Research note

In situ growth rates of *Sargassum horneri* (Fucales, Phaeophyta)*

Kunshan Gao and Wenqing Hua
Institute of Energy and Environmental Science, Science Center, Shantou University, Shantou, Guangdong, People's Republic of China

SUMMARY

The relative growth rate of the brown alga *Sargassum horneri* (Turner) C. Agardh in the sea at Maizuru Bay, Japan, was investigated from summer to winter to examine the impact of declining solar radiation and temperature. The observed change in the growth rate between summer and winter was insignificant, in spite of a major decline in solar radiation and water temperature. The mean relative growth rate was 4.6% per day, equivalent to the daily net photosynthetic production previously reported for this species.

Key words: Phaeophyta, relative growth rate, *Sargassum horneri*.

In nature, seasonal changes in solar radiation give rise to seasonal fluctuations in temperature. *Sargassum* plants show various growth patterns in accordance with the seasonal changes in solar radiation and temperature. Daily net photosynthetic production of *Sargassum thunbergii* (Mert.) O. Küntze has been shown to decrease with decreased solar radiation (Gao and Umezaki 1989). However, rapid growth of *Sargassum* plants has been reported to occur primarily during the periods of late fall and winter for both coastal species (DeWreede 1976; Prince 1980; Umezaki 1984) and pelagic species (Carpenter and Cox 1974), although Prince and O'Neal (1979) and Prince (1980) showed that growth and net photosynthesis of *Sargassum pteropleuron* Grunow was greatest in summer. Further examination of growth rate of *Sargassum* plants in the sea is needed to elucidate the above discrepancy. This note presents the daily relative growth rates in the sea of *Sargassum horneri* (Turner) C. Agardh, with special reference to temperature, solar radiation, individual sizes and previously reported rates of daily photosynthetic production (Gao 1990).

Sargassum horneri, an annual species, is distributed from 1 m to 20 m deep along the coasts of both the Sea of Japan and the Pacific Ocean throughout the Archipelago of Japan. The plant often reaches several meters in length. *Sargassum horneri* in Japan matures in spring and disintegrates entirely after the maturation period (May to June); after this juveniles germinating from fertilized eggs begin to appear. Experiments were carried out from August to December 1987 at the Fisheries Research Station of Kyoto University located at the head of Maizuru Bay, one of the branches of Wakasa Bay facing the Sea of Japan. Samples of *S. horneri* were collected at a depth of about 1 m, taking care not to damage their holdfasts. The cleaned plants were gently shaken and blotted with tissue paper to remove excess surface water. They were then quickly weighed (to the nearest 1 mg) and returned to the seawater. The plants were anchored in an erect position using concrete blocks by inserting their holdfasts through cords which were secured to the blocks (cube-shaped, about 30 cm wide), which were then positioned in the same place and depth as where the plants were collected. After 7–9 days the plants were removed from the blocks and their fresh weight determined; no apparent grazing was observed. Relative growth rate (RGR, %) was calculated as:

$$RGR = \frac{100\, ln(Nt/No)}{t},$$

where No is the initial fresh weight and Nt the fresh weight after t days.

Water temperature at the site was measured daily (9:00), and daily solar radiation was obtained from Maizuru Weather Monitoring Station. Experimental plants

*Dedicated to the memory of the late Dr Isamu Umezaki (1925–1995), Professor of Fukui Prefectural University, and the late Dr Kelton R. McKinley (1948–1995), Technical Program Administrator of Hawaii Natural Energy Institute, University of Hawaii.

Communicating editor: T. Horiguchi.
Received 14 June 1996; accepted 25 October 1996.

Table 1. Relative growth rates (RGR) of *Sargassum horneri* in the sea

Period (1987)	Mean temperature (°C)	MSR (E m^{-2} day^{-1})	Mean RGR ± SD (% day^{-1})
17–25 Aug.	28.5	63.1	5.2 ± 1.1 (n = 10)
12–21 Oct.	21.4	34.8	4.2 ± 0.6 (n = 6)
9–18 Nov.	19.1	36.0	5.0 ± 1.1 (n = 5)
8–15 Dec.	12.7	20.3	4.0 ± 1.0 (n = 7)

MSR, mean solar radiation.

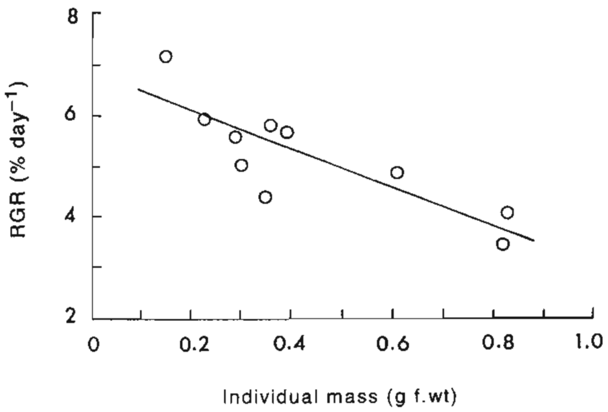

Fig. 1. Daily relative growth rate (RGR) of *Sargassum horneri* as a function of individual mass ($Y=6.82-3.71x$, $r^2=0.75$).

were 1–3 cm long in August, approximately 10 cm long in October, 10–20 cm in November and 20–30 cm long in December.

Table 1 indicates the relative growth rates of *S. horneri* over the study period. The mean growth rate ranged from 4.0 to 5.2%, highest in August and lowest in December. However, the difference was insignificant ($P>0.05$, ANOVA). Daily net photosynthetic production of *S. horneri* was reported to be 4.7 to 5.5% (47–55 mg dry wt g^{-1} dry wt day^{-1}) in August and October on fine days (Gao 1989, 1990), paralleling the growth rates observed in this study.

Hanisak and Samuel (1987) reported maximal daily doubling rates of apical tips to be 7–11% in *Sargassum cymosum* C. Ag., *Sargassum filipendula* C. Ag., *Sargassum fluitans* Boerg., *Sargassum natans* (L.) J. Meyen, *Sargassum polyceratium* Montagne and *S. pteropleuron* Grunow. Apical segments of *Sargassum* plants are photosynthetically more active (in spite of their lower chlorophyll contents) as compared to other parts of the thallus (Gao 1989). In the present study, whole plants were used for the assessment of growth in the sea. The individual size of *S. horneri* is also an important parameter in considering growth rates. When *S. horneri* plants of various sizes were maintained in the sea for the same period in August, their relative growth rates varied significantly ($P<0.01$) with individual size (Fig. 1). Relative growth rate decreased linearly with larger initial sizes. The larger the initial size of the plant the lower lamina proportion it has (Table 2). Photosynthetic capacity of laminae, 'leaves', is the highest in a *S. horneri* plant compared to vesicles and axes (Gao 1991). A reduced proportion in percentage laminae in a larger *S. horneri* plant probably lowers its photosynthetic productivity on a weight basis, which results in decrease of relative growth rate.

Irrespective of the decline in temperature and solar radiation from August to December, neither change is significantly ($P>0.05$) correlated with growth rate. However, daily growth rate of *S. cymosum, S. filipendula* and *S. pteropleuron* decreased 2–4 times as temperature was lowered from 24 to 12 °C under laboratory conditions (Hanisak and Samuel 1987). Gao and Umezaki (1989) reported diurnal photosynthesis of *S. thunbergii* on fine, cloudy and rainy days with negligible temperature changes, and found that daily net photosynthetic production decreased linearly with decrease of daily accumulated solar radiation within a range of 4–37 mol m^{-2} day^{-1}. In the present study, when temperature and solar radiation declined from August to December, the relative growth rate change was insignificant. It is possible that other factors counterbalanced the unfavorable effects of declining temperature and solar radiation. These could be either biological factors, such as physiological rhythms adjusted to seasonal changes, or environmental ones, such as nutrient values during the later fall and winter seasons. Photosynthesis and growth of *S. thunbergii* have been shown to be nutrient-sensitive (Gao and Nakahara 1990). Nevertheless, length of day or photoperiod does control the morphogenesis of *S. horneri* (Uchida 1993).

It is concluded that the growth of *S. horneri* gives rise to a constant percentage of biomass increase (about 4.6% per day) over the period from August to December at the study site, and that seasonally-adjusting physiological rhythms and/or positive nutrient availability could have counterbalanced the negative impacts of declining solar radiation and temperature.

Table 2. Relative proportions of different parts of *Sargassum horneri* plants at different growth stages. 'Axes' include main axis (or stem), axes of branches and holdfast. Data are the means of 10–30 plants

Month (1987)	Length (cm)	Vesicle (%)	Lamina (%)	Axes (%)	Receptacle (%)
Aug.	2	0	88	12	0
Oct.	7	0	79	21	0
Nov.	18	3	69	28	0
March	150	46	21	33	0
Jun.	180	14	8	12	66

REFERENCES

Carpenter, E. J. and Cox, J. L. 1974. Production of pelagic *Sargassum* and a blue-green epiphyte in the western Sargasso Sea. *Limnol. Oceanogr.* **19**: 429–36.

De Wreede, R. E. 1976. The phenology of three species of *Sargassum* (Sargassaceae, Phaeophyta) in Hawaii. *Phycologia* **15**: 175–84.

Gao, K. 1989. Studies on photosynthesis of *Sargassum* plants. PhD thesis, Kyoto University 320pp.

Gao, K. 1990. Diurnal photosynthetic performance of *Sargassum horneri*. *Jpn. J. Phycol.* **38**: 163–5 (in Japanese with English summary).

Gao, K. 1991 Comparative photosynthetic capacities of different parts of *Sargassum horneri*. *Jpn. J. Phycol.* **39**: 245–52.

Gao, K and Nakahara, H. 1990. Effects of nutrients on the photosynthesis of *Sargassum thunbergii*. *Bot. Mar.* **33**: 375–83.

Gao, K and Umezaki, I. 1989. Studies on diurnal photosynthetic performance of *Sargassum thunbergii*. I. Changes in photosynthesis under natural sunlight. *Jpn. J. Phycol.* **37**: 89–98.

Hanisak, M. D. and Samuel, M. A. 1987. Growth rates in culture of several species of *Sargassum* from Florida, USA. *Hydrobiologia* **151/152**: 399–404.

Prince, J. S. and O'Neal, S. W. 1979. The ecology of *Sargassum pteropleuron* Grunow (Phaeophyceae, Fucales) in the waters off South Florida. 1. Growth, reproduction and population structure. *Phycologia* **18**: 109–14.

Prince, J. S. 1980. The ecology of *Sargassum pteropleuron* Grunow (Phaeophyceae, Fucales) in the waters off South Florida. II. Seasonal photosynthesis and respiration of *S. pteropleuron* and comparison of its phenology with that of *S. polyceratium* Montagne. *Phycologia* **19**: 190–3.

Uchida, T. 1993. The life cycle of *Sargassum horneri* (Phaeophyta) in laboratory culture. *J. Phycol.* **29**: 231–5.

Umezaki, I. 1984. Ecological studies of *Sargassum horneri* (Turner) C. Agardh in Obama Bay, Japan Sea. *Bull. Jap. Soc. Sci. Fish.* **50**: 1193–200.