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Nutrients composition changes in leaves of *Quercus semecarpifolia* at different seasons and altitudes

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Abstract. *Quercus semecarpifolia* J.E. Smith leaves were collected for evaluation of chemical composition between four seasons i.e before growing season, after growing season, on growing season, on late maturity, respectively, in 2008-2009 from five geological isolated sites ranging from 2450 to 2725 m a.s.l. Seasonal variability ($p < 0.01$) was found in the chemical composition of the *Q. semecarpifolia* foliage. Dry matter and Ash Content significantly decreased in July (after growing season) as compared to the other months. Crude protein (CP) and phosphorus (P) contents significantly increased before growing season (January) and after growing season (July), finally declined in late maturation in October. Calcium contents and soluble protein (SP) significantly decreased before growing season (January) to late maturity (October), Ether extract (EE) decreased before growing season (January), after growing season (July) but increased in late maturity (October). Ash contents, CP, EE, P and SP exhibited significant variation among populations. CP was significantly higher in middle to higher altitudinal populations. P significantly decreased with increasing altitude. The rest of the studied mineral contents did not show any trend in the present study. The nutritive value of the leaves of *Q. semecarpifolia* was continually changing, especially CP and soluble protein. *Q. semecarpifolia* harvested at the proper stage of maturity (winter months) offers considerable potential as high quality forage for livestock to fulfill the deficiency of protein.
Keywords *Quercus semecarpifolia*, altitude, seasonal variation, composition changes.

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Introduction

Trees and shrubs have been used for centuries as fodder, fuel, timber in many parts of the world (Smith 1992, Kababya et al. 1998, Perevolotsky et al. 1998). Tree leaves are an important feed of livestock (Holechek 1984, Papachristou & Nastis 1996, Saklani 1999) and play an important role in the nutrition of livestock in areas where few or no alternatives are available (Meuret et al. 1990). However use of tree and shrub leaves by livestock is restricted by defending or inhibitory mechanisms due to the high tannin content (Provenza 1995, Rubanza et al. 2003, Bakshi & Wadhwa 2004). Oak leaves and twigs are often grazed by animals or lopped to use as livestock fodder during fodder deficit periods (Singh et al. 1996, Saklani 1999). *Q. semecarpifolia* leaf contents are: CP (9.49), OM (94.86), EE (4.07), NDF (64.20), ADF (50.60), Ca (1.60), P (0.2) and tannins (4.40) on %DM basis (Singh et al. 1998). Its leaves can be used as a fodder source for maintenance and to support a little growth in pashmina goat kids provided supplemented with minerals. Paul et al. (2006) recorded higher total extractable phenols in younger leaves of *Quercus semecarpifolia* as compared to old ones. In *Q. semecarpifolia,* the apparent degree of polymerisation increased, and the content of protein, phenolics and specific activity decreased as the leaves getting matured (Paul et al. 1991).

As in many other regions of the world, farmers in the Garhwal Himalaya region of Indian Himalaya depend largely on this for sustaining their livestock (during winter and summer season) for almost half of the year. The dependence is very high (>70%) during the period, beginning from October to February (Verma and Mishra, 1999). Owing to changing climatic conditions, a farmer's preference for a particular tree species is also variable, according to the low, mid and high hill regions depending on where he lives (Verma et al. 1989).

Fodder availability in hill villages of Uttarakhand Himalayan region is insufficient and a part of it is supplemented through lopping of tree foliage. Knowledge of mineral nutrient concentrations of the foliage, at different time during a growth season can be used as one indicator to determine the appropriate lopping period of a particular tree species, in a defined agro-climatic region. *Q. semecarpifolia* J.E. Smith is a commonly preferred fodder tree species of temperate region of Uttarakhand. Its foliage provides fodder for the livestock during critical periods (winter), when quality and quantity of pasture herbages is limited.

There is little information about the compositional changes in nutritive value of *Quercus semecarpifolia* leaves with respect to altitude and season. The aim of this study was to determine the effect of season (maturity stage) on the nutritive value of *Quercus semecarpifolia* in terms of chemical composition.

Materials and methods

Tree leaf samples

To assess the nutrient composition change in leaves of *Q. semecarpifolia,* foliage was harvested from five sites ranging from 2450 to 2725 altitude (mean above sea level), situated between 30°26' to 30°40'29.4'' N latitude and 78°29'50'' to 79°16' E longitude (Table 1). Leaf samples were collected at 90 days intervals between January, April, July, and October (before growing season, after growing season, growing season, late maturity, respectively) in 2008. Leaves from the top, middle and lower part of the canopy were hand harvested from all four directions, at least from five different trees, which were pooled to make a composite sample. Collected leaves were sun dried. Sun dried leaves were crushed in mechanical grinder to obtain fine powder for determination of the chemical composition. Each composite leaf sample was divided into five groups, to make five replication.

The dry matter (DM), crude protein (CP), crude fibre (CF), ether extracts (EE) and ash were estimated following the procedure of Association of Official Analytical Chemist (A.O.A.C.)(1995). CF was estimated in defatted samples. Calcium (Ca) was estimated as per the procedure of Underwood (1977) and the estimation of phosphorus (P) was carried out as per the method described by Okaebo et al. (1993). Soluble protein was estimated as described by Bradford (1978).

In dried leaf samples ash, EE, CF and CP contents were determined according to the procedure of AOAC (1995), from which the Nitrogen Free Extract (NFE), Organic Matter (OM) and Total Carbohydrate (TC) were estimated as follows.

Nitrogen Free Extract. The nitrogen free extract or carbohydrate of the samples was calculated by using following formula:

NFE% = 100 – (%CP + %EE + %CF + %Ash)

Organic matter (*OM*). The organic matter of the samples was calculated by using following formula:

OM = CP + EE + CF + NFE

Total carbohydrate (*TC*). The total carbohydrate of the samples was calculated by adding the percentage of crude fiber and the percentage of nitrogen free extract.

TC = %CF + %NFE

Statistical analysis

Statistical analysis was done using SPSS software package, 10.0.1 (SPSS Inc., Chicago, USA). Variation in nutrient composition of the foliages was analyzed by ANOVA. The model included altitude and season as a source of variation. Pearson's correlation analysis was performed to study the association between different experimental parameters (Sharma 1996).

Results

Effect of the season

The nutritive value of *Q. semecarpifolia* leaves recorded in four seasons is shown in (Table 2). On average, the ash percent in the foliage varied from 3.36 to 4.47, with the greatest value in the April (growing season). The crude protein content concentration was significantly higher in July (after growing season), whereas ether extract was higher before growing season (January). The crude fibre content concentration was maximum (54.78%), during the growing season, and a significant decrease was recorded from July (33.21% after growing season) to October (37.58% late maturity). The P concentration in leaves was maximum (0.16%) in July (after growing season) which later decreased to 0.12% in October, the lowest value of 0.10% was observed in January. The Ca concentration decreased during growing season and leaf fall. NFE, OM and TC (52.01%), (96.64%) and (85.22%) respectively were higher in July. SP concentration in foliage showed accumulating trend over season relative to leaf fall (Table 2).

Effect of the altitude

The concentration of DM in the leaves var-

Table 1 Geographical description of foliage collection sites

Provenance	District	Altitude (m a.s.l.)	Latitude (N)	Longitude (E)
Chaurangikhal	Uttarkashi	2450	30°40'29.4"	79°02'32"
Jungle chetti	Rudraprayag	2525	30°38'41"	78°29'50"
Trijuginarayan	Rudraprayag	2575	30°38'29"	78°58'38"
Kasturgamirgbihar	Chamoli	2675	30°26'	79°16'
Dugalbita	Rudraprayag	2725	30°29'15"	79°10'28"

ied from 52.17 to 67.44% with mean value 61.36 %, regardless of the altitude. Ash content ranged from 3.69 to 4.07% with maximum value in the Trijuginarayan population. Dugalbita population had highest crude protein and EE contents. The crude fibre and P contents varied from 40.62% (Dugalbita population) to 47.43% (Jangle chetti population) and 0.15% (Chaurangikhal population) to 0.12% (Dugalbita population) respectively. On average, the crude fibre and P contents in *Q. semecarpifolia* were recorded 42.81 % and 0.13 % respectively, regardless of the altitude (Table 3). Calcium contents ranged from a maximum of 1.82% in Jungle chetti population to a minimum of 1.74% in the Dugalbita population. Regardless of the population, the calcium content in the foliage was recorded 1.77% (Table 3).

The NFE, OM and SP contents were recorded maximum 44.26, 96.31 and 0.77% respectively in the Kasturgamirgbihar population. Similarly, TC content was highest (85.27 %) in the Jungle chetti population and lowest (83.98 %) in Trijuginarayan population (Table 3).

Correlation coefficients were tested between altitude of foliage collection and nutritive values. Significantly ($p < 0.01$) negative correlation was recorded between ash and phosphorus content with altitude (Table 3). While, crude protein and soluble protein were significantly ($p < 0.05$) positively correlated with altitude. Similarly organic matter was also significantly positively correlated with altitude (Table 3).

One-way ANOVA showed that all studied nutritive value parameters were significantly affected by season ($p < 0.01$). The analysis of variance also showed that AC, CP and EE contents significantly varied ($p < 0.01$) among the populations, while CF and SP also significantly ($p < 0.05$) varied among the populations (Table 4).

Discussion

The present study revealed that altitude as well as season significantly influenced the chemical composition of *Quercus semecarpifolia* foli-

Table 2 Analysis of variance for nutritive value of *Q. semcarpifolia*

		Mean sum of Square										
	Df	DM%	A C%	C P%	EE%	CF%	P%	Ca%	NFE %	OM%	SP%	TC%
Altitude	4	0.88	14.42**	5.03**	8.64**	2.44	3.33*	0.51	2.09	0.88	5.35*	2.80
Season	3	8.77**	35.64**	47.95**	16.53**	34.55**	12.62**	87.43**	36.59**	8.77**	147.97**	174.72**

Note: * significant at $p < 0.05$, significant at $p < 0.01$. Abbreviation: DM - dry matter, AC - ash contents, CP - crude protein, EE - ether extract, CF - crude fibre, P - phosphorus, Ca - calcium, NFE - nitrogen free extract, OM - organic matter, SP - soluble protein, TC - total carbohydrates.

Table 3 Effects of season on nutritive value of *Q. semecarpifolia* foliage, irrespective of altitudinal variation

Season	D M %	A C %	C P %	EE %	CF %	P %	Ca %	NFE %	O M %	SP %	TC %
January	64.29[a]	3.98[b]	8.39[b]	**3.62[a]**	45.70[ab]	0.10[c]	**2.25[a]**	38.31[bc]	96.02[bc]	0.60[b]	84.01[b]
April	**69.30[a]**	**4.47[a]**	8.38[b]	2.72[b]	**54.76[a]**	0.14[ab]	1.96[a]	29.66[c]	95.53[c]	0.66[ab]	84.42[b]
July	50.28[b]	3.36[c]	**9.22[a]**	2.20[b]	33.21[c]	**0.16[a]**	1.46[b]	**52.01[a]**	**96.64[a]**	0.76[ab]	**85.22[a]**
October	61.56[a]	3.65b[c]	9.18[a]	2.65[b]	37.58[bc]	0.12[bc]	1.42[b]	46.94[ab]	96.35[ab]	**0.92[a]**	84.52[b]

Note: * significant at $p < 0.05$, ** significant at $p < 0.01$. Means followed by the same letter are not significantly dif ferent ($p < 0.05$) . Abbreviations: DM - dry matter, AC - ash contents, CP - crude protein, EE - ether extract, CF - crude fibre, P - phosphorus, Ca - calcium, NFE - nitrogen free extract, OM - organic matter, SP - soluble protein, TC - total carbohydrates.

age. Leaves of *Q. semecarpifolia* are harvested in lean period or during the scarcity of other green foliage. However, season of harvesting (Bhandari et al. 1979, N.C.A., 1976, Pal et al. 1979, Singh 1982) and source of collection (Morecroft et al. 1992b, Woodward 1986, Friend et al. 1989, Korner 1989, Vitousek et al. 1990) influence the chemical composition of tree foliage. Therefore, foliage has been harvested seasonally from five different sources to see the effect of season and altitude on chemical composition and nutritive values of *Q. semecarpifolia* foliage. Average nutritive value of *Q. semecarpifolia* foliage recorded in the present study is well within the range as reported by Singh et al. (1998).

Other researchers have also reported seasonal patterns in the concentration of nutrients in the tree foliage (Mead & Will 1976, Carlyte & Malcolm 1986, Ralhan & Singh 1987, Negi 1986, Saklani 1999). Further altitudinal and seasonal variation in nutritive values of fodder species has also been documented elsewhere (Mauffett & Oechel 1989, Woodward 1986, Field & Mooney 1986, Evens 1989). The results of the present study also revealed significant seasonal variability in mineral content composition. In earlier study, Verma & Mishra (1999) reported that N, and P concentration decreased with the advancement of growing season towards the leaf fall. Our findings are in agreement with this study. In the present study, CP and P content concentration was decreased in winter months after maturation. The decrease in the foliage nutrient concentration over the growing season has been attributed generally to the dilution effect, i.e., the rate of inflow of nutrient into the leaves may be lower than the amount of dry matter produced at a particular growth stage. Increase in Ca concentration in the foliage of *Q. semecarpifolia* also follows patterns reported in earlier studies (Tamm 1951, Hoyle 1965, Verma et al. 1992). Kamalak et al. (2005). In these studies it was reported that ether extract (EE) increased with increasing maturity, whereas the crude protein (CP) and ash content decreased. But, in the present study EE decreased with increased maturity, whereas crude protein increased with increasing maturity.

Morecroft et al. (1992a) reported that nitrogen concentration in plants increased with the altitudinal gradient. The present findings are also in agreement with earlier findings of Morecroft et al. (1992a). Maximum level of crude protein in spring season has also been recorded in *Quercus serrata* foliage (Ponnuvel et al. 1996). But in the present study maximum crude protein was recorded in the month of July (Rainy season). Significant variations

Table 4 Effects of altitude on nutritive value of *Quercus semecarpifolia*, irrespective of seasonal variation

Altitude (m)	Provenance	D M %	A C %	C P %	EE %	CF	P %	Ca %	NFE %	O M %	SP %	TC %
2450	Chaurangikhal	52.17^{c}	4.07^{a}	8.58^{d}	2.77^{bc}	40.70^{c}	0.15^{a}	1.75^{b}	43.88^{a+b}	95.93^{b}	0.72^{c}	84.58^{b}
2525	Jungle chetti	63.43^{ab}	3.95^{a}	8.69^{cd}	2.09^{d}	47.43^{a}	0.14^{ab}	1.82^{a}	37.84^{d}	96.05^{b}	0.72^{c}	85.27^{a}
2575	Trijuginarayan	67.44^{a}	3.93^{a}	8.90^{ab}	3.19^{ab}	41.89^{b}	0.13^{bc}	1.75^{b}	42.09^{bc}	96.07^{b}	0.73^{bc}	83.98^{c}
2675	Kasturga-mirgbihar	63.45^{ab}	3.69^{b}	8.78^{bc}	2.65^{cd}	40.62^{c}	0.12^{c}	1.79^{a}	44.26^{a}	96.31^{a}	0.77^{a}	84.88^{ab}
2725	Dugalbita	60.30^{b}	3.69^{b}	9.02^{a}	3.29^{a}	43.43^{b}	0.12^{c}	1.74^{b}	40.58^{c}	96.31^{a}	0.75^{ab}	84.01^{c}
Mean		61.36	3.87	8.79	2.80	42.81	0.13	1.77	43.88	96.13	0.74	84.54
‘*r*’		0.43	-0.98**	0.84*	0.46	-0.07	-0.97**	-0.17	0.06	0.98**	0.84*	-0.35

Note: * significant at $p < 0.05$, ** significant at $p < 0.01$, Means followed by the same letter are not significantly ($p < 0.05$) different. Abbreviations: DM - dry matter, AC - ash contents, CP - crude protein, EE - ether extract, CF - crude fibre, P - phosphorus, Ca - calcium, NFE - nitrogen free extract, OM - organic matter, SP - soluble protein, TC - total carbohydrates.

in nitrogen, phosphorus, potassium, calcium and magnesium in the foliage of *Albizia lebbek* provenances have been observed by Kumar and Toky (1994). Seasonal variations in ash, crude protein and protein precipitation of Arto*carpus lakoocha* and *Quercus spp.* foliage have also been recorded by Wood et al. (1995). Kamalak et al, (2005) reported that ether extract (EE) in *Gundelia tournefortii* increased with increasing maturity which was in agreement with the present study.

The continuous supply of protein is required by ruminant animals if they have to maintain a normal metabolism. Rumin bacteria require a minimum of 6-8% of crude protein for efficient fermentation of plant tissue (NAS 1981, Van Soest 1982). Considering this, all the populations and seasons provide at least the required amount of protein. During the course of the present study, significant seasonal variations in crude protein content were recorded (Tables 2-4). Variation in protein content may partly be attributed to re-translocation of leaf nitrogen into branches before leaf fall and partly due to a dilution factor with expansion and maturity of the leaves (Khosla et al. 1992). It is well established that animal production is reduced, as the quality of forage declines with plant development and maturity over the growth period (Steen 1992). Generally as plant mature, CP decreases, fibre increases, while digestibility and energy content decline.

Conclusions

The study showed that chemical composition of *Q. semecarpifolia* foliage is significantly influenced by season. Nutritive values from all the populations exhibited considerable variation. However, altitude also play an important role in the nutritive value of *Q. semecarpifolia*. Crude protein, phosphorus, nitrogen free extracts, organic matters and total carbohydrates were higher in July while, ash contents, dry matter, crude fibre and soluble sugars were higher in April.

These findings also suggested that among various populations, middle to higher altitudinal populations exhibited comparatively higher values for crude protein, ether extract, ash content, soluble sugars and soluble protein. Thus, these populations should be selected for collection of the nutritive fodder for the livestock by the mountain villages. Harvesting stage (maturity) is an important factor affecting nutritive value of *Q. semecarpifolia* leaves. Its leaves harvested at the correct stage of maturity offers considerable potential as high quality forage for live stock during winter feeding season.

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