Litter production pattern and nutrients discharge from decomposing litter in an Himalayan alpine ecosystem

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Abstract: The amount of standing litter biomass varied both in the protected and unprotected sites and was maximum in the protected area. The mineral nutrients concentration *viz*., organic carbon, total nitrogen, total potassium and total phosphorus was also found maximum in the protected area compared to the unprotected area. Also, total nutrient concentration released to soil was also maximum by the protected sites than the unprotected sites. In the present communication, an attempt has been made to study the litter production pattern and nutrients discharge from decomposing litter in an Himalayan alpine ecosystem. [New York Science Journal. 2009;2(6):54-67]. (ISSN: 1554-0200).

Keywords: Alpine, litter, nutrient concentration, nutrient discharge, PRs (protected sites), UNPRs (unprotected sites).

Introduction:

The importance of forest floor components to productivity is well known. The dead organic matter (litter) is one of the most important pathways for the nutrients to the soil surface. Agren and Bosatta (1996) described litter as 'the bridge between plant and soil'. It represents an energy source of heterotrophic organisms, a nutrient reservoir for cycling and a factor influencing hydrology (Christensen, 1975; Chapman *et al*., 1975). Litter on the soil surface intercepts and stores a certain amount of precipitation thus reduce run - off and soil erosion. On the forest floor, it is the imperative link between the autotrophs and heterotrophs (Bray and Gorham, 1964), reduces bulk density, increase water holding and cation - exchange capacity of soil and serves as reserve store of plant nutrients (Hoyle, 1973). Forests litter is an important stage in habitat conservation providing nutrient return and organic matter replenishment (Ashton, 1975). The standing state of litter provides an estimate of the net production of the vegetation (Golly, 1978). Besides having enormous utilities to the ecosystem, the litter paradox yet needs to be explored.

Litter production varies with climate, season, substrate quality and type of vegetation (Hobbie, 1992; Melillo *et al*., 1982; Upadhyay *et al*., 1989; Vitousek *et al*., 1994). Chemical composition of litter, which changes with type of plant community, influences structure and activity of microbial communities inhabiting soils (Kutsch & Dilly, 1999), and biological and physico - chemical properties of topsoil (Heal

& Dighton, 1986). Knowledge of litter production is important when estimating nutrient turnover, C and N fluxes, and C and N pools in different ecosystems.

Litterfall production is related to environmental factors (Finer, 1996; Florence and Lamb, 1975; Kozlowski *et al*., 1990; Hart *et al*., 1992), the vegetation biomass and plant community composition (Pedersen and Hansen, 1999; Hosking, 2003). Because litterfall production reflects the interactions between biological heredity of plants and the influence of environmental fluctuations, litterfall production can be perceived as an indicator of forest condition (Pedersen and Hansen, 1999). Evaluation of litterfall production is also important for understanding nutrient cycling, carbon fluxes and disturbance ecology. For example, significant accumulation or reduction of litterfall amount in some forest communities can cause changes in frequencies of wildfire disturbance (Edmonds *et al*., 2000). The main emphasis in earlier litterfall studies was placed on the amount, composition (Chandler, 1943; Viro, 1955) and distribution (Kittredge, 1948) (summarized by Pedersen and Hansen, 1999). More recently, this literature has shifted to evaluating the ecological role of litterfall in nutrient cycling in forests (Bringmark, 1977; Waring and Schlesinger, 1985; Stevens *et al*., 1989; Haase, 1999; Gordon *et al*., 2000; Zimmermann *et al*., 2002) and its interactions with biotic and non - biotic variables (Prescott *et al*., 2000; Ca´rcamo *et al*., 2000; Trofymow *et al*., 2002; Prescott *et al*., 2004). This shift is important for understanding litterfall production patterns along forest development stages and environmental gradients. For example, based on numerous studies in litter production from world forests, Bray and Gorham (1964) and Albrektson (1988) found that annual litterfall production increased rapidly during stand development until canopy closure, and then remained relatively constant over a long period of time before decreased in old stands. In another study Xiao *et al*. (1998) used data on litterfall and its relationship to environmental variables to calibrate the Terrestrial Ecosystem Model for assessing the sensitivity of net ecosystem production of the terrestrial biosphere to transient changes in atmospheric CO_2 concentrations and climate. The monthly litterfall production pattern is mainly controlled by community characteristics and environmental factors (Huebschmann *et al*., 1999; Sundarapandian and Swamy, 1999; Lu and Liu, 1988; Kavvadias *et al*., 2001; Pedersen and Hansen, 1999). Finer (1996) reported that litterfall in September was 41% of the annual total due to high effective temperature totals. Our results show that litterfall production amounts were much higher in hot and wet months (from April to September) than the rest of year for all studied forests, which is also consistent with studies of similar vegetation types and nearby areas (Chen *et al*., 1992; Tu *et al*., 1993; Weng *et al*., 1993).

Litter production and nutrient release are controlled by a wide variety of chemical properties of the litter, including nitrogen (N) concentration, C : N ratio, phosphorus (P) concentrations or C : P ratio, phenolics concentration and phenolics to N or P ratio and lignin concentration or lignin to N ratio (Coulson and Butterfield, 1978; Meentemeyer, 1978; Schlesinger and Hasey, 1981; Mellilo *et al*., 1982; Berg, 1984; Taylor *et al*., 1989; Van Vuuren *et al*., 1993; Vitousek *et al*., 1994; Aerts and De Caluwe, 1997a; Shaw and Harte a & b, 2001). Litter nutrients release not only depends upon litter composition but also upon soil type, microbial communities and soil properties (Kutsch& Dilly, 1999; Scholes & Walker, 1993; Vitousek & Matson, 1984).

Several studies have been carried out on various aspects of litter in various forest types throughout the world and in India by several workers *viz*., George and Varghese (1990), Gupta and Rout (1992), Pant and Tiwari (1992), Shaver *et al.* (1992), Khiewtam and Ramakrishnan (1993), Pande and Sharma (1993), Das *et al.* (1993), Upadhyay (1993), Visalakshi (1993), Vitousek *et al*. (1994), Woodwell (1994), Chapin *et al*. (1995), Hobbie (1996), Nautiyal (1996), Cadish and Giller (1997), Aerts (1997), Singh and Upadhyay (1997), Singh, Srivastava and Singh (1997), Aerts and Chapin (2000), Gopikumar (2000), Pande *et al.* (2000), Hobbie and Vitousek (2000), Harmon *et al*. (2000), Shaw and Harte a & b (2001), Bahar *et al.* (2001), Lodhiyal *et al.* (2002), Loranger *et al.* (2002) and Aerts *et al.* (2003). Some studies on litter nutrients have been carried out by Venkataramanan *et al*. (1983) and George and Varghese (1990) in India. However, information on litterfall patterns and nutrient release from forests of Garhwal Himalaya, especially from the alpine Himalaya is still in small pockets.

Material and Methods

1. **Field inventory**: We conducted our study in Tungnath, Garhwal Himalaya, Uttarakhand, India. The area lies between 30°14’ N Latitudes and 79°13’ E Longitudes of Western Himalaya and at altitudes between 3400 m and 3750 masl forming two well famed summits *viz*., Rawanshila (3500 m) and Chandrashila (3750 m). Like other alpine and arctic zones of the globe, the climate of this alpine zone is cold, with

intense irradiance and low partial gas pressure. Heavy frost, blizzards and hailstorms prevail throughout the year except for a few months of summer. The timberline in this area reaches upto 3200 m altitude especially on west and north aspects. The meadows here are gentle at the base, becoming gradually steeper until they form summits. Meadows with deep soil cover are seen in northern aspects, while the southern faces generally have large rock spurs and crevices are either barren or have a few lithophytes. The important species of timber line are *Quercus semecarpifolia*, *Abies pindrow*, *Betula alnoidis* and *Rhododendron campanulatum* (Sundriyal and Joshi, 1990; 1992). Above and beyond the tree line, the region is predominated by herbaceous cushion plants. A total of 280 species with 157 genera and 50 families have been reported from this alpine zone (Semwal and Gaur, 1981; Nautiyal *et al*., 2001).

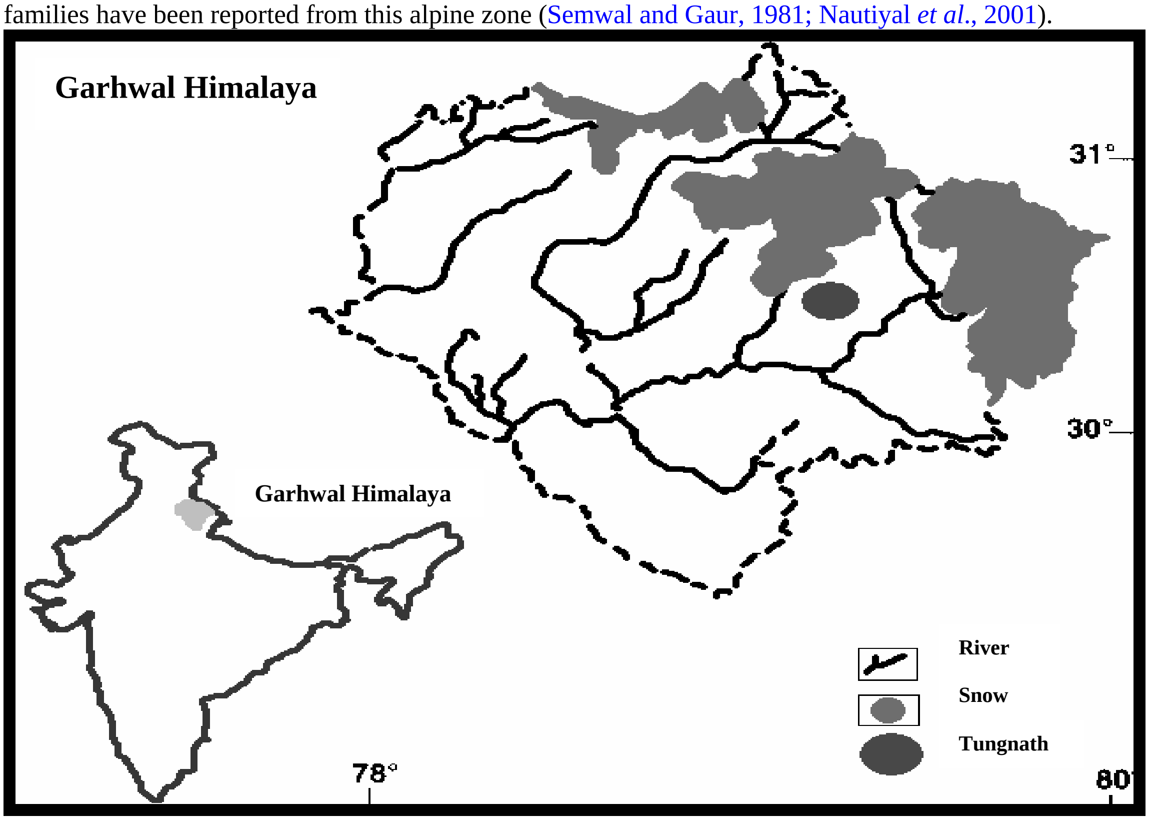

Figure 1. Location map of the study area

2. **Climatological features**: Climatological observations are being presented in Figure 2 - 4. Maximum temperature was recorded in June (26.65 ^{0}C) wherein minimum in October (3.37 ^{0}C). Highest humidity was recorded in August (81.42 %) wherein lowest in June (50.23 %). Maximum rainfall was recorded in July (700.80 mm) wherein minimum in October (88.00 mm). Likewise, number of rainy days were again recorded highest in July (28.00) wherein lowest in October (9.00).

3. **Site description**: The investigations were carried during the growth period (May – October, 2005). Six sites located on different topographical positions were selected. The sites were marked as protected (PR 1, PR 2, PR 3) and unprotected (UNPR 1, UNPR 2, UNPR 3).

Sites	Site characteristics		
	Global position	Altitude (masl)	Aspect
PR 1	N 30^0 29.509' E O79^0 13.110'	3279	North East
PR 2	N 300 29.524' E O79^0 13.090'	3256	North East
PR 3	N 30^0 29.542' E O79^0 13.077'	3243	North East
UNPR 1	N 30^0 29.488' E O79^0 13.081'	3262	North East
UNPR 2	N 30^0 29.467' E O79^o 13.061'	3268	North East
UNPR 3	N 30^0 29.455' E O79^0 12.999'	3259	North East

4. **Experimental methodology**: The litter input was measured from 10 random quadrats laid on the floor of the protected and unprotected areas of the present alpine region. Each quadrat was of 25*25 cm^2 size. Standing litter samples were collected monthly during whole growth period (May – October, 2005). All the litter samples were brought to the laboratory and were accounted for their dry weight (oven dried, 80^0C). Thenafter, the samples from the protected and unprotected areas were grounded separately and analyzed for the macro – nutrients *viz*., organic carbon, total nitrogen, total potassium and total phosphorus. The nutrient concentration was multiplied by the weight of annual litter fall to compute the amounts of nutrients transferred to the forest floor.

5. **Standard methods opted for nutrients analysis**: Following methods were employed for nutrient analysis,
Organic carbon - Okalebo *et al*. (1993),
Total nitrogen - Allen (1974),
Total potassium and total phosphorus - Mahapatra *et al*. (1999).

Results

1. **Monthly variation in the amount of standing litter biomass (gm^{-2})**: Amount of standing litter varied from 22.50 gm^{-2} to 632.50 gm^{-2} in protected sites and from 20.00 gm^{-2} to 167.50 gm^{-2} in unprotected sites. Maximum standing litter was recorded in PR 1 (632.50 gm^{-2}) in October wherein minimum in UNPR 1 (20.00 gm^{-2}) in June (Table 1).

2. **Monthly variation in organic carbon content of standing litter (%)**: Organic carbon content of standing litter varied from 1.83±0.06 % to 4.75±0.06 % in protected sites and from 1.05±0.03 % to 3.60±0.26 % in unprotected sites. Maximum organic carbon content was recorded in PR 3 (4.75±0.06 %) in September wherein minimum in UNPR 1 (1.05±0.03 %) in October. Variation on account of ANOVA (among months in individual site and between sites in each month) was found significant at $p<0.001$ (Table 2).

3. **Monthly variation in total nitrogen content of standing litter (%)**: It is evident from Table 3 that total nitrogen content of standing litter varied from 0.08±0.03 % to 0.36±0.04 % in protected sites and from 0.05±0.01 % to 0.25±0.04 % in unprotected sites. Maximum total nitrogen was recorded in PR 3 (0.36±0.04 %) in October wherein minimum in UNPR 2 (0.05±0.01 %) in May. Variation on account of ANOVA, among months in individual site was found significant at $p<0.001$ except UNPR 3 ($p<0.01$) and between sites in each month was also found significant at $p<0.001$ except September ($p<0.01$).

4. **Monthly variation in total potassium content of standing litter (%)**: Total potassium content of standing litter varied from 2.54±0.08 % to 7.17±0.22 % in protected sites and from 1.53±0.42 % to 5.28±0.15 % in unprotected sites. Maximum total potassium was recorded in PR 3 (7.17±0.22 %) in October wherein minimum in UNPR 3 (1.53±0.09 %) in May. Variation on account of ANOVA (among months in individual site and between sites in each month) was found significant at $p<0.001$ (Table 4).

5. **Monthly variation in total phosphorus content of standing litter (%)**: It is evident from Table 5 that total phosphorus content of standing litter varied from 0.0082±0.0011 % to 0.0173±0.0015 % in protected sites and from 0.0037±0.0021 % to 0.0157±0.0031 % in unprotected sites. Maximum total phosphorus was recorded in PR 2 (0.0173±0.0015 %) in October wherein minimum in UNPR 3 (0.0037±0.0021 %) in July. Variation on account of ANOVA, among months in individual site was found significant at $p<0.01$ (PR 2, PR 3, UNPR 2) and at $p<0.001$ (UNPR 3) wherein rest of the sites, variation was observed as non – significant. Variation among sites in each month was found significant at $p<0.001$ except May ($p<0.05$).

6. **Monthly variation in C: N ratio of standing litter**: Table 6 displays that C: N ratio of standing litter varied from 7.20 to 35.00 in protected sites and from 4.20 to 45.00 in unprotected sites. Maximum C: N ratio was recorded in UNPR 2 (45.00) in September wherein minimum in UNPR 1 (4.20) in October.

7. **Monthly variation in total nutrient concentration (gm^{-2}) released into the soil**: Table 7 executes that maximum nutrient concentration was released by the protected sites compared to the unprotected sites.

Total organic carbon content of standing litter released into the soil varied from 6095.72 gm^{-2} (PR 1) to 127.41 gm^{-2} (UNPR 2). Total nitrogen content of standing litter released into the soil varied from 830.16 gm^{-2} (PR 1) to 4.22 gm^{-2} (UNPR 2). Total potassium content of standing litter released into the soil varied from 11954.25 gm^{-2} (PR 1) to 129.09 gm^{-2} (UNPR 2). Total phosphorus content of standing litter released into the soil varied from 35.10 gm^{-2} (PR 1) to 0.69 gm^{-2} (UNPR 3)

Table 1. Monthly variation in the amount of standing litter biomass (gm^{-2})

Months	Standing litter biomass (gm^{-2})					
	PR 1	PR 2	PR 3	UNPR 1	UNPR 2	UNPR 3
May	37.50	60.00	45.00	52.50	22.50	42.50
June	102.50	22.50	180.00	20.00	22.50	55.00
July	150.00	70.00	87.50	45.00	30.00	97.50
Aug.	122.50	72.50	87.50	95.00	87.50	42.50
Sep.	223.50	105.80	98.99	101.30	99.75	78.89
Oct.	632.50	246.63	220.00	167.50	120.00	147.50

Table 2. Monthly variation in organic carbon content of standing litter (%)

Months	Organic Carbon content (%)						P value
	PR 1	PR 2	PR 3	UNPR 1	UNPR 2	UNPR 3	
May	2.23±0.10	2.46±0.09	2.73±0.12	1.31±0.07	1.51±0.04	2.04±0.04	*
June	3.34±0.15	3.33±0.24	3.69±0.36	2.70±0.23	2.61±0.37	2.08±0.07	*
July	3.44±0.05	3.70±0.10	3.47±0.12	2.38±0.18	2.44±0.05	2.17±0.03	*
Aug.	2.80±0.10	2.60±0.10	1.83±0.06	1.18±0.08	1.08±0.02	1.45±0.06	*
Sep.	3.88±0.10	4.55±0.06	4.75±0.06	3.20±0.10	3.60±0.26	3.04±0.04	*
Oct.	2.57±0.21	2.52±0.26	2.67±0.11	1.05±0.03	1.20±0.09	1.84±0.05	*
P value	*	*	*	*	*	*	

* Significant at $p<0.001$

Table 3. Monthly variation in total nitrogen content of standing litter (%)

Months	Total Nitrogen content (%)						P value
	PR 1	PR 2	PR 3	UNPR 1	UNPR 2	UNPR 3	
May	0.17±0.02	0.11±0.01	0.15±0.04	0.07±0.02	0.05±0.01	0.08±0.01	*
June	0.23±0.01	0.22±0.05	0.20±0.03	0.09±0.03	0.11±0.03	0.15±0.03	*
July	0.24±0.04	0.22±0.04	0.25±0.04	0.11±0.02	0.14±0.03	0.09±0.03	*
Aug.	0.08±0.03	0.15±0.03	0.16±0.03	0.09±0.01	0.05±0.03	0.07±0.03	*
Sep.	0.27±0.02	0.22±0.05	0.20±0.06	0.17±0.03	0.08±0.04	0.17±0.02	**
Oct.	0.35±0.04	0.35±0.04	0.36±0.04	0.25±0.04	0.19±0.03	0.14±0.05	*
P value	*	*	*	*	*	**	

* Significant at $p<0.001$, ** $p<0.01$

Table 4. Monthly variation in total potassium content of standing litter (%)

Months	Total Potassium content (%)						P value
	PR 1	PR 2	PR 3	UNPR 1	UNPR 2	UNPR 3	
May	2.54±0.08	3.24±0.25	3.85±0.05	2.09±0.09	1.53±0.42	1.53±0.09	*
June	2.98±0.02	3.75±0.07	3.98±0.02	3.12±0.09	2.53±0.07	2.44±0.05	*
July	5.02±0.14	5.13±0.07	5.22±0.22	4.13±0.05	4.39±0.32	3.08±0.09	*
Aug.	5.44±0.10	5.38±0.11	6.89±0.17	4.10±0.10	4.17±0.34	3.74±0.22	*
Sep.	5.35±0.21	5.75±0.14	6.38±0.14	5.10±0.06	4.58±0.27	3.97±0.31	*
Oct.	5.04±0.10	6.61±0.08	7.17±0.22	5.28±0.15	4.65±0.34	4.10±0.05	*
P value	*	*	*	*	*	*	

* Significant at $p<0.001$

Table 5. Monthly variation in total phosphorus content of standing litter (%)

Months	Total Phosphorus content (%)						P
	PR 1	PR 2	PR 3	UNPR 1	UNPR 2	UNPR 3	
May	0.0153±0.0025	0.0167±0.0025	0.0153±0.0015	0.0100±0.0010	0.0143±0.0025	0.0157±0.0031	***
June	0.0128±0.0016	0.0142±0.0016	0.0170±0.0010	0.0087±0.0015	0.0100±0.0026	0.0061±0.0021	*
July	0.0147±0.0030	0.0082±0.0011	0.0110±0.0010	0.0063±0.0031	0.0075±0.0022	0.0037±0.0021	*
Aug.	0.0133±0.0016	0.0160±0.0026	0.0127±0.0021	0.0053±0.0042	0.0073±0.0015	0.0043±0.0025	*
Sep.	0.0146±0.0022	0.0148±0.0023	0.0167±0.0015	0.0047±0.0047	0.0047±0.0031	0.0060±0.0020	*
Oct.	0.0148±0.0023	0.0173±0.0015	0.0127±0.0015	0.0043±0.0025	0.0067±0.0025	0.0047±0.0021	*
P value	NS	**	**	NS	**	*	

* Significant at $p<0.001$, ** $p<0.01$, *** $p<0.05$, NS = Non - significant

Table 6. Monthly variation in C:N ratio of standing litter

Months	C:N ratio					
	PR 1	PR 2	PR 3	UNPR 1	UNPR 2	UNPR 3
May	13.12	22.36	18.20	18.71	30.20	25.50
June	14.52	15.14	18.45	30.00	23.73	13.87
July	14.33	16.82	13.88	21.64	17.43	24.11
Aug.	35.00	17.33	11.44	13.11	21.60	20.71
Sep.	14.37	20.68	23.75	18.82	45.00	17.88
Oct.	7.34	7.20	7.63	4.20	6.32	13.14

Table 7. Monthly variation in total nutrients concentration (gm^{-2}) released into the soil

Months	Total nutrient concentration (gm^{-2}) released into the soil					
	Organic carbon					
	PR 1	PR 2	PR 3	UNPR 1	UNPR 2	UNPR 3
May	313.59	553.50	460.69	257.91	127.41	325.13
June	1283.81	280.97	2490.75	202.50	220.22	429.00
July	1935.00	971.25	1138.59	401.63	274.50	793.41
Aug.	1286.25	706.88	600.47	420.38	354.38	231.09
Sep.	3251.93	1805.21	1763.26	1215.60	1346.63	899.35
Oct.	6095.72	2330.65	2202.75	659.53	540.00	1017.75
	Total nitrogen					
May	23.91	24.75	25.31	13.78	4.22	12.75
June	88.41	18.56	135.00	6.75	9.28	30.94
July	135.00	57.75	82.03	18.56	15.75	32.91
Aug.	36.75	40.78	52.50	32.06	16.41	11.16
Sep.	226.29	87.29	74.24	64.58	29.93	50.29
Oct.	830.16	323.70	297.00	157.03	85.50	77.44
	Total potassium					
May	357.19	729.00	649.69	411.47	129.09	243.84
June	1145.44	316.41	2686.50	234.00	213.47	503.25
July	2823.75	1346.63	1712.81	696.94	493.88	1126.13
Aug.	2499.00	1462.69	2260.78	1460.63	1368.28	596.06
Sep.	4483.97	2281.31	2368.34	1937.36	1713.21	1174.47
Oct.	11954.25	6113.34	5915.25	3316.50	2092.50	2267.81
	Total phosphorus					
May	2.15	3.76	2.58	1.97	1.21	2.50
June	4.92	1.20	11.48	0.65	0.84	1.26
July	8.27	2.15	3.61	1.06	0.84	1.35
Aug.	6.11	4.35	4.17	1.89	2.40	0.69
Sep.	12.24	5.87	6.20	1.79	1.76	1.78
Oct.	35.10	16.00	10.48	2.70	3.02	2.60

Table 8. Relationship between temperature and monthly nutrient concentration of different sites

Sites	OC		TN		TK		TP	
	r	r^2	r	r^2	r	r^2	r	r^2
PR 1	0.61	0.37	-0.32	0.10	0.72	0.52	-0.59	0.35
PR 2	0.42	0.18	0.01	0.00	0.43	0.18	-0.35	0.12
PR 3	0.05	0.00	-0.12	0.01	0.51	0.26	-0.22	0.05
UNPR 1	0.32	0.10	-0.06	0.00	0.49	0.24	-0.58	0.34
UNPR 2	0.23	0.05	-0.13	0.02	0.64	0.42	-0.72	0.51
UNPR 3	-0.02	0.00	0.00	0.00	0.62	0.39	-0.79	0.63

Table 9. Relationship between rainfall and monthly nutrient concentration of different sites

Sites	OC		TN		TK		TP	
	r	r^2	r	r^2	r	r^2	r	r^2
PR 1	-0.09	0.01	-0.76	0.57	0.52	0.27	-0.24	0.06
PR 2	-0.20	0.04	-0.43	0.18	0.19	0.04	-0.08	0.01
PR 3	-0.58	0.33	-0.37	0.14	0.43	0.19	-0.52	0.27
UNPR 1	-0.35	0.12	-0.33	0.11	0.09	0.01	-0.31	0.09
UNPR 2	-0.40	0.16	-0.45	0.21	0.31	0.09	-0.21	0.05
UNPR 3	-0.49	0.24	-0.69	0.47	0.28	0.08	-0.29	0.08

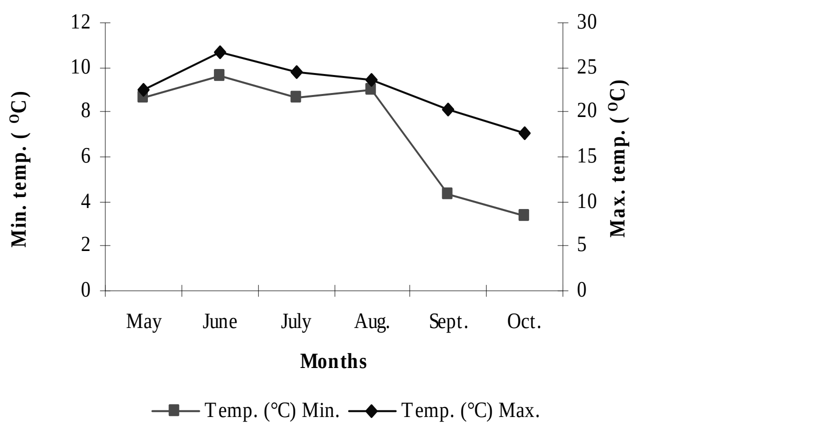

Figure 2. Monthly variation in min./max. temperature (^{0}C)

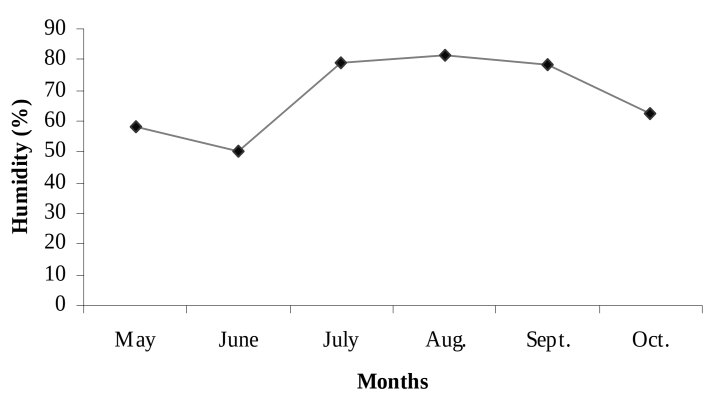

Figure 3. Monthly variation in humidity (%)

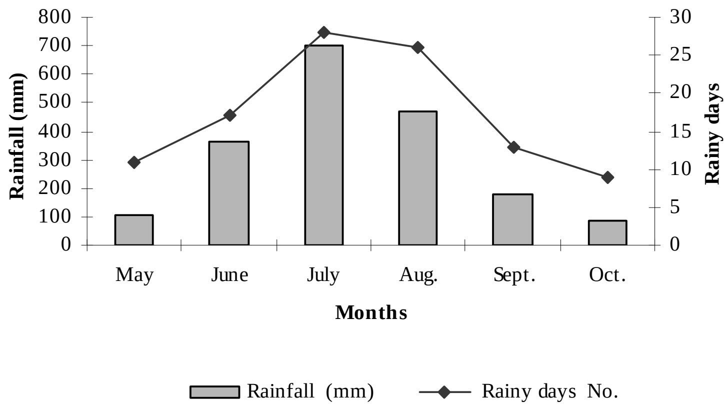

Figure 4. Monthly variation in rain fall (mm) and No. of rainy days

Discussion

The relocate of matter and energy between autotrophs, heterotrophs and decomposers maintains the reliability of an ecosystem. A major part of the annual gain of energy and matter by plants is shed as litter, which enters into decomposition subsystem as detritus and plays a key role in the ecosystem structure and function (Christensen, 1975).

Evaluation of litterfall production is important for understanding nutrient cycling, forest growth, successional pathways and interactions with environmental variables in forest ecosystems (Zhou *et al*., 2007). Litter production varies with climate, season, substrate quality and type of vegetation (Hobbie, 1992; Melillo *et al*., 1982; Upadhyay *et al*., 1989; Vitousek *et al*., 1994). Chemical composition of litter, which changes with type of plant community, influences structure and activity of microbial communities inhabiting soils (Kutsch & Dilly, 1999), and biological and physicochemical properties of topsoil (Heal & Dighton, 1986). Knowledge of litter production is important when estimating nutrient turnover, C and N fluxes, and C and N pools in different ecosystems. Release of nutrients not only depends upon litter composition but also upon soil type, microbial communities and soil properties (Kutsch & Dilly, 1999; Scholes & Walker, 1993; Vitousek & Matson, 1984).

In the present study, amount of standing litter was found maximum in the protected sites compared to the unprotected sites which could be accredited to the rich vegetation cover of the particular area. Also, the topographic, biotic and anthropogenic pressures are not much more pronounced in the protected area. Grazing pressure, types of interactions, seasonal invading by localites and tribes, unusual curiosity of the tourists, mythological believes, the trend of flower offering in temples, illegal harvesting from wild and natural calamities are some of the factors which directly or indirectly affect the vegetation cover and same is true for the present study area (Rawat, N. - Personal observations). Sundriyal (1994) has also reported some of the abovementioned factors as important in maintaining the vegetational outlook of an area. Nautiyal (1996), Nautiyal *et al*. (2001), Semwal (2006) and Anthwal (2006) had also pointed out the abovmentioned factors responsible for variation in the structural composition of an area which in turn are responsible for the litter production and nutrient release patterns.

Amount of all the four macro – nutrients, was recorded maximum in the protected sites compared to the unprotected sites. Number of possible reasons could be attributed, but through the present annotations, it appears that high turnover rate (TR), low atmospheric and soil temperatures (Cadisch and Giller, 1997; Sangha *et al*., 2006) in the unprotected area compared to protected one are the doable reasons. Other litter parameters such as toughness and lignin content including cellulose and hemicellulose have been reported as factors which affect the nutrient release patterns (Taylor *et al*., 1989) and yet, also needs to be investigated in detail. Another probable reason is poor documentation of the litterfall production patterns and nutrient release, especially, from the belowground compartment in alpine ecosystems which needs immediate attention in order to understand the role of plant species completely in releasing nutrients.

C: N ratio was found maximum in the unprotected site compared to the protected site. This variation could be attributed to the mode of organic matter which the unprotected area receives through uniform distribution of animal feces/excreta, trampling and human influenced land disturbance. The most commonly mentioned factors that may regulate the litter decay are related with litter quality including N elemental concentrations and ratios such as C: N and C: P (Berg *et al*., 1982; Berg and Ekbohm, 1983; Berg and McClaugherty, 1989); organic matter fractions such as lignin (Meentemeyer, 1978; Taylor *et al*., 1989), ligno - cellulose index (Berg *et al*., 1984), lignin: N index (Berg and Ekbohm, 1983; Taylor *et al*., 1989), alkyl C content of waxes and cutin (Trofymow *et al*., 1995), elevated CO_2 concentration.(De Angelis *et al*., 2000) and tannin contents (Mesquita *et al*., 1998). These considerations are more important under litter diversity conditions. However, when the substrate is the same, the chemical composition cannot be correlated to the decomposition rate.

When monthly organic carbon content of each site was co – related with temperature, positive correlation was recorded mostly at all sites (r = 0.61, 0.42, 0.05, 0.32, 0.23) and there was 0.37, 0.18, 0.00, 0.10 and 0.05 percent variation. Only, the organic carbon content of UNPR 3 was found negatively co – related with temperature (r = 0.02) and there was negligible percent variation. Likewise, monthly total nitrogen content of each site was co – related with temperature, negative correlation was recorded mostly at all sites (r = 0.32, 0.12, 0.06, 0.13) and there was 0.10, 0.01, 0.00 and 0.02 percent variation. Only, the organic carbon content of PR 2 and UNPR 3 was found positively co – related with temperature (r = 0.02) and there was 0.01 and 0.00 percent variation. Monthly total potassium content of each site when, was co – related with temperature, positive correlation was recorded for all sites (r = 0.72, 0.43, 0.51, 0.49, 0.64 and 0.62) and there was 0.52, 0.18, 0.26, 0.24, 0.42 and 0.39 percent variation. Similarly, monthly total phosphorus content of each site when, was co – related with temperature, negative correlation was recorded for all sites (r = 0.59, 0.35, 0.22, 0.58, 0.72 and 0.79) and there was 0.35, 0.12, 0.05, 0.34, 0.51 and 0.63 percent variation (Table 8).

When monthly organic carbon content of each site was co – related with rainfall, negative correlation was recorded mostly at all sites (r = 0.09, 0.20, 0.58, 0.35, 0.40 and 0.49) and there was 0.01, 0.04, 0.33, 0.12, 0.16 and 0.24 percent variation. Likewise, monthly total nitrogen content of each site was co – related with temperature, negative correlation was recorded mostly at all sites (r = 0.76, 0.43, 0.37, 0.33, 0.45 and 0.69) and there was 0.57, 0.18, 0.14, 0.11, 0.21 and 0.47 percent variation. Monthly total potassium content of each site when, was co – related with temperature, positive correlation was recorded for all sites (r = 0.52, 0.19, 0.43, 0.09, 0.31 and 0.28) and there was 0.27, 0.04, 0.19, 0.01, 0.09 and 0.08 percent variation. Similarly, monthly total phosphorus content of each site when, was co – related with temperature, negative correlation was recorded for all sites (r = 0.24, 0.08, 0.52, 0.31, 0.21 and 0.29) and there was 0.06, 0.01, 0.27, 0.09, 0.05 and 0.08 percent variation (Table 9).

Release of nutrients not only depends upon litter composition but also upon soil type, microbial communities and soil properties (Kutsch & Dilly, 1999; Scholes & Walker, 1993; Vitousek & Matson, 1984). Plant chemical composition significantly impacts on (e.g. microbial immobilization and nitrification) nutrient cycling, as these ecosystem functions improve with increased plant diversity (Hooper, 1996; Hooper & Vitousek, 1998). Also, high stocking rates lead to reduced litter production and root biomass (Cantarutti *et al*., 2002; Christie, 1979). From an ecological perspective, Grubb (1989) explained with examples from different ecosystems that poor soils support vegetation communities which are adapted to poor nutrient status. There is a two - way relationship between structure or type of vegetation communities and soils, and it is still not clear which plays a greater role in determining the other (Grubb, 1989).

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