The Microbiological Studies of the Lakes of Volcano Bandai II. Ecological Study on Aquatic Hyphomycetes in the Goshikinuma and Akanuma Lake Group

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Most natural fresh waters contain various kinds of fungi often designated roughly as water-molds. Not only do these molds abound in fresh waters of all sorts, but they also represent many genera and species. The aquatic Phycomycetes are the members of a dominating group among aquatic fungi, but many other species have been found in lakes and rivers.

Aquatic Fungi Imperfecti, particularly representatives of Hyphomycetes, are very common in various types of habitats such as lakes and running waters of brooks and rivers^{1,2,3}). Though extensive works have been accumulated concerning the distribution and taxonomy of these fungi, no attention has been paid to the ecology of them. The writers visited the lakes of the Goshikinuma and Akanuma Group in July, 1959, for the ecological studies on aquatic Hyphomycetes.

Experimental method

Leaves fallen in the water and attacked by the fungi were brought back into the laboratory in stoppered polyethylene sacks as soon as possible. Six to eight leaves were collected in each lake at the different stations. The leaves were put in shallow petri dishes with sterilized water immersing almost all of the leaves or stems, and allowed to stand at 20°. The conidiophore and conidia were found on the submerged leaves within a day. Later examination was carried out under low microscopic power. A piece of leaf was stained with lactic phenol cotton blue to make observation in detail. The frequency of fungi in the total leaf samples was examined in each lake.

Physico-chemical specificity of lakes

The lakes studied by the writers belong to the Goshikinuma and Akanuma Group, and are situated at the foot of Volcano Bandai, Fukushima Prefecture. They were formed at the time of the famous eruption of Volcano Bandai in 1888. They have small and shallow basins. Table 1 shows the physico-chemical data of the lake waters sampled in July 1959⁴). The surface water temperature was 14–23°.

According to physico-chemical characters, the lakes were divided into the following two types:

1. Acidotrophic type (pH:3.8–5.8)
Bishamon-numa, Midoronuma, Benten-numa, Aonuma, Rurinum, Akanuma, Koke-numa, Hyōtan-numa, Aodoronuma
2. Harmonic type (pH:6.2–6.5)
Yanaginuma, Jimushonuma, Nishiyanaginuma, Yarokunuma. Tatsunuma

One of the most remarkable characters of the former type is the strong acidity

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Table 1. Physico-chemical data of the Goshikinuma and Akanuma Lake Group.

Lake types	Lakes	Water Temp. °C	pH	SO ₄ mg./l.	Ca mg./l.	Cl mg./l.	Fe mg./l.	Mn mg./l.
Acidotrophic	Akanuma	14.0	3.8	324	166	106	14.55	1.8
	Hyotan-numa	16.5	4.1	442	133	162	0.25	1.9
	Kokenuma	16.0	4.3	442	144	202	0.16	2.6
	Aodoronuma	19.0	4.4	326	101	150	0.07	1.7
	Aonuma	17.5	4.6	260	181	116	0.04	1.7
	Rurinuma	22.0	4.7	353	195	68	0.17	2.2
	Benten-numa	23.0	5.2	364	186	148	0.01	1.7
	Bishamon-numa	21.0	5.2	429	76	128	0.18	1.4
	Midoronuma	15.0	5.8	235	134	182	0.76	1.0
Harmonic	Tatsunuma	19.0	6.2	300	95	122	0.28	0.9
	Nishiyaginuma	18.5	6.3	154	76	106	—	0.2
	Yanaginuma	19.5	6.5	178	65	116	0.08	0.1
	Jimushonuma	19.0	6.5	153	64	112	1.75	0.2
	Yarokunuma	18.0	6.5	235	70	130	0.04	—

of the lake water, caused by the sulphuric acid from the acidic rivers of volcanoes or underground springs. The lakes belonging to this type are the inorganic acidotrophic type. The water colour of these lakes is wonderfully pale blue. On the other hand, the harmonic type reacts as neutral and the water is dark yellow green as in the water of other eutrophic lakes in general.

The water contains large amounts of mineral components and it is measured about 1-2 g./l.^{5,6}). Especially sulphate, calcium and chlorine are present in large amounts. The amounts in the surface water of each type are as follows:

	Acidotrophic type	Harmonic type
SO ₄ mg./l.	235-442	153-300
Ca mg./l.	76-195	64-95
Cl mg./l.	68-202	106-130
Mn mg./l.	1.0-2.2	0.1-0.9

It is an interesting fact that the water of the harmonic type reacts neutral in spite of containing large amounts of mineral elements.

Distribution of aquatic Hyphomycetes

The aquatic Hyphomycetes were distributed widely in the harmonic lakes as well as in the acidotrophic ones. The standing crop of aquatic Hyphomycetes, however, differed with the lake type, and it was more abundant in the harmonic lakes than in the acidotrophic ones. The fungi were found on almost all leaves sampled from the harmonic lakes, while they were very scarce in the acidotrophic ones. The result indicated that the fungus production in lakes had close correlation with the pH value of water as well as the amount of mineral elements.

The temperature of the water plays a rather important role in the production of aquatic Hyphomycetes. According to Tubaki's experiment³), the limiting of temperature for the growth of these fungi is about 25-27°, while the sporulation occurs only below 25°. During the writers' visits in July, 1959, the water temperature of the Goshikinuma Lake Group was 14-23°, and the aquatic fungi were found abundantly

in these lakes.

With some possible exception of certain species, the fungus flora of the lakes of Volcano Bandai seems to have close relation with the diversity in chemical properties of the lake waters (Table 2).

Table 2. Distribution of aquatic Hyphomycetes in the lakes of the Goshikinuma and Akanuma Group

Lake types	Lakes	<i>Anguillospora longissima</i>	<i>Articulospora tetracledia</i>	<i>Flagellospora curvula</i>	<i>Lemonniera aquatica</i>	<i>Lunulospora curvula</i>	<i>Tetrachaetum elegans</i>	<i>Tetracledium marchalianum</i>	<i>Tricladium gracile</i> var. <i>oxyphilum</i>	<i>Triscelophorus monosporus</i>	<i>Alternaria</i> sp.
Acidotrophic	Akanuma	-	-	-	+	-	-	-	+	-	-
	Hyotan-numa	-	-	-	-	-	-	-	≠	-	-
	Kokenuma	-	-	-	-	-	-	-	+	-	-
	Aodoronuma	-	-	-	-	-	-	-	+	-	-
	Aonuma	+	-	-	-	-	-	+	+	-	-
	Rurinuma	-	-	-	-	-	-	-	+	-	+
	Benten-numa	-	-	-	-	+	-	-	-	-	-
	Bishamon-numa	+	-	-	+	-	-	-	-	-	-
	Midoronuma	+	-	-	-	-	-	-	+	-	-
Harmonic	Tatsunuma	-	-	-	-	+	≠	-	-	≠	-
	Nishiyaginuma	≠	-	-	-	+	≠	-	-	+	-
	Yanaginuma	-	≠	-	≠	≠	≠	≠	-	≠	-
	Jimushonuma	-	-	-	+	-	-	-	-	-	-
	Yarokunuma	+	+	+	-	-	-	-	-	-	+

Five species were obtained from the acidotrophic lakes, while nine species were found in the harmonic lakes. The group of aquatic Hyphomycetes seems generally to have a world-wide distribution. Among the fungi belonging to known species, *Tricladium gracile* var. *oxyphilum*, *Tetrachaetum elegans*, *Lunulospora curvula* and *Triscelophorus monosporus* were the most common in the lakes. However, some of the fungi require their own special biotope.

The most interesting species is *Tricladium gracile* var. *oxyphilum*. This species was found in the acidotrophic lakes, but never in the harmonic lakes. The fungus somewhat differed from *T. gracile* in either morphological or physiological natures.

Lemonniera aquatica and *Anguillospora longissima* were distributed both in the acidotrophic and the harmonic lakes. These species were found in the acidic water containing large amounts of mineral acids. On the other hand, many species were obtained from the harmonic lakes, but *Tricladium gracile* var. *oxyphilum* was not obtained from the harmonic lakes.

Physiological characters of some aquatic Hyphomycetes

So far as the studies in the lakes of Volcano Bandai are concerned, the chemical specificity of lake waters seems to be the most essential factor. Because of physico-chemical specificity of acidotrophic lakes, the occurrence of a dominating quality of some one species was seen, and other species of aquatic Hyphomycetes were very

rare or non-existent. In order to understand the adaptability of fungi to the acidotrophic water, the writers made the following experiment.

The aquatic Hyphomycetes were inoculated in pure culture on yeast extract glucose agar, on which the conidia formation did not take place. A piece of mycelium of these fungi was submerged in the lake water which was taken from the lakes Goshikinuma Group. After this was allowed to stand for a day or two at room temperature (15–20°), the formation of conidia in the lake water was examined. The results of these experiments are given in Table 3.

Table 3. Effect of the lake waters upon the formation of conidia in some aquatic Hyphomycetes

Lake types	Lakes	<i>Anguillospora longissima</i>	<i>Articulospora tetracladia</i>	<i>Clavariopsis aquatica</i>	<i>Lemonniera aquatica</i>	<i>Tetrachaetum elegans</i>	<i>Tricladium gracile</i>
Acidotrophic	Akanuma	⦿	—	—	+	—	⦿
	Hyotan-numa	⦿	—	—	+	—	⦿
	Kokenuma	⦿	—	—	+	—	⦿
	Aodoronuma	⦿	—	—	+	—	⦿
	Aonuma	⦿	+	+	+	—	⦿
	Rurinuma	⦿	—	—	⦿	—	⦿
	Benten-numa	⦿	—	—	+	—	⦿
	Bishamon-numa	⦿	+	⦿	⦿	—	⦿
	Midoronuma	⦿	⦿	⦿	⦿	⦿	⦿
Harmonic	Tatsunuma	⦿	⦿	⦿	⦿	⦿	⦿
	Nishiyanaginuma	⦿	⦿	⦿	⦿	+	⦿
	Yanaginuma	⦿	⦿	⦿	⦿	⦿	⦿
	Jimushonuma	⦿	⦿	⦿	⦿	⦿	⦿

The different features of the formation of conidia are recognized with each species and different kinds of lake water. *Tricladium gracile* had the highest resistance against the disharmonic water. The conidia formed in the water of the acidotrophic lakes as well as in the harmonic ones. *Anguillospora longissima* is perhaps suitable to the acidotrophic lakes. The conidia formed even in the strong acidic water containing large amounts of mineral acids.

On the other hand, the formation of conidia of *Tetrachaetum elegans* and *Articulospora tetracladia* took place only in the sampled waters of the harmonic lakes and a weak acidic lake, Lake Midoronuma, but never in the other acidotrophic lakes. The experimental result of conidia formation of *Clavariopsis aquatica*, which was not obtained from the lakes of Volcano Bandai, is the same as the above mentioned two species.

The conidia of *Lemonniera aquatica* are abundantly produced in the harmonic lakes, while they are relatively scarce and slow in production in the acidotrophic lakes. The fungus seems to be suitable to the acidotrophic water more easily than do *Tetrachaetum elegans*, *Articulospora tetracladia* and *Clavariopsis aquatica*. The writers also isolated *Lemonniera aquatica* from Lake Benten-numa and Akanuma, waters of which show in testing strong acidity. These facts are in accordance with the

results in the laboratory experiments.

According to these cultural experiments, the waters of Lake Akanuma, Hyōtanuma, Kokenuma, Aodoronuma, Rurinuma and Benten-numa are toxic to the aquatic Hyphomycetes. On the other hand, the waters of Lake Aonuma and Bishamon-numa are not so toxic to the fungi as was considered previously. These differences in the toxicity may perhaps be caused by the acidity of lake water, but not the chemical components.

Summary

The distribution of aquatic Hyphomycetes was studied in the lakes of Volcano Bandai, Fukushima Prefecture, Japan.

According to the physico-chemical characters, the lakes are divided into acidotrophic and harmonic types. The lake waters of the former type contain large amounts of mineral acids, while those of the latter contain relatively few acids.

The aquatic Hyphomycetes are more prevalent as well as better in quality in the harmonic lakes than the acidotrophic ones. *Tricladium gracile* var. *oxyphilum* is distributed only in the acidotrophic lakes, but never in the harmonic ones. *Lemonniera aquatica* and *Anguillospora longissima* seem to adapt to the acidotrophic lakes containing large amounts of mineral acids. On the other hand, *Articulospora tetraccladia*, *Lunulospora curvula*, *Tetrachaetum elegans* and *Triscelophorus monosporus* are distributed only in the harmonic lakes.

The experiments were carried out in the laboratory on the resistance of the aquatic Hyphomycetes against the acidotrophic water. *Tricladium gracile*, *Lemonniera aquatica* and *Anguillospora longissima* have a high resistibility to the acidotrophic water. These results are in accordance with the observations by the writers in natural lakes.

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摘 要

鈴木静夫・二村坦孝：磐梯山周辺の湖沼の微生物学的研究

II. 五色沼・赤沼湖群の水棲不完全菌類

裏磐梯の五色沼および赤沼湖群において、水棲不完全菌類の分布と湖水の水質との関係を観察した。湖水が中性の調和湖には水棲不完全菌類の種類が豊富であるが、多量の無機塩類を含有し強酸性を呈する酸栄養湖には *Tricladium gracile* var. *oxyphilum* が優占的で、その他に *Anguillospora longissima* と *Lemonniera aquatica* が少数見られるにすぎない。

純粋に培養した水棲不完全菌類をこれら湖群から採水した湖水中で培養したところ、上記の種は酸栄養型の湖水中でも分生子が形成されるが、調和湖だけに分布している *Tetrachaetum elegans*, *Articulospora tetraccladia*, *Clavariopsis aquatica* では非調和性の強い酸栄養湖の湖水中では分生子の形成は見られない。この事実は湖沼型によって分布する水棲不完全菌類の種類が異なることを裏づけるものといえる。(東京理科大学薬学部微生物化学教室・東京教育大学理学部植物学教室)