Research Article

Effect of Season of Use on the Nutritive Value of Browse Vegetation in Kherimurat Scrub Forest, District Attock, Punjab, Pakistan

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Abstract | The nutritive value of browse vegetation varies significantly with season, influencing livestock health and productivity in rangeland ecosystems. In the semi-arid Kherimurat Scrub Forest of District Attock, Punjab, seasonal changes affect the availability and quality of key browse species. Understanding these variations is essential for developing sustainable, climate-resilient grazing strategies tailored to local ecological conditions. This study evaluated the seasonal variation in the nutritive value of four predominant browse species: Kikar (*Acacia nilotica*), Bakain (*Melia azedarach*), Kahu (*Olea cuspidata*), and Zaitoon (*Olea europaea*) within the semi-arid Kherimurat Scrub Forest (12,533 acres; 33°N, 72°E), which receives 450–600 mm annual rainfall and experiences temperatures ranging from 5 to 40 °C. Fresh leaves and twigs were harvested from three randomly selected trees per species during summer (June–July) and winter (December–January). These samples were analyzed to determine crude protein (CP) using the Kjeldahl method, crude fibre (CF) via acid–alkali digestion, and *in vitro* dry matter digestibility (IVDMD). Results revealed statistically significant seasonal differences ($P < 0.05$) in all three nutritive parameters. Crude protein levels increased by 4.3–5.1 percentage points, crude fibre by 4.7–6.6 percentage points, and digestibility improved notably in winter (from 54.1% to 61.3%) compared to spring (10.15–14.13% vs. 26.7–31.5%). Among the species studied, Bakain showed the greatest increase in CP, Kikar exhibited the highest decrease in CF, and Zaitoon demonstrated the most pronounced rise in digestibility. Overall, the total nutritive value of the browse species improved from 95.8% in summer to 102.1% in winter, confirming winter as the optimal season for livestock grazing in this ecosystem. These findings highlight the importance of seasonally informed grazing management. Based on the results, the study recommends adopting rotational grazing systems that prioritize winter grazing, as this season provides significantly higher crude protein content and digestibility in browse species.

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Keywords | Browse vegetation, Nutritive value, Seasonal variation, Kherimurat Scrub Forest, Crude protein (CP), Crude fibre (CF), *In vitro* dry matter digestibility (IVDMD)

Introduction

Browse vegetation plays a crucial role in ruminant diets, particularly in semi-arid regions such as the Kherimurat Scrub Forest in District Attock, Punjab, where cultivated forage is often scarce or unavailable (Ahmad *et al*., 2007; Anonymous, 1992). In such environments, livestock including cattle, sheep, and goats rely heavily on native browse species such as *Acacia nilotica* (Kikar), *Melia azedarach* (Bakain), *Olea europaea* (Zaitoon), and *Olea cuspidata* (Kahu). These species are especially important during periods of drought or low rainfall, when herbaceous vegetation is limited (Austin and Heyligers, 1989). Their ability to survive under harsh climatic conditions and maintain nutritional value makes them a key component of sustainable livestock production systems in the region (Ahmed *et al*., 2023).

However, the nutritive value of browse species is not constant throughout the year. Seasonal variations in temperature, precipitation, and plant physiological processes significantly influence the chemical composition of browse foliage (Anonymous, 2010). During the hot and dry summer months, increased evapotranspiration and reduced soil moisture limit plant growth and productivity, leading to forage that is more fibrous and less digestible, with lower crude protein and essential mineral content (Ashfaque and Rafique, 1999; Jamil *et al*., 2022). In contrast, the cooler and wetter winter season enhances soil moisture availability, supports active plant growth, and improves the nutritional quality of browse by increasing crude protein, soluble carbohydrates, and overall digestibility (GoP, 2007; Chaudhry *et al*., 2010).

Generally, the wet season promotes increased photosynthetic activity and biomass accumulation, resulting in improved nutrient content (Hussain, 1968). Nevertheless, excessive rainfall can sometimes cause stress to the vegetation, particularly if the area lacks proper drainage which may negatively affect inner forage productivity (Khan *et al*., 2024). Meanwhile, the dry season prompts plants to allocate energy toward structural components like cellulose and lignin, enhancing their survival but reducing their palatability and digestibility for ruminants (Khan, 1966; Khan *et al*., 1999). This seasonal increase in fiber content further limits voluntary intake by livestock, making it difficult for animals to meet their nutritional requirements during these periods (Hussain, 1989).

A clear understanding of how forage quality shifts seasonally is essential for effective livestock management. By aligning grazing periods with times of peak nutritional value and planning for supplementation during low-quality periods, pastoralists can improve animal health, productivity, and resilience (Khan and Zarif, 1982; Mohammad, 1989). Additionally, such knowledge is fundamental to rangeland conservation and ecological sustainability. Coordinating livestock grazing with seasonal vegetation cycles reduces pressure on vulnerable plant communities and supports pasture regeneration (Stoddart *et al*., 1975). In the context of increasing climate variability, understanding seasonal forage dynamics is also critical for building adaptive management strategies that can respond to shifting weather patterns (Hussain, 1989; Arshadullah *et al*., 2007).

Despite the importance of browse vegetation in the feeding systems of semi-arid areas, there is a notable lack of research focused on the seasonal variation in the nutritive value of browse species in the Kherimurat Scrub Forest (Rehman and Abbas, 2022). Most existing studies provide only general observations and are not tailored to the specific environmental conditions of this region. Addressing this gap, the present study aims to evaluate how the nutritional composition of major browse species changes with the seasons in the Kherimurat Scrub Forest. It further seeks to determine the most appropriate season for utilizing these species as forage, with a focus on identifying the periods when crude protein, fiber content, and digestibility are most favorable for ruminant nutrition. This information will not only benefit livestock producers but will also contribute to sustainable rangeland and forest resource management in semi-arid ecosystems.

Materials and Methods

The study area is Kherimurat Scrub Forest, District Attock, Punjab, Pakistan. The forest contains a range of rangeland that comprises seeded (improved) and un-seeded (natural) rangelands. These are important areas to understand land use and land management practice effects, particularly the effect on forage biomass production and livestock carrying capacity.

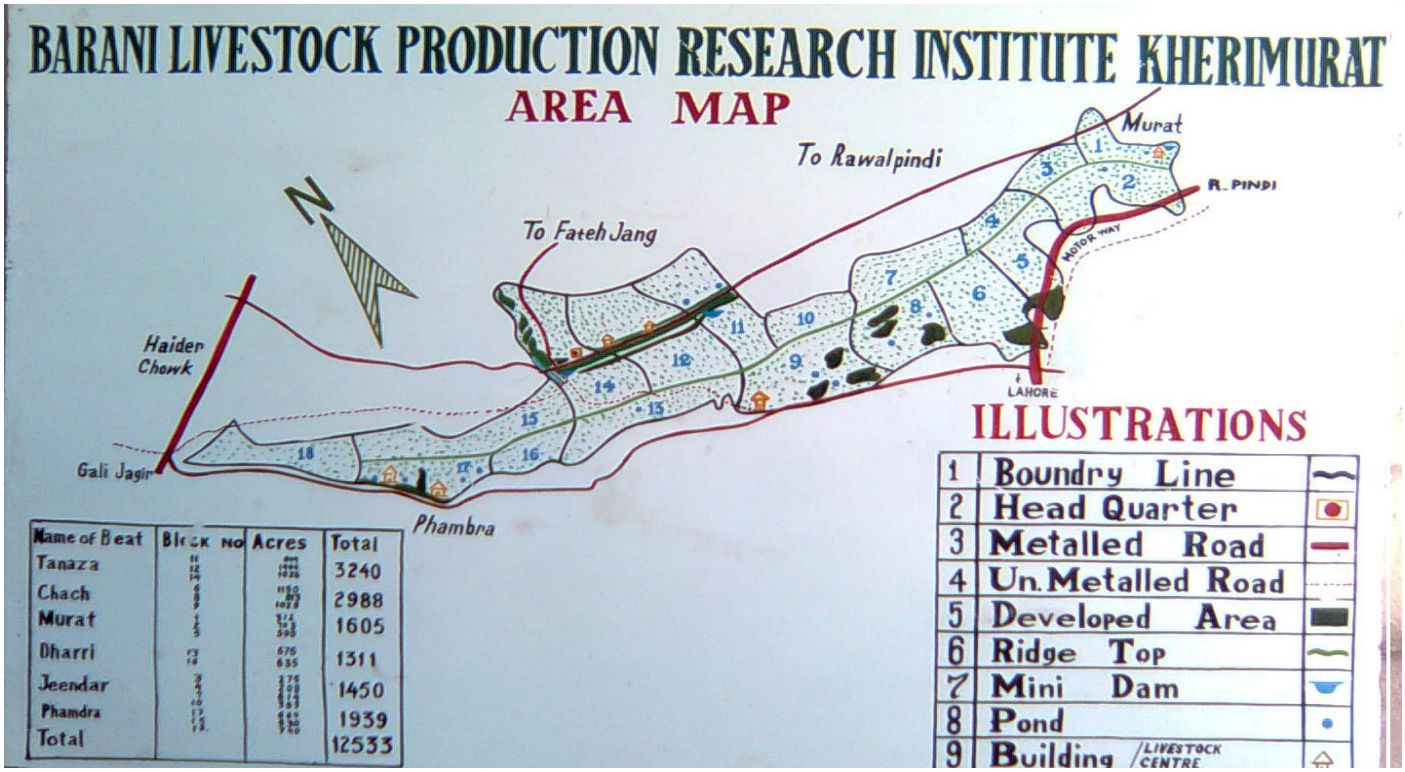

Figure 1: *Map of Kherimurat Scrub Forest.*

The area is classified as semi-arid with palpable seasonal changes (hot summer and cold winter). The temperature varies between 40 °C during summer to 5°C during winter. The average altitude is 600 meters above sea level. Rainfall in the forest averages 450-600 mm each year and is received in a monsoon period (July-September).

This research focuses on four commonly browsed plant species that are integral to local livestock diets in the Kherimurat Scrub Forest. These species were selected based on their abundance in the area and their recognized nutritional value. The first, Kikar (*Acacia nilotica*), is a drought-resistant leguminous tree that provides high-quality forage throughout both wet and dry seasons. Bakain (*Melia azedarach*) is a fast-growing tree whose leaves offer excellent forage during the wet season. Kahu (*Olea cuspidata*), a hardy shrub, thrives in arid conditions and serves as a reliable source of livestock feed. Lastly, Zaitoon (*Olea europaea*) is a perennial shrub valued for its nutritional foliage, particularly during drier periods. These species represent the typical vegetation available to local livestock and offer a diverse range of forage options across different seasons. Their significance in local grazing systems and the documented seasonal variations in their nutritional quality make them ideal candidates for this study. Samples were collected during two distinct seasons to assess the seasonal variation in the nutritional value of the browse species. The first collection took place in summer (June–July), a period characterized by high temperatures and minimal rainfall. During this time, plants are typically under water stress, which often leads to increased fiber content and reduced levels of essential nutrients. The second collection occurred in winter (December–January), when cooler temperatures and winter rains promote plant growth. As a result, the nutritional quality of the browse species tends to improve, with higher levels of crude protein and soluble carbohydrates observed during this season. Sampling was done by picking the young, mature, and leaf-bearing branches of each of the four species. To be representative of the forest, three random samples of the different parts were taken in each species. Pruning shears were used to collect samples, and great care was taken not to overharvest any single species to ensure ecological balance. Samples collected were taken to the laboratory to be analyzed to identify the nutritional composition of the samples. Analysis of the following parameters was carried out:

- Crude Protein (CP): This was calculated by the Kjeldahl method, whereby the sample is digested in concentrated sulfuric acid and then distilled and titrated.
- Crude Fiber (CF): To identify the fiber in the food, the standard acid and alkali digestion method was applied to eliminate all the non-fibrous contents.

- Digestibility: The digestibility was estimated using the *in vitro* dry matter digestibility (IVDMD) procedure, where the rumen fluid was applied to the sample to replicate rumen digestion in the ruminal.

These laboratory procedures are based on the common procedures defined by the AOAC (2005), so that the findings are consistent and comparable.

Laboratory analysis data were analysed statistically to determine changes in the nutritive value of the browsing species used on a seasonal basis. Paired t-tests were conducted to determine whether there was any significant difference in the nutritive values of the summer and winter seasons of each species. In this test, the means of two related groups (summer vs. winter) are compared to find out whether their nutritive content is statistically significantly different. All statistical tests and graphical representations (e.g., bar graphs and pie charts) were done using a professional statistical package of software (SPSS and Microsoft Excel with Statistical Add-ons).

Results and Discussion

Seasonal variation in nutritive value of four browse species

The Table 1 and Figure 2 presents the seasonal changes in crude protein (CP), crude fiber (CF), and digestibility for four key browse species: *Kikar (Acacia nilotica)*, *Bakain (Melia azedarach)*, *Kahu (Olea cuspidata)*, and *Zaitoon (Olea europaea)*. Data were collected during summer (June–July) and winter (December–January).

Table 1: *Two-way ANOVA results for seasonal crude protein, crude fiber, and digestibility of selected tree species with LSD (p<0.05).*

Trait	Species	Summer	Winter	Mean (Across seasons)
Crude protein (%)	Kikar	10.5[a]	14.8[d]	12.65[b]
	Bakain	12.1[b]	17.2[e]	14.65[d]
	Kahu	8.7[c]	12.9[c]	10.8[a]
	Zaitoon	9.3[b]	12.6[b]	10.95[a]
LSD (p<0.05)	-	0.245	0.245	0.245
Crude fiber (%)	Kikar	29.3[a]	22.7[c]	26.0[b]
	Bakain	30.6[b]	25.3[d]	27.95[c]
	Kahu	35.1[e]	31.2[b]	33.15[e]
	Zaitoon	32.0[c]	28.5[b]	30.25[d]
LSD (p<0.05)	-	1.73	1.73	1.73
Digestibility (%)	Kikar	55.2[b]	62.4[c]	58.8[b]
	Bakain	59.4[c]	65.1[d]	62.25[c]
	Kahu	50.1[a]	57.3[b]	53.7[a]
	Zaitoon	53.8[b]	61.2[c]	57.5[b]
LSD (p<0.05)	-	2.74	2.74	2.74

Superscript letters ([a], [b], [c]…) indicate significance. Means sharing the same letter are not significantly different. Means with different letters are significantly different. LSD = Least Significant Difference.

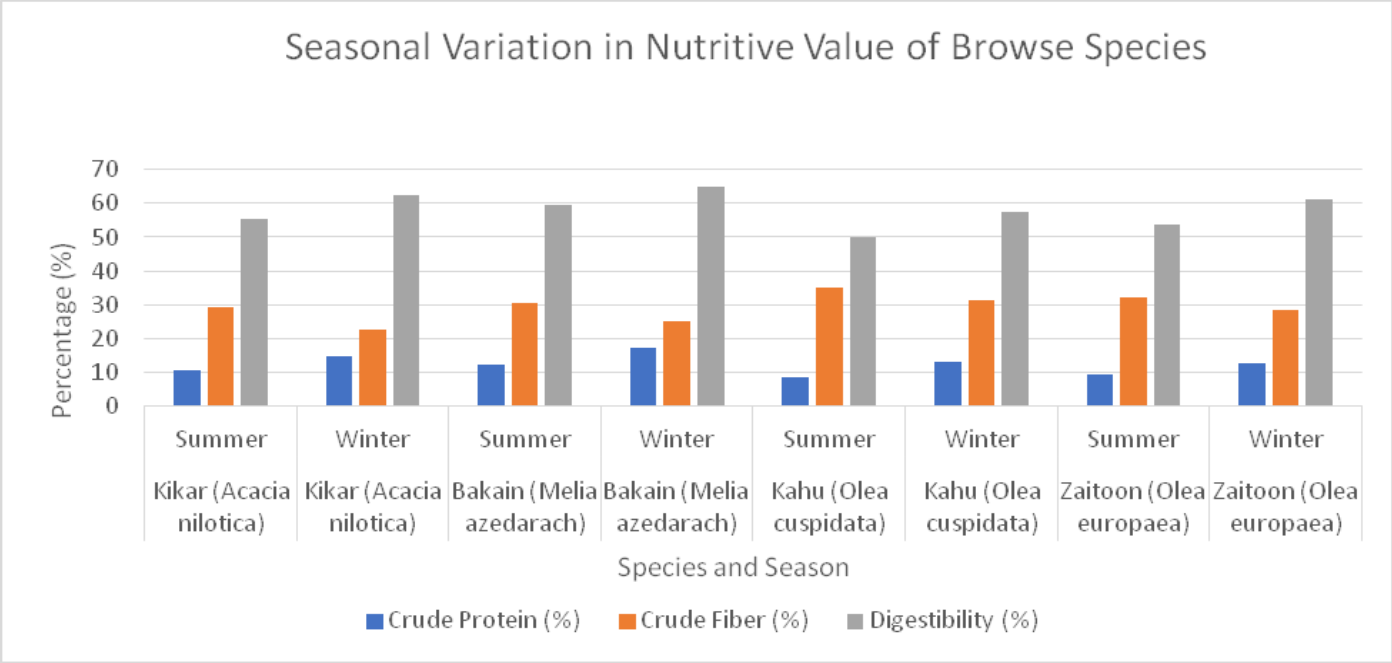

Figure 2: *Seasonal variation in nutritive value of browse species.*

Comparison of seasons

The average values of crude protein, crude fiber, and digestibility are compared (Table 2) between the summer and the winter seasons as follows.

Table 2: *Comparison of mean seasonal nutritive value.*

Variable	Summer mean	Winter mean	LSD (α=0.05)
Crude protein (%)	10.12[a]	14.14[b]	0.49
Crude fiber (%)	31.53[b]	26.73[a]	0.16
Digestibility (%)	54.14[a]	61.23[b]	0.44

Superscript letters indicate significant differences (α=0.05). Means with different letters differ significantly. LSD = Least Significant Difference.

The two-way ANOVA revealed that species, season, and their interaction significantly affected crude protein (CP), crude fiber (CF), and digestibility ($p < 0.05$). LSD comparisons further clarified the specific differences among means. For CP, Bakain had the highest values, significantly exceeding Kikar, Kahu, and Zaitoon, while Kahu and Zaitoon were not significantly different. CP was also significantly higher in winter compared to summer, and the species × season interaction indicated that the increase in CP from summer to winter was more pronounced in Bakain and Kikar than in Kahu and Zaitoon. For CF, Kahu had the highest fiber content, significantly higher than all other species, while Kikar had the lowest; fiber was higher in summer than winter, with the interaction showing species-specific seasonal responses. Digestibility was highest in Bakain and lowest in Kahu, with winter values exceeding summer for all species. The interaction revealed that the seasonal improvement in digestibility varied among species, being greatest in Bakain. Overall, these results demonstrate that nutritional quality of the studied species is both species and season dependent, and that LSD analysis provides precise identification of which species and seasonal combinations differ significantly, highlighting Bakain in winter as the most nutritious fodder option and Kahu as the least favorable.

Discussion

The findings of this study clearly demonstrate that the nutritive quality of browse species: *Acacia nilotica*, *Melia azedarach*, *Olea cuspidata*, and *Olea europaea* improves significantly during the winter season compared to summer. This is evident from the rise in crude protein (CP) levels, which averaged 14.13% in winter versus 10.15% in summer. The seasonal increase in CP is likely due to the slower growth rate of plants in cooler temperatures, leading to reduced lignification and greater nitrogen retention in foliage (Kumar *et al.*, 2022; Habib *et al.*, 2015). Studies conducted in northern Pakistan have reported similar trends in CP variation, particularly in species such as *Melia azedarach*, which consistently showed higher protein levels and digestibility compared to others (Ali *et al.*, 2024; Habib *et al.*, 2015). These seasonal shifts are crucial because protein availability is directly linked to animal growth, milk production, and reproductive performance.

Simultaneously, the crude fiber (CF) content of all four browse species declined during the winter season, dropping from an average of 31.50% in summer to 26.73% in winter. This decline in fiber improves digestibility, as higher fiber especially lignin reduces the accessibility of nutrients to rumen microbes (Woldemariam *et al.*, 2012; Bibi and Ahmad, 2024). The results are consistent with studies from both Pakistan and other semi-arid regions, where browse foliage collected during cooler or wetter seasons generally contained lower fiber and was more digestible (Islam *et al.*, 2023; Kumar *et al.*, 2023). Lower CF during winter indicates that plant tissues are less mature and contain fewer structural carbohydrates, thereby enhancing their palatability and digestibility.

Digestibility, which is influenced by both CP and CF, also improved significantly in winter, increasing from 54.13% in summer to 61.25%. This result reinforces the relationship between nutrient composition and forage utilization by ruminants. Higher digestibility during cooler months may result from increased microbial activity in the rumen due to better-quality forage inputs, as well as reduced anti-nutritional factors that often accumulate during hot or dry seasons (Chaudhary *et al.*, 2025; de Souza *et al.*, 2024). In particular, *Melia azedarach* emerged as the most digestible species across both seasons, highlighting its importance as a high-quality browse option. Habib *et al.* (2015) and Ali *et al.* (2024) similarly noted that *Melia* performed better than other species in terms of protein and digestibility in northern Pakistan, reinforcing the potential of this species for winter feeding programs.

The cumulative nutritive value, calculated by

combining CP, CF (inversely), and digestibility, showed an overall increase from 95.78% in summer to 102.10% in winter. This pattern aligns with findings from studies on Himalayan fodder trees, where higher nutritive values were associated with the early winter and post-monsoon seasons, when plant leaves are still young and metabolically active (Kumar *et al*., 2022). In summary, the pronounced seasonal variation in forage quality highlights the need for strategic feeding management in livestock systems. Utilizing nutrient-rich browse species during the winter months can help minimize reliance on costly supplemental feeds. Conversely, in summer when crude protein levels decline and fiber content increases farmers should consider using conserved forages, such as leaf meals or silage made from winter-pruned branches, alongside protein-rich supplements to sustain animal productivity. These findings reinforce and extend previous research conducted in Pakistan and comparable agro-climatic zones, advocating for a regionally tailored approach to optimizing sustainable livestock nutrition (Islam *et al*., 2023; Woldemariam *et al*., 2012; Bibi and Ahmad, 2024).

Conclusions and Recommendations

This study concludes that winter is the most favorable season for livestock grazing in the Kherimurat Scrub Forest due to the significantly higher nutritional value of browse species, including improved crude protein content, crude fiber, and digestibility. These findings emphasize the importance of adopting seasonal grazing strategies, such as optimizing winter grazing and providing supplementary feeding during summer, to enhance livestock productivity and ensure sustainable forage use. However, the study is limited by its focus on only four browse species, its short seasonal scope, and the lack of direct data on livestock performance. Future research should expand species selection, incorporate multi-year climatic data, and investigate the impacts of extreme weather events and broader ecological factors. Additionally, linking forage quality directly to livestock outcomes like weight gain and milk yield would provide a more comprehensive understanding of how seasonal forage variation influences pastoral systems and inform more effective rangeland management strategies.

The following recommendations are proposed to enhance grazing efficiency and ensure sustainable use of forage resources in the Kherimurat Scrub Forest:

- Emphasize winter grazing on *Kikar*, *Bakain*, *Kahu*, and *Zaitoon*, as these species provide higher protein content and better digestibility during the winter season.
- Provide protein-rich supplements during the summer months to offset the decline in forage quality caused by lower protein and higher fiber content.
- Adopt rotational grazing practices to minimize overgrazing and support the natural regeneration of vegetation.
- Protect and restore key forage species through regulated harvesting and rehabilitation of degraded forest areas.
- Implement water conservation strategies, such as rainwater harvesting and mulching, to sustain forage production throughout the year.

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Novelty Statement

This study presents assessment of seasonal variations in the nutritive value of browse vegetation in the Kherimurat Scrub Forest, offering valuable insights for optimizing grazing strategies and improving forage management in arid and semi-arid regions of Pakistan.

Author's Contribution

Muhammad Abuzar: Literature review, data collection and analysis.
Ashar Farooq: Writing the manuscript, critical thinking, concept, design and proof reading.
Murtaza Ali Tipu: Collaboration and Institutional support.
Asad Abbas Khan: Collaboration, communication and institutional support.

Generative AI and AI-assisted technology statement
The authors declare that no Genrative AI was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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