japonicus* (49.44%). The variation in NDF and ADF levels may be linked to the maturity of the species, as indicated by previous studies (Hameed *et al.*, 2016; Gaikwad *et al*., 2017). The elevated levels of ADF and NDF typically signify a rise in structural components and leaf maturity, as highlighted in previous studies (Van Soest, 1965; Sultan *et al*., 2008). The ADF range observed in our study aligns with that of well-known high-quality fodder tree species. Studies conducted by Paudel *et al*. (2017) and Katoch *et al*. (2017) also yielded results comparable to our findings. The highest moisture content was found in *Rosa webbiana* (43.36%) and lowest was found in *Acer pictum* (39.83%) (Table 2). The low moisture content suggests that fodder species may have an extended shelf life and reduced microbial contamination. Ash content is significant for promoting balanced animal growth. Higher ash values indicate a greater amount of mineral matter in the leaves and shrubs of fodder trees. The variation in ash content across different plants in all pasture lands may be attributed to differences in soil and other habitat features, which require further exploration (Ahmed *et al*., 2013; Gaikwad *et al*., 2017). In our study, the highest ash content was found in *Cynodon dactylon* (4.27%) and lowest in *Bromus japonicus* (2.20%). Fodders with high levels of fiber are typically more suitable for cattle, sheep, and goats (Edwards, 1948). However, excessive fiber content can potentially interfere with the absorption of essential minerals (Unuofin *et al*., 2017). The highest crude fiber content was observed in *Berberis lycium* (33.85%), while the lowest was found in *Rosa webbiana* (27.44%). Ruminants depend on protein for growth and reproduction. A deficiency in protein can lead to reduced appetite, lower feed intake, and poor feed efficiency, ultimately resulting in stunted growth and development in livestock (Ahmed *et al.*, 2013). Therefore, plants with relatively high protein content serve as valuable supplements for diets. The highest crude protein content was found in *Berberis lycium* (5.10%), while the lowest was in *Acer pictum* (4.25%). Furthermore, their high carbohydrate content makes them a valuable source of energy, which can be used to improve the energy density of diets (Sahay *et al*., 2017). The highest carbohydrate content was found in *Bromus japonicus* (21.81%) and lowest in *Berberis lycium* (13.87%). Livestock primarily obtain their dietary nutrients from the feed they consume.

Table 2: Nutritional analysis of fodder leaves collected from Batseri village.

Sr. No.	Botanical Name	Moisture%	Ash%	Crude Fat%	Crude Fiber%	Crude Protein%	Carbohydrate%	NDF%	ADF%
1	*Acer pictum* Thunb.	39.83± 0.30	3.20± 0.15	1.24± 0.08	32.82± 0.38	4.25± 0.03	18.66± 0.24	57.50± 0.24	53.35± 0.27
2	*Berberis lycium* Royle	42.47± 0.18	2.22± 0.11	2.49± 0.12	33.85± 0.38	5.10± 0.03	13.87± 0.22	58.32± 0.29	51.83± 0.25
3	*Bromus japonicus* Thunb	39.93± 0.35	2.20± 0.11	2.26± 0.11	29.30± 0.31	4.50± 0.03	21.81± 0.12	59.40± 0.28	49.44± 0.24
4	*Cynodon dactylon* (L.) Pers.	41.49± 0.41	4.27± 0.16	1.09± 0.05	32.79± 0.33	4.80± 0.03	15.56± 0.18	55.49± 0.28	49.54± 0.22
5	*Rosa webbiana* Wall. ex Royle	43.36± 0.39	3.24± 0.14	1.76± 0.08	27.44± 0.30	4.60± 0.04	19.60± 0.17	56.50± 0.35	56.55± 0.29

The mineral content in plants is influenced by several factors, including soil type, plant species, stage of maturity, dry matter yield, grazing management, and climate (McDowell, 1993; Khan *et al.*, 2006; Khan *et al*., 2009). Minerals are essential components for the growth and development of animal bodies, playing a crucial role in the composition of bones and teeth (Khan *et al.*, 2013). Fodder trees and shrubs serve as valuable sources of minerals for ruminants (Ahmad *et al.*, 2008) and are often readily accepted by livestock (Paterson *et al*., 1998). Tree fodder leaves were assessed for their mineral content, particularly focusing on sodium (Na) and potassium (K) levels. Potassium levels varied between 24.11 and 77.23 ppm, consistent with previous findings by Fadel *et al*. (2002), who noted high potassium and low sodium concentrations in fodder tree species. Both sodium and potassium play crucial roles in maintaining osmotic pressure in body fluids and cell permeability. Species with higher levels of phosphorus (P) and potassium (K) in their leaves are considered more beneficial for livestock, as these elements are essential for their well-being (Ashraf *et al*., 1992). The potassium (K) content observed in the present study was lower compared to highland fodder in Ethiopia, as reported by Mekonnen *et al*. (2009). Derero and Kitaw (2018) classified phosphorus (P) content above 0.5% as high and calcium (Ca) content below 2% as low. The low levels of phosphorus led to a

higher Ca: P ratio, which can hinder the efficient utilization of calcium, despite the leaves containing an adequate amount of calcium, as observed by Fadel *et al.* (2002). Nitrogen, essential for plant growth and a supplementary energy source for animal feeding, was found to be less than 1% in fodder leaves. The highest nitrogen content was observed in *Berberis lycium* (0.817%). A study by Fadel *et al*. (2002) suggested that nitrogen in fodder tree leaves has low ruminal degradability, which may limit the nitrogen supply in the rumen for microbial fermentation. Phosphorus, an essential nutrient for plant growth and development, varied across different species. In our study phosphorus was found to be highest in *Bromus japonicus* (5.01%) and lowest in *Acer pictum* (2.27%). Das (2019), noted that many trees and grasses provided rich sources of calcium, iron, and manganese, which could mitigate reproductive disorders in dairy cattle related to mineral deficiencies. Research by Khanal and Subba (2001) found that most fodder tree leaves had high calcium contents, often exceeding 1% on a dry matter basis, with some species, such as *Brassaiopsis hainla*, reaching as high as 5.72%. More than 75% of the species analysed had calcium levels exceeding the typical requirement range. This higher calcium content could be beneficial for high-yielding ruminants during the early stages of lactation, potentially helping to prevent milk fever (Khanal and Subba 2001). In present study highest Ca content was found in *Cynodon dactylon* (56.72 ppm) and lowest in *Acer pictum* (38.19 ppm) (Table 3). The analysis of micronutrients such as zinc, copper, manganese, and iron revealed slight differences in their values. Zinc, recognized for its metabolic importance in plant growth and development, is considered an essential trace element or micronutrient (Tripathi *et al.*, 2015). Given its significance in animal nutrition as well, proper zinc application in soil can rectify deficiencies in animals (Kumar *et al.*, 2016). Iron, magnesium, and copper levels in our findings varied compared to those reported by others (Aganga and Tshwenyane, 2003; Derero and Kitaw, 2018). The highest iron content was detected in *Berberis lycium* (2.33 ppm) while the lowest was found in *Bromus japonicus* (1.98 ppm). A study determined that the harmful effects of iron (Fe) are unlikely to occur in ruminants, as they can tolerate much higher levels of Fe (>1000 ppm) from natural feed sources (NRC, 1968). However, high levels of Fe are likely to be excreted through feces (Khanal and Subba 2001). This finding has prompted researchers to adopt a novel approach to explore potential applications of every plant in food or medicine. Plants are generally rich in essential primary metabolites, including proteins, carbohydrates, vitamins, sterols, and lipids, which are vital for their survival. However, the consistent intake of specific elements through dietary habits may influence the functional activities of certain organs, potentially leading to the bioaccumulation of these elements beyond normal or safe levels (Jaishankar *et al*., 2014).

Table 3: Minerals composition in some selected fodder leaves from Batseri village.

Sr. No.	Fodder species	N %	P ppm	K ppm	Na ppm	Mg ppm	Ca ppm	Mn ppm	Fe ppm	Cu ppm	Zn ppm
1.	*Acer pictum*	0.680	2.27	47.12	3.76	76.09	38.19	0.86	2.10	0.088	0.47
2.	*Berberis lycium*	0.817	3.51	25.09	3.28	72.13	51.60	0.93	2.33	0.057	0.79
3.	*Bromus japonicus*	0.720	5.01	27.54	3.11	54.82	42.50	0.81	1.98	0.092	0.39
4.	*Cynodon dactylon*	0.767	4.07	28.77	2.87	66.80	56.72	1.03	2.21	0.014	0.51
5.	*Rosa webbiana*	0.737	4.93	29.11	3.21	61.03	48.91	0.95	2.17	0.082	0.57

CONCLUSIONS

The study evaluated the nutritional and mineral profiles of five commonly used fodder plants from Batseri village in the Kinnaur district of the Northwestern Himalaya, revealing their significant potential for sustainable livestock management. The findings demonstrated that these plants are rich sources of essential nutrients, including proteins, carbohydrates, fibers, and critical minerals like calcium, potassium, and iron. Among the species studied, *Berberis lycium* exhibited the highest protein and nitrogen content, while *Rosa webbiana* stood out for its high moisture levels, which could extend shelf life and reduce contamination risks. The research highlights the importance of these indigenous plants as dietary supplements to address nutritional deficiencies in livestock. However, the study also highlights challenges such as declining traditional knowledge due to modernization and reduced interest among younger generations. This knowledge erosion poses a risk to the conservation of these valuable fodder resources. To mitigate these challenges, the study calls for urgent documentation and scientific validation of traditional practices. Integrating this knowledge with modern agricultural and veterinary systems can enhance livestock productivity and biodiversity conservation in fragile ecosystems like the cold deserts of the Himalayas. Overall, the findings emphasize the dual role of these fodder plants in providing nutritional support and contributing to the ecological sustainability of pastoral systems, reinforcing the need for focused conservation strategies and community-driven initiatives.

Author contribution list: Niharika Sharma conceptualized the study, collected the data, analysed the data and scientific literature. Radha and Samar edited and refined the final draft. All authors wrote and read different sections of the manuscript and approved the final manuscript.

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