ANNAL. BIOL. TIHANY | 28 | 99—104 | HUNGARIA 1961

ON THE CHLOROPHYLL CONTENT AND BIOLOGICAL PRODUCTIVITY OF PERIPHYTIC DIATOM COMMUNITIES ON THE STONY SHORES OF LAKE BALATON

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Received: 10th March, 1961

The study of bacillariophytic mass vegetation (G. ENTZ and SEBESTYÉN 1946, SZEMES 1948, FELFÖLDY 1958, 1961) which develops on the stony shores of Lake Balaton in early spring and late autumn months is important in two respects.

Its importance is due partly to the significance of the organic matter production by autotrophic organisms constituting coverings on different surfaces, especially in lakes with small phytoplankton productivity (ASSMAN 1951), and partly because the experiences obtained in the course of quantitative investigations into the attached communities of periphyton can be well-applied to the study of the heterogeneous assemblages of phytoplankton.

In 1957 (FELFÖLDY 1958, 334) the assessment of biological productivity of this living covering was performed on the basis of the light-dark bottle method. In this paper results of the chlorophyll estimations are given and production measurements on this basis are briefly summarized.

Materials and methods

In late March and in the first days of April in 1960 there was a well-developed diatom girdle on the stony shores of Lake Balaton, near water surface, in which four physiognomically different girdles were discernible. The most conspicuous and with naked eye easily distinguishable was the thin, little mucilageous, bright yellow belt, consisting almost exclusively of *Diatoma elongatum* var. *tenuis* (*Diatoma*-zone).

A dark brown, laciniated-racemose mass vegetation was attached in some places to the upper part of this belt, consisting mainly of *Gomphonema olivaceum*. This *Gomphonema*-zone located above the water surface developed only sporadically, mostly behind sheltered jutting corners not directly exposed to waves.

Beneath the pure diatom girdles a thick, light-brown spotted, dirtysandy girdle (sandy-zone) was situated to the yellow *Diatoma*-belt attached with a "transition zone" (cf. FELFÖLDY 1958, 332—333). In our present paper investigations carried out only on the *Gomphonema*- and *Diatoma*zones are discussed.

The samples for dry-matter determination and for estimation of pigment content were collected from a known area of stone surfaces. Dry-matter content was determined by drying the samples to constant weight in electric

oven at 105°C. Samples for chlorophyll determinations were collected on filter paper pieces. Thereafter they were kept for some minutes into hot water vapour, and were left to stand in aqueous acetone (90%) for 12—15 hours. After extraction the solutions were carefully filtered and filled up to known volume. Their transmittancies were measured at wave lengths 665, 645, 630, 510 and 480 mμ, by a BECKMAN D. U. spectrophotometer. For the calculation of the individual pigments equations of RICHARD and THOMPSON were used (BARNES 1959, 242—244). The values were converted into 100 cm^2 surface area.

Photosynthetic measurements were performed in the late morning hours on the 29th March, 1960. A known mass of diatoms was washed from the stones with a soft brush and was suspended into partly desoxigenized Balaton-water (FELFÖLDY and KALKÓ 1958). The measurement was made by the usual light-dark bottle method, as it is reported in detail in the paper mentioned previously (FELFÖLDY 1958, 334).

In order to calculate the assimilation number of the diatom population the chlorophyll *a* content in an aliquot part of the experimental suspension was determined. The assimilation number (AZ) = carbon dioxide in grammes per hour: chlorophyll content in grammes.

Results and discussion

From the substances listed in *Table 1*, the dry matter content taken from a unit area, is not suitable basis to express the quantity of photosynthetically active organisms, because the mass of dry matter depends greatly on the quantity of inorganic impurities and of dead detritus present. The dry matter content of covering ranges between 1,37—2,26 g/100 cm^2 and 0,53—1,99 g/100 cm^2 respectively. The great spread of chlorophyll *a* content in per cent of dry matter (0,09—3,82% in the *Diatoma*-zone), also proves that the amount of dry residue is inadequate to assess productivity.

Total N-content (determined by the semi-micro KJELDAHL method in aliquots of oven-dried samples) is greatly influenced by the protein content of animal bodies always present in the "Aufwuchs" of algae, consequently no conclusion can be drawn from these figures as to the photosynthesizing living material.

The chlorophylls are special components of autotrophic organisms. The relationship between chlorophyll and total organic matter content is very variable in different organisms, therefore chlorophyll estimation should be used with caution as a measure of quantity of autotrophic organisms. If the plant population (phytoplankton or periphyton) is very mixed, conversion of pigment values to other parameters can be only approximate. If, however, the photosynthetic power of the unit quantity of chlorophyll *a* present in autotrophic organisms of some natural populations is determined, this value can be used as a measure of productive capacity of producents in the population in question. For that purpose photosynthesis in suspensions with known chlorophyll *a* content was measured and the assimilation number (AZ) of the bacillariophytic covering was assessed on this basis. The assimilation number expresses the quantity of carbon dioxide assimilated by a unit quantity of chlorophyll *a* in one hour.

Table 1 — 1. táblázat

Dry-matter and pigment content in 100 cm² surfaces of different parts of diatom mass vegetation

A kovamoszat öv különböző részeinek szárazanyag- és pigment tartalma 100 cm² felületre számítva

Sample No. Minta	Dry matter g/100 cm² Szárazanyag	Total-N mg/100 cm² Össz-N	Chlorophyll *a* mg/100 cm²	Chlorophyll *b* mg/100 cm²	Chlorophyll *c* mSPU/100 cm²	Chlorophyll *a* % in dry matter Szárazanyag %
7	1,83	3,86	15,4	3,4	4,0	0,84
27	2,26	2,04	6,0	3,5	3,0	0,26
101	1,37	1,52	6,6	2,9	2,3	0,48
35	1,03	0,90	2,3	0,0	0,8	0,22
66	0,74	0,85	2,8	0,0	1,6	3,82
68	1,81	1,39	2,9	0,4	2,6	0,16
102	1,04	1,28	2,6	0,8	0,9	0,25
102/a	—	—	2,9	0,9	0,9	0,28
108/1	0,53	0,76	2,5	0,0	0,5	0,47
108/2	—	—	2,2	0,0	0,5	0,41
108/3	—	—	2,1	0,0	0,5	0,40
115	1,99	1,57	1,9	0,0	0,5	0,09
115/1	—	—	2,0	0,0	0,4	0,10
115/2	—	—	1,8	0,0	0,4	0,09

Notes. 7, 27 and 101: Samples from the dark brown coloured girdle in which Gomphonema olivaceum dominates. The other samples originate from the yellow Diatoma elongatum girdle. In samples No. 68 and 102 green algal filaments. mSPU = the thousandth part of so called specified pigment units representing a specific but indetermined weight of pigment which should be about 1 g (BARNES 1959, 244).

The results of photosynthetic experiments are summarized in *Table 2*. One litre of the experimental suspension (500 cells/μl) contains 5,1 mg chlorophyll *a*, and the average amount of eliberated oxygen is 3,83 mg per one hour in 1 litre of suspension, which is equal to 5,26 mg carbon dioxide/litre/hour. From this the assimilation number, AZ = 5,26 : 5,10 = 1,03.

This value is unusually low. To our present knowledge, referring to natural phytoplankton populations or to cultures of planktonic organisms, the values of assimilation number range between 5—14 (GESSNER 1959, 619—625).

For controlling the order of magnitude of this low value, the assimilation number was calculated in another way too. When working with a diatom suspension collected in like manner, but measuring photosynthesis under artificial circumstances by the usual manometric WARBURG method, it was found that one mg of chlorophyll *a* produced 408 μl oxygen at 15° C and *c.* 7000 lux illumination. The weight of 408 μl oxygen is 0,58 mg, and the photosynthetic force expressed in mgs of carbon dioxide is 0,71 mg CO_2/hour. From this AZ = 0,71. The results of the two experiments accomplished by two different methods and at different illumination closely conform with each other.

The organic matter production of photosynthesis can be expressed also by the amount of glucose produced during carbon assimilation. One mg oxygen evolved is equal to 0,937 mg glucose. Our results expressed in glucose units are summed up in *Table 3*.

Table 2 — 2. táblázat

Rate of photosynthesis in a 500 cells/μl suspension exposed in natural habitat on stony shores under 30 cm from the water surface (c. 15 000 lux, 9,8°C)

500 sejt/μl sűrűségű szuszpenzió fotoszintézise (1960. március 29-én a természetes termőhelyen 30 cm vízmélységben; c. 15 000 lux, 9,8 C°)

	mg/litre				Középérték Average
O_2-content in the starting suspension A kiindulási szuszpenzió O_2-tartalma	5,28	5,28	5,28	5,28	5,28
O_2-content after 3 hours, in light O_2-tartalom 3 óra múlva, fényben	17,75	17,90	18,08	17,62	17,89
O_2-content after 3 hours, in darkness O_2-tartalom 3 óra múlva, sötétben	1,07	1,20	1,10	1,09	1,11
Assimilated O_2 per 3 hours 3 óra alatt keletkezett O_2	11,40	11,42	11,70	11,25	11,50
Assimilated O_2 per one hour Egy óra alatt keletkezett O_2	3,80	3,80	3,90	3,75	3,83

Table 3 — 3. táblázat

Organic matter production of periphytic diatom communities expressed in glucose units

A kovamoszat bevonat szervesanyag termelése glukóz-egységben

Sample No. Minta	mg O_2/hour 100 cm²	mg glucose/hour 100 cm²
7	11,5	10,8
27	4,6	4,3
101	5,1	4,8
35	1,7	1,6
66	2,1	2,0
68	2,2	2,1
102	2,0	1,9
108	1,9	1,8
115	1,4	1,3

In April 1957 the productivity of the diatom covering was determined as 1,7 mg oxygen and 1,62 mg glucose per 100 cm² surface during one hour. Comparing the results of these two series of experiments performed in a three-year interval, it is seen, that the values obtained by the chlorophyll method is a little higher, obviously because it measures the chlorophyll content of other algal species too, which fell otherwise victim to the wet combustion by sulphuric acid, preceding diatom cell count.

The previous assumption, therefore, that the diatom belt is able to reproduce daily its organic content matter in favourable weather, may be regarded correct.

The quantitative data reported here were computed only for the mass vegetation of *Diatoma elongatum* constituting a characteristic coherent zone, whereas in the case of *Gomphonema*-zone a similar calculation did not seem reasonable because it grows in discontinuous little patches.

It has been pointed out already by GESSNER that the quantitative study of periphyton is not an easy task because of the so called "microbiotopes" characteristic for such mosaic-like habitats.

Nevertheless the difference existing between the two zones of different character is well illustrated by chlorophyll estimation *(Table 1)*. The more luxuriant vegetation of *Gomphonema* zone contains more photosynthetically active pigments (samples No. 7, 27, 101). The chlorophyll *b* content of the bacillariophyte covering reveals the presence of other algae (mostly Chlorophyceae) which are caught and held always in the racemose *Gomphonema* tangle.

Appreciation is extended to Mrs. ZSUZSA F. KALKÓ for her able assistance in research work and for the English translation.

Summary

The chlorophyll content was measured and computed to unit surfaces in two characteristic zones *(Diatoma elongatum-* and *Gomphonema olivaceum-*zones) of periphytic diatom mass vegetation developing seasonally on stony shores of Lake Balaton exposed to wave action.

The quantity of chlorophyll *a* is higher in the *Gomphonema*-zone (6,0—15,4 mg/100 cm²), whereas in the *Diatoma*-zone it is lower (1,8—2,9 mg/100 cm²). Very little assimilation number was obtained either by the light-dark bottle method (1,03) or by the manometric method of WARBURG (0,71). The value of glucose content computed on the basis of the assimilation number (1,3—2,1 mg glucose/100 cm²/hour) falls very near to the value obtained four years ago (1,6 mg/100 cm²/hour) which was calculated on the basis of the number of diatom frustules in the covering. It can be stated also on the basis of new estimations that in advantageous weather the diatom belt is able to reproduce itself daily (24,6 kg dry matter on a 1 km long section of shore).

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A BALATON KÖVES PARTJAIN ÉLŐ KOVAMOSZAT BEVONAT KLOROFILL-TARTALMÁRÓL ÉS BIOLÓGIAI PRODUKCIÓJÁRÓL

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Összefoglalás

A Balaton hullámjárta köves partjain, a vízfelszín közvetlen közelében késő ősszel és kora tavasszal dús kovamoszat tömegvegetáció szokott kialakulni. Az 1960. évi március végén és április elején igen szépen kifejlődött sáv két különböző együttesében (*Diatoma elongatum* var. *tenuis* és *Gomphonema olivaceum* zónák) méréseket és kísérleteket végeztünk a szervesanyag-termelés ütemének megbecsülésére. A bevonat által fedett felület egységére (100 cm^2) vonatkoztatva meghatároztuk az élő bevonat szárazanyag tartalmát, a benne található össz-nitrogén (KJELDAHL-N) és klorofill mennyiségét (*1. Táblázat*).

Az autotróf növények mennyiségére sem a szárazanyag-, sem az össz-nitrogén tartalomból nem lehet következtetni, mert az első tulajdonság a bevonatban levő szervetlen szennyeződés, a második pedig a mindig jelenlevő állatok testében levő anyagok okozta hibával terhelt. A klorofill (különösen az a-klorofill) tartalom jól jellemzi a két zóna közti különbséget, sőt — tekintve, hogy a kovamoszatokban nincs b-klorofill — annak jelenléte az idegen algák (elsősorban Chlorophycea-k) nagyobb mennyiségét is jelzi (7, 27, 101, illetve 68 és 102 sz. minták az *1. Táblázat*-ban).

Fotoszintézis kísérletekkel (WINKLER-f. O_2-módszer) meghatároztuk a kovamoszat övben levő a-klorofill hatásfokát, kiszámítva, hogy 1 mg a-klorofill a termőhelyen uralkodó környezettani adottságok között 1,03 mg széndioxidot asszimilál egy óra alatt. Ez az asszimiláció szám rendkívül kicsi, a fitoplanktonra és növényi plankton szervezetekre vonatkozó irodalmi adatoknak csaknem egytized része. Ellenőrzésként WARBURG manometriás módszerével is végeztünk asszimiláció szám meghatározásokat mesterséges környezetben. A kovamoszat populáció asszimiláció számának alacsony voltát ezek is igazolták: 0,71 mg CO_2/1 mg a-klorofill/1 óra.

Más számítással a klorofill tartalomból a fotoszintézis alatt keletkező glukóz értékét kalkuláltuk ki (1 mg a-klorofill 0,75 mg O_2-t termel óránként a termőhelyen uralkodó körülmények között, 1 mg O_2 felszabadulásával 0,937 mg glukóz keletkezik). Az eredmények a *3. Táblázat*-ban láthatók.

Érdemes megemlítenünk, hogy 1957 áprilisában a bevonat egységnyi felületén talált sejtszám felhasználásával számítottuk ki a kovamoszat öv termelékenységét. Az összefüggő sávot alkotó *Diatoma*-zónában ez átlagosan 1,7 mg oxigén, illetve 1,62 mg glukóz/100 cm^2/óra értéknek adódott. A kétféle módszer eredményei nagyságrendileg jól egyeznek (1960. évi vizsgálataink szerint a klorofill módszerrel 1,4—2,2 mg O_2 és 1,3—2,1 mg glukóz/100 cm^2/óra eredményt adtak). 1957 évben tett megállapításunkat tehát, hogy ti. kedvező időben a kovamoszat öv naponta képes újratermelni saját szervesanyag mennyiségét, helyesnek fogadhatjuk el.