Range Mgmt. & Agroforestry 40 (1) : 137-142, 2019
ISSN 0971-2070

Variation in proximate principles and correlation studies in *Grewia optiva* along altitudinal gradient in Garhwal Himalaya

D. R. Prajapati[1*], N. V. Saresh [2], Ram Gopal[3] and V. P. Khanduri[4]
[1]Navsari Agricultural University, Navsari-396450, India
[2]Agricultural Research Station, Jodhpur Agriculture University, Jalore-343001, India
[3]Forest Research Institute, Dehradun-248006, India
[4]Veer Chandra Singh Garhwali Uttarakhand University of Horticulture and Forestry, Bharsar-248199, India
*Corresponding author e-mail: dhvlfor@gmail.com
Received: 30th January, 2018 Accepted: 18th January, 2019

Abstract
Grewia optiva is known for its fodder value in Garhwal Himalaya. Its leaves were harvested in the loping season from upper (above 1600 m), middle (1300-1600 m) and lower (1000-1300 m) altitudinal ranges to determine variation and relation of proximate principles with altitude and diameter classes. The data revealed that the proximate principles were strongly influenced by the altitudinal gradient. The correlation coefficient showed significant positive relation between altitude and dry matter (P<0.01) and negative with ash content (P<0.01). Diameter class showed significant positive relation with ether extract and crude fibre while negative relation with dry matter, crude protein and ash content. Highest crude protein and low crude fibre contents were observed at the mid-altitude and the higher altitude had better dry matter, ether extract, crude fibre and nitrogen free extract contents. On an average, in mid altitude range, leaves had better nutrient content than other selected range of altitudes. Therefore, it was suggested that the trees growing in this range of altitude should be harvested for better nutrition to the livestock.

Keywords: Altitudinal variation, Diameter class, Fodder quality, *Grewia optiva*

Introduction
The agriculture sector plays an important role in the economy of India and about 70 per cent of the total population of the country directly dependent on it. In the hilly regions of India, livestock rearing with agriculture is common practice where trees provide fodder to the livestock population of farmers. At the same time due to rain-fed conditions in the hills and small land holding of the farmers, they have limited scope of producing green fodder on their land. Therefore, planting of trees on their farmland, that will provide fodder, should be highly nutritious and can be incorporated in animal's diet as a mixture with dry straws/stovers to provide optimum nutrition for better livestock based production. This can only be possible by the way of selecting the trees having better nutritious fodder from its natural geographical area and cover a region under it through its mass multiplication.

Grewia optiva, commonly known as *Biul/Bihul/Bhimal*, belong to family Tiliaceae, is a very popular tree grown in low and mid-hill regions in agroforestry systems in the western and central Himalaya. This tree is preferred by the majority of the hill farmers of the Uttarakhand as it is superior to other fodder tree species for the attributes like palatability, faster growth, ease of propagation and forage yield (Mukherjee *et al*. 2018). It provides fodder during winter months when no other green fodder is available. Leaves of this tree are excellent source of fodder in mid Himalayan region which retained appreciable amount of nutrients in leaves (Katoch *et al*. 2017) and therefore, it has been classified under good quality fodder trees (Sahoo *et al*., 2016). It has over 70% potential DM digestibility and effective degradability (56.7%) that considered it as superior energy source for ruminants (Singh *et al*. 1989). Its leaves contains 17.4-21.0% crude protein, 17.0-21.5% crude fiber, 10.4-21.5% total ash, 4.2-6.0% ether extract and 40.4-50.2% nitrogen free extract (Sankhyan and Bhagta, 2016). It has been grown widely in Himalayan region and found up to an elevation of 2000 m and is the most common tree in the Tehri district (Bijalwan, 2013). The quality of this fodder tree is varying due to the fact that the factors of the locality act upon it or it may be the combined expression of genetic constitution of the tree species and the environmental conditions of the locality. Hence, keeping this in view and to improve the animal production in the selected region, the present investigation was executed to find out the variation in fodder quality parameters among altitudes, and diameter class and to find out the correlation between altitude and proximate principles and to choose best population among them for the selected region.

Materials and Methods

Study area: The experiment was conducted in Tehri district of Uttarakhand. A survey was conducted in October, 2014 for the purpose of identifying the population where *G. optiva* occurred almost in abundant quantity. There were three altitude ranges selected *viz.* A_1 (>1600 m), A_2 (1300-1600 m) and A_3 (1000-1300 m) above mean sea level (Table 1). In each altitude range, three different sites were selected, where, each site was divided into three diameter classes *i.e.* 10-20 cm (D_1), 20-30 cm (D_2), >30 cm (D_3) and in each diameter class, three trees were selected.

Table 1. Sites at different altitude in meter above mean sea level

Altitude range	Sites	Altitude (m)
A_1-Higher	S_1- Duvakoti	1931
(>1600 m)	S_2- Ranichauri	1730
	S_3- Dargi	1712
A_2-Middle	S_1- Jagdhar	1585
(1300 - 1600 m)	S_2-Sondkothi	1520
	S_3- Sabli	1507
A_3-Lower	S_1- Chopadiyali	1287
(1000 - 1300 m)	S_2-Kutuldi	1136
	S_3- Nagni	1066

Collection of leaf sample: The collection of leaf samples was carried out from selected areas during November-December, 2014. The leaves were collected from the entire crown (top, middle and base) of each tree including leaves of all sizes (Suri and Dalal, 1963). The collected leaf samples were first cleaned with water to remove the dirts/deposited matter and then sun dried. The dried leaves were then crushed and ground using mortar to get uniform fine powder. All the ground samples were labeled to get the result of a particular site and of a tree.

Sample analysis: These samples were used for the analysis of proximate principles *i.e.* dry matter (DM), ether extract (EE), crude fiber (CF), crude protein (CP), ash content (AC) and nitrogen free extract (NFE) by following standard procedures (AOAC, 1995).

Statistical analysis: The data derived were analyzed using the RBD factorial method. Statistical analysis was done by using SPSS software. An ANOVA table was prepared for the analysis of nutritional composition of fodder leaves and Pearson's correlation was analyzed to study the association between different experimental parameters (Sharma, 1998).

Results and Discussion

It was observed that the average value for proximate principles, varied significantly with altitude, site, diameter class and interactions among each other except the AC for the interaction between altitude and diameter class and NFE for diameter class (Table 2-5). It was recorded that there was a considerable variation in the values of proximate principles among altitude and the size of the tree. The difference in chemical composition between species and within genera was associated with the inherent nature of the species (Shekunte *et al*., 2012). A strong variation existed in leaf composition of a tree growing in different localities with the different environmental condition (Kovas *et al*., 1985; Kaushal *et al*., 1986). Other researchers have also worked on the proximate principles of *G. optiva* (Bakshi and Wadhwa, 2004; Osti *et al*., 2006; Hashmi and Waqar, 2014). Variation in proximate principles were also reported earlier in *Grewia optiva* (Jaswal, 1992) and other fodder trees like *Artocarpus lacoocha* (Pandey and Noseberger, 1985), in *Dalbergia sissoo* (Gera *et al*., 2002) and in *Bauhinia variegata* (Thakur *et al*., 2009).

Dry matter: Dry matter was ranged from 59.57% ($A_1S_1D_1$) to 42.79% ($A_3S_3D_3$). Among sites, it was found highest (57.11%) in the S_1 site of higher altitude range (A_1). Thakur *et al.* (2009) showed that the DM was varied from 45.98% to 62.73% in *Bauhinia variegata*. The average highest value for DM was observed at higher altitudes in *Anogeissus latifolia* (Sankhyan *et al*., 2013). Similar results were obtained in the present study for DM. The diameter class with the highest value (51.64%) of DM was observed in D_1. It was found positively correlated with the altitude while negatively correlated with the diameter class. Plant performances are limited by low temperature, high irradiance and strong wind at high altitudes. Therefore, leaf support structure provides laminas with both mechanical support and a pathway for water and nutrient transport. Low temperature limits the transportation efficiency and thus, leaves may require a high investment in the transporting structure (Li *et al*., 2008). High irradiance and strong wind increase the proportion of biomass allocation to leaf support structure (Niklas, 1992; Niinemets and Kull, 1999) and this might be the reason for the higher DM% at A_1 Altitude range.

Table 2. Mean values of proximate principles in leaves of *Grewia optiva* under different altitudes and diameter class

Altitude	Dia. class	Proximate principles					
		DM (%)	EE (%)	CF (%)	CP (%)	Ash (%)	NFE (%)
A_1-Higher (>1600 m)	D_1	54.49	3.16	16.45	13.90	9.80	56.71
	D_2	52.93	3.45	17.77	13.43	9.48	55.88
	D_3	51.79	4.06	18.69	11.93	9.02	56.31
A_2-Middle(1300 - 1600 m)	D_1	52.80	2.44	14.78	16.77	10.51	55.50
	D_2	49.71	2.91	16.31	14.76	10.47	55.54
	D_3	46.15	3.40	17.43	12.58	10.21	56.38
A_3-Lower(1000 - 1300m)	D_1	47.61	2.81	16.55	14.09	10.77	55.78
	D_2	46.79	2.91	16.97	12.97	10.60	56.57
	D_3	44.27	3.98	18.44	12.72	10.31	54.54
Overall Mean of diameter class	D_1	51.64	2.80	15.93	14.92	10.36	56.00
	D_2	49.81	3.09	17.02	13.72	10.18	56.00
	D_3	47.40	3.81	18.18	12.41	9.85	55.74

Table 3. Analysis of variance for proximate principles in leaves of *G. optiva*

Source of variation	Mean Sum of Square						
	DF	DM %	EE %	CF %	CP %	Ash %	NFE %
Altitude	2	316.29**	2.76**	15.99**	21.25**	10.00**	3.23**
Site	2	115.75**	5.60**	10.35**	1.02**	0.49**	10.95**
Diameter	2	121.84**	7.34**	34.39**	42.58**	1.82**	0.56^{NS}
Altitude × Site	4	32.97**	0.96**	5.36**	1.68**	0.35**	6.43**
Altitude × Diameter class	4	10.94**	0.23**	0.85**	5.70**	0.14^{NS}	6.33**
Altitude × Site × Diameter class	8	8.84**	0.40**	2.74**	1.47**	0.25**	2.53**

*Significant at P<0.05; **Significant at P<0.01; NS: Non-significant, DF: Degrees of freedom

Table 4. Mean values of proximate principles under different altitudes, sites, diameter classes and their interactions

Altitude	Site	Diameter	DM (%)	EE (%)	CF (%)	CP (%)	Ash (%)	NFE (%)
A_1 (> 1600m)	S_1	Mean	57.11	2.97	18.86	12.52	9.37	56.29
	S_2	Mean	52.97	4.22	17.61	13.55	9.44	55.21
	S_3	Mean	49.13	3.47	16.45	13.20	9.49	57.40
	Mean of Altitude A_1		**53.07**	**3.55**	**17.64**	**13.09**	**9.43**	**56.30**
A_2 (1300-1600m	S_1	Mean	50.16	2.85	16.78	14.98	10.45	54.93
	S_2	Mean	51.00	3.17	16.61	14.34	10.35	55.52
	S_3	Mean	47.50	2.73	15.13	14.79	10.39	56.96
	Mean of Altitude A_2		**49.55**	**2.92**	**16.17**	**14.70**	**10.40**	**55.81**
A_3 (1000-1300m)	S_1	Mean	47.34	3.17	17.23	12.88	10.41	56.31
	S_2	Mean	45.70	3.88	17.13	13.50	10.29	55.20
	S_3	Mean	45.64	2.65	17.60	13.40	10.96	55.38
	Mean of Altitude A_3		**46.23**	**3.23**	**17.32**	**13.26**	**10.56**	**55.63**
Overall mean of altitude range			**49.62**	**3.23**	**17.04**	**13.68**	**10.12**	**55.91**
Source of variation			**DM (%)**	**EE (%)**	**CF (%)**	**CP (%)**	**Ash (%)**	**NFE (%)**
Altitude (A)			0.61	0.04	0.2	0.19	0.15	0.29
Site (S)			0.61	0.04	0.2	0.19	0.15	0.29
Diameter (D)			0.61	0.04	0.2	0.19	0.15	NS
Altitude (A) × Site (S)			1.05	0.07	0.35	0.33	0.27	0.49
Altitude (A) × Diameter (D)			1.05	0.07	0.35	0.33	NS	0.49
Altitude (A)×Site (S) × Diameter (D)			1.82	0.13	0.61	0.57	0.46	0.85

Ether extract: EE depicted significantly higher value of 3.56% in higher altitude (A_1) and among sites significant higher value (4.22%) was found in site S_2 of higher altitude range (A_1). It was found maximum (3.81%) in D_3 diameter class and corroborated with the results found in *Anogeissus latifolia* by Gupta (2012), where the highest EE content (3.14%) was recorded in the larger diameter class (30-40 cm). EE did not exhibit any type of relationship with the altitude.

Crude fibre: CF content were ranged from 20.94% ($A_1S_1D_3$) to 14.05 % ($A_2S_3D_1$) where altitude range A_1 having significantly higher (17.64%) value. Among sites, the maximum (18.86%) value was exhibited by site S_1 of higher altitude range (A_1). Crude fibre (%) values showed non-significant difference among diameter classes. Values on CF contents were in line with the study on *Celtis australis* leaves (Singh *et al.*, 2010). The low to moderate fiber contents of browse foliage positively influenced their voluntary intake and digestibility in small ruminants (Bakshi and Wadhwa, 2004) and as the percentage of crude fiber increased, digestibility decreased because crude fiber is resistant to decomposition and it often envelops digestible nutrients rendering them unavailable (Maynard, 1937). In our study, the crude fiber% was found lowest (16.17%) in middle altitude A_2 which indicated better digestibility in the ruminant animals.

Table 5. Correlation of proximate principles with altitude and diameter class

Proximate principle	Value of 'r' for altitude	Value of 'r' for diameter class
Dry matter	0.89**	-0.99*
Ether extract	0.13	0.97*
Crude fibre	0.18	0.99*
Crude protein	-0.07	-0.99*
Ash	-0.84**	-0.98*
Nitrogen free extract	0.32	-0.86

*Significant at P< 0.05, **Significant at P < 0.01

Crude protein: Earlier studies indicated that some tree leaves are nutritionally desirable for their crude protein contents (Bissell and Strong, 1955; Oldmeyer *et al.*, 1977), since it is the most important nutrient (Negi, 1986). In our study, CP content showed significant differences among different altitudes and ranged from 17.33% ($A_2S_3D_1$) to 11.50% ($A_3S_3D_3$). Subba (1999) reported that a higher proportion of the CP in the fodder tree leaves is actually in the form available to ruminants and it was found highest (14.70%) in middle altitude (A_2) whereas D_1 holds higher value (14.92%) among diameter classes. Morecroft *et al.* (1992) reported that if the altitudinal gradient increases, the concentration of nitrogen is also increased, but our results did not show any such relation with CP. The variation in crude protein was mainly attributed to the environmental condition (Langille and MeClean, 1976; Jaswal, 1992) or night be a result of the application of various levels of nitrogen fertilizers during farming. An increase in the fiber composition and a decrease in crude protein content of shrub and tree species as the plant matures were also reported earlier (Papachristou and Nastis, 1990; Papachristou and Papanastasis, 1994). Similarly in our study, diameter class or more mature plants showed positive correlation with crude fibre and negative correlation with crude protein.

Ash content: It was reported that mineral concentrations in both soils and plants affect the mineral status of grazing livestock (Towers and Clark, 1983). The ash content of the leaf is the inorganic residue, which provides a measure of the total amount of minerals within a leaf fodder which supplement the mineral requirement of livestock. It was found maximum (11.48%) in $A_3S_3D_1$ and minimum (8.66%) in $A_1S_1D_3$. Results revealed that the lower altitude (A_3) showed significantly higher (10.56 %) ash content and found declining as elevation increased and was consistent with study of Saklani (1999) in *Quercus leucotrichophora,* where a significant inverse correlation between ash content and altitude was reported. It was described that low temperature might influence soil nutrient availability by reducing soil microbial activities and mineralization rate, which probably be the cause of low amount of ash content in plant at higher altitude (Vitousek and Farrington, 1997; Brady and Weil, 2004). The D_1 diameter class had the highest value (10.36%) among three diameter classes compared.

Nitrogen free extract: NFE significantly varied from 59.47% ($A_1S_3D_3$) to 52.93% ($A_3S_2D_3$). McCreary (1927) reported that NFE increased with increase in altitude, but in our case, no such trend was observed. The results showed the highest mean value of NFE at higher altitude in the manner of increasing from lower, similar results were also reported by Singh and Todaria (2012) in *Quercus semicarpifolia* leaves collected for evaluation of chemical composition at different altitudes.

Conclusion

The study revealed that the proximate principles of leaves of *G. optiva* are significantly influenced by the altitudinal gradient and diameter class. Among three altitude ranges, the mid altitude range showed highest crude protein and lowest crude fiber content and good ash content. But the higher altitude showed the highest value for dry matter content, ether extract, crude fiber and nitrogen free extract content. Among three diameter classes, 10-20 cm diameter class was found superior in all the fodder quality parameters except ether extract. The results indicated that the trees from the mid altitude range had relatively more nutritious leaves compared to other altitude ranges and should be harvested for the better nutrition of the animal in Garhwal Himalaya. It was noticed from the study of variation in fodder quality parameters that there were sites available where trees of this species had higher nutritional potentials than the others. Hence, it was also suggested that the improvement programme should also be considered to harvest the potential of this species in this region.

Acknowledgement

The authors wish to thank the College of Forestry, Ranichauri for the financial assistance and the faculties of the Department of Forestry whose consistent guidance made this work possible. This study would not have been possible without the cooperation of my classmates, both during collection of samples and analysis. I am also thankful to Madam Rajni Ramola for the help during laboratory work.

References

AOAC 1995. *Official Methods of Analysis*. Association of Official Analytical Chemists. 16th ed. Arlington, VA, USA.

Bakshi, M.P.S. and M. Wadhwa. 2004. Evaluation of forest tree leaves of semi-hilly arid region as livestock feed. *Asian-Australasian Journal of Animal Science* 17: 777-783.

Bijalwan, A. 2013. Vegetation status of agroforestry systems in Tehri district of Garhwal Himalaya, India. *Asian Journal of Science and Technology* 4: 11-14.

Bissell, H.D. and H. Strong. 1955. The crude protein variations in the browse diet of California deer. *California Fish and Game* 41: 145-155.

Brady, N.C. and R.R. Weil. 2004. *Elements of the Nature and Properties of Soils*, Prentice Hall, New Jersey.

Gera, M., N. Gera, R. Agarwal, and B.N. Gupta. 2002. Genetic variation in biochemical contents in foliage of twenty seed sources of *Dalbergia sissoo* Roxb. *The Indian Forester* 128: 726-737.

Gupta, T. 2012. Variability studies for morphological and fodder quality traits of *Anogeissus latifolia* Wall. in Himachal Pradesh. Ph.D. Thesis, Dr. Y.S. Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh, India.

Hashmi, M.M. and K. Waqar. 2014. Nutritional evaluation of *Grewia optiva* and *Grewia populifolia* in different seasons and sites of Chakwal district in Pakistan. *European Academic Research* 2: 5047-5057.

Jaswal, S. C. 1992. Seed sources studies in *Grewia optiva* Drummond: an agroforestry tree species. Ph.D. Thesis, Dr. Y.S. Parmar University of Horticulture and Forestry, Solan Himachal Pradesh, India.

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.

Kaushal, A.N., J. Rattan and S.D. Bhardwaj. 1986. Effect of locality, tree size and season on nutrient of *Robinia pseudoacacia* L. leaves in Himachal Pradesh. *Journal of Tree Science* 5: 43-46.

Kovas, M., J. Podhani, P. Klinczek, M. Dinka and K. Torok. 1985. Urban ecology. In: R. Borbkamm, J.A. Lee and M.R.D. Seaward (eds). *Element Composition of the Leaves of Some Deciduous Trees and the Monitoring of Heavy Metals in an Urban Industrial Nnvironment*, New York, Oxford, U.K.

Langille, W. M. and K. S. MeClean. 1976. Some essential nutrient elements in forest plants as related to species, plant part, season and location. *Plant and Soil* 45: 17-26.

Li, G., D. Yang and S. Sun, 2008. Allometric relationships between lamina area, lamina mass and petiole mass of 93 temperate woody species vary with leaf habit, leaf form and altitude. *Functional Ecology* 22: 557–564.

Maynard, L. A. 1937. Interpretation of variations in plant composition in relation to feeding value. *Journal of the American Society of Agronomy* 29: 504-511.

McCreary, O. 1927. Wyoming forage plants and their chemical composition. *Wyoming Experiment Station Bulletin* 157: 91-105.

Morecroft, M.D., R.H. Marrs and F.I. Woodward. 1992. Altitudinal and seasonal trends in soil nitrogen mineralization rate in the Scottish highlands. *Journal of Ecology* 80: 49-56.

Mukherjee, A., T. Modal, J.K. Bist and A. Pattanayak. 2018. Farmers' preference of fodder trees in mid hills of Uttarakhand: A comprehensive ranking using analytical hierarchy process. *Range Management and Agroforestry* 39: 115-120.

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, Himachal Pradesh, India, pp. 111-120.

Niinemets, Ü. and O. Kull. 1999. Biomass investment in leaf lamina versus lamina support in relation to growth irradiance and leaf size in temperate deciduous trees. *Tree Physiology* 19: 349–358.

Niklas, K.J. 1992. *Plant Biomechanics: An Engineering Approach to Plant Form and Function*. University of Chicago Press, Chicago.

Oldmeyer, J.L., A.W. Franzmann, A.L. Brundage, P.D. Arneson and A. Flynn. 1977. Browse quality and the Kenai moose population. *Journal of Wildlife Management* 41: 533-542.

Osti, N.P., C.R. Upreti, N.P. Shrestha and S.B. Pandey. 2006. Review of nutrients content in fodder trees leaves, grasses and legumes available in buffalo growing areas of Nepal. In: Proc. *5th Asian Buffalo Congress* (April 18-22, 2006), Nanning, China. pp. 366-371.

Panday, K.K. and J. Noseberger. 1985. Nutrient contents of the leaves of the fodder tree *Artocarpus lacoocha* Roxb. *Agroforestry Systems* 3: 297-303.

Papachristou, T.G. and A.S. Nastis. 1990. Nutritive value of two broad leaved fodder trees (*Carpinus duinensis* L. and *Fraxinus ornus* L.) in early summer and autumn. In: Proc. *6th Meeting of FAO Sub Network on Mediterranean Pastures and Fodder Crops* (Oct. 17-19, 1990), Bari, Italy. pp. 147-151.

Papachristou, T.G. and V.P. Papanastasis. 1994. Forage value of Mediterranean deciduous woody fodder species and its implication to management of silvo-pastoral systems for goats. *Agroforestry systems* 27: 269-282.

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.

Saklani, K.P. 1999. Altitudinal and seasonal variation in relation to fodder quality of oak (*Quercus leucotrichophora.* A. Camus ex. Bahadur) in Garhwal Himalaya. Ph.D. Thesis, H.N.B. Garhwal University, Uttarakhand, India.

Sankhyan, H.P. and S. Bhagta. 2016. Fodder quality analysis of open pollinated seedling seed orchard of *Grewia optiva* Drommond. *The Bio Scan* 11: 709-713.

Sankhyan, H.P., N.B. Singh, R. Bawa and T. Gupta. 2013. Variability in fodder quality traits of *Anogeissus latifolia* Wall. in Himachal Pradesh. *The Indian Forester* 139: 1017-1023.

Sharma, J.R. 1998. *Statistical and Biometrical Techniques in Plant Breeding*. New-Age International Publication Pvt. Ltd. New Delhi. pp. 432.

Shekunte, B., A. Hassen, T. Assafa, N. Amen, and A. Ebro. 2012. Identification and nutritive value of potential fodder trees and shrubs in the mid Rift valley of Ethiopia. *Journal of Animal and Plant Sciences* 22(4): 1126-1132.

Singh, B. and N.P. Todaria. 2012. Nutrients composition changes in leaves of *Quercus semecarpifolia* at different seasons and altitudes. *Annals of Forest Research* 55: 189-196.

Singh, B., B.P. Bhatt and P. Prasad. 2010. Altitudinal variation in nutritive value of adult- juvenile foliage of *Celtis australis* L.: A promising fodder tree species of Central Himalaya, India. *Journal of American Science* 6: 108-112.

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

Subba, D.B. 1999. Tree fodder and browse plant as potential nutrition suppliers for ruminants. In: Proc. *3rd National Workshop on Livestock and Fisheries Research in Nepal* (R.C. Khanal, and S.P. Neopane, eds). National Animal Science Research Institute, Nepal Agricultural Research Council (NARC) (June 26-28, 1999), Khumalter, Lalitpur, Nepal. pp. 1-14.

Suri, S.K. and S.S. Dalal. 1963. Study of some vegetational factors of *Shorea robusta* (Sal). *The Indian Forester* 89: 134-141.

Thakur, I.K., K.C. Chauhan and A. Wani. 2009. Estimation of mineral nutrients and proximate principles in the progeny of *Bauhinia variegate* tree. *Indian Journal of Forestry* 32: 85-90.

Towers, N.R. and R.G. Clark, 1983. Factors in diagnosing mineral deficiencies. In: *The Mineral Requirements of Grazing Ruminants*. Occasional Publication No 9, New Zealand Society of Animal Production.

Vitousek, P.M. and H. Farrington. 1997. Nutrient limitation and soil development: experimental test of a biogeochemical theory. *Biogeochemistry* 37: 63-75.