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Lichen litter decomposition impact on soil nutrients, Kumaun Himalaya, India

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Abstract
In one-year experiment, we assessed decomposition rate of three lichen genera viz. *Usnea* Dill. ex Adans, *Everniastrum* Hale ex Sipman and *Parmotrema* Mass. in 15 sample buckets at botanical garden of S.S.J. Campus Almora. Fresh samples of theses lichens were removed from *Quercus* twigs situated in Morunaula temperate forest of Kumaun Himalaya. Agricultural soil samples were also collected for their chemical analysis and lichen decomposition activity. Individuals of selected lichen thalli were mixed separately with this soil. After six months of decomposition, observations were taken. *Usnea* was found to be the fastest decomposed lichen (about 91%) and increased the value of soil macronutrients- pH, N, P & K. Value of all the macronutrients was found higher in lichen decomposed soil as compared to lichen free soil. Lichen improves soil fertility after their decomposition. Changing weather and climate is a challenge to maintain the fertility of the soil of the area.

Keywords: decomposition, Kumaun Himalaya, lichen litter, soil nutrients, *usnea*

1. Introduction
Lichens are undoubtedly one of the most successful forms of symbiosis (Galloway, 1996) [9], with partnership based on a wide variety of symbiotic interaction which are manifested in many, often unique, morphological and physiological adaptations to wide differing environmental conditions throughout the world. Lichen tissue contains nitrogen largely in the form of proteins, chitin, small amount of soluble amino acids and nucleic acids that are released when decomposition occur (Greenfield, 1993) [11]. Therefore lichens are a source of high quality N in ecosystem (Becker, 1980; Forman, 1975; Godoy *et al.*, 2001; Greenfield, 1993; Oyarun *et al.*, 1998) [1, 7, 10, 11, 23]. The secondary chemicals are unique to lichens and which are considered to have important ecosystem level effects at lichen-dominated areas. These secondary substances can be located extra cellular on cell walls of fungal hyphae and can constitute a significant proportion of the lichen biomass (Elix, 1996) [6].
Lichen litter play an important role in many ecosystems through driving nutrient cycling such as capturing atmospheric nitrogen, serving as a food source for primary consumers and providing shelter for invertebrates (Biasi *et al.*, 2008; Frederickson, 1983; Hodgeman, 1985; Knops *et al.*, 1991; Knops *et al.*, 1996; Lang *et al.*, 1980; Matveyeva and Chernov, 2000; Matveyeva, 1994; Nadkarni, 1986; Nash, 2008; Pike, 1978; Sharnoff, 1994; Stubbs, 1989) [2, 8, 13, 14, 15, 16, 18, 19, 21, 22, 25, 27, 28] . Many lichens are habitat specific and thus a diversity of lichens at a site indicates habitat heterogeneity (Cameron, 2002) [5]. More than 50% of lichen species have antibiotic properties such as lactic acid prepared from *Usnea* species (Burkholders and Evans, 1945) [4]. Besides lichens are also used as pollution monitors. They are the plants which occur in most adverse conditions of climate and substrate. Thus the importance of this group in an ecosystem is very high in its own way. In India, mostly Himalayan region is a rich centre of lichen diversity. This region holds a rich variety of ecological systems. Because of their vertical dimension, mountain creates gradient of temperature, precipitation and insulation. High biomass of epiphytic lichen is a characteristic feature of many old-growth forest ecosystems in temperate and boreal areas. Lichen litter fall rates up to 320 kg ha^{-1} yr^{-1} were reported by Pike (1978) [25].
The main aim of present study was to assess the impact of lichen litter decomposition and composition of nutrients with or without lichen decomposed soil in a temperate region of Kumaun Himalaya. These lichen rich areas of the Himalaya are studied by various workers in the past in terms of its diversity, occurrence, biomass, monitoring, management and conservation. But lichen litter decomposition and conformation of chemical nutrients in a lichen decomposed soil are still awaited. They can be treated to improve soil nutrients in an ecosystem and fertility of agricultural land for better yield.

2. Materials and methods
Samples of fresh thalli of lichen litter fall viz. *Usnea*, *Everniastrum* and *Parmotrema* were removed from *Quercus* twigs from forest situated at 2000 m altitude of Kumaun Himalaya and selected for decomposition test. In this region, macrolichens form species rich and abundant epiphytic communities in Morunaula forest. Three of the most abundant macrolichens in the litter were selected in order to study mass loss rate and changes in the soil nutrients over time.
Soil samples from agricultural field (pesticide free soil) at Mukteshwar (Nainital) were also collected for their chemical analysis and lichen decomposition activity. It was collected from fifteen spots of agricultural land and then mixed all the fifteen samples carefully. After chemical analysis of this soil was categorized into two- first type was used directly for sowing of seeds of selected crops called lichen- free soil. The

second type of soil was used for lichen decomposition test called lichen decomposed soil. Chemical analysis of soil was done at Uttarakhand Government Soil Testing Laboratory, Bhimtal (Nainital). During the study chemical nutrients of both lichen free soil and lichen decomposed soil were also studied. These nutrients of soil were recorded as macronutrients and micronutrients.

The lichen decomposition experiment was performed at botanical garden of Botany department in S.S.J. Campus Almora (Uttarakhand). Total 20 sample buckets of same size were used for lichen decomposition activity. Out of these, five sample buckets each were used for selected three lichen genera and remaining five buckets were used for lichen free soil. A fixed amount of lichen was mixed with the soil samples in these 15 buckets of the three selected lichen genera (Fig. 1 A-D). The lichen mass, mixed in each of these 15 buckets was estimated with the help of electronic weighing machine. This soil-lichen mixture was left for six months. After this period, the observations on lichen mass loss were taken.

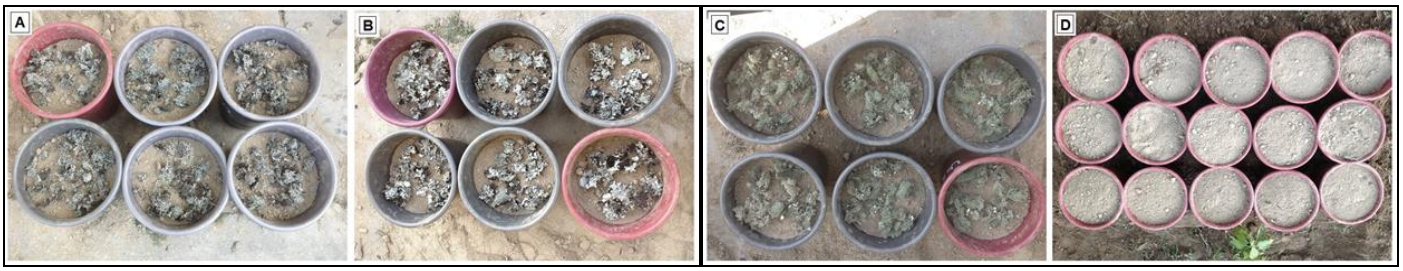

Fig 1: A-D. Lichens genera used for decomposition experiment: (A) *Everniastrum* (B) *Parmotrema* (C) *Usnea* (D) Soil mixed with lichens kept for decomposition

Decomposition was represented as mass loss, i.e. quantity of the litter mass paced for decomposition minus mass remains after decomposition (oven dry mass). Value of lichen litter decomposition (%) was calculated as net quantity of mass loss divided by quantity of mass placed for decomposition multiplied by 100. Following formulas were applied

$$\text{Net mass loss (g)} = \text{Mass placed for decomposition} - \text{mass remains after decomposition}$$

$$\text{Decomposition rate (\%)} = \frac{\text{Net mass loss (g)}}{\text{Mass placed for decomposition}} \text{X } 100$$

3. Results and discussion

Usnea (fruticose form) was found to be the fastest decomposed lichen (about 91%) followed by foliose forms *Parmotrema* (79%) and *Everniastrum* (68%). *Usnea* considered fast decomposing lichen because it is morphologically smooth, spongy and hair like. *Usnea* has also found high decomposition rate about 1.7 g/month followed by *Parmotrema* (1.5 g/month) and *Everniastrum* (1.3 g/month) (Table 1).

Table 1: Assessment of lichen decomposition rate

Lichen litter	Litter mass placed for decomposition (g/pot)	Observation time	Mass remaining (g/pot)	Net mass loss (g/pot)	Lichen litter loss (%)	Mass loss or decomposition rate (g/month)
Everniastrum	11.2	6 months	3.6	7.6	68	1.3
Parmotrema	11.2	6 months	2.3	8.9	79	1.5
Usnea	11.2	6 months	1.0	10.2	91	1.7

Usnea is a thin hair like branched thallus and decomposed fast. The decomposition of lichen may depend on soil moisture condition and morphology of thallus. The soil nutrients were studied into two- macronutrients and micronutrients. Macronutrients of soil are highly observed by the plants. These are responsible for the high production of our food crops like wheat and rice. Value of all the macronutrients (main soil elements) was found higher in lichen decomposed soil as compared to lichen free soil. Potassium (K) was found maximum than other macronutrients such as N, P and pH. In comparison to lichen free soil potassium value (55.4 ± 4.31 kg/ha) increased approximately triple after the decomposition of *Everniastrum* (140 ± 26.29 kg/ha). This value of K was found double by the decomposition of *Usnea* and *Parmotrema* represented by 118.4 ± 22.83 kg/ha and 116.2 ± 40.49 kg/ha. Nitrogen value of lichen free soil was also increased after decomposition of *Usnea*, *Parmotrema* and *Everniastrum* represented by (1.28 ± 0.07 kg/ha), (1.24 ± 0.14 kg/ha) and (1.22 ± 0.02 kg/ha) respectively (Table 2). This study also shows that pH value of soil can be improved through decomposition of lichens. The standard value of pH is considered between 6.1 to 8.5 kg/ha. In the present test, pH was increased maximum 6.84 ± 0.14 kg/ha by decomposing *Usnea* followed by *Everniastrum* (6.78 ± 0.07 kg/ha) and *Parmotrema* (6.8 ± 0.11 kg/ha) (Table 2). It was also observed that less impact of lichen decomposition was found on phosphorus (P) as compared to P value of normal soil i.e. lichen free soil about 20.1-40 kg/ha.

Table 2: Impact assessment lichen litter on macronutrients of soil

Chemical nutrients	Standard value*			Lichen free soil	Lichens decomposed soil		
	Low	Normal	High		*Usnea*	*Everniastrum*	*Parmotrema*
pH	< 6.0	6.1-8.5	> 8.5	6.56 ± 0.10	6.84 ± 0.14	6.78 ± 0.07	6.8 ± 0.11
N (%)	0.1-0.2	0.2-0.5	0.5-1.0	1.0 ± 0.04	1.22 ± 0.02	1.28 ± 0.07	1.24 ± 0.14
P (kg/ha)	10.1-20	20.1-40	> 40.0	13.5 ± 4.02	5.4 ± 1.80	7.2 ± 2.20	8.1 ± 1.80
K (kg/ha)	51-100	101-250	> 251	55.4 ± 4.31	118.4 ± 22.83	140 ± 26.29	116.2 ± 40.49

****Source***: Standard values of soil; Soil Testing Lab. Agr. Dept. Uttarakhand, Bhimtal

Micronutrients of soil viz. Zn, Mn, Fe, Cu, S etc. also play a significant role in the plant's life. These elements are also responsible for the growth and development of plants. Plants absorb these nutrients from air and water. But trend of crop rotation and desire of crop diversity reduce the amount of these micronutrients in the soil. In such case micronutrients like Manganese (Mn) can be increased by the decomposition of *Parmotrema* about 1.52 mg/ha and *Usnea* (0.43 mg/ha). Fe can also be increased by *Usnea* (5.49 mg/ha) followed by *Everniastrum* (1.32 mg/ha). It was also found that Fe is decreased by the decomposition of *Parmotrema* (about 0.81mg/ha). Value of copper (Cu) also found to be increased with *Usnea* and *Everniastrum* represented by 0.50mg/ha and 0.16 mg/ha (Table 3). It was also observed that the increased value of S, Cu and Zn of normal soil (i.e. lichen free soil) was minimized but came under standardized range by decomposing lichens. Lichen improves Zn value of soil. It was found high (about 1.02 ± 0.19 mg/kg) in lichen free soil. But after decomposition of different lichen thalli in such soils, it reduces this higher value and brings it to its standard value between 0.6 to 1.2 mg/kg. In this case *Usnea* contributes maximum in reduction (about 0.94 ± 0.23 mg/kg) followed by *Parmotrema* (0.81 ± 0.19 mg/kg) and *Everniastrum* (0.64 ± 0.10 mg/kg) (Table 3). Fe and Cu value was found lesser in the lichen free soil represented by 3.95 ± 0.72 mg/kg and 0.36 ± 0.24 mg/kg as compared to their standard values (4.5-8 mg/kg and 0.5-1.2 mg/kg). Lichen improves this decreased amount of Fe and Cu. In such case decomposition of *Usnea* also contributes maximum in increasing the value of Fe and Cu about 5.48 ± 0.45 mg/kg and 0.36 ± 0.24 mg/kg in comparison to other two lichens (Table 3). Similarly, Mn value of lichen free soil was also estimated lesser than its standard value but it was improved maximum by the decomposition of *Everniasturm* (2.51 ± 1.51 mg/kg). In case of Sulphur (S) which is responsible for increasing soil capacity of oil plants, no impact of lichen decomposition was found.

Table 3: Impact assessment of lichen litter on micronutrients of soil

Chemical nutrients	Standard value*			Lichen free soil	Lichens decomposed soil		
	Low	Normal	High		*Usnea*	*Everniastrum*	*Parmotrema*
Zn(mg/kg)	< 0.6	0.6-1.2	> 1.2	1.02 ± 0.19	0.94 ± 0.23	0.64 ± 0.10	0.81 ± 0.19
Mn(mg/kg)	< 2.0	2-4.0	> 4.0	1.92 ± 0.27	2.36 ± 0.43	2.51 ± 1.51	3.45 ± 0.7
Fe(mg/kg)	< 4.5	4.5-8	> 8.0	3.95 ± 0.72	5.48 ± 0.45	5.23 ± 1.10	3.99 ± 1.59
Cu(mg/kg)	< 0.5	0.5-1.2	> 1.2	0.36 ± 0.24	0.86 ± 0.36	0.52 ± 0.17	0.34 ± 0.19
S(mg/kg)	< 10	10-12	> 12	10.57 ± 0.51	10.52 ± 0.43	10.37 ± 0.34	11.24 ± 0.22

****Source***: Standard values of soil; Soil Testing Lab. Agr. Dept. Uttarakhand, Bhimtal

Lichen genus- *Usnea*, *Everniastrum* and *Parmotrema* were found abundantly in the temperate regions of Kumaun Himalaya. They play a key role in forest ecosystem functioning. In an ecosystem where nutrient availability is limited, litter fall decomposition is a fundamental component of nutrient cycling, soil formation and ecosystem productivity (Lousier and Parkinson, 1976; Pike, 1978; Moore, 1983; Harmon *et al.*, 1990; Taylor *et al.*, 1991) [12, 17, 20, 25, 29]. Lichens are the first organisms to appear primary succession in an area known as pioneer species. Pioneer communities help enrich soil. Shah (1997) [26] studied four grades of lichens traded from India. Best grade (grade I) lichens use in high grade perfumery i.e. *Parmotrema nilgherense* (Nyl.). Grade II consists of mixture of the *P. nilgherense* along with species of *Everniastrum* while III and IV generally consist of *Usnea longissima*. As generations of the lichens die, their remains decompose and added to the soil.

4. Conclusion

Agriculture is a prime occupation in the region but changing weather pattern and climate has influenced the fertility of the soil. Therefore, it is suggested that the farmers residing in lichen rich areas of temperate regions can apply these valuable lichens to enhance soil fertility for better crop yields. For this purpose lichen litter (fallen lichen) can be used. The present study does not suggest the removal of lichens for the said purpose due to conservational point, however, lichen removal has no effect on the growth of the oak trees and it influences nutrient cycling fluxes significantly (Knops *et al.*, 1997) [15].

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