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Ethnopharmacological and therapeutic potential of macrolichens of Kumaun Himalaya

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Abstract
The Kumaun Himalayan region of India hosts a rich diversity of macrolichens, yet their pharmacological potential remains underexplored. Present study synthesizes available knowledge on the ethnopharmacological uses and bioactivities of macrolichens from this region. A systematic collation of 38 macrolichen species belonging to 19 genera and 6 families was made from oak-dominated forests at altitudes of 1600–2400 m. The majority were foliose (25 species), followed by dimorphic (8) and fruticose (5) forms. Notably, 33 species (87%) possess documented pharmacological properties. The most prevalent activities include antioxidant (20 species), traditional medicinal use (19 species), and antibacterial (19 species). Significant numbers also exhibit anticancer (17 species), broad-spectrum antimicrobial (16 species), antifungal (14 species), anti-inflammatory, and inhibitory properties (9 species each). The study succinctly elaborates on the ethnopharmacological legacy of these symbiotic organisms and exhibits critical research gaps, advocating for targeted bioprospecting and phytochemical validation to unlock their full therapeutic potential.

Keywords: Forest types, lichens, medicinal properties, therapeutic uses

Introduction

Lichens are unique miniature ecosystems between two components i.e. fungi (mycobiont) and algae (photobiont) (Hale, 1983; Sudarshan & Ramachandra, 2010; Shivanna & Garampalli, 2015) [1-3]. They are considered as the 'pioneers of plant succession.' The unique physiology and peculiar structure of lichens enable them to withstand the microclimatic conditions as epiphytes on different phorophytes. The symbiotic phenotype of the lichens dominates about 8% of the terrestrial ecosystems. More than 50 percent of all lichen species reported all over the world possess antibiotic properties (Vartia, 1973; Bhattarai *et al*, 2008) [4-5]. From the prehistoric times, the lichens are utilized in traditional medicines, for production of alcohol, in preparation of dyes, food, perfumes. Along the worldwide, different species of lichens are also used as ingredient to add flavour to food. Especially the lichen powder is used as popular Indian condiment such as meat masala, Garam masala etc. (Upreti *et al*, 2005) [6]. In Arabic *Parmotrema tinctorum* is pronounced as *Al-Sheba* which is used as spice in food Khatwa *et al*, 1997) [7]. During, 15th century "Doctrine of Signature" stated that 'a plant could cure a disease it most look like.' This laid the foundation for phytotherapeutics in conventional medical systems such as Western Medical Herbalism, Traditional Chinese Medicine (TCM), and Traditional Indian Medicine (TIM), often known as Ayurveda (Bown, 1995) [8]. These symbiotically associate organisms represent a unique division under plant kingdom.

The bioactive compounds derived from lichens holds a great potential for biopharmaceutical applications as antibacterial, cytotoxins, antidermatophytic, antimicrobial, antioxidant agents for the betterment of human health. The traditional use of lichens by the humans is termed as 'Ethnolichenology' (Elkhateeb *et al*, 2021) [9]. Traced back to 18th dynasty (1700-1800 BC) *Evernia furfuracea* (L.) was first used as a drug (Launert, 1981) [10]. Since millennia lichens are utilized as traditional foods, medicines and in sacred sacrificial ritual known as '*Havan'* or '*Homa*'. They play essential role in human welfare as well as ecosystem. Lichens were widely used by medicinal practitioners in the Middle Ages (Devkota *et al*, 2017) [11]. Medicinal values of Indian lichen have a long historical backdrop (Saklani& Upreti, 1992; Lal *et al*, 1995; Kumar *et al*, 1996; Kumar & Upreti, 2001; Hawksworth, 2015) [12-16].

In Himalayas and in South-eastern China, it is prevalent to use lichens and are frequently consumed as a decoction to treat various diseases related to pulmonary and digestive systems. The other species of lichens are also helpful in treating the gynaecological disorders, especially diseases regarding sexually transmitted infections and urinary tract ailments (Elkhateeb *et al*, 2019) [17]. Lichens are also utilized to cure several diseases like alopecia, leprosy, kidney diseases, heart and stomach disorders, asthma, spleen enlargement, constipation, ringworm, cancer, arthritis, rabies, and dysentery (Gonza *et al*, 1995; Salgado *et al*, 2017; Calcott *et al*, 2018; Crawford, 2019) [18-21]. At present times, the secondary metabolites of lichens have been receiving maximum upliftment due to their nutraceutical potential (Crawford, 2007) [22]. Being a source of various natural classes, they possess many biological potentials such as antifungal (Oh *et al*, 2006) [23], antiviral and analgesic effects (Fazio *et al*, 2007) [24], antidiuretic, antipyretic, antioxidant (Molnar & Farkas, 2010; Shrestha & Clair, 2013) [25-26], anticancer (Yang *et al*, 2018; Awasthi, 2007) [27-28]. Despite this, the traditional applications of lichens were documented previously, but commercial prospects of lichens as pharmacological sources have not been thoroughly investiga ted and compiled in the previous studies.

Materials and Methods

Study area

This study was conducted in two oak-dominated forests of the Kumaun Himalaya (Uttarakhand): *Quercus leucotrichophora* (Banj oak) forest in Kilbury, Nainital (1600-2600 m) and *Q. floribunda* (Tilonj oak) forest in Mornaula, Almora (1800-2200 m). The Banj oak site supported associated tree species such as *Rhododendron arboreum*, *Cedrus deodara*, and *Cupressus torulosa*, while the Tilonj oak site was associated with *Betula*, *Myrica esculenta*, and conifers. Both the forests are recognized for their rich lichen diversity, which is promoted by their altitudinal gradients and microclimates, characterized by high precipitation and moisture levels.

Collection of lichen specimens

During the field survey lichen samples were collected systematically from all the possible substratum such as bark, rock, soil etc. Each sample was collected along with field notes like altitude, longitude, latitude, slope, aspect, host, forest type, etc. All the samples were collected followed by standard protocols (Awasthi, 2007) [28].

Identification of lichen taxa

The collected macrolichen samples were sorted, cleaned, and identified using taxonomic keys (Awasthi, 2007) [28]. The herbarium was prepared (Figure 1) and the voucher specimens were deposited at the Biodiversity Conservation Laboratory, Department of Botany, S.S.J. University, Campus Almora (Uttarakhand). The specimens were identified based on their morphology, anatomy, and chemistry. The stereo-zoom binocular microscope was used to examine the morphology of the taxa. The anatomy of thallus and fruiting bodies were examined in detail through compound microscope. The color test was performed on the cortex and medulla using common chemical regents including aqueous potassium hydroxide (K), Steiner's stable paraphenylene diamine (PD), and aqueous calcium hypochlorite (C). Furthermore, thin layer chromatography (TLC) was used to identify the lichen compounds in solvent system A (Toluene 180: 1-4 Dioxane 60: Acetic acid 8) (Walker & James, 1980; Orange *et al*, 2001) [29- 30]. The medicinal properties and the therapeutic uses of lichens were documented by using concerned literatures. Besides, Scopus, Google Scholar, PubMed, ScienceDirect sites were also consulted.

Results and Discussion

Enumeration of medicinal lichen flora of the study area

During the present investigation, a sum of 38 species of macrolichen belonging to 19 genera under six families were recorded from the study area. Out of which, maximum 25 species of foliose followed by eight species of dimorphic and five species of fruticose lichens were recorded. Across the study sites, mixed *Q. leucotrichophora* forest possess with 31 lichen species at Kilbury followed by *Q. floribunda* forest (22 species) at Mornaula region. Out of 38 species, maximum 33 macrolichens possess their medicinal and therapeutic properties (Table 1; Figure 2). Maximum, 20 macrolichen species shows their antioxidant properties followed by 19 species evaluated for their antibacterial properties, and utilized as ethnomedicine across the globe. Similarly, 17 have been assessed for their anticancerous activities, while 16 possess their antimicrobial activities. About 14 species were utilized for their antifungal values while nine species tested positive for α-amylase inhibitory and anti-inflammatory activities. Furthermore, six species also possess antidermatophytic, antimycobacterial, anti-insecticidal and anti-helmintic activities. Likewise, five different lichen species exhibit antiproliferative, antidiabetic and healing tendency to cure wounds, cuts, and burns. Besides, four species such as *Heterodermia barbifera*, *H. diademata*, *H. hypochraea* and *Parmotrema tinctorum* were recorded as immunomodulators (Figure 3). Additionally, lichen species are enriched with several secondary metabolites that makes them useful for their phytopharmacological uses. It was observed that only *P. tinctorum* (a foliose lichen) showing its allelopathic and antiarthritic properties (Peres *et al*, 2009; Ahmed *et al*, 2019) [31-32]. However, another foliose lichen *C. texana* shows its mitodepressive and clastogenic activity (Campos *et al*, 2008) [33]. Likewise, three species of macrolichens such as *Cetrelia cetrarioides, C. subradiata* and *H. comosa* were also collected from the study area but no information was found about their medicinal properties (Table 1).

Utilization pattern of macrolichens

To develop utilization pattern of different macrolichens for their pharmaceutical and therapeutic uses, different utilization ranges were prepared (Figure 4). Thus, all the species were recorded as per their uses and placed in the respective utilization range. Maximum, eight species of macrolichens were recorded under 30.01-40 % range followed by six species found between 40.01-50%. Similarly, five species each were recorded for their utilization range <10%, 10.01-20% and 20.01-30% respectively. Two species such as *H. cirrhata* and *P. tinctorum* exhibits their utilization range between 70.01-80%. It was also found that only two species i.e. *H. diademata* (foliose lichen) and *R. conduplicans* (fruticose form) recorded for their highest level of medicinal uses and represented by 50.01-60% and 60.01-70% respectively. These species are responsible for their multi ethnopharmacological properties.

Medicinal potential of lichen species of the study area: A detail account of macrolichens of the study area which are applied for various medicinal uses has been described in table 1.

a. **Ethnomedicinal uses:** The lichens are widely used across the globe as traditional medicines to cure common illness, cough, cold etc. From the time immemorial lichens are used as a source of food, dyes, perfumes, cosmetics, spices. The Limbu community of eastern Nepal utilizes *Heterodermia diademata* with *Eupatorium odoratum* for curing the wounds and injuries (Limbu & Rai, 2013) [34]. During the study it was observed that out of 38 macrolichen species of the study area, 19 species are used by different communities of Indian Himalayan regions and China regions traditionally to cure fever, flu, jaundice, blurred vision (Lindley, 1838; Pennington, 1963; Wei *et al*, 1982; Sati & Usman, 1992; Wang *et al*, 2001; Ding, 2010; Jorim *et al*, 2012; Singh *et al*, 2012; Ul *et al*, 2012; Prasad, 2013; Wang & Qian, 2013; Rogers, 2014; Upreti *et al*, 2015; Jain, 2016; Pathak *et al*, 2016; Ali *et al*, 2024; O'Neil *et al*, 2017; Rawat *et al*, 2024) [35- 52].

b. **Anticancerous properties:** Globally, cancer ranks as the second leading cause of mortality, after heart diseases. The word 'Cancer' originates from Greek word 'karkinos' which means carcinoma. Many studies have been reported anticancerous activities of lichens (Kumar & Muller, 1999a-b; Russo *et al*, 2006; Tokiwano *et al*, 2009; Ranković *et al*, 2011; Poornima *et al*, 2016; Yang *et al*, 2021; Bhat *et al*, 2022; Tripathi *et al*, 2022; Koopaie *et al*, 2023; Soundararajan *et al*, 2023) [53- 63]. In the present study a sum of 17 macrolichen species were recorded from the study area which contribute to cure cancer.

c. **Antifungal properties:** It was also analysed that 14 lichen species of the study area were tested against several fungal strains of *Fusarium solani, F. fujikuroi, F. oxysporum, Aspergillus flavus* by several authors (Oh *et al*, 2006; Wei *et al*, 2008; Tiwari *et al*, 2011; Babiah *et al*, 2014) [64-67]. Their antifungal capability was tested in methanol, acetone and in chloroform solvents through Disc diffusion method. The maximum activity was observed in acetone extracts, and found to be more effective to hinder the growth of mycelium.

d. **Antimicrobial properties:** About sixteen species of lichens of the study area were reported for the experimental purpose to inhibit the growth of gram-positive, gram-negative bacteria and to hault the colonies of fungus such as *Candida albicans, Aspergillus niger, Fusarium oxysporum and Penicillium verrucosum* (Rankovic & Misic, 2008; Nayaka *et al*, 2010; Swathi *et al*, 2010; Kambar *et al*, 2014; Ankith *et al*, 2017; Shiromi *et al*, 2021; Tamta *et al*, 2024) [68-74].

e. **Antibacterial properties:** Several investigations have been documented to determine the antibacterial efficacy of crude lichen extracts. In 1940, Burkholder began the study on antibacterial activity of lichens. In the present investigation out of 33 species of macrolichens, 19 species were evaluated to inhibit and suppress the bacterial growth against *E. coli, Streptococcus faecalis, Staphylococcus aureus* and *Bacillus* (Burkholder *et al*, 1944; Cui & Duan, 2000; Mastan *et al*, 2014; Gunasekaran *et al*, 2015; Pandey *et al*, 2018; Safarkar *et al*, 2020; Ismed *et al*, 2021; Pius & Sequeira, 2022; Bhat *et al*, 2024; Karki *et al*, 2024; Prabhakar *et al*, 2024) [75-85].

f. **Antidermatophytic properties:** The lichen extracts of 6 macrolichens (*B. setschwanensis, L. retigera, M. aurulenta, P. nilgherrense, R. conduplicans, U. orientalis*) possess promising antidermatophytic activity that inhibits a variety of dermatophytes such as *Epidermophyton* and *Trichophyton* (Pathak *et al*, 2016a-b) [86-87].

g. **Antihelmintic properties:** The study revealed that six macrolichen species were also evaluated for their antihelmintic activities in different roundworms. At present times, helmintic infections is exhibited as major contributing factor to the chronic illness and lethargic behaviour (Kumar *et al*, 2009; Vinayaka *et al*, 2009; Kumar *et al*, 2010; Prabhu & Sudha, 2016) [88-91]. These filarial worms also attacks and acta s parasites on cattles, living organisms ultimately resulting in significant financial losses. The effectiveness of several natural products in eradicating helminthes is reported by the traditional medical system.

h. **Anti-insecticidal properties:** Currently six species of lichens were also reported that exhibits the insecticidal efficacy of lichens against plant pests. Many investigations conducted by various different authors and demonstrated that lichens crude solvent extracts is potent to kill mosquito vectors and plant pests (Kavana & Rashmi, 2024; Khader *et al*, 2018; Silva *et al*, 2021) [92-94]. The different extracts were tested against *Aedes aegyptii, Sitophilus granarius* causing damage to plants. Thus, lichens seem to be potential resources of insecticidal compounds and may be implemented to manage insect infestations.

i. **Antiproliferative properties:** Five species of macrolichens such as *H. nepalensis, R. conduplicans, P. tinctorum, F. caperata, R sinensis* have been demonstrated to have bioactive compounds like usnic acid, depsides, dibenzofurans and depsidones that induces the tumour cell lines, apoptosis. Also, the lichens extracts were investigated on colon cancer adenocarcinoma cell line (Mitrović *et al*, 2011) [95].

j. **Anti-inflammatory properties:** The systemic study of chemical compounds of lichens demonstrated that nine species of lichens produce unique bioactive compounds that helps lichens to survive in the microclimatic conditions of the nature. The lichens also possess anti-inflammatory properties that were also previously reported to be utilized in the folk medicine to treat skin problems, coughs, rabies and bleeding (Nguyen *et al*, 2021; Rajendran *et al*, 2023) [96-97].

k. **Antioxidant properties:** The methanol, acetone, ethanol, and aqueous extract of 20 species of lichen were screened *in vitro* by using different methods such as reducing power, DPPH radical scavenging etc. for evaluating the antioxidant potential of the lichens (Balasubramanian & Nirmala, 2014; Kosanić *et al*, 2014; Selvaraj *et al*, 2015; Xia *et al*, 2015; Behera *et al*, 2016; Rajan *et al*, 2016; Rajaram *et al*, 2016; Thadani & Karunaratne, 2017; Kekuda *et al*, 2018; Maurya *et al*, 2018; Singh *et al*, 2019; Sargsyan *et al*, 2021) [98-109].

l. **Antidiabetic properties:** About five species of lichen *viz. P. tinctorum, P. reticulatum, F. caperata, H. cirrhata* and *P. subrudecta* were found as potent source of antidiabetic agents (Vinayaka *et al*, 2013; Shivanna *et al*, 2015; Hengameh *et al*, 2016) [110-112]. The lichens had long back history as phytopharmacologically beneficial as these organisms have proved to have maximum amounts of bioactive compounds that marked its enormity in curing fatal diseases.

m. **Antimycobacterial properties:** The ethanol extracts of six lichen species namely, *L. pedicellatum, F. caperata, H. hypochraea, P. tinctorum, H. cirrhata* and *C. pyxidata* were evaluated for their antimycobacterial potentialities against different strains of *Mycobacterium tuberculosis*. For this, several lichens were also examined for antibacterial capabilities during the beginning of the antibiotic era in 1950 (Gupta *et al*, 2007; Honda *et al*, 2010; Thuan *et al*, 2022) [113-115]. Later, some lichen compounds against *Mycobacterium* were also studied (Ingolfsdottir *et al*, 1998) [116].

n. **Immunomodulatory uses:** Out of 33 species, four macrolichen species such as *H. barbifera, H. diademata, H. hypochraea* and *P. tinctorum* were also identified as immunomodulatory (Santos *et al*, 2004) [117]. These lichens have been reported to have a detrimental effect on the immune cells, phagocytosis response through the action of their polysaccharides and secondary metabolites.

α-amylase inhibitory: Among all the lichens studied, nine species were found to possess anti-amylase inhibitory properties. The zone of inhibition was found effective in these lichens (Verma *et al*, 2008; Raj *et al*, 2014; Valadbeigi *et al*, 2016) [118-120]. It was also investigated that lichen extracts exhibited strong inhibition against α-amylase, that was found to be promising in producing anti-hyperglycemic medications with fewer adverse effects.

Lichens applied on wounds, cuts, and burns: Since the earliest Chinese and Egyptian civilizations lichens have been utilized in traditional therapeutic practices.

Thus, five species of macrolichens namely *F. caperata, H. diademata, U. orientalis, H. cirrhata* and *H. nepalensis* have been reported in several international pharmacopoeias as folk medicine. The local commodities and tribal people of the world utilize lichens as remedies to cure the common diseases such as jaundice, rabies, cuts, wounds, burns, blisters, boils, skin eruptions (Moskalenko, 1986; Poudel, 2008; Uprety *et al*, 2010; Shrestha *et al*, 2016) [121-124].

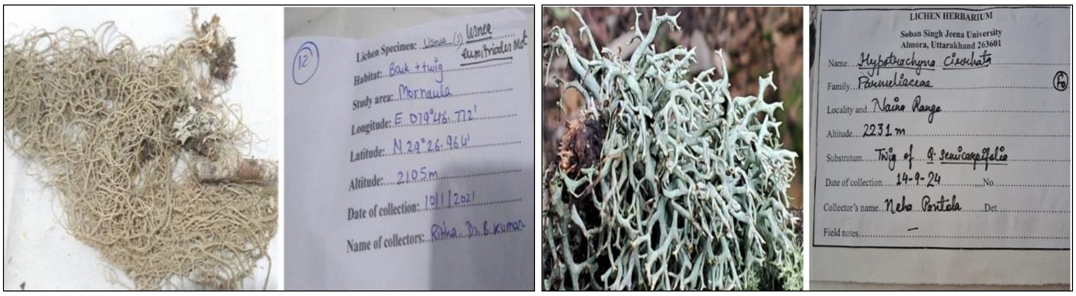

Fig 1: Lichen herbarium sample of *Usnea eumitrioides* collected from Mornaula forest and *Hypotrachyna cirrhata* collected from Kilbury region along with their herbarium packets (17 cm x 10 cm)

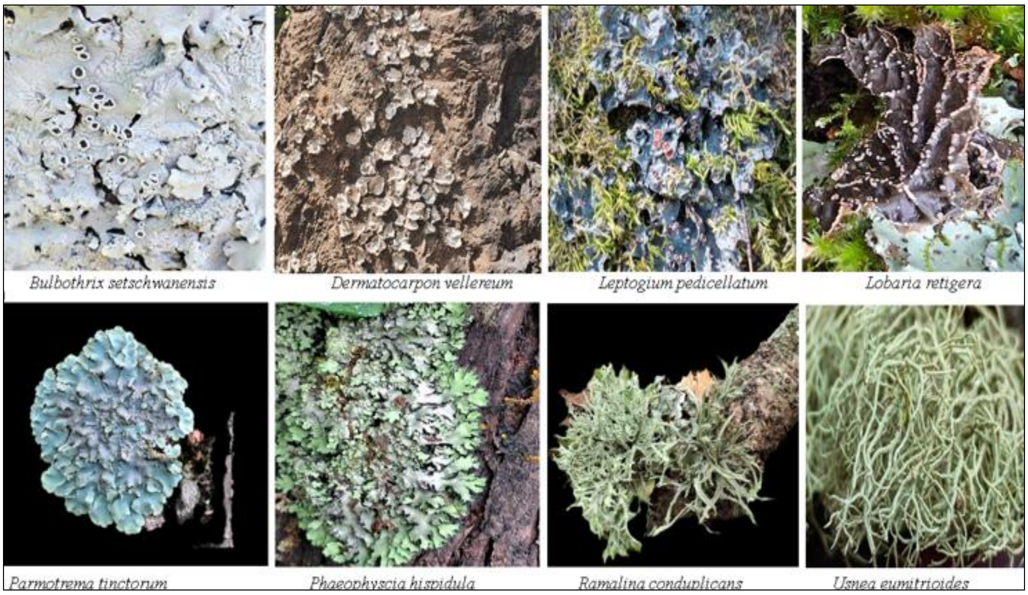

Fig 2: Illustration of some medicinally important macrolichens of the study area

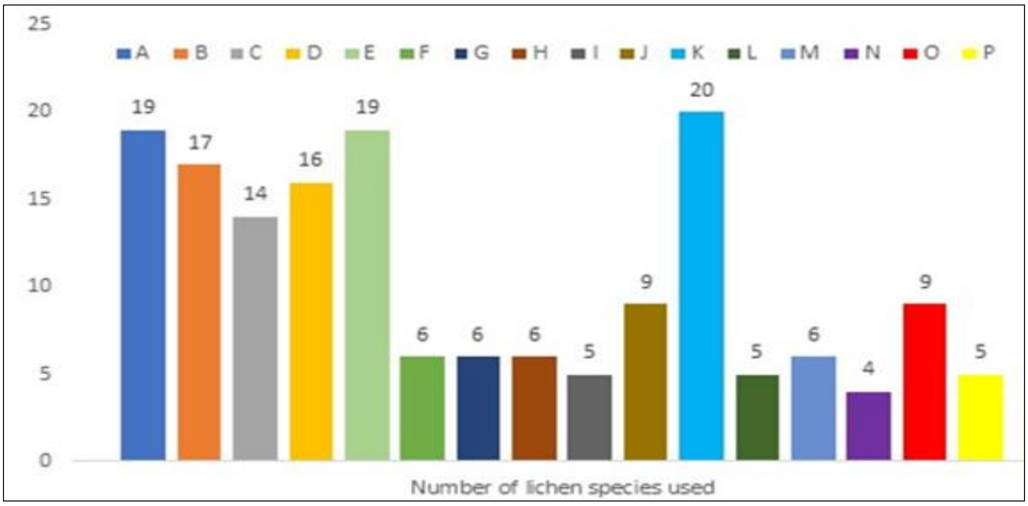

Fig 3: Different pharmacological uses of various macrolichen species of the study area

Table 1: Occurrence of lichen species in the study area and their phytopharmacological uses

	Lichen taxa	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Medicinal use (%)
1.	*Bulbothrix meizospora* (Nyl.) Hale	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.25
2.	*B. setschwanensis* (Zahlbr.) Hale	+	+	+	+	-	+	-	-	-	-	+	-	-	-	+	-	43.75
3.	*Canoparmelia texana* (Tuck.) Elix and Hale	+	+	-	+	-	-	-	+	-	-	+	-	-	-	-	-	31.25
4.	*Cladonia cartilaginea* Müll. Arg.	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.25
5.	*C. coniocraea* (Flörke) Spreng.	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	12.5
6.	*C. fruticulosa* Kremp.	+	+	-	-	+	-	-	-	-	+	-	-	-	-	-	-	25
7.	*C. furcata* (Huds.) Schrader	-	+	+	+	+	-	-	-	-	-	+	-	-	-	-	-	31.25
8.	*C. pyxidata* (L.) Hoffm.	+	+	-	+	-	-	-	-	-	-	+	-	+	-	-	-	31.25
9.	*C. scabriuscula* (Delise) Nyl.	+	+	+	-	+	-	-	-	-	-	+	-	-	-	-	-	31.25
10.	*C. verticillata* (Hoffm.) Schaerer	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	6.25
11.	*Collema subflaccidum* Degel.	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.25
12.	*Dermatocarpon vellereum* Zschacke	-	-	-	+	+	-	-	-	-	-	+	-	-	-	-	-	18.75
13.	*Flavoparmelia caperata* (L.) Hale	+	+	-	-	-	-	-	-	+	-	+	+	+	-	+	+	50
14.	*Heterodermia barbifera* (Taylor) D.D. Awasthi	-	+	-	+	-	-	+	-	-	+	+	-	-	+	-	-	37.5
15.	*H. diademata* (Taylor) D.D. Awasthi	+	+	+	+	+	-	-	-	-	+	+	-	-	+	-	+	56.25
16.	*H. hypochraea* (Vai.) Swinscow & Krog	-	+	-	+	-	-	+	-	-	+	+	-	+	+	-	-	43.75
17.	*Hypotrachyna cirrhata* Divakar, A. Crespo, Sipman, Elix & Lumbsch	+	+	+	+	+	-	+	+	-	-	+	+	+	-	+	+	75
18.	*H. nepalensis* (Taylor) Divakar, A. Crespo, Sipman, Elix & Lumbsch	+	+	+	-	+	-	-	-	+	-	-	-	-	-	-	+	37.5
19.	*Leptogium pedicellatum* P.M. Jørg.	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	6.25
20.	*Leucodermia boryi* (Fée) Kalb	-	+	-	-	-	-	+	+	-	-	+	-	-	-	-	-	25
21.	*Lobaria retigera* (Bory) Trevis.	+	-	+	-	+	+	-	-	-	+	+	-	-	-	-	-	37.5
22.	*Myelochroa aurulenta* (Tuck.) Elix & Hale	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	12.5
23.	*Parmotrema austrosinense* (Zahlbr.) Hale	-	-	-	+	-	-	-	-	-	+	+	-	-	-	+	-	25
24.	*P. nilgherrense* (Nyl.) Hale	+	-	-	-	+	+	-	-	-	+	-	-	-	-	-	-	25
25.	*P. reticulatum* (Taylor) M. Choisy	+	+	+	-	+	-	-	+		-	+	+	-	-	+	-	50
26.	*P. tinctorum* (Dèspr. ex Nyl.) Hale	+	-	-	+	+	-	+	+	+	+	+	+	+	+	+	-	75
27.	*Phaeophyscia hispidula* (Ach.) Moberg	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	12.5
28.	*Physcia dilatata* Nyl.	-	+	-	+	+	-	-	-	-	-	+	-	-	-	-	-	25
29.	*Punctelia subrudecta* (Nyl.) Krog	+	-	+	-	+	-	-	-	-	-	+	+	-	-	+	-	37.5
30.	*Ramalina conduplicans* Vain.	+	-	+	+	+	+	+	+	+	+	+	-	-	-	+	-	68.75
31.	*R. sinensis* Jatta	+	+	+	+	+	-	-	-	+	-	+	-	-	-	+	-	50
32.	*Usnea eumitrioides* Motyka	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	6.25
33.	*U. orientalis* Motyka	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	+	18.75

A-Ethnomedicinal; **B**-Anticancerous; **C**-Antifungal; **D**-Antimicrobial; **E**-Antibacterial; **F**-Antidermatophytic; **G**-Antihelmintic; **H**-Anti-insecticidal; **I**-Antiproliferative; **J**-Anti-inflammatory; **K**-Antioxidant; **L**- Antidiabetic; **M**-Antimycobacterial; **N**-Immunomodulatory; **O**- α-amylase inhibitory; **P**- Lichens applied on wounds, cuts, and burns

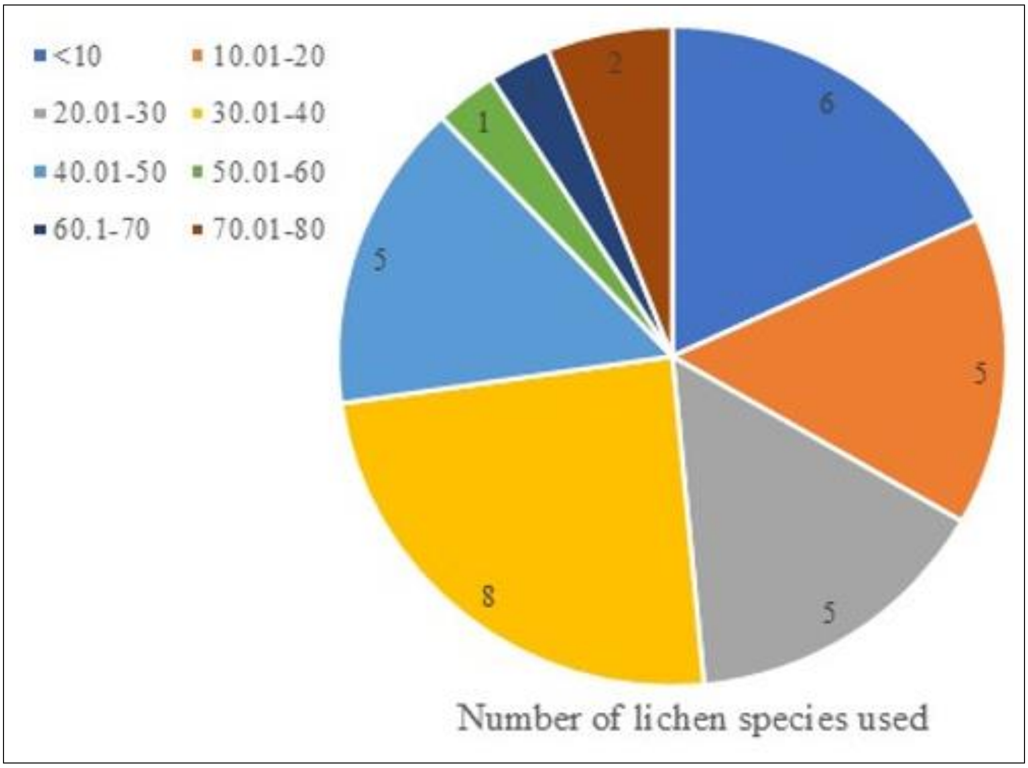

Fig 4: Utilization pattern of different macrolichens possess their medicinal properties

Application

The thallus of lichen possesses several ethnopharmacological, nutraceutical and therapeutic properties. Also, these lichens are scrubbers of pollution. The lichens are of great advantage for the several local commodities across the entire world. They are frequently used traditionally by the inhabitants residing in Indian Himalayan regions to cure common illness, cold, cough, cuts, burns or boils.

Conclusion

Lichens are a source of physiologically active substances that have demonstrated encouraging results. Previously, lichenological studies were limited to its taxonomy and ecological aspects, but at present scenario lichen-derived biologically active compounds is contributing for its phytopharmacological applications as reported for antiproliferative, anticancerous, antimicrobial, antidermatophytic. But still there is a scarcity of information regarding the metabolites obtained from macrolichens that still needs to be inspected, screened and evaluated.

Lichens are also a source of income for the local commodities residing in the Indian Himalayan regions and for the tribal communities across the globe. They play a pivotal role in maintenance of nutrients worldwide, including nitrogen, carbon, trace elements, soil composition and weathering of rocks. The previous studies focused more on its taxonomic studies, but there is a massive need to conserve these small cryptogams in nature to study the pharmacological uses as well. The decline in their natural habitat, the substratum, is the prime cause of the shifting of lichens from the pre-existing localities to the higher altitudes. The paradigm shift in their habitat and specific substratum due to excessive vehicular pressure and rapid urbanization is becoming a global concern for the areas that were previously laden with the diversity of lichen taxa.

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