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OCCURRENCE, DISTRIBUTION AND ECOLOGY OF WATERMOLDS IN NANAKSAGAR RESERVOIR, KUMAUN HIMALAYAS NAINITAL, UTTAR PRADESH, INDIA

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Water of Nanaksagar from July 1994 to June 1996 was assessed with reference to watermolds, temperature, pH, dissolved oxygen and organic matter. A total of 38 fungal species were isolated. Maximum number of fungal species were recorded in winter and spring, while minimum in summer and rainy seasons. Occurrence of fungal species showed a significant negative correlation with temperature, organic matter, and significant positive correlation with ph and dissolved oxygen.

Some of the factors determining the ecology, distribution and occurrence of watermolds are temperature (Alabi; 1971a, b; Khulbe & Bhargava, 1977; Manoharachary, 1981; Barlocher, 1992; Kitancharoen *et al.*, 1996), pH (Dayal & Tandon, 1963; Khulbe *et al.*, 1995 Manoharachary, 1991), dissolved oxygen (Sparrow, 1968; Gupta & Mehrotra, 1991) and organic content (Roberts, 1963; Cooke, 1965; Mer, 1992).

Most of the previous work, however, has been restricted to the lakes, rivers and fish hatcheries in the central Himalayas. Foot-hill water reservoirs have remained unexplored. The present study deals with the ecology, distribution and occurrence of water-molds in relation to certain physico-chemical characteristics of the water in Nanaksagar reservoir.

MATERIALS AND METHODS

Study site: Nanaksagar is located at 29°40' E, 200 m above sea level and has an area of 4662 ha in district Nainital, Kumaun hills, Uttar Pradesh, India.

Determination of physico-chemical factors: The temperature of the surface water was measured with centrigrate thermometer at the time of sampling. A Naina NPC 3600 portable pH meter was used for measuring the pH, and the mean of 5 readings was taken. The Winkler method (APHA, 1989) was employed for the estimation of dissolved oxygen content. Organic content was estimated as per APHA (1989).

Isolation of watermolds: Samples of water, soil, and organic debris were collected monthly from July 1994, from different sites of the reservoir. Eight samples of surface water were collected in sterilized plastic bottles, and brought to the laboratory. 20 ml of the water of each sample was poured into sterilized petridishes and baited with different sterilized animal and plant baits and incubated at 18-25°C. Freshly colonized baits were placed in different sterilized petri dishes containing sterilized water. The isolates were purified by the single hyphal culture method and identified with the help of various standard monographs (Middleton, 1943 Johnson, 1956, 1971; Scott, 1961; Sparrow, 1968; Rao, 1963, Waterhouse, 1967, Seymour, 1970; 1980 and Dick, 1990).

RESULTS

Occurrence and distribution of watermolds: A total of 38 fungal species of 8 genera of watermolds belonging to 4 orders of Mastigomycotina were isolated from the water samples of Nanaksagar (Table 1). Saprolegniacious and Pythiacious species contributed a major bulk, and accounted for 60.52% and 23.68% to the total species, respectively. *Pythium* appeared to be doninant with 9 species, followed by *Achlya* and *Saprolegnia* (8 species), *Aphanomyces* (5 species), *Allomyces* and *Olpidiopsis* (3 species each) and *Thraustotheca* and *Leptolegnia* (1 species each).

An analysis of the occurrence and distribution of Watermolds (Table 1) revealed that *Saprolegnia parasitica*, *Saprolegnia* sp. and *Pythium proliferum* were constantly present in the reservoir. *Allomyces* spp., and *Aphanomyces* spp. showed their presence

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from spring to the rainy seasons. *Leptolegnia* and *Thraustotheca* dominated in autumn and winter, while *Olpidiopis* flourished in spring.

Periodicity of Watermolds: Watermolds are of ephemeral nature and consequently exhibit seasonality in the aquatic ecosystem. The total fungal counts were higher during winter, early spring and rainy seasons (Table 1). Thereafter, with the commencement of the dry hot period, a sharp decline in the fungal population was recorded from May to July. In September the number built up again with a decrease in water temperature. Total fungal counts were higher from September to March. Consequently, the fungal population tended to decrease from April to June. Eccentric species exhibited their dominance from spring to the rainy seasons and centric and subcentric from autumn to the early spring.

Watermolds and physicochemical variables of water: The temperature recorded during the study period ranged between 15-30°C, with a minimum (15°C) in January and maximum (30°C) during May and June. Most of the species were found to be temperature dependent, and fluctuated with change in the temperature (Fig. 1A). As a consequence, the fungal flora of Nanaksagar showed a negative significant correlation with temperature (r = - 0.5375; P 0.01; Table III).

The pH of water was recorded at 7.1-9.4, which according to Lund's classification fell into the "neutrally alkaline" (fig. 1B). A critical perusal of the results revealed that watermolds showed a significant positive correlation with water pH (r = 0.5843; p 0.01; table II).

Oxygen availability in water fluctuated between 8.2 22.0 mg/L, with a minimum value in october and maximum in February (Fig. IC). Fungal species of the water of Nanaksagar showed a positive correlation with dissolved oxygen (r = 0.4666; P 0.05; Table II).

The value of organic matter was found to be between 10-110 mg/L (Fig. 1D). There is a sifnificant positive correlation between fungal species and organic content of water (r = 0.4063; P 0.05; Table II).

DISCUSSION

A review of the seasonal occurrence of different species indicates that watermolds showed a marked seasonal fluctuation in their occurrence and distribution. Occurrence of maximum species during winter and spring seasons might be due to moderate temperature (15-20°C), and a slightly higher values of pH (7.1.-9.2) and organic matter (10-90 mg/L). Dayal & Tandon (1962), Manoharachary (1981) and Khulbe *et al.* (1995) also recorded maximum fungal counts in the winter and spring seasons. In conjuction with this a pronounced drop was recorded in the summer and rainy seasons. Similar to the present study, several investigators including Fox & Wolf (1977), Manoharachary *et al.* (1984) and Khulbe *et al.* (1995) have also noted a summer decline from a spring peak with a subsequent fall increase in the number and frequency of watermolds. Higher temperature during summer and rainy seasons has also been found unfavourable for most of the aquatic fungi (Dayal & Tandon, 1962; Khulbe, 1991). Higher temperature is thought to suppress the growth and asexual reproduction and also induce formation of resistant bodies, like gemmae, chlamydospores, which require a certain period of dormancy. Whereas, high turbidity due to flood, low level of dissolved oxygen and dilution of nutrients during rainy season might be the probable factors for the scarcity of fungi. Infrequent occurrence of watermolds in flood water has previously been reported by Chowdhary & Agrawal (1981) and Alabi (1971a).

It was also observed that eccentric species of Saprolegniacae were maximum in number during warmer months (April to July), while centric and subcentric species were found to be dominant during a period of low temperature months. These findings support that observations of Hughes (1962), Srivastava (1967), Manoharachary (1981), Mer (1992), all of whome noted a large nimber of eccentric species during the warmer months.

The occurrence, distribution, behaviour and activity of watermolds are markedly influenced by a variety of environmental variables of water including temperature, pH, dissolved oxygen and organic content. Temperature shows a significant negative correlation with total fungal counts of the water. In winter moderate temperature (15-24°C), coupled with higher dissolved oxygen (12.0-22 mg/L) and pH (7.1-9.2) favoured the growth of the watermolds. Higher temperature (>28°C) adversely affected the growth and multiplication of watermolds. Like our observations

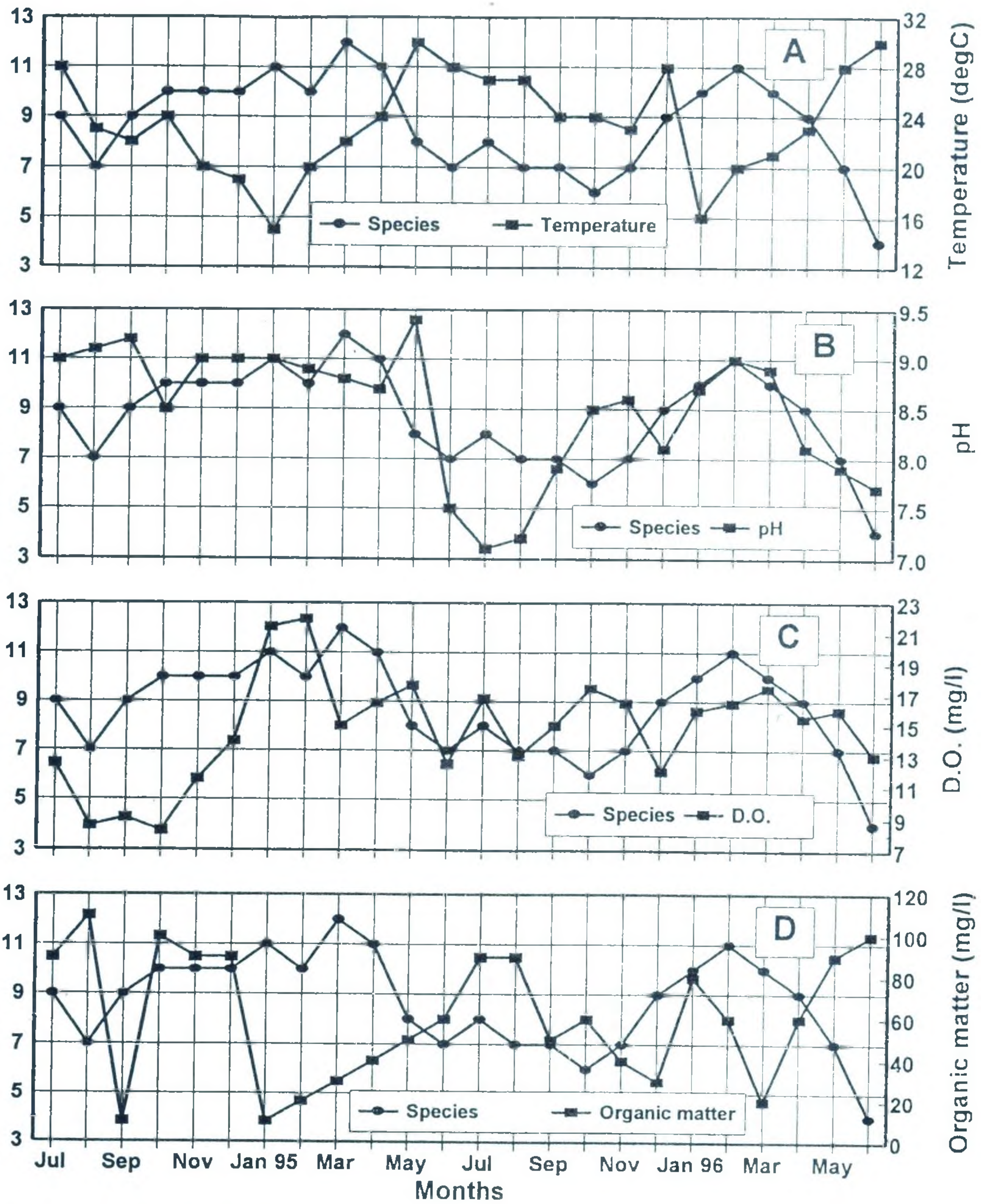

Figure 1. Relationship between number of fungal species and water and physico-chemical variables: A. Temperature, B. pH, C. Dissolved Oxygen, D. Organic matter.

high temperature during summer has been reported as unfavourable for watermolds (Dayal and Tandon, 1962; Willoughby, 1986; Khulbe *et al.*, 1995). Hydrogen-ion concentration of water is in the alkaline range (7.1-9.2), and showed a significant positive correlation with fungal flora of water. At moderate temperature, putrification of organic contents and an increase in correlation of the ionic content might have led to shift of the ph towards more alkalinity (Suzuki, 1962; Alabi, 1971b). Different watermolds showed a wide divergence in the tolerance of pH. However, more species occurred at the range of ph

Table 1: Percentage occurrence (A-J)* of watermolds in Nanaksagar from July 1994 to June 1996 (monthwise 1-12)+.

Fungal species	1994						1995												1996					
	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6
Allomyces:																								
A. arbuscula	*H*	-	-	-	-	-	-	-	-	D	J	J	-	-	-	-	-	-	-	-	-	-	-	J
A. amonalus	-	-	-	-	-	-	-	-	-	-	J	-	-	-	-	-	-	-	-	-	-	-	-	-
Allomyces sp.	F	-	-	-	-	-	-	-	-	-	-	J	-	-	-	-	-	-	-	-	-	-	J	-
Achlya:																								
A. americana	-	-	-	B	-	-	-	B	D	-	-	-	-	-	-	-	-	-	H	J	-	-	-	-
A. deharyana	-	-	-	-	-	-	-	I	J	-	-	-	-	-	-	-	-	-	-	H	J	-	-	-
A. Flagellata	-	-	-	-	-	-	-	F	J	J	-	-	F	-	-	-	-	-	-	D	-	J	-	-
A. klebsina	-	-	-	-	-	-	-	-	I	-	J	J	-	-	-	-	-	-	-	-	J	J	-	-
A. orion	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	J	-	-	-
A. prolifera	-	-	-	-	-	-	-	-	D	J	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A. racemasa	-	-	-	-	-	-	-	-	-	J	J	J	-	-	-	-	-	-	-	-	I	F	-	-
Adhya sp.	-	-	-	-	-	-	-	-	D	J	J	-	-	-	-	-	-	-	-	-	-	-	-	-
Aphanomyces:																								
A. helicoides	H	J	-	-	-	-	-	-	-	-	-	J	-	H	-	-	-	-	-	-	B	-	-	-
A. laeuis	G	J	I	-	-	-	-	-	-	-	D	-	J	-	D	-	-	-	-	-	-	I	J	-
A. scaber	-	-	-	-	-	-	-	-	-	-	-	-	J	-	-	-	-	-	-	-	-	D	J	-
A. stellatus	-	-	-	-	-	-	-	-	-	F	F	J	-	-	-	-	-	-	D	-	-	J		
Aphanomyces sp.	-	J	-	-	-	-	-	-	-	-	-	J	I	I	-	-	-	-	-	-	-	J	-	-
Leptolegnia caudata	-	-	F	F	I	J	-	H	-	-	-	-	-	-	-	-	C	D	H	-	-	-	-	-
Saprolegnia:																								
S. anisaspora	-	-	I	-	J	-	-	-	-	-	-	-	-	-	H	-	D	-	I	-	-	-	-	-
S. diclina	-	-	-	I	J	J	J	J	I	F	-	-	D	F	I	J	-	I	J	J	I	-	-	-
S. ferax	-	-	I	D	I	J	J	I	J	D	-	-	-	D	D	J	-	J	J	J	F	D	-	-
S. floccasa	-	-	-	-	F	J	I	J	J	-	-	-	-	B	J	-	J	J	J	J	-	-	-	-
S.hypogyana	-	-	D	H	-	-	-	-	-	-	-	-	-	-	F	-	-	-	-	-	-	-	-	-
S.lopponica	-	-	-	-	-	J	J	-	-	-	-	-	-	-	-	-	D	-	F	-	-	-	-	-
S.parasitica	-	D	F	J	J	J	J	J	-	I	-	-	A	-	-	I	H	J	-	J	J	F	D	-
Saprolegnia sp.	C	D	D	J	J	-	J	J	J	J	I	-	C	-	-	H	I	J	J	J	J	I	D	-
Thraustotheca:																								
T. davata	-	-	-	-	-	D	-	-	-	-	-	-	-	-	-	-	D	-	-	C	-	-	-	-
Olpidiopsis:																								
O. luxurians	-	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	d	-
O.fusiformis	-	-	-	-	-	-	-	-	I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O. saprolegniae	-	-	-	E	-	-	J	D	J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pythium:																								
P. aphanidermatum	-	-	-	D	-	-	-	-	-	-	-	-	-	-	-	-	-	H	-	-	-	-	-	-
P.echinulatum	-	-	-	-	J	B	B	-	-	-	-	-	-	-	-	J	-	-	-	H	-	-	-	-
P.hypogymum	-	-	-	-	-	-	J	-	-	J	-	-	-	-	-	F	-	-	-	-	-	-	-	-
P.inflatum	-	A	-	J	I	F	-	-	-	-	-	-	-	-	-	-	-	D	J	-	-	-	-	-
P.proliferum	C	-	D	-	J	J	-	-	-	-	-	-	-	J	-	-	-	-	-	D	-	-	-	I
P. torulosum	B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	D	J	-	-	-	-	-
P. undulatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	D	-	-	-	-	-	-	-	-	-
P.vexans	F	-	-	-	-	-	I	J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pythium sp.	-	C	-	-	-	-	J	-	J	-	-	-	H	-	-	-	-	-	-	-	-	-	-	D

Months (1-12): 1-January, 2-February, 3-March, 4-April, 5-May, 6-June 7-July, 8-August, 9-September, 10-October, 11-November, 12-December

* **Percentage occurrence** (A-J): A-12.5, B-25, C-37.5, D-50,E-60, F-62.5, G-65.5, H-75, I-87.5, J-100.

7.1-9.2. Gupta & Mehrotra (1991) reported maximum number of fungal species between 8.0-8.7 pH. The alkaline waters have been reported to harbor more watermolds (Dayal & Tandon, 1963; Alabi, 1971b; khulbe *et al.*, 1995). The higher dissolved oxygen during winter, spring and rainy seasons might be due to rich population of phytoplankton and enrichment of aquatic body by entrance of the nutrients from the catchment area. Dissolved oxygen showed a least positive correlation with total fungal species of the water. Similar relationship has also been reported earlier (Sparrow, 1968; Smith *et al.*, 1984, Willoughby, 1986; Gupta & Mehrotra, 1991; Khulbe *et al.*, 1995), Organic content of the reservoir also showed a low degree of negative correlation with the total fungal flora. Due to low water level and higher temperature, the higher organic matter of Nanaksagar increased the activity of microbes, which ultimately decreased

Table 2. Correlation coefficient (r) values for the fungal population of water with certain physico-chemical parameters.

Physico chemical factors	Correlation coefficient (r) (a)	Regression equation Y = bx + a (b)
Temperature	-0.5375**	Y= -0.2667x +14.92
pH	-0.5843**	Y= 1.8074x - 6.5645
Dissolved oxygen	-0.4666*	Y= 0.109x + 7.1
Organic matter	0.4063*	Y= -0.025x +10.239

(a) *Significant at 0.05, ** Significant at 0.01
(b) Y = predicted number of fungal colonies;
x = physico-chemical factors;
a = intercept with Y axis

the oxygen availability and the fungal counts of the water (Alabi, 1971a, b). In the present study values of organic matter (40 mg/L) in winter coincided with the reports of Cooke (1965),Alabi (1971b), and Manoharachary and Rao (1978) who isolated maximum number of watermolds during a period of higher organic matter (4-5%) in the spring season.

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