The Diversity and Distribution of Mosses in Gujarat: Current Status

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The Diversity and Distribution of Mosses in Gujarat: Current Status

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Abstract

Gujarat harbors a large diversity of habitats ranging from deserts to moist deciduous forest to grasslands and coastal areas which provide a variety of microhabitats necessary for colonisation by bryophytes. An earlier study reported 44 species of mosses in Gujarat. 75% of the districts however remained unsurveyed. Hence, to understand the diversity of bryophytes in the state and its distribution, an intensive study was carried from November 2013 to February 2015. The present study reports the presence of 24 species of mosses which belong to 12 genera falling under 7 families. Pottiaceae, Bryaceae, Plagiothiaceae and Fissidentaceae are the dominant moss families of Gujarat while *Bryum, Stereophyllum* and *Hyophila* are the dominant moss genera with four species each. *Gymnostomiella. vernicosa* (Hook.) Fleish. and *Hyophila. involuta* (Hook.) Jaeg. were the most common and found in almost all the districts of Gujarat. The other common species included *Hydrogonium consanguineum* (Thw. *et* Mitt.), *Barbula indica* (Hook.) Spreng., *Bryum coronatum* Schwaegr, *Bryum capillare* L. ex Hedw. *Brachyemenium turgidium* Broth. ex Dix., *Fissidens curvatoinvolutus* Dixon. and *Barbula indica* (Hook.) Spreng . *Physcomitrium eurystomum* Sendth. and *Hyophila spathulata* (Harv.) Jaeg. are being reported for the first time from the state. Moss records are being reported for the first time for more than 20 districts of the state. Dangs district has the highest diversity followed by Junagadh, Panchmahal and Valsad districts

1. INTRODUCTION:

India has a rich diversity of mosses and several workers have undertaken studies on this group of plants in different parts of the country. Major contributions to the diversity of mosses from different parts of India include, Eastern Himalayas (Gangulee 1969-1980), Western Himalayas (Chopra *et al*.1981), North Konkan –Maharahstra (Chaudhary *et al.* 2008), Rajasthan (Chaudhary *et al* 1993), Western Ghats (Frahm *et al.* 2013; Manju *et al* 2009), North India (Asthana and Sahu 2013) and monographs on Pottiaceae (Aziz 2008). A recent compilation (Dandotiya *et al.*2011), revealed that a total 1786 species of mosses have been reported from India. 210 species of mosses have been reported from the Central Indian region which includes Gujarat (Alam *et. al.* 2015). Mosses in Gujarat have been generally neglected and very little work had been carried out on its diversity in the state till 2006. A preliminary report on the mosses of Pavagadh, a hill in central Gujarat was published in 1961 (Chavan *et al* 1961) in which 8 species of mosses were reported. A compilation on the biodiversity of the state (GEC 1996) also reported the presence of only 8 species. The "*Bryophyte Flora of Gujarat*" in 2006 (Chaudhary *et al* 2006) was a major contribution to the moss flora of the state. It also forms the basis of the reported distribution of different mosses in Gujarat by Alam *et. al.* (2015). The study reported a total 44 Mosses from different locations in the state. The flora was an outcome of periodic visits to 18 locations across the state. A closer analysis of the findings however showed that several districts like Vadodara, Chhota Udepur, Naramada, Bharuch and Tapi etc. were not covered under the study despite of having a good forest cover. Further, out of 44 species of mosses reported, sporophytic phase was not found in 34 species. A detailed study was hence required to cover the unexplored areas and understand the diversity of mosses in Gujarat. The present work is an outcome of the exploration work conducted during November2013- February2015 across different locations in the state.

2. METHODOLOGY:

A total of 75 localities spread over 31 out of the 33 districts of the state were visited (Fig.1). Only Jamnagar

Table 1: Diversity of Mosses.

Sr. no	Species	Families
1.	*Anomobryum auratum* (Mitt.) Jaeg.	Bryaceae
2.	*Brachymenium turgidium* Broth ex Dix	Bryaceae
3.	*Bryum coronatum* Schwaegr.	Bryaceae
4.	*Bryum paradoxum* Schwaegr.	Bryaceae
5.	*Bryum capillare* L. ex. Hedw	Bryaceae
6.	*Bryum cellulare* Hook.	Bryaceae
7.	*Fissidens curvatoinvolutus* Dix.	Fissidentaceae
8.	*Fissidens flaccidus* Mitt.	Fissidentaceae
9.	*Fissidens zollingeri* Mont.	Fissidentaceae
10.	*Funaria hygrometrica* Hedw.	Funariaceae
11.	*Gymnostomiella vernicosa* (Hook.)Fleich	Splachnobryoideae
12.	*Hydrogonium arcuatum* (Griff.) Wijk & Marg.	Pottiaceae
13.	*Hydrogonium consanguineum* (Thw. et Mitt.) Hilp	Pottiaceae
14.	*Hyophila involuta* (Hook).Jaeg	Pottiaceae
15.	*Hyophila walkeri* Broth.	Pottiaceae
16.	*Hyophila spatulata* (Harv.)Jaeg.	Pottiaceae
17.	*Hyophila nymanniana* (Fleish.) Menzel	Pottiaceae
18.	*Philonotis revoluta* Bosch & Lac.	Batramiaceae
19.	*Philonotis hastata* (Dub.) Wijk & Marg.	Batramiaceae
20.	*Physcomitrium eurystomum* Sendth.	Funariaceae
21.	*Semibarbula orientalis* (Web.) Wijk & Marg.	Pottiaceae
22.	*Stereophyllum decorum* (Mitt.)Wijk & Marg.	Plagiotheciaceae
23.	*Stereophyllum tavoyense* (Hook.) Jaeg.	Plagiotheciaceae
24.	*Stereophyllum ligulatum* Jaeg.	Plagiotheciaceae

and Devbhoomi Dwarka districts which were located to the south of the Gulf of Kachchh could not be covered in the present study. A total of 90 days of field work was conducted during November 2013-February 2015. All the districts were visited during monsoon and post monsoon.

2.1 STUDY AREA:

Gujarat is the sixth largest state in India. It covers an area of approximately 1,96,022 km^2 (Anon, 2013). It has a varied climate with different regions having an annual rainfall ranging from 489 mm in arid or semi arid region like Kutch and Saurashtra to 2300 mm in Dangs. The state has been divided into 4 Bryological zones *viz* Arid Peninsular region, Semiarid plains and Saurashtra region, Northern subhumid hilly region and Southern humid hilly region (Chaudhary *et al* 2006).

2.2 Collection strategy and sample collection:

Random sampling strategy was employed for the collection of the samples from the different sites. All the different species of mosses encountered during the field visit were collected preferably with the sporophytic stage. The geographic coordinates of the site were recorded using a Garmin E-trex10 GPS receiver. Photographs of the samples in their natural habitat were taken. The samples were collected in brown paper bags, labeled and air dried for further analysis and voucher preparation. The voucher specimens were deposited in the Maharaja Sayajirao University of Baroda herbarium (BARO).

2.3 LABORATORY ANALYSIS AND IDENTIFICATION:

The micromorpological and anatomical features of the

Table 2: Diversity in different regions of Gujarat.

Sub Region of Gujarat	Diversity
Saurashtra	13
North Gujarat	5
South Gujarat	18
Central Gujarat	11
Kutch	1

plants were observed under Leica SD6 stereo binocular microscope and the photographs of the relevant parts were taken with the help of a 3.2 MP Tucsen camera. Based on characters and the available literature, preliminary identification of the plants was carried out. The samples were then taken to the National Botanical Research Institute (NBRI), Lucknow where the identity was confirmed after consultation with the experts.

3. RESULTS:

A total of 38 moss species were collected in the present study. Of these the identity of 24 species belonging to 12 genera and 7 families could be established (Table 1). Pottiaceae was the most dominant families with 7 species followed by Bryaceae (6 Species) and Fissidentaceae and Plagiotheciaceae with 3 species each. *Hyophila spatulata* and *Physcomitrium eurystomum* Sendth. are new record for the state. The later is the new genus record for the state. *Gymnostomiella. vernicosa* (Hook.) Fleish. and *Hyophila. involuta* (Hook.) Jaeg. were the most common species, inhabiting almost all the studied locations. While eight different species of the genus *Fissidens* were collected, only three species whose identity could be established have been included in the current list. Mosses were collected from different substratums *viz* soil, bark, wall, rock etc., however, most of the taxa were found growing on soil and bark (Figure 2). The highest diversity of mosses was found in South Gujarat 18 species (Table 2).

4. DISCUSSION:

All the districts in South Gujarat, particularly Dangs district have a high forest cover as well as high rainfall compared to other regions of the state. The northernmost extensions of the Western Ghats reach South Gujarat. These could be the major reasons for the high diversity of mosses in the area. Kutch on the other hand has an arid climate and shows the presence of only one species of moss. 21 species reported by earlier workers could not be collected during the current study. The major part of these specimens were earlier collected from Saputara which has seen a huge development as a tourist destination. The loss of habitat could be one of the reasons for the absence of several of the earlier reported taxa. Changes in nomenclature have also resulted in reduction of species diversity e.g. *Fissidens xiphoides* which was reported as separate species is now considered as a synonym of *F. zollingeri*. 14 moss taxa

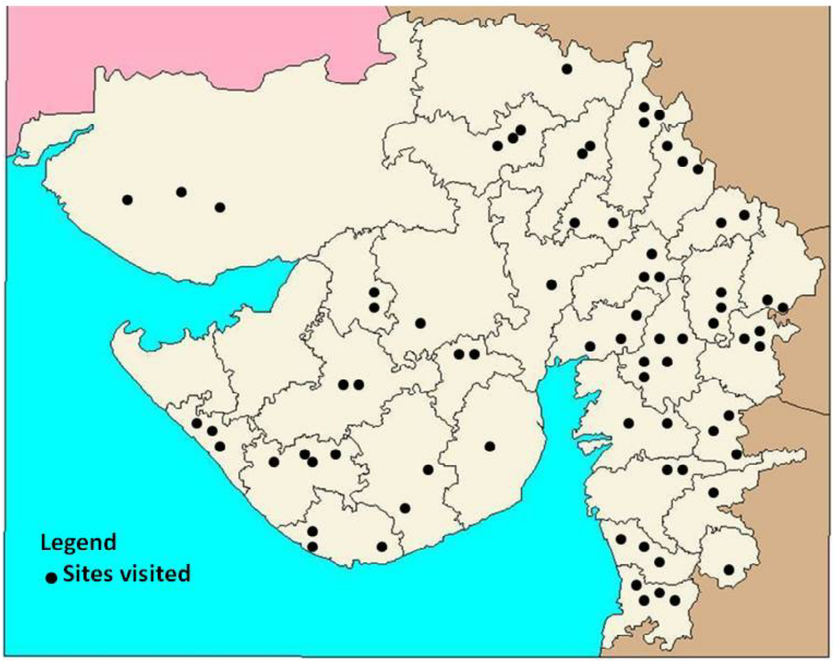

Fig. 1 Map showing the Study area.

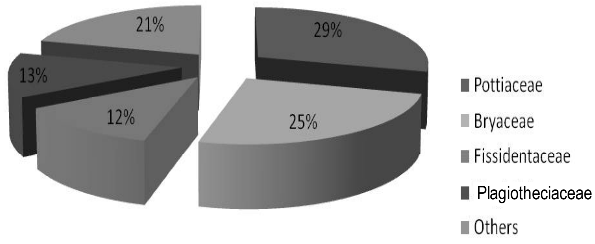

Fig. 2. Distribution of Families

collected during the current study could not been identified till the species level. While some of them have been identified to the genera level further identification has been difficult due to the absence of sporophytes or sexual reproductive structures. As the present study was a state-wide survey, visiting each locality more than twice was not possible. Intensive surveys in selected localities could result in the collection of fertile stages of the above species. This study, thus highlights the need to take up further studies on mosses in the state.

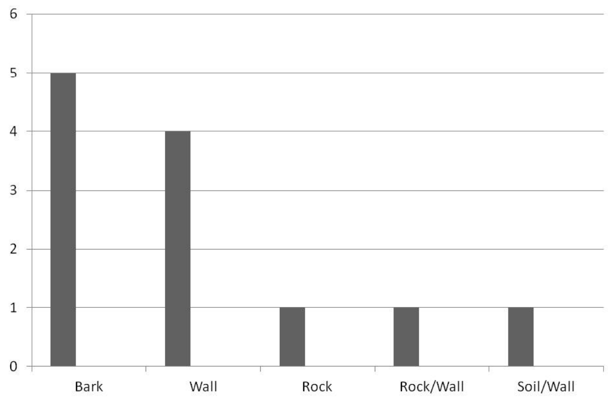

Fig. 3. Distribution of substratum of different species

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Status of Family Fissidentaceae in Gujarat

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Abstract

Bryophytes are the second largest group of land plants and are also known as the amphibians of the plant kingdom. sixty seven species of bryophytes have been reported from select locations across the state of Gujrat. The status of family fissidentaceae which is a large moss family is being presented in this paper. Globally the family consists of 10 genera but only one genus, *Fissidens* Hedw. has been collected from Gujarat. *Fissidens* is characterized by a unique leaf structure and shows the presence of three distinct lamina, the dorsal, the ventral and the vaginant lamina. A total of 8 species of *Fissidens* have been reported from the state based on vegetative characters as no sporophyte stages were collected earlier. *S*pecies reported from the neighboring states also showed the absence of sporophytes. The identification of different species was difficult due to substantial overlap in vegetative characters. Hence a detailed study on the diversity of members of Fissidentaceae in Gujarat was carried out between November 2013 and February 2015. In present study 8 distinct species of *Fissidens* have been collected from different parts of the state. Three species *Fissidens splachnobryoides* Broth., *Fissidens zollingerii* Mont. and *Fissidens curvato-involutus* Dixon. have been identified while the other five are still to be identified. *Fissidens zollingerii* Mont. and *Fissidens xiphoides* M. Fleisch., which have been reported as distinct species are actually synonyms according to TROPICOS database. The presence of sexual reproductive structures and sporophytes for several *Fissidens* species are also being reported for the first time from the state.

Keywords: Bryophytes, Mosses, Fissidentaceae, Diversity.

1. Introduction:

Bryophytes are the second largest group of land plants after the angiosperms and are generally found in moist and damp habitats. They are divided into three groups, liverworts, hornworts and mosses. Mosses are the largest group among bryophytes and constitute comprise about 13,000 species (Goffinet et. al, 2009). They are differentiated from other two groups by the presence of a distinct juvenile gametophytic phase called the protonema stage. The genus *Fissidens* was established by Hedwig in 1801 (Prussel, 2007). The family Fissidentacea comprises of acrocarpic haplolepideous mosses. Fissidentaceae is a distinct and homogenous family related to the Dicranales in peristome structure is but unique in leaf characters. The family consists of 10 genera in the world of which the most common genus is *Fissidens* and is characterized by equitant and distichous leaves and a unique leaf structure consisting of dorsal, ventral and vaginant lamina (Prussel, 2007). The majority of the species in the family are distributed in warm, humid tropical regions of the world. (Pursell, Bruggeman – Nannenga, 2004). The name *Fissidens* is derived from two Latin roots (fissus= cleft + dens= tooth), in reference to the peristome teeth that are divided for much of their length. The plants of *Fissidens* are either corticolous or terricolous. The leaves of *Fissidens* are distichously arranged on the stem. The adaxial end near the leaf base is differentiated into two vaginant laminae clasping the stem i.e., *Fissidens* leaf has three lamina: 1) Vaginant lamina, 2) Dorsal lamina and 3) Ventral lamina (Fig.1). The apical portion of the vaginant lamina is often unequal, one vaginant lamina is continuous with the apical lamina and the other lamina is fused with costa and the rest of apex is open. *Fissidens* leaves have costae which are usually stout and divide the leaves in two parts. Costae are either percurrent or excurrent. *Fissidens* leaves have limbidium (thick walled cells at the margin), hyaline and smooth cells. Limbidia are often more than two cells thick. The fertile species of *Fissidens* may be monocious or diocious. Sporophyte is usually smooth, seta long and short, capsule mostly cylindrical and ovate in shape.

The bryophyte diversity in India is represented by 2489 species (Dandotiya et. al. 2011) of which includes 1786 species of mosses under 355 genera. They have reported 88 species of *Fissidens* which makes it one of the largest moss genera in terms of numbers. While a

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monograph on the family Fissidentaceae in India is not available the family and its members have been described in papers and floras from all over the country viz., Eastern Himalayas (Gangulee, 1980), Western Himalayas (Chopra et al,1981), North Konkan –Maharahstra (Chaudhary et al, 2008), Rajasthan (Chaudhary et al, 1993), Western Ghats (Frahm et al. 2013; Manju et al, 2009) and North India (Asthana et al 2013). In Gujarat the earliest report of *Fissidens* dates back to 1961 (Chavan et. al,). Eight species of *Fissidens* were reported from Gujarat 2006 (Chaudhary et. al,) making it the largest moss family in terms of number from the state. All the *Fissidens* species collected and reported from the state were sterile. The moss flora of the nearby areas Konkan and Rajasthan were consulted and even in them only sterile species were reported. The vegetative characters that were described also had a substantial amount of overlap and hence a lot of difficulty was encountered while trying to identify the different species of the Family. It was hence decided to take up a detailed study on the family Fissidentaceae in Gujarat and prepare an updated identification key.

2.Methodology:

The methodology followed in the study included detailed field studies as well as analysis in the lab. 31 out of the 33 districts of Gujarat were covered during the study and a total of 75 localities were visited. The study was carried out from 2013 to 2015.

2.1 Study area:

Gujarat ranges between 22°17'N latitude and 71°10'E longitude in India. Gujarat has an area of 196,024 km² with a coastline of 1,600 km. Gujarat is a state of western part of the India. The state is bordered by Rajasthan to the north, Maharashtra to the south and Madhya Pradesh to the east. It has tropical arid dry climate. Except one all the earlier reports on the occurrence of Fissidens have been from Girnar, Pavagadh or Dangs district which are characterized by hills and forested habitats.

2.2 Collection:

Samples are collected from the different locations of Gujarat in monsoon and post monsoon season. Photography in the field was done with the help of a Celestron hand-held digital microscope. Whereever available the samples were collected along with the sporophytic stage. The geographic coordinates were collected using the Garmin E-trex 10 GPS receiver. The samples were collected in brown paper bags and air dried for further analysis and voucher preparation.

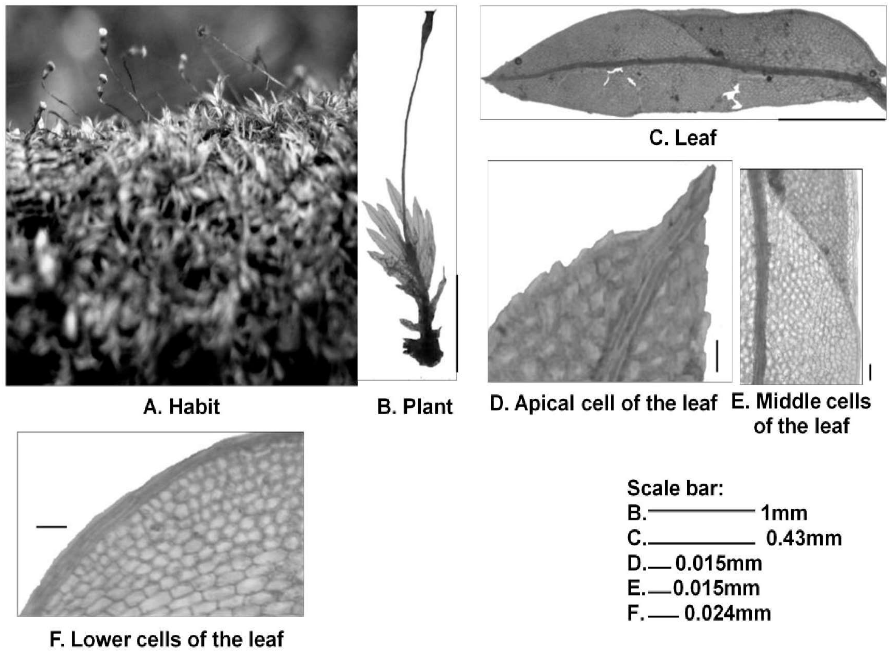
2.3 Laboratory analysis and identification:

The collected samples were studied using the Leica SD6 Stereo-binocular microscope. Morphological and micro-morphological characters were analysed and quantitative data on its dimensions was collected.

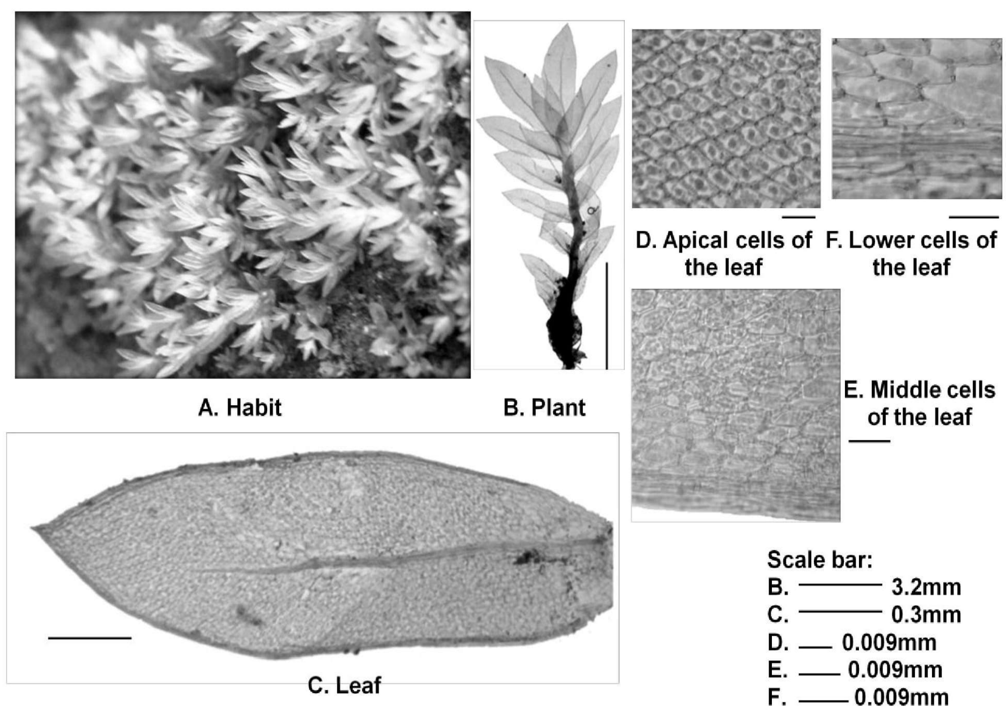
Table 1.

Sr. No.	Name of the Species	Locations					
		Present Study			Past Study		
		Girnar	Saputara	Pavagadh	Girnar	Saputara	Pavagadh
1.	*Fissidens splachnobryoides*	+	-	-	-	+	+
2.	*Fissidens curvato-involutus*	+	+	-	-	-	+
3.	*Fissidens zollingerii*	+	+	-	-	+	-
4.	*Fissidens gaminiflorus*	-	-	-	-	-	+
5.	*Fissidens bryoides*	-	-	-	+	-	-
6.	*Fissidens bryoides ssp schimidii*	-	-	-	-	+	-
7.	*Fissidens involutus*	-	-	-	-	-	+
8.	*Fissidens macrosporoides*	-	-	-	+	-	-
9.	*Fissidens* sp. 1	+	-	-	-	-	-
10.	*Fissidens* sp. 2	+	-	-	-	-	-
11.	*Fissidens* sp. 3	-	+	+	-	-	-
12.	*Fissidens* sp. 4	-	+	-	-	-	-
13.	*Fissidens* sp. 5	-	+	+	-	-	-

+, indicate presence of species & -, indicate absence of species.
Table 1: Distribution of different species of Fissidens in major sites of Gujarat
Key to species

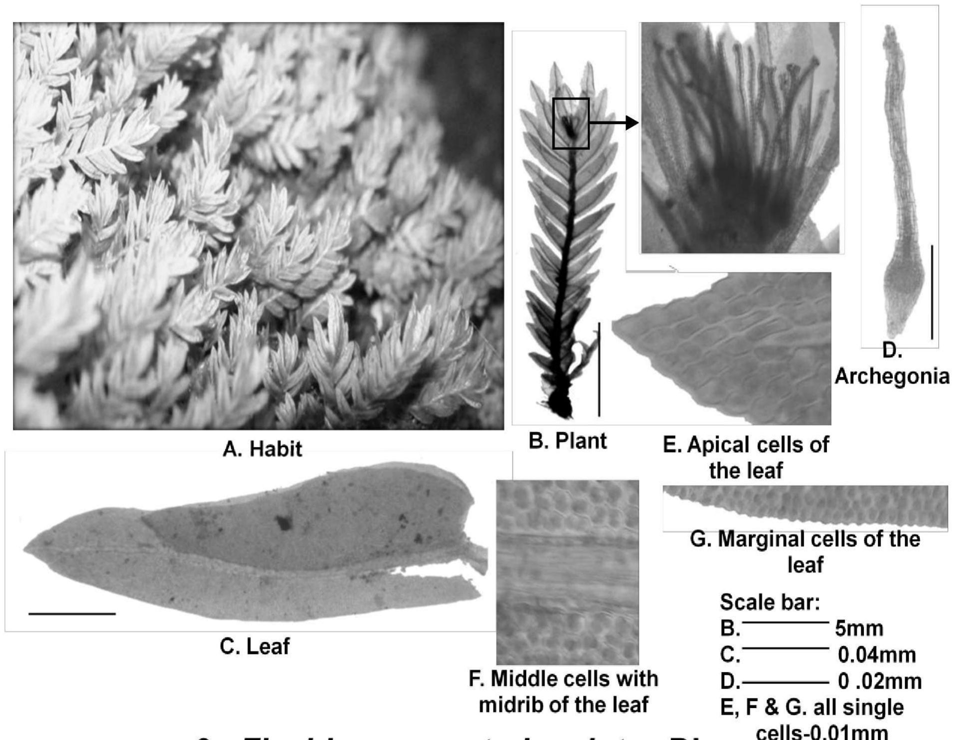


1. *Fissidens zollingeri* Mont.

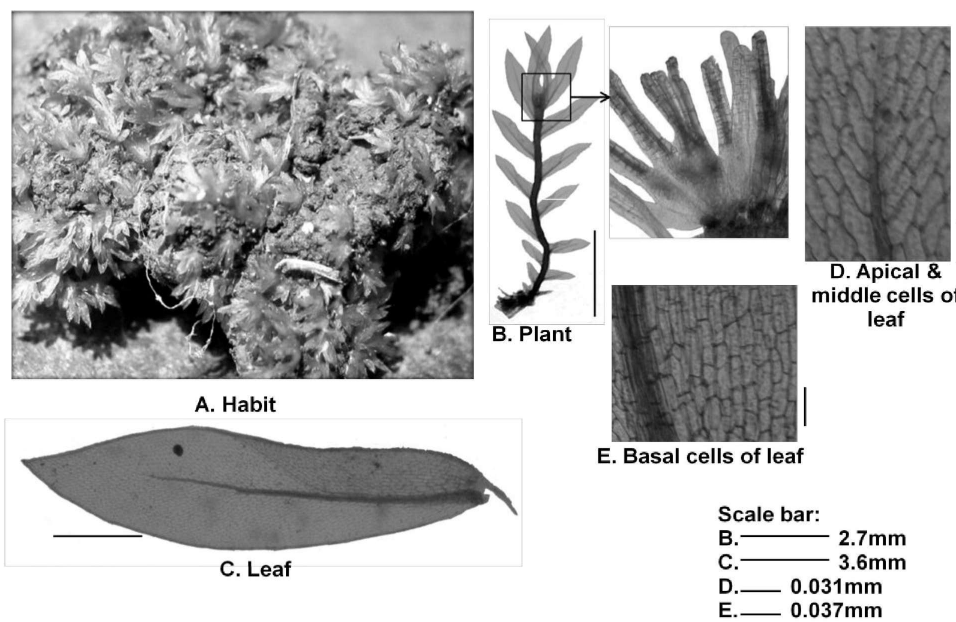


2. *Fissidens splachnobryoides* Broth.

PLATE 1

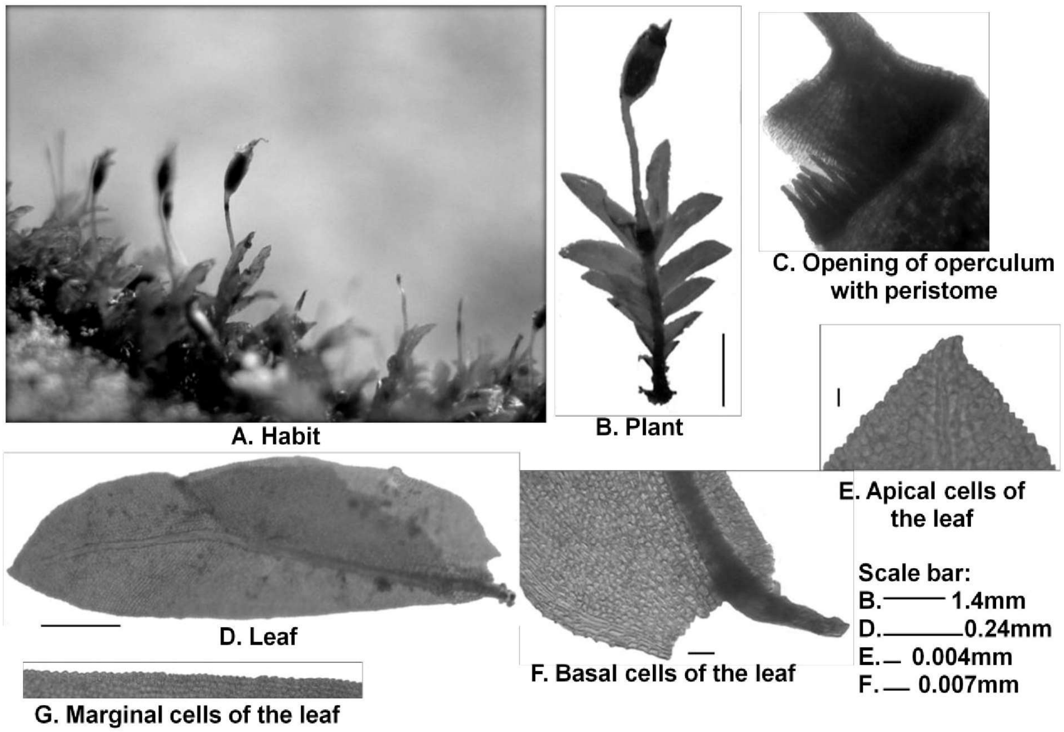


3. *Fissidens curvato-involutus* Dixon.

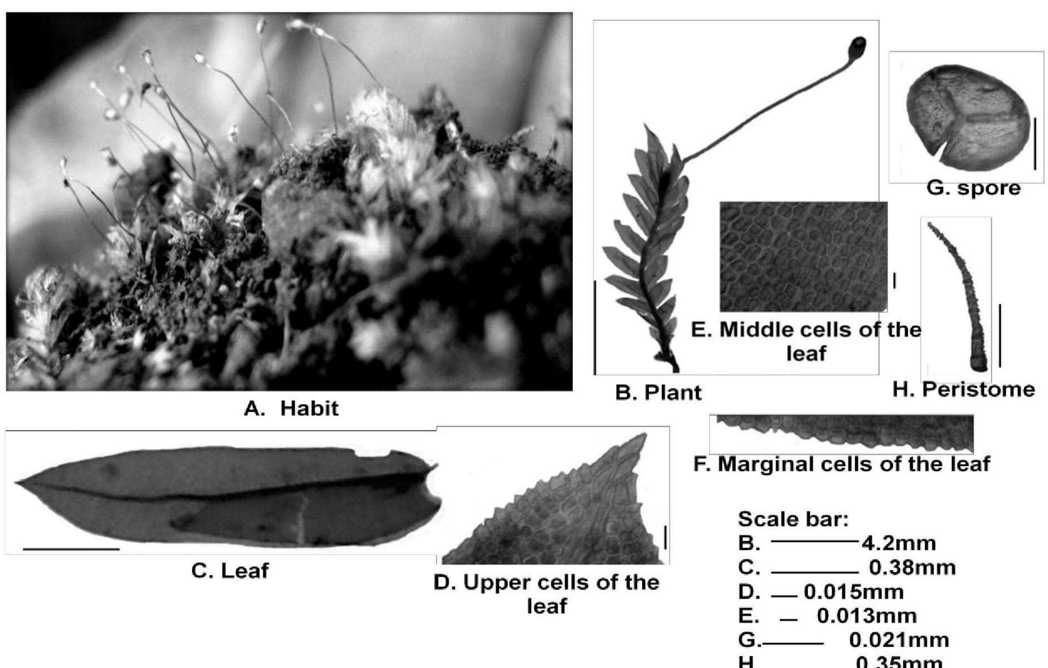


4. *Fissidens* sp. 1

PLATE 2

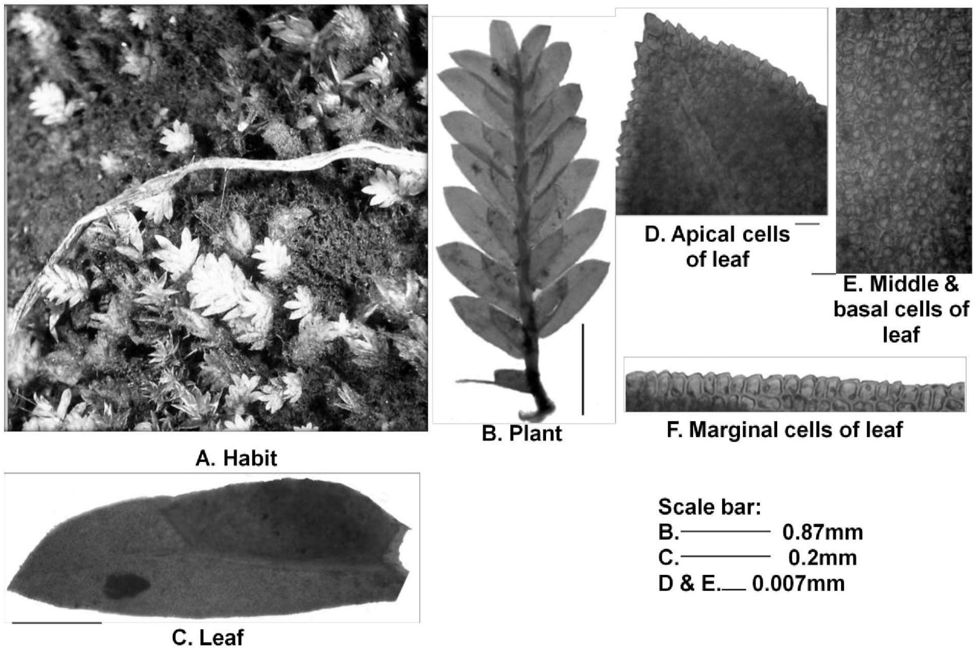


5. *Fissidens* sp. 2

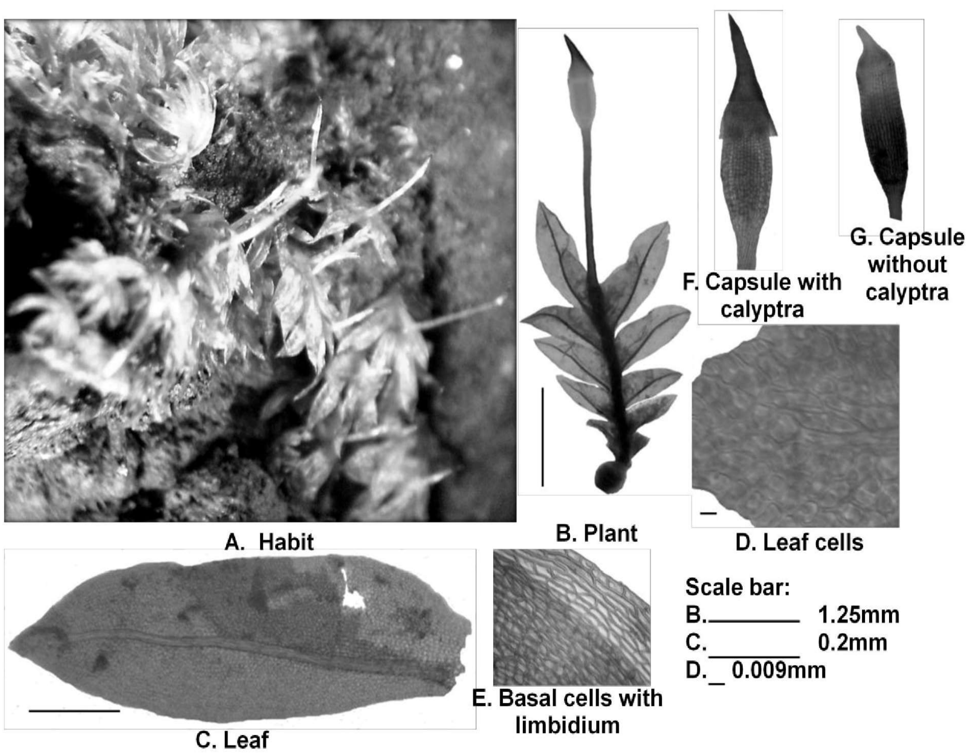


6. *Fissidens* sp. 3

PLATE 3



7. *Fissidens* sp.4



8. *Fissidens* sp.5

PLATE 4

Table 2. Key to the different species of *Fissidens* in Gujarat.

Sr. No.	Characters	Species
1	Leaf cells large, reticulate hexagonal, transparent or translucent; nerve ending far below the apex.	2
	Leaf cells small neither transparent nor translucent; nerve often percurrent or excurrent	3
2	Leaves lanceolate without curved margins.	*Fissidens splachnobryoides*
	Leaves lanceolate with curved lower margin	*Fissidens* sp.1
3	Leaves with complete limbidium.	4
	Leaves without or with incomplete limbidium.	5
4	Leaves subulate to narrowly triangular, one or two row apical limbidium.	*Fissidens xiphioides*
		(Synonym-*Fissidens zollingerii*)
	Leaves often oblong to lingulate, lax and deflexed; apical lamina decurrent with the base; limbidium present at the base of apical and sheathing lamina.	*Fissidens bryoides* (NF)
5	Leaves with incomplete limbidium, limbidium present only on the perichaetial and a few subperichaetial leaves, nerve percurrent.	*Fissidens macrosporoides(NF)*
	Leaves without limbidium, leaf margin unistratose, cells clear, nerve ending a few cells below the apex.	6
6	Plant length 5mm.	7
	Plant length up to 2cm.	9
7	Small leaves arranged below	8
	Small leaves arranged upper	*Fissidens* sp. 4
8	Oblong to lanceolate leaf shape and dorsal lamina curved at end of the vaginant lamina	*Fissidens* sp. 2
	Lanceolate leaf shape and dorsal lamina slightly curved at end of the vaginant lamina	*Fissidens* sp. 4
9	Whole leaf broad.Costa just below the apex and dentate margin of upper part leaf	*Fissidens* sp. 3
	Dorsal lamina sharply rounded portion at base & decurrent with fold also at base. Costa 4-5cells below apex and dentate margin absent.	*Fissidens curvato-involutus*
	Dorsal lamina pronounced decurrent at base.	*Fissidens gaminiflorus* var. *nagasakinus*. (NF)

Note: NF - means not found in the current study

Photography was carried out using a 3.2 MP Tucsen camera. Based on the characters the identification of the plands was carried out with the following flora, Bryophyte flora of Gujarat (Chaudhary et al,2006), Bryophyte flora of North Konkan (Chaudhary et al,2008), Moss Flora of the Rajasthan (Chaudhary et al,1993), Mosses of Eastern Himalayas and adjacentregions – a monograph (Gangulee, 1969-1980). Information from the TROPICOS website was also used in the identification. The plants were then carried to the National Botanical Research Institute, Lucknow where the identity was confirmed by experts. The samples were deposited in the herbarium at the Maharaja Sayajirao University of Baroda (BARO), Vadodara.

3. Results:

In the present study a total 8 species have been collected from different parts of the state. 4 species were collected with sporophytes while 2 species were collected with female reproductive structures. The past and present occurrence of the species has been depicted in table 1. All the eight species were tentatively identified but the identity of only 3 species could be confirmed by the experts while the identity of the other 5 are yet to be confirmed. The three species whose identity has been confirmed are *Fissidens splachnobryoides* Broth., *Fissidens zollingerii* Mont. and *Fissidens curvato-involutus* Dixon.. The other species have thus been named as *Fissidens sp*.1 to *Fissidens sp*.5. The tentative identity of the different species is *F. splachnobryoides* Broth., *F. orishae* Gangulee, *F. involutus* Wilson ex. Mitt., *F. macrosporoides* Dixon. & P. de la Varde and *F. kurzii* Mull. Hal. respectively. The lack of proper photographs and illustrations has been one of the major reasons for difficulty in identification of the collected species. Plates 1 - 4 depict the important morphological and micromorphological features of all the eight collected species. Based on the identification keys that are present in the given references and the characters that were collected during the present study an updated identification key of the Fissidens of Gujart has been depicted in Table 2.

4. Discussion:

In present study *Fissidens* curvato-involutus and *Fissidens splachnobryoides* were commonly found in different places like Aravalli, Girnar, Pavagadh and Sabarkantha while *F. zolliingeri* was found from Dahod and Valsad. If the tentatively identified species are confirmed then two more species reported by earlier workers would have been located. *Fissidens xiphoides* M. Fleisch is now considered the synonym of *F. zollingerii* Mont. Two species *F. gaminiflorus* and *F. bryoides* could not be located in the current study. The earlier reports on the distribution of members of *Fissidens* have been from Pavagadh, Girnar and Saputara. All these three locations are being developed as tourist locations by the government of Gujarat and has seen substantial development in the past decade. This habitat loss could one of the reasons for the lack of collection in the present study. The identification key that has been generated in the present study as well as the photographic places would aid in the identification of the species of Fissidens.

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Research Article

Diversity and Distribution of Liverworts in Gujarat – Current Status

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Abstract

The liverwort diversity in Gujarat has been mostly neglected by biodiversity researchers across the state and more than 75% of the districts have never been investigated for their bryo-diversity. A detailed study was conducted during 2013-2015 covering 75 locations spread over 31 of the 33 district of the state to understand the diversity and distribution of liverworts in the state. The liverwort diversity in the state now stands at 22 species of which 16 species were located in the current study. Genus *Riccia* has the maximum diversity in the state. *Cyathodium cavernarum* Kunze. was the most widely distributed species being located in 17 out of the 31 districts studied. *Taxilejeunea ghatensis, Riccia crystallina* and *R. cavernosa* are new records to the state. Genus *Marchantia* is also being reported for the first time. Dangs and Panchmahal districts have the highest liverwort diversity with 10 species each.

Keywords
Liverwort; Gujarat; Diversity; *Riccia*

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Introduction

Liverworts constitute one of the three major groups of bryophytes. They are estimated to be around 391 genera and 5000 species (Stotler *et al.*, 2009). They are found in a large variety of habitats ranging from rock crevices, old walls, bark of trees to road cuts. Like other group of bryophytes the gametophyte is the independent and dominant phase of the life cycle while the sporophyte is subsidiary and dependent on the gametophyte for its nutritional needs. 675 species in 121 genera of liverworts have been described from different parts of India (Dandotiya *et al.*, 2011). According to Singh (2001) the eastern Himalayas harbor about 64 percent of the liverworts while the Western Ghats and the Western Himalayas have about 33 and 28 percent of reported liverwort taxa of the country. The western part of the country which includes Gujarat, Maharashtra and Rajasthan has received little attention from bryologists partially due its arid climate (Afroz *et. al.*, 2011, Lavate *et al.*, 2015).

In Gujarat till 2000, only 22 species of bryophytes which included 11 species of liverworts had been reported from different parts of the state (Anon. 1996). Chavan (1937a, 1937b) pioneered bryophyte research in the state. He along with his co-workers (Chavan and Mahabale, 1945) reported 19 species of bryophytes from different locations of Gujarat including Abu and Mahabaleshwar which were earlier part of the presidency of Bombay. Out of the 19 species reported by them 9 were liverworts including *Plagiochasma appendiculatum, Asterella angusta, Riccia discolor, R. cruciata, R. gangetica, R. melanospora, Cyathodium barodae, C. tuberosum* and *Fossombronia himalayensis.* Another contribution to the bryophyte flora of the state was made by Patel in 1977. While working on the algal diversity of different parts of Gujarat, he

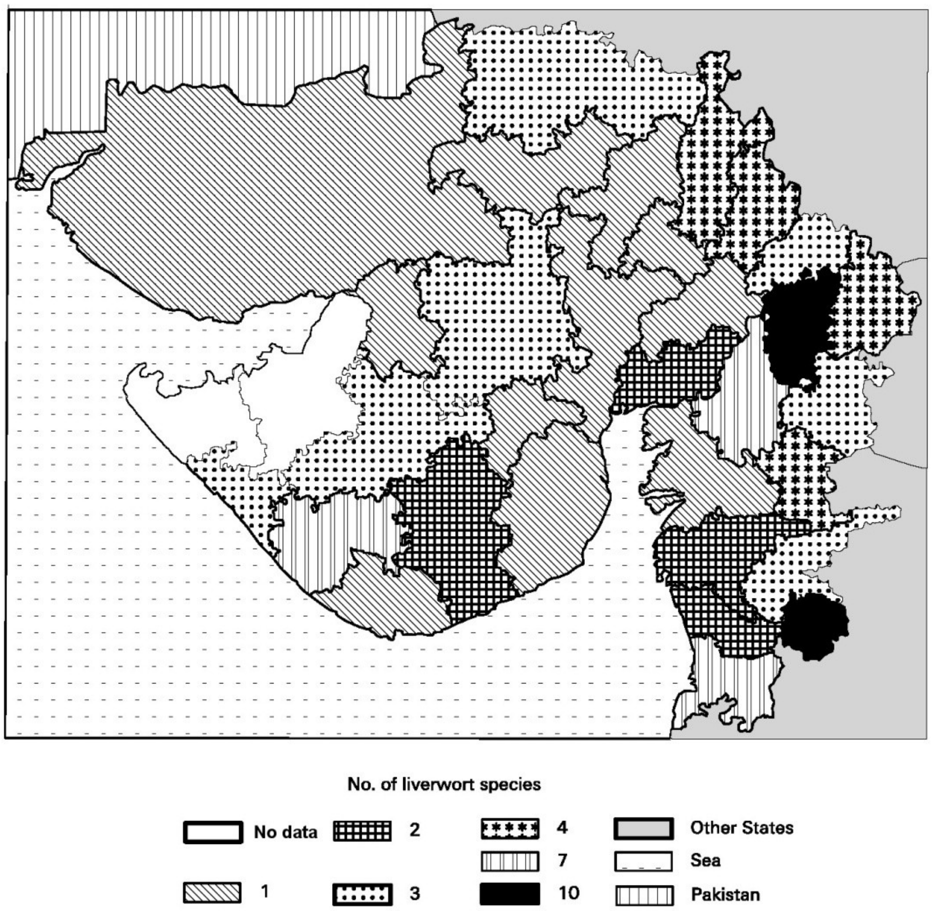

Fig. 1 Distribution of liverworts in different districts of Gujarat

made a discovery of the genus *Riella* in the state and reported the presence of *Riella affinis* and *R. cossoniana* (Patel 1977a; Patel, 1977b). The major contribution to the liverwort flora of the state was made by Chaudhary *et al.* (2006). Their work, published in the form of a book 'Bryophyte flora of Gujarat – (India)' was the culmination of a survey undertaken from 1999 to 2004. They reported 13 species of liverworts including *Lejeunea aloba, Targionia hypophylla, Plagiochasma rupestre, P. microcephalum, P. intermedium*, *Riccia grollei, R. billardieri* and *R. gangetica* for the first time from Gujarat. Their work had however, covered only 10 districts of the state and several districts like Surat, Narmada, Aravalli and Vadodara which had a good forest cover were not investigated. Chauhan (2009) indicated that there was a huge gap in information on the diversity and distribution of bryophytes in the state. To fill the gap, present study was conducted between 2013 and 2015.

Materials & Methods

The study incorporated detailed field studies as well as lab analysis. A total of 75 localities spread over 31 out of the 33 districts of the state were visited. A total of 90 days of field work was conducted during the two year study. They were visited during monsoon (July-Sept) and post monsoon (Oct-Jan).

The Study area

The state of Gujarat is situated on the western coast of India between 22°07' N and 24°43' N latitude and 68°10' E and 74°29' E longitude (Anon, 2011a). It is bounded by the Arabian Sea on the west, Pakistan on the Northwest, Rajasthan on the North and Northeast, Madhya Pradesh to the East and Maharashtra to the South. It has a coastline of about 1650 km, land area of 196,024 sq. km. and population of 60,383,628 which accounts for approximately 5 percent of total population of India (Anon, 2011b). The state is located on the tropic of cancer and shows sub-tropical type of climate. Ecologically, Gujarat is gifted with a diversity of natural ecosystems ranging from desert, semi-arid, mangroves, coral-reefs and forests with dry deciduous, moist deciduous and evergreen trees. The major forests in Gujarat are concentrated along the eastern tribal belt of the state.

Collection strategy and sample collection

Random sampling strategy was employed for the collection of the samples from the different sites. All the liverworts encountered during the field visit were sampled. Wherever possible the samples with the sporophyte were collected. The geographic coordinates of the site were collected using a Garmin E-trex10 GPS receiver.

Table 1. Distribution of liverworts in Gujarat according to the past and present studies

Sr. No.	Species	Family	Number of Districts showing distribution of the species.		
			Only from past studies	Past distribution confirmed in current study	Only from current study
1.	*Rectolejeunea aloba* (Sande Lac.) Stephani.	Lejeuneaceae	-	3	1
2.	**Taxilejeunea ghatensis* Verma & S.C. Srivast.	Lejeuneaceae	-	-	1
3.	*Fossombronia himalayensis* Kash.	Fossombroniaceae	-	1	1
4.	**Marchantia* sp.	Marchantiaceae	-	-	1
5.	*Targionia hypophylla* L.	Targioniaceae	2	1	-
6.	*Cyathodium cavernarum* Kunze.	Cyathodiaceae	1	3	14
7.	*Cyathodium tuberosum* Kash.	Cyathodiaceae	1	-	2
8.	*Asterella angusta* (Steph.) Kachroo	Aytoniaceae	-	2	1
9.	*Plagiochasma rupestre* (Forst.) Steph.	Aytoniaceae	1	-	1
10.	*Plagiochasma appendiculatum* Lehm. et. Lindenb.	Aytoniaceae	3	-	-
11.	*Plagiochasma microcephalum* (Steph.) Steph.	Aytoniaceae	1	-	2
12.	*Plagiochasma intermedium* Lindenb. & Gott.	Aytoniaceae	-	1	-
13.	*Riccia discolor* Lehm. & Lindenb.	Ricciaceae	1	1	1
14.	*Riccia grollei* Udar	Ricciaceae	1	-	-
15.	*Riccia billardieri* Mont. et Nees.	Ricciaceae	3	5	6
16.	*Riccia gangetica* Ahmad.	Ricciaceae	1	1	2
17.	**Riccia cavernosa* Hoffm.	Ricciaceae	-	-	4
18.	**Riccia crystallina* L.	Ricciaceae	-	-	1
19.	*Riccia cruciata* Kash.	Ricciaceae	1	-	-
20.	*Riccia melanospora* Kash.	Ricciaceae	1	-	-
21.	*Riella cossoniana* Trab.	Riellaceae	1	-	-
22.	*Riella affinis* Howe and Underw.	Riellaceae	1	-	-

Note: Family names are according to Stotler *et. al.* (2009)

* New records for the state.

Photographs of the samples in their natural habitat were taken. The samples were collected in brown paper bags, labeled and air dried for further analysis and voucher preparation. The collection method given by Glime (2013) was followed with minor modifications. More than 145 samples were collected during the study.

Laboratory analysis and identification

The micro-morphological and anatomical features of the plants were observed under Leica SD6 stereo binocular microscope and the photographs of the relevant parts were taken with the help of a 3.2 MP Tucsen camera. Preliminary identification of the plants was carried out using available standard literature (Bapna and Kachroo, 2000a; 2000b; Kashyap, 1929; 1932; Singh, 2014). The samples were then taken to the National Botanical Research Institute (N.B.R.I), Lucknow where the identity was confirmed after consultation with experts. The Vouchers were deposited in the herbarium of Maharaja Sayajirao University of Baroda (BARO).

Results and Discussion

A total of 18 species of liverworts were collected out of which 15 were identified till the species level while one was identified till the genus level only, thus a sum of 16 taxa were identified. Two specimens could not be identified due to the lack of sexual as well as asexual reproductive structures. Table 1 lists all the 22 species that have been reported in the past as well as in the present study. The table provides information on the number of districts from which the species are known only from the past study, only from the current study and the number districts where past distribution has been confirmed in the current study. *Taxilejeunea ghatensis*, *Riccia crystallina* and *R. cavernosa* are new records for the state.

Fig. 2:- Liverwort species found in Gujarat A. *Asterella angusta* (Steph.) Kachroo.; B. *Cyathodium cavernarum* Kunze.; C. *Fossombronia himalayensis* Kash.; D. *Rectolejeunea aloba* (Sanda Lac.) Stephani.; E. *Plagiochasma appendiculatum* Lehm. et Lindenb.; F. *Riccia billardieri* Mont. et Nees.; G. *Riccia gangetica* Ahmad.; H. *Targionia hypophylla* L .

Marchantia with gemma cup was also collected during the study but due to absence of sexual reproductive features the exact species could not be identified. *Riccia* was the most abundant genus with 5 species; however, three earlier reported species of *Riccia* could not be collected during the current study. The most commonly found liverwort was *Cyathodium cavernarum* which was observed in 17 of the 33 districts that were surveyed. On the other hand *Taxilejeunea ghatensis, Targionia hypophylla, Plagiochasma rupestre, P. intermedium* and *Riccia crystallina* were found in one district only. Fig. 1 depicts a few of the liverworts that were found during the study.

The distribution of liverworts across the state has been depicted in fig. 2. The paper reports the distribution of liverworts in 20 districts for the first time. Eleven districts show the presence of only single species of liverwort while 4 districts show the presence of two species of liverworts. Most parts of Saurashtra and Kachchh show low liverwort diversity. These areas are characterized by low rainfall. Girnar Hills in Junagadh district is however the highest point in Gujarat characterized by high liverwort diversity due to high moisture during the rainy season. Dangs and Panchmahal district with 10 species of liverworts has the highest diversity in the state. In addition to Junagadh, Valsad and Vadodara districts also report the presence of seven species of liverworts. The eastern tribal belt of Gujarat shows moderate to high diversity of liverworts.

Six earlier reported species could not be located in the current study. Two species of *Riella* have been reported from Nal Sarovar and Lake Kanewal. However, both these locations could not be investigated in detail due to high level of water. Further significant changes have occurred in both the localities, and as a result the localities are facing severe anthropogenic influence. Similarly, few other species, earlier reported from Pavagadh in Panchmahal district and Saputara district, could not be collected. Both of these locations have seen huge development in the past several years and are important sites for religious pilgrimage and tourists respectively. More than 3 lakh visitors visit each of these locations every year and though these sites were surveyed several times all the species could not be found. In several of the districts only a few sites have been visited during the study and hence, there are possibilities that some bryophytes may have been overlooked during the study. This highlights the need for sustained bryophyte studies in the state.

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CHAPTER 6

Bryodiversity of Wilson Hill and Surrounding Area of Valsad, Gujarat

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Abstract: Valsad district lies in the southern part of the state which harbours some locations embracing good diversity of bryophytes. In the present study, the bryodiversity of a potential location, *i.e.*, Wilson hill and surroundings has been explored and reported. The study reveals the existence of 15 species of bryophytes that included 5 liverworts, 2 hornworts and 8 mosses under 9 families. Three new additions to the Bryoflora of Gujarat have also reported, *viz*., *Taxilejeunea ghatensis, Notothylas anaporta,* and *Notothylas himalayensis.* Interestingly, the majority of species found were terricolous in nature.

Keywords: Mosses, Liverworts, Hornworts, South Gujarat.

INTRODUCTION

Gujarat is the sixth largest state in India and lies in the Western part of India. It covers an area of approximately 1,96,022 km^2 [1] with 18,827 km^2 [2] forest area. The study of the lower groups, especially, bryophytes have been neglected in the state. The major work consists of "Bryophyte Flora of Gujarat" [3]. It included 18 locations across Gujarat and several districts, including Vadodara, Narmada, Bharuch and Surat that were not covered in the flora. In the south Gujarat, only 6 sites were visited. Moreover, Valsad District was not included in the study (Fig. **1**). There are few locations that were potentially bryo-rich but not covered. One of these locations is Wilson hill. It is named as 'Wilson hill' in the honour of Lord Wilson – the governor of Mumbai during 1923-1928. It has a good forest track with some scenic locations in the Pangarbari Wildlife Sanctuary. This location was not at all visited by past workers and no reports related to bryophytes are found from the district. This work is the first kind of data gathered form the place.

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MATERIALS AND METHOD

Study Area

Gujarat lies on the western side of the India. It has been divided into 33 districts. It mainly has an arid or semiarid region like Kutch and Saurashtra and South Gujarat that receives good rainfall *viz*., Dangs, Valsad, Navsari, Tapi Surat *etc*. The District Valsad is unique in its atmosphere with Wilson Hill, a hill station situated at a distance of 60 km from Valsad district. It comes in type 3B Tropical moist deciduous forest [4]. Its average elevation is 750 m above the sea level. During the winter, the weather is cool and in summer, it becomes warm with occasional cool breezes. The average rainfall throughout the year is about 2000 mm. Near the Wilson hill, small waterfall locally called as *Shankar Dhodh* also exists with 30 m high waterfall.

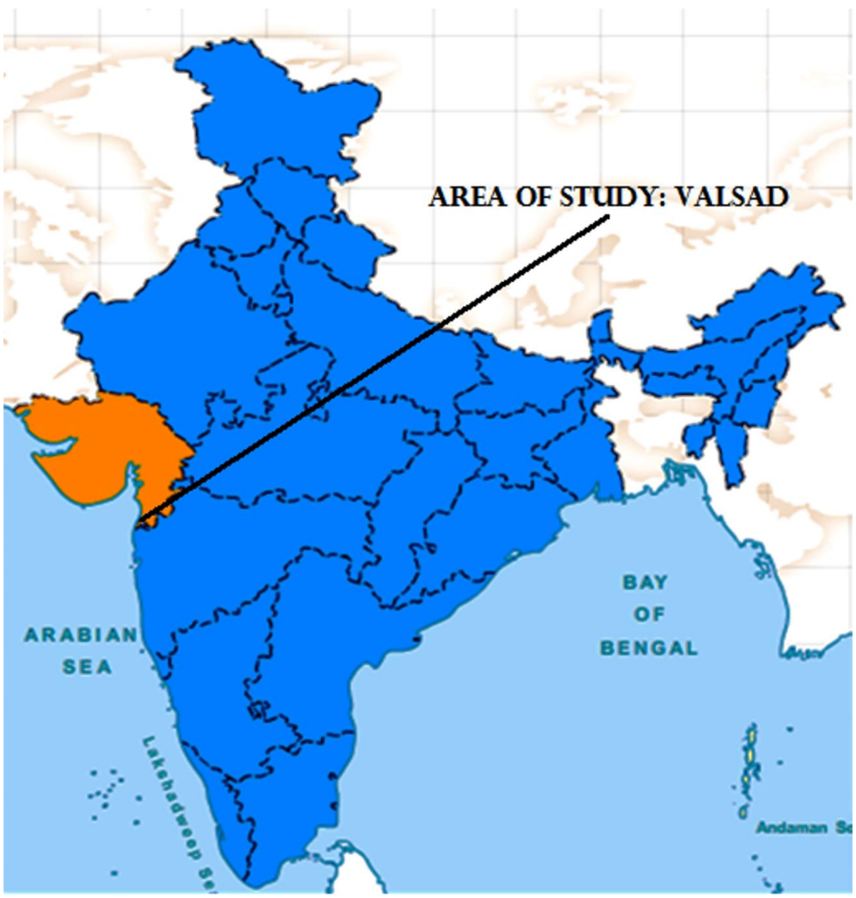

Fig. (1). Map of India showing Valsad (Gujarat).

The samples were collected from different locations from Wilson hills and surrounding. The samples were collected in paper bags with the help of a scalpel or knife. The samples were preferably collected in sporophytic stages. The samples were collected in brown bags and air dried for voucher preparation. The brown bags also consist of a label with the preliminary information of substratum, temperature, type of sample, GPS location using a Garmin E-trex10 GPS receiver *etc.* Photography of the relevant parts was taken in the field using Canon Powershot A480. The samples are identified with the help of standard available literature [5 - 11]. The confirmation of some samples was done from National Botanical Research Institute (NBRI) Lucknow. The Voucher specimens were deposited in the BARO herbarium. The authentication of the scientific name and its present status was checked from the "the Plant List".

RESULTS AND DISCUSSION

A total 20 samples were collected from which the identity of 15 samples could be established, during the study. 15 species were recorded from 9 families containing 5 liverworts, 2 hornworts and 8 mosses (Table **1**). Among liverworts 5 genera, mosses 7 genera whereas in hornwort only one genera are reported. *Taxilejeunea ghatensis, Notothylas anaporta* and *Notothylas himalayensis* are new to Gujarat state. Valsad lies close to the Dangs district that hold a small portion of Western Ghats hence an endemic species of the Western Ghat, the leafy liverworts - *Taxilejeunea ghatensis* was discovered from the area. Before this study, there were no reports of leafy liverworts from the area, but now there are two leafy liverworts in the state. These species occupy different habitats (Fig. **2**), some occur on soil (7 sp.), some on bark (4 sp.), wall (3 sp.) and on rock (1 sp.). Thus, terricolous species were more than phycocolous and corticolous. The second most dominant (27%) habitat was of bark (epiphyte) as the elevation and other topographic parameters favours growth of many epiphytic liverworts and mosses since the precipitation and humidity is higher than the other parts of the district. In mosses, Bryaceae appeared as the dominant family, while in liverworts, Lujeneaceae was the sole representative and in case of hornworts, Notothylaceae was reported with only one genus. Most of the habitats suitable for the growth of bryophytes had been found in the area (Fig. **3**). The pocket of Wilson hills in many places has grasslands kept the surface moist and thus favoured the diversity of terricolous bryophytes.

Table 1. Table shows the diversity of bryophytes in Wilson hill and surrounding with Habitat.

Sl. No.	Name of Species	Family	Habitat
1	*Rectolejeunea aloba* (Sande Lac.) Steph.	Lejeuneaceae	Bark
2	*Taxilujenea ghatensis* Verma & S.C. Srivast.	Lejeuneaceae	Bark

(Table 1) cont.....

Sr. No	Name of Species	Family	Habitat
3	*Cyathodium cavernarum* Kunze	Targioniaceae	Soil
4	*Riccia bilardieri* Mont. *et* Nees.	Ricciaceae	Soil
5	*Asterella angusta* (Steph.) Kachroo.	Ayotoniaceae	Wall
6	*Notothylas anaporta* Udar *et* Singh.	Notothylaceae	Soil
7	*Notothylas himalayensis* Udar *et* Singh.	Notothylaceae	Soil
8	*Fissidens zollingeri* Mont.	Fissidentaceae	Bark
9	*Hyophila involuta* (Hook.) Jaeg.	Pottiaceae	Rock
10	*Hydrogonium consanguineum* (Thw. *et* Mitt.)	Pottiaceae	Soil
11	*Gymnostomiella vernicosa* (Hook.) Fleisch.	Splachnaceae	Wall
12	*Anomobryum auratum* (Mitt.) Jaeg.	Bryaceae	Soil
13	*Brachymenium turgidum* Broth. *ex* Dix.	Bryaceae	Bark
14	*Bryum coronatum* Schwaegr.	Bryaceae	Wall
15	*Bryum capillare* (L.) Hedw.	Bryaceae	Soil

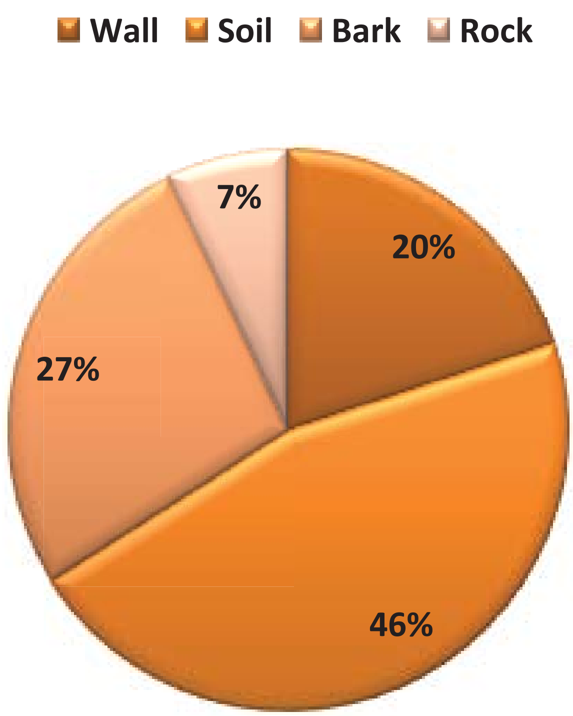

Fig. (2). Percentage distribution of bryophyte's habitat.

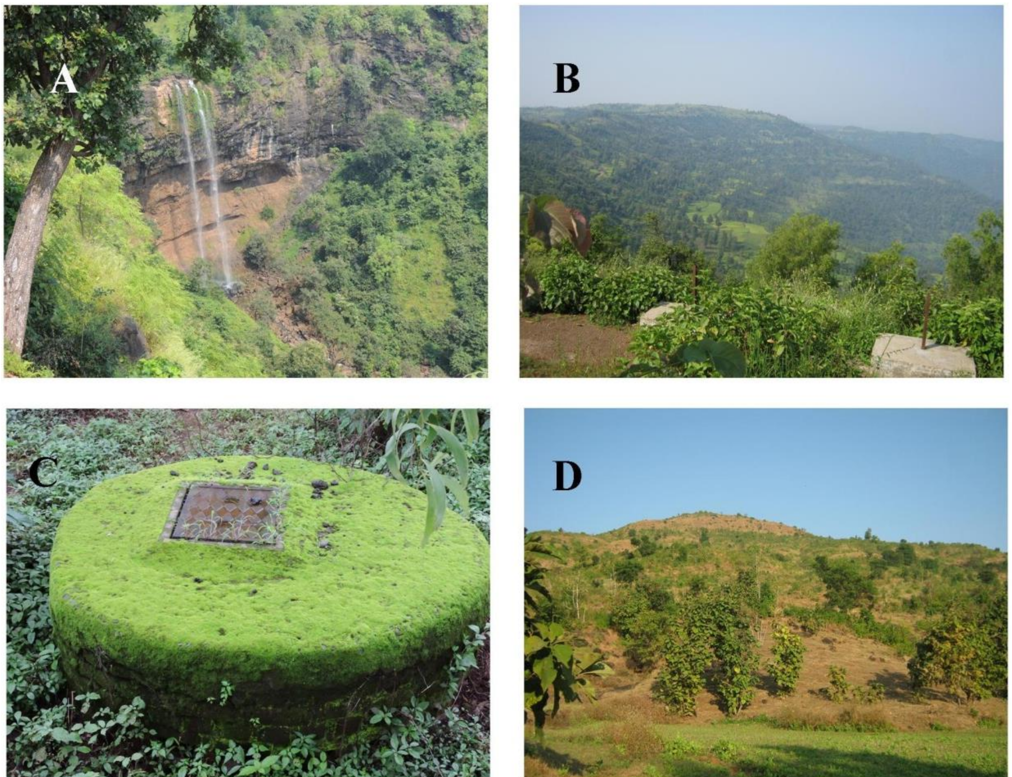

Fig. (3). Bryorich habitats of the study area Sample Collection and Analysis.

CONCLUSION

The study area was rich in bryophyte diversity. The area lies near the Pangarbari Wildlife Sanctuary, hence, diversity was somewhat protected and conserved to a larger extent as it is close to the Dangs district that holds a small portion of the Western Ghats. Total species have been reported from all over the Gujarat till date. Among them in the present study, 15 are reported from this small pocket of the state. This shows that the area has congenial habitats, thus favoured the growth of diverse terricolous bryophytes. Based on this study, it is evident that Gujarat should be explored more for the bryophytes before they become extinct and remain highly unexplored.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The authors confirm that this chapter contents have no conflict of interest.

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