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Tree fodder for mitigating the forage requirement in Himalayan region

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Abstract
In Himalayan region, fodder scarcity during lean periods has often been associated with serious economic loses to small hold farmers. Considering this, it has become pertinent to put adequate efforts for investigating alternative feed resources with superior traits over conventional forages. Forage trees, as an alternative or supplementary feed to conventional grasses, are effective sources to overcome scarcity of fodder in some regions. Tree foliages have appreciable amounts of nutrients which keep intestinal micro flora active for digesting cellulosic biomasses. The presence of anti-nutrients in tree foliage reduces the nutrient utilization in animals and results in discontinuation of various metabolic processes in body. The level of different anti-nutrients in tree foliage changes with the seasonal variations. Hence, a better understanding of seasonal variations and anti-nutrients level would help the farmer to predict optimum lopping time to harvest fodder trees with minimal amount of anti-nutrients. The purpose of reviewing the obnoxious effects of anti-nutrients in this article is to keep farmer aware rather than discourage the use of tree foliage for ruminant feeding. Different processing techniques have been developed to alleviate the ill effects of anti-nutrients in animals. Beside utilization of fodder trees as an excellent feed source, they do have significant values for sustainability of different agroforestry systems. This review emphasize the need of awareness, integration, cultivation and intensification of fodder trees in local farming systems through agroforestry for improving livestock productivity and sustenance of rural livelihoods in Himalayan region.

Keywords: Anti-nutrients, Livestock, Nutritional composition, Phenolic compounds, Tree fodder

Abbreviations: ADF: Acid detergent fiber**, CP:** Crude protein; **EE:** Ether extract; **IVDMD:** *In vitro* dry matter digestibility; **NDF:** Neutral detergent fiber; **NFE:** Nitrogen free extract; **OM:** Organic matter

Introduction
A mixed farming based agriculture production system involves complementary interactions between crop and livestock. In India this system is predominant from centuries and has become a crucial source of food, income, and social capital for farmer's livelihood. Although, India has large population of livestock in the world, the productivity is rather low, mainly attributed to inadequacy of quality fodder. According to the report of United Nations, the current world population of 7.2 billion is projected to increase by 1 billion in coming next 12 years and will touch around 9.6 billion in 2050 and importantly, most of the population growth is expected in developing countries like India. As a result, the increased pressure on land for production of food crops will leave meager available land for forage production. The above circumstances necessitate the identification of non-conventional feed resources, not only for their effective utilization but also for identification and introduction of new and lesser known plants capable to grow well in harsh conditions and do not compete with human food (Raghuvansi *et al.*, 2007). The propagation of such non-conventional feed resources could be utilized to combat desertification, drought, to provide economic benefits to farmer, create multiple job opportunities and bridge the gap between supply and demand for animal feeds (Fig 1). This would also lead to diversification of traditional agriculture and conservation of biodiversity through sustainable utilization of natural resources. However, the alternative feed resources must be compatible to existing farming systems and should be well adapted with economic conditions of farmer. The preference of the farmer for different feed resources is mainly based on their feeding value, ease in their availability and their importance in sustainability of agroforestry systems. Fodder trees are considered as best alternative feed resource because they are long lived, require minimum efforts and interventions, source of numerous side products and maintain soil fertility (Rawat and Subhas, 2011). They are also a good source of nutrients and could help in reducing the gap between the demand and supply of essential nutrients when other fodder resources are

not available (Katoch, 2009; Nautiyal *et al.,* 2017; Nabi *et al.,* 2017). To promote the utilization of fodder trees as a component of ruminant diets and for maintaining the sustainability of agroforestry systems, knowledge on points given below is imperative-

- Easy establishment
- Growth pattern and adaptability to local environment conditions
- Tolerance to various management practices
- Effect of different environmental condition
- Voluntary intake by the livestock
- Nutritive value of tree foliage
- Ability to regenerate foliage

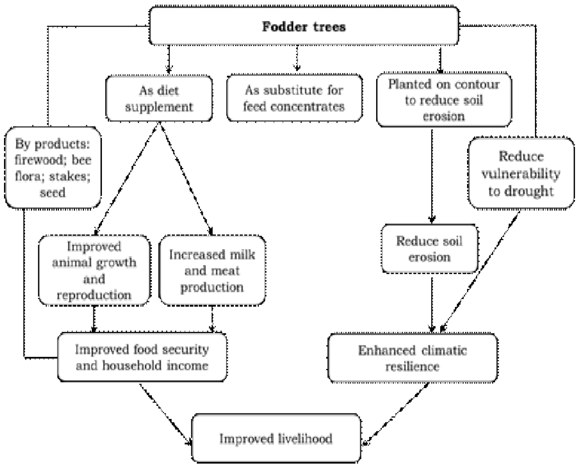

Fig 1. Model presenting fodder trees as a resource for improving rural livelihoods in Himalayan region

Fodder trees in livestock feeding

Fodder trees have long been considered as an alternative resource to ensure feed to animals during pronounced dry periods when other feeds have been exhausted (Verma *et al.,* 2015; Kaushal *et al.,* 2016; Sahoo *et al.,* 2016; Nag *et al.,* 2017; Katoch *et al.,* 2017). These are green or less affected by seasonal dry conditions due to extensive root system which enable water and nutrients extraction from deep in soil profile and longer life span (Teferi *et al*., 2008). The small scale farmers of Himalayan region particularly rear cattle, goats and sheep to generate income by producing milk, meat, leather, wool and manure. To maintain a stable condition of the ruminants, farmer generally feed conventional feed resources which contain low amount of protein and energy. Concentrate feeds which contain enough protein are usually recommended to supplement the basic diets of poor quality forages. But the leaves of fodder trees contain high level of proteins (10 to 30% of dry matter) and can replace concentrates to supplement low quality feeds without any adverse effects.

Nutritional composition of fodder trees prevalent in Himalayan region

Fodder trees form an integral part of ruminant diets in Himalayan region due to excellent nutrient profile with high feeding value, tolerance of a wide range of management practices, longevity and capacity to provide fodder when other fodder species are scare (Katoch, 2009; Bhardwaj *et al.,* 2018). In general, fodder tree leaves from Himalayan region have high protein and mineral content particularly calcium and phosphorus as compared to conventional grasses (Rana *et al*., 1999). High level of calcium and phosphorus in fodder trees could be due to rocky mountainous ranges in Himalayan region (Sharma *et al.,* 2003).Tree leaves also have high level of micro minerals well above than their critical levels (Sahoo *et al.,* 2016). The nutrients from fodder trees initiate the microbial activity in digestive tract of ruminants, which increases their ability to digest fiber, and enable livestock for better utilization of dry season pastures (Singh *et al.,* 2015; Nautiyal *et al.,* 2017; Katoch *et al.,* 2017). However, their nutritive value is significantly affected by various plant and environment based factors such as plant maturity, plant parts, season, altitude and harvesting time.

Nutritional composition for a range of tree fodders was reviewed earlier (Table 1). The crude protein content in tree leaves from mid Himalayan region ranged from 9.13 to 22.08% while calcium and phosphorus content ranged from 0.50 to 6.31mg/100g and 0.12 to 0.27 mg/100g of dry matter, respectively (Sharma *et al*., 1966). Sahoo *et al.* (2016) reported that calcium content ranged from 1.2 to 2.7% in fodder trees of sub-temperate Himalayas. High calcium content in *Ficus palmata* (2.7%) than the critical level (<0.30%) could be useful in early stage of lactation in animals. Pal *et al*. (1979) reported that average dry matter composition (%) of fodder trees growing in mid Himalayan region varied in respect of crude protein from 10.29% in *Ficus benghalensis* to 20.99% in *Albizzia stipulata,* crude fiber from 14.38% in *Morus alba* to 33.74% in *Atriplex stipulata*, nitrogen free extract (NFE) from 35.41% in *Bambusa nutans* to 60.41% in *Syzygium cumini*, total ash from 7.40% in *Bauhinia variegata* to 17.41% in *Cordia dichotoma*, insoluble ash from 0.35% in *Syzygium cumini* to 8.05% in *Banksia nutans*, calcium from 0.76% in *Dendrocalamus hamiltonii* to 4.79% in *Aegle marmelos* and phosphorus from 0.11% in *Syzygium cumini* and *Quercus incana* to 0.25% in *Callicarpa dichotoma*.

Bauhinia variegata had excellent nutritive profile and collated well with green leguminous fodder in its nutritive value (Negi, 1986). Khosla *et al*. (1992) observed high protein content (32%) in immature leaves of *Grewia optiva*, *Celtis australis* and *Robinia pseudoacacia*. The digestibility of protein form *Grewia oppositifolia* and *Bambusa arundinacea* leaves resembled to leguminous forages (Sharma *et al*., 1966). In *Artocarpus_lakoocha*, protein content ranged from 13.17 to 16.00% (Brandis, 1978). The comparative analysis of different fodder trees was also done by Khatta and Katoch (1983) and reported that *Bambusa arundinacea* is a nutritionally superior, ecologically adaptable, fast growing plant with more palatable foliage than other fodder trees. Mulberry (*Morus alba* var. *multicolis*) is considered as an excellent alternative for low quality forages in Himalayan region due to excellent nutrient profile with 15.00 to 27.60% of crude protein, 2.30 to 8.0% of ether extract, 9.10 to 15.30% of crude fiber, 48.00 to 49.70% of nitrogen free extract, 63.30% of total carbohydrates, 14.30 to 22.90% of ash, 2.42 to 4.71% of calcium, 0.23 to 0.97% of phosphorus, 30 to 50 ppm of iron, 0.5 to 1.0% of potassium, 33 to 46% of NDF, 28 to 35% of ADF, 5 to 10% of hemicelluloses, 19 to 25% of cellulose and around 11% of lignin content on dry matter basis (Singh *et al*., 1989; Makkar *et al*., 1989). Makkar and Becker (1998) observed that protein content in fodder trees prevailing in foot hills of Himalayas ranged from 8.0 to 25.90%. Dhungana *et al*. (2012) reported that among different fodder trees *Artocarpus lakoocha* contained substantial amount of crude protein, *Ficus lacor* had highest crude fiber (42.07%) and *Machilus odoratissima* yielded highest amount of digestible carbohydrates (21.92%). Sahoo *et al.* (2016) also observed that OM, CP, EE, NDF and ADF contents in fodder trees of sub-temperate Himalayan region varied from 90.60 to 97.40%, 9.50 to 21.10%, 3.90 to 5.90%, 38.40 to 69.40% and 40.10 to 70.50%, respectively (Table 2). Katoch *et al.* (2017) reported that *Morus alba* and *Grewia oppsitifolia* are excellent source of fodder in mid-Himalayan region for containing appreciable amount of nutrients.

Anti-nutrients in fodder trees and their seasonal variation

Fodder trees are nutrient-rich and valuable source of green fodder to sustain livestock during lean period in the hills of Indian Himalayas. However, their nutritional potential is significantly affected due to the presence of anti-nutrients (Table 3). The seasonal variations affect the levels of anti-nutrients in foliage and have been greatly emphasized as main determinants of forage quality. A seasonal pattern generally consisting of an increase in

Table 1. Nutritional composition of common fodder trees in Himalayan region

Fodder tree	Scientific name	% DM basis							mg/100g			
		CP	CF	EE	Ash	NFE	NDF	ADF	Ca	P	Cu	Zn
Beri	(*Zizyphus nummularia*)	14.99	16.48	2.20	10.70	55.63	70.90	59.63	0.48	0.32	1.32	3.50
Biul	(*Grewia oppositifolia*)	18.32	20.95	3.39	10.63	46.71	45.56	29.67	2.41	0.28	1.69	2.06
Dheon	(*Artocarpus lakoocha*)	14.45	21.10	2.40	12.13	49.92	54.48	38.72	1.11	0.31	0.96	4.48
Kachnar	(*Bauhinia variegata*)	15.25	24.36	3.42	6.72	50.25	59.81	46.59	2.13	0.27	2.80	3.50
Khirak	(*Celtis australis*)	18.08	18.10	2.19	16.43	45.20	37.21	27.12	3.16	0.26	1.68	2.63
Oee	(*Albizzia stipulata*)	10.35	32.75	3.86	7.71	45.33	68.37	33.29	1.12	0.23	1.24	5.17
Magar	(*Bambusa arundinacea*)	18.02	29.25	5.05	11.54	36.14	70.05	30.06	0.65	0.22	1.46	2.87
Robinia	(*Robinia pseudoacacia*)	17.55	18.02	4.28	4.09	43.94	51.68	34.20	1.46	0.21	1.90	-
Siras	(*Albizzia lebbek*)	17.59	33.10	3.88	8.83	36.62	52.68	33.80	2.65	0.11	0.54	1.04
Toot	(*Morus alba*)	26.40	11.63	5.06	16.28	40.63	41.20	23.77	2.38	0.35	2.08	4.83
Tuni	(*Cedrela toona*)	14.83	12.03	12.50	11.99	48.65	37.46	20.03	2.50	0.13	0.81	-

Source: Katoch (2009)

Table 2. Nutritional composition of preferred fodder tree species in sub-temperate Himalayan region

Tree species	% DM basis					
	OM	CP	EE	NDF	ADF	IVDMD
Ficus nemoralis	93.30	14.50	5.70	43.00	48.70	72.80
Ficus palmata	91.50	13.80	4.90	38.40	40.30	68.50
Ficus roxburghii	91.20	13.30	5.90	47.50	53.50	66.50
Quercus semicarpifolia	97.40	9.50	5.30	64.50	60.50	65.40
Quercus leucotricophora	96.70	10.50	5.60	66.20	60.10	64.70
Quercus floribunda	96.40	9.70	4.40	58.80	58.20	62.30
Quercus glauca	90.60	11.00	5.20	69.40	70.50	52.60
Alnus nepalensis	92.80	10.20	5.50	63.50	65.70	56.40
Mean	93.3	13.2	5.2	55.8	54.7	65.1
SE(m)	0.75	1.17	0.32	3.25	3.37	2.17

Source: Sahoo *et al.* (2016)

total phenols content during summer and decrease in winter season was reported by Rana *et al*. (2006) and Amaral *et al*. (2010). Similar trend was also observed for condensed tannins in fodder tree leaves.

Rana *et al*. (2006) reported that condensed tannins start to accumulate during winter season and reaches highest level during summer season. The condensation of tannins during winter season contributes to plant defense system in order to avoid any damage from stress full environment (Salaj and Karmutak, 1995). Onyeonagu *et al*. (2013) reported that in tree foliage harvested from the month of July to October had high levels of alkaloids, phytate, saponins and tannin content, than those harvested in dry season (November to February). The different stages of phonological development of plants also affect the livestock performance (Aganga and Tshwenyane, 2003; Rana *et al*., 2006; Jones *et al*., 2009; Pandey *et al*., 2011). Frutos *et al*. (2004) observed that variation in anti-nutrients also correlates with phenological stages of plants. During early stages of plant growth, most of the anti-nutrients are present at higher concentration. This may be due to high susceptibility of plant to various pests at younger stages. Pandey *et al*. (2011) reported a decreasing trend in hydrocyanic acid content with the advancement in plant maturity. Similar trend was also reported for oxalate content in fodder tree leaves earlier (Davis, 1981).

Detrimental effects of anti-nutrients

Foliages from the fodder trees have varying levels of anti-nutrients which exert varying affects on the physiology and productivity of livestock, as mentioned below-

Table 3. Major anti-nutritional compounds in foliage of fodder trees

Anti-nutritional compounds	Fodder tree species
Polyphenolic compounds	
(A) Tannins	All vascular plants
(B) Lignins	All vascular plants
Non protein amino acids	
(A) Mimosine	*Leucaena leucocephala*
Glycosides	
(A) Cyanogens	*Acacia giraffae*
	A. cunninghamii
	A. sieberiana
	Bambusa bambos
(B) Saponins	*Albizia stipulata*
	Bassia latifolia
	Sesbania sesban
Phytohaemagglutinins	
(A) Robin	*Bauhinia purpurea*
	Robinia pseudoacacia
Alkaloids	
(A) *N*-methyl-β-phene thylamine	*Acacia berlandieri*
(B) Sesabine	*Sesbania vesicaria*
	S. drummondii
	S. punicea
Oxalates	*Acacia aneura*

Source: Kumar (2003)

Digestibility: Tannins in fodder trees form the most common incriminating factors. Several *in vitro* and *in vivo* studies have shown that tannins decreases the protein digestibility either by inactivating digestive enzymes or by reducing the susceptibility of substrate proteins to digest after complex formation. The two types of tannins differ in their nutritional and toxic effects. Condensed tannins have profound reducing effect on digestibility than hydrolysable tannins. Hydrolysable tannin reduces the digestibility after hydrolysis in rumen (Akande *et al*., 2010). The high level of condensed tannins in feeds have been implicated in low milk production, decreased absorption of methionine and lysine, degenerative changes in intestine, liver, spleen and kidney. The unavailability of methionine also increases the toxicity of cyanogenic glucosides, because methionine play crucial role in cyanide detoxification. Tannins also reduces the availability of vitamins particularly vitamin A and vitamin B_{12} to livestock.

Palatability: The elevated levels of tannins in fodder trees also have negative impact on appetite for short period (within 20 to 60 minutes) and long period (from days to weeks). The short term effects of tannins are mainly due to astringent nature of tannins and adverse post-ingestive influences on the epithelium of oral cavity and foregut of ruminants, whereas, long term effects are mainly attributed to reduced concentration of ammonia and volatile fatty acids which in turn serves as metabolic cue for deficiency of nitrogen, energy or both.

Toxicity: Nitrate poisoning is probably the most widespread toxicity associated with grazing animals. If a significant amount of nitrate accumulated inside the body of grazing animal, it converts hemoglobin into the less oxygenic form and as a result animal dies due to hypoxia and circulatory collapse. Fodder trees also suffer from the problem of releasing hydrocyanic acid. However, cyanogens are not toxic themselves but become toxic when tree foliage is exposed to ruminal enzymes especially β-glucosidase that release hydrocyanic acid. The increased levels of cyanide in body inhibit the action of cytochrome oxidase in electron transport chain as a result tissues suffer from energy deprivation and ultimately lead to death. Maslin *et al*. (1987) suggested that in fodder species, hydrocyanic acid above than 200 mg/kg of fresh weight cause toxicity in ruminants. High oxalate concentration (> 2% or more soluble oxalates) also leads to acute toxicosis in ruminants. During the early stages of growth, there is a rapid rise in oxalate content followed by a decline in oxalate levels as plant matures (Davis, 1981).The high levels of other anti-nutritional factors in fodder trees such as non-protein amino acids, glycosides, phytohemagglutinins, polyphenols, and alkaloids are also considered as toxicogenic compounds as their increased levels produce several toxic symptoms in animals. For example alkaloid Sesabine from *Sesbania vesicaria* interacts with intestinal epithelial cells and causes haemorrhagic diarrhea in ruminants.

Techniques to alleviate the toxic effects of anti-nutrients

The direct consumption of forage trees with high levels of anti-nutrients produces toxicological symptoms in grazing animals. Therefore, it is necessary to investigate various processing techniques to reduce the concentration of anti-nutrients. For this purpose, the simplest approach is dilution of anti-nutrients by supplementing tree leaves with other feeds. This mixing reduces anti-nutrients levels in tree leaves and certainly reduces the risk of toxicity. Feeding of tree leaves in combination with feed concentrates mitigate the effect of tannins without any adverse effect in animals. This method is quite favorable as animals consume proteins beyond their requirements from concentrate. As a result, anti-nutritional effects of tannins will be masked. Soaking of tree leaves in water remove soluble anti-nutritional factors. However, some metabolic reactions can take place during soaking which will also affect some nutritive compounds. It has been reported that repeated soaking/washing of tree leaves effectively remove the bitterness associated with saponins (Joshi *et al*., 1989). The supplementation of tree leaves with polyethylene glycol-4000 (PEG-4000) is also an effective method to reduce or to neutralize tannin content in tree leaves (Ben Salem *et al*., 2000; Salem *et al*., 2007). PEG-4000 prevents the formation of tannin-protein complexes and assists the breakdown of already formed complexes (Reddy, 2001). Makkar and Singh (1992) reported 95% reduction in tannins with 0.03 M potassium permanganate and 0.02 M potassium dichromate in tree leaves. These oxidizing agents convert tannins to quinones, which are not capable of forming complexes with proteins and can be used for large scale removal of tannins. The alkalis like sodium hydroxide, sodium carbonate and sodium bicarbonate act by oxidation of phenolics at higher pH (Makkar and Singh, 1992). Among them, Sodium hydroxide (0.05 M) is most effective, followed by sodium carbonate (0.05 M) and sodium bicarbonate (0.1 M). The reduction in tannins in oak leaves using these alkalis ranged between 70 and 90% (Makkar and Singh, 1991). The alkaline treatment with calcium hydroxide can be very effective in preventing the toxic or anti-nutritional effects of tannins. Charcoal has also been advocated as an effective alternative to alkalis, oxidizing agents and PEG whose high cost limits their use and in few cases their utilization could have adverse effects on environmental health (Bhat *et al.,* 2013).

Russel and Lolley (1989) observed that extra nitrogen supplied by urea increases the crude protein concentr-

-ation by destabilizing tannin–protein complexes. The application of ferrous sulphate (0.015 M) also reduces tannins by 85% (Bhat *et al.,* 2013). Fermentation also improves the sensory characteristics, such as flavor and taste by increasing nutrient concentration and availability from tree foliage. In this method, changes are mainly due to increased activity of endogenous enzymes and microbiota present in tree leaves. Simple heating or autoclaving improves protein quality by inactivating heat labile anti-physiological factors and by unfolding the protein structure, which make them more susceptible to digestive enzymes. The proper knowledge of the effect of active season on anti-nutrients also an effective strategy for obtaining tree fodder with minimal amount of anti-nutrients.

Conclusion

Fodder trees represent an alternative feed resource to overcome fodder scarcity due to their less susceptibility to sudden climatic changes and longer life spans than conventional forages. In addition to fodder, these trees are also important for sustainability of different agroforestry systems. Fodder trees of Himalayan region have excellent nutritive profile and have the potential to provide quality feed to cattle particularly during off seasons. However, their incorporation in existing farming systems require additional efforts like introduction of promising local fodder tree species, supply best planting material suitable to particular niche area for farmers and facilitation of knowledge intensive practices.

References

Adams, H.R. and B.J. Camp. 1966. The isolation and identification of three alkaloids from *Acacia berlandieri*. *Toxicon* 4: 85-90.

Aganga, A.A. and S.O. Tshwenyane. 2003. Feeding values and anti-nutritive factors of forage tree legumes. *Pakistan Journal of Nutrition* 2: 170-177.

Akande, K.E. and E.F. Fabiyi. 2010. Effect of processing methods on some anti-nutritional factors in legume seeds for poultry feeding. *International Journal of Poultry Science* 9: 996-1001.

Amaral, J.V., P. Valentao, P. Andrade and R. Martins. 2010. Phenolic composition of hazelnut leaves: Influence of cultivar, geographical origin and ripening stage. *Scientia Horticulturae* 126: 306-313.

Ben Salem, H., A. Nefzaoui, L. Ben Salem and J.L. Tisserand. 2000. Deactivation of condensed tannins in *Acacia cyanophylla* Lindl. foliage by polyethylene glycolin feed blocks. Effects on feed intake, diet digestibility, nitrogen balance, microbial synthesis and growth by sheep. *Livestock Production Science* 64: 51-60.

Bhardwaj, D.R., P. Sharma, R. Bishist, M.R. Navale and R. Kaushal. 2018. Nutritive value of introduced bamboo species in the northwestern Himalayas, India. *Journal of Forestry Research* https://doi.org/10.1007/s11676-018-0750-2

Bhat, T. K., A. Kannan, B. Singh and O.P. Sharma. 2013. Value addition of feed and fodder by alleviating the anti-nutritional effects of tannins. *Agricultural Research* 2: 189–206.

Brandis, D. 1978. *Indian Trees*. Bishen Singh and Mahendra Pal Singh. Dehradun, India.

Davis, A.M. 1981. The oxalate, tannin, crude fiber and crude protein composition of young plants of some *Atriplex* species. *Journal of Range Management* 34: 329-331

Dhungana, S., H.P. Tripathee, L. Puri, Y.P. Timilsina and K.P. Devkota. 2012. Nutritional analysis of locally preferred fodder trees of middle hills of Nepal: A case study from Hemja VDC, Kaski District. *Nepal Journal of Science and Technology* 13: 39-44.

Frutos, P., M. Raso, G. Hervas, A.R. Mantecon, V. Perez and F.J. Giraldez. 2004. Is there any detrimental effect when a chestnut hydrolysable tannins extract is included in the diet of finishing lambs? *Animal Research* 56: 127-136.

Jones, P.D., S.L. Edwards and S. Demarais. 2009. White-tailed deer foraging habitat in intensively established loblolly pine plantations. *The Journal of Wildlife Management* 73: 488-496.

Joshi, D.C., R.C. Katiyar, M.Y. Khan, R. Banerji, G. Misra and S.K. Nigam. 1989. Studies on Mahua (*Bassia latifolia*) seed cake saponin (nowrin) in cattle. *Indian Journal of Animal Nutrition* 6: 13–17.

Katoch, R., S.K. Singh, A. Tripathi and N. Kumar. 2017. Effect of seasonal variation in biochemical composition of leaves of fodder trees prevalent in the mid-hill region of Himachal Pradesh. *Range Management and Agroforestry* 38: 234-240.

Katoch, R. 2009. Tree Fodder: An alternative source of quality fodder in Himachal Pradesh. *Range Management and Agroforestry* 30: 16-24.

Kaushal, R., A. Verma, H. Mehta, D. Mandal, J.M.S. Tomar, C. Jana, Rajkumar, J. Jayparkash and O. P. Chaturvedi. 2016. Soil quality under *Grewia optiva* based agroforestry systems in western sub-Himalaya. *Range Management and Agroforestry* 37: 50-55.

Khatta, V. and B. S. Katoch. 1983. Nutrients composition of some fodder tree leaves available in sub-mountainous region of Himachal Pradesh. *Indian Forestry* 109: 17-24.

Khosla, P.K., O.P. Toky, R.P. Bisht and S. Hamidullah. 1992. Leaf dynamics and pH content of six important fodder trees of Western Himalaya. *Agroforestry Systems* 19: 109-118.

Kumar, R. 2003. Anti-nutritive factors, the potential risks of toxicity and methods to alleviate them. http://www.fao.org/DOCREP/003/T0632E/T0632E10.html.

Makkar, H.P.S. and B. Singh. 1991. Effect of drying conditions on tannin, fiber and lignin levels in mature oak (*Quercus incana*) leaves. *Journal of the Science of Food and Agriculture* 54: 323–328.

Makkar, H.P.S. and B. Singh. 1992. Detannification of oak leaves: treatments and their optimization. *Animal Feed Science and Technology* 36: 113–127.

Makkar, H.P.S. and K. Becker. 1998. Do tannins in leaves of trees and shrubs from African and Himalayan regions differ in level and activity? *Agroforestry Systems* 40: 59-68.

Makkar, H.P.S., B. Singh and S.S. Negi. 1989. Relationship of rumen digestibility with microbial colonization, cell wall constituents and tannin levels in some tree leaves. *Animal Production* 49: 299-303.

Maslin, B.R., E.E. Conn and J.E. Dunn. 1987. Cyanogenic Australian species of *Acacia*: a preliminary account of their toxicity potential. In: J.W. Turnbull (ed). *Australian Acacias in Developing Countries*. Proceedings, International workshop held at Gympie, August 1986. Canberra, Australia.

Nabi, S., K.N. Qaisar, P.A. Khan, S.A. Rather and B. Nabi.2017. Seasonal nutrient profile of some preferred fodder tree species of Kashmir Valley. *International Journal of Chemical Studies* 6: 1311-1314.

Nag, S. K., S. Singh, R. K. Raman, S. K. Mahanta and B. K. Bhadoria. 2017. Nutritional value of top feeds from Dharwad region of Karnataka with special reference to mineral contents. *Range Management and Agroforestry* 38: 108-114.

Nautiyal, M., J. K. Tiwari and D. S. Rawat. 2017. Exploration of some important fodder plants of Joshimath area of Chamoli district of Garhwal, Uttarakhand. *Current Botany* 8: 144-149.

Negi, S.S. 1986. Foliage from forest trees: a potential feed resource. In: P.K. Khosla, S. Puri and D.K. Khurana (eds). *Agroforestry Systems: A New Challenge.* Indian Society of Tree Scientists, Nauni.

Onyeonagu, C. C. and J. E. Asiegbu. 2013. Harvest frequency effect on plant height, grass tiller production, plant cover and percentage dry matter production of some forage grasses and legumes in the derived savannah. *Nigeria African Journal of Agriculture Research* 8: 608-617.

Pal, R.N., K.K. Dogra, L.N. Singh and S.S. Negi. 1979. Chemical composition of some fodder trees in Himachal Pradesh. *Forage Research* 5: 109-115.

Pandey, S., B.S. Meena, P. Sharma and R.N. Dwivedi. 2011. Gender involvement in decision making of on farm and off farm activities. *Journal of Community Mobilization and Sustainable Development* 6: 42-45.

Raghuvansi, S.K.S., R. Prasad, A.S. Mishra, O.H. Chaturvedi, M.K. Tripathi, A.K. Mishra, B.L. Saraswat and R.C. Jakhmola. 2007. Effect of inclusion of tree leaves in feed on nutrient utilization and rumen fermentation in sheep. *Bioresource Technology* 98: 511-517.

Rana, K.K., M. Wadhwa and M.P.S. Bakshi. 2006. Seasonal variations in tannin profile of tree leaves. *Asian-Australian Journal of Animal Sciences* 19: 1134-1138.

Rana, R.S., F. Yano, S.K. Khanal and S.B. Pandey. 1999. Crude protein and mineral content of some major fodder trees of Nepal. Lumle Seminar paper No. 99/13, Lumle Agriculture Research Center, Nepal.

Rawat, Y. S. and C. R. Subhash. 2011. Pattern of fodder utilization in relation to sustainability under indigenous agroforestry systems, north-western Himalaya, India. *International Journal of Science and Technology* 6: 1-13.

Reddy, D.V. 2001. *Principles of Animal Nutrition and Feed Technology*. Oxford & IBH Pub. Co., New Delhi.

Russel, R.W., and J. Lolley. 1989. Deactivation of tannins in high tannin milo by treatment with urea. *Journal of Dairy Science* 72: 2427-2430.

Sahoo, B., A. K. Garg, R.K. Mohanta, R. Bhar, P. Thirumurgan, A.K. Sharma and A.B. Pandey. 2016. Nutritional value and tannin profile of forest foliages in temperate sub-Himalayas. *Range Management and Agroforestry* 37: 228-232.

Salaj, J. and A. Karmutak. 1995. Structural change in mesophyll cells of *Abies alba* Mill. during the autumn spring period. *Biologia Bratislava* 50: 93-98.

Salem, A.Z.M., P.H. Robinson, M.M. El-Adawya, and A.A. Hassan. 2007. *In vitro* fermentation and microbial protein synthesis of some browse tree leaves with or without addition of polyethylene glycol. *Animal Feed Science and Technology* 138: 318-330.

Sharma, D.D., R.S. Gill, S. Chander and S.S. Negi. 1966. Chemical composition of some fodder tree leaves in Kangra district. *Journal of Research, Ludhiana* 3: 438-442.

Sharma, M.C., C. Joshi and T. K. Sarkar. 2003. Status of macro minerals in soil, fodder and serum of animals in Kumaon hills. *Indian Journal of Animal Sciences* 73: 308-311.

Singh, B., H.P.S. Makkar and S.S. Negi. 1989. Rate and extent of digestion and potentially digestible dry matter and cell walls of various tree leaves. *Journal of Dairy Science* 72: 3233-3239.

Singh, A., R. Dev, S.K. Mahanta and R.V. Kumar. 2015. Characterization of underutilized shrubs for forage potentials in rainfed and dry areas. *Range Management and Agroforestry* 36: 194-197.

Teferi, A., M. Solomon and N. Lisanework. 2008. Management and utilization of browse species as livestock feed in semi-arid district of North Ethiopia. *Livestock Research for Rural Development* 20.

Verma, A., N.B. Singh, N.V. Saresh, P. Choudhary, M. Sankanur, G. Aggarwal and J.P. Sharma. 2015. RAPD and ISSR markers for molecular characterization of *Grewia optiva*: an important fodder tree of north western Himalayas. *Range Management and Agroforestry* 36: 26-32.