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# Assessment of fodder potential of *grewia optiva* drummond ex burret in northern himalaya: A comprehensive review

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## ABSTRACT

*Grewia optiva Drummond ex Burret, a multipurpose tree species native to the Western Himalayas, plays a vital role in sustaining integrated crop-livestock systems by serving as a high-quality fodder source during lean winter months. This review assesses the fodder potential of G. optiva, highlighting its adaptability to varied altitudinal zones, ecological significance, and contribution to rural livelihoods. The species demonstrates excellent palatability, digestibility, and nutritional value, making it a preferred choice among traditional Himalayan communities. It thrives under a wide range of climatic conditions, displays strong coppicing ability, and is widely planted on terrace risers and field boundaries. This review assesses G. optiva fodder potential in the Northern Himalayas by analyzing scientific literature and traditional knowledge. It examines the tree's distribution, nutritional value, palatability, traditional use, productivity, environmental influences, and comparison with other fodder, considering factors like location, altitude, genetics, and seasonality for optimal livestock nutrition.*

**Keywords:** *Grewia optiva, Fodder potential, Morphological characteristics, Nutritional composition, Himalaya fodder trees, Palatability, Traditional use, Productivity, Environmental influences, altitude, genetics, and livestock nutrition*

## 1. Introduction

Livestock husbandry forms a critical component of the agricultural systems and supports the livelihoods of numerous communities residing in the Northern Himalayas, particularly the smallholder farmers who practice integrated crop and animal farming [1]. The region grapples with the persistent challenge of fodder scarcity, a situation that becomes particularly acute during the extended winter months, typically spanning from October to April. This seasonal deficit in forage availability significantly impacts livestock productivity, necessitating the exploration and utilization of alternative fodder resources, such as the leaves from various tree species [1, 3].

Multipurpose trees (MPTs) are essential components of sustainable land management systems in this context, providing a range of ecosystem services and valuable products [4]. Among these, *G. optiva* stands out as a prominent multipurpose tree species prevalent in the sub-Himalayan belt. This tree is highly valued by the local communities not only for its provision of high-quality fodder but also for its versatile uses, including the production of fibre for diverse applications and its utility as fuelwood, thereby playing an integral role in sustaining local livelihoods [5]. Its leaves are excellent fodder, and its soft bark contains saponin used in hair care, and provides strong fibre for ropes. Bhimal based goat feed has proven suitable and beneficial for farmers in Northern India and Nepal Hills. This review aims to provide a comprehensive assessment of the fodder potential of *Grewia optiva* within the Northern Himalayan context by critically analyzing existing scientific literature and integrating the wealth of traditional knowledge accumulated by local communities over generations. Understanding factors such as the geographical location, altitude, the genetic provenance, and seasonal variations is therefore crucial for determining the optimal nutritional requirements of livestock at different times of the year. The scope of this review encompasses various aspects, ranging from the geographical distribution and abundance of the tree to a detailed examination of its nutritional composition, palatability, digestibility for livestock, traditional utilization practices, fodder productivity under different conditions, the influence of environmental factors on its yield and quality, and a comparative evaluation of its fodder value in relation to other commonly used fodder species in the region.

## 2. Botanical and ecological descriptions

### 2.1 Taxonomy and Distribution:

The *Grewia* genus comprises around 150 species globally, of which 42 are found on the Indian subcontinent [6]. *Grewia optiva* is a valuable "wonder tree" naturally found in moist deciduous and evergreen forests of the subtropical zone of Western Himalaya. It belongs to the family Tiliaceae (Table 1) and is native to the Indian sub-continent. It is widely distributed across the Western Himalayan range, extending through states such as Jammu & Kashmir, Himachal Pradesh, Uttarakhand, and further into Nepal and Bhutan [4]. It is commonly known by its vernacular names beul, bhimal, bhiunal, beulang, bihul, biul, dhaman, dhaman/beul, dhamman and dhanvanah, todana in Hindi and Sanskrit simultaneously, and is a synonym for *G. oppositifolia* Roxb [7].

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*Table 1: Taxonomy Details*

| | |
|---|---|
| Kingdom | *Plantae* |
| Division | *Phanerogams* |
| Class | *Dicotyledones* |
| Sub-class | *Polypetalae* |
| Series | *Thalamiflorae* |
| Order | *Malvales* |
| Family | *Malvaceae* |
| Genus | *Grewia* |

It is a moderate-sized deciduous tree species that thrives at a maximum temperature of 38°C and a minimum of -2°C, where frost is common during the autumn and winter seasons. The species is common up to an elevation of 2500 m where annual rainfall varies from 1200 to 2500 mm mainly in the summer season. These ecological factors are crucial for understanding its potential in different microclimates within the Himalayan region and for guiding successful propagation efforts. In India, *Grewia* is ranked in the top 20$^{th}$ among trees under an agroforestry system [8].

The observation that *Grewia optiva* is more frequently encountered on farmland boundaries and near villages rather than in forests suggests a strong influence of human management practices in shaping its current distribution and abundance across the landscape. Bhimal is found prominently in agricultural landscapes, cultivated or retained by farmers rather than urban areas (Table 2). This higher prevalence in agroforestry systems indicates active management and utilization by local communities, underscoring its practical value within these integrated farming systems [9, 10].

*Table 2: Number of Trees and Their Volume in Rural and Urban Areas of Different states*

| State | Rural Areas | | Urban Areas | |
|---|---|---|---|---|
| | Number of trees ('000) | Volume (M m³) | Number of trees ('000) | Volume (M m³) |
| Himachal Pradesh | 17617 | 1.308 | 239 | 0.017 |
| Jammu and Kashmir | 15905 | 1.843 | 233 | 0.021 |
| Uttarakhand | 34551 | 1.622 | N/A | N/A |

*N/A = Data not available (Source:- [10])*

## 2.2 Ecological Adaptability, Phenology and Morphological Characteristics

A fully grown *G. optiva* reaches a height of 12 m with a spreading crown, a clear bole of 3-4 m, and a girth of 80 cm. It is a frost-hardy, drought-hardy, strong light-demander, coppices well and coppice shoots have rapid growth [11]. With enough rainfall, it can thrive in any type of soil, however, sandy loam with enough moisture is best for the tree's development. It can also survive under rain-fed conditions but trees along with irrigated lands grow much better than rain-fed areas. Bhimal is a light-demanding species that requires complete light for its growth and easily propagates through seeds or cuttings [12, 13]. Leaves are oblong, acuminate, sharply serrate, rough, and hairy on the upper surface, measuring 5-13 cm × 3-6 cm. The bark is smooth and pale grey. It sheds its old leaves in March-April, with new ones appearing in April-May, and flowers also appear this period. Flowers (1-8 per cluster), either solitary or axillary and show entomophily (insect-pollination). The inflorescence is a cyme bearing yellowish-red flowers [11]. Flowers are monoecious and lemon-yellow in colour. The fruits develop in June to July and attain their full size by September and the ripening of fruits occurs between October - December (Table 3) [14, 15]. The fruit is a fleshy drupe, 2-4 lobed, olive green when immature and black when ripe and edible. Pollen grains are yellow, with 75 per cent viability [16].

*Grewia optiva* is a light-demanding, frost tolerant and drought-tolerant species but susceptible to fire and browsing [12, 13]. Due to its superior palatability, quick growth, ease of propagation, and high forage output compared to other tree species, it is planted for fodder in the highlands of Uttarakhand, Himachal Pradesh, and Nepal, among other places [17]. Raised mostly on terrace risers for its nutritious fodder, it is the most significant species of fodder in the lower and middle Himalayas.

*Table 3: Tree Phenology of Grewia optiva*

| Characteristics | Duration |
|---|---|
| Leaf-fall | March-April |
| Leaf renewal | April-May |
| Flowering | April-May |
| Fruiting | June-July |
| Fruit ripe | October-November |

# 3. *Grewia optiva* as fodder tree

## 3.1 Fodder value of *Grewia optiva*

*Grewia optiva* is highly valued among the local communities in the Himalayan region for its superior palatability, rapid growth and high-quality fodder during winter months when other sources are scarce [17, 18]. It is an established and integral component of traditional agroforestry systems in the Northern Himalayas, where it is commonly grown in association with various crops, such as maize, millet, and pulses, as well as with other tree species on farmland, field boundaries, and terrace risers [9]. It is also observed that in the lower hills and the tarai region, there is a shortage of green fodder from crops in three months of summer i.e. from April to June in the year [4]. This multipurpose tree yields fuelwood, fibre, and leaf feed [15]. This long-standing practice demonstrates the deep integration of *G. optiva* into the traditional animal husbandry systems of the area. The fodder productivity and yield of *Grewia optiva* in the Northern Himalayas exhibit considerable variation depending on the specific location and prevailing environmental conditions. Studies have reported significantly higher fresh fodder productivity in valley locations, ranging from 4.1 to 4.5 kg plant$^{-1}$, compared to middle hill elevations, where the yield is typically between 1.3 and 1.7 kg plant$^{-1}$. This substantial difference highlights the significant influence of altitude and associated environmental factors on the overall fodder yield of this species [4]. Estimates of leaf fodder yield from mature *G. optiva* trees range from 12-30 kg per tree annually. This yield potential demonstrates the capacity of individual trees to contribute a substantial amount of feed for livestock, making even a small number of trees on a farmer's land a valuable resource.

In silvipastoral systems, where trees are integrated with pasture and livestock, the average biomass production of *Grewia optiva* has been reported to range from approximately 1.5-1.8 tonnes of dry matter per hectare. This level of productivity indicates the potential of *Grewia optiva* to make a significant contribution to overall fodder availability when incorporated into integrated land management practices [10]. High palatability scores (up to 95.69%) for *Grewia optiva* in heifers have been reported [15], indicating strong preference and high intake in ruminants.

The leaves are rich in nutrients, proteins, and mineral elements, with over 70% dry matter digestibility and making them suitable for use as fodder due to their lack of tannins [19, 11]. Crude protein, which is generally used as an index of nutritive value, ranges between 17.4–21.0 % [20]. The green fodder made from the leaves and succulent branches of *G. optiva* is similar in terms of crude protein, crude fibre, calcium, and phosphorus content to the green fodder obtained from crops like berseem, alfalfa, and cowpea. Furthermore, the pruned branches of *G. optiva* have the remarkable ability to regenerate their biomass and contribute to carbon storage [21]. The chemical makeup of leaves determines the quality of fodder- which includes ether extract, crude fibre, crude protein, total ash content, organic matter, carbohydrates, minerals, and nutrients. Because leaf fodder has high crude protein content and minerals, so it is highly digestible by cattle and is regarded as comparable to nutritious leguminous fodder crops.

The primary method of harvesting the fodder involves the lopping of branches to collect the leaves, a task that is often undertaken in the late autumn and winter to provide a readily available feed source during the lean period [22]. This traditional lopping practice appears to be a sustainable harvesting method, allowing the trees to regenerate and continue providing fodder in subsequent seasons. *G. optiva* leaves are frequently used as a supplement to other available fodder sources, such as dry straws and crop residues, to enhance their nutritional value, particularly by increasing the protein content in the overall diet of the livestock. This complementary use highlights the important role of *G. optiva* in improving the nutritional quality of basal feeds that might otherwise be of lower nutritional value [22].

Research efforts have also focused on standardizing the traditional lopping techniques, with studies suggesting that a lopping intensity of around 75% might be the optimal approach for achieving sustainable green fodder and fibre production, effectively balancing the immediate needs of the community with the long-term health and productivity of the *G. optiva* trees. This indicates an ongoing effort to refine traditional practices through scientific understanding to ensure the continued availability of this vital resource [5]. Beyond its use as fodder, traditional knowledge also encompasses the utilization of *G. optiva* for a variety of other purposes, including obtaining strong fibre from the bark for making ropes, baskets, and other essential items, as well as using the wood for fuel and crafting agricultural implements. This multifaceted utility underscores the integral role of *G. optiva* in the rural economy and the daily lives of the people in the Northern Himalayas [5].

These trees continue to provide fodder during the dry season due to theirdeep root system. In some regions, farmers even practice the preservation of *G. optiva* leaves during times of abundance to ensure a reliable supply of nutritious fodder for their dairy cows throughout the harsh winter months. This practice of preserving the leaves further underscores the high level of reliance and value that local communities place on *G. optiva* as a critical fodder resource during periods of scarcity [2].

This extensive root system plays an important role in soil conservation, especially on the steep slopes and terrace risers characteristic of the Himalayan terrain. The decomposition of its leaf litter contributes to soil organic matter and nutrient cycling, thereby enhancing soil fertility, and it also provides fuelwood and fibre, diversifying the resources available to local communities [23]. Furthermore, *Grewia optiva* has the potential to sequester carbon, contributing to climate change mitigation efforts [10].

In the Agrihortisilviculture systems prevalent in the Garhwal Himalaya, *G. optiva* demonstrates its ecological significance by exhibiting dominance, with the highest frequency, density, and Importance Value Index (IVI) observed in both north-facing and south-facing slopes. This high IVI signifies its substantial contribution to the structure and function of these traditional mixed land-use systems, highlighting its adaptation to the local environmental conditions and its importance to the local farmers [9].

Optimizing tree spacing within *Grewia optiva*-based agroforestry systems is crucial for balancing the growth and productivity of the trees with the yield of intercropped agricultural species. Research has shown that wider spacing, such as 8 × 3 m, can enhance biomass and fodder yield per tree [3]. Similarly, implementing integrated nutrient management strategies that combine organic and inorganic nutrient sources can improve soil fertility and sustain the yields of both the tree and the associated crops. While generally beneficial, it is important to acknowledge that the presence of *Grewia optiva* in agroforestry systems can sometimes lead to a reduction in the yield of certain intercrops, such as millet, due to competition for resources like light and nutrients. Therefore, careful selection of compatible intercrops and the adoption of appropriate management practices are necessary to minimize any potential negative impacts and to maximize the overall benefits of these integrated farming systems [3].

### 3.2 Nutritional Composition

According to the findings of Sankhyan et al. [23], crude protein emerged as a critical determinant of fodder quality, particularly in the context of the rising demand for meat-producing animals, as it contributes significantly to the muscle-building component of the diet and serves as a reliable index of overall nutritive value. In their evaluation of 40 *Grewia optiva* families, crude protein content exhibited considerable variation, ranging from 18.09 to 22.11 per cent, with the highest value observed in family HA-2 (22.11%) and the lowest in family MA-2(18.09%) [23].

***Table 4: Fodder quality parameters across different district in Himachal Pradesh***

| Sr. No. | District | Location | Ether extract (%) | Crude fibre (%) | Crude protein (%) | Total ash (%) | Nitrogen Free Extract (%) |
|---|---|---|---|---|---|---|---|
| 1 | **Bilaspur** | Bilaspur (BI-1) | 4.85 | 20.54 | 20.46 | 12.09 | 42.06 |
| | | Auhar (BI-3) | 5.56 | 20.18 | 20.60 | 12.31 | 41.35 |
| | | Kuthira (BI-4) | 5.06 | 20.52 | 20.65 | 12.14 | 41.63 |
| 2 | **Chamba** | Chanad (CH-1) | 5.62 | 21.81 | 20.56 | 13.09 | 38.92 |
| | | Balu (CH-3) | 5.82 | 21.40 | 21.97 | 11.84 | 38.97 |
| | | Audhpur (CH-4) | 4.83 | 20.86 | 19.85 | 11.92 | 42.54 |
| | | Saru (CH-6) | 5.72 | 18.73 | 21.63 | 12.37 | 41.55 |
| 3 | **Hamirpur** | Patta Balakhar (HA-2) | 4.87 | 21.84 | 22.11 | 11.34 | 39.84 |
| | | Bassi (HA-3) | 5.80 | 19.30 | 18.85 | 11.80 | 44.25 |
| | | Hamirpur Kanal (HA-4) | 5.55 | 21.68 | 21.03 | 12.85 | 38.89 |
| | | Ghahar (HA-5) | 5.30 | 19.24 | 19.57 | 12.46 | 43.43 |
| 4 | **Kangra** | Dharamshala (KA-1) | 4.96 | 20.92 | 19.53 | 12.17 | 42.42 |
| | | Bhalun (KA-2) | 5.04 | 20.17 | 19.84 | 10.93 | 44.02 |
| | | Varal (KA-3) | 5.71 | 19.68 | 20.31 | 12.55 | 41.75 |
| 5 | **Mandi** | Bachhwan (MA-2) | 5.51 | 20.96 | 18.09 | 13.03 | 42.41 |
| | | Bambla (MA-3) | 5.88 | 19.73 | 19.93 | 12.66 | 41.80 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 6 | Shimla | Ninmun (SH-2) | 5.26 | 19.30 | 18.98 | 12.69 | 43.77 |
| | | Jeury (SH-3) | 4.65 | 19.29 | 20.03 | 12.95 | 43.08 |
| | | Taradevi (SH-7) | 5.10 | 21.43 | 19.84 | 15.26 | 38.37 |
| 7 | Sirmour | Deothal (SI-3) | 5.20 | 21.33 | 19.98 | 12.66 | 40.83 |
| | | Dilman (SI-4) | 5.62 | 18.78 | 21.59 | 11.96 | 42.05 |
| | | Deyoltikkeri (SI-5) | 5.35 | 21.00 | 21.47 | 11.38 | 40.80 |
| | | Kalaghat (SI-6) | 5.56 | 18.87 | 21.64 | 11.83 | 42.10 |
| | | Nandel (SI-7) | 5.10 | 21.32 | 20.66 | 11.85 | 41.07 |
| | | Seenaghat (SI-10) | 5.31 | 20.31 | 21.58 | 11.95 | 40.85 |
| | | Adgu (SI-11) | 5.54 | 18.59 | 21.73 | 11.90 | 42.24 |
| | | Sarpadol (SI-13) | 5.25 | 19.44 | 19.69 | 12.82 | 42.80 |
| | | Saraha Chakli (SI-14) | 4.97 | 21.44 | 21.67 | 10.74 | 41.18 |
| | | Madhobag (SI-15) | 5.84 | 21.64 | 21.57 | 10.84 | 40.11 |
| | | Nainatikker (SI-16) | 5.86 | 21.07 | 21.64 | 11.49 | 39.94 |
| 8 | Solan | Gaura (SO-1) | 5.77 | 21.35 | 21.30 | 11.76 | 39.82 |
| | | Nauni (SO-2) | 5.71 | 19.77 | 20.57 | 10.82 | 43.13 |
| | | Dharja (SO-3) | 5.78 | 19.84 | 21.89 | 11.47 | 41.02 |
| | | Deog (SO-4) | 5.08 | 21.65 | 21.07 | 10.90 | 41.30 |
| | | Badhlech (SO-5) | 5.21 | 21.23 | 20.57 | 12.23 | 40.76 |
| | | Oyali (SO-7) | 5.81 | 21.34 | 21.46 | 11.43 | 39.96 |
| | | Kailar (SO-8) | 4.90 | 21.13 | 21.74 | 11.35 | 40.88 |
| | | Deothi (SO-9) | 4.82 | 20.72 | 21.71 | 11.25 | 41.50 |
| | | Jaunaji (SO-10) | 4.84 | 21.76 | 21.86 | 11.72 | 39.82 |
| | | Kasholi (SO-12) | 5.25 | 20.86 | 20.68 | 13.13 | 40.08 |
| | Mean | | 0.46 | 0.58 | 0.28 | 0.41 | 0.82 |

*(Source:- [23])*

The study also revealed notable differences in crude fibre content across families. The highest crude fibre concentration was recorded in family HA-2 (21.84%), while family SI-11 exhibited the lowest value (18.58%), suggesting variability in the structural carbohydrate component, which influences digestibility. Ether extract content, representing the lipid fraction of the fodder, also varied significantly. The maximum ether extract was found in family MA-3 (5.88%), indicating a potential for higher energy contribution, whereas the minimum was recorded in family SH-3 (4.65%) [23].

With respect to mineral content, as indicated by total ash percentage, values ranged between 10.74 to 15.26 per cent, with family SH-7 recording the highest ash content (15.26%), reflecting its potential contribution to essential mineral intake in livestock. Furthermore, significant differences were observed among families in terms of nitrogen-free extract (NFE), which reflects the readily available carbohydrate fraction of the fodder. The NFE ranged from 28.37 to 44.25 per cent, with family HA-3 showing the highest value (44.25%), indicative of superior energy-yielding potential, while the lowest NFE was noted in family SH-7 (38.37%) [23].

***Table 5: Fodder quality parameters across different locations***

| Sr. No. | District | Locations | Ether extract (%) | Crude fibre (%) | Crude protein (%) | Total ash (%) | Nitrogen Free Extract (%) |
|---|---|---|---|---|---|---|---|
| 1 | Bilaspur | Auhar (BI-3) | 5.49 | 20.48 | 21.81 | 12.84 | 39.38 |
| | | Kuthira (BI-4) | 5.15 | 21.05 | 20.16 | 12.41 | 41.23 |
| 2 | Chamba | Chanad (CH-1) | 5.60 | 21.78 | 21.22 | 11.96 | 39.44 |
| | | Balu (CH-3) | 5.69 | 21.60 | 22.30 | 11.88 | 38.53 |
| | | Saru (CH-6) | 5.71 | 18.73 | 21.98 | 12.49 | 41.09 |
| 3 | Hamirpur | Patta Balakhar (HA-2) | 4.88 | 21.77 | 21.40 | 13.83 | 38.12 |
| | | Bassi (HA-3) | 5.73 | 19.43 | 23.51 | 11.78 | 39.55 |
| | | Kanal (HA-4) | 5.58 | 21.64 | 21.50 | 12.62 | 38.66 |
| 4 | Mandi | Bachhwan (MA-2) | 5.59 | 20.75 | 19.78 | 11.84 | 42.04 |
| 5 | Shimla | Jeury (SH-3) | 4.71 | 19.35 | 21.05 | 13.05 | 41.84 |
| | | Taradevi (SH-7) | 5.25 | 21.49 | 19.93 | 12.38 | 40.96 |
| 6 | Sirmour | Nandel (SI-7) | 5.19 | 21.42 | 22.17 | 12.36 | 38.87 |
| | | Seenaghat (SI-10) | 5.42 | 20.43 | 21.31 | 11.92 | 40.92 |
| | | Saraha chakli (SI-14) | 4.97 | 21.33 | 19.37 | 12.95 | 41.37 |
| | | Madhobag (SI-15) | 5.69 | 21.61 | 20.82 | 12.37 | 39.52 |
| | | Nainatikker (SI-16) | 5.80 | 21.63 | 20.41 | 12.32 | 39.85 |
| 7 | Solan | Gaura (SO-1) | 5.69 | 21.24 | 21.44 | 11.76 | 39.86 |
| | | Dharja (SO-3) | 5.72 | 19.77 | 20.52 | 13.79 | 40.21 |
| | | Deog (SO-4) | 5.24 | 21.65 | 20.37 | 12.99 | 39.75 |
| | | Oyali (SO-7) | 5.76 | 21.40 | 21.87 | 13.71 | 37.27 |
| | | Jaunaji (SO-10) | 4.84 | 21.37 | 23.01 | 13.29 | 37.50 |
| | | **Mean** | **5.41** | **20.95** | **21.23** | **12.60** | **39.81** |

*(Source:- [24])*

Thakur *et al.* [24] assessed the fodder quality of *Grewia optiva* across multiple clones and locations, reporting notable variation in key nutritional traits. Clone SI-16 recorded the highest ether extract (5.80%), indicating greater lipid content and energy value. Crude fibre, essential for rumen function and digestibility, was highest in clone CH-1 (21.78%). The maximum crude protein a critical indicator of fodder quality was observed in clone HA-3 (23.51%), highlighting its superior nutritive potential. Total ash, reflecting mineral content, peaked in clone HA-2 (13.83%), while nitrogen-free extracts (NFE), representing readily available carbohydrates, was highest in clone MA-2 (42.04%). These findings underscore significant genotypic and locational variability in fodder quality traits of *G. optiva*, offering a basis for selecting high-performing clones for livestock nutrition improvement [24] (Table 6).

### 4. Influence of environmental factors on fodder yield and quality

Climatic conditions, including temperature and rainfall, play a critical role in the growth and overall productivity of the species. *Grewia optiva* thrives in subtropical climates characterized by specific temperature ranges and an annual rainfall between 1200 and 2500 mm, with most of the rainfall occurring during the summer months. Deviations from these optimal climatic conditions can potentially impact both the quantity and the nutritional content of the fodder produced.

### 4.1 Altitudinal Difference

Significant differences in growth and productivity parameters have been observed between trees grown in valley regions and those at middle to higher elevations. Therefore, altitude exerts a considerable influence on both fodder yield and leaf morphometric traits. Therefore, overall leaf biomass and consequently the fodder yield, have also been shown to vary with altitude, indicating an indirect impact of environmental gradients on productivity [3].

*Table 7: Altitude-wise Variation in Fodder quality of Grewia optiva*

| Sr. No. | Altitude | Locations | Ether extract (%) | Crude fibre (%) | Crude protein (%) | Total ash (%) | Nitrogen free Extract (%) |
|---|---|---|---|---|---|---|---|
| 1 | A1-Higher (>1600m) | S1-Dargi | 3.32 | 17.30 | 13.20 | 10.05 | 56.13 |
| | | S2-Duvakoti | 2.97 | 15.13 | 12.52 | 9.95 | 59.44 |
| | | S3-Ranichauri | 4.22 | 16.61 | 13.52 | 9.47 | 56.18 |
| 2 | A2-Middle (1300-1600m) | S1-Sabli | 2.31 | 18.97 | 14.79 | 9.78 | 54.16 |
| | | S2-Jagdhar | 2.97 | 16.68 | 13.96 | 10.70 | 55.69 |
| | | S3-Sondkothi | 3.14 | 17.61 | 14.39 | 10.35 | 54.51 |
| 3 | A3-Lower (1000-1300m) | S1-Nagni | 2.65 | 17.60 | 13.41 | 9.37 | 56.97 |
| | | S2- Kutuldi | 3.88 | 16.78 | 13.50 | 10.13 | 55.70 |
| | | S3-Chopadiyali | 3.17 | 17.23 | 14.28 | 10.34 | 54.98 |

*(Source: - [25])*

According to the findings of Prajapati et al. [25], altitude significantly influences the fodder quality of *Grewia optiva*, with notable variation observed in key nutritional parameters across different altitudinal zones. Ether extract content, which contributes to the energy value of fodder, was highest at higher altitudes (>1600 m), with a maximum of 4.22% recorded at Rani Chauri, indicating increased lipid accumulation in cooler environments. Crude protein content, essential for livestock growth, peaked at middle altitudes (1300–1600 m), with Sabli showing the highest value of 14.79 per cent, suggesting optimal nitrogen assimilation under moderate climatic conditions. Similarly, crude fibre was also greatest at middle altitudes (18.97% at Sabli), pointing to enhanced cell wall development in these zones. Nitrogen-free extract (NFE), representing digestible carbohydrates, was highest at higher altitudes (59.44% at Duvakoti), likely due to physiological adaptations such as increased carbohydrate storage under cold stress. Overall, the study indicates that middle altitudes favour higher protein and fibre content, while higher elevations promote energy-rich and carbohydrate-dense fodder, and lower altitudes enhance mineral accumulation-providing a clear direction for site-specific selection and cultivation of superior *Grewia optiva* genotypes [25].

**Dry Matter (DM):** The highest DM observed in lower altitudes (Zone1). This decline in DM at higher zones may be linked to delayed leaf maturity and greater moisture availability, aligning with previous findings [25].

**Crude protein (CP):** Maximum (20.74%) recorded in high-altitude (zone 3). The positive correlation with altitude may be attributed to enhanced nitrogen availability and reduced nutrient translocations before leaf fall, aligning with earlier studies.

*Table 8: Fodder quality parameters among different Agroclimatic zones*

| Sr. No. | Agroclimatic zones | Sites | Dry matter (%) | Crude Protein (%) | Ether Extract (%) | Crude Fibre (%) | Total ash (%) | Nitrogen free Extract (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | Zone-1 (<1000 m) | S-1 | 55.51 | 15.82 | 2.71 | 18.45 | 10.36 | 52.77 |
| | | S-2 | 59.25 | 15.06 | 3.16 | 18.82 | 10.19 | 52.99 |
| | | S-3 | 57.28 | 16.23 | 2.45 | 16.23 | 10.62 | 54.47 |
| | | S-4 | 56.21 | 16.11 | 2.87 | 17.65 | 10.14 | 53.23 |
| 2 | Zone-2 (1000-1500 m) | S-1 | 49.75 | 16.80 | 3.57 | 15.23 | 9.76 | 54.65 |
| | | S-2 | 52.82 | 17.13 | 3.85 | 14.60 | 9.60 | 54.82 |
| | | S-3 | 54.43 | 17.52 | 3.89 | 14.35 | 9.54 | 54.70 |
| | | S-4 | 50.59 | 18.31 | 3.69 | 15.66 | 9.87 | 52.47 |
| 3 | Zone-3 (1500-2000 m) | S-1 | 44.62 | 19.34 | 3.95 | 13.55 | 9.45 | 53.71 |
| | | S-2 | 42.90 | 21.86 | 4.19 | 11.56l | 9.26 | 53.13 |
| | | S-3 | 42.90 | 20.89 | 4.08 | 12.85 | 9.35 | 52.83 |
| | | S-4 | 46.58 | 20.86 | 3.99 | 13.14 | 9.44 | 52.58 |

**Ether Extract (EE):** The maximum EE (4.19%) was recorded at high altitudes (S2Z3). The increase in EE content with altitudes aligns with earlier findings [25] suggesting enhanced lipid accumulation in cooler, high-altitude environments.

**Crude fibre (CF):** CF ranged between 11.56 to 18.82%, which is declining with increasing altitude. This reduction at higher elevations may be linked to delayed lignification and lower dry matter content, enhancing the fodder's digestibility and quality [25].

**Total ash content:** This ranged from 9.26 to 10.62%, decreasing with increasing altitude. Higher content at lower zones may be due to greater mineral accumulation from topsoil movement and higher microbial activity, while lower values at higher altitudes may result from reduced mineralization and cooler temperatures [25].

**Nitrogen-free Extract (NFE):** The range varies from 52.77 to 54.82%. The highest NFE was observed in mid-altitude zones, suggesting better digestibility and energy availability, while lower values at higher altitudes may reflect reduced carbohydrate accumulation [3].

### 4.2 Seasonal Changes

The nutritional composition of *G. optiva* fodder also exhibits significant seasonal variations (Table 5). Crude protein levels tend to be higher during the spring and winter months compared to the summer season. This seasonal fluctuation makes *G. optiva* a particularly valuable protein source during the lean winter months when other green fodder is scarce. The dry matter content is generally highest in the summer and lowest in the winter, showing an inverse relationship with moisture content, which typically peaks during the winter [15]. This variation in water content affects the concentration of other nutrients when expressed on a fresh weight basis, with winter fodder having a higher proportion of water. The crude fibre content may also vary seasonally, with some studies reporting lower fibre content during the winter months. This potential decrease in fibre during winter could enhance digestibility at a time when animals might be relying on less digestible dry fodder sources. It is important to note that comparisons of nutritional values across different studies reveal some discrepancies. These variations can be attributed to inherent genetic differences between *G. optiva* populations (genotype), variations in environmental conditions where the trees are grown (edapho-climatic factors), differences in management practices (such as lopping intensity and fertilization), and the specific phenological stage of the leaves at the time of sampling [26]. These factors highlight the need for localized studies to obtain accurate nutritional information relevant to specific regions and conditions. While most research suggests that *G. optiva* leaves are generally devoid of tannins, which is beneficial for digestibility, one study reported the presence of varying levels of total tannins across different seasons. This inconsistency warrants further investigation to definitively determine the presence and concentration of tannins under various conditions and their potential impact on the fodder's nutritional value.

*Table 9: Seasonal Variation in Nutritional Composition of G. optiva Fodder (Mean % on Dry Matter Basis)*

| Nutritional Analysis | Spring (March-April) | Summer (May-June); | Autumn (September-November); | Winter (December-February) |
|---|---|---|---|---|
| Moisture Content (%) | 45.50 | 28.60 | N/A | 55.63 |
| Dry matter | 54.60 | 71.40 | 57.62 | 55.63 |
| Crude protein | 17.47 | 15.12 | 22.5 | 21.0 |
| Crude fibre | 20.82 | 25.60 | 21.57 | 17.77 |
| Ether extract | 3.74 | 2.21 | 1.77 | 3.59 |
| Total ash content (%) | 9.17 | 10.34 | 10.51 | 9.83 |
| Nitrogen free extract (%) | 38.80 | 46.72 | 65.23 | 65.27 |
| Carbohydrate content (%) | 73.11 | N/A | 65.23 | 65.27 |
| Organic matter content (% | 89.92 | N/A | 89.49 | 90.17 |

### 4.3 Management Techniques

In agroforestry systems, the spacing between *Grewia optiva* trees and the overall management practices employed have a significant impact on fodder yield. Wider spacing can enhance the availability of sunlight and reduce competition for other resources, leading to increased biomass and fodder yield per individual tree [9, 10]. Traditional lopping practices also have a significant impact on fodder yield, and research suggests that moderate lopping intensities might be more sustainable in the long term compared to very heavy lopping, allowing the trees to regenerate effectively [22].

The implementation of integrated nutrient management strategies, which combine both organic and inorganic nutrient sources, can improve the overall health and productivity of the trees, ultimately benefiting fodder production [3].

## 5. Comparing with other fodder species

In terms of nutritional composition, *G. optiva* generally exhibits a higher crude protein content compared to some other prevalent fodder trees, such as *Quercus incana* and *Morus alba* in certain studies (Table 7). This makes it a particularly valuable source of protein for livestock in the region. Furthermore, its protein content is comparable to that of other known nutritious fodder species like *Melia azedarach* [27, 4]. Regarding digestibility, *Grewia optiva*is easily digestible due to its relatively lower crude fibre content compared to some other fodder trees, which facilitates better nutrient absorption by the animals. Palatability comparisons reveal that farmers in the Northern Himalayas often prioritize *Grewia optiva* over other fodder trees due to its high palatability and its perceived positive impact on milk yield in their livestock [15].

While some species, such as *Leucaena leucocephala*, might exhibit slightly higher palatability in specific studies, *Grewia optiva* remains a highly preferred choice among farmers based on their practical experience. The advantages of utilizing *Grewia optiva* as fodder include its high protein content, good digestibility, high palatability, and its availability during the crucial lean winter season when other green fodder sources are scarce. Potential disadvantages might include seasonal variations in its nutrient content and the possibility of lower yields in certain high-altitude locations compared to its performance in valley areas.

*Table 10: Comparative Nutritional Composition of common fodder species*

| Species | Crude Protein (%) | Crude Fibre (%) | In-vitro Digestibility (%) |
|---|---|---|---|
| *Grewia optiva* | 10.07-26.0 | 12.72-33.04 | 56.7-76.92 |
| *Morus alba* | 16.09-24.69 | N/A | N/A |
| *Bauhinia variegata* | 17.94-26.71 | N/A | N/A |
| *Quercus incana* | 9.27-10.2 | 52.1 | N/A |
| *Celtis australis* | N/A | N/A | N/A |

*Ranges are provided where significant variation was reported.*

## Conclusion

*G. optiva* demonstrates significant potential as a valuable fodder resource in the Northern Himalayas. Its favourable nutritional profile, characterized by medium to high crude protein content, good digestibility, and high palatability, makes it a preferred choice for livestock among local farmers. The tree's adaptability to the region's diverse agro-ecological conditions, its integration into traditional agroforestry systems, and its provision of multiple benefits beyond fodder further underscore its importance to the livelihoods of Himalayan communities. To sustainably utilize and promote *G. optiva* as livestock feed, it is recommended to actively encourage the cultivation of identified high-yielding provenances and clones through targeted propagation programs. The adoption of sustainable lopping practices is crucial for ensuring continued fodder availability and maintaining the health of the trees. Integrating *G. optiva* leaves with other fodder sources can help provide a balanced diet for livestock, particularly during the critical winter months. Optimizing tree spacing and implementing integrated nutrient management strategies in agroforestry systems will be key to maximizing overall productivity. Future research should focus on further investigating the seasonal variations in nutrient content, conducting detailed studies on digestibility and palatability for specific livestock breeds, assessing the potential impacts of climate change, identifying optimal intercropping systems, and exploring methods for preserving and enhancing the nutritional value of *G. optiva* fodder for year-round use.

**FUTURE SCOPE**: The future scope of research on *Grewia optiva* lies in identifying and improving high-yielding, nutrient-rich genotypes adaptable to diverse Himalayan conditions. Further studies should emphasize its integration into agroforestry systems, nutritional profiling, and climate resilience. Exploring value addition and assessing its socio-economic benefits can enhance livelihood opportunities. Efficient propagation and conservation strategies are also needed to ensure large-scale cultivation and sustainable utilization of this valuable fodder species.

**CONFLICT OF INTEREST**

There is no potential conflict of interest was reported by the authors.

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