Range Mgmt. & Agroforestry 38 (1) :108-114, 2017
ISSN 0971-2070

Nutritional value of top feeds from Dharwad region of Karnataka with special reference to mineral contents

Subir K. Nag[1,2]*, Sultan Singh[1], R. K. Raman[2], S.K. Mahanta[1] and B.K. Bhadoria[1]
[1]ICAR-Indian Grassland Fodder Research Institute, Jhansi-284003, India
[2]ICAR-Central Inland Fisheries Research Institute, Kolkata-700120, India
*Corresponding author e-mail: nagsk_67@rediffmail.com
Received: 6th October, 2016 Accepted: 29th April, 2017

Abstract
In the present study, the top feeds of 14 tree species (legume and non-legume) from Dharwad region of Karnataka were assessed for their nutritional value. Mean crude protein (CP) contents of top feeds were higher for legume (21.91%) than non-legume (16.07%) tree species, while fiber contents were comparable between legume and non-legume tree species. The condensed tannin (CT) levels were less than the threshold value (~ 5%) baring three non-leguminous plants. The macro and micro mineral contents varied plant to plant like Ca 0.98 (*H. binnata*) to 4.03% (*S. sesban*), Mg 0.46 (*A. lebbek*) to 1.55% (*S. grandiflora*), P 0.11 (*F. racemosa)* to 0.41% (*Pithecellobium dulce*), Na 0.01 (*G. sepium*) to 0.05 % (*F. tsiela*), K 0.34 (*H. binnata*) to 0.96% (*F. tsiela*), Fe 154.9 (*F. tsiela*) to 546.6 ppm (*F. racemosa*), Zn 15.47 (*A. heterophyllus*) to 44.02 ppm (*S. sesban*), Cu 6.85 (*D. latifolia*) to 11.62 ppm (*F. tsiela*) and Mn 38.16 (*A. lebbek*) to 106.48 ppm (*S. sesban*). In the top feeds calcium (Ca) and magnesium (Mg) were adequate while phosphorus (P), sodium (Na) and potassium (K) were inadequate to meet the ruminant animals's requirement. Among the micronutrients copper (Cu) was adequate in some plants and deficit in others. Iron (Fe) content was much in excess of the requirement and cobalt (Co) was found in sufficient amount in all the plants. Manganese (Mn) was present in adequate amount while the critical element zinc (Zn) was deficient in few plants. Thus most of evaluated top feeds are rich in protein, low in tannin, adequate to deficit in macro and micro minerals and may be utilized as protein and mineral feed resources with suitable supplementation as per the requirement.

Keywords: Dharwad, Minerals, Nutritional value, Tannin, Top feeds

Abbreviations: **ADF:** Acid detergent fiber; **CP:** Crude protein; **CT:** Condensed tannins; **NDF:** Neutral detergent fiber; **TP:** Total phenolics

Introduction

Top feed plants have been traditionally used as important animal feed resources as they fill the gap between demand and supply of cultivated fodders and feeds particularly during lean period (Pailan *et al*., 2004). They are mostly rich in protein and increase the intake and digestibility of low quality roughages (Singh *et al*., 2005[a]). Top feeds/browse materials from tree species maintain higher protein and mineral contents than grasses (Shelton, 2004) and provide nutritional and economical benefits on their use as supplement (Bhatta *et al*., 2005; Singh *et al*., 2015). Most of the top feed plants also contain a number of phytochemicals like flavonoids and other polyphenolic compounds which have potential health benefits being antioxidants, free radical scavengers and thus act as nutraceuticals. Another important characteristic of these feed resources is that they are also a good source of minerals. Minerals have immense role in growth, production, reproduction and normal physiological functions of animals. In ruminant feeding protein and mineral supplements are expensive feed ingredients, which limit the profit margin of livestock production. Top feeds from different tree species could be an alternate inexpensive source of protein and minerals to enhance the rural livelihood through higher livestock production. So there was imperative need to evaluate the locally available top feeds for protein contents, macro and micro minerals concentration along with other nutritional and anti-nutritional traits to test their suitability for use in the local or region specific feeding practices.

Materials and Methods

Experimental materials: Samples of 14 top feeds of different tree species (Table 1) were collected from Research Farm of Southern Regional Research Station of ICAR-Indian Grassland and Fodder Research Institute and University of Agricultural Sciences, Dharwad, Karnataka. Samples were dried under shade, pulverized and passed though 1mm sieve using electrically operated grinding mill and preserved for laboratory analysis.

Analytical methods: Chemical analysis for proximate constituents and fiber fractions were done following methods of AOAC (2000) and Van Soest *et al*. (1991), respectively. Condensed tannin was measured by vanillin-HCl method (Burns, 1971). For mineral estimation dried and sieved plant samples were digested with tri-acid mixture in a hot plate at a high temp. (120-270°C).The extractable aliquot was subjected to estimation of Ca, Mg, Fe, Mn, Zn, Cu and Co in a Flame Atomic Absorption Spectrophotometer (Make-Varian, Model 240 FS). Na and K were measured in a flame photometer while P was determined spectrophotometrically. SAS (Version 9.3; 2012) was used for statistical analysis.

Results and Discussion

Protein, fiber, tannin and phenolic contents: Mean CP content, 21.91% in leguminous and 16.07% in non-leguminous plants (Table 2), may be considered adequate to maintain the level of ammonia (70 mg N/l) required by microbial population in the rumen for optimum rumen fermentation (Satter and Slyter, 1974). Cell wall fractions varied among the species in both legumes and non-legumes. Average NDF (neutral detergent fiber) content was 45% in both the groups while ADF (acid detergent fiber) was slightly higher (34%) in legumes than in non-legumes (32%). Cellulose and lignin content were similar in both the groups while hemicellulose was higher in non-legumes (12%) than the legumes (9%). So the fibre fractions like cellulose, hemicellulose and lignin were adequately present for rumination, ensalivation and buffering due to cation exchange required for voluntary intake (Van Soest and Mason, 1991). Condensed tannin (CT) levels were within the threshold limit of 5% in all the legumes (mean value: 1.51%). But the CT contents in three non-legumes viz., *Gymnosporia montana*, *Ficus racemosa* and *Artocarpus heterophylus* was 6-7% while in others 0.47-1.53%. About 2-3% dietary tannins was found to have beneficial effect against bloat (Waghorn and Jones, 1989) and also by augmenting by-pass protein (Wang *et al*., 1994) in ruminant animals. Being phenolic compounds, tannins can exert anti-oxidants effect and also moderate parasitic load in ruminant animals. However, beyond the threshold level, they might reduce the dry matter intake, digestibility, palatability and protein utilization subsequently affecting growth and milk production in animals (Negi *et al*., 2003).

Macro and micro minerals: Significant differences were observed in mineral contents of top feeds of different tree species. Among the legumes, Ca was highest (4.03%) in *Sesbania sesban* while in case of non-legumes *Moringa oleifera* had the highest Ca content (3.49%; Table 3). The mean Ca content was almost same in both the groups. The Ca requirement for maintenance of dairy animals was 0.27-0.57% and for lactating animals, it was 0.43-0.77% (NRC, 2001). The concentration of Ca was, therefore, higher than the recommended levels. However, it was reported that excess Ca can disturb absorption of trace elements (NRC, 2001). Mg, one of the key constituent of chlorophyll in green plants, is normally present in abundance in top feeds. Its content did not vary much and the mean values were 0.79% and 0.73% in legumes and non-legumes, respectively. Ruminant animals are generally at risk from hypomagnesemia when Mg in feed and forages is less

Table 1. Top feeds of tree species collected from Dharwad region of Karnataka

Plant species	Family	Common name
Dalbergia latifolia	*Fabaceae*	Blackwood, Rosewood
Cardiospermum helicacabum	*Sapindaceae*	Baloon vine, Kanphuti
Pterocarpus marsupium	*Fabaceae*	Indian Kino tree
Albizzia lebbek	*Fabaceae*	Siris
Gymnosporia montana	*Celastraceae*	Vikalo
Ficus racemosa	*Moraceae*	Indian Fig tree, Gular
Moringa oleifera	*Moringaceae*	Drumstick tree, Horseradish tree
Ficus tsiela	*Moraceae*	Bilibasuri
Sesbania grandiflora	*Fabaacee*	Hummingbird tree, Gaach-munga, Agasti
Sesbania sesban	*Fabaacee*	Common sesban, Jayanti
Glyricidia sepium	*Fabaacee*	Quickstick
Hardwicka binata	*Fabaceae*	Anjan
Artocarpus heterophylus	*Moraceae*	Jack fruit
Pithecellobium dulce	*Fabaacee*	Madras thorn, Manila tamarind

than the recommended level i.e. 0.12%-0.2% on DM basis (NRC, 1980; 1985). So from nutritional point of view, both Ca and Mg contents were adequate in top feeds to meet the requirement.

The P content varied from 0.14-0.41% in legumes and 0.11-0.34% in non legumes, the mean being 0.24 and 0.21% in legumes and non-legumes, respectively. Since the critical level of P for ruminants is 0.22%, many of the top feeds could not meet the requirement. Limitation of P in forages is quite common in many places (Underwood, 1981). Sahoo *et al.* (2016) observed P deficiency in 11 tree species commonly used for livestock foraging in low and high altitude temperate sub-Himalayas in Northern India. Ca: P ratio was quite high and exceeded ideal value (10:1) for livestock (Khan *et al*., 2007) in 10 out of 14 plants. So there is a need for supplementation of P in the diet of animals to bring the ratio down leading to better utilization of the nutrients (McDowell, 1997).

The mean Na content of leguminous top feeds was higher (0.07%) than non-leguminous (0.04%) while on the other hand K content was marginally higher (0.66%) in the later than that in the former (0.61%). Recommended level of Na in forages is 0.08-0.1% (NRC, 2001) while for K, it is 0.6-0.8% (McDowell, 1997). So both Na and K contents in the evaluated top feed plants were inadequate and require supplementation for maintaining the normal requirement level. The K: Ca+Mg ratio of the top feeds varied from 0.08 - 0.26 which was quite low and thus there is no risk of grass tetany which normally occurs when the ratio exceeds 2.2 (Kemp and Hart, 1957).

Like macro minerals, significant differences were also observed in contents of different micronutrient in the tree species (Table 4). Among the micronutrients, Fe concentration was much higher (207.8-490.3 ppm in legumes and 154.9-546.6 ppm in non-legumes) than its normal requirement of 30-60 ppm on DM basis for ruminant animals (McDowell, 1992). Fe is a vital constituent of blood haemoglobin and cofactor of many enzymes. While deficiency can cause anemia, over abundance might result in nutritional imbalances. Higher Fe might interfere with Cu and phosphate absorption and metabolism. Maximum tolerable of Fe in forages is 1000 ppm and it is least toxic of all the essential trace elements for livestock (Mcdowell and Arthington, 2005). Mn deficiency was reported to cause impaired growth, skeletal and infant abnormalities in animals (Hussain and Durrani, 2008) but excessive amount decreases appetite. The level of Mn in both legumes and non-legumes was quite higher than its requirement level of 20 ppm. Higher levels of Fe and Mn in top feeds are in agreement with other reports (Singh *et al*., 2005[b], Das *et*

Table 2. Chemical composition (% DM basis) of top feeds from different tree species

Tree species	CP	NDF	ADF	Hemi cellulose	Cellulose	Lignin	CT	TP
Legumes								
Dalbergia latifolia	19.47	52.16	36.41	15.74	19.84	16.1	1.89	0.91
Pterocarpus marsupium	20.44	59.11	51.59	7.52	21.4	30.19	0.56	0.30
Albizzia lebbek	17.59	56.10	50.40	5.7	26.0	24.4	3.29	1.30
Sesbania grandiflora	21.72	33.90	31.38	10.44	17.9	13.48	0.54	0.55
Sesbania sesban	32.89	29.35	21.74	8.11	15.28	6.46	0.86	0.61
Glyricidia sepium	24.46	37.39	27.35	10.04	17.02	10.33	0.46	0.63
Hardwicka binata	9.67	56.24	31.31	2.49	15.04	16.28	3.63	1.00
Pithecellobium dulce	29.01	36.58	21.98	14.59	14.59	7.29	0.85	0.90
Mean	21.91	45.10	34.02	9.33	18.38	15.57	1.51	0.78
SD	6.65	11.16	10.82	4.11	3.65	7.71	1.20	0.29
Non-legumes								
Cardiospermum helicacabum	19.60	30.90	19.97	10.93	14.11	5.06	1.53	0.60
Gymnosporia montana	19.37	55.92	38.33	17.58	16.78	21.56	7.11	0.57
Ficus racemosa	8.48	54.39	44.47	9.91	24.94	19.53	6.24	0.85
Moringa oleifera	23.91	26.61	22.46	9.67	13.84	8.57	0.47	0.49
Ficus tsiela	12.49	59.33	37.45	13.42	20.04	17.41	0.47	0.48
Artocarpus heterophylus	12.54	44.88	31.84	13.29	23.55	8.29	7.07	1.09
Mean	16.07	45.34	32.42	12.47	18.88	13.40	3.82	0.68
SD	5.29	12.58	8.76	2.72	4.33	6.31	3.03	0.22

al., 2002). Zinc (Zn) is very much essential element for activation of many enzymes (Sher *et al*., 2011). Deficiency of it may cause parakeratosis, retarded growth and stiffness of joints (Ganskopp and Bohnert, 2003); anemia, sterility (Hidiroglu and Knipfell, 1984), absence of sexual maturity and dwarfism in severe Zn deficiency (Sher *et al*., 2011). The element was either at par or below the critical level of 30 ppm in most of the plants of both the groups excepting two legumes viz., *S. sesban* (44.02 ppm) and *P. dulce* (33.64). Deficiency of Zn in fodder tree and shrubs is quite common, particularly in non-legume forages as reported earlier by many authors (Singh *et al*., 2005[a,b]; Garg *et al*., 2005; Abdullah *et al*., 2013). Cu is very important for bone formation along with Ca. Against the recommended level of 8 ppm to meet the dietary requirement of dairy animals (Mc Dowell, 1997) its content (6.85-11.62 ppm) was adequate in some plants, while deficient in others. Co content was sufficient in all the top feeds to meet the required level of 0.11 ppm (Mc Dowell, 1997).

Correlation and principal component analysis: Positive and significant correlations were noticed between Mg-Na and Co with Ca, Mg, Na and P in legumes (Table 5) and between P-Zn and K-Co in non-legumes (Table 6). Cu-Mn and Cu-Zn were negatively, although not significantly correlated in both leguminous and non-leguminous top feeds and non-significant negative correlation between Cu-P was also observed. Negative and significant correlation between Cu and Mn in forage legumes was also reported by Kaplan (2013).

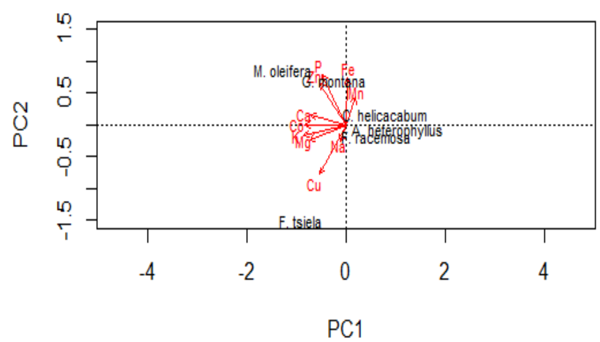

Fig 1. PCA biplot polygon for mineral contents of non legumes

Fig.1 is a biplot with a polygon view for mineral content of nonlegume. Principal component 1(PC1) and principal component 2 (PC2) explain 42% and 25% variability in the data, respectively and together constitute 67% variability. The nutrients K, Co, Mg and Ca were explained by PC1 and P, Fe Zn and Cu explained by PC2. The nonlegume species *M. oleifera* found dominated by Zn, P, Fe while *F. tsiela* was dominated by Cu.

Table 3. Macro mineral contents (%) in top feeds of different tree species

Tree species	Ca	Mg	Na	K	P	Ca:P	K: (Ca+Mg)
Legumes							
Dalbergia latifolia	2.79^{ab}	0.66^{bcd}	0.033^{b}	0.44^{d}	0.17^{d}	16.41	0.127
Pterocarpus marsupium	2.68^{ab}	0.86^{b}	0.022^{b}	0.88^{a}	0.21^{cd}	12.76	0.248
Albizzia lebbek	2.05^{bc}	0.46^{d}	0.025^{b}	0.65^{bc}	0.16^{d}	12.81	0.259
Sesbania grandiflora	3.74^{a}	1.55^{a}	0.204^{a}	0.43^{d}	0.27^{bc}	13.85	0.081
Sesbania sesban	4.03^{a}	0.79^{bc}	0.18^{a}	0.82^{ab}	0.36^{ab}	11.19	0.17
Glyricidia sepium	3.11^{ab}	0.52^{cd}	0.01^{b}	0.48^{cd}	0.19^{cd}	16.37	0.132
Hardwicka binata	0.98^{c}	0.55^{cd}	0.037^{b}	0.34^{d}	0.14^{d}	7.0	0.22
Pithecellobium dulce	3.17^{ab}	0.91^{b}	0.027^{b}	0.81^{ab}	0.41^{a}	7.73	0.198
Mean	2.82	0.79	0.07	0.61	0.24	11.75	0.169
SD	0.90	0.33	0.07	0.20	0.09		
Non-legumes							
Cardiospermum helicacabum	2.31^{b}	0.52^{c}	0.023^{c}	0.43^{c}	0.22^{b}	10.5	0.152
Gymnosporia montana	2.68^{ab}	0.65^{bc}	0.03^{c}	0.77^{b}	0.34^{a}	7.88	0.231
Ficus racemosa	3^{ab}	0.7^{b}	0.085^{a}	0.48^{c}	0.11^{c}	27.27	0.13
Moringa oleifera	3.49^{a}	0.92^{a}	0.047^{b}	0.89^{ab}	0.37^{a}	9.43	0.202
Ficus tsiela	2.88^{ab}	0.88^{a}	0.05^{b}	0.96^{a}	0.12^{c}	24.0	0.255
Artocarpus heterophylus	1.96^{b}	0.68^{b}	0.028^{c}	0.44^{c}	0.11^{c}	17.82	0.166
Mean	2.72	0.73	0.04	0.66	0.21	12.95	0.191
SD	0.49	0.14	0.02	0.22	0.11		

Significance level ($P<0.05$)

Table 4. Micro mineral contents (ppm) in top feeds of different tree species

Tree species	Fe	Mn	Zn	Cu	Co
Legumes					
Dalbergia latifolia	267.66^{c}	49.68^{bc}	30.25^{bc}	6.85^{b}	0.55^{cd}
Pterocarpus marsupium	224.02^{cd}	59.65^{b}	24.65^{bc}	7.19^{ab}	0.61^{bcd}
Albizzia lebbek	207.88^{d}	38.16^{c}	23.83^{c}	7.01^{b}	0.54^{cd}
Sesbania grandiflora	474.96^{a}	55.87^{b}	23.89^{c}	9.72^{ab}	0.83^{a}
Sesbania sesban	490.93^{a}	106.48^{a}	44.02^{a}	8^{ab}	0.76^{ab}
Glyricidia sepium	397.02^{b}	43.05^{c}	27.08^{bc}	10.56^{a}	0.61^{bcd}
Hardwicka binata	382.37^{b}	39.95^{c}	30.31^{bc}	8.27^{ab}	0.48^{d}
Pithecellobium dulce	259.54^{c}	41.54^{c}	33.64^{b}	7.98^{ab}	0.67^{abc}
Mean	338.05	54.30	29.71	8.20	0.63
SD	105.25	21.01	6.34	1.24	0.11
Non-legumes					
Cardiospermum helicacabum	296.18^{c}	38.8^{b}	23.43^{b}	7.45^{b}	0.62^{bc}
Gymnosporia montana	433.89^{b}	38.28^{b}	30.55^{a}	7.7^{b}	0.65^{abc}
Ficus racemosa	546.69^{a}	42.21^{b}	16.57^{cd}	7.56^{b}	0.59^{c}
Moringa oleifera	551.14^{a}	69.04^{a}	29.52^{a}	8.48^{b}	0.72^{a}
Ficus tsiela	154.93^{d}	26.61^{b}	19.76^{bc}	11.62^{a}	0.69^{ab}
Artocarpus heterophylus	399.72^{b}	83.98^{a}	15.47^{d}	7.87^{b}	0.61^{bc}
Mean	397.09	49.80	22.55	8.45	0.65

Significance level (P<0.05)

Table 5. Correlation coefficients among mineral contents of legume top feeds

	Ca	Mg	Na	K	P	Fe	Mn	Zn	Cu	Co
Ca	1.000									
Mg	0.573	1.000								
Na	0.623	0.722*	1.000							
K	0.390	0.028	-0.013	1.000						
P	0.701	0.471	0.441	0.601	1.000					
Fe	0.444	0.408	0.776*	-0.313	0.262					
Mn	0.627	0.227	0.679	0.455	0.487	0.549	1.000			
Zn	0.364	-0.113	0.339	0.333	0.609	0.423	0.726*	1.000		
Cu	0.306	0.300	0.277	-0.399	0.086	0.674	-0.061	-0.117	1.000	
Co	0.879*	0.825*	0.833*	0.276	0.720*	0.609	0.572	0.256	0.425	1.000

*Significance level (P < 0.05)

Table 6. Correlation coefficients among mineral contents of non-legume top feeds

	Ca	Mg	Na	K	P	Fe	Mn	Zn	Cu	Co
Ca	1.000									
Mg	0.718	1.000								
Na	0.587	0.383	1.000							
K	0.669	0.803	0.070	1.000						
P	0.462	0.140	-0.337	0.432	1.000					
Fe	0.389	0.057	0.384	-0.205	0.386	1.000				
Mn	-0.205	0.118	-0.221	-0.282	0.070	0.492	1.000			
Zn	0.459	0.127	-0.351	0.527	0.973*	0.212	-0.141	1.000		
Cu	0.271	0.674	0.128	0.726	-0.254	-0.677	-0.380	-0.118	1.000	
Co	0.618	0.803	-0.129	0.912*	0.542	-0.151	-0.005	0.574	0.620	1.000

*Significance level (P < 0.05)

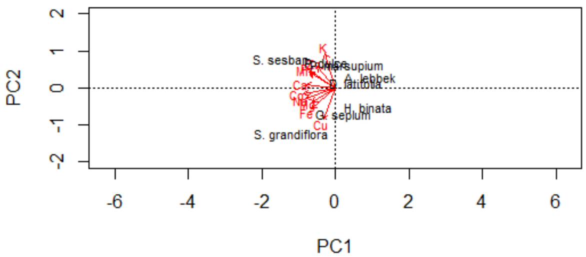

Fig 2. PCA biplot polygon for mineral contents of legumes

Fig.2 is a biplot with a polygon view for mineral content of legume. Principal component 1(PC1) and principal component 2 (PC2) explain 50.54% and 22.29% variability in the data respectively and together constitute 73% variability. The nutrients Ca, Co, Na, Mn, Mg, P and Fe were explained by PC1 and K and Cu were explained by PC2. The legume species *S. sesban* dominated by Ca, Co, Na, Mn, Mg, P and Fe minerals and species *S. grandiflora* dominated by Cu.

Conclusion

Evaluated top feed plants had adequate CP and moderate fiber contents. CT was within threshold limit of 5% in most of the plants except three non-legumes where the level exceeded by 1-2%. Calcium and Mg were in adequate concentration while Na, K and P were inadequate in few top feeds. Fe was in excess of the requirement for the ruminant animals. Co was sufficient but Cu, Mn and Zn contents were inadequate in few plants. Ca: P ratio was higher than the ideal value of 10:1 in most of the plants. The nonlegume species *M. oleifera* was found dominated by Zn, P, Fe, while legume species *S. sesban* was dominated by Ca, Co, Na, Mn, Mg, P and Fe. Non-legume, *F. tsiela* and legume, *S. grandiflora* was also dominated by Cu. Thus evaluated top feed plants could be utilised as qulaity feed resources when supplemented with deficient minerals, particularly P and Zn.

Acknowledgement

The authors are grateful to the Director, ICAR-Indian Grassland and Fodder Research Institute, Jhansi for providing necessary facilities and financial support for carrying out the research work.

References

Abdullah, M., R. A. Khan, S. Yaqoob and M. Ahmad. 2013. Mineral profile of browse species used as feed by grazing livestock in Cholistan rangelands, Pakistan. *Pakistan Journal of Nutrition* 12: 135-143.

AOAC. 2000. *Official Methods of Analysis*. 17th Edition. Association of Official Analytical Chemists, Washington DC, USA.

Bhatta R., S. Vaithiyanathan, N.P. Singh, A.K. Shinde and D.L.Verma. 2005. Effect of feeding tree leaves as supplements on the nutrient digestion and rumen fermentation pattern in sheep grazing on semi-arid range of India. *Small Ruminant Research* 60: 270-280.

Burns, R. E. 1971. Methods for estimation of tannins in grain sorghum. *Agronomy Journal* 63: 511-512.

Das, P., S. Biswas, T. K. Ghosh, and S. Haldar. 2002. Micronutrient status of dairy cattle maintained by farmers in the new alluvial zone of West Bengal. *Animal Nutrition and Feed Technology* 2: 19-26.

Ganskopp, D. and D. Bohnert. 2003. Mineral concentration dynamics among the northern Great Basin grasses. *Journal of Range Management* 54: 640-647.

Garg, M. R., B. M. Bhanderi and P. L. Sherasia. 2005. Assessment of adequacy of macro and micro mineral content of feedstuffs for dairy animals in semi arid zone of Rajasthan. *Animal Nutrition and Feed Technology* 5: 9-20.

Hidiroglu, M. and J. E. Knipfell. 1984. Zinc in mammalian sperm: A review. *Journal of Dairy Science* 67: 1147-1156.

Hussain, F. and M. J. Durrani. 2008. Mineral composition of some range grasses and shrubs from Harboi rangeland Kalat, Pakistan. *Pakistan Journal of Botany* 40: 2513-2523.

Kaplan, M. 2013. Mineral contents of natural pasture crops in Central Anatolian region of Turkey. *Range Management and Agroforestry* 34: 155-161.

Kemp, A. and M. L. Hart. 1957. Grass tetany in grazing milking cows. *Netherlands Journal of Agricultural Science* 5: 4-17.

Khan, Z. I., M. Ashraf and A. Hussain. 2007. Evaluation of macro mineral contents of forages: Influence of pasture and seasonal variation. *Asian Australian Journal of Animal Science* 20: 908-913.

McDowell, L. R. 1992. *Minerals in Animal and Human Nutrition*. Academic Press, San Diego, CA. pp. 49-51.

Mcdowell, L. R. and J. D. Arthington. 2005. *Minerals for Grazing Ruminants in Tropical Regimes*. Bulletin (4th Edn.), University of Florida, Ginessville. pp. 1-86.

McDowell, L.R. 1997. *Minerals for Grazing Ruminants in Tropical Regions*. Extension Bulletin, Animal Science Department, Centre for Tropical Agriculture, University of Florida. pp. 81.

Negi, A. S., B. K.Bhadoria, S. K. Nag and S. S. Kundu. 2003. Chemical composition of some browse species of Bundelkhand. *Animal Nutrition and Feed Technology* 3: 53-59.

NRC (National Research Council). 1980. *Mineral Tolerance of Domestic Animals*. National Academy Press, Washington, D.C.

NRC (National Research Council). 1985. *Nutrient Requirement of Sheep*. 6th Revised Edition. National Academy Press, Washington, D.C.

NRC (National Research Council). 2001. *Nutrient Requirement of Dairy Cattle*. 7th Revised Edition. National Academy Press, Washington, D.C.

Pailan, G. H., M. M. Das, J. P. Singh, S. K. Nag and Vinod Shanker. 2004. Nutritional evaluation of leaf fodder from tropical shrubs. *Indian Journal of Animal Sciences* 74: 771-774.

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: 155-161.

SAS. 2012. *Statistical Analytical System, Version 9.3*. SAS Institute Inc., Cary, NC, USA.

Satter, L. D. and L. L. Slyter. 1974. Effect of ammonia concentration on rumen microbial protein production in vitro. *British Journal of Nutrition* 32: 199-208.

Shelton, H. M. 2004. The importance of silvopastroal systems in rural livelihoods to provide ecosystem services. In: Proceedings of 12th International Symposium on Silvopastoal Systems (L. tMarnietje, L. Ramirez, M. Ibrahim, C. Sandoval, N. Ojeda and J. Ku, (eds). Universidad Antronoma de Yucatan, Merida, Yucatan, Mexico. pp. 158-174.

Sher, Z., F. Hussain and L. Badshah. 2011. Micro-mineral contents of eight forage shrubs at three phonological stages in a Pakistan's rangeland. *African Journal of Plant Science* 5: 557-564.

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

Singh, K. K., S. K. Nag, A. B. Majumdar and M. R. Garg. 2005[a]. Mineral status of some commonly available trees and shrubs in rangeland. *Indian Journal of Animal Nutrition* 22: 55-58.

Singh, K. K., S. K. Nag, M. R. Garg and A. B. Mojumdar. 2005[b]. Mineral status of some commonly used feeds and forages vis-à-vis their requirements. *Animal Nutrition and Feed Technology* 5: 171-177.

Underwood, E. J. 1981. *The Mineral Nutrition of Livestock*. Commonwealth Agricultural Bureaux, London. pp.180.

Van Soest, P. J. and V. C. Mason. 1991. The influence of millard reaction upon nutritive value of fibrous feed. *Animal Feed Science Technology* 32: 45-53.

Van Soest, P. J., J. B. Robertson and B. A. Lewis. 1991. Methods of dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science* 74: 3583-3597.

Waghorn, G. C. and W. T. Jones. 1989. Bloat in cattle. 46. Potential of dock (*Rumex obtusifolius*) as an anti bloat agent for cattle. *New Zealand Journal of Agricultural Research* 32: 227-235.

Wang, Y., G. C. Waghorn, T.N. Barry and I.D. Shelton. 1994. The effect of condensed tannins in *Lotus corniculatus* upon plasma metabolism of methionine, cystine and inorganic sulphate by sheep. *British Journal of Nutrition* 72: 923-635.