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AQUATIC FUNGI: FIRST REPORT FROM LOTIC WATER BODIES OF PACHMARHI DISTRICT HOSHANGABAD M.P. INDIA.

Sheikh Sayir[1*], Ajaz Ahmad[1], Ranjana Singh[2*] and Suman Trivedi[2]

[1*,1]Research Scholars, Govt. M.V.M. Bhopal.
[2*]Asstt. Professor Govt. M.V.M. Bhopal.
[2]Professor and Head Govt. M.L.B girls P.G. (auto) college, Bhopal.

***Corresponding Author: Sheikh Sayir**
Research Scholars, Govt. M.V.M. Bhopal.

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ABSTRACT
Taxonomy of aquatic fungi is the most ignored field or very little work in that particular field has been done especially in India. Pachmarhi is the biosphere reserve and hill station of Madhya Pradesh and is totally virgin with respect to taxonomy of aquatic fungi. To explore the aquatic fungi from lotic water bodies of Pachmarhi efforts was made by authors and during the study period aquatic fungi belong to different groups and orders has been isolated. A total of 10 species has been isolated and identified belong to order Moniliales and Blastocladiales during the study period of Aug 2014 to July 2015. Physico-chemical factors have also been studied in order to see the effect of these physico-chemical factors on the occurrence and activity of these fungi.

KEY WORDS: New reports, Aquatic fungi, Pachmarhi, Lotic water, Physico-chemical factors.

INTRODUCTION
Biodiversity or biological diversity refers to the variety of life forms and habitats found in a defined area. The existence of biological diversity on this planet is due to the evolution and co-evolution of different types of life form, habitats and culture or it may be the result of evolutionary plasticity of living forms present on this planet. Every organism resent on earth plays its significant role, harms and benefits each other in some way or the other, in order to study its significance it must be explored. In over-all reviews of biodiversity and global genetic resources, micro-organisms in general and fungi in particular did not receive attention they deserve on account of their abundance and extend to which they can be exploited commercially (Cronke et al., 1988; Wolf, 1987) . Fungi is the most important group of organisms without these the earth would be heaps of garbage as these organisms plays important role in decomposition of dead organic matter. Fungi are also source of important antibiotics that can save the lives of human. For example, Penicillin it is difficult to comprehend that how many lives have been saved by this particular antibiotic during the World War II.

The tremendous discrepancy between the numbers of known verses estimated species appears to relate to the fact that there has been woefully inadequate sampling of fungi in many parts of the world, most notably tropical and subtropical regions. This is the need of an hour to explore the unexplored populations of world's fungi. One third of the fungal diversity exists in India. Out of 1.5 million fungi, only 50% are characterized until now. These fungi need to be characterized because of their high medicinal value and beneficial for human beings; its importance is increasing day by day. They also exhibit great degree of biodiversity with respect to aquatic environment. But the assessment of aquatic fungal biodiversity is still not complete.

MATERIALS AND METHODS
Collection: Water samples along with decaying leaves, roots, twigs from different lotic water bodies of Pachmarhi was collected. Foam, scum samples were also collected with the help of plastic cup or spoon, spores being lighter get trapped in foam and scum samples. Temperature and pH were recorded and dissolved oxygen was fixed on the spot.

Isolation: Isolation of fungi was done through various techniques, Viz., baiting technique, aerated water technique. In this method water samples were placed in pre-sterilized petriplates and baits were added to provide nourishment for the growth of fungal forms. In each petridish pinch of antibiotic was added to prevent bacterial contamination. After couple of days of incubation, baits infected with fungi are observed under the compound microscope.

Identification: The camera lucida drawings along with measurement were made from freshly isolated fungal

forms and prepared slides. Identification of aquatic fungi was done with the help of manuals, monographs and published work of some eminent scientists like Ingold (1942, 1975a). Ellis (1971, 1976), Webster and Descals (1981), Barnett and Hunter (1972), Coker and Mathews (1937), Sparrow (1942, 1960), Johnson (1956), Khulbe (2001), Karling (1977.)

Preservation: Preservation of fungal forms was done with F.A.A. 1:1:1 Ratio.

OBSERVATION, RESULTS AND DISCUSSION

A total of 118 isolations were made which belong to 6 genera and 10 species. Of these, 6 species belong to Deuteromycotina order Moniliales and 4 species belong to Mastigomycotina order Blastocladiales.

Occurrence and distribution of aquatic fungi during 2014 – 2015 in Denwa River (Table 1)

Species Name	2014-2015												Frequency
	Aug	Sep	Oct	Nov	Dec	Ja Jan	Feb	Mar	Apr	May	Jun	Jul	
Deuteromycotina													
Moniliales													
Flagellospora curvula			+										0.08%
F. Penicilloides	+	+		+			+						0.33%
Meria sp.				+			+						0.16%
Monodictys flauctuata			+			+							0.16%
Scopulariopsis brevicaulis		+				+	+						0.25%
Trichocladium canadense						+	+			+			0.25%
Mastigomycotina													
Blastocladiales													
Allomyces arbuscula		+		+	+	+			+	+		+	0.58%
A. javanicus	+	+		+		+		+			+		0.50%
TOTAL	**2**	**4**	**2**	**4**	**1**	**5**	**4**	**1**	**1**	**2**	**1**	**1**	

Total 28

Total of 28 isolations has been from Denwa River during the study period of Aug 2014 to Jul 2015. In this site maximum number of fungi 5, were recorded in winter, while as minimum number 1 was recorded in summer (Table 1). The most dominant species in Denwa River was *Allomyces arbuscula* having frequency of 0.58%. *Allomyces javanicus* was having the frequency of 0.50%. *Flagellspora penicilloides* was having the frequency of 0.33%. *Scopulariopsis brevicaulis*, *Trichocladium canadense* were having the frequency of 0.25%. (Table 1).

Occurrence and distribution of aquatic fungi during 2014 – 2015 in Panar Pani. (Table 2)

Species Name	2014-2015												Frequency
	Aug	Sep	Oct	Nov	Dec	Ja Jan	Feb	Mar	Apr	May	Jun	Jul	
Deuteromycotina													
Moniliales													
Flagellospora curvula	+	+	+										0.25%
F. Penicilloides				+		+							0.16%
Meria sp.		+					+					+	0.25%
Monodictys flauctuata		+			+				+	+			0.33%
Scopulariopsis brevicaulis	+		+			+				+			0.33%
Trichocladium canadense		+			+		+						0.25%
Mastigomycotina													
Blastocladiales													
Allomyces anomalus	+			+		+			+	+			0.41%
A. arbuscula		+			+	+		+			+	+	0.50%
A. moniliformis			+		+	+	+					+	0.41%
TOTAL	**3**	**5**	**3**	**2**	**4**	**5**	**3**	**1**	**2**	**3**	**1**	**3**	

Total 35

Total 35 isolations have been isolated from Panar pani during the study period of Aug 2014 to Jul 2015. In this site maximum number of fungi 5 was recorded in the winter and monsoon while as minimum fungi 1 recorded in summer (Table 2). The most dominant species in Panar pani was *Allomyces arbuscula* having the frequency of 0.50%, *Allomyces anomalus*, *Allomyces moniformis* were having the frequency of 0.41%.

Monodictys flacuctuata, *Scopulariopsis brevicaulis* were having the frequency of 0.33%. (Table 2).

Occurrence and distribution of aquatic fungi during 2014 – 2015 in B-Fall. (Table 3)

Species Name	2014-2015												Frequency
	Aug	Sep	Oct	Nov	Dec	Ja Jan	Feb	Mar	Apr	May	Jun	Jul	
Deuteromycotina													
Moniliales													
F. Penicilloides	+	+					+	+					0.33%
Meria sp.				+		+						+	0.25%
Trichocladium canadense	+				+		+						0.25%
Mastigomycotina													
Blastocladiales													
Allomyces anomalus	+	+			+	+		+		+	+		0.58%
A. arbuscula		+	+		+		+		+		+	+	0.58%
A. javanicus	+			+		+	+			+		+	0.50%
A. moniliformis				+		+	+						0.25%
TOTAL	**4**	**3**	**1**	**3**	**3**	**4**	**5**	**2**	**1**	**2**	**2**	**3**	

Total 33

Total 33 isolations have been isolated from B- Fall during the study period of Aug 2014 to Jul 2015. In this site maximum number of fungi 5 was recorded in the winter, while as minimum fungi 1 recorded in summer (Table 3). The most dominant species in B-Fall was *Allomyces anomalus*, *Allomyces arbuscula* having the frequency of 0.58%, *Allomyces javanicus*, was having the frequency of 0.50%. *Flagellospora penicilloides* was having the frequency of 0.33% (Table 3).

Occurrence and distribution of aquatic fungi during 2014 – 2015 in Bade Mahadev. (Table 4)

Species Name	2014-2015												Frequency
	Aug	Sep	Oct	Nov	Dec	Ja Jan	Feb	Mar	Apr	May	Jun	Jul	
Deuteromycotina													
Moniliales													
Monodictys fluctuata		+			+			+					0.25%
Scopulariopsis brevicaulis		+				+						+	0.25%
Trichocladium canadense			+			+			+		+		0.33%
Mastigomycotina													
Blastocladiales													
Allomyces anomalus			+		+	+	+				+	+	0.50%
A. arbuscula		+	+	+			+	+			+		0.50%
TOTAL	**-**	**3**	**3**	**1**	**2**	**3**	**2**	**2**	**1**	**-**	**3**	**2**	

Total 22

Total 22 isolations have been isolated from B- Fall during the study period of Aug 2014 to Jul 2015. In this site maximum number of fungi 3 was recorded in the winter and monsoon, while as minimum fungi 1 and even zero was recorded in summer (Table 4). The most dominant species in B-Fall was *Allomyces anomalus*, *Allomyces arbuscula* having the frequency of 0.50%, *Trichocladium canadense* was having the frequency of 0.33%. *Monidictys flauctuata*, *Scopulariopsis* was having the frequency of 0.25% (Table 4).

Physico-chemical characteristics of water

Temperature and pH of all sampling stations of Pachmarhi (Table -5)

Site Name		Denwa River		Panar Pani		Bee Fall		Bade Mahadev	
Months	Seasons	2014-2015 Temp.	2014-2015 pH	2014-2015 Temp.	2014-2015 pH	2014-2015 Temp.	2014-2015 pH	2014-2015 Temp.	2014-2015 pH
August	Monsoon	**24**	**7.1**	**23**	**7.0**	**23**	**6.9**	**21**	**6.2**
September	Monsoon	**25**	**7.4**	**26**	**6.9**	**25**	**7.1**	**25**	**6.4**
October	Monsoon	**26**	**6.9**	**26**	**6.8**	**26**	**6.9**	**25**	**6.5**
November	Winter	**23.5**	**7.5**	**22**	**6.8**	**23**	**6.5**	**22**	**7.1**

December	Winter	**22**	**7.4**	**21**	**7.1**	**20**	**6.8**	**20**	**7.2**
January	Winter	**18**	**7.3**	**18**	**7.2**	**18**	**7.1**	**16**	**7.1**
February	Winter	**19**	**7.4**	**19**	**7.2**	**18**	**7.1**	**17**	**7.5**
March	Summer	**26**	**7.6**	**25**	**7.5**	**25**	**7.6**	**23**	**7.4**
April	Summer	**28**	**7.8**	**27.5**	**7.6**	**27**	**7.2**	**26**	**7.3**
May	Summer	**29**	**8.0**	**28**	**7.9**	**28**	**7.8**	**27**	**7.5**
June	Summer	**31.5**	**8.2**	**30**	**8.0**	**29**	**7.9**	**29**	**7.6**
July	Monsoon	**31**	**6.7**	**30**	**6.7**	**29**	**6.9**	**28**	**6.6**

Temp= Temperature pH= Hydrogen ion concentration

Seasonal variation in Calcium and Magnesium hardness of sampling stations of Pachmarhi (Table -6)

Site Name / Seasons	Denwa River		Panar Pani		Bee Fall		Bade Mahadev	
	2014-2015 Ca^{++}	2014-2015 Mg^{++}	2014-2015 Ca^{++}	2014-2015 Mg^{++}	2014-2015 Ca^{++}	2014-2015 Mg^{++}	2014-2015 Ca^{++}	2014-2015 Mg^{++}
Monsoon	**25.2**	**32**	**35.7**	**38**	**31.5**	**36**	**37.8**	**40**
Winter	**48.3**	**56**	**46.2**	**56**	**48.3**	**52**	**44.1**	**56**
Summer	**44.1**	**54**	**48.3**	**58**	**42.0**	**46**	**48.3**	**54**

Ca++ = Calcium hardness Mg++ = Magnesium hardness

Seasonal variation in Dissolve oxygen and BOD of sampling stations of Pachmarhi. (Table -7)

Site Name / Seasons	Denwa River		Panar Pani		Bee Fall		Bade Mahadev	
	2014-2015 DO	2014-2015 BOD	2014-2015 DO	2014-2015 BOD	2014-2015 DO	2014-2015 BOD	2014-2015 DO	2014-2015 BOD
Monsoon	**10**	**16**	**11.2**	**24**	**12**	**18**	**8.4**	**12**
Winter	**12**	**24**	**13.2**	**26**	**18**	**30**	**12**	**10**
Summer	**8**	**20**	**7.2**	**14**	**10**	**12**	**7.6**	**14**

DO= Dissolved oxygen BOD= Biological oxygen demand

Seasonal variation in Carbonate alkalinity and Bicarbonate alkalinity of sampling stations of Pachmarhi. (Table 8)

Site Name / Seasons	Denwa River		Panar Pani		Bee Fall		Bade Mahadev	
	2014-2015 C	2014-2015 B	2014-2015 C	2014-2015 B	2014-2015 C	2014-2015 B	2014-2015 C	2014-2015 B
Monsoon	**18.0**	**148**	**16.0**	**130**	**12.0**	**110**	**10.0**	**108**
Winter	**24.0**	**240**	**24.0**	**200**	**22.0**	**190**	**24.0**	**186**
Summer	**26.0**	**212**	**26.0**	**198**	**24.0**	**168**	**28.0**	**142**

C= Carbonate alkalinity B= Bicarbonate alkalinity

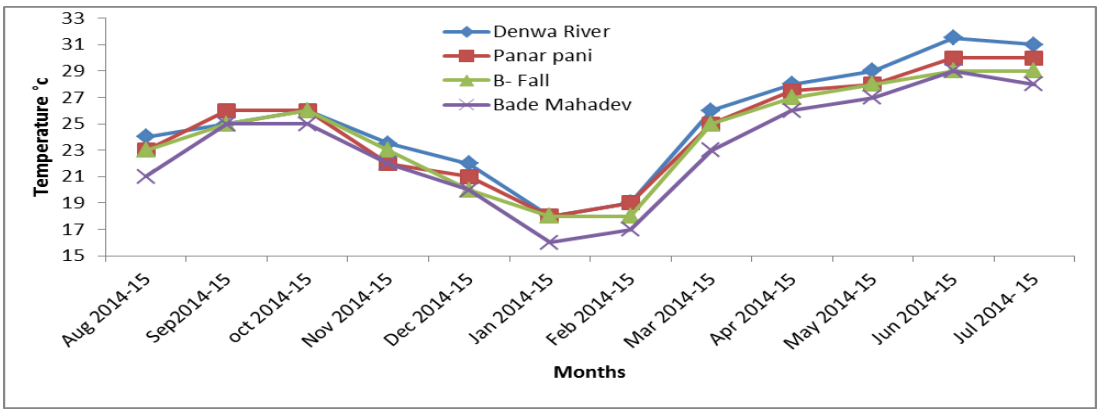

Figure 1

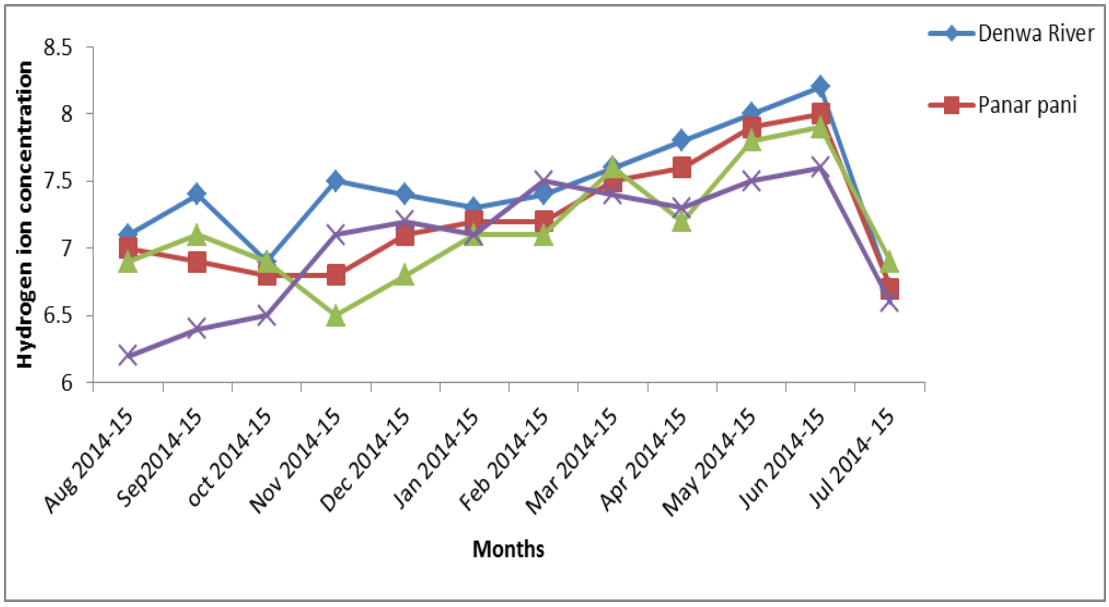

Figure 2

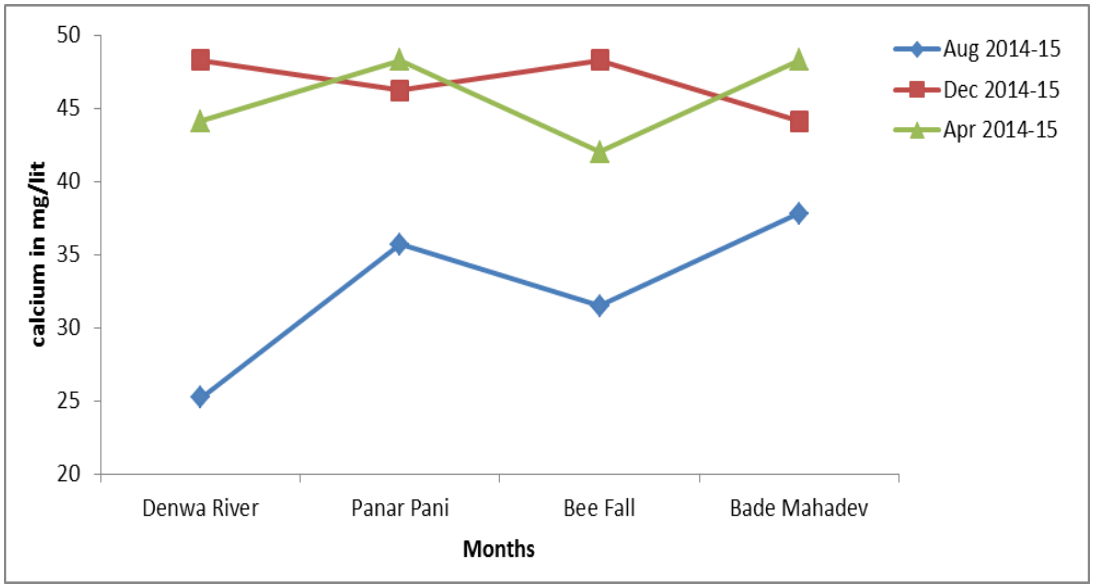

Figure 3

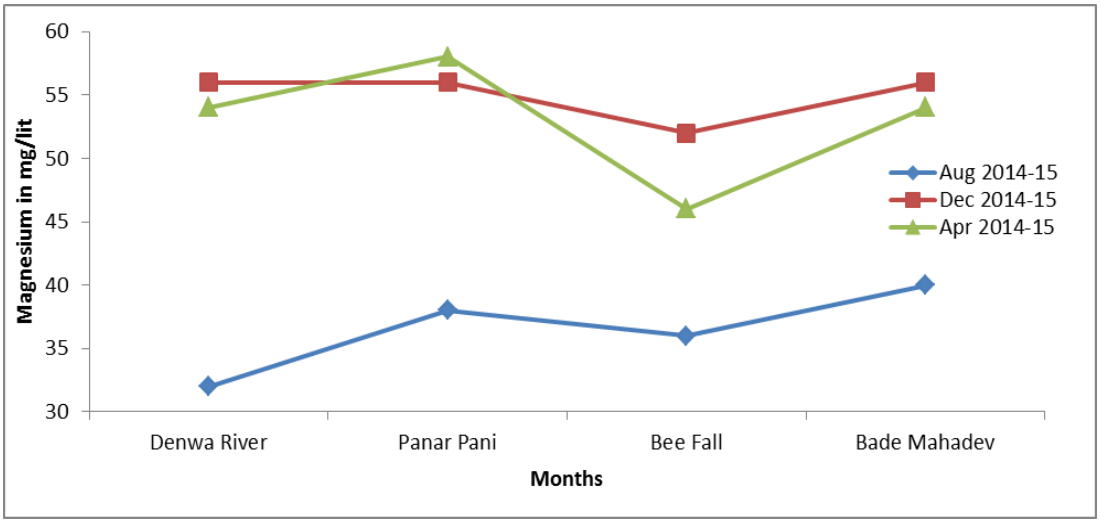

Figure 4

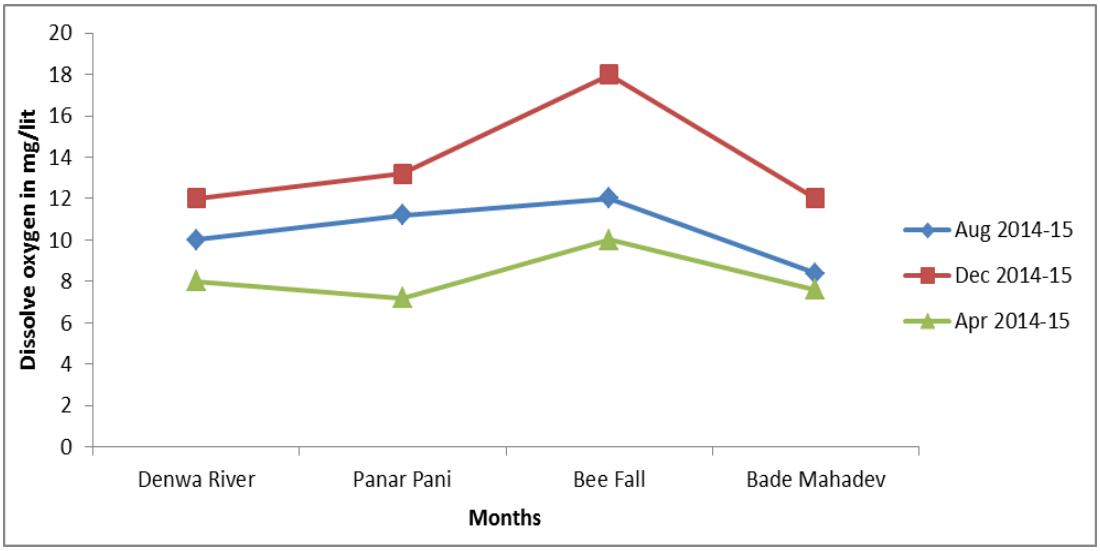

Figure 5

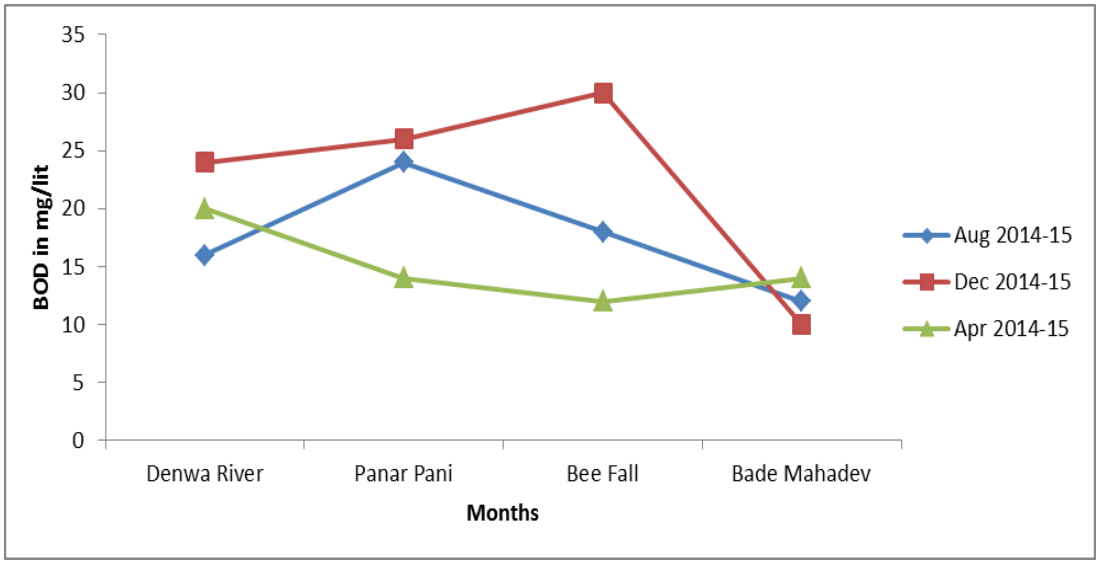

Figure 6

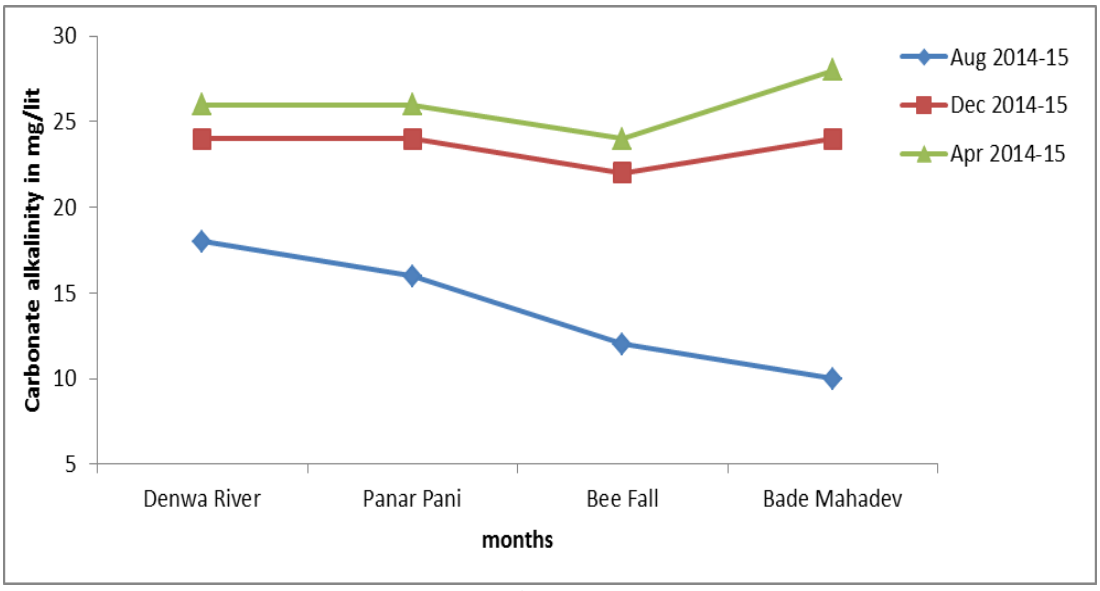

Figure 7

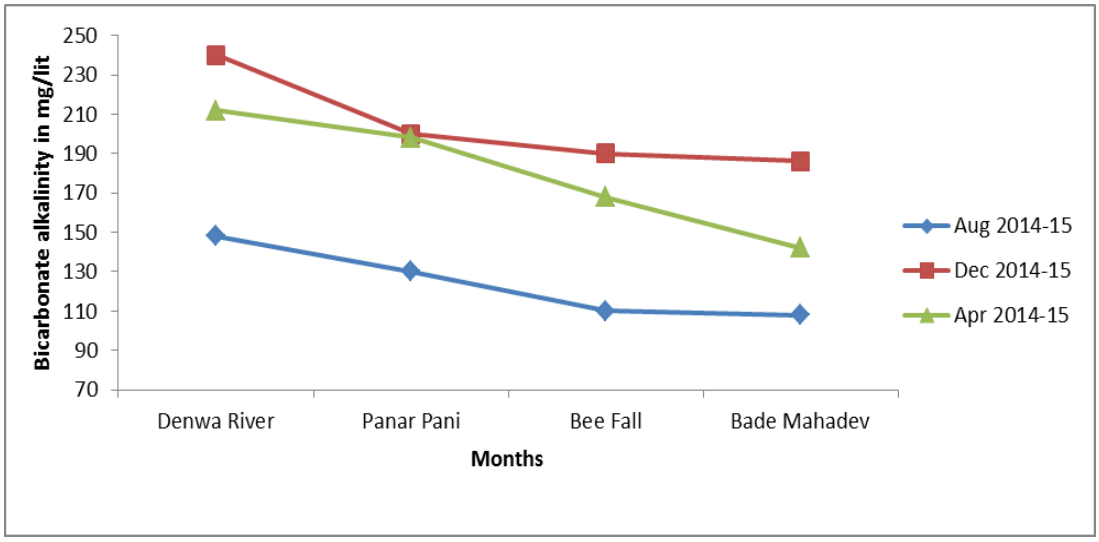

Figure 8

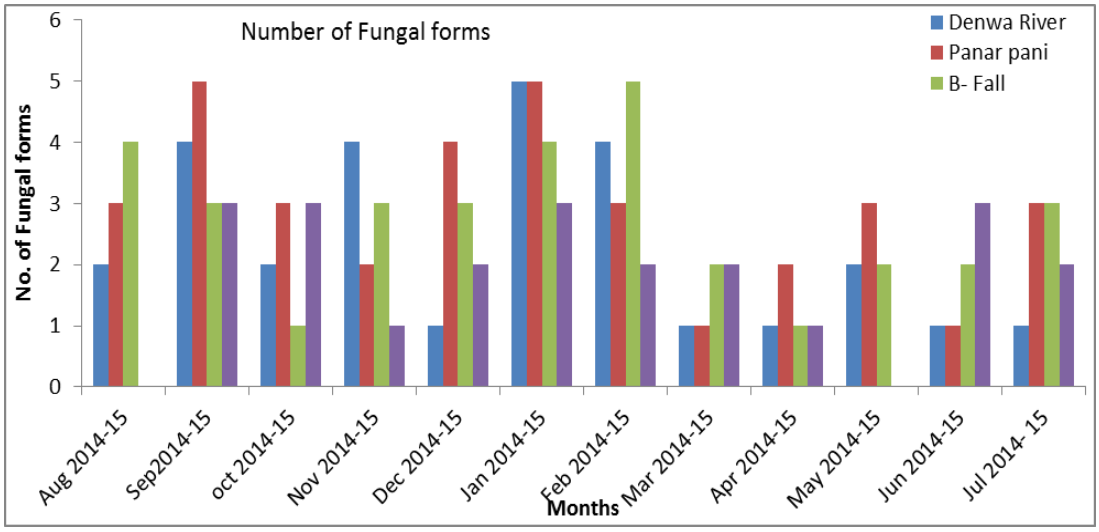

Figure 9

DISCUSSION

Temperature the most significant and essential factor that directly affects the growth, distribution and development of fungal community in nature (Mishra, 1982; Suberkropp, 1984; Iqbal and Webster. 1973a) totally agrees with the present investigation. Fungal diversity shows inverse relation with temperature. During winters fungal diversity was found to be high as compared to monsoon and summer. Table 5 and Figure 1 and 9.

In chemistry, pH (potential of hydrogen) is a numeric scale used to specify the acidity or basicity of an aqueous solution. The pH value ranges from 6.2 to 8.2 in the alkaline range. pH shows variations during different seasons thus with other factors it can affect the fungal diversity. Table 5 Figure 2 and 9.

Calcium and Magnesium hardness was found to be high during winters corresponding to the number of fungal species. In monsoon the calcium and Magnesium was found to be lower than summer but fungal diversity was found to be high as compared to summer. Dayal and Tandon (1962) and Mishra (1982) did not find any significant correlation between total hardness and fungal diversity agrees with the present investigation. Table 6 and Figure 3,4 and 9.

Dissolve oxygen is found one of the significant parameter as it regulates the metabolic process of the aquatic organisms. Their diversity may be determined with the dynamic and distribution of oxygen. Dissolved oxygen and fungal diversity was found to be high during winters as compared to the monsoon and summer. Thus from the table 7 and figure 5 and 9 it can be concluded that oxygen plays direct in growth and activity of fungal diversity thus is a significant factor. BOD content was found to high during winters corresponding to the number of fungal species. During monsoon it shows moderate value and fungal diversity was found to be moderate and in summer both BOD and fungal diversity was found to be low. The survey of available literature reveals that there has been no work on the diversity of fungi in relation to BOD. Table 7 and Figure 6 and 9.

Table 8 and Figure 7 and 9 show that in the present course of study during monsoon, carbonate alkalinity was present in very low quantity. It gradually increases in winter and maximum recorded in summer. In summer fungal diversity was found to be low while in winter its values are moderate but the fungal diversity was found to be high. Bicarbonates show maximum value than carbonates. Bicarbonates were high during the winter when fungal diversity was found to be high. In summer bicarbonates shows moderate values but the fungal diversity was found to be low. At all sampling sites alkalinity was comparatively higher in winter than other seasons due to presence of carbonates and bicarbonates, when maximum fungal occurrence was recorded. Table 8 and Figure 8 and 9.

Taxonomic Description

Flagellospora curvula Ingold. Trans. Br. Mycol. Soc. **25:** 339-417, 1942. (Fig 1)
Hyphae smooth, thin- walled, hyaline, septate, 1µm to 2µm, conidiophores mononematous, branched, straight or flexuous 10µm to 28 µm and 1µm to 3 µm. conidiophores cells phialidic. Conidia hyaline, sigmoid slongate, aspetate, thin walled , 16 µm to 30 µm long 1µm to 3 µm wide.

Fladellospora penicilloides Ingold *Trans. Br. Mycol. Soc.* **28:** 35- 43, 1944. (Fig 2)
Mycelium branched septate. Conidiophores hyaline, septate, branched at the apex penicilately, up to 200 µm long and 8 µm wide; phialides apical, 4 – 8, 12 – 16 µm long and 3 – 4 µm wide; conidia hyaline 28 – 54 µm long and 2 – 3 µm wide, tapering at both ends, unicellular or often uniseptate, curved or slightly sigmoid, produced in basipetal succession.

Meria sp. Vuill. (Fig 3)
Mycelium hyaline, branched, conidiophores simple, elongate, septate; conidia, hyaline, 1-celled, produced singly or in clusters on lateral or apical sterigmata; attacking and destroying nematodes.

Monodictys flactuata (Tandon & Bilgrami) M.B.Ellis, 1971, *Mycol. Pap.* **124:** 5. (Fig 4)
Colonies effuse, velvety, pale to dark mouse grey. Conidia very variable in size and shape, many celled, often constricted at the septa, at first smooth, later verruculose, mid dark golden brown, up to 40 µm in diameter.

Scopulariopsis brevicaulis (Sacc.) Bainier, 1907, *Bull. Trimmest. Soc. Mycol. Fr.*, **23:** 98-100. (Fig 5).
Colonies at first whitish, later buff to nut brown with a narrow white margin. Annelides sometimes arising singly from hyphae but more frequently in groups of 2 – 3 or arranged penicillately in more complex conidiophores conidiophores, 10 – 25µm long, colourless or very pale. Conidia brown in mass, spherical or obovoid, truncate at the base, smooth when young, coarsely verrucose when mature, 5–8 × 5–7 µm.

Trichocladium canadense Hughes, 1959, *Can. J. Bot.*, **37:** 85 –859. (Fig 6)
Colonies effuse, black. Conidiophores 3–5 µm thick. Conidia acropleurogenous, predominantly 1- celled, occasionally 2- septate, clavate or ellipsoidal, truncate at the base, mid to dark brown, smooth, 15–30 µm long, 8–12 µm in the broadest part.

Allomyces anomalus Emerson. (Fig 7)
Thallus large in size, principal hyphae stout, slender, hyaline, sympodially branched, pseudo-septate, 25-50µm wide, tips blunt, zoosporangia oval, hyaline 50-75 × 25-37.5 µm, zoospores escaping through an apical pore, encysted zoospores 12.5µm in diameter, resting zoospores abundant, ovoid, 25-50 × 12.5-37.5µm, Sex organs absent.

Allomyces arbuscula Butler. (Fig 8)
Hyphae stout, dichotomously branched, pseudoseptate, 12.5-50µm in diameter at base, tips blunt, hyaline, zoosporangia oval, hyaline, 25-50 × 56.25-62.5µm, encysted zoospores 6.25-12.5µm in diameter; resting sporangia abundant, oval 46.87-56.25µm long, 31.25-46.87µm in diameter, producing zoospores after a period of rest, sex organs abundantly in pairs, female gametangia terminal, spherical, hyaline, 40.62-50µm in diameter, male gametangia hyphogynous, orange coloured, barrel shaped 34.37-40.62µm in diameter.

Allomyces javanicus Kniep. (Fig 9)
Thallus sympodially or dichotomously branched; basal cell variable in size, zoosporangia ovoid, apical or catenulate, 50-78.12 × 25-50µm with one to many papillae, zoosphores ovoid, 12.5µm in diameter, resting sporangia spherical, ovoid, 31.25-56.25 × 25-50µm, gametangia terminal in pairs, simple to catenulate, male gametangia terminal, 25-34.37 × 18.75-25µm, female gametangia ovoid 53.12-56.25 × 28.12-37.5µm.

Allomyces moniliformis Coker and Braxton. (Fig 10)
Thallus branched, zoosporangia cylindrical, 78.12-125 × 9.37-12.5µm, primary sprorangia calvate, 62.5-93.75 × 15.62-25µm with an apical papilla, resting spores ovoid, 37.5-62.5 × 25-46.87µm, exospores thick walled, orange brown and pitted.

Diagrams

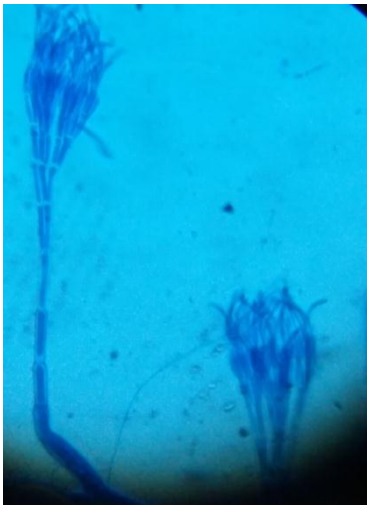

Fig 1

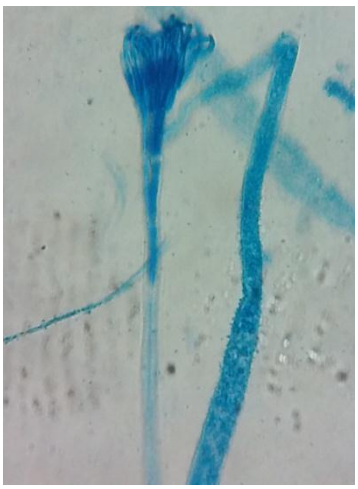

Fig 2

Fig 3

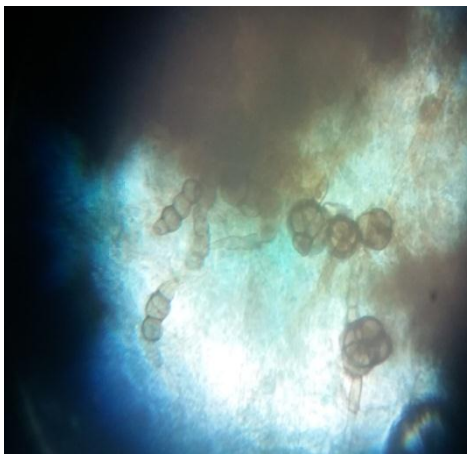

Fig 4

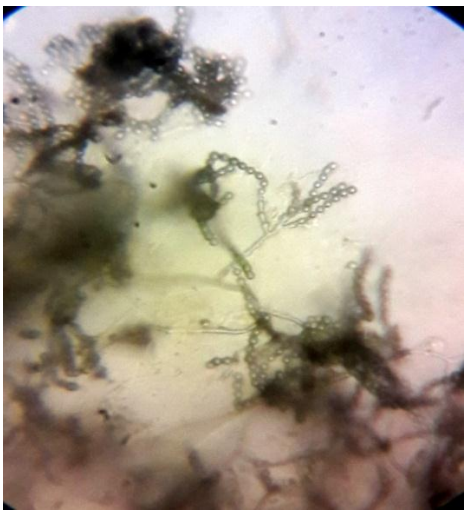

Fig 5

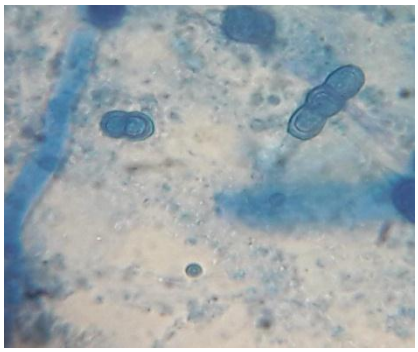

Fig 6

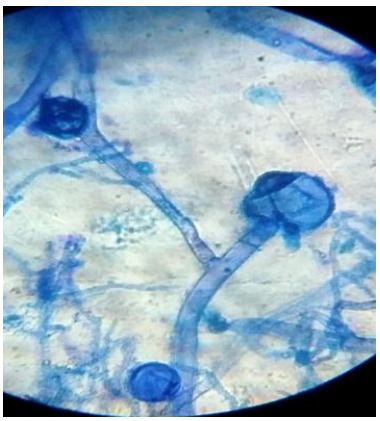

Fig 7

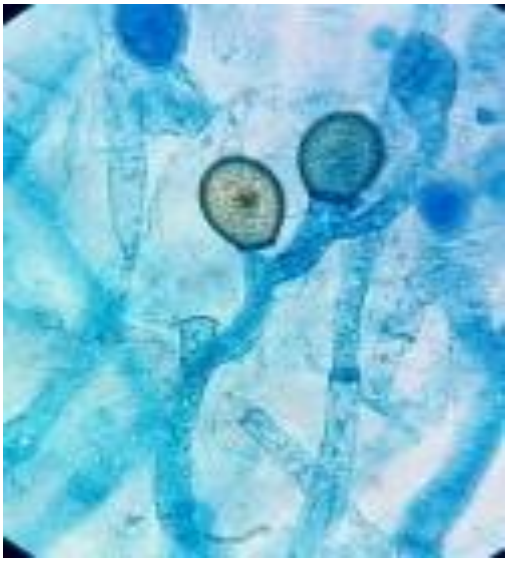

Fig 8

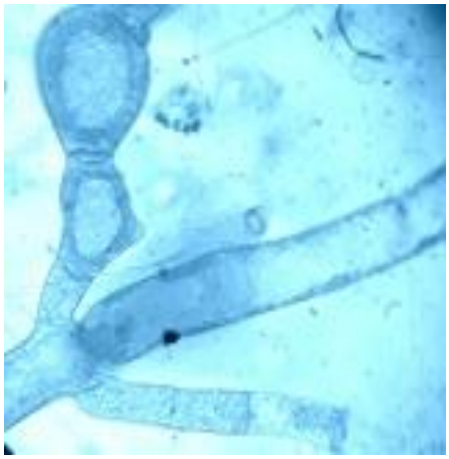

Fig 9

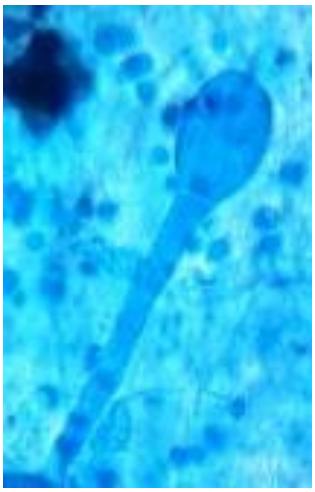

Fig 10

CONCLUSION

Very little work is being done on Taxonomy of aquatic fungi particularly in India therefore the authors tried to explore some aquatic fungi from the Pachmarhi Biosphere Reserve Madhya Pradesh first time and reported total 10 species of fungi belonging to the *Moniliales, Blastocladiales*. From this study we are concluding that there are large numbers of fungi which are yet to be explored from many places particularly in India.

As the Fungal diversity is fundamental to the success of biotechnology and is critical if the commercial potential of fungi is to be fully realized. So it is very important to study the taxonomy of this kingdom.

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