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SOIL ALGAL VEGETATION OF γ-IRRADIATED FIELD AND NATURAL STRONGLY RADIOACTIVE DISTRICT IN JAPAN*

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Introduction

We have as yet very little information as to the soil algal vegetation of natural strongly radioactive districts and of γ-irradiated fields. In 1962 M. SHIELDS and F. DROUET investigated the distribution of terrestrial algae within the Nevada Test Site, and twelve terrestrial algal species, such as *Anacystis montana* (LIGHTF.) DROUET et DAILY, *Microcoleus paludosus* (KUETZ.) GOMONT, *Nostoc commune* VAUCHER, *Schizothrix acutissima* DROUET, *Scytonema hofmannii* AGARDH, *Protosiphon cinnamoeus* (MENEGH.) DROUET et DAILY and etc., were recognized by microscopic examination of natural soil growths, and four species, namely, *Coccochloris stagnina* SPRENG., *Coccochloris elabens* (BRÉB.) DROUET et DAILY, *Nostoc fumifusum* CARM., and *Plectonema nostocorum* BORN., by soil culture examination.

In Japan, H. HIROSE and M. MIFUNE investigated the fresh-water algae found in several strongly radioactive thermal region which are irradiated mostly by Radon, but an account of soil algae found in such districts has not been published. In 1960, an experimental γ-irradiated plantation has been established in Ohmiya, Ibaragi Prefecture, Japan, and several works on the environmental change concerned with the succession of soil microbes, especially on soil fungi and *Nematodes*, have been done. Recently the present author investigated the soil algal vegetation of a natural radioactive district in Ningyôtôge, Tottori Prefecture, and several interesting algae are found.

In this paper the author wishes to make an account of a comparative study of soil algal vegetations found in an artificially γ-irradiated field and natural radioactive district in Japan.

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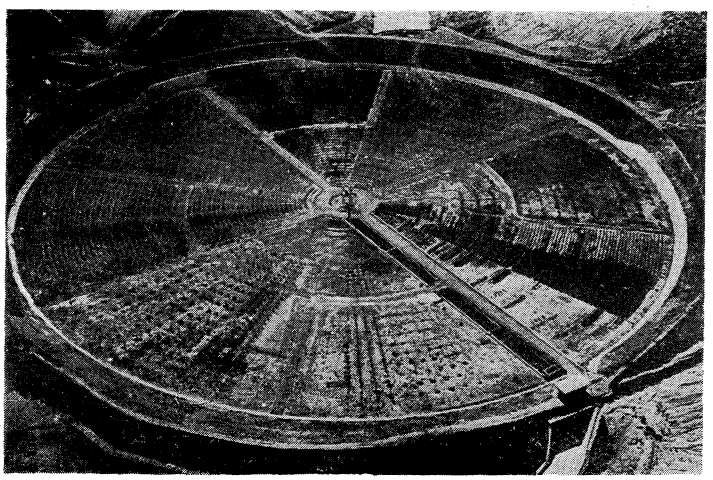
Materials and Methods

1) Sources of soil samples. The soil samples used in this study were obtained from Ningyôtôge, Tottori Prefecture and the Radiation Plantation of Ministry of Agriculture and Forestry in Ohmiya, Ibaragi Prefecture.

a) Ningyôtôge : This is one of the most famous product of Uranium ore and also a strongly radioactive district in Japan. The soil samples are collected from the surface of several stations on the grassy plain in this district. The intensity of radiation of each station is shown in table II.

b) γ-irradiated field : This plantation is constituted with many boundaries arranged in concentric circular, and on the center of the field, there is an irradiation tour (2.6 m)



Text figure 1. A view of γ-irradiated field in Ohmiya, Ibaragi Prefecture. (200 meters in diameter)

of γ-source of Co^{60} (2071.3 curie) (text-figure I). The samples of examined soil are collected from ten points which are disposed in linearly from the central irradiation tour of γ-source to the centrifugal direction, and the distance of each interval is ten meters. The dose rate of Co^{60} in each collected stations and the chemical data are shown in table I.

2) Methods of culture. A crude culture or mixed culture are generally used in this study. Media used in this study are BRISTOL's agar (BOLD, 1949) and BRISTOL's solution containing soil extracts. Both artificial and natural light are used in illuminating the cultures and the intensity of the light reaching the cultures was generally ranging from

TABLE I. Dose rate of γ-field in 1963 and 1964.

Distance (m) / Dose Rate	10	20	30	50	75	100
1963 (Jan.) γ/day	262.5	121.5	60.3	25.9	7.5	1.4
1964 (Jan.) γ/day	230.0	106.5	52.9	22.7	7.0	1.3

pH=4.4~6.3 total N=0.461~4.260 (mg/soil 1 g.) E. C.=180~340 ($\mu\mho$/cm)

ca. 200 to 300 lux. The cultures were set up at temperatures which fluctuated, according to seasons, between ca. 20 C° to 30 C°.

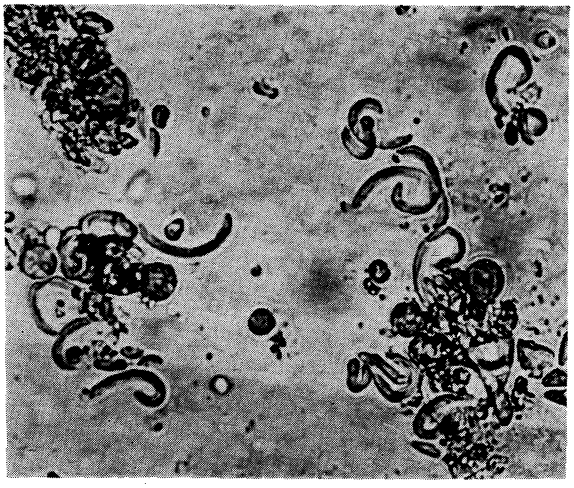
Results and Discussion

1) Soil algal vegetation of Ningyôtôge. Six soil samples obtained from Ningyôtôge are examined by means of crude culture. The soil algae occurred in this region are shown in table II. It will be seen from table II that the relatively common algae found in this

TABLE II. Distribution of soil algae in Ningyotoge.

Station / mγ/h / Algae	Na-1	Nb-1	Nd-1	Nd-2	Nd-3	Ne-1
	0.024	0.023	0.016	0.9	1.9	0.6
Chlamydomonas	+	+	+		+	+
Ourococcus	+					
Stichococcus		+	+	+		+
Hormidium	+	+	+	+	+	+
Koliella		+				+
Leptosira	+			+		
Chlorococcum		+	+	+	+	+
Selenastrum					+	+
Scenedesmus						+
Mesotaenium	+	+				
Cylindrocystis	+			+		+
Cosmarium	+					
Zygogonium		+			+	
Monodus	+	+	+	+	+	+
Botrydiopsis	+		+			
Bumilleria	+			+	+	
Tribonema				+	+	
Phormidium	+			+	+	
Oscillatoria	+			+		+
Anabaena				+	+	
Nostoc		+		+	+	
Hantzschia	+				+	
Nitzschia						+
Eunotia						+
Pinnularia	+			+	+	+
Euglena	+				+	

district are *Stichococcus bacillaris* NAEG., *Hormidium flaccidum* (KUETZ.) A. BR., *Monodus subterraneus* PETERSEN, and some species of *Chlamydomonas* and *Chlorococcum*. The present algae are common species in Japan. *Koliella concortica* HINDÁK (syn. *Raphidonema terrestre* AKIYAMA) is an interesting short filamentous alga which is frequently found in



Text figure 2. Twisted cells of *Koliella concortica* HINDÁK (syn. *Raphidonema terrestre* AKIYAMA).

TABLE III. Distribution of soil algae in γ-field.

Algae \ Station	R12	R21	10	20	30	40	50	60	70	80	90	100
Chlamydomonas			+		+		+	+	+	+	+	+
Stichococcus					+					+	+	
Hormidium	+	+	+	+	+	+	+	+	+	+	+	+
Koliella					+							
Leptosira	+	+	+							+		
Oedocladium						+						
Selenastrum	+	+	+	+	+	+	+	+				+
Scenedesmus	+	+	+									+
Chlorococcum	+	+	+	+	+	+	+	+	+	+	+	+
Scotiella					+				+		+	+
Tetraëdron												+
Protosiphon				+								
Cylindrocystis			+	+								
Monodus		+	+	+	+	+	+	+	+	+	+	+
Bumilleria							+					
Phormidium	+	+	+	+	+	+	+	+	+	+	+	+
Oscillatoria			+	+								
Nostoc	+		+	+	+	+	+	+	+	+	+	+
Cylindrospermum	+	+										
Hantzschia	+	+			+	+	+	+	+	+	+	+
Nitzschia	+	+	+			+					+	+
Pinnularia					+	+	+	+			+	+

Ningin region, Japan also occurs in this district. This alga is a unicellular or frequently 2-8 celled short filament composed of slightly bent and elongate cells, but in some materials obtained from this district, the cells are markedly twisted (text-figure 2) ; however, in the present state, we can not be concluded whether the morphological trend is one of the peculiarity of this alga found in this region or not.

The general conclusion to be drawn from this table is that the soil algal vegetation of this district has a typical constitution of algal components like as that of commonly found in Japanese soil algal flora.

2) Soil algal vegetation of γ-irradiated fields. Twelve soil samples obtained from this district are examined and the soil algae occurred in the crude cultures are shown in table III. It should be noticed from the data given in table III that the soil algal vegetation of this district shows also one of the most common type of the algal components in Japanese soil algal flora. *Hormidium flaccidum* (KUETZ.) A. BR., *Chlorococcum* sp., *Monodus subterraneus* PETERSEN, and *Phormidium tenue* (MENEGH.) GOM., are widely distributed in this district, and also certain species of cyanophycean and bacillariophycean algae are commonly occur in this district. On the contrary, *Stichococcus bacillaris* NAEG., *Oedocladium* sp., *Tetraëdron minimum* (A. BR.) HANSG., *Protosiphon botryoides* (KUETZ.) KLEBS, *Bumilleria exilis* KLEBS and the certain species of *Scenedesmus* occur scarcely in several stations. And it is also noteworthy fact that the chlorophycean alga *Fritschiella tuberosa* IYENGAR, one of the most common soil alga in Japan, is not found in this district.

3) A genral consideration of soil algal vegetations of strongly radioactive districts. We have several informations on the algal vegetations of strongly radioactive districts in Japan by H. MIFUNE, H. HIROSE et al. (1959, 1964). According to them, six species of Cyanophyceae, one of Xanthophyceae, one of Bacillariophyceae and one of Chlorophyceae are recognized in Masutomi spa (Rn=12 000 mache), and also in Ikeda mineral spring (Rn $=13.6 \times 10^{-7}$ curie per liter) four species of Cyanophyceae, one of both Chlorophyceae and Xanthophyceae, and twelve species of Bacillariophyceae are recognized. And they pointed out that the dominant species in both floras is a cyanophycean alga *Calothrix parietina* THURET.

TABLE IV. Soil and thermal algal communities of strongly radioactive districts in Japan.

Habitat / Locality / Class	Soil Community			Thermal Community		
	Ningyotoge	γ-field	*1	Masutomi	Ikeda	*2
CHLOROPHYCEAE	13	16	68	1	1	49
XANTHOPHYCEAE	4	2	13	1	1	1
CYANOPHYCEAE	5	9	34	13	4	270
BACILLARIOPHYCEAE	4	4	15	1	12	93
EUGLENOPHYCEAE	1		2			4
RHODOPHYCEAE			1			1
Total	27	31	133	16	18	418

*1 : Hitherto known soil algal species ; cited from AKIYAMA (1965).

*2 : Hitherto known thermal algal -pecies ; cited from HIROSE (1953).

Table IV gives the soil and thermal algal components of strongly radioactive districts in Japan. From the table IV, it should be noticed that there is a similarity of the algal composition of soil communities between Ningyôtôge and γ-irradiated field, and also there is scarcely any differences on the trends of algal composition between those of unusual radioactive districts and of usual districts. But there are some differences of constitution of algal components in the comparison with soil and thermal algal communities; however, it seems improbable that those differences will be occurred, owing to the presence of another ecological factors in each different habitats (differentiation of soil and aquatic condition).

In quantitatively it is observed that the certain cyanophycean algae such species as *Phormidium tenue* (MENEGH.) GOM., *Nostoc punctiforme* (KUETZ.) HARIOT, and *Nostoc paludosum* KUETZ., are remarkably developed in crude cultures of soils obtained from the following points in γ-irradiated field, viz., γ-R12, γ-R21, γ-10, γ-30, and γ-60. The dominancy of cyanophycean members in the strongly radioactive districts has been recognized in such cases as in Masutomi and Ikeda by M.MIFUNE, H. HIROSE and et al.; and also L. M. SHIELDS and F. DROUET recognized the similar phenomenon in the Nevada Test Site. But for the present state of our knowledge, we have not as yet sufficient data to give an accurate conclusion on both the general constitution of the algal vegetation of radioactive districts and the details of biological influence of the radiation on the soil microbes, especially on the soil algae.

A List of the Soil Algae found in α-and γ-irradiated Fields in Japan

CLASS CHLOROPHYCEAE

Twenty species of chlorophycean algae are recognized. Such algae as *Hormidium flaccidum* (KUETZ.) A. AG. and some species of *Chlorococcum* are important dominant members in the soil flora. A mophological variation (twisted form) of *Koliella concortica* HINDÁK (syn. *Raphidonema terrestre* AKIYAMA) is observed.

Order Volvocales

1. **Chlamydomonas** sp.
   Loc. Na-1, Nb-1, Nd-1, -3, Ne-1, γ-(50, 60, 70, 80,90).

Order Tetrasporales

2. **Ourococcus bicaudatus** GROBÉTY
   Loc. Na-1.

Order Ulotrichales

3. **Koliella concortica** HINDÁK (syn. *Raphidonema terrestre* AKIYAMA)
   Loc. Nb-1, Ne-1, γ-30.
4. **Stichococcus bacillaris** NAEG.
   Loc. Nb-1, Nd-1, -2, γ-80.
5. **Stichococcus exiguus** GERNEK
   Loc. γ-90.

6. **Hormidium flaccidum** (KUETZ.) A. BR.
Loc. Na-1, Nb-1, Nd-1, -2, -3, Ne-1,γ-(R21, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100).

Order Chaetophorales

7. **Leptosira terricola** (BRISTOL) PRINTZ (syn. *Gongrosira terricola* BRISTOL)
Loc. Na-1, Nd-2, γ-10, γ-80.

Order Oedogoniales

8. **Oedocladium** sp.
Loc. γ-50.

Order Chlorococcales

9. **Chlorococcum** sp.
Loc. Nb-1, Nd-1, Ne-1, -2, -3, γ-(R12, R21, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100).
10. **Scotiella nivalis** (SCHUTT) FRITSCH
Generally this alga is known as a cryophytic alga in alpine regions, however, the occurence of this alga in lowland soils already been recognized by the present author in 1965.
Loc. γ-(30, 70, 80, 100).
11. **Tetraëdron minimum** (A. BR.) HANSG.
Loc. γ-100.
12. **Bracteacoccus irregularis** (PETERSEN) STARR
Loc. Nd-1.
13. **Selenastrum westii** G. M. SMITH
Loc. γ-(R12, 10, 20, 30, 40, 50, 60, 100).
14. **Scenedesmus bijuga** (TURPIN) LAGERH.
Loc. γ-(R12, R21, 10, 20, 100).
15. **Scenedesmus obliquus** (TURPIN) KUETZ.
Loc. Ne-1, γ-100.
16. **Scenedesmus dimorphus** (TURPIN) KUETZ.
Loc. γ-R12.

Order Zygnematales

17. **Mesotaenium** sp.
Loc. Na-1, Nb-1.
18. **Cylindrocystis brebissonii** MENEGH.
Loc. Na-1, Ne-1, Nd-2, γ-10, γ-20.
19. **Cosmarium urceum** W. et G. S. WEST
Loc. Na-1.
20. **Zygogonium ericetorum** KUETZ.
Loc. Nb-1, Nd-3.

CLASS XANTHOPHYCEAE

Five species of xanthophycean algae are recognized, and *Monodus subterraneus* PETERSEN is one of the most dominant species in everywhere.

Order Heterococcales

21. **Monodus subterraneus** PETERSEN
Loc. Na-1, Nb-1, Nd-1, -2, -3, Ne-1, γ-(R21, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100).
22. **Botrydiopsis arhiza** BORZI
Loc. Nd-1.
23. **Botrydiopsis** sp.
Loc. Na-1.

Order Heterotrichales

24. **Bumilleria exilis** KLEBS
Loc. Na-1, Nd-2, -3, γ-50.
25. **Tribonema aequale** PASCHER
Loc. Nd-2, -3.

CLASS BACILLARIOPHYCEAE

Seven species of diatoms are recognized, and the certain species of *Nitzschia* and *Hantzschia* are commonly occured.

Order Pennales

26. **Eunotia crista-galli** CLEVE ?
Loc. Ne-1.
27. **Epithemia** sp.
Loc. γ-70.
28. **Pinnularia borealis** EHREMB.
Loc. Nd-2, -3, γ-(R12, 50, 70, 90, 100).
29. **Pinnularia** sp.
Loc. Na-1, Nd-2, Ne-1, γ-R12.
30. **Frustulia rhomboides** (EHREMB.) DE TONI var. **saxonica** (EHREMB.) DE TONI
Loc. Na-1, Ne-1.
31. **Nitzschia obtusa** W. SMITH var. **scalpelliformis** GRUNOW
Loc. Ne-1, γ-(R12, R21, 10, 40, 90).
32. **Hantzschia amphioxys** (EHREMB.) GRUNOW
Loc. Na-1, Nd-3, γ-(R12 R21, 20, 30, 50, 60, 80, 100).

CLASS EUGLENOPHYCEAE

One species of *Euglena* is recognized in a mixed culture of grassy plain soil of Ningyotoge.

Order Euglenales

33. **Euglena** sp.
Loc. Na-1, Nd-3.

CLASS CYANOPHYCEAE

Seven species of cyanophycean algae are recognized. Such algae as *Phormidium tenue* (MENEGH.) GOM. and two species of *Nostoc* are most dominately occured.

Order Oscillatoriales

34. **Phormidium tenue** (MENEGH.) GOM.
Loc. Na-1, γ-(R12, R21, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100).
35. **Oscillatoria** sp.
Loc. Na-1, Nd-2, Ne-1.
36. **Nostoc punctiforme** (KUETZ.) HARIOT.
Loc. Nb-1,-3, γ-(R21, 10, 20, 40, 50, 60, 80, 90, 100).
37. **Nostoc paludosum** KUETZ.
Loc. γ-(R12, R21, 10, 30).
38. **Cylindrospermum majus** KUETZ.
Loc. γ-R21.
39. **Anabaena oscillarioides** BORY.
Loc. γ-(R21, 60, 90).
40. **Calothrix marchica** LEMM ?
Loc. γ-(R12, R21, 30, 40, 60, 100).

Résumé

1. Soil algal vegetaions in the certain radioactive districts in Japan are researched by means of crude cultures of soil samples.

2. The examined soils are obtained from a grassy plain in Ningyôtôge, Tottori Prefecture (Na-1, Nb-1, Nd-1, -2, -3, Ne-1) and the experimental γ-irradiated field in Ohmiya, Ibaragi Prefecture (γ-R12, γ-R21, γ-10, γ-20, γ-30.....γ-100).

3. Thirty species of Chlorophyceae, five of Xanthophyceae, six of Bacillariophyceae, three of Cyanophyceae and one of Euglenophyceae are recognized from the soils of Ningyôtôge, and fifty species of Chlorophyceae, two of Xanthophyceae, five of Bacillariophyceae, and six of Cyanophyceae are recognized from the soils of γ-irradiated field.

4. It seems that there is scarcely any differences on the algal composition of soil communities of unusual radioactive districts and of another usual districts.

5. In quantitatively, the soil algal micro-vegetaions researched in this study are dominately occupied by several cyanophycean members such as *Phormidium tenue* (MENEGH.) GOM., *Nostoc punctiforme* (KUETZ.) HARIOT, and *Nostoc paludosum* KUETZ.

6. A list of soil algae recognized in α-and γ-irradiated fields is given.

Literature Cited

AKIYAMA, M. (**1965**) : Some Soil Algae from Japan. *Bull. Shimane Univ.*, **15** : 96～117.

HINDÁK, F. (**1963**) : Systematik der Gatt. *Koliella* Gen. Nov. u. *Raphidonema* LAGERH. *Nov. Hedwig.* **VI** : 95～125.

HIROSE, E. (**1953**) : Thermal Spring and Algae. *Bull. Jap. Soc. Phycol.*, **1** : 10～16.

MIFUNE, M., HIROSE, H., and TSUMURA, K. (**1959**) : The Thermal Algae in a certain strongly Radioactive Springs in Japan. I. *Onsen Kagaku*, **10** : 60～64.

MIFUNE, M., EMOTO, Y., and HIROSE, H. (**1966**) : The Thermal Algae in a Strongly Radioactive Springs in Japan. II. *Ibid.*, **16** : 129～135.

SHIELDS, L. M., and DROUET, F. (**1962**) : Distribution of Terrestrial Alage within the Nevada Test Site. *Amer. Jour. Bot.*, **49** : 547～554.

SUZUKI, et al. (**1961**) : Succession of Soil Microbes in a γ-irradiated Field. *Contrib. Soil Microbiol. Labor. of Inst. Agricult. Technol.* (Shôwa **39**) : 77～80.

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