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Tree Fodder: Enhancing Livestock Mineral Nutrition – A Review

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ABSTRACT

The livestock farmers often face the challenge of ensuring adequate nutrition for their livestock. This paper aims to review the potential of tree leaves as a valuable and sustainable feed resource for livestock, particularly in regions of green fodder scarcity. Tree fodders are a rich source of protein, energy, and essential minerals, significantly contributing to health and productivity. While the mineral composition varies across tree species, geographical locations, and the stage of growth of fodder trees, they can reduce reliance on conventional, often costly, feed supplements. This paper aims to provide an overview of the mineral content of tree leaves, their significance in livestock nutrition and the potential for sustainable livestock production systems.

Keywords: Livestock, tree leaves, minerals, farmers' preferences

INTRODUCTION

The livestock sector continues to face a hurdle in terms of the limited availability of quality fodder (Chandran and Athulya, 2021; Zam *et al.,* 2022). This scarcity forces farmers to rely on minimal and low-quality feed supplements, which ultimately reduces livestock productivity (Sasi *et al.,* 2021). There's now a growing concern about exploring sustainable options. Tree leaves have emerged as a promising alternative, offering potentially rich nutrients. With poor access to the already shrinking natural pastures, livestock increasingly rely on manufactured feeds. Fodder trees are a vital feed source for livestock across diverse farming systems in India, providing cheaper protein and micronutrients (Kumar *et al.,* 2019). In addition to fodder production, integration of trees in cropping systems offers a desirable ecosystem, such as enhanced carbon storage and associated climate change mitigation (Rocha *et al.,* 2017). The mineral content of tree fodder directly reflects the mineral profile of the soil they are grown in.

SIGNIFICANCE OF FODDER TREES IN LIVESTOCK FEEDING

Tree fodders include leaves, pods, and young shoots of some palatable tree species that were specifically chosen for their nutritional value and suitability as fodder for animals. Fodder trees not only provide fodder but also yield sufficient fuelwood. *Prosopis cineraria, Acacia nilotica, Albizia lebbek, Azadirachta indica*, *Dalbergia sissoo,* etc., are the native fodder tree species in India. They exhibit wide variations in growth rate, biomass production, nutritive value, and fruit size (Rai and Samanta, 2007). Tree leaves are fairly rich in protein, yet a poor source of fibre. They are rich in calcium but poor in phosphorus. Due to the presence of tannins, part of the proteins in tree leaves are rumen-undegradable proteins. The tree leaves contain 8-33% crude protein, 1-19% ether extract, 11-50% crude fibre, 36-66% nitrogen-free extract, 22-57% neutral detergent fibre, 0.2-3.0% calcium and 0.1-0.3% phosphorus. The digestibility coefficients of dry matter, crude protein, crude fibre, ether extract and nitrogen-free extract in tree leaves range between 40-75, 28-83, 24-82, 32-65, and 51-85%, respectively (Rai and Samanta, 2007).

Compared to grasses, tree fodders have double protein content and essential macro minerals like calcium and sodium and microminerals like sulphur, zinc and iron. This advantage can significantly reduce farmers' expenses on the purchase of concentrate feeds (Moleele, 1998), and tree leaves, being a rich source of supplementary protein, minerals and vitamins, could enhance the microbial growth in the rumen and help in digestion (Cheema *et al.,* 2011). Leaves of *Moringa oleifera* have high-quality nutrients and a better biomass production even during the lean season (Nouman *et al.,* 2014). Fodder trees are relatively less affected by drought due to their deep root systems, enabling them to extract water and nutrients from deep soil even during dry seasons, and allowing them to retain fresh foliage (Teferi *et al.,* 2008). Research and development efforts aim to broaden the resource base by evaluating a wider range of tree leaves, defining optimal management strategies, and developing systems that capitalize on the advantages. Integrating fodder trees as hedgerows within existing cropping systems not only provides a readily available source of nutritious fodder but also minimizes competition with main crops and simplifies harvesting (Raj *et al.,* 2019), known as agri-silvi farming. In a silvipastoral system, where the trees are integrated with pastures, allows for the integration of livestock grazing in a mutually beneficial way. Studies have shown that implementing effective silvipastoral models can significantly increase land productivity, from a range of 0.5-1.5 tons to over 15 tonnes per hectare per year (Ramteke *et al.,* 2021). Among 15 multipurpose trees studied (MPTs), i.e., *Acacia catechu*, *Albizia chinensis*, *Bauhinia variegata*, *Celtis australis*, *Ficus roxburghii*, *Grewia optiva*, *Leucaena leucocephala*, *Melia composita*, *Morus serrata*, *Olea glandulifera*, *Ougienia oojeinensis*, *Pittosporum floribundum*, *Quercus glauca*, *Q*. *leucotrichophora* and *Salix tetrasperma in* north-western Himalayan mid-hills *L*. *leucocephala* had the highest palatability (97.86%). In contrast, *M*. *composita* (38.47%) had the lowest (Navale et al., 2022).

TREE FODDER: A MINERAL TREASURE TROVE

Macro Minerals in Tree Fodder

The mineral status of feeds and fodder mainly depends upon the cropping pattern, soil type and rainfall of a specific region (Bhanderi *et al*., 2014). Thus, deficiency and surplus of a particular mineral is area specific (Garg *et al*., 2005). The mineral composition of leaves from 10 leguminous trees (*Acacia leucocephala, Acacia planifrons, Albizzia lebbeck, Bauhinia variegata, Dalbergia sisoo, Hardwickia binata, Leucaena leucocephala, Pithecolobium dulce, Prosopsis cineraria, and Sesbania grandiflora*) and seven non-leguminous trees (*Artocarpus heterophyllus, Ficus bengalensis, Ficus racemosa, Ficus religiosa, Madhuca longifolia, Melia azardirach and Thespesia populnea*) in both drought-prone and non-drought-prone areas in nine districts of Tamil Nadu indicated that while no significant differences were found in major mineral concentrations between the two regions among the micro minerals, manganese levels were significantly high in the leaves of trees in drought-prone areas. However, the iron content was higher in the leaves of legume trees. There were no significant differences in the major mineral contents of legume and non-legume tree leaves (Valli and Murugan, 1998). The macro-mineral contents (calcium, phosphorus, sodium, and potassium) of leaves and shrubs from 15 different fodder species in Chakwal district, Pakistan, were investigated by Ghazanfar *et al.* (2011) and it was reported that the regions' average percentages of calcium, phosphorus, sodium, and potassium in the leaves of shrubs were 1.66%, 0.26%, 0.08%, and 0.069%, respectively. It was also suggested that these fodder trees and shrubs could be a valuable source of macro-minerals for livestock in that district. It was reported that among tree leaves, *Acacia nilotica* had the highest calcium and potassium contents, while *Morus alba* had the highest phosphorus content, and *Ziziphus jujuba* had the highest magnesium and sodium (Cheema, 2011).

A study examined the mineral consistency of ash tree (*Fraxinus excelsior* L.) leaves from seven sites across three French regions, differentiating between pollarded and high-stem trees. Calcium and sodium concentrations in ash leaves exhibited high variability, while potassium, magnesium and phosphorus showed less variation. Pollarded trees had significantly higher nitrogen levels and lower calcium content compared to high-stem trees, confirming that the ash leaves had a rich calcium essential for dairy cattle (Mahieu *et al.,* 2018). While examining the macro mineral profile of four fodder trees (*Salix nigra, Salix alba, Populus nigra and Elaeagnus angustifolia*) and two shrubs in three villages, the seasonal changes in macro mineral concentrations, it was reported that except for sulfur (0.82%) in *Salix alba*, substantial amounts of macro and micro minerals of phosphorus (0.41%), potassium (2.14%), calcium (2.64%) were identified in *Populus nigra.* Phosphorus (0.54%) and potassium (1.87%) were found to be in high concentrations in the spring, while calcium (3.04%) and magnesium (0.34%) were found in high concentrations in the autumn. Hence, it was suggested that the leaves from all fodder species should be mixed before being fed to ruminants to ensure the supply of all the minerals in the ration (Roomi *et al.,* 2022).

Navale *et al.* (2022) reported that in 15 MPTs (*Acacia catechu*, *Albizia chinensis*, *Bauhinia variegata*, *Celtis australis*, *Ficus roxburghii*, *Grewia optiva*, *Leucaena leucocephala*, *Melia composita*, *Morus serrata*, *Olea glandulifera*, *Ougienia oojeinensis*, *Pittosporum floribundum*, *Quercus glauca*, *Quercus leucotrichophora* and *Salix tetrasperma*), the mineral composition showed a significant ($P<0.05$) variation amongst different MPTs. The maximum phosphorus content was present in *B. variegata* and *M. serrata* leaves, each displaying identical values (0.25%), whereas the minimum phosphorus content was found in *A. catechu* (0.03%) leaves. Similarly, potassium and calcium contents showed wide variations from 0.98% (*S. tetrasperma*) to 2.18% (*M. serrata*) and 10.53% (*C. australis*) and 1.66% (*A. chinensis*). Macro-minerals varied significantly ($P< 0.001$) among different tree species. *Ziziphus spina-christi* was the phosphorus-rich tree species, and *Acacia tortilis* had the lowest phosphorus content. The *Citrus sinensis* and *Ziziphus spina-christi* had the highest and highly comparable amount of potassium, and *Tamarindus indica* foliage had the least content of the same. Calcium was the highest in *Dovyalis glabra,* and the lowest in *Ziziphus spina-christi*, and magnesium was the highest in *Dovyalis glabra* but the lowest in *Acacia nilotica.* Out of the macro-minerals, calcium was the most abundant mineral and constituted 73%, followed by potassium (18%) and magnesium (7%), and phosphorus accounted for only 2% of the amount of the macro-minerals (Adane and Anjulo, 2023).

Calcium (Ca) and Phosphorus (P)

The optimum calcium (Ca) and phosphorus (P) ratio was between 1.5:1 and 2:1. This ratio is crucial as the requirements of Ca and P change with animals' ages and stages of production, as a lactating cow needs 0.30% Ca and 0.20% P of dry matter intake, while non-lactating cows require less. Maintaining calcium homeostasis is crucial, particularly during the transition period of calving to early lactation. Moreira *et al.* (2017) investigated the impact of dietary calcium on bone health markers in transition cows and suggested that the diets with low calcium content (less than 0.60% of dry matter) might lead to increased Ca mobilization from bones to meet Ca requirements for milk production. The importance of adequate calcium intake for dairy cows suggests a requirement of up to 3.4 g/kg of milk during peak lactation to maintain calcium balance and prevent milk fever. Effective calcium management both before and after calving is crucial for optimal cow health and milk production (Grum *et al.,* 1996). An increase in milk protein content is directly linked to higher phosphorus excretion, as per a study on the relation between phosphorus metabolism and milk protein synthesis (Goselink *et al.,* 2015). Goats fed on diets with adequate calcium (0.60% or 0.80% of dry matter) exhibited superior average daily gain, better feed efficiency and bone mineral density compared to those on a calcium-deficient diet (0.40%), as reported by Liu *et al.* (2013) on investigating the impact of varying dietary calcium levels on growing goats. Calcium: phosphorus ratio of 1.5:1 is an optimal ratio for lactating goats, for nutrient digestibility, and calcium and phosphorus homeostasis, as reported by Chen *et al*. (2018) in a study comparing diets with Ca:P ratios of 1.2:1, 1.5:1, and 1.8:1. *Leucaena leucocephala* was reported to exhibit the highest phosphorus content (0.93%), followed by *Erythrina indica* (0.91%) and *Manihot esculenta* (0.88%), while *Moringa oleifera* was distinguished by its superior levels of both calcium (2.75%) and magnesium (0.60%), as observed by Mubeena *et al.* (2022).

Magnesium (Mg)

Magnesium plays a crucial role in several physiological processes, including muscle function, enzyme activity and carbohydrate metabolism (Kincaid, 1986). Lactating cows require 0.20% magnesium in their diet dry matter, while gestating cows need 0.12%. However, lush, fast-growing pastures often contain high potassium levels that hinder magnesium absorption in both plants and cows. To prevent grass tetany in lactating cows on such pastures, a high-magnesium mineral supplement (8-13% Mg) should be provided two to four weeks before turnout, increasing their intake to 0.25% of diet dry matter. Goats fed diets with a moderate magnesium level (60 mg/kg DM) had the highest milk yield and milk fat content compared to those on lower or higher magnesium diets (Wang *et al.,* 2017).

Potassium (K)

When feeding cattle and sheep fed with high K diets, it is important to assess the Ca and Mg status of the animal as well as balance minerals in the ration to optimize animal health and productivity. Supplementation with K also increased the fractional excretion of K in the urine of sheep, but decreased the fractional excretion of Ca and Mg ($P < 0.05$), showing that K supplementation significantly affected Ca and Mg metabolism (Bhanugopan *et al.,* 2014). Mubeena *et al.* (2022) observed that potassium content ranged from 1.0 to 2.70%

across all feed sources, with *Musa acuminate* (2.70 %) having the most, followed by *Moringa oleifera* (2.55 %) and *Sesbania grandiflora* (2.45 %).

Sodium (Na) and Chloride (Cl)

Sodium, along with potassium, plays a crucial role in regulating the movement of nutrients into and out of cells. Together, sodium and chloride work to maintain cellular volume, pH balance and overall osmolarity of body fluids. Chen (2014) suggested that moderate dietary salt (NaCl) levels could improve feed intake and digestibility, while excessive intake can have negative effects in lambs.

Sulphur (S)

Cattle on pasture typically require 0.15% sulfur in their diet. Hence, testing forages and water is crucial before adding sulfur to a mineral supplement. Many forages naturally contain adequate sulfur, and sulfur content in water adds to the total intake. Wallace *et al.* (1994) highlighted the role of sulphate-reducing bacteria in sulphur metabolism and the conversion of dietary sulphur to forms usable by the animals.

Micro Minerals in Tree Fodder

Tree fodders also provide essential micro-mineral elements like copper, zinc, and iron, though the specific mineral profile may vary depending on the tree species, soil conditions, and the stage of maturity of leaves. Tree leaves provide essential micronutrients, such as zinc (24–34 ppm), copper (9–31 ppm), manganese (34–68 ppm), and iron (555–801 ppm) (Shinde *et al.,* 2007). Absorption of selenium and copper is much lower in ruminants than in non-ruminants. Phytate does not affect zinc absorption in ruminants because microbial phytase in the rumen degrades phytate. Manganese is poorly absorbed in ruminants, and high dietary calcium and phosphorus may reduce manganese absorption (Spears, 2003). Rao *et al*. (2011), in a study of 17 tree and bush leaf samples, *viz., Acacia nilotica, Ailanthus excelsa, Ficus religosa, Dichrostachys nutans, Leucaena leucocephala, Ficus glomerata*, *Prosopis cineraria* (L.) Druce, *Azadirachta indica*, *Morus alba*, *Zizyphus mauritiana ,Ficus bengalensis* L., *Balarites aegyptica* L., *Alzebia lebbek* (L.), *Pithocellobium dulce* (Roxb) *Salvodora perisica*, *Capparis horrida*, *Chlorodendron phlemides* L. which were collected in two seasons (January and June), reported that the copper content (ppm) was found to be adequate for sheep and goats, based on sole feeding of Acacia *nilotica* and *Chlorodendron phlemides* (> 15 ppm) and deficient in the others. The iron content was found in excess in all the fodders analysed (>100 ppm). The manganese was found to be sufficient (>30 ppm) in 10 out of 17 tree species, with the highest being in *Indian jujube* and the lowest in *Albizia lebbeck*. Micro-minerals, except for iron, varied significantly (P< 0.001) among the leguminous species (*Acacia nilotica, Acacia tortilis* and *Tamarindus indica*) and non-leguminous species (*Berchemia discolour*, *Cordia sinensis, Dobera glabra* and *Ziziphus spina-christi*). The amount of manganese was exceptionally high in *D. glabra.* In the other six species, the values ranged from 43 to 90 ppm. Copper was undetectable in *Acacia tortilis*, *Berchemia discolor*, and *Cordia sinensis*. Among the remaining species, concentrations ranged from 4 to 28 ppm, with the highest value observed in *Tamarindus indica* foliage. The iron content was not statistically different across all species; iron was exceptionally high in *Tamarindus indica*; in all other species, it ranged from 218 to 457 ppm. Zinc was the highest in *B. discolor* and the lowest in *A. nilotica*. The micro-mineral pool across all seven species (both leguminous and non-leguminous), iron and manganese were the most dominant minerals (Derero and Kitaw, 2018).

Navale *et al.* (2022) reported that in 15 MPTs, the copper and iron contents showed less but significant variations ranging from 16.91 ppm (*M. serrata*) to 22.94 ppm (*A. catechu*) and 504.38 ppm (*O. glandulifera*) to 701.27 ppm (*A. chinensis*). *Q. glauca* had the highest manganese content (264.99 ppm), while *O. oojeinensis* (33.32 ppm) had the lowest. The minimum zinc content was observed in *A. catechu* (4.29 ppm), while the maximum was in *S. tetrasperma* (56.29 ppm), displaying a huge variation among MPTs. Seasonally, the highest Copper (22.89 ppm) and Iron (699.13 ppm) contents were recorded during the winter season, while the lowest Copper (16.54 ppm) and Iron (653.84 ppm) contents were in summer and autumn, respectively. However, Mn content was the highest in spring (89.96 ppm) and the lowest in summer (60.51 ppm). The micro mineral profile of four fodder trees (*Salix nigra, Salix alba, Populus nigra and Elaeagnus angustifolia*) and two shrubs in three villages indicated that substantial amounts of zinc (217.5), and copper (11.63mg/kg DM) were recorded in the leaves of *Populus nigra.* The level of copper was found in high concentrations in the spring, and zinc (102.0 mg/kg DM), manganese (69.6 mg/kg DM), and iron (514.1 mg/kg DM) were found in high concentrations in the autumn, suggesting that the leaves of all fodder species should be mixed and fed to ruminants to ensure supply of all minerals (Roomi *et al.,* 2022).

The mineral concentrations in various tree leaves, as reported by several authors, are summarized in Table I. According to Shinde *et al.* (2007), tree leaves typically contained the following ranges: Magnesium (Mg): 0.46 – 0.86%, Iron (Fe): 555 – 801 ppm, Manganese (Mn): 34 – 68 ppm, Zinc (Zn): 24 – 34 ppm, Copper (Cu): 9 – 31 ppm. While the contents of copper, manganese, and zinc varied significantly across species, Buragohain (2006) noted that concentrations of calcium, magnesium, and iron consistently exceeded the critical recommended levels for livestock. Specifically, the critical levels for essential macro-minerals are generally recognized as 0.30% for calcium and 0.20% for magnesium, while the critical level for iron is significantly lower, at approximately 50 ppm.

CONCLUSION

Tree fodders appear to emerge as a promising and sustainable solution to address the issue of a critical challenge to livestock nutrition, particularly in regions facing fodder scarcity**.** Their potential to provide essential macro and micronutrients, including calcium, phosphorus, magnesium, potassium, sodium, chloride and sulphur is evident. While variations in mineral composition existed among tree species, geographical locations, and growth stages, incorporating tree leaves into livestock diets can significantly enhance overall animal health and productivity. However, successful integration of tree fodders requires a comprehensive understanding of their mineral profile, taking into account factors such as soil type, climate, and animal species. Careful mineral analysis, coupled with appropriate supplementation, is crucial for preventing deficiencies and optimising livestock performance. Thus, integration of tree fodders into livestock feeding systems can offer a promising pathway towards more resilient, sustainable and profitable livestock production.

Table I: Macro and micro mineral values of common tree fodders

Fodder Tree	Ca (%)	P (%)	Mg (%)	Na (%)	K (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Sources
Morus alba	3.60	0.57	0.72	0.20	1.75	-	-	-	-	Cheema *et al.* (2011)
Acacia nilotica	3.80	0.45	0.84	0.15	1.10	-	-	-	-	
Syzygium cumini	2.40	0.10	0.72	0.51	1.33	-	-	-	-	
Ziziphus jujuba	3.60	0.09	0.94	0.54	1.00	-	-	-	-	
Areca catechu	4.47	0.03	-	-	1.22	22.94	700.49	91.27	4.29	Navale *et al.* (2022)
Actinidia chinensis	1.66	0.13	-	-	1.29	20.25	701.27	33.73	8.98	
Bauhinia variegata	2.42	0.25	-	-	1.03	22.44	690.59	42.10	33.80	
Citrus australis	10.53	0.22	-	-	1.29	17.50	665.53	38.60	19.26	
Ficus roxburghii	6.21	0.11	-	-	1.54	19.07	681.41	70.36	6.87	
Grewia optiva	4.28	0.20	-	-	1.79	19.50	680.92	59.40	54.93	
L. leucocephala	4.09	0.15	0.39	0.02	1.95	19.71	683.62	39.44	19.88	
Melia composita	7.75	0.22	-	-	1.26	17.52	679.57	33.95	28.20	
Ficus bengalensis	2.6	0.49	-	-	-	-	2458	958	73.00	Gaikwad *et al.* (2017)
Moringa oleifera	2.6	0.26	-	-	-	-	5128	1953	98.00	
Ficus religiosa	4.5	0.24	-	-	-	-	5720	65	63.00	
Ziziphus maurintina	1.2	0.21	-	-	-	-	2100	90	45.00	
Tamarindus indica	1.9	0.20	-	-	-	-	3418	40	80.00	
Gliricidia sepium	1.19	0.23	0.45	0.04	2.71	12	153	-	35.00	
Sesbania sesban	1.4	0.27	0.35	0.03	1.16	-	2820	65	48.00	Bonsi *et al.* 1995
Albizia lebbeck	4.5	0.21	-	-	-	-	1498	20	02.00	Abdul Razak *et al.* (1996)
Azadirachta indica	1.83	0.25	0.31	-	-	13	1012	-	114	Amanullah *et al.* (2006)
Erythrina indica	0.79	0.75	0.25	-	-	30.31	412	45.50	-	Gowda *et al.* (2002)
S. grandiflora	1.41	0.46	0.38	0.24	2.04	18	881	-	179	Gowda *et al.* (2004)

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