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Research Article

Documenting And Evaluating Key Forage Plants Of Mid-Altitude Forests: Insights From Gaddi Shepherds' Migration Routes

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Abstract: This study systematically records and assesses important forage plants browsed by sheep and goats in the mid-altitude forests along the migratory paths of the Gaddi shepherds, emphasising their traditional applications and ecological importance. Through fieldwork and thorough analysis, 51 forage plant species used by sheep and goats were identified and classified according to their botanical nomenclature, family, habit, and use value. Species like *Rhododendron arboreum*, *Ziziphus mauritiana*, and *Carissa spinarum* demonstrated the highest use values, underscoring their significance in supporting livestock during transhumance. This study highlights the complex understanding possessed by Gaddi pastoralists and their reliance on mid-altitude ecosystems for livestock grazing. The results highlight the importance of incorporating traditional ecological knowledge into forest management and conservation approaches to enhance the sustainability of these vital ecosystems and the pastoralist lifestyle.

Keywords: Forage plants, Mid-altitude forests, Gaddi shepherds, Ethnobotanical analysis, Livestock forage, Transhumance.

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INTRODUCTION

The Indian Himalayan Region (IHR) is acknowledged globally as a biodiversity hotspot, distinguished by its intricate ecosystem and a wide variety of plant and animal species. The IHR encompasses multiple states in northern India, showcasing a diverse array of ecological zones that range from subtropical to alpine environments. Himachal Pradesh, located in the western Himalayas, showcases this diversity through its vast forests, diverse altitudes, and distinct climatic conditions that together sustain a rich variety of flora and fauna (Rawal *et al.*, 2018; Chandra *et al.*, 2024). The mid-altitude forests of this region are crucial for maintaining ecological balance, serving as

transitional zones that connect the lower scrublands with the higher alpine pastures.

The Gaddi shepherds are integral to the cultural and ecological landscape of Himachal Pradesh, representing a semi-nomadic pastoralist community recognised for their transhumant way of life (Nehria and Ghosh, 2024). This customary practice entails the seasonal movement of livestock, such as sheep, goats, horses, and dogs, in reaction to climatic and environmental factors. In the summer season, Gaddi shepherds move to elevated pastures that offer abundant grazing opportunities. As winter approaches, snow blankets the pastures, necessitating the shepherds' migration to lower altitudes in search of accessible forage (Bhasin, 2011).

The mid-altitude forests, located along the migration paths of the Gaddi shepherds, function as essential stops that support both livestock and shepherds throughout their travels (Bhasin, 2011). The temporary grazing grounds play a crucial role in sustaining the health and productivity of livestock, offering forage that fulfils their nutritional requirements. Although they are crucial, there is still an insufficient amount of detailed documentation concerning the particular forage plants found in these mid-altitude areas. Grasping the preferences and use values of these forage species is essential for guiding sustainable forest management practices and aiding traditional pastoral activities (Srivastava, 2022; Malhotra, 2023).

REVIEW OF LITERATURE

The study of biodiversity in the Indian Himalayan Region has highlighted the importance of forest ecosystems, especially in mid-altitude areas, for sustaining both human and animal populations. Research conducted by (Bhat *et al.*, 2020; Das *et al.*, 2020; Negi *et al.*, 2024) has established a fundamental comprehension of the various vegetation types present across different altitudinal gradients, emphasising the ecological roles of mid-altitude forests in soil conservation, water regulation, and the creation of habitats for a wide range of wildlife (Lukina *et al.*, 2021). The forests play a crucial role in enhancing regional biodiversity and act as essential resources for local communities and their livestock (Wani and Sahoo, 2021).

Ethnobotanical studies have consistently highlighted the profound understanding that indigenous communities possess regarding their surroundings. Gaddi shepherds have a profound understanding of plant resources and their uses, developed through generations of engagement with these ecosystems (Malhotra *et al.*, 2021). The traditional ecological knowledge of shepherds includes insights regarding the availability, palatability, and nutritional value of forage plants that support their livestock throughout transhumance (Sharifian *et al.*, 2023). Nevertheless, a significant portion of the existing literature primarily emphasises plants utilised for human consumption or medicinal applications (Samant *et al.*, 2007; Prakash, 2015), while there is a scarcity of research specifically addressing livestock forage.

The importance of combining local knowledge with scientific research to improve the understanding and

conservation of the IHR's biodiversity has been highlighted by many researchers (Dhiman and Muthanarasimha, 2022; Sahana and Mishra, 2024). The mid-altitude forests hold significant importance for Gaddi pastoralism due to their rich variety of shrub, herb, and grass species that contribute to livestock nutrition (Pullaiah *et al.*, 2017). Despite the frequent documentation of plant species in ethnobotanical surveys, the particular applications of these plants in transhumant practices remain inadequately addressed in scholarly works.

Recent investigations have started to address this gap by cataloguing the forage plants that shepherds most commonly use (Chadda, 2022; Prakash *et al.*, 2022; Chaudhary and Garkoti, 2024). It has also been observed that this type of documentation can guide sustainable forest management strategies that are in harmony with the requirements of traditional pastoralist communities (Sinthumule, 2023; Akalibey *et al.*, 2024). Examining the significance of mid-altitude forests in the seasonal migration of the Gaddi shepherds reveals important connections between human activities and ecological preservation.

This study seeks to systematically record and assess the primary forage species found in mid-altitude forests that align with the migration paths of Gaddi shepherds. This study aims to deliver an in-depth examination of the botanical traits, utility values, and ecological significance of these plants, highlighting the essential role these forests have in bolstering traditional pastoralist practices and promoting the enduring sustainability of mid-altitude ecosystems in Himachal Pradesh.

MATERIAL AND METHODS

Study Sites: The study was conducted in the mid-altitude forested regions of Palampur forest division, specifically in the areas of Manai, Deol Khas, Kanarthu, and Kandral in tehsil Baijnath, district Kangra Himachal Pradesh. These regions serve as significant transitory grazing grounds for the Gaddi shepherds' livestock during their seasonal migration to low altitudes. Additionally, the Gaddi shepherds have established their residences in these regions, and some of their family members reside there. This allows them the opportunity to engage with their family members while their livestock are grazing in the nearby forested regions. In this study the total no. of informants were 80 shepherds.

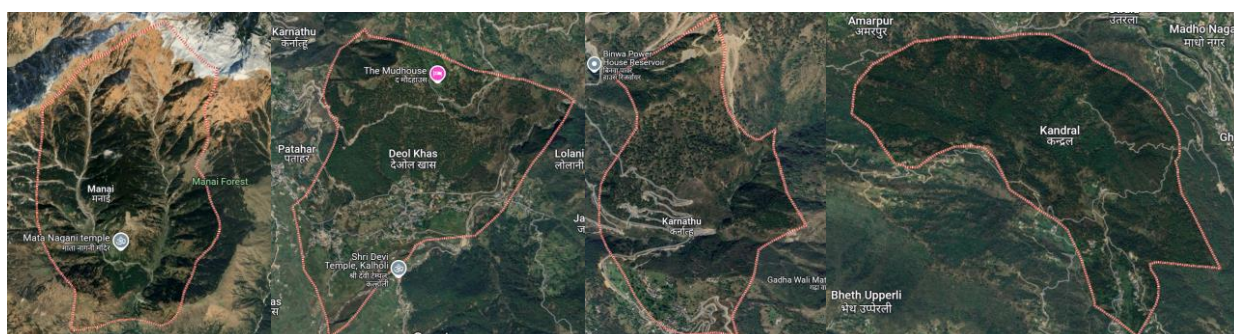


Fig. 1-4. Areas of study at mid-altitude study site. 1. Manai 2. Deol Khas, 3. Kanarthu 4. Kandral

Survey, Collection, Identification, and Herbarium Preparation: Field surveys were conducted in these areas,

where forage plants commonly used by Gaddi shepherds were identified and collected. Specimens were

documented, labelled, and processed for herbarium preparation. The identification of plant species was confirmed through botanical keys and consultations with experts to ensure accuracy.

The Gaddi shepherds' livestock, primarily sheep and goats, were observed browsing various forage plant species. Use Value (UV) was calculated to determine the sustainability of their usage, focusing on the most browsed species. UV was calculated by the following formula $UV = \sum \frac{U_i}{N}$, where U_i denotes the uses cited by each informant for a species, while N represents the total number of informants (Silva *et al.*, 2004).

The ten most commonly used forage plants (Plate 1) were gathered from mid-altitude forests and assessed for nutritional quality parameters. The leaf samples underwent a series of tests to evaluate moisture, ash, crude protein, crude fat, crude fibre, carbohydrate content, fibre composition (NDF and ADF) and mineral analysis in order to assess their suitability for sustaining the livestock of Gaddi shepherds.

Moisture (%): An empty container was dried at 105°C for 1 hour, chilled in a desiccator, then weighed to estimate moisture content (W1). A leaf sample (W2) weighing 2.000 ± 0.001 g was dried at 105°C until constant weight (W3) was reached, chilled, and reweighed. We estimated moisture (%) by the formula of Unuofin *et al.* (2017).

$$\text{Moisture (\%)} = \frac{W2 - W3}{W2 - W1} \times 100$$

Ash (%): The ash content was assessed by placing 2 g of a powdered leaf sample into a pre-weighed crucible (W1), followed by combustion at 250°C for 1 hour and subsequently at 550°C for 5 hours in a muffle furnace. Following the cooling process in a desiccator, the crucible underwent reweighing (W3), and the ash content (%) was determined using the following calculation of Unuofin *et al.* (2017).

$$\text{Ash (\%)} = \frac{W2 - W3}{W2 - W1} \times 100$$

Crude Fat (%): Crude fat was extracted from a 5 g leaf powder sample utilising 100 mL of diethyl ether, agitated for a duration of 24 hours, and subsequently filtered. The extract underwent evaporation, followed by the drying and reweighing of the beaker (W2). The calculation for crude fat content (%) was performed as given by Unuofin *et al.* (2017).

$$\text{Crude Fat (\%)} = \frac{\text{Weight of Flask with Fat} - \text{Weight of Empty Flask}}{\text{Weight of Original Sample}} \times 100$$

Crude Fiber (%): The determination of crude fiber involved digesting a 2 g dried leaf sample in 100 mL of 1.25% sulphuric acid for a duration of 30 minutes, after which filtration and rinsing were performed. The procedure was conducted again using 1.25% sodium hydroxide (NaOH). The residue underwent drying, followed by weighing (C1), combustion, and subsequent reweighing (C2). The calculation for crude fibre (%) was performed by the formula of Unuofin *et al.* (2017).

$$\text{Crude Fiber (\%)} = \frac{C2 - C1}{\text{Weight of Original Sample}} \times 100$$

Crude Protein: The determination of protein content was conducted utilising the Kjeldahl method. A 2 g leaf sample underwent digestion, distillation, and titration to quantify nitrogen, subsequently converting this measurement to protein using a factor of 6.25 (Unuofin *et al.*, 2017).

$$\begin{aligned} &[(\text{ml Standard Acid} \times N \text{ of Acid}) \\ &- (\text{ml Blank} \times N \text{ of Base})] \\ &- (\text{ml Standard Base} \times N \text{ of Base}) \\ &\times 1.4007) \\ &/(\text{Weight of Sample in Grams}) \end{aligned}$$

Carbohydrate: The carbohydrate content was calculated by deducting the total values of moisture, ash, crude fat, crude fibre, and crude protein from 100 (Unuofin *et al.*, 2017).

$$\begin{aligned} \% \text{ Total Carbohydrate} &= 100 - \\ &(\% \text{Moisture Content} + \% \text{Ash Content} + \\ &\% \text{Crude Fat} + \% \text{Crude Fiber} + \% \text{Crude Protein}) \end{aligned}$$

Neutral Detergent Fibre: The determination of NDF was conducted following the method established by Soest and Wine (1967). A 500 mg dried leaf sample underwent reflux in 100 mL of a neutral detergent solution, which included 2 mL of decahydronaphthalene and 0.5 g of sodium sulphate, for a duration of 60 minutes. The residue underwent filtration, followed by washing with hot distilled water and acetone. It was then dried at 100°C for a duration of 8 hours, allowed to cool, and subsequently weighed. NDF percentage was determined using the following formula:

$$\text{NDF (\%)} = \frac{((\text{Weight of Crucible} + \text{Fiber Content}) - \text{Weight of Empty Crucible})}{(\text{Weight of Sample}) \times 100}$$

Acid Detergent Fibre: The determination of ADF was conducted following the method established by Soest and Wine (1967). A 500 mg sample of dried leaf was subjected to reflux in 100 mL of acid detergent solution, incorporating 2 mL of decahydronaphthalene, for a duration of 1 hour. Following this, the mixture was filtered, washed with hot water (90-100°C) and acetone, and subsequently dried at 100°C for 8 hours. The residue was subsequently weighed.

$$\begin{aligned} \text{ADF (\%)} &= \frac{((\text{Weight of Crucible} \\ &+ \text{Fiber Content}) \\ &- \text{Weight of Empty Crucible})}{/(\text{Weight of Sample}) \times 100} \end{aligned}$$

Mineral Analysis: Leaf samples were thoroughly washed with tap and deionized water, air-dried, and then placed in a hot air oven at $60 \pm 5^\circ\text{C}$ for 48 hours. The dried samples were pulverized, milled, and stored in polyethylene bags at room temperature.

Nitrogen (N): Measured using the Microkjeldahl method (Singh *et al.*, 2005). One gram of finely ground leaf sample was digested with concentrated H_2SO_4 and a digestion accelerator. After a multi-step heating and

cooling process, ammonia was distilled, collected, and titrated against 0.1 N H₂SO₄ to determine nitrogen content. Phosphorus (P): Determined using vanadate–molybdate colorimetry (Singh *et al.*, 2005). A pre-digested sample was treated with vanadate-molybdate reagent, and absorbance was measured at 420 nm. Phosphorus concentration was calculated from a standard curve.

Potassium (K): Measured after di-acid digestion. The digested sample was diluted, and K concentration was determined by comparing with a standard curve (Singh *et al.*, 2005).

Calcium (Ca), Magnesium (Mg), Sulfur (S), Iron (Fe), Manganese (Mn), Zinc (Zn), Sodium (Na), Chromium (Cr), Copper

(Cu): Analyzed using an Atomic Absorption Spectrophotometer after di-acid digestion. One gram of dried leaf sample was digested using concentrated HNO₃ and HClO₄, followed by heating until clear and colorless. The cooled digest was diluted to 100 mL, filtered, and analyzed (Singh *et al.*, 2005).

Sample Digestion for Nutrients: The di-acid digestion involved treating 1 gram of leaf sample with concentrated HNO₃ for pre-digestion, followed by the addition of

HClO₄. The sample was heated gradually from 100°C to 200°C until thick white vapors indicated complete digestion. The solution was cooled, filtered, and diluted for analysis of Ca, Mg, S, Fe, Mn, Zn, Na, Cr, and Cu.

RESULTS AND DISCUSSION

Research carried out in the mid-altitude forests of Baijnath tehsil, Kangra district, recorded a detailed inventory of 51 fodder plant species (Table 1) used by the livestock of Gaddi shepherds. This collection comprised 18 herbs, 12 shrubs, 11 grasses, 8 trees, 1 climber, and 1 fern (Fig. 6), highlighting the botanical diversity that underpins the pastoral lifestyle. This study identified several key species of interest, including most foraged (Photo Plate 1) *Rhododendron arboreum*, *Ziziphus mauritiana*, *Carissa spinarum*, *Mallotus philippensis*, *Grewia optiva*, *Debregeasia longifolia*, *Rubus ellipticus*, *Jasminum laurifolium*, and *Cynodon dactylon* belonging to 28 plant families. The Poaceae family included 10 species, while the Fabaceae family was represented by 6 species (Fig. 5). This is consistent with earlier research that has also emphasised the prevalence of grasses and legumes as key elements of rangeland forage, owing to their adaptability and nutritional benefits (Batello *et al.*, 2008; Tracy *et al.*, 2018).

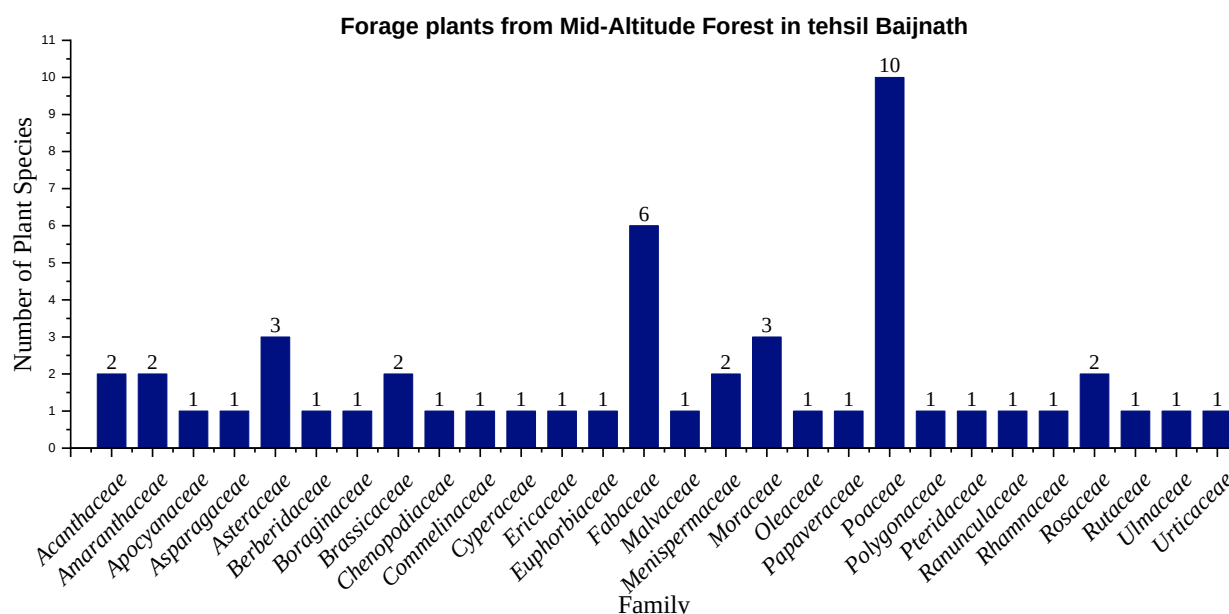


Fig. 5. No. of forage plants belonging to various families in the Mid-Altitude study site

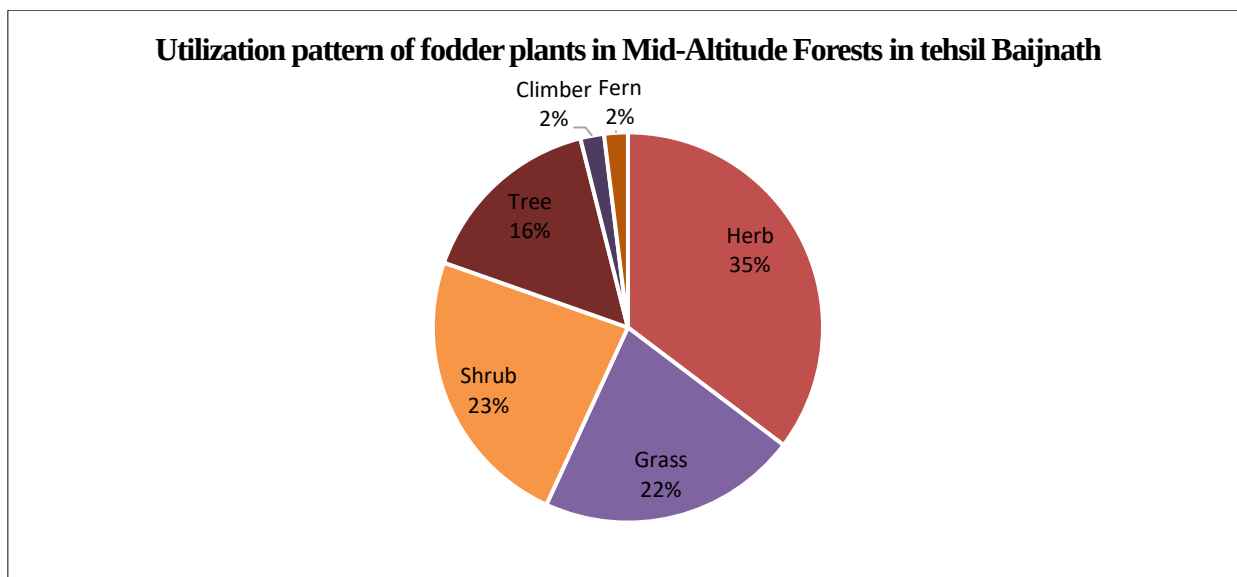


Fig. 6. Utilization pattern of fodder plants in Mid-Altitude study site.

Herbs made up 35% of the plant components utilised, with shrub leaves at 23%, grasses at 22%, trees at 16%, and both climbers and ferns contributing 2% each. This comprehensive inventory emphasises the variety and

favoured forage plants accessible to the livestock of Gaddi shepherds in the mid-altitude forests of Baijnath tehsil. It is important to highlight that tree forage species additionally functioned as sources of fuelwood.

Table 1: Forage plants of Mid- Altitude Forest which are preferably browsed by sheep and goats.

Sr. No.	Botanical name	Family	Common Name	Voucher No.	Habit	Use Value
1	<i>Rhododendron arboreum</i> Sm.	Ericaceae	Barah	SUBMS/BOT-6453	Shrub	0.98
2	<i>Ziziphus mauritiana</i> Adans	Rhamnaceae	Malhi	SUBMS/BOT-6154	Shrub	0.98
3	<i>Carissa spinarum</i> L.	Apocyanaceae	Gama	SUBMS/BOT-6160	Shrub	0.98
4	<i>Mallotus philippensis</i> Muell.-Arg.	Euphorbiaceae	Kamal	SUBMS/BOT-6439	Shrub	0.98
5	<i>Grewia optiva</i> J.R.Drumm. ex Burret	Malvaceae	Dhaman	SUBMS/BOT-6147	Tree	0.98
6	<i>Debregeasia longifolia</i> (Burm.f.) Wedd.	Urticaceae	Dhoyen	SUBMS/BOT-6445	Shrub	0.98
7	<i>Rubus ellipticus</i> Sm.	Rosaceae	Aakhe	SUBMS/BOT-6167	Shrub	0.98
8	<i>Jasminum laurifolium</i> Roxb. ex Hornem.	Oleaceae	Chameli	SUBMS/BOT-6148	Shrub	0.97
9	<i>Cynodon dactylon</i> (L.) Pers.	Poaceae	Dhruv	SUBMS/BOT-6444	Grass	0.97
10	<i>Rumex hastatus</i> D. Don	Polygonaceae	Khatti Mitthi	SUBMS/BOT-6168	Herb	0.97
11	<i>Brassica campestris</i> L.	Brassicaceae	Sarhon	SUBMS/BOT-6155	Herb	0.97
12	<i>Cyperus rotundus</i> Hook. F.	Cyperaceae	Motha	SUBMS/BOT-6450	Grass	0.97
13	<i>Commelina benghalensis</i> L.	Commelinaceae	Chhura	SUBMS/BOT-6161	Herb	0.95
14	<i>Berberis lycium</i> Hort.ex K. Koch	Berberidaceae	Kasmal	SUBMS/BOT-6149	Shrub	0.95
15	<i>Lepidagathis cuspidata</i> Nees	Acanthaceae	Braalu	SUBMS/BOT-6438	Herb	0.95
16	<i>Amaranthus viridis</i> L.	Amaranthaceae	Chulai	SUBMS/BOT-6156	Herb	0.95
17	<i>Brassica napus</i> L.	Brassicaceae	Sarhon	SUBMS/BOT-6442	Herb	0.95
18	<i>Chenopodium album</i> L.	Chenopodiaceae	Bathua	SUBMS/BOT-6169	Herb	0.95
19	<i>Bidens Pilosa</i> L.	Asteraceae	Gumbar	SUBMS/BOT-6447	Herb	0.90
20	<i>Achyranthes aspera</i> L.	Amaranthaceae	Puthkanda	SUBMS/BOT-6150	Herb	0.89
21	<i>Eclipta prostrata</i> L.	Asteraceae	Bhringraj	SUBMS/BOT-6436	Herb	0.89
22	<i>Indigofera heterantha</i> Wall. ex Brandis.	Fabaceae	Kathu	SUBMS/BOT-6157	Shrub	0.89

Documenting And Evaluating Key Forage Plants Of Mid-Altitude Forests: Insights From Gaddi Shepherds' Migration Routes

23	<i>Bauhinia variegata</i> L.	Fabaceae	Karyaleya	SUBMS/BOT-6162	Tree	0.89
24	<i>Acacia catechu</i> Brandis	Fabaceae	Khair	SUBMS/BOT-6440	Tree	0.89
25	<i>Asparagus filicinus</i> Buch.-Ham. ex D.Don	Asparagaceae	Sanspayi	SUBMS/BOT-6170	Herb	0.87
26	<i>Xanthium strumarium</i> L.	Asteraceae	Jhinjhre	SUBMS/BOT-6454	Herb	0.87
27	<i>Albizia lebbeck</i> (L.) Benth.	Fabaceae	Sarin	SUBMS/BOT-6151	Tree	0.87
28	<i>Ficus palmata</i> Forssk.	Moraceae	Faguda	SUBMS/BOT-6437	Tree	0.87
29	<i>Morus alba</i> L.	Moraceae	Toot	SUBMS/BOT-6158	Tree	0.87
30	<i>Cissamplos pareira</i> L.	Menispermaceae	Patindu	SUBMS/BOT-6163	Herb	0.86
31	<i>Acacia nilotica</i> (L.) P.J.H.Hurter & Mabb.	Fabaceae	Dhurgadi	SUBMS/BOT-6441	Shrub	0.85
32	<i>Broussonetia papyrifera</i> (L.) Vent.	Moraceae	Not known	SUBMS/BOT-6171	Tree	0.85
33	<i>Fumaria parviflora</i> Lam.	Papaveraceae	Kainth	SUBMS/BOT-6451	Herb	0.85
34	<i>Oplismenus undulatifolius</i> (Ard.) P.Beauv.	Poaceae	Puthkanda	SUBMS/BOT-6152	Grass	0.85
35	<i>Digitaria ciliaris</i> (Retz.) Koeler	Poaceae	Gumbar	SUBMS/BOT-6435	Grass	0.85
36	<i>Dicliptera bupleuroides</i> Nees	Acanthaceae	Kaali basuti	SUBMS/BOT-6159	Herb	0.85
37	<i>Bambusa arundinacea</i> Bonpl.	Poaceae	Bainj	SUBMS/BOT-6164	Grass	0.85
38	<i>Cocculus hirsutus</i> (L.) Diels	Menispermaceae	Jal Jamni	SUBMS/BOT-6443	Herb	0.84
39	<i>Sorghum helepence</i> (L.) Pers.	Poaceae	Baru	SUBMS/BOT-6172	Grass	0.84
40	<i>Brachiaria ramosa</i> (L.) Stapf	Poaceae	Butri	SUBMS/BOT-6448	Grass	0.84
41	<i>Bothriochloa pertusa</i> (L.) A. Camus	Poaceae	Khatiambi	SUBMS/BOT-6449	Grass	0.83
42	<i>Cymbopogon martini</i> (Roxb.) Wats.	Poaceae	Makoda	SUBMS/BOT-6434	Grass	0.83
43	<i>Paspalum notatum</i> Flügge	Poaceae	Kodri	SUBMS/BOT-6455	Grass	0.83
44	<i>Rosa moschata</i> Herm.	Rosaceae	Kujeya	SUBMS/BOT-6165	Shrub	0.83
45	<i>Murraya koenigii</i> (L.) Spreng.	Rutaceae	Kandhela	SUBMS/BOT-6446	Shrub	0.83
46	<i>Cynoglossum lanceolatum</i> Hochst. ex DC.	Boraginaceae	Ghaa	SUBMS/BOT-6173	Herb	0.83
47	<i>Lepidium virginicum</i> L.	Fabaceae	Alon	SUBMS/BOT-6452	Herb	0.83
48	<i>Adiantum venustum</i> D.Don	Pteridaceae	Morshikha	SUBMS/BOT-6153	Fem	0.82
49	<i>Celtis australis</i> L.	Ulmaceae	Khidak	SUBMS/BOT-6432	Tree	0.82
50	<i>Arundinaria falcata</i> Nees	Poaceae	Bainjhi	SUBMS/BOT-6166	Grass	0.81
51	<i>Clematis grata</i> Wall.	Ranunculaceae	Santai	SUBMS/BOT-6433	Climber	0.81

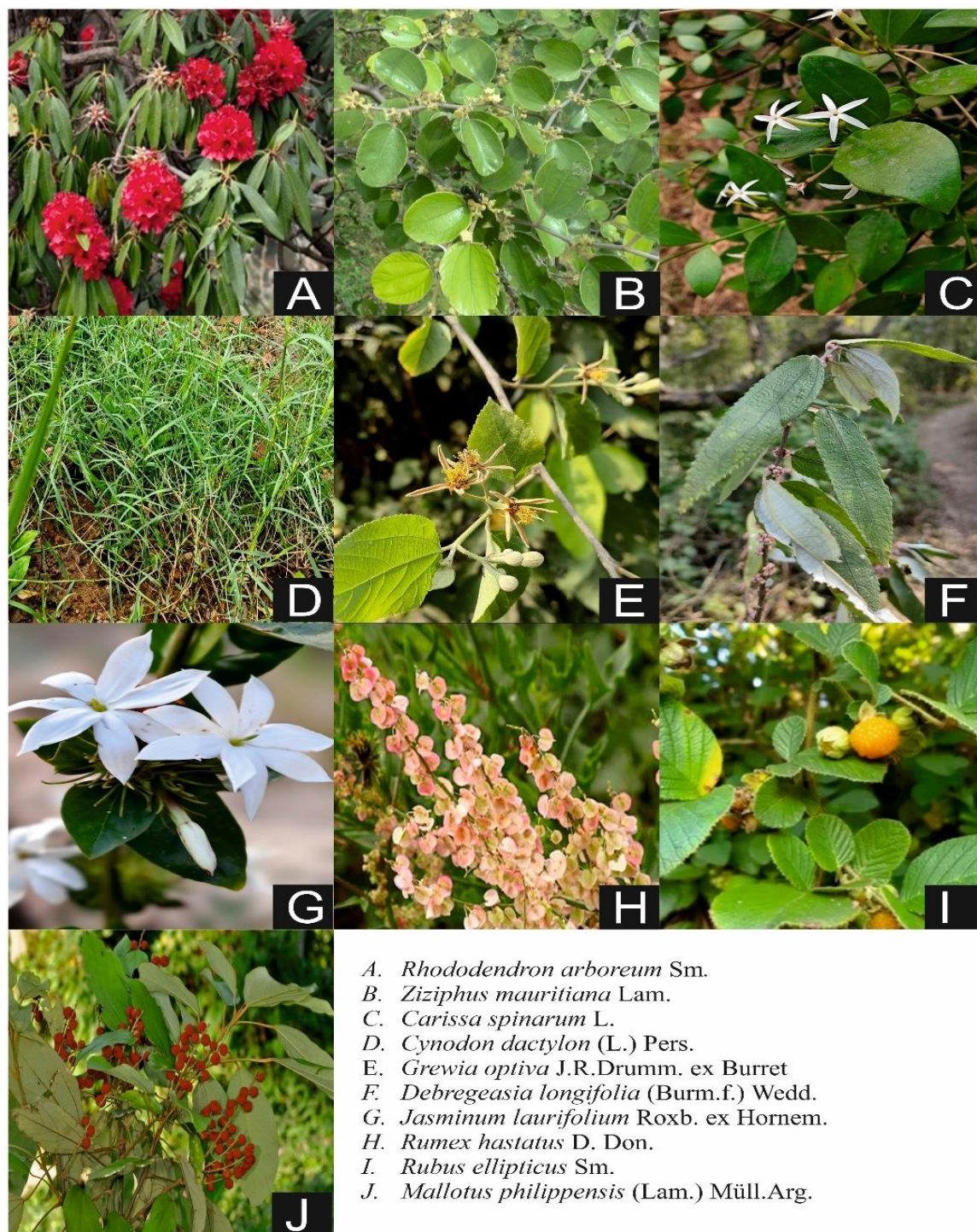


Photo Plate. 1. Most browsed forage plant species in Mid-Altitude study site

The proximate and mineral analysis of forage plants from the mid-altitude forests of Baijnath tehsil, Kangra district, demonstrated notable variability in nutritional composition among the species examined.

Proximate Analysis (Table 2):

The moisture content (Fig. 7) recorded in this study varied from 42.09% in *Rubus ellipticus* to 32.05% in *Carissa spinarum*. The findings indicate notable water retention abilities, consistent with earlier research demonstrating that moisture levels in wild forage plants can differ significantly based on species and environmental conditions (Lutatenekwa *et al.*, 2020; Kumar *et al.*, 2022).

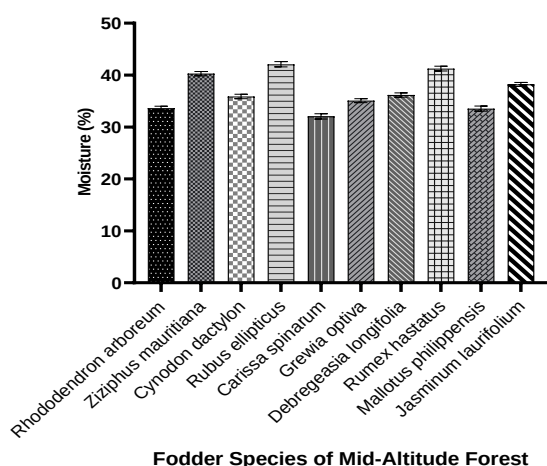
The ash content (Fig. 8), peaking at 7.82% in *Rhododendron arboreum* and 7.55% in *Carissa spinarum*, indicates a substantial mineral composition. This aligns with previous studies that emphasised the mineral richness of *Rhododendron* species (Kumar *et al.*, 2019). The minimal ash content in *Debregeasia longifolia* (4.12%) suggests reduced mineral reserves, aligning with observations from regional studies regarding nutrient-deficient forest undergrowth.

The crude fat (Fig. 9) content reached its highest at 2.70% in *Carissa spinarum* and 2.67% in *Rhododendron arboreum*, aligning with findings on elevated lipid levels

in certain shrubs and small trees that provide vital fatty acids (Morales *et al.*, 2013). The low percentage of *Jasminum laurifolium* (2.29%) corresponds with findings that suggest variations in fat content in flowering plants due to various factors (Boufaïed *et al.*, 2003). The highest crude fibre (Fig. 10) content was observed in *Rhododendron arboreum* (36.04%) and *Cynodon dactylon* (36.00%), supporting the findings of Birinci *et al.*, (2020) and Chowdhury *et al.* (2017), which indicated elevated fibre levels in resilient and woody plants. *Debregeasia longifolia*, exhibiting the lowest crude fibre at 26.07%, demonstrated diminished structural components, aligning with observations made by Ball *et al.* (2001) in other soft-leaved species.

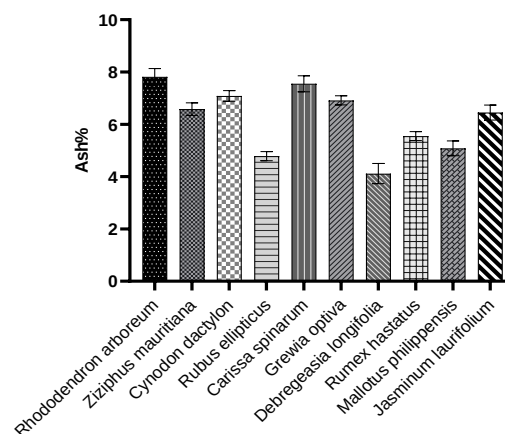
The protein content (Fig. 11) exhibited significant variation, with *Grewia optiva* recorded at 5.83% and *Cynodon dactylon* at 4.40%. The observed levels align with findings from studies indicating moderate protein content in typical forage grasses and trees (Simbaya *et al.*,

2020; Katoch, 2023). The observed variability highlights the significance of choosing the right species to achieve optimal nutritional benefits. Carbohydrate levels (Fig. 12) reached their peak in *Debregeasia longifolia* at 25.82%, indicating a notable energy content, whereas *Rubus ellipticus* exhibited the lowest levels at 12.76%. This observation aligns with previous studies that associate lower carbohydrate content with fruit-bearing plants that possess high moisture content (Navale *et al.*, 2022). The patterns of Neutral Detergent Fibre (NDF) (Fig. 13) and Acid Detergent Fibre (ADF) (Fig. 14) reveal that *Rhododendron arboreum* possesses the highest values at 61.50%, suggesting lower digestibility. This finding is consistent with the established understanding that woody plants typically have more resilient cell walls (Navale *et al.*, 2022). The reduced values in *Cynodon dactylon* indicate its established higher digestibility (Nawaz *et al.*, 2008). Statistical analysis of results was done using one-way ANOVA and Duncan Multiple Range Test (DMRT).



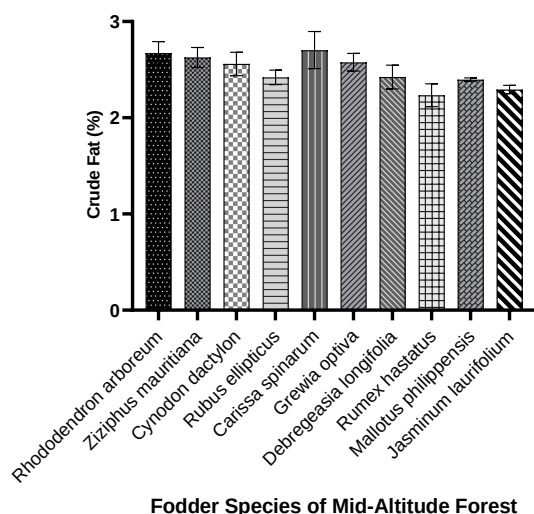
Fodder Species of Mid-Altitude Forest

Fig. 7: Moisture content in leaves of fodder species in mid-altitude study site (n=3, mean $\pm$ SE).



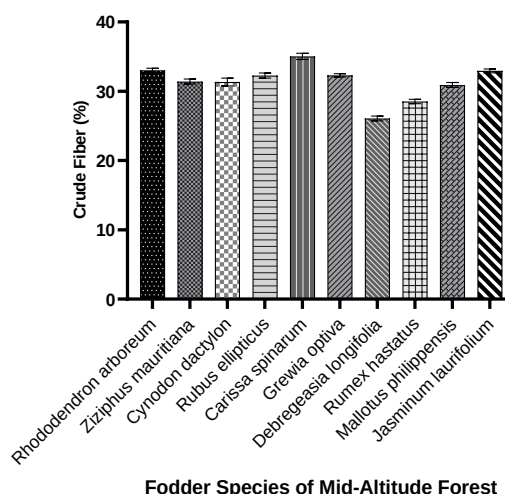
Fodder Species of Mid-Altitude Forest

Fig. 8: Ash content in leaves of fodder species in mid-altitude study site (n=3, mean $\pm$ SE).



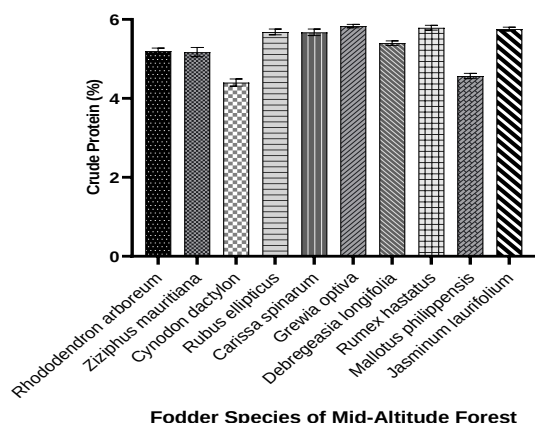
Fodder Species of Mid-Altitude Forest

Fig. 9: Crude Fat content in leaves of fodder species in mid-altitude study site (n=3, mean $\pm$ SE).

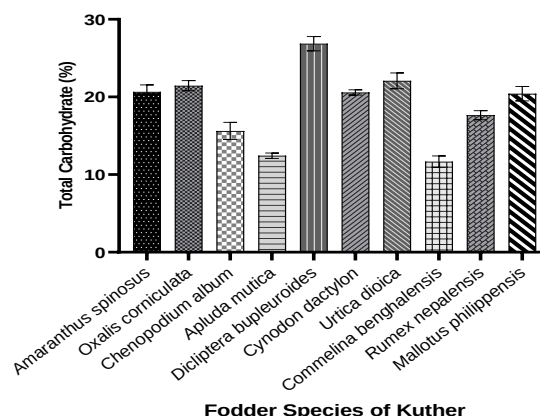


Fodder Species of Mid-Altitude Forest

Fig. 10: Crude Fiber content in leaves of fodder species in mid-altitude study site (n=3, mean $\pm$ SE).



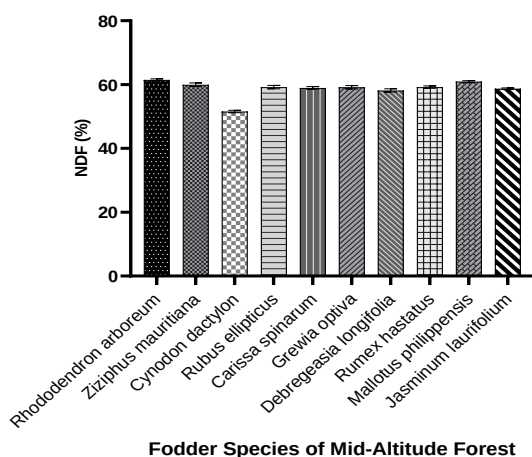
Fodder Species of Mid-Altitude Forest



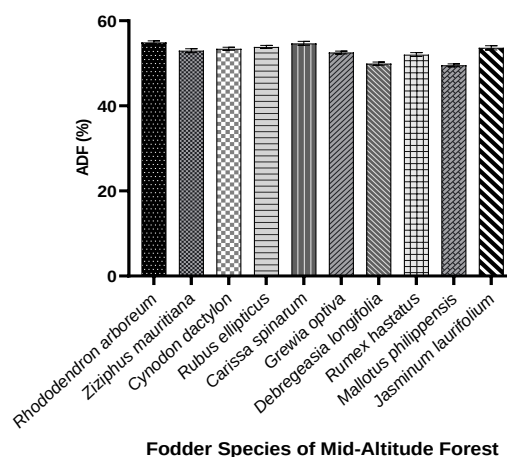
Fodder Species of Kuthar

Fig. 11: Crude protein content in leaves of fodder species in mid-altitude study site (n=3, mean $\pm$ SE).

Fig. 12: Carbohydrate content in leaves of fodder species in mid-altitude study site (n=3, mean $\pm$ SE).



Fodder Species of Mid-Altitude Forest



Fodder Species of Mid-Altitude Forest

Fig. 13: NDF content in leaves of fodder species in mid-altitude study site (n=3, mean $\pm$ SE).

Fig. 14: ADF content in leaves of fodder species in mid-altitude study site (n=3, mean $\pm$ SE).

Sr. No.	Name of Plant	Moisture	Ash	Crude Fat	Crude Fiber	Crude Protein	Total Carbohydrate	NDF	ADF
1.	<i>Rhododendron arboreum</i>	33.65 ± 0.361	7.82 ± 0.318	2.67 ± 0.118	36.04 ± 0.507	5.20 ± 0.075	17.62 ± 0.324	61.50 ± 0.312	54.93 ± 0.366
2.	<i>Ziziphus mauritiana</i>	40.28 ± 0.418	6.58 ± 0.240	2.63 ± 0.103	31.40 ± 0.362	5.17 ± 0.116	13.93 ± 0.942	59.96 ± 0.556	52.97 ± 0.451
3.	<i>Cynodon dactylon</i>	35.88 ± 0.438	7.08 ± 0.203	2.56 ± 0.122	36.00 ± 0.330	4.40 ± 0.090	18.74 ± 0.530	51.56 ± 0.378	53.42 ± 0.353
4.	<i>Rubus ellipticus</i>	42.09 ± 0.518	4.78 ± 0.176	2.42 ± 0.076	32.27 ± 0.359	5.68 ± 0.073	12.76 ± 0.754	59.20 ± 0.518	53.85 ± 0.344
5.	<i>Carissa spinarum</i>	32.05 ± 0.503	7.55 ± 0.306	2.70 ± 0.192	35.04 ± 0.453	5.67 ± 0.082	16.99 ± 0.840	58.97 ± 0.378	54.70 ± 0.441
6.	<i>Grewia optiva</i>	35.08 ± 0.384	6.92 ± 0.176	2.58 ± 0.092	32.29 ± 0.234	5.83 ± 0.044	17.30 ± 0.626	59.17 ± 0.512	52.53 ± 0.326

7.	<i>Debregeasia longifolia</i>	36.17 ±0.409	4.12 ±0.384	2.42 ±0.124	26.07 ±0.348	5.40 ±0.058	25.82 ±0.857	58.17 ±0.503	49.52 ±0.365
8.	<i>Rumex hastatus</i>	41.25 ±0.451	5.55 ±0.285	2.23 ±0.119	28.51 ±0.317	5.79 ±0.062	16.66 ±0.681	59.19 ±0.369	52.05 ±0.453
9.	<i>Mallotus philippensis</i>	33.53 ±0.492	5.08 ±0.285	2.40 ±0.017	30.90 ±0.356	4.57 ±0.067	23.52 ±0.959	60.93 ±0.294	49.53 ±0.326
10.	<i>Jasminum laurifolium</i>	38.22 ±0.383	6.45 ±0.289	2.29 ±0.043	32.95 ±0.281	5.76 ±0.047	14.34 ±0.698	58.72 ±0.233	53.64 ±0.507

Mineral analysis: The nitrogen content was highest in *Rubus ellipticus* at 0.79%, while *Jasminum laurifolium* exhibited the lowest level at 0.55%. This observation aligns with earlier findings that highlighted differences in nitrogen levels influenced by plant physiology and nutrient uptake (Muratore *et al.*, 2021). In *Rumex hastatus*, potassium (K) was found to be the most abundant at 3.57%, whereas *Rubus ellipticus* exhibited the lowest concentration at 1.8%. This pattern reflects observations in potassium-rich forage plants, which are crucial for maintaining dietary balance (Hussain and Durrani, 2008). The phosphorus (P) content varies, with *Cynodon dactylon* exhibiting the highest level at 0.36% and *Mallotus philippensis* showing the lowest at 0.23%. This aligns with previous studies that highlight the variability of phosphorus, which is frequently associated with soil type and plant adaptation (Shen *et al.*, 2011; Melo *et al.*, 2022). Sodium (Na) levels reached a maximum of 42 ppm in *Rhododendron arboreum*, aligning with its established saline tolerance (Kumar *et al.*, 2019). In contrast, the lower sodium values observed in *Rubus ellipticus* and *Mallotus philippensis* (18 ppm) suggest restricted sodium absorption, as evidenced by regional forage studies (Maathuis *et al.*, 2014).

The concentrations of Zinc (Zn) were found to be highest in *Rhododendron arboreum* at 55.71 ppm, which supports its notable micronutrient profile highlighted in previous studies on plants rich in antioxidants (Gautam *et al.*, 2020). The iron (Fe) content in *Rhododendron arboreum*, measured at 325.78 ppm, aligns with earlier studies that highlight its effective iron uptake, which is advantageous for mitigating micronutrient deficiencies (Turner *et al.*,

2020). The observed lower iron levels in *Ziziphus mauritiana* (168.82 ppm) correspond with the findings reported in arid zone species (Mahawar *et al.*, 2023).

The levels of copper (Cu) and manganese (Mn) were significantly higher in *Rhododendron arboreum*, measuring 67.67 ppm and 90.08 ppm, respectively, which aligns with its recognised contribution to micronutrient-rich diets (Sharma *et al.*, 2022). Reduced values in *Rubus ellipticus* and *Carissa spinarum* support earlier findings regarding their restricted metal uptake (Gransee and Führes, 2013; Xu *et al.*, 2024). Calcium (Ca) was found to be most abundant in *Rhododendron arboreum* at 75105 ppm, aligning with studies that emphasise its notable calcium storage (Thakur *et al.*, 2020). In contrast, *Debregeasia longifolia* exhibited the lowest calcium concentration at 41876 ppm, which is consistent with findings related to other lower-calcium plants (Katoch, 2022, 2023).

Magnesium (Mg) concentrations reached their peak in *Rumex hastatus* (46879 ppm), reinforcing its established reputation for a mineral-rich composition (Ahmad *et al.*, 2016). Sulphur (S) concentrations reached their highest level in *Debregeasia longifolia* at 2799 ppm, consistent with observations from high-sulphur accumulating plants (Zenda *et al.*, 2021), whereas *Rhododendron arboreum* exhibited the lowest concentration at 1750 ppm. The highest chromium (Cr) content is observed in *Grewia optiva* and *Debregeasia longifolia*, reaching 5 ppm. This finding aligns with established variations in trace element uptake, as documented in environmental chromium studies (Sharma *et al.*, 2020; Ugulu *et al.*, 2021).

Table 3. Forage Nutrition Quality: Mineral analysis in most used forage plants of Mid Altitude Forest in Baijnath tehsil of Kangra District

Sr. No.	Plant Name	N %	K %	P%	Na (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)	Ca (ppm)	Mg (ppm)	S (ppm)	Cr (ppm)
1	<i>Rhododendron arboreum</i>	0.72	1.93	0.32	42	55.71	325.78	67.67	90.08	75105	17690	1750	4
2	<i>Ziziphus mauritiana</i>	0.65	2.38	0.35	19	31.78	168.82	46.98	57.98	70315	23980	1969	3
3	<i>Cynodon dactylon</i>	0.7	2.68	0.36	22	38.78	259.82	48.98	60.98	71577	25270	2588	4
4	<i>Rubus ellipticus</i>	0.79	1.8	0.27	18	45.03	180.76	43.32	54.55	67340	18860	2698	4
5	<i>Carissa spinarum</i>	0.64	2.57	0.34	24	51.89	215.08	45.43	51.78	67670	23897	1889	4
6	<i>Grewia optiva</i>	0.68	2.57	0.32	23	39.51	270.99	43.76	62.34	62549	36798	2398	5
7	<i>Debregeasia longifolia</i>	0.77	2.28	0.34	20	46.34	171.1	49.87	55.89	41876	24671	2799	5

8	<i>Rumex hastatus</i>	0.62	3.57	0.3	25	49.58	235.14	49.35	60.56	45468	46879	2586	3
9	<i>Mallotus philippensis</i>	0.57	2.44	0.23	18	50.13	170.12	50.11	56.88	43588	24450	2476	4
10	<i>Jasminum laurifolium</i>	0.55	2.63	0.25	20	50.58	176.12	50.11	57.98	44588	25450	2376	4

CONCLUSION

This investigation provided a comprehensive evaluation of forage plants found in the mid-altitude forests of Baijnath tehsil, Kangra district, emphasising their nutritional value and the potential benefits for livestock during seasonal migrations. The results underscore notable differences in the proximate and mineral composition among different plant species, stressing the necessity of recognising these variations for effective forage selection. This understanding is essential for livestock herders who rely on these natural resources throughout their traditional migration paths. The capacity of particular forage species to provide a well-rounded combination of essential macronutrients and micronutrients is crucial for sustaining animal health and productivity throughout these migrations. The appropriateness of migration pathways is significantly influenced by the presence of nutrient-dense forage vegetation that ensures a balanced mineral supply. Paths that showcase a varied selection of premium forages are more effectively equipped to meet the nutritional requirements of livestock, leading to enhanced and sustainable grazing methods. The variety of forage along these paths plays a crucial role in reducing the likelihood of nutrient imbalances or toxicities, while also ensuring that animals have access to a diverse diet that promotes their overall health and resilience.

The management of these forage resources necessitates a critical focus on sustainability. The study highlights the significance of sustainable practices in maintaining the ecological equilibrium of mid-altitude forests. The excessive harvesting of nutrient-dense species may result in their scarcity, consequently affecting the sustainability of migration pathways in the long run. Implementing rotational grazing and conservation practices is essential to preserve plant biodiversity and safeguard the integrity of forage ecosystems, thereby preventing undesirable outcomes. Utilising forage plants in a sustainable manner is crucial for preserving their availability for upcoming grazing seasons and for supporting the overall health of the ecosystem.

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