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Nutritional value and tannin profile of forest foliages in temperate sub-Himalayas

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Abstract
Tree leaves (11 species) commonly used for livestock foraging in low (1000-1500 metres) and high (2000-2500 metres) altitudes of temperate sub Himalayas in Northern India were evaluated for their nutritional values. Leaves had wide variation in CP, NDF, ADF, total tannin, condensed tannin (0.02-5.82%) and hydrolysable tannin (0.50-9.20%). The *IVOMD* of tree leaves was negatively correlated with NDF and ADF content and positively correlated with CP. Tree leaves were rich in Ca, Fe and Mn, but poor in P and Mg. In most of the tree leaves Cu (5.2-8.0 ppm) and I (0.05-0.09) contents were below critical level. The concentration of minerals in foliages grown in high elevation was found to be lower than low elevation. The results indicated that most of the tree leaves are good source of protein and fibre. Among the evaluated tree leaves, *Grewia* and *Ficus* spp. of tree leaves can be classified as good quality forage.

Keywords: Digestibility, Minerals, Tannins, Temperate Himalayas, Tree leaves

Abbreviations: ADF: Acid detergent fibre; **CP**: Crude protein; **CT**: Condensed tannin; **DM**: Dry matter; **EE**: Ether extract; **HT**: Hydrolysable tannin; **IVOMD**: *In vitro* organic matter digestibility; **NDF**: Neutral detergent fibre; **OM**: Organic matter; **SEM**: Standard error of mean; **TT**: Total tannin

Introduction

Most parts of the temperate sub-Himalayas are characterized by heavy rainfall (> 2,000 mm/year), poor soil fertility (due to leaching and unsustainable farming practices), high soil acidity and subsequently low farm productivity. To improve productivity, technologies must be developed for villagers to adopt sustainable natural resource management practices that promote integration of tree crops, livestock and field crop production practices to provide high quality forage for livestock feeding. There is an acute shortage of conventional green forages in hilly areas especially in winter season due to harsh climatic condition and snow fall (Dev, 2001). Therefore, majority of the livestock in this region are dependent on the forest foliages which are major substitute of conventional fodders. Although the humid forest zone is endowed with a large variety of indigenous forest foliages (Marcelo *et al*., 2014), but not all have potentials to be used as good quality forages for livestock and there are seldom any deliberate attempts to incorporate these highly valued top feeds into existing farming systems. Thus, identification of fodder trees species with high potentials for providing good quality fodder for livestock and maintaining soil fertility is a major focus of agroforestry research in the region. Forest foliages form a major part in the feeding regimens of animals during scarcity periods. There is paucity of information in respect of chemical composition, fibre fraction, mineral profile, *in vitro* organic matter digestibility (*IVOMD*) and comparison of nutritional worth of forage tree species at different elevation in temperate hills (Min *et al*., 2003). Therefore, this study was conducted to assess the nutritive value of locally available forest foliages in temperate sub Himalayan region.

Materials and Methods

Study site: The study was conducted in temperate hills of northern trans-Himalayan moist zone which extends from foot hills of 1000 to 2500 m altitude. The ambient temperature and relative humidity ranges from -7.4°C to 29°C and 40 to 80%, respectively, whereas average annual rainfall is about 2000 mm. The medium to steep hill slopes are mainly used for rain fed agriculture and forage harvest. The steeper hill slopes are generally used for free grazing by settled livestock throughout the year. The farmers of various social groups at two elevations, i.e. high (2000-2500 m) and low (1000-1500 m) elevations were interviewed through a questionnaire to collect the information about the commonly used forage sources, their local names, growing season, distribution and frequency in relation to location, elevation and preference by the livestock. Sixty farmers (30 × 2, at each elevation) were interviewed in 6 villages (3 × 2, villages at each elevation) and eleven species of tree leaves commonly available in both the elevation were selected for the study.

Sampling and laboratory analyses: The forest foliages were harvested at mature stages and dried at 60°C for 72 h. The dried foliage samples were then milled to 1.0 mm particle size for use in laboratory analysis. The crude protein (CP), neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined using methodologies of AOAC (2005) and Van Soest *et al.* (1991). Minerals i.e. Ca (Talpatra *et al*., 1940), P (AOAC, 2005) and I (Bedi, 1999) and Mg, Fe, Mn, Zn, Cu, Mo, Se and Co were estimated by atomic absorption spectrophotometer (AOAC, 2005) following standard methods. Total tannins (TT) of tree leaves were estimated as per Makkar *et al*. (1993). Condensed tannins (CT) were determined using Butanol-HCl (Porter *et al*., 1986), whereas hydrolysable tannins (HT) concentration was calculated by subtracting the CT from TT. *In vitro* organic matter digestibility (*IVOMD*) of tree leaves were determined as per Tilley and Terry (1963).

Statistical analysis: The data were subjected to analysis of variance as a randomized complete block design using the General Linear Model procedure of SPSS (2005) and means were compared for statistical significance by Duncan's multiple range tests (Snedecor and Cochran, 1994).

Results and Discussion

***Chemical composition, tannins and in vitro organic matter digestibility*:** The OM, CP, EE, NDF and ADF contents of tree leaves varied widely from 90.6-97.4, 9.5-21.1, 3.9-5.9, 38.4-69.4 and 40.1-70.5%, respectively (Table 1). Makkar and Becker (1998) reported similar level of protein (8-25.9%) in different tree leaves found in the foot hills of Himalayan range. The level of protein (10.4-20.5%), NDF (49.8-77.1%) and ADF (30.3-66.1%) analyzed in different tree leaves of south eastern Nigeria also supported the present findings in proximate composition and fibre fractions (Anyanwu and Etela, 2013). The mean OM content of tree leaves was more at high elevation than mean value of tree leaves in low elevation due to leaching of minerals at higher elevation.

Total tannin content was highest in *Quercus semicarpifolia* (10.71%) and lowest in *Ficus palmata* (0.92%) (Table 1). CT content varied from 0.02% (*Ficus palmata*) to 5.82% (*Quercus floribunda*). HT content ranged from 0.5% (*Ficus nemoralis*) to 9.20% (*Quercus semicarpifolia*). The tannin content of tree leaves were low to moderate as compared to arid and semi arid region of India and African forest in which tree leaves were reported to have higher level of tannin activity than temperate Himalayan region. Climate,

Table 1. Chemical composition, *in vitro* digestibility and tannin contents of tree leaves

Scientific name	Local name	Chemical composition (% DM basis)					Tannin (%)			IVOMD (%)
		OM	CP	EE	NDF	ADF	TT	CT	HT	
Grewia oppositifolia	Bhimal	92.6	21.1	3.9	52.3	44.4	1.80	0.05	1.75	77.2
Ficus nemoralis	Dudila	93.3	14.5	5.7	43.0	48.7	3.33	2.83	0.50	72.8
Ficus palmata	Bedu	91.5	13.8	4.9	38.4	40.3	0.92	0.02	0.90	68.5
Ficus roxburghii	Timla	91.2	13.3	5.9	47.5	53.5	3.88	2.87	1.01	66.5
Celtis australis	Kharik	91.1	16.5	5.8	48.5	40.1	1.94	0.08	1.86	63.9
Bauhinia variegata	Quiral	93.2	15.1	4.9	62.1	59.3	6.82	3.35	3.47	62.3
Quercus semicarpifolia	Kharsu	97.4	9.5	5.3	64.5	60.5	10.71	1.51	9.20	65.4
Quercus leucotricophora	Banj	96.7	10.5	5.6	66.2	60.1	8.08	3.05	5.03	64.7
Quercus floribunda	Tilonj	96.4	9.7	4.4	58.8	58.2	7.86	5.82	2.04	62.3
Quercus glauca	Phaliyant	90.6	11.0	5.2	69.4	70.5	9.93	5.55	4.38	52.6
Alnus nepalensis	Utis	92.8	10.2	5.5	63.5	65.7	7.83	3.22	4.61	56.4
Mean (low elevation)		92.5	13.4	5.5	54.5	54.2	5.95	2.12	3.82	66.8
Mean (high elevation)		94.1	12.9	4.8	57.2	55.3	5.87	2.75	3.11	63.5
Mean		93.3	13.2	5.2	55.8	54.7	5.92	2.42	3.43	65.1
SEM		0.75	1.17	0.32	3.25	3.37	1.07	0.63	0.82	2.17

Table 2. Mineral profile of tree leaves

Scientific name	Local name	Macro-mineral (% DM basis)			Micro-mineral (ppm)							
		Ca	P*	Mg*	Fe*	Mn	Zn	Mo	Cu*	I*	Se	Co
Grewia oppositifolia	Bhimal	2.1	0.38	0.34	155	57	47	0.69	6.3	0.07	0.25	0.39
Ficus nemoralis	Dudila	2.3	0.35	0.34	153	107	83	0.71	5.8	0.06	0.32	0.38
Ficus palmata	Bedu	2.7	0.38	0.35	163	42	52	0.68	5.2	0.07	0.27	0.37
Ficus roxburghii	Timla	2.6	0.50	0.34	139	123	32	0.58	7.9	0.09	0.33	0.49
Celtis australis	Kharik	1.7	0.27	0.23	173	68	33	0.79	7.0	0.07	0.21	0.24
Bauhinia variegata	Quiral	1.3	0.21	0.21	177	149	50	0.63	6.9	0.08	0.25	0.25
Quercus semicarpifolia	Kharsu	1.3	0.23	0.22	134	242	48	0.39	6.4	0.06	0.25	0.41
Quercus leucotricophora	Banj	1.7	0.27	0.25	121	402	37	0.49	8.0	0.09	0.29	0.38
Quercus floribunda	Tilonj	1.2	0.24	0.22	143	116	51	0.51	7.0	0.09	0.32	0.47
Quercus glauca	Phaliyant	1.4	0.25	0.18	174	146	37	0.54	6.2	0.05	0.22	0.35
Alnus nepalensis	Utis	1.6	0.25	0.27	155	127	49	0.59	6.7	0.07	0.23	0.35
Mean (low elevation)		2.0	0.42	0.38	168	154	52	0.65	7.2	0.09	0.31	0.45
Mean (high elevation)		1.7	0.25	0.23	140	136	43	0.58	6.2	0.05	0.25	0.30
Mean		1.8	0.31	0.28	153	144	47	0.61	6.7	0.07	0.27	0.37
SEM		0.21	0.09	0.07	5.75	31.7	4.57	0.09	0.38	0.02	0.03	0.09
Critical level		<0.30	<0.25	<0.18	<50	<40	<30	<0.5	<8.0	<0.1	<0.1	<0.1
Good resource level		1-2	1-3	>0.5	>100	>100	>150	>1.0	>30	>0.2	>0.3	>0.2

*Mean values differ significantly (P<0.05) at different altitudes

soil, water availability, age of plant and maturity of leaves are known to influence tannin levels, toughness and fibrosity (Makkar and Becker, 1998; Bharathidhasan *et al*., 2013). The anti-nutritional factors such as tannin of tree leaves, their level and type of tannin influence the feed intake and nutrient utilization in animals (Jeon *et al*., 2003; Patra and Saxena, 2011). High level of CT in tree leaves lowers *IVOMD*. Bakshi and Wadhwa (2004) also reported that tree leaves containing more than 3% CT were negatively correlated with nutrient digestibility which supported the present findings.

The lower value of IVOMD of tree leaves in high elevation can be attributed to their higher fibre content. In consistent with the present findings, fibre fraction of tree leaves were observed to be higher (P<0.05) in winter than summer season and potential fibre degradability were lower during winter season when the leaves were highly fibrous and lignified especially in high elevation witnessing cold climate (Bakshi *et al*., 2011). In the present study, *Quercus glauca, Alnus nepalensis, Heteropogon contortus* and *Saccharum spontaneum* having higher fibre fractions showed lower IVOMD.

Macro and micro mineral contents: Perusal of the data revealed that tree leaves were rich source of Ca containing 1.2% (*Quercus floribunda*) to 2.7% (*Ficus palmata*) Ca (Table 2). Tree leaves were poor in P content ranging from 0.21% (*Bauhinia variegata*) to 0.50% (*Ficus roxburghii*), whereas magnesium content varied from 0.18% (*Quercus glauca*) to 0.35% (Ficus palmata). The level of Ca, P and Mg in Grewia and Ficus species of tree leaves were higher than *Quercus* spp. However, a wide ratio of Ca: P: Mg (above 2.5:1:0.5) was recorded in various samples of tree leaves indicating the poor bioavailability of these macro minerals to animals (McDowell *et al*., 1993). Indeed, P deficiency is widely prevalent throughout the world as P itself is limiting mineral in the soil (McDowell, 1992). However, the higher level of Ca and P in the plants in the present study might be due to rocky mountainous region of temperate hills in Himalayan region (Sharma *et al*., 2003).

Forest foliages were found to be rich source of Fe and Mn with a wide variation from 121 ppm (*Quercus leucotricophora*) to 177 ppm (*Bauhinia variegata*) and 42 ppm (*Ficus palmata*) to 402 ppm (*Quercus leucotricophora*), respectively. Zinc concentration varied from 32 ppm (*Ficus roxburghii*) to 83 ppm (*Ficus nemoralis*). Se and Co content were highest in *Ficus roxburghii* and lowest in *Celtis australis*. The mean micro minerals *viz*., Zn, Mo, Se and Co levels in the tree leaves were higher than their critical levels (Table 2). However, in most of the tree leaves, Cu and I levels were below critical level indicating their deficiency in tree leaves. Minson (1990) reported that decrease in soil temperature from 20 to 12°C reduced Cu concentration in plants and the temperate forages had less Zn content than tropical forages, which supports the present findings of lower micro mineral level in temperate forages. In temperate hills, heavy rainfall and humidity, results in marked leaching and weathering of soil, making them deficient in certain minerals. Application of meagre quantity of inorganic fertilizers and promoting practices of organic farming by the framers in hill states of temperate sub Himalayas might be another reason for low level of mineral content in most of the forest foliages and grasses (Sharma *et al*., 2003).

In consistent with the present findings, the mineral status in soil, tree leaves and serum samples of cattle in north eastern Himalayan zone of India revealed highly deficient in P, Mg, Zn followed by Cu and Co, but rich source of Fe, Mn and Co (Das *et al*., 2009; Chatterjee *et al*., 2011). Deficiency of Cu in different feed stuffs was observed due to poor biological availability of Cu mostly caused by increased lignifications in the fodders of tropical countries and the susceptibility of Cu to form biologically unavailable complexes (Cu-Fe, Cu-Zn, and Cu-phytase), which are also responsible for high incidence of Cu deficiency syndrome. However, the mean values of P, Mg, Fe, Cu and I in high elevation were lower ($P<0.05$) than low elevation due to heavy rain fall and leaching of minerals in high elevation of temperate hills. Although most of the mineral contents of tree leaves in both the elevation were higher than the critical levels, but none of the plants had minerals which can be considered as good resource level. The concentration of Cu and I were below critical level showing severe deficiency of these two essential minerals in top feeds of Himalayan hills. Mineral imbalances in soil and forages have long been responsible for low level of production and reproductive performance among ruminants (Gowda *et al*., 2004).

Conclusion

Based on the nutritional attributes, tree leaves of Himalayan foot hills can be grouped into high, medium and low quality forages. Tree leaves of *Grewia* and *Ficus* spp. are of good quality, C*eltis, Bauhinia and Quercus* spp. are of medium quality, whereas *Quercus glauca* and *Alnus* spp. of tree leaves are of poor quality fodder. The results further revealed that most of the tree leaves are good source of protein and fibre. The tannin content in most of the tree leaves were low to medium and may exert beneficial effect on nutrient utilization and health attributes in animals. But foliages are low in Cu and I contents, and the deficiency is aggravated at high altitude; emphasizing the need of extraneous supplementation of these minerals in animal diets.

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