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PHOTOSYNTHESIS, RESPIRATION AND EXUDATION OF ORGANIC MATTER BY SOME MARINE MACRO-ALGAE

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ABSTRACT

Photosynthesis, respiration and exudation of organic matter in three common benthic marine macro-algae *Chaetomorpha linum* (Mull.) kutz., *Hypnea musciformis* (Wulfen) Lamouroux and *Padina gymnospora* (Kutz.) Vickers were studied. Net photosynthetic rates of 3.46 mg C g^{-1} dry wt. h^{-1} for *C. linum*, 3.89 mg C g^{-1} dry wt. h^{-1} for *H. musciformis* and 3.25 mg C g^{-1} dry wt. h^{-1} for *P. gymnospora* were observed. All the three algae excreted extracellular organic matter both in light and dark. The exudation of carbon in the dark ranged from 33% to 44% of that during photosynthesis (light). The loss of fixed carbon due to exudation in the light was greater than that due to respiration in all three algae. The estimated daily organic matter flux (g C $m^{-2}d^{-1}$) by these algae were gross production 4.4, net production 2.7, exudation 1.4, respiration 1.3 and assimilation 1.7. The excreted organic nitrogen and phosphorus fractions were very less compared to carbon.

INTRODUCTION

BENTHIC macro-algae contribute significantly to marine productivity primarily through their greater biomass in shallow littoral waters (Ryther, 1963). The primary productivity of the littoral macrophytes has been documented extensively elsewhere (Johnston, 1969 ; John, 1971 ; Littler and Murray, 1974 ; Johnston *et al.*, 1977 ; Wallentinus, 1978 ; Littler and Arnold, 1980), but data from tropical marine environments, especially from Indian waters are scarce. The method of estimation of organic matter production by macro-algae has also been criticised, because of the possible errors (Littler, 1979 ; Littler and Arnold, 1980) and omissions. One of the major omissions in previous productivity studies is the excretion of organic matter by macro-algae. Although, this has long been a subject of controversy, the evidence for existence of such a phenomenon has been documented by Fogg (1983) for phytoplankton and demonstrated in macro-algae by Hanson (1977), Hatcher *et al.* (1977) and Johnston *et al.* (1977).

The excreted extracellular products of photosynthesizing organisms exert a significant influence on the productivity of natural waters due to their utilization by other organism in both autotrophic and heterotrophic processes (Sieburth, 1969 ; Sieburth and Jensen, 1970 ; Hellebust, 1974 ; Wangersky, 1978 ; Fogg, 1983). This signifies the importance of qualitative and quantitative information about these compounds to the study of ecology and estimation of primary production. In the present study, photosynthesis, respiration and exudation of organic matter by three common benthic marine macro-algae *viz. Chaetomorpha linum* (Mull.) Kutz., *Hypnea musciformis*

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(Wulfen) Lamouroux and *Padina gymnospora* (kutz.) Vickers were estimated. The difference in excreted fractions during dark and light incubation were measured. A daily organic matter flux based on the standing crop of these algae was also formulated.

Material and Methods

Algal samples : *Chaetomorpha linum*, *Hypnea musciformis* and *Padina gymnospora* were carefully collected from the littoral region of the marine zone of the Vellar Estuary, Porto Novo, India (11° 30′ N ; 79° 49′ E). The collected samples were washed thoroughly in filtered seawater to remove the associated fauna and flora before subjected to experiment.

Incubation : The experiments were designed to have optimum conditions so as to avoid any possible error due to the sample weight, incubation time and volume, initial oxygen concentration, attached epiphytes, bacterial breeding population in incubation medium and variations in incubation light and temperature from *in situ* conditions. About 3 gm (wet weight) of algae was introduced into light and dark bottles of 3 l capacity containing filtered and autoclaved (120°C, 15 lb/in, 20 min) seawater. The bottles were attached to anchored buoys and suspended in the estuary at 1 m depth. The incubation was carried out between 0600 hrs and 1800 hrs. Water samples were siphoned out at the end of the 6th hour for the estimation of oxygen and carbon and 12th hour for the estimation of organic phosphorus and nitrogen. The incubation seawater quality was as follows : Salinity 34.6‰, pH 7.8, dissolved oxygen 3.2 ml l^{-1}, inorganic nitrogen-nitrate 3.4 μg at l^{-1}, nitrite 2.1 μg at l^{-1} and ammonia 1.7 μg at l^{-1}, phosphate 1.8 μg at l^{-1}. The water temperature during incubation was 28 ± 2°C.

Standing crop measurements : The algal standing crop was measured by quadrate sampling method.

Analytical procedure : The total dissolved oxidizable organic matter was determined by the permanganate oxidation method (Golterman, 1970) and from these the dissolved organic carbon concentration was calculated by multiplying the COD values by a factor of 0.588 (proposed by Duursma, per. Comm.). Organic phosphate was estimated by the method of Menzel and Vaccaro (1965). Dissolved organic nitrogen was analyzed by the alkaline persulphate oxidation method of Dahl (1972). Photosynthesis and respiration were estimated by light and dark bottle method (Strickland and Parsons, 1968). The carbon values were calculated from oxygen using a conversion factor of 0.536 and a P.Q. of 1.2. The algae were dried in an oven at 60-70°C to constant weight and the results expressed on dry weight basis. The experiments were conducted in triplicate and the results are means of three estimates.

Background concentration of organic fractions : The concentrations of different organic fractions in the incubation water were as follows : dissolved organic carbon 2.04 mg l^{-1} total organic nitrogen 13.2 μg at nitrate N l^{-1} and total organic phosphorus 0.71 μg at phosphate P l^{-1}.

Results and Discussion

The average rate of net photosynthesis for the three macro-algae studied were *C. linum* 3.46 mg C g^{-1} dry wt. h^{-1} ; *H. musciformis* —3.89 mg C g^{-1} dry wt. h^{-1} and *P. gymnospora* 3.25 mgC g^{-1} dry wt. h^{-1} (Fig.1). The reported rates of net photosynthesis among macro-algae vary considerably. Even intraspecific variation greatly exceeds inter-specific variation (Wallentinus, 1978). However, rates of 2 to 4 mg C g^{-1} dry wt. h^{-1} were frequently reported (King and Schramm, 1976 ; Wallentinus, 1978 ; Littler and Arnold, 1980). The respiration rates were 0.78 mg C g^{-1} dry wt. h^{-1} for *C. linum*, 0.74 mg C g^{-1} dry wt. h^{-1} for *H. musciformis* and 1.07 mg C g^{-1} dry wt. h^{-1}

for *P. gymnospora*. The P : R ratios were 4.4, 5.3 and 3.0 for *C. linum*, *H. musciformis* and *P. gymnospora* respectively.

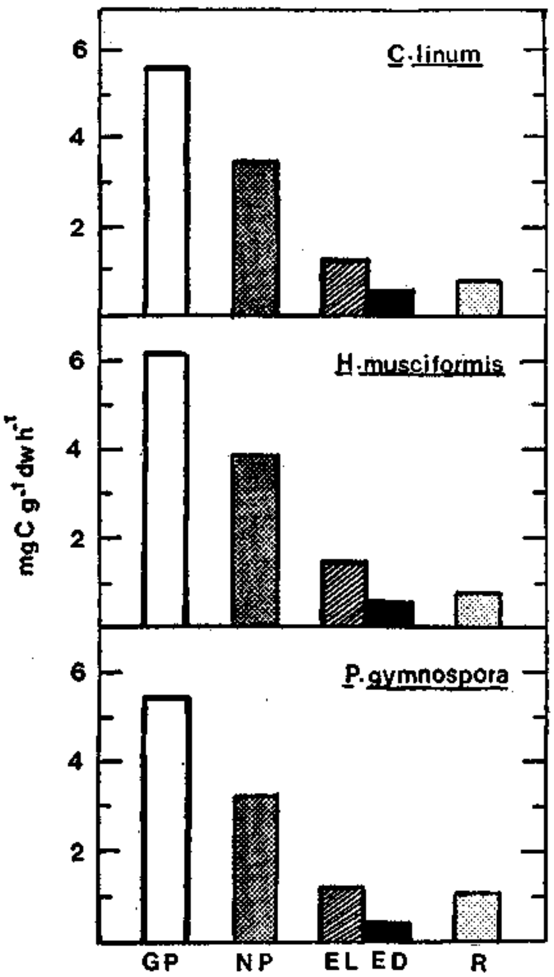

Fig. 1. Rates of photosynthesis, respiration and exudation of the benthic macro-algae. GP—Gross production = Net photosynthesis +Respiration + Exudation in light; NP—Net production; EL—Exudation in light; ED—Exudation in dark; R—Respiration.

As for as the exudation is concerned, all the three algal species were found to exude dissolved organic matter both in the light and in the dark, with greater exudation in the light. The exudation of carbon during the dark period ranged from 33% to 44% of that excreted during photosynthesis (light). Sieburth and Jensen (1970) found that the exudation rate in the dark was about 60 % of that in light. Hellebust (1965) also pointed out differences in exudation due to differences in light intensity. Exudation in the range of 20 to 37% of net photosynthesis has been reported by Khailov and Burlakova (1969), Sieburth (1969), Hanson (1977), Hatcher *et al.* (1977) and Johnston *et al.* (1977). In the present study the exudation in the light amounted to 37 to 38% of net photosynthesis or 22 to 24% of gross photosynthesis (Fig. 1).

The loss of fixed carbon due to exudation in the light was greater than that due to respiration in all three algae (Fig. 1). Sieburth (1969) and Sieburth and Jensen (1970) have also reported similar greater losses due to excretion rather than respiration. However, in the daily budget of organic matter flux, the loss by respiration is greater (38.6%) than that by exudation (29.6%) in *P. gymnospora* (Table 3).

Studies with phytoplankton both *in situ* and in laboratory conditions (Anita *et al.*, 1963; Hellebust, 1965; Fogg, 1977) also clearly demonstrated the release of extracellular organic matter. The few studies which contradicted the amount of extracellular exudation have admittedly differred in experimental design and conditions *e.g.* Moebus and Johnson (1974). Variations in the amount of excretion among the species are also common (Hellebust, 1965). The general consensus regarding the exudation is that it is an overflow mechanism (Fogg, 1983) and occurs when the supply is in excess of requirement. Exudation could also be a reflection of a poor mechanism of conservation (Sieburth and Jensen, 1970). The increased rate of exudation with the increased rate of photosynthesis (Sorensen and Halldall, 1977) could also substantiate this notion. As

Wangersky (1978) pointed out exudation may be energetically advantages over storage.

Based on the observed rates of photosynthesis, respiration and exudation, a daily balance sheet of organic matter productivity per square meter area for the total standing crop is presented in Table 3. The values presented for m^{-2} area are computed by multiplying the values of photosynthesis, respiration and exudation of each species by their respective standing crop (Table 1) and the average values

TABLE 1. *Distribution of macro-algae in the littoral area of the marine zone of Vellar Estuary*

Species		Distribution g wet wt m^{-2}	Water content %
Chaetomorpha linum	..	155±10	90.5
Hypnea musciformis	..	180± 8	90.8
Padina gymnospora	..	97± 4	91.0
Others	..	201± 5	90.5
Total	..	633	

thus obtained for g dry wt. were assumed for the other species also. This average value for g dry wt. was then multiplied by 63, the total standing crop per square metre area. The total standing crop per square metre area could fix about 4.4 g C d^{-1}, exude 1.4 g C d^{-1} and assimilate 1.7 g C d^{-1}. The theoretical maximum production rate for phytoplankton has been calculated to be 20 g C m^{-2} d^{-1} (Sieburth and Jensen, 1970), while yields of 10 g C m^{-2} d^{-1} have been obtained in *Chlorella* culture. The maximum rates observed in nature have been 3 to 6 g C m^{-2} d^{-1}. Macro-algal production (net) rates similar to the present study were reported by Johnston (1969), John (1971) and Littler and Murray (1974).

Analyses of different fractions of the excreted matter also revealed interesting results. Excretion of nitrogenous matter was observed only in the light and amounted to 113 to 187 μg N g^{-1} dry wt. in 12 hours. Excretion of organic nitrogen compounds by macro-algae was reported earlier by Newell *et al.* (1972). Generally excretion of nitrogenous matter

TABLE 2. *Excretion of organic nitrogen and phosphorus by macro-algae*

Species	Incubation period hrs	μg P g^{-1} dry wt.		μg N g^{-1} dry wt	
		light	dark	light	dark
Chaetomorpha linum	6	2.2	2.5	101	no production
	12	1.7	1.7	187	,,
Hypnea	6	4.5	4.6	107	,,
musciformis	12	5.5	2.8	186	,,
Padina	6	1.6	2.3	74	,,
gymnospora	12	5.8	7.4	113	,,

has been studied more frequently in blue-green algae than in other organisms. Stewart (1963) reported that the extent of nitrogen excretion could be upto 45% nitrogen fixed in blue-green algae. About 30% of fixed nitrogen was found to be excreted in cultures of two marine nitrogen fixing blue-green algae by Ramachandran (1982). Fogg (1966), Sieburth (1969) and Sieburth and Jensen (1970) also showed that exudation of nitrogenous matter occurred only to a lesser extent when compared to carbon. Exudation of organic phosphorus was not significant in either light or dark (Table 2).

The biological and biochemical advantages of extracellular excretion to algae are not yet evident, however, the ecological significance has been well documented (Williams and Yentsch, 1976; Dawson and Duursma, 1981). From the present study it is clear that benthic macro-algae, by virtue of their high photosynthetic efficiency and significant production of extracellular organic matter form a primary source of utilizable organic matter which enhances the productivity in shallow littoral waters.

TABLE 3. *Daily budget for organic matter flux in benthic marine macro-algae* (mg C g^{-1} dry wt. d^{-1})

Species	NP	R	Exudation L	Exudation D	GP[a]	Assimilation[b]	Loss by R% of GP	Loss by E% of GP
Chaetomorpha linum ..	41.5	18.6	15.4	6.7	66.2	25.5	28	33
Hypnea musciformis ..	46.7	17.9	17.4	7.4	74.0	31.3	24	34
Padina gymnospora ..	39.0	25.8	14.9	4.9	66.8	21.2	39	30
g C m^{-2} d^{-1} (for a total Standing crop of 63 g dry wt.) ..	2.7	1.3	1.4		4.4	1.7	30	32

NP—Net Production; R—Respiration; L—Light; D—Dark; GP—Gross Production; E—Exudation.

[a] Gross Production — Photosynthesis in light (Net production—12 hrs)+Respiration (12 hrs)+Exudation (12 hrs in light).

[b] Assimilation — Gross Production — Respiration (24 hrs)+Exudation (24 hrs—12 hrs in Light and 12 hrs in Dark).

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