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RELEASE OF EXTRACELLULAR MATTER DURING PHOTOSYNTHESIS BY A *TRICHODESMIUM* BLOOM

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ABSTRACT

Data presented are interpreted as suggesting the release of dissolved ^{14}C labelled organic matter during the photosynthetic fixation of carbon supplied as Na H $^{14}CO_3$ by a natural bloom consisting largely of the blue-green alga, *Irichodesmium*.

INTRODUCTION

IT is well established that most phytoplankton cells both in culture and the natural environment release extracellular products during the course of normal photosynthesis (*see* review by Fogg, 1975 *a*)[1]. The occurrence of *Trichodesmium* blooms on the west coast of India have been reported earlier (Qasim[2], Ramamurthy *et al.*[3]). During March to May of 1975 productivity estimations were carried out on a bloom of the blue-green alga *Trichodesmium* which occurred between the 10–20 m depth-zone (1 to 4 km off shore) in the neritic waters off Goa (Devassy *et al.* to be published). This report concerns estimates of the production of extracellular matter during photosynthetic carbon fixation on samples collected during the course of this investigation.

METHODS AND MATERIALS

The bloom was originally sighted in the 10 to 20 m depth-zone off Goa in late February. Regular collections were made thereafter at 5–8 day intervals. Stations were fixed arbitrarily depending on the position and apparent density of the bloom patches. The depth of the *Trichodesmium* patch seldom exceeded 0·5 m. The dominant organism present was *T. erythraeum*, although some *T. thiebutii* was also found in the initial stages of the investigation.

Water samples were collected from the surface and 2 m depths and subsampled into 120 ml light and dark glass bottles. Following inoculation with ^{14}C labelled sodium bicarbonate (4 μCi) they were incubated in a deck incubator in full sunlight. Samples from the 2 m depth were covered with ‹ocks of blue net to cut down light to the appropriate intensity of 35% surface irradiance. Light and dark bottles from both depths were filtered in the laboratory using 0·45 μ. Sartorius membrane filters. The period between incubation and filtration did not exceed 1 hour. The samples were kept in the dark at water temperature during the intervening period.

A 50 ml aliquot of the filtrate was strongly aerated at a pH of 4 for 45–60 minutes and, following neutralization to a pH of 10, a 100 μl sample was counted in 10 ml of a dioxan-based scintillation cocktail. Radioactivity on the filters was counted using a similar geometry. Radioactivity determinations in the light filtrates have not been corrected for dark values (*see* Fogg, 1975 *b*)[4].

Chlorophyll *a* and phaeophytin determinations were made spectrophotometrically following the method published in Strickland and Parsons (1968)[5]. Cell counts and other data have been taken from Devassy *et al.* (to be published).

RESULTS AND DISCUSSION

Evidence leading to the hypothesis that this *Trichodesmium* bloom was the result of a convergence rather than a sudden growth of the alga in a discrete water mass has been discussed by Devassy *et al.* (to be published). It is worth reiterating here that whereas nitrate values do not vary significantly from the normal, phosphate values in these samples are in the region of 1–2 μ gatom per litre, almost 4 times higher than the expected average of 0·5 μ gatom per litre at this time of year. This, in conjunction with high phaeophytin, suggests that the bloom may have already passed its peak at the time of investigation. However, particulate fixation of inorganic carbon was 3 to 4 times higher (Table I) than the average of 16·25 mg $Cm^{-3}h^{-1}$ recalculated from Qasim *et al.*[6] 1969, for the Cochin Backwaters and suggest that a substantial part of the population consists of viable cells.

It is possible that the delay in filtration has influenced determinations of radioactivity of both particulate carbon fixation and the production of extracellular material. Dark fixation of inorganic carbon and bacterial uptake of organic carbon in the dark, for example, may lead to an overestimation of inorganic carbon fixation by algae and an underestimation of extracellular production. In

TABLE I

Light bottle measurements of particulate fixation and extracellular material. Production has been calculated according to Watt (1966) Dark extracellular production is presented as per cent fixation of corresponding particulate carbon uptake

Date	Station and depth	Chlorophyll *a* mg m^{-3}	Pheophytin mg m^{-3}	% Trichodesmium (cell count)	Light bottle values only: Particulate fixation mg C m^{-3} hr^{-1}	Light bottle values only: Extracellular production mg C m^{-3} hr^{-1}	Light bottle values only: % Extracellular release	Dark values: % Extracellular release
5-3-75	St. 1 0m	0 05	0 0	58·9	6·14*	0·0	0 0	0·0
10-3-75	St. 1 0m	0·05	0.0	10 0	3·0 ± 0%	0·0	0 0	0·0
22-3-75	St. 1 0m	0·5	0 9	57·5	46·4 ±30%	2·7 ±16%	5·9	19·57
	2m	0·0	0 0	26	6·6 ±16%	0·98 ±30%	14·85	50
	St. 2 0m	26·7	46·7	75·8	45·26 ±18%	31·3 ±21%	69·2	31·98
	2m	0 59	0 0	57·5	13·9 ±58%	2·7*	19·2	28·1
29-3-75	St. 1 0m	0·0	3 6	0·96	27·7 ±63%	1·8 ±100%	6·5	4·7
	2m	0 0	0·5	0·0	29 6 ±15%	0·2 ± 0%	0·6	75·1
	St. 2 0m	6·0	0 0	92·6	89·96 ±71%	10·6 ± 76%	11·2	51·8
	2m	0·08	0 22	3·45	25·15 ±5%	2·0 ±100%	7·7	..
2-4-75	St. 1 0m	0·0	2·8	37·0	10·7 ±10%	1·2 ±55%	11·4	..
	2m	0·0	7·2	0·3	16 41 ±29%	0 0 ±0%	44·2	100·0
	St. 2 0m	4·1	0·0	99 6	54·2 ±10%	10 9 ±29%	20 2	57·1
	2m	0·9	0 0	18·2	17·4 ±78%	..	..	23·3
7-4-75	St. 1 0m	0·5	0·4	21·7	38·7 ±84%	19·7 ±53%	50·8	..
	2m	0·07	0·09	0·0	15·5 ±51%	5·9 ±22%	38·14	100·0

* Only one sample.

spite of such errors, however, the data presented in Table I suggest that some release of organic matter occurred during photosynthesis in these samples. On the whole, production of extracellular material varies from 0·2 mg $m^{-3}hr^{-1}$ to 31 mg $m^{-3}hr^{-1}$ in the light bottles, which is within a range of 1–69% of the light bottle inorganic carbon fixation by algal material. Even in cases where as much as 99% of the cell population consists of *Trichodesmium* filaments some apparent release of ^{14}C labelled organic matter occurs.

In terms of mg C $m^{-3}hr^{-1}$, dark bottle release of extracellular material is lower than in the light, although such fixation expressed as a percentage of carbon uptake is higher. A certain amount of difficulty has been experienced in the processing

of these samples due to the sticky nature of the clumps of *Trichodesmium* filaments and the mucilaginous material they produce. Perhaps as a result of this standard deviations of both inorganic carbon fixation and extracellular production were high even on samples taken on the same day and depth. However, the overall averages for per cent light and dark bottle release are 18·2 and 37·3% respectively and in spite of the high standard deviations from the samples it seems likely that the differences are real. The higher values of per cent release in dark bottles are a probable result of low inorganic carbon uptake in the dark.

Samples from the surface generally yield higher values of extracellular production in terms of mg C $m^{-3}hr^{-1}$ (Table 1) than the samples from the 2m depth when both sets of samples were incubated under simulated *in situ* conditions. This may be a result of both the inhibiting light intensity at the surface ($>$ 500 gm cal $cm^{-2}day^{-1}$) and lower cell concentrations at the 2m depth leading to lower actual production values. Watt (1966)[7] has found that there is an increase in per cent release of extracellular matter with depth associated with the dark fixation of inorganic carbon. Per cent release in these samples, however, shows a great deal of variation depending both on stations and dates of sampling.

While it is known that some blue-green algae liberate nitrogenous products (Fogg, 1952)[8], little information is available on the extracellular products of *Trichodesmium* during photosynthetic carbon fixation either in laboratory cultures or the natural environment. The series of histograms presented in Fig. 1 represent data from those surface samples

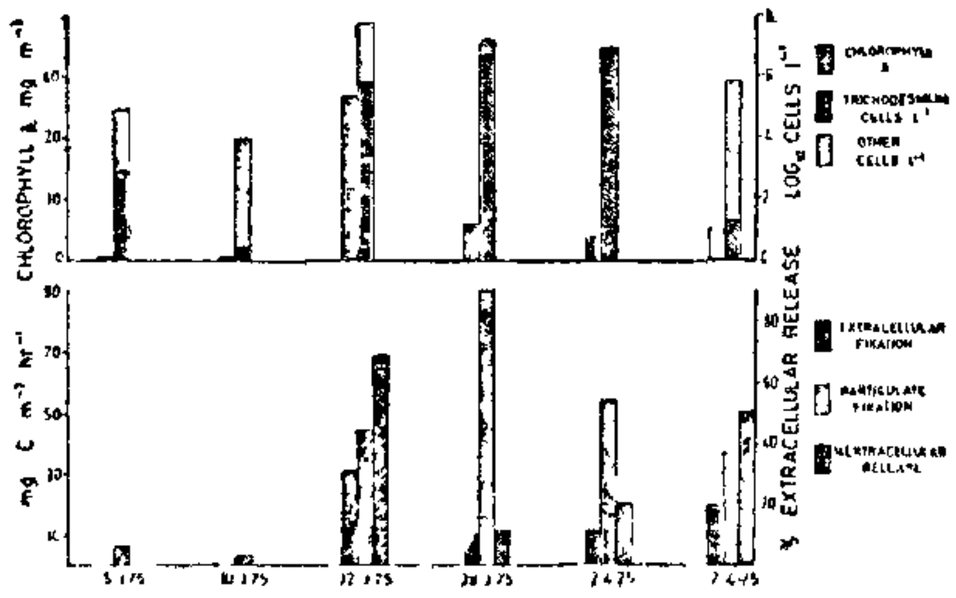

Fig. 1. Histograms representing data from selected stations. Surface light bottle samples only. Particulate fixation has not been corrected for dark uptake.

where cell concentrations were comparatively high on any given day of sampling. Neither particulate carbon fixation nor extracellular production show a correlation with total cell counts. The peaks in both extracellular production and per cent release of organic matter, however, seem to follow a trend similar to that of chlorophyll *a* where the latter values have been corrected for phaeophytin. This appears to suggest that extracellular release in these samples may be related to photosynthetic precursors in *Trichodesmium*, particularly in those cases where the alga is clearly the dominant organism and perhaps responsible for most of the active chlorophyll.

Samuel *et al.* (1971)[9] found that phytoplankton populations in the Cochin Backwater release extracellular matter as a result of inorganic ^{14}C fixation. Work in this laboratory substantiates these results for natural populations under non-bloom conditions in waters off Goa. It seems possible therefore, that both flagellates and diatoms associated with the *Trichodesmium* bloom are responsible for part of the extracellular production reported here and that this is likely to originate from recently fixed photosynthetic products.

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1. Fogg, G. E., *I. B. P.*, 1975 *a*, 3, 437.
2. Qasim, S. Z., *Deep-Sea Res.*, 1970, 17, 655.
3. Ramamurthy, V. D., Selvakumar, R. A. and Bhargava, R. M. S., *Curr. Sci.*, 1972, 41, 803.
4. Fogg, G. E., In *Chemical Oceanography* (Eds. Riley, J. P. and G. Skirrow), Acad. Press, 1975 *b*, 2, 386.
5. Strickland, J. D. H. and Parsons, T. R., *Fish. Res. Bd. Canada, Bull.*, 1968, 167, 311.
6. Qasim, S. Z., Wellershans, S., Bhattithiri, P. M. A. and Abidi, S. A. H., *Proc. Ind. Acad. Sci.*, 1969, 69 B, 51.
7. Watt, W. D., *Proc. Roy. Soc.*, 1966, 164 B, 521.
8. Fogg, G. E., *Ibid.*, 1952, 139, 372.
9. Samuel, S., Shah, N. M. and Fogg, G. E., *J. Mar. Biol. Assoc.* (U.K.), 1971, 51, 793.