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OCCURRENCE, DISTRIBUTION AND SEASONALITY OF WATERMOLDS IN SELECTED FOREST ECOSYSTEMS OF CENTRAL HIMALAYA

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Introduction

Ecological studies of aquatic Phycomycetes have been carried out by a number of investigators; Petersen (1910) was among the first to study the occurrence of some aquatic fungi in Denmark and reported *Apodachlya* sp. to be of common occurrence. Later, Coker (1923) studied the distribution and seasonal periodicity of watermolds in Chapel Hill, North Carolina and found that *Laptomitus* and *Apodachlya* were the most common and rare species, respectively. He reported that such differences in occurrence could be attributed to local factors; on a larger geographical scale the species distribution would be governed by the climatic conditions. Coker and Matthews (1937) also pointed out that certain species of Saprolegniaceae showed seasonal periodicity in occurrence and variation in abundance. In his study, *Saprolegnia ferax* and *Achlya racemosa* appeared more frequently during the spring season.

Raper (1928) studied distribution of watermolds in soil within defined areas using quadrat method. He observed aggregate distribution of *Brevilegnia linearis* and *Achlya imperfecta* among six quadrats.

Ivimey-Cook and Morgan (1934) also recorded seasonal periodicity of Saprolegniaceae in soil as well as water.

Forbes (1935) in a study of watermolds in Manchester district found a marked periodic variation in their abundance. She reported gradual increase in the number of records leading to maximum abundance during winter, followed by a corresponding decrease until the species nearly disappeared in the summer.

Burges (1939) and Garrett (1951) held the view that Phycomycetes occupied a static position in soil, and their population flared up when suitable conditions became available. Reinboldt (1951) used 0.25 m^2 quadrats and observed that Saprolegniaceous fungi (*Saprolegnia* and *Geolegnia*) were not uniformly distributed even over a small area of soil.

Waterhouse (1942) dealt primarily with the members of Blastocladiaceae, Leptomitaceae and Pythiaceae of River Hogsmill, Surrey and reported that most watermolds had a seasonal rhythm, which appear during September and October, rise to a maximum level during December to February and then disappear in the summer.

McLaughlin (1947) found that the percentage of *Pythium* spp. in soils was high in winter as well as in fall and low in summer.

Ziegler (1952) studied the occurrence and distribution of Saprolegniaceae in Florida and found that *Saprolegnia* spp. occurred more frequently in winter and spring than in other seasons. Later, Ziegler (1958) observed that eccentric species of Saprolegniaceae were dominant during the warm weather, while centric and sub-centric species occurred frequently in cooler season.

Ingold (1954) emphasized the importance of water for soil watermolds and reported that these soil fungi required water for their metabolic activities, viability and dispersal.

Perrott (1960) in an extensive study on the ecology of some aquatic Phycomycetes of North Staffordshire, Cheshire and South Wales reported that the occurrence of many species of aquatic Phycomycetes in spring and autumn could be related to periods favourable for germination and growth, while during summer and winter the fungi remained dormant.

Suzuki (1960) studied seasonal changes in the occurrence of aquatic fungi and indicated that temperature had a profound effect under field conditions, on the production of zoospores, and unfavourable temperature reduced the zoospore development.

Dick and Newby (1961) observed significant fluctuations in the frequency of species with maximum abundance in spring and autumn. Hughes (1962) also studied the seasonal periodicity of Saprolegniaceae in the South Eastern United States.

Roberts (1963) studied the distribution of Saprolegniales in 21 natural waters in the United Kingdom. He placed all the species into three groups, *viz*., winter, summer and constant species; most species fell into the winter group. He further classified the species into three groups on the basis of hydrogen ion concentration of the habitat, i.e., acidic group (pH below 5.2), alkaline group (pH above 7.8), and neutral

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group (pH 5.6-7.4), with the greatest number of species distribution from pH 5.2-7.4 range.

Miller and Ristanovic (1969) isolated 17 species of Saprolegniaceae in Athens and maximum species (72%) were collected during August to October and minimum (20%) during November to February. They found *Saprolegnia ferax* and *S. diclina* to be the most frequent species.

Alabi (1971) investigated the distribution of Saprolegniaceae in Ibadan, Nigeria, and classified the members of Saprolegniaceae into three groups, *viz.*, dry, rainy and all season species; noticeable fluctuation was observed in the seasonal occurrence of the members of the above groups. He isolated most eccentric species during the dry season (high temperature) and centric species in the rainy season (low temperature).

Robertson (1973) observed that *Pythium* population peaked from July to September, conditions of low soil temperature and high moisture. Subsequently, Johnson and Seymour (1974), Hunter (1975), Fox and Wolf (1977), Okane (1978 & 1981), Ismail *et al.* (1979), Suzuki (1981), Klich and Tiffani (1985) and Barlocher (1992) also contributed to the knowledge regarding the distribution, abundance and species of this group of fungi.

In India, Hamid (1942) described the occurrence and distribution of Phycomycetes. Chaudhari *et al.* (1947) studied periodicity of watermolds in India for the first time and found October to mid-December, and February to May as best periods for the growth of watermolds.

Dayal and Tandon (1962) reported higher number of species in winter. Dayal and Tandon (1963) noted that several chemical variables including pH, nitrate and dissolved oxygen could markedly influence the occurrence and distribution of watermolds.

Chowdhry and Agarwal (1980 a & b) in their studies on seasonal periodicity of aquatic fungi of Delhi isolated a number of species and classified them into four groups, *viz., Saprolegnia delica, S. diclina, S. ferax, S. parasitica* and *Dictyuchus monosporus* into winter season species (November to February, 10-25°C); *Allomyces anomalus* and *Aphanomyces laevis* into summer season species (March to June, 30-45°C); *Allomyces arbuscula, Achlya orion, Aphanomyces laevis, Pythium aphanidermatum, P. ultimum* and *P. vexans* into rainy season species (July to October, 20-30°C) and *Achlya prolifera, A. proliferoides, A. klebsiana* and *Pythium middletonii* into all seasons species (January to December, 10-45°C). They collected maximum number of centric and sub-centric species during winter, while no eccentric species were recorded throughout the year and showed no seasonal variation.

Gupta and Mehrotra (1992) while working on watermolds of Kurukshetra reported that the maximum number of species tended to increase in winters, thereafter decreasing during the rainy season. The ecological studies on watermolds in the central Himalayan region were first initiated by Khulbe (1977). Later, Khulbe and Bhargava (1977) reported the population maxima of watermolds during autumn and spring in the temperate region. They observed that eccentric species flourished during warm weather, while centric and sub-centric species appeared in cooler months.

Mer (1982) found highest number of species in August and September in soil and water samples, respectively. According to him enrichment of organic matter with moderate temperature might account for the appearance of higher number of watermolds. He categorised the species into three groups, *viz.*, "aquatic", "terricolous", and "amphibious", and found that *Pythium* species were dominant in the soil.

Most of the previous investigations of watermolds took into consideration mainly the aquatic habitats for ecological studies; the work on watermolds inhabiting the soils is rather limited.

Material and Methods

Collection

Three different study sites, viz., *Cupressus torulosa*, *Quercus floribunda* and *Pinus roxburghii* forests were selected for the study of watermolds during 1999-2001. At each study site 50 x 50 m area was selected and within this area four permanent quadrats of 1 x 1 m were marked. Each selected quadrat site was relatively flat and with a uniform vegetation cover. Each quadrat was further subdivided into four smaller sub-squares (25 cm x 25 cm) and numbered 1-4. Studies in each quadrate were carried out at a monthly interval.

From each sub-square, after the removal of surface vegetation and litter, about 100 g soil was collected every month from November 1999 to October 2001. Such soil samples collected from different study sites were brought to the laboratory under aseptic conditions in individual polyethylene bags.

Analysis of soil samples

Quantitative estimation of watermolds: 16 soil samples were taken at a monthly interval from each study site. The frequency of occurrence of individual species of watermolds was calculated out of the sixteen samples analysed, by the formula given below (Misra, 1968):

$$\% \text{ frequency} = \frac{\text{No. of sample in which the species occurred}}{\text{Total no. of samples taken}} \times 100$$

Percentage contribution of different species and genera to the population of watermolds was calculated on the basis of their relative frequency.

Observations

Occurrence and distribution of watermolds in different study sites

During the course of this study from Nov. 1999 to Oct. 2001, a total of 46 fungal species, representing 6 families and 14 genera, namely *Rozella* (Olpidiaceae); *Allomyces* (Blastocladiaceae); *Achlya, Aphanomyces, Brevilegnia, Dictyuchus, Leptolegnia, Protoachlya, Saprolegnia* and *Thraustotheca* (Saprolegniaceae); *Olpidiopsis, Petersenia* (Olpidiopsidaceae); *Myzocytium* (Lagenidiaceae) and *Pythium* (Pythiaceae) were isolated from the soil samples collected from different study sites. Saprolegniales and Peronosporales contributed 43.5% and 34.8%, respectively, whereas, Chytridiales, Blastocladiales and Lagenidiales accounted for 2.17%, 4.34% and 15.2% of the total population of mycoflora of the forest soils. Occurrence, distribution and frequency of the fungal species are shown in the Tables 1-3.

Table 1: Occurrence, distribution and frequency (%) of watermolds in the cypress forest ecosystem, China Peak, Nainital during Nov. 1999-Oct. 2001

Months / Fungal species	Nov. 1999	Dec. 1999	Jan. 2000	Feb. 2000	Mar. 2000	Apr. 2000	May 2000	Jun. 2000	Jul. 2000	Aug. 2000	Sep. 2000	Oct. 2000
Aphanomyces species 1												12.50
Saprolegnia diclina	25.00	37.50										12.50
Saprolegnia ferax	6.25											6.25
Saprolegnia parasitica	62.50		56.25		37.50				81.25	75.00	68.70	37.50
Thraustotheca clavata		12.50	6.25	12.50				68.70	75.00	75.00	75.00	56.00
Olpidiopsis pythii											12.50	37.50
Olpidiopsis saprolegniae											56.25	
Petersenia irregulare												
Pythium aristosporum												
Pythium debaryanum		12.50	37.50	25.00	12.50							
Pythium echinulatum		12.50	25.00	37.50								
Pythium graminicola					6.25							
Pythium helicum												
Pythium inflatum												
Pythium iwayamai												
Pythium middletonii						25.00	37.50		62.50	56.25		
Pythium pulchrum											6.25	
Pythium undulatum							25.00				50.00	
Pythium 1									6.25			

Months / Fungal species	Nov. 2000	Dec. 2000	Jan. 2001	Feb. 2001	Mar. 2001	Apr. 2001	May 2001	Jun. 2001	Jul. 2001	Aug. 2001	Sep. 2001	Oct. 2001
Aphanomyces species 1										12.50		
Saprolegnia diclina	12.50				25.00			12.50	12.50			25.00
Saprolegnia ferax												
Saprolegnia parasitica	37.50			56.25	43.75				68.75	75.00	81.25	
Thraustotheca clavata	56.00		25.00	12.50	12.50	12.50			56.00			
Olpidiopsis pythii				6.25								
Olpidiopsis saprolegniae				12.50								
Petersenia irregulare				56.25	56.25	37.50			37.50			
Pythium aristosporum								6.25				
Pythium debaryanum	6.25	6.25						12.50	56.25			
Pythium echinulatum				12.50	25.00							
Pythium graminicola					12.50		56.25	37.50				
Pythium helicum								6.35				
Pythium inflatum									6.25			
Pythium iwayamai							43.75	43.75				
Pythium middletonii							75.00		50.00			
Pythium pulchrum												
Pythium undulatum							50.00	43.75				
Pythium 1								25.00				

Table 2: Occurrence, distribution and frequency (%) of watermolds in the mixed oak forest ecosystem, Tiffin Top, Nainital during Nov. 1999-Oct. 2001

Months / Fungal species	Nov. 1999	Dec. 1999	Jan. 2000	Feb. 2000	Mar. 2000	Apr. 2000	May 2000	Jun. 2000	Jul. 2000	Aug. 2000	Sep. 2000	Oct. 2000
Allomyces arbuscula				6.25								
Achlya americana								25.00	12.50			
Achlya species 1												
Aphanomyces helicoides										12.50		
Dictyuchus monosporus												
Leptolegnia caudata										6.25		
Protoachlya nainitalensis										6.25		
Saprolegnia asterophora												
Saprolegnia diclina				31.25								7.50
Saprolegnia ferax									56.25	18.75		
Saprolegnia lapponica											37.50	
Saprolegnia litoralis												
Saprolegnia parasitica	43.75						25.00	43.75	56.25			
Saprolegnia sterile species 1					75.00	56.25			56.25			
Thraustotheca clavata						25.00			81.25	93.75	87.50	
Olpidiopsis pythii			25.00	56.25							12.50	
Petersenia irregulare												
Pythium artotrogus									12.50			
Pythium echinulatum			43.75									
Pythium graminicola							56.25					
Pythium inflatum		12.50	31.25									
Pythium iwayamai				56.25				25.00				
Pythium middletonii		31.25								68.70		
Pythium proliferum				6.25								
Pythium pulchrum								18.75		37.50		
Pythium undulatum		56.25								25.00		12.50
Pythium 1										25.00		
Pythium 2												

Months / Fungal species	Nov. 2000	Dec. 2000	Jan. 2001	Feb. 2001	Mar. 2001	Apr. 2001	May 2001	Jun. 2001	Jul. 2001	Aug. 2001	Sep. 2001	Oct. 2001
Allomyces arbuscula				6.25								
Achlya americana								6.25				
Achlya species 1						6.25						
Aphanomyces helicoides												
Dictyuchus monosporus				6.25								
Leptolegnia caudata												6.25
Protoachlya nainitalensis												
Saprolegnia asterophora										12.50		
Saprolegnia diclina										12.50		
Saprolegnia ferax												12.50
Saprolegnia lapponica												
Saprolegnia litoralis										6.25		
Saprolegnia parasitica			43.75	31.25								
Saprolegnia sterile species 1						31.25	56.25	68.75	68.75			
Thraustotheca clavata						12.50	31.25					
Olpidiopsis pythii				12.50								
Petersenia irregulare				56.25	56.25							
Pythium artotrogus								37.50				
Pythium echinulatum				68.75	56.25							
Pythium graminicola												
Pythium inflatum		18.75										
Pythium iwayamai			42.50						43.75			
Pythium middletonii		6.25	12.50		37.50		12.50	37.50	56.25	25.00		
Pythium proliferum												
Pythium pulchrum												
Pythium undulatum				56.25					42.50			
Pythium 1												
Pythium 2												

Table 3: Occurrence, distribution and frequency (%) of watermolds in chir pine forest ecosystem, Pines, Nainital during Nov. 1999-Oct. 2001

Months / Fungal species	Nov. 1999	Dec. 1999	Jan. 2000	Feb. 2000	Mar. 2000	Apr. 2000	May 2000	Jun. 2000	Jul. 2000	Aug. 2000	Sep. 2000	Oct. 2000
Rozella allomycis												
Allomyces anomalus		6.25	31.25	31.25				12.50				
Achlya flagellata												
Achlya crenulata												
Achlya species 1					12.50							
Aphanomyces laevis												
Aphanomyces species 1				12.50				6.25				
Brevilegnia indica												
Leptolegnia caudata												6.25
Protoachlya species 1												
Saprolegnia diclina	43.75			37.50					18.75			50.00
Saprolegnia ferax												12.50
Saprolegnia parasitica									31.25	68.75	56.25	
Saprolegnia sterile species 1	25.00						25.00		43.75			
Thraustotheca clavata	12.50			12.50	12.50	25.00	12.50	56.25	68.75	68.75	56.25	
Olpidiopsis achlyae												
Olpidiopsis fusiformis										12.50		
Olpidiopsis pythii	25.00		12.50	18.75				18.75		6.25		
Olpidiopsis saprolegniae									37.50	12.50	37.50	18.75
Olpidiopsis varians								12.50	18.75			
Petersenia irregulare												
Myzocytium proliferum							6.25					
Pythium artotrogus				25.00								
Pythium coloratum								12.50				
Pythium debaryanum				18.35							6.25	
Pythium dissotocum												
Pythium echinulatum				12.50		12.50						
Pythium graminicola								12.50				
Pythium inflatum												
Pythium iwayamai							12.50	12.50	12.50			
Pythium middletonii										37.50		
Pythium proliferum												
Pythium pulchrum							50.00		18.75			
Pythium undulatum									43.75			
Pythium 1												
Pythium 2												

Months / Fungal species	Nov. 2000	Dec. 2000	Jan. 2001	Feb. 2001	Mar. 2001	Apr. 2001	May 2001	Jun. 2001	Jul. 2001	Aug. 2001	Sep. 2001	Oct. 2001
Rozella allomycis							6.25					
Allomyces anomalus				6.25								
Achlya flagellata										6.25		
Achlya crenulata										6.25		
Achlya species 1												
Aphanomyces laevis										12.50		
Aphanomyces species 1									6.25			6.25
Brevilegnia indica										6.25		
Leptolegnia caudata												
Protoachlya species 1				6.25								
Saprolegnia diclina		37.50										6.25
Saprolegnia ferax												12.50
Saprolegnia parasitica									68.75	68.75	56.25	12.50
Saprolegnia sterile species 1							6.25		68.75	56.25	12.50	6.25
Thraustotheca clavata					31.25	68.75	56.25	56.25			31.25	12.50
Olpidiopsis achlyae				12.50								
Olpidiopsis fusiformis												
Olpidiopsis pythii				6.25			6.25					6.25
Olpidiopsis saprolegniae							12.50	37.50	37.50	56.25	37.50	12.50
Olpidiopsis varians									12.50			

Petersenia irregulare					37.5	37.5						
Myzocytium proliferum												
Pythium artotrogus			12.50									
Pythium coloratum												
Pythium debaryanum												
Pythium dissotocum								6.25				
Pythium echinulatum				68.75								
Pythium graminicola							25.00					
Pythium inflatum	12.50	12.50										
Pythium iwayamai							12.50					
Pythium middletonii								37.50	68.75	68.75	56.25	
Pythium proliferum									12.50			
Pythium pulchrum				25.00								
Pythium undulatum				6.25								
Pythium 1						12.50	50.00					
Pythium 2							6.25					

An analysis of the data of Tables 1-3 indicates that the species richness, mycofloral composition and frequency of occurrence of individual species varied considerably from month to month. *Pythium* species were found to be dominant (16 species) followed by *Saprolegnia* (7 species), *Olpidiopsis* (5 species), and *Achlya* (4 species), while *Aphanomyces* had three species. *Allomyces* and *Protoachlya* were represented by two species each. *Rozella*, *Brevilegnia, Dictyuchus, Leptolegnia, Thraustotheca, Myzocytium* and *Petersenia* had one species each.

Table 1 shows that in cypress forest ecosystem during first year (1999-2000) of the study (1999-2000) *Saprolegnia parasitica* (81.25%), *T. clavata* (75.00%) and P. *middletonii* (62.50 %) were observed as most frequent species. And during second year of the study *S. parasitica* (81.25 %), *P. middletonii* (75.00 %) and *T.clavata* (75%) were found as most frequent species.

At mixed oak forest study site during first year of the study *T.clavata* (93.75%), *Saprolegnia* sterile sp.1 (75.00%) and *P. middletonii* (68.70%) were found as most frequent species. During second year of study Saprolegnia sterile sp.1 (68.75%) and *P. echinulatum* (68.75%); *Petersenia irregulare* (56.25%), *P. middletonii* (56.25%) and *P. undulatum* (56.25%); *S. parasitica* (43.75%) were found as most frequent species.

Similarly at pine forest study site during first year (1999-2000) *S. paracitica* (68.75%) and *T. clavata* (68.75%); *S. diclina* (50.00%) and *P. pulchrum* (50.00%); *Saprolegnia* sterile sp.1 (43.75%) and *P. undulatum* (43.75%) were found as most frequent species. During second year of study *S. paracitica* (68.75%), *Saprolegnia* sterile sp.1 (68.75%), *T. clavata* (68.75%), *P. echinulatum* (68.75%), *P. middletonii* (68.75%); *O. saprolegniae* (56.25%), *P. middletonii* (56.25%) and *Pythium* 1 (50.00%) were observed as most frequent species.

It was found that the greater number of fungal species was observed during the rainy, summer and winter months followed by autumn and spring. An analysis of occurrence and frequency of species (Tables 1-3, 4) revealed that *Saprolegnia parasitica, Saprolegnia* sterile species, *Thraustotheca clavata, Olpidiopsis pythii, Pythium debaryanum, P. echinulatum, P. graminicola, P. iwayamai, P. middletonii, P. pulchrum, P. undulatum, Pythium* 1 were constantly present across all the study sites. Most species, on the other hand were present for a few months only with a considerable difference in their frequency.

Species of *Rozella, Olpidiopsis* and *Myzocytium* flourished in the rainy season only. In terms of percent contribution, *Pythium* emerged as the dominant genus which contributed 34.8% to the total fungal population (Fig. 1). Among other genera, *Saprolegnia, Olpidiopsis, Achlya,* and *Aphanomyces* contributed 15.2%, 10.8%, 8.7% and 6.5%, respectively. *Allomyces* and *Protoachlya* contributed 4.3% each. Similarly, *Rozella, Brevilegnia*, *Dictyuchus, Leptolegnia, Thraustotheca, Myzocytium* made up 2.2% each of the total fungal population(Fig.1).

Fig. 1: Percent contribution of various genera across the study sites during 1999-2001

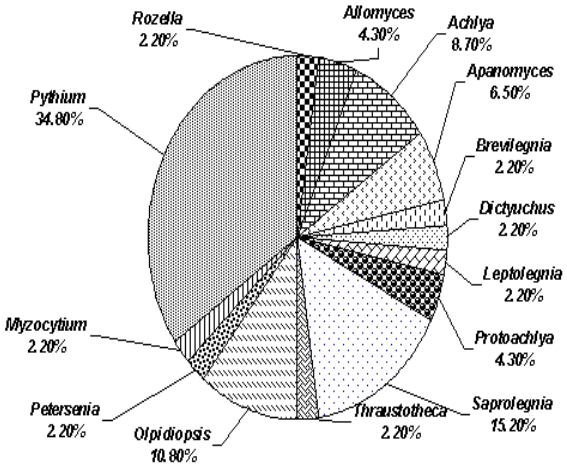

Table 4:Occurrence of watermolds in cypress, oak and pine forest ecosystems (soils and decomposing leaf litters) of Nainital during Nov. 1999-Oct. 2001

Fungal species	Forest Type		
	Cypress	Mixed oak	Chir pine
Rozella allomycis	-	-	+
Allomyces anomalus	-	-	+
Allomyces arbuscula	-	+	-
Achlya americana	-	+	-
Achlya crenulata	-	-	+
Achlya flagellata	-	-	+
Achlya species 1	-	+	+
Aphanomyces helicoides	-	+	-
Aphanomyces laevis	-	-	+
Aphanomyces species 1	+¶	-	+
Brevilegnia indica	-	-	+
Dictyuchus monosporus	-	+	-
Leptolegnia caudata	-	+	+
Protoachlya nainitalensis	-	+	-
Protoachlya species 1	-	-	+
Saprolegnia asterophora	-	+	-
Saprolegnia diclina	+	+	+
Saprolegnia ferax	+	+	+
Saprolegnia lapponica	-	+	-
Saprolegnia litoralis	-	+	-
Saprolegnia parasitica	+⊕	+⊕	+⊕
Saprolegnia sterile species 1	-	+	+
Thraustotheca clavata	+	+⊕	+⊕
Olpidiopsis achlyae	-	-	+
Olpidiopsis fusiformis	-	-	+
Olpidiopsis pythii	+	+⊕	+⊕
Olpidiopsis saprolegniae	+	-	+⊕
Olpidiopsis varians	-	-	+⊕
Petersenia irregulare	+	+	+
Myzocytium proliferum	-	-	+
Pythium aristosporum	+	-	-
Pythium artotrogus	-	+	+
Pythium coloratum	-	-	+
Pythium debaryanum	+	-	+
Pythium dissotocum	-	-	+⊕
Pythium echinulatum	+	+	+
Pythium graminicola	+⊕	+	+⊕
Pythium helicum	+⊕	-	-

Pythium inflatum	+	+	+
Pythium iwayamai	+	+	+⊕
Pythium middletonii	+⊕	+⊕	+⊕
Pythium proliferum	-	+	+
Pythium pulchrum	+	+	+
Pythium undulatum	+	+	+
Pythium 1	+	+	+
Pythium 2	-	-	+¶
TOTAL	19	27	36

Note:
¶ = isolated from decomposing leaf litters only
⊕ = isolated from soil as well as decomposing leaf litters
All others from soil only.

Seasonal Periodicity

An analysis of the results obtained from various study sites, sampled regularly for a period of two years, from Nov. 1999 to Oct. 2001, indicates that the watermolds showed a marked seasonal fluctuation in their occurrence. The total fungal counts were relatively higher during the rainy, summer and winter seasons followed by lower counts in the autumn and spring with almost the same number of species. After mid-June the number of fungal species was found to increase with moderate temperature and higher soil moisture content. The total fungal counts were high from mid-June to September and conversely the fungal populations tend to decrease from October to January with a concomitant decrease in soil moisture content and temperature.

A perusal of the results obtained in the present study also revealed that each species showed a marked periodicity in its occurrence (Table 5).

Table 5: Seasonal occurrence of watermolds in forest ecosystems (soils and decomposing leaf litter) of Nainital during Nov. 1999-Oct. 2001

Fungal species	Seasons				
	Winter	Spring	Summer	Rainy	Autumn
Rozella allomycis	-	-	+	-	-
Allomyces anomalus	+	-	+	-	-
Allomyces arbuscula	+	-	-	-	-
Achlya americana	-	-	+	+	-
Achlya crenulata	-	-	-	+	-
Achlya flagellata	-	-	-	+	-
Achlya species 1	-	+	-	-	-
Aphanomyces helicoides	-	-	-	+	+
Aphanomyces laevis	-	-	-	+	-
Aphanomyces species 1	+	-	+	+	+
Brevilegnia indica	-	-	-	+	-
Dictyuchus monosporus	+	-	-	-	-
Leptolegnia caudata	-	-	-	+	+
Protoachlya nainitalensis	-	-	-	+	-
Protoachlya species 1	+	-	-	-	-
Saprolegnia asterophora	-	-	-	+	-
Saprolegnia diclina	+	+	+	+	+
Saprolegnia ferax	-	-	-	+	+
Saprolegnia lapponica	-	-	-	+	-
Saprolegnia litoralis	-	-	-	+	-
Saprolegnia parasitica	+	+	+	+	+
Saprolegnia sterile species 1	-	+	+	+	+
Thraustotheca clavata	+	+	+	+	+
Olpidiopsis achlyae	+	-	-	-	-
Olpidiopsis fusiformis	-	-	-	+	-
Olpidiopsis pythii	+	-	+	+	+
Olpidiopsis saprolegniae	+	-	+	+	+
Olpidiopsis varians	-	-	+	+	-
Petersenia irregulare	+	+	-	+	-
Myzocytium proliferum	-	-	+	-	-
Pythium aristosporum	-	-	+	-	-
Pythium artotrogus	+	-	+	+	-
Pythium coloratum	-	-	-	+	-
Pythium debaryanum	+	-	+	+	+
Pythium dissotocum	-	-	-	+	-

Pythium echinulatum	+	+	-	-	-
Pythium graminicola	-	-	+	+	-
Pythium helicum	-	-	+	-	-
Pythium inflatum	+	-	-	+	-
Pythium iwayamai	+	-	+	+	-
Pythium middletonii	+	+	+	+	-
Pythium proliferum	+	-	-	+	-
Pythium pulchrum	+	-	+	+	-
Pythium undulatum	+	-	-	+	+
Pythium 1	-	+	+	+	-
Pythium 2	-	-	+	-	-
TOTAL	21	9	22	34	12

Note: Spring = March – April; Summer = May – June; Rainy = July – September; Autumn = October – November; Winter = December – February

It was interesting to note that some species appeared only in a particular seasons. *A. crenulata, A. flagellata, A. laevis, Brevilegnia indica, Protoachlya nainitalensis, Saprolegnia asterophora, S. lapponica, S. litoralis, Olpidiopsis fusiformis, Pythium coloratum,* and *P. dissotocum* occurred during the rainy season only. Whereas, *Allomyces arbuscula, Dictyuchus monosporus, Protoachlya* species 1, *Olpidiopsis achlyae,* and *Pythium inflatum* occurred only in the winter; *Aphanomyces helicoides, Saprolegnia ferax, S. lapponica, S. litoralis* in autumn; *Rozella allomycis, Myzocytium proliferum, Pythium aristosporum, P. helicum* and *Pythium* 2 occurred in the summer season only, and *Achlya* species 1 was seen to occur in spring season only.

Saprolegnia diclina, S. parasitica, Thraustotheca clavata were found across all seasons. While *Aphanomyces* species 1, *Saprolegnia* sterile species 1, *Olpidiopsis pythii, O. saprolegniae, Pythium debaryanum* and *P. middletonii* occurred during four seasons of the year, others were present either in two or three seasons only.

Discussion and Summary

During the present investigation a total of 46 fungal species were isolated from the soil samples of central Himalayan forests under observation. Of these *Allomyces anomalus, Allomyces arbuscula, Achlya americana, Achlya crenulata, Achlya flagellata, Aphanomyces helicoides, Aphanomyces laevis, Saprolegnia diclina, Saprolegnia ferax, Saprolegnia parasitica, Thraustotheca clavata, Pythium middletonii,* and *Pythium undulatum* have been already reported by Khulbe (1985) from temperate sites and by others from different climatic regions (Mer, 1982; Verma, 1984). Khulbe and Upadhyay (2002) have reported habitats of some watermolds of Kumaun Himalaya (Table 6). Observations of these authors show that the species composition of watermolds varies considerably across months, which can be attributed to variations in physicochemical characteristics of different forest ecosystems as well as cultivated soils.

Saprolegniaceae, Pythiaceae and Olpidiopsidaceae contributed to the major bulk of the flora of watermolds of the forest ecosystems and accounted for 43.5%, 34.8% and 15.2%, respectively. Members of Saprolegniaceae have been reported as the major fungal components of both aquatic and terrestrial environments (Perrott, 1960; Khulbe and Bhargava, 1977; Mer, 1992; Khulbe *et al.,* 1995).

In terms of percent contribution *Pythium* (34.8%) emerged as the dominant genus, among others *Saprolegnia* and *Olpidiopsis* contributed 15.2% and 10.8%, respectively to the total fungal population (Fig. 1). The remaining genera contributed less than 7% to the total fungal population across all the study sites.

The maximum number of species (34) were isolated from soils and decomposing leaf litters of chir pine, it was followed by mixed oak (27 species) and cypress (19 species).

Rozella allomycis, Allomyces anomalus, Achlya crenulata, A. flagellata, Aphanomyces laevis, Brevilegnia indica, Protoachlya species 1, *Olpidiopsis achlyae, O. fusiformis, O. varians, Myzocytium proliferum, Pythium coloratum, P. dissotocum,* and *Pythium* 2 were present at chir pine forest site only. Whereas, *Allomyces arbuscula, A. americana, Aphanomyces helicoides, Dictyuchus monosporus*, *Protoachlya nainitalensis, Saprolegnia asterophora, S. lapponica* and *S. litoralis* were present only at mixed oak forest study site and *Pythium aristosporum* and *P. helicum* were present in cypress forest study site only. *Saprolegnia diclina, S. ferax, S. parasitica, Thraustotheca clavata, Olpidiopsis pythii, Petersenia irregulare, Pythium echinulatum, P. graminicola, P. inflatum, P. iwayamai, P. middletonii, P. pulchrum, P. undulatum,* and *Pythium* 1 were common to all the study sites (Table 4). The results indicate a wide occurrence of Saprolegniaceae and Pythiaceae.

A perusal of seasonal occurrence of different species in three different forest ecosystems of central Himalaya indicates that the watermolds showed a marked seasonal fluctuation in their occurrence. Most fungal species were present during the rainy season followed by the winter and summer season; minimum

number of species occurred during autumn and spring months.

Clausz (1974), Prabhuji (1979) and Mer *et al.* (1980) also observed maximum number of watermolds during the rainy season in aquatic and terrestrial habitats. Robertson (1973) while working on *Pythium* species found that most species occurred from July to September (rainy season). Okane (1978) found that *Saprolegnia* was dominant in all the seasons except summer, while *Pythium* grew well in winters. Similarly, Chowdhry and Agarwal (1980b) recorded both aquatic and terrestrial species of *Pythium* during the rainy season. Raghu Kumar (1980) showed that the zoosporic fungal population exhibited a seasonal fluctuation; a high number of species occurring in September and extremely low number occurring in March. Further, he observed that a high number of propagules per litre (up to 73,000) were found in the sediment portion compared to the water (up to 384). Miller and Ristanovic (1969) collected 72% watermolds during August from the Athens County (south-eastern Ohio, USA). Manoharachary and Rao (1983) isolated maximum number of watermolds during the monsoon season. Season undoubtedly plays an important role in the distribution of fungi both in qualitative and quantitative terms.

The least square difference test (Snedecor & Cocharan, 1969; Box *et al.,* 1978; Sokal & Rohlf, 1995) yielded some significant results. The number of species varied significantly between mixed oak and chir pine forests ($P<0.05$).

Table 6:Occurrence and distribution of some members of Saprolegniaceae (also recorded in the present study, 1999-2002) in Kumaun Himalaya (1974-1999)

Fungal species	Aquatic habitat			Terrestrial habitat	
	Dams/ Reservoirs	Lake	Rivers	Forest soil	Cultivated soil
Achlya americana	+	+	-	+	+
Allomyces anomalus	+	+	+	+	+
A. arbuscula	+	+	+	+	+
Achlya flagellata	+	+	+	-	+
Aphanomyces laevis	+	+	+	+	-
A. helicoides	+	+	+	-	-
Dictyuchus monosporus	-	-	-	+	-
Leptolegnia caudata	-	+	+	+	+
Saprolegnia diclina	+	+	+	+	+
S. ferax	+	+	+	-	+
S. lapponica	+	+	-	-	-
S. litoralis	+	-	-	-	-
S. parasitica	+	+	+	+	+
Thraustotheca clavata	+	+	+	+	+

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