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Diversity and Distribution of lichens on some monuments in Jaipur, Udaipur, and Bharatpur Districts of Rajasthan, India

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***Abstract*:** This study provides information on the diversity and dispersion of lichen species growing over monuments in the Udaipur, Bharatpur, and Jaipur districts by analysing the species' diversity and distribution. Nine genera, including *Phylliscum*, *Naetrocymbe*, *Peltula*, *Endocarpon*, *Zahlbrucknerella*, *Anema*, *Lichinella*, *Lepraria*, and *Anisomeridium*, as well as six families, contained a total of 19 species together with some algae, fungus, and other microorganisms, the Peltulaceae, Verrucariaceae, Lichinaceae, Monoblastiaceae, Naetrocymbaceae, and Leprocaulaceae families were found to be colonizing monuments in these three districts, from which lichinaceae is the dominating family and *Phylliscum indicum* is the dominating species. Diversity indices were produced. Predominance of Lichinaceae show a particular type of climate.

Index terms: Diversity, Distribution, Ecology, RTU, Climate,

1. INTRODUCTION

Lichens are capable of colonizing even the most dangerous environments, as pioneers they can be found anywhere, including the highlands and the desert (Kappen 1988). Around 8% of terrestrial ecosystems have them as the main species (Larson 1987). Lichen diversity is influenced by a variety of environmental gradients, including temperature, precipitation, humidity, etc (Pausas & Austin 2001, Nimis et al. 2002). Lichens develop at their best at a certain intermediate level (Pinokiyo 2008). Researchers' interest has recently been piqued by a variety of species richness patterns and relationships between elevations and diversity (Pinokiyo 2008, Das 2012, Gupta et al. 2014, Nanda et al. 2021).

Plant distribution and diversity are influenced by climate (Harrison 2020). In this work, we looked at the relationships between lichen diversity and climatic conditions. A specific location's climate creates a microenvironment that supports the development of a certain species there. Rajasthan belongs to the WDR (Western Dry Regions), one of the eight lichen-geographic zones (Singh and Sinha 1997), which does not promote luxurious lichen growth. This study documents the variety of lichens on Rajasthani monuments. This research adds for the first time to our understanding of the lichens that grow at Rajasthani monuments. In the past, studies of this kind have been conducted in Madhya Pradesh (Uppadhyay et al. 2016), Assam (Chaudhary et al. 2016), Orissa (Behera et al. 2020), Andhra Pradesh (Devi et al. 2013), and Uttarakhand (Singh and Upreti 1991), Uttar Pradesh (Ayub et al.2005), but none of these investigations have examined the impact of the climate on the development of lichens over monuments. As previously observed by (Bajpai et al. 2012), different exposed regions of monuments offer lichens and other microorganisms an appropriate location and habitat. So, in this study, we looked at the relationship between the local climate and the variety and distribution of lichens found on historical structures.

2. MATERIAL AND METHODS

2.1 Area of study

Rajasthan's capital city, Jaipur, is situated in the north eastern region of the country, on the edge of the Thar Desert. It is located between 26° 46' and 27° 01' N latitude and between 75° 39' and 75° 57' E longitude. It is encircled by the Jhalana Hills in the east, the Aravali Range and Nahargarh Hills in the north. Overall, Jaipur exhibits a continental environment with temperatures ranging from 8 °C to 47 °C and rainfall from 100 mm to 390 mm; this climate does not promote a good growth of lichen diversity (Table 1, Fig 1).

In Rajasthan's southwest is Udaipur. The "Venice of the East" is the name given to it. The Aravali Hills encircles it, and three lakes connect it. It is situated between 73°9' and 74°35' E and 23°46' and 25°5' N and E, respectively. The temperature fluctuates from 38.3 °C (max) to 28.8 °C (min) in the summer and from 28.3 °C (max) to 11.6 °C in the winter (min). (Kundu et al.2015) Due to the late monsoon, minimal rainfall, and hot summers, Udaipur's climate is generally semi-arid. There are drought conditions in this area. (Fig 1, Table 1) (Bhuiyan et al 2006). Bharatpur is located in Rajasthan's eastern region (Fig 1). Delhi, the Indian capital, lies 180 miles from the district. Between 26° 22' N and 76° 53' to 78° 17' E, it is situated (Table 1, Fig 1).

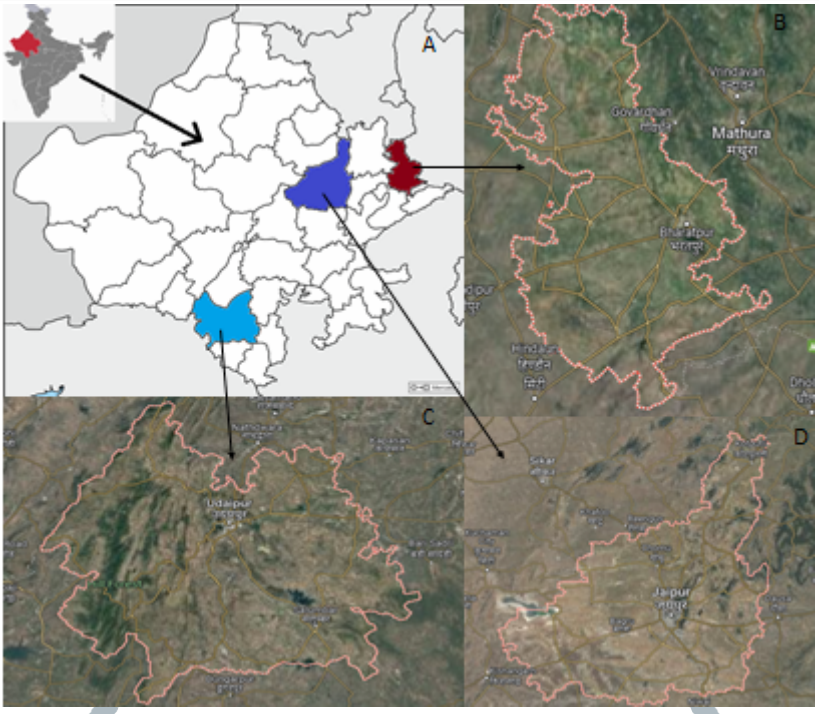

Figure 1. Study area (A) Rajasthan in India, (B) Bharatpur, (C) Udaipur, (D) Jaipur

2.2 Collection of samples

The method for gathering specimens was random sampling (Negi 2000). Bharatpur, Jaipur, and Udaipur were the three districts chosen as transect types (Table 1). 51 plots (10 x10) m. in all were surveyed, 23 of them were in the city of Jaipur, including Mundhota Village, certain Dhanies inside the city, and wayside constructions; 13 were in the city of Bharatpur, including Deeg Town and Kumher Village; and 16 were in the city of Udaipur (Fig 5, Table 2,3,4). Only lichen-rich sites were preferred for the sampling because most monuments have been anthropogenically altered. Almost 300 samples were gathered. Number of packets considered as the no. of individual per species, sample is an RTU, or recognized taxonomic unit (Negi 2000). All samples were examined using an optical microscope for anatomical investigations, under a stereo zoom microscope for morphological studies, and for chemical studies (Orange et al. 2001). These samples were recognized with the aid of pertinent keys and monographs. (Lucking, R. 2017) (Awasthi, 1979; 1991; 2007). Calculations were made for lichen assemblage density and frequency (Curtis and Machintosh 1950). IVI (Important Value Index) was determined in accordance with Philips (1959), the Shannon-Wiener index (Shannon & Wiener 1949) was used to assess species richness alpha diversity (H').

3.RESULTS AND DISCUSSIONS

The lichen family Lichinaceae, which has 4 genera, dominates the study with 19 species from 9 genera and 6 families. The predominance of Lichinaceae reflects both the low species variety of lichens and the semi-arid region or Mediterranean climate (Shultz 2011). Most species are found in the squamulose growth form, followed by leprose, sub fruticose and crustose. *Phylliscum indicum* Upreti, which symbolizes its abundance in the research region, (Table 7, 8, 9) has the highest IVI value, followed by *Zahlbrucknerella indica* D.D. Awasthi, and S.R. Singh. *Peltula obscurans* (Nyl.) Gyeln, respectively (Fig 4) In addition, *Zahlbrucknerella indica* is the second most prevalent and widely dispersed species in the research region after *Phylliscum indicum* Upreti. The least frequent species are *Naetrocymbe saxicola* (A. massal.) R.C. Harris, *Leprocaulon coriense* Hue. Lendemer, and *Peltula obscurans* (Nyl.) Gyeln., which are each only found in a single locality (Table 5,6,7). Also, the *Phylliscum indicum* Upreti. Shannon and Simpson indices are maximum, in the study area indicating that it is a dominant species in the study area (Fig 3, Table 8).

Jaipur (0.11751098) has the lowest Simpson index score, indicating both its strongest dominance and lowest heterogeneity. While Udaipur (0.177272727) has the greatest Simpson index value, its lichen distribution is also the most heterogeneous and has the lowest dominance (Table 9). The study area comes under WDR, that represent by Shannon index value that is (1.08047) and less than 3.5, and indicates low lichen diversity for the study area, (Singh and Sinha 1997). Up till now 104 species of lichens are listed, this indicates a low diversity of lichens in WDR (Sinha 2021). The temperature range of the study area does not support the luxurious growth of lichens (Bajpai et al. 2012).

On monuments, the exposed surface to the outdoors exhibits greater lichen colonization than the shaded portion. The distribution of lichens on monuments varies as well; the uppermost portion has the least lichen growth.

In the studied area, *Phylliscum indicum* Upreti demonstrates its propensity for all kinds of substrata and found mostly on the shady part of the monuments along with *Peltula* (Bajpai et al.2012). The majority of the monuments in the studied region are composed of calcareous substrate, and lichen genera like *Peltula* thrive there better than on marble. The monuments in the Jaipur district have the highest species diversity, with 16 species (Table 6), followed by 13 species in Bharatpur (Table 5) and 10 species in Udaipur (Table 7), respectively. Compared to roadside ruins and well-maintained buildings, lichen growth is more common in rural and abandoned places. The changing seasons have an impact on lichen growth on monuments. During times of high atmospheric humidity, some lichens, like *Peltula* and *Endocarpon*, absorb moisture, restore their natural color, and become readily apparent in the field. The bottom portions of the monuments are dominated by *Zahlbrucknerella indica* D.D. Awasthi & S.R. Singh and *Phylliscum indicum* Upreti. Moreover, the cyanolichens in the Lichinaceae family are vulnerable to acidity brought on by air pollution. These families are numerous in the research area, which is indicative of good local air quality (Cameron and Rechardson 2006).

Naetrocymbe saxicola was well thrive along road side structures and anthropogenetically active areas, compare to *Laprocaulon coreinse* Hue. that found on untouched parts of abandoned monuments.

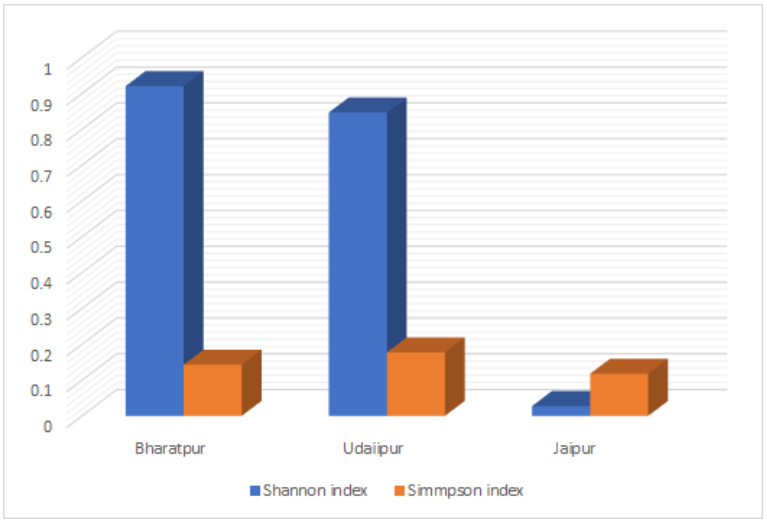

Figure 2. Shannon and Simpson index of the Bharatpur, Jaipur, and Udaipur district

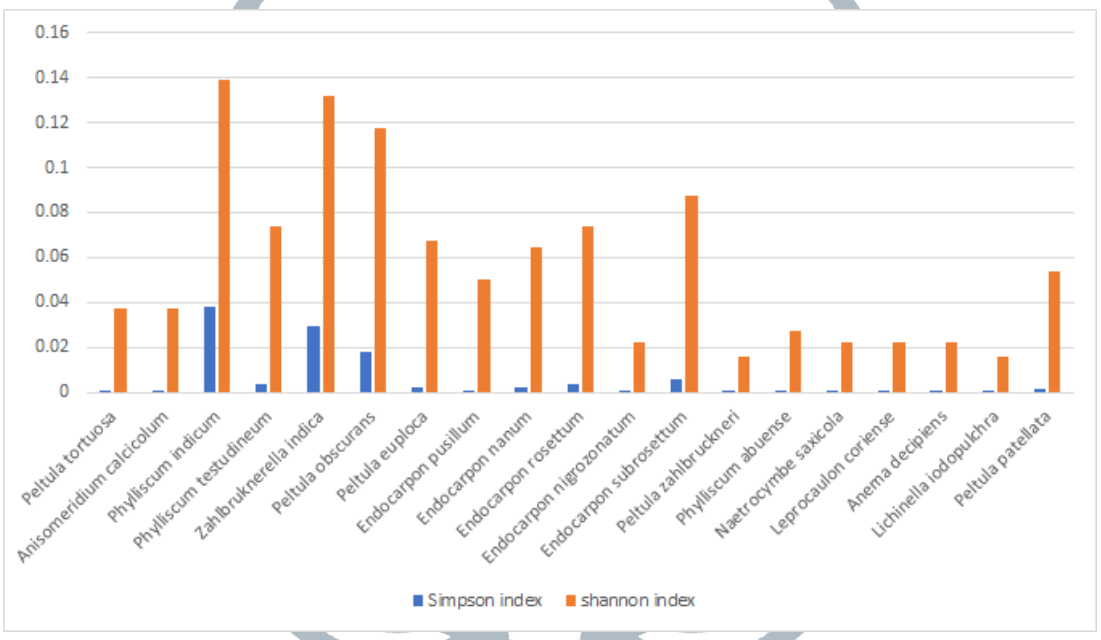

Figure 3. Simpson and Shannon index of various species

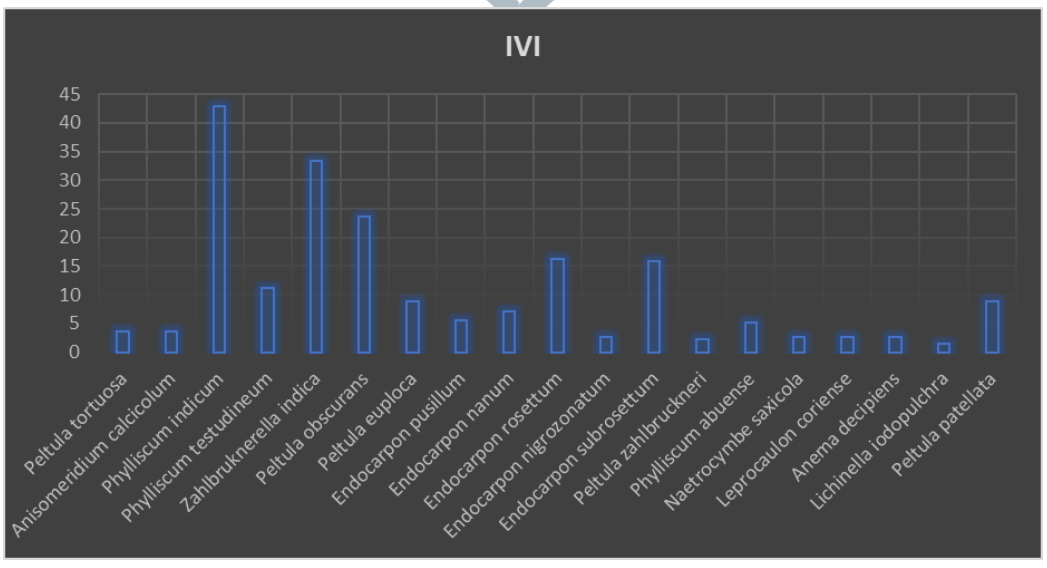

Figure 4. IVI of various species

Figure 5. Various study sites in districts. (A) Roadside structure Bharatpur, (B) Deeg Palace, (C) Abandoned structure, Jaipur, (D) Nahargarh Fort Jaipur, (E) Growth of lichen on Road side abandoned structure, (F) Growth of lichens on roadside structures Udaipur, (G) Abandoned monument Jaipur

Table 1: Geographic location and other characteristics of study transect

Study Transect	Elevation range	Geographical Coordinates	Vegetation type	Climate
Jaipur	1000-3000m	26°46' N, 27° 01N', 75° 39'E, &75°57'E	Mixed xerophytic and Mesophytes	Continental
Udaipur	837m-10,000m	23°46' N, 25°5' N a 73°9' E & 74°35'E	Dry deciduous forest	Semi-arid
Bharatpur	165m-191m	26° 22'N 27° 83'N 76 53 E 78 17E	Scrub forest	Subtropical steppe

Table 2. Monuments of Bharatpur region Explored

S.No.	Study sites	Construction material	Coordinates
1.	Road side shelter, on SH-44, Kumher	Lime plaster, brick	27°19'53" N 77°22'10" E
2.	Roadside shelter (Sarai)	Brick, Lime plaster	27°28'11" N 77°29'43" E
3.	Deeg Jal Mahal	Lime plaster	27°28'20" N 77°19'25" E
4.	Deeg fort	Lime plaster	27°28'14" N 77°19'45" E
5.	Jawahar Burj	Lime plaster	27°13'23" N 77°29'40" E
6.	Lohagarh Fort	Lime plaster	27°13'19" N 77°29'39" E
7.	Fort wall	Lime plaster	27°13'20" N 77°29'34" E
8.	Lohagarh park	Lime plaster	27°13'15" N 77°29'44" E
9.	Kile Wale Hanumanji	Lime plaster	27°13'05" N 77°29'49" E
10.	Kila Udhyan	Lime plaster	27°13'21" N 77°29'45" E
11.	Ghora ghat	Brick, lime plaster	27°13'08" N 77°29'47" E
12.	Wall of Kishori Mahal	Red sand stone	27°13'14" N 77°29'42" E

Table 3. Monuments of Jaipur region explored

S.No.	Study sites	Construction material	Coordinates
1.	Kesar kyari garden Amer fort	Lime plaster	26°59'06" N 75°51'08" E
2.	Jaigarh fort	Lime plaster	26°58'53" N75°50'41" E
3.	Siyaram baba ki dungari amer fort	Lime plaster	26°59'07" N75°51'04" E
4.	Department of education University of Rajasthan	Lime plaster	26°53'08" N75°49'04" E
5.	Near Vivekananda Garden Univ. Law college, Playground University of Rajasthan	Lime plaster	26°53'10" N75°48'43" E
6.	Wall of temple Shri Gyan Gopal ji	Lime plaster	26°55'00" N75°51'28" E
7.	Wall of Galtaji temple	Lime plaster	26°54'56" N75°51'47" E
8.	Nahargarh fort	Lime plaster	26°56'14" N75°48'55" E
9.	Mundhota Village Road side structure	Lime plaster	27°00'53" N75°34'37" E
10.	Kalwar garh fort Palace	Lime plaster	26°59'15" N75°34'57" E
11.	Near Kalwar fort	Lime plaster	26°57'13" N75°30'50" E
12.	Mundhota fort	Lime plaster, brick	27°00'42" N75°34'50" E
13.	Devnarayan temple Mundhota Village	Lime plaster	27°00'52" N75°34'46" E
14.	Mishra Mohalla Mundhota Village Jaipur	Lime plaster, brick	27°00'53" N75°34'37" E
15.	Ward no.5, Mundhota	Lime plaster, brick	27°00'51" N75°34'39" E
16.	Near Dev narayana Temple Mundhota	Lime plaster	27°00'52" N75°34'46" E
17.	Bhuteshwar Mahadev Mundhota	Lime plaster	27°01'07" N75°34'41" E
18.	Mundhota mewa Baba Kali Ravana Mundhota	Lime plaster	26°34'51" N75°23'46" E
19.	Army Area Mundhota	Lime plaster	27°00'49" N75°33'29" E
20.	Road side ruins Mundhota	Lime plaster	27°00'53" N75°34'45" E
21.	Road side ruins neem ki Dhani Mundhota Village	Lime plaster	27°00'56" N75°34'34" E
22.	Road side old Buildings, Mundhota village	Lime plaster	27°00'50" N75°34'26" E
23.	Sherawaton ki dhani Mundhota village Jaipur	Lime plaster	27°00'33" N75°33'15" E

Table 4. Monuments of Udaipur district

S.No.	Study sites	Construction materials	Coordinates
1.	Wall of Udaipole gate	Lime plaster	24º34’34” N,73°41’59” E
2.	Gulab Bagh, Navlakha temple Bawdi	Lime plaster	24º34’31” N,73°41’36” E
3.	Gulabeshwar Mahadev Zoo	Lime plaster	24º34’15” N73°41’30” E
4.	Bhatiyani chauatta bazaar	Lime plaster	24°34’38” N73°41’04” E
5.	Public Library Jagadeesh chowk	Lime plaster	24°34’44” N73°41’02” E
6.	City Palace Udaipur	Lime plaster	24º34’35” N73º41’00” E
7.	Near Shri eklingji temple	Limeplaster, Marble	24°44’49” N73°43’24” E
8.	Lake view Fatah Sagar	Lime plaster	24°34’45” N73°40’14” E
9.	Aravali Vatika, Fatah Sagar Road	Lime plaster	24°35’32” N73º40’57” E
10.	Near Dron acharya Ekalavya Park	Lime plaster	24º34’05” N73°41’05” E
11.	Sajjan garh monsoon fort	Lime plaster	24º35’35” N73°38’22” E
12.	Shilpgram road	Lime plaster	24º36’44” N73°39’50” E
13.	Hanuman chowk	Lime plaster	24º35’30” N73°43’20” E
14.	Haldighati khamnore	Lime plaster	24°52’59” N73°41’24” E
15.	Walls of Manik Lal Verma park	Lime plaster	24°34’08” N73°41’08” E
16.	Bagore ki Haveli	Lime plaster	24°34’46” N73º40’56” E

Table 5. Diversity of Lichens on various monuments of Bharatpur

	Lichen taxa	GF	Localities surveyed											
			1	2	3	4	5	6	7	8	9	10	11	12
1.	*Anema decipiens*	S											+	
2.	*Phylliscum abuense*	S	+		+	+	+							
3.	*Phylliscum indicum*	S	+			+	+		+				+	
4.	*Zahlbrucknerella indica*	SF	+	+		+	+			+	+	+	+	
5.	*Anisomeridium calcicola*	C		+		+	+							
6.	*Peltula euploca*	S	+		+								+	
7.	*Peltula obscurans*	S	+	+	+	+	+		+				+	
8.	*Peltula patellata*	S									+			
9.	*Endocarpon nanum*	S	+											
10.	*Endocarpon pusillum*	S	+				+							
11.	*Endocarpon rosettum*	S	+	+			+		+					
12.	*Endocarpon subrosettum*	S	+		+	+	+	+	+				+	+
			9	5	4	7	8	1	4	1	2	1	7	1

GF= Growth factor, S= squamulose, SF= Sub fruticose, C= Crustose

Table 6 Diversity of lichens on various monuments of Jaipur

	Lichen taxa	GF	Localities surveyed																						
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	*Peltula tortuosa*	S	-	-						-										-					-
2	*Peltula petallata*	S	-	-		+					-					-						+			
3	*Anisomeridium calcicola*	C								-															
5	*Phylliscum indicum*	S	+	-		-	+	-		-			-	-	+	-	-		+	-	-	-	+	-	-
6	*Phylliscum testudinate*	S		-	-				+			-	-	-	+		-	-	+	-					
7	*Zahlbruckner ella indica*	S F		-	-				+	-		-	-	-	+		-	-	+	-	-	-	+	-	
8	*Peltula Zahlbruckneri*	F									-														
9	*Peltula Obscurans*	S	+	-					+		+	-			+		-	-							
10	*Peltula euploca*	S									+			-											
11	*Endocarpon pussilum*	S		-										-							-				
12	*Endocarpon nanum*	S								-								-	-			-			-
13	*Endocarpon rosettum*	S					+	-	+										+						
14	*Endocarpon subrosettum*	S			-							-						-					-		
15	*Endocarpon nigrozonatum*	S		-							+												-		
16	*Phylliscum abuense*	S		-																					
	Total		2	9	1	2	2	2	5	5	4	5	3	5	4	2	6	5	4	4	3	4	4	2	3

GF= Growth factor S= Squamulose, F=Fruticose, C= Crustose

Table 7. Diversity of Lichens on various monuments of Udaipur

S. No	Lichen taxa	GF	Localities surveyed															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	*Phylliscum indicum*	S	+		+	+		+	+	+		+		+			+	+
2.	*Zahlbrucknerella indica*	S F	+	+			+											
3.	*Endocarpon subrosettum*	S	+										+					

4.	***Leprocaulon coriense***	**Lp**	+																
5.	***Peltula patellata***	**S**				+													
6.	***Naetrocymbe saxicola***	**C**							+										
7.	***Lichinella iodopulchra***	C														+		+	
8.	***Endocarpon rosettum***	**S**							+		+						+		
9.	***Peltula obscurans***	**S**													+				
10.	***Anema decipiens***	**C**												+					
	Total		**4**	**1**	**1**	**2**	**1**	**1**	**3**	**1**	**1**	**1**	**1**	**2**	**1**	**1**	**2**	**2**	

GF= Growth factor, S= Squamulose, C= crustose, LP= Leprose, SF= sub fruticose

Table 8: IVI (Important value Index) values of the study area

S. No	Name of Species	Bharatpur	Jaipur	Udaipur
1.	*Peltula tortuosa* (Nees.) Wetmore	–	7.362355953	–
2.	*Anisomeridium calcicola* Upreti&Nayaka	6.54177	4.438753734	–
3.	*Phylliscum indicum* Upreti	21.3145	45.15578318	75.71428571
4.	*Phylliscum testudineum* Henssen.	–	16.99743918	–
5.	*Zahlbruknerella indica* D.D Awasthi & S.R Singh	28.71622	41.4746052	26.28571429
6.	*Peltula obscurans* (Nyl.) Gyeln.	40.78624	19.05676483	15.14285714
7.	*Peltula euploca* Ach. Poelt.	11.5172	10.39265898	–
8.	*Endocarpon pusillum* Hedw.	7.678133	5.089628681	–
9.	*Endocarpon nanum* Ajay Singh & Upreti	8.384521	8.877507469	–
10.	*Endocarpon rosettum* Upreti	6.111794	19.49423815	32.07142857
11.	*Endocarpon nigrozonatum* Ajay Singh & Upreti	–	4.332052923	–
12.	*Endocarpon subrosettum Upreti*	40.23342	8.664105847	9.357142857
13.	*Peltula zahlbruckneri* (Hasse) Wetmore	–	4.332052923	–
14.	*Phylliscum abuense* Ajay Singh & Upreti	12.65356	4.332052923	–
15.	*Naetrocymbe saxicola* (A. Massal)	–	–	7.571428571
16.	*Leprocaulon coriense* (Hue)	–	–	7.571428571
17.	*Anema decipiens* (A. Massal) Forssel.	7.678133	–	7.571428571
18.	*Lichinella iodopulchra* Couderc ex. Croz.	–	–	7.571428571
19.	*Peltula patellata* (Bagl.) Swinscow & Krog.	8.384521	–	11.14285714

Table 9. IVI of the all three districts

S.No.	Districts	Shannon Index	Simpson Index
1.	**Bharatpur**	0.920201287	0.142894462
2.	**Jaipur**	0.846588276	0.177272727
3.	**Udaipur**	0.027568848	0.117510988

4.CONCLUSIONS

The lichen richness at Rajasthan's archaeological monuments will be supported by the current investigation. In Bharatpur, brick and lime plaster are primarily used in the construction of monuments. Sandstone brick and lime plaster are primarily used in the construction of monuments in the Jaipur district. Marble, sandstone, and lime plaster are primarily used in the construction of monuments in Udaipur. According to the WDR (western dry region) classification system, Rajasthan is the Northwesternmost state in India and does not support the luxurious growth of the lichens (Singh and Sinha 1997). Consequently, the current study will offer baseline information for lichen investigations at the Rajasthani archaeological site and be useful in future biodeterioration and biomonitoring studies, particularly in anthropogenically active areas.

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REFERENCES

1. Ayub, A. 2005. Lichen Flora of some major historical monuments & buildings of Uttar Pradesh, Ph.D. Thesis, Dr. R.M.L Awadh University, Faizabad.
2. Awasthi DD. 1991. A key to microlichens of India, Nepal, and Sri Lanka. Bibliotheca Lichenologica, (40):1-136.
3. Awasthi DD. 2007. A Compendium of the Macro lichens from India, Nepal and Sri Lanka. Bishen Singh, Mahendra Pal Singh, DehraDun, India.
4. Awasthi DD, Singh, SR. 1979. New or otherwise interesting lichens from Mt. Abu, Rajasthan, India. Norwegian Journal of Botany, (26): 91–97.
5. Bajpai R, Upreti DK, Nayaka S, Dwivedi, SK. 2012. Lichen biodeterioration studies in India: An overview. In Bioremediation of pollutants (eds Dubey. R.C. and Maheswari, D.K.) I.K. International Publishing house, New Delhi, pp. 63-73.
6. Behera PK, Nayaka S. 2020. Updated checklist of lichen biota of Meghalaya, India with 93 new distributional records for the state. The Journal of Indian Botanical Society, 100(3&4): 134-147. http://dx.doi.org/10.5958/2455-7218.2020.00033.9
7. Bhuiyan C, Singh R P, Kogan F N. 2006. Monitoring drought dynamics in the Aravalli region (India) using different indices based on ground and remote sensing data. International Journal of Applied Earth Observation and Geoinformation, 8: 289–302. https://doi.org/10.1016/j.jag.2006.03.002
8. Cameron RP, Richardson DH. (2006). Occurrence and abundance of epiphytic cyanolichens in protected areas of Nova Scotia, Canada. *Opuscula Philolichenum*, 3(5): 5-14.
9. Choudhury, M P., Sarma M. and Nayaka S. 2016. A preliminary study on lichens of ancient ruins of Bamuni hills, Tezpur, Assam, North-East India. The Bioscan, 11(3): 1493-1496.
10. Curtis J T, Mcintosh R P. 1950. The interrelations of certain analytic and synthetic phytosociological characters. Ecology, 31(3): 434-455. https://doi.org/10.2307/1931497
11. Das P, Joshi S, Rout J, Upreti D K. 2012. Shannon diversity index (H) as an ecological indicator of environmental pollution—A GIS approach. Journal of Functional and Environmental Botany, 2(1): 1–8. http://dx.doi.org/10.5958/j.2231-1742.2.1.003
12. Devi A, Mohabe S, Madhusudhana Reddy A, Nayaka S, Chandramati Shankar P. 2013. Diversity and distribution of lichens in YSR District, Andhra Pradesh with several new additions. 2(4):1-9.
13. Gupta S, Khare R, Rai H, Upreti DK, Gupta R K, Sharma P K, Srivastava K, Bhattacharya P. 2014. Influence of macro-scale environmental variables on diversity and distribution pattern of lichens in Badrinath valley, Western Himalaya. Mycosphere, 5(1): 229-243. http://dx.doi.org/10.5943/mycosphere/5/1/12.
14. Kappen L. 1988. Eco physiological relationships in different climatic regions. Handbook of lichenology, (2): 37-100.
15. Kent M, Coker P. 1992. Vegetation Description and Analysis Belhave press London pp. 363.
16. Kumar R. 2019. Analytical Study on Recent Trends of Climate in the Jaipur City. IJRAR, 6 (1): 197-200.
17. Kundu A, Chatterjee S, Dutta D, Siddiqui, A R. 2015. Meteorological trend analysis in Western Rajasthan (India) using geographical information system and statistical techniques. J Environ Earth Sci, 5(5): 90-99.
18. Larson D W. 1987. The absorption and release of water by lichens. Bibliotheca Lichenologica 25: 351-360.

19. Lucking R, Hodkinson B P, Leavitt SD. 2017. The 2016 classification of lichenized fungi in the Ascomycota and Basidiomycota- Approaching one thousand genera. The Bryologist, 119(4): 361-416. doi.org/10.1639/0007-2745-119.4.36.
20. Mishra G K, Upreti D K. 2016. Diversity and distribution of macro-lichen in Kumaun Himalaya, Uttarakhand. International Journal of Advanced Research, 4(2): 912-925.
21. Nanda S A, Haq M U, Singh S P, Reshi Z A, Rawal R S, Kumar D, Pandey, A. 2021. Species richness and β-diversity patterns of macrolichens along elevation gradients across the Himalayan Arc. Scientific Reports, 11(1): 1-15. https://doi.org/10.1038/s41598-021-99675-1
22. Negi H R. 2000. On the patterns of abundance and diversity of macrolichens of Chopta- Tunganath in the Garhwal Himalaya. Journal of Biosciences, 25(4): 367-378. https://doi.org/10.1007/BF02703790
23. Nimis P L, Purvis WO. 2002. Monitoring lichens as indicators of pollution. An introduction. In: Nimis, P.L., Scheidegger, C., Wolseley, P. (Eds.), Monitoring with Lichens e Monitoring Lichens. Kluwer, Dordrecht, pp. 7-10.doi: 10.1007/978-94-010-0423-7_2
24. Orange A, James PW, White, F J. 2001. microchemical methods for the identification of lichens. British Lichen Society, London.doi.org/10.1006/lich. 2002.0376
25. Pausas J G, Austin M P. 2001. Patterns of plant species richness in relation to different environments: an appraisal. Journal of Vegetation Science, 12 (2): 153-166.
26. Phillips E A. 1959. Methods of Vegetation Study. Holt, Rinehart and Winston, New York, p107.
27. Pinokiyo A, Singh K P, Singh J S. 2008. Diversity and distribution of lichens in relation to altitude within a protected biodiversity hot spot, north-east India. Lichenologist, 40(1): 47–62. https://doi.org/10.1017/S0024282908007214
28. Schultz M, Moon K H. 2011. Notes on taxonomy and distribution of some critical cyanobacterial lichens from South Korea. Nova Hedwigia, 92(3): 479. DOI: 10.1127/0029-5035/2011/0092
29. Shannon C E, Weaver W. 1949. the mathematical Theory of communication. Urbana, IL: University Illinois Press.
30. Singh A, Upreti D K. 1991. Lichen flora of Lucknow with special reference to its historical monuments. In: Agarwal, O.P. & Dhawan. S., (Eds.) Biodeterioration of cultural property. Mac Millan, India. New Delhi Vol.1, pp. 219-231.
31. Singh K P, Sinha G P. 1997. Lichens, In: Floristic diversity and conservation strategies in India.Vol1 Cryptogams and Gymnosperms (Mudugal V and Hajara PK eds.), BSI, Ministry of Environment and Forest, Govt. of India, pp 195-234.
32. Sinha, G. P. 2021. ILS eLetters1:5 Uppadhyay, V., Ingle, K. K., Trivedi, S. and Upreti, D.K. (2016). Tropical Plant Research3(2):384

33. Uppadhyay V, Ingle K K, Trivedi S, Upreti D K. 2016. Diversity and distribution of lichens from the monuments of Gwalior division, Madhya Pradesh with special reference to rock porosity and lichen growth. Tropical Plant Research, 3(2): 384-389.