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Effect of emersion on the growth and photosynthesis of the *Porphyra yezoensis* thallus*

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The influence of emersion on the growth, thickness, dry weight per unit thallus area, pigment content, photosynthesis rate and emersion tolerance was investigated with *Porphyra yezoensis* thalli grown under laboratory conditions with periodical emersion and submersion treatments. Growth rate of thalli with periodical emersion was slower than that of thalli without emersion. Thalli with periodical emersion were obviously thinner than those without emersion. However, the dry weight per unit thallus area was about 1.3 times greater in thalli with periodical emersion than in thalli without emersion. The photosynthetic activity per chlorophyll *a* was not changed by emersion treatment. However, chlorophyll *a* content on a thallus area basis was higher in thalli with periodical emersion than in thalli without emersion. On a dry weight basis chlorophyll *a* content was lower in thalli with periodical emersion than in thalli without emersion. The ratio of phycoerythrin to phycocyanin was higher in thalli with periodical emersion than in thalli without emersion. The ability of thalli to resume photosynthesis activity when re-submerged was greater in those cultured with periodical emersion than in those cultured without emersion as seen after both thalli with and without emersion treatment were emerged for 23 hrs.

Key Index Words: *culture*; *emersion tolerance*; *emersion treatment*; *growth*; *pigment content*; *photosynthesis*; Porphyra yezoensis; *Rhodophyta*.

Intertidal algae suffer great exposure stress, the effects of which were reviewed by GESSNER and SCHRAMM (1971). Most of the studies to date were concerned with the photosynthetic and respiratory activities in air (STOCKER and HOLDHEIDE 1938, TSURUGA and NITTA 1957, CHAPMAN 1966, OGATA 1968. JOHNSON *et al.* 1974, BRINKHUIS *et al.* 1976, QUADIR *et al.* 1979).

In the cultivation of *Porphyra*, economically important marine algae in Japan, the effect of emersion is one of the most important considerations. In recent years, *Porphyra* cultivation in Japan is performed in a floating system as well as in a fixed pole system. The Nori net in the latter system is exposed to air during low tide, while the Nori net in the former system is continually below the surface of water held in place by buoys. The Nori net in the floating system, however, is exposed to air by an emersion control raft in order to get rid of other seaweeds so that the *Porphyra* thalli can grow well.

Early studies about the effects of emersion on *Porphyra* were reported by FUJIKAWA (1932, 1937). KANEKO (1940, 1941) and KURAKAKE (1941). A number of recent works about the effects of emersion (IWASAKI and MATSUDAIRA 1956, OGATA 1963, OGATA and MATSUI 1963, 1965, IWASAKI 1965, IMADA *et al.* 1970, OGATA and SCHRAMM 1971, WATANABE *et al.* 1971, OOHUSA *et al.* 1978) dealt with the influence on physiological activity. The effects on growth and photo-

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synthesis of *Porphyra* thalli, cultured under emerged and submerged conditions over a long period of time, were only reported by OGATA and SCHRAMM (1971). They observed the rate of growth and O_2 evolution of the intertidal red alga *Porphyra umbilicalis* during a 3-week culture period.

In the present study, it was attempted to determine the influence of emersion on the growth, photosynthesis and pigment contents of *Porphyra yezoensis* under defined laboratory conditions over an extended period of time.

Material and Methods

Stocks of free-living conchocelis stage of *Porphyra yezoensis* UEDA (strain No. C-13) were maintained in the laboratory. From the stocks, a cluster of filaments was collected and cultured in an incubator under 10 : 14 LD cycle at 15°C (light period : 08 : 00-18 : 00 at about 10 klux). Illumination was provided by fluorescent lamps (Toshiba white, 30W). Synthetic fibers (Cremona monofilaments) about 3 cm long were put into the culture. After 6 to 10 days, conchospores were shed, immediately attached to the synthetic fibers and started to grow into thalli. Zero-day was assigned to the age of the thalli on the day of attachment. When they reached 23 and 24 days in age, the thalli were detached from the synthetic fiber and transfered into 1-liter flasks and aerated. From this point, the culture medium was renewed every other day throughout the culture period. The seawater collected from the Kuroshio off the Izu Oshima Island was filtered with a glass fiber filter (Whatman GF/C) and used. After measuring the chlorinity by AKANUMA's hydrometer and adjusting it to 16-17‰ by adding deionized water (TAKAYAMA 1937), the seawater was autoclaved and enriched with ESP medium (PROVASOLI 1966).

Four series of experiments were performed. In the first experiment, 200 thalli were exposed to air for 3 hrs daily (10 : 00-13 : 00, light period emersion), while another 200 thalli of similar size were simultaneously maintained in seawater. In the second and third experiments, 75 thalli were exposed to air for 3 hrs daily (10 : 00-13 : 00, light period emersion), and 75 thalli of similar size were simultaneously maintained in seawater. In the fourth experiment, 200 thalli were exposed to air for 3 hrs daily (21 : 00-24 : 00, dark period emersion), and another 200 thalli of similar size were simultaneously maintained in seawater. Emersion treatment in all experiments started when the thalli were about 2 cm long. At this stage the thalli were between 36 and 39 days old. The net used to expose the thalli to air was placed in the same incubator used for maintaining the cultures (Fig. 1).

The rate of growth, determined by measuring the length and width of thalli every

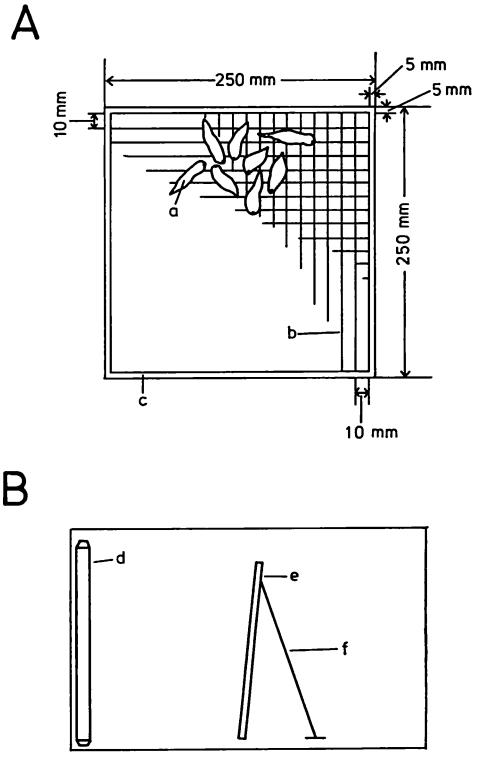

Fig. 1. A net (A) used to expose thalli to air was placed in an incubator (B). Illumination at the net was approximately 10 klux. a, *Porphyra* thallus; b, Cremona monofilament; c, acrylic resin frame; d, fluorescent lamp; e, net; f, stand.

7-10 days, was obtained with 100 samples collected at random from each treatment in the first and the fourth experiments, and with 50 samples from each treatment in the second and the third experiments. In the first experiment, however, 59 sample thalli with periodical emersion and 89 sample thalli without emersion were measured at an age of 69 days.

The time course of water loss under emersion treatment was measured in the first and fourth experiments. The equation used to compute the water content (D) is as follows:

$$D=\frac{\text{air-dry weight}-\text{dry weight}}{\text{wet weight}-\text{dry weight}}\times 100.$$

After air-dry weight was determined, the thallus was rewetted with seawater, and then fresh weight was determined after carefully blotting off the seawater on the surface of the thallus. Dry weight of the thallus was determined after drying at 85°C or in a desiccator with silica gel for 24 hrs. Each point determined from the first and fourth experiments is the average value measured at intervals of 7-10 days. Three thalli were used for each measurement.

Thallus thickness was measured directly using a hand section as well as was indicated indirectly using the ratio of dry weight to thallus area. With hand sectioning, 40 thalli of 50-day old from each emersion and submersion treatment in the fourth experiment were selected. The thalli were preserved in 10% formalin-seawater. Hand sections of each thallus were made in the transverse plane. The thickness of thalli and the inside diameter of the cells (Fig. 2) were measured by a Nikon ocular screw micrometer. A sample size of 100 cells were selected for each treatment. Twelve to fourteen cells from sections of a group of 5 thalli were measured at random. The ratio of dry weight to thallus area was obtained in all experiments. Thallus area was measured by making photographic outlines, which were cut out and weighed.

Chlorophyll *a* in the thalli was extracted with 90% acetone. The absorbances of the acetone extract were measured with a Hitachi 101 spectrophotometer. The concentration of chlorophyll *a* was calculated by the formula of SCOR-UNESCO W.G. 17 (1966). Phycoerythrin and phycocyanin of the thalli were extracted with distilled water by 4 repeated combinations of freezing and melting. After extraction, the clear extract of biliproteins were obtained by centrifuge (ca. $4000\times g$, 10 min). The absorbances of the extract were measured with a Hitachi 101 spectrophotometer. The concentrations of phycoerythrin and phycocyanin were calculated using the extinction coefficients of Ó CARRA and Ó hEOCHA (1978).

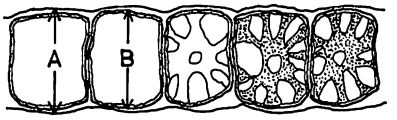

Fig. 2. A transverse section of *P. yezoensis* thallus indicating thallus thickness (A) and inside diameter of the cell (B).

For *in vivo* absorption measurements a Shimadzu UV-365 double monochromator recording spectrophotometer was used with an integrating sphere attachment at wavelengths of 350-750 nm. The recorded absorbances at 676, 567 and 620 nm were used as the indices of chlorophyll *a*, phycoerythrin and phycocyanin, respectively (ARUGA 1974).

Photosynthetic and dark respiratory capacity of thalli of the first and fourth experiment were measured at 15°C as changes in the O_2 tension using a differential gas-volumeter (Productmeter, NIKKO KAGAKU Co., Ltd.) (YOKOHAMA and ICHIMURA 1969). For each measurement, the middle part (3-9 cm^2) of a thallus (cf. NOZAWA 1967) was placed in the reaction flask with unenriched filtered seawater. Each photosynthesis-light curve was obtained by measurements with 7-9 thalli. In the first experiment illumination was supplied by a 100V-150W projector lamp (KP-8, KONDO Co., Ltd.), while in the fourth experiment a 100V-150W projector lamp (KP-8, KONDO Co., Ltd.) was used for low light intensities and a 100V-300W projector lamp (KP-8 1/2, KONDO Co., Ltd.) for high light

intensities. The light intensity was measured with a photocell illuminometer (Toshiba SPI-5). All data were taken during the light period in order to avoid possible variation due to daily rhythms (cf. MISHKIND *et al.* 1979). Thalli of emersion and submersion treatments were simultaneously measured.

In order to know the after-effects of desiccation, photosynthesis and respiration rates of thalli following re-transfer to seawater were determined by measuring the increase and decrease in oxygen concentration using the Winkler titration technique under short term incubations. Middle portions of thalli (4–9 cm^2) were placed in 100 ml DO bottles and incubated at 15°C and 30 klux provided by a photoreflector lamp (Toshiba, 100V-500W, spot) (the photosynthetic rate was presumed to be saturated at 30 klux) and also in the dark. With thalli cultured in both emersion and submersion conditions the measurements were continuously made at 15 or 30 min intervals for a 1 hr period. The same thalli were then exposed to air for 23 hrs in an incubator at 15°C with a 10 : 14 LD cycle at about 10 klux, after which they were placed in seawater for continuous measurements of photosynthesis and respiratory rates for another 2 hrs at 15 and 30 minute intervals, respectively. The measurements were done on 3 emersion treatments: 13 days emersion (=48 days old thalli), 24 days emersion (=58 days old thalli) and 32 days emersion (=67 days old thalli).

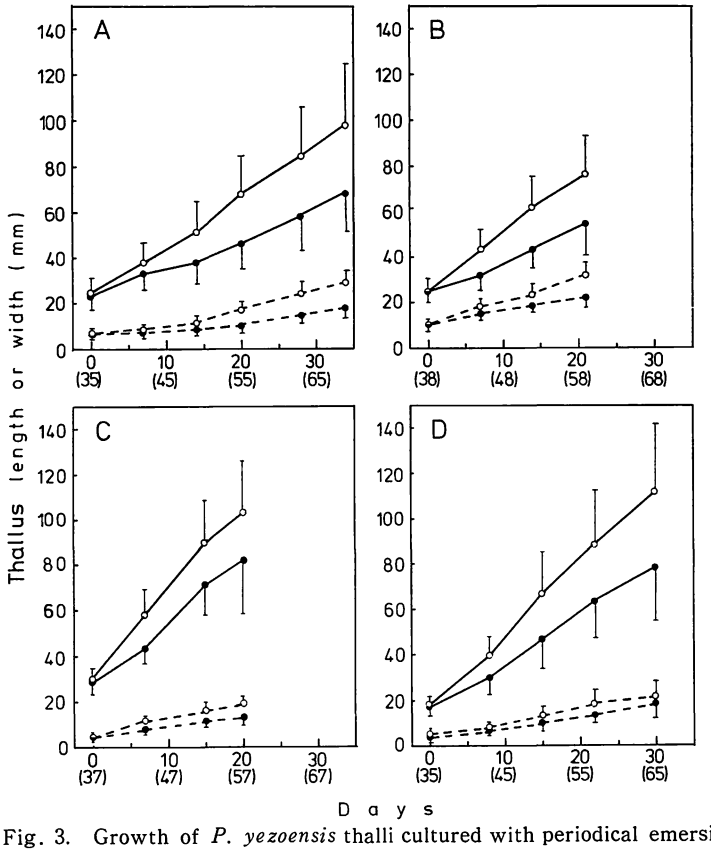

Fig. 3. Growth of *P. yezoensis* thalli cultured with periodical emersion (●) and without emersion (○) under laboratory conditions. Mean length (solid lines) and mean width (dotted lines) of the thalli are indicated with $\pm\frac{1}{2}$ S.D. Abscissae: days of culture (days after conchospore attachment in parentheses). A, B and C: light period emersion (Exp. 1, 2 and 3, respectively). D: dark period emersion (Exp. 4).

Results

Growth in length and width of *Porphyra yezoensis* thalli cultured with or without periodical emersion treatment was illustrated in Fig. 3. Differences of the growth were quite clear between the thalli with and without emersion. In all the experiments including light period emersion and dark period emersion, the growth rate of thalli with periodical emersion was slower than that of thalli without emersion. After 3 weeks of treatment, the length of thalli with periodical emersion was 0.7-0.8 times shorter than that of thalli without emersion.

Thallus thickness was compared with *P. yezoensis* thalli cultured with or without periodical emersion treatment (dark period emersion). The data shown in Fig. 4 indicate that the thalli with periodical emersion were obviously thinner than those without emersion. The average thickness of thalli with periodical emersion was 33.2 μm, and that of thalli without emersion was 35.6 μm. The average inside diameter of thallus cells with periodical emersion was 30.6 μm and that of thallus cells without emersion was 33.2 μm.

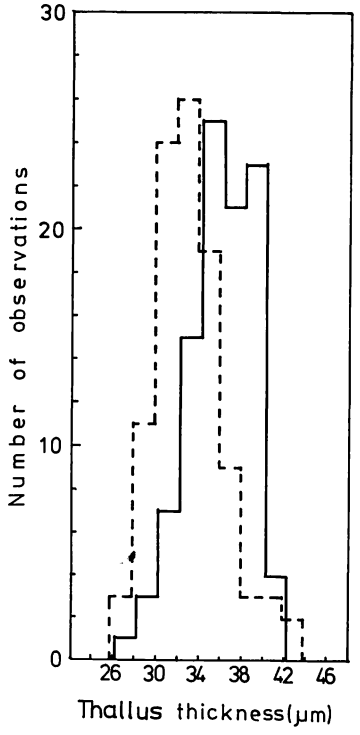

Fig. 4. Comparison of the thallus thickness of *P. yezoensis* cultured with periodical emersion (dotted histograms) and without emersion (solid histograms).

Changes in dry weight per unit thallus area of *P. yezoensis* were followed during the cultures with or without emersion treatment. As illustrated in Fig. 5, the dry weight per unit thallus area was about 1.3 times higher in thalli with periodical emersion than in thalli without emersion in all the experiments including both light and

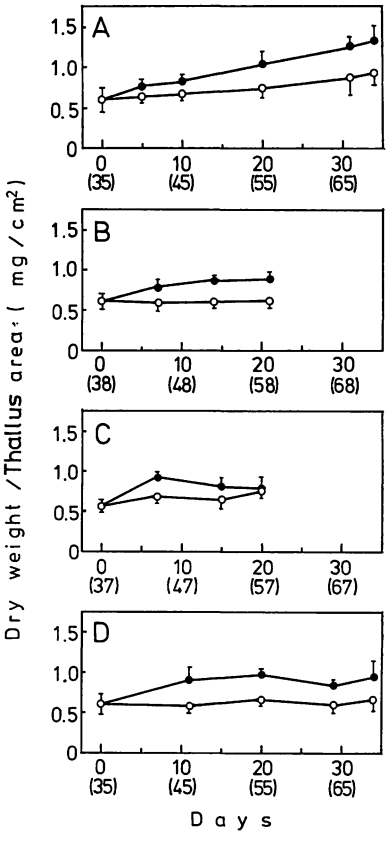

Fig. 5. Changes in dry weight per unit area ($\pm\frac{1}{2}$ S. D.) of *P. yezoensis* thalli cultured with periodical emersion (●) and without emersion (○) under laboratory conditions. Abscissae: days of culture (days after conchospore attachment in parentheses). A, B and C: light period emersion (Exp. 1, 2 and 3, respectively). D: dark period emersion (Exp. 4).

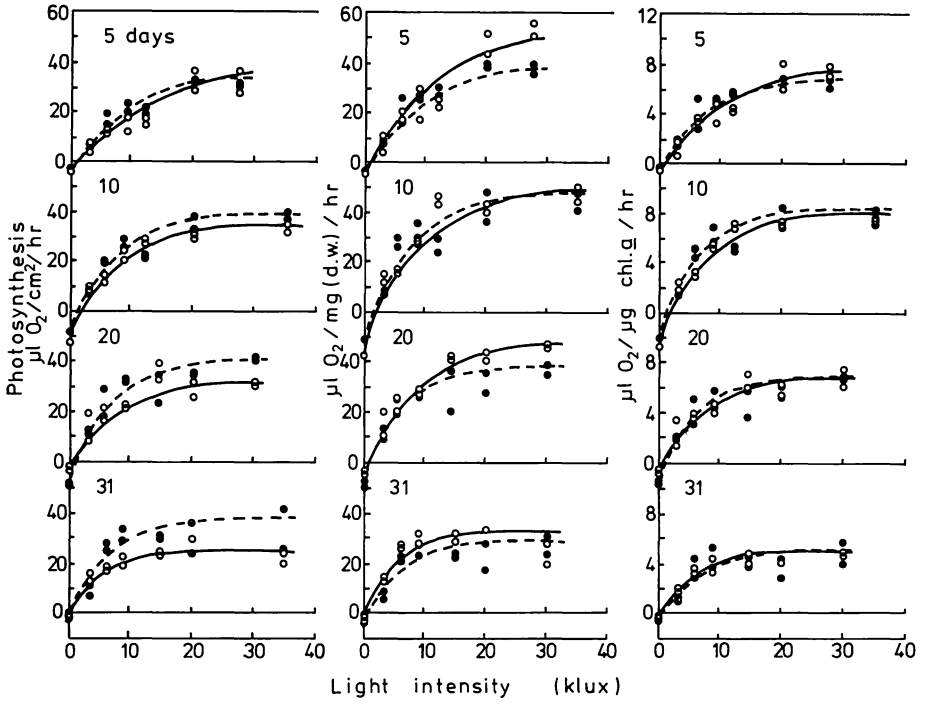

Fig. 6. Photosynthesis-light curves of *P. yezoensis* thalli cultured with periodical emersion (●) and without emersion (○) under laboratory conditions (Exp. 1, light period emersion). Measured at 15°C. Days in culture are indicated in each diagram.

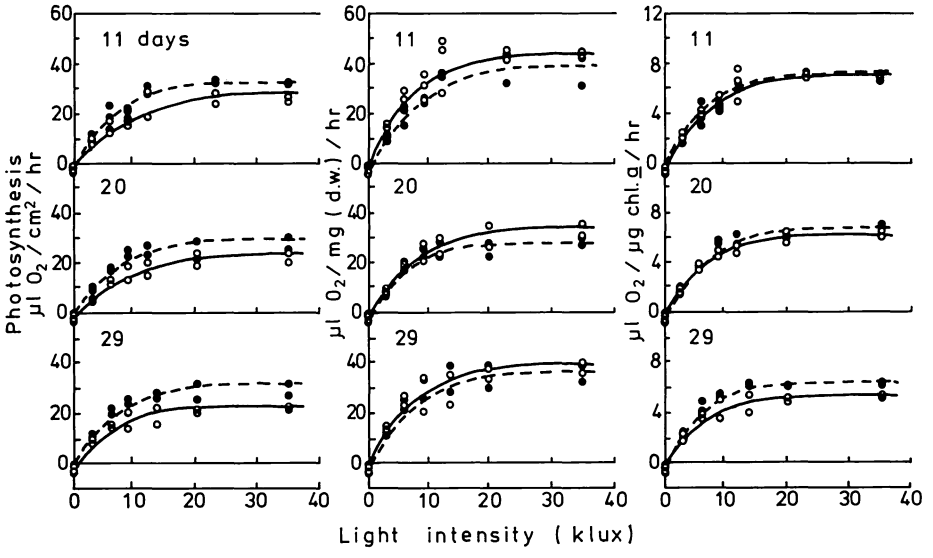

Fig. 7. Photosynthesis-light curves of *P. yezoensis* thalli cultured with periodical emersion (●) and without emersion (○) under laboratory conditions (Exp. 4, dark period emersion). Measured at 15°C. Days in culture are indicated in each diagram.

dark period emersion.

The photosynthesis-light curves of *P. yezoensis* thalli with periodical emersion and without emersion were shown in Figs. 6 and 7. These curves indicate that great variations in photosynthetic rate occurred between thalli with periodical emersion and those without emersion. In light period emersion (Fig. 6), the photosynthetic rates of thalli with periodical emersion were higher than those of thalli without emersion when expressed on a thallus area basis, the difference increasing with time (days of culture). When expressed on a dry weight basis the rate was slightly lower in thalli with periodical emersion than in those without emersion, while when expressed on a chlorophyll *a* basis the rates did not differ much (Fig. 6). In dark period emersion (Fig. 7), the difference in photosynthetic rates was as great as that found in light period emersion when expressed on a thallus area basis. The photosynthetic rates on a dry weight basis did not show any significant difference even after continued emersion. When expressed on a chlorophyll *a* basis, however, the rates were slightly higher in thalli with periodical emersion 29 days of culture (Fig. 7).

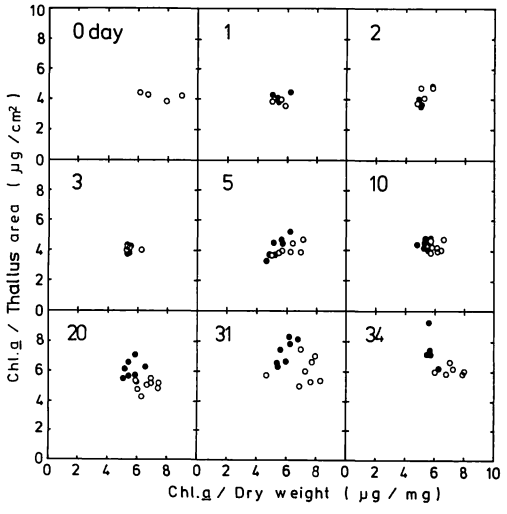

Fig. 8. Chlorophyll *a* content on a dry weight basis and on a thallus area basis of *P. yezoensis* thalli cultured with periodical emersion (●) and without emersion (○) under laboratory conditions (Exp. 1, light period emersion). Days in culture are indicated in each diagram.

Contents of photosynthetic pigments were measured with *P. yezoensis* thalli cultured under periodical emersion or submersion conditions. Figs. 8-10 show the vartiations in the contents of photosynthetic pigments with time (days of culture). With continued periodical emersion treatment, chlorophyll *a* content of thalli was higher than that of thalli without emersion on a thallus area basis, but chlorophyll *a* content on a dry weight basis of thalli with periodical emersion was lower than that without emersion (Fig. 8; Exp. 1, light period emersion). In other experiments (Exp. 2 and 3, light period emersion; Exp. 4, dark period emersion), the same tendency as in Exp. 1 was observed.

In *P. yezoensis* thalli both cultured with light period emersion or dark period emersion, the ratio of phycoerythrin to chlorophyll *a* content showed large variations, but that of

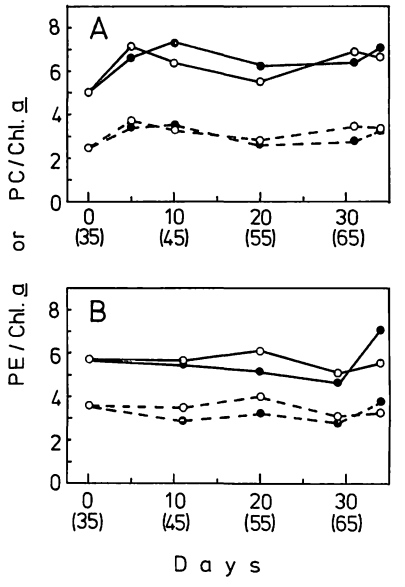

Fig. 9. Changes in the ratio of phycoerythrin to chlorophyll *a* content (solid lines) and that of phycocyanin to chlorophyll *a* content (dotted lines) of *P. yezoensis* thalli cultured with periodical emersion (●) and without emersion (○) under laboratory conditions. Abscissae: days of culture (days after conchospore attachment in parentheses). A: light period emersion (Exp. 1). B: dark period emersion (Exp. 4).

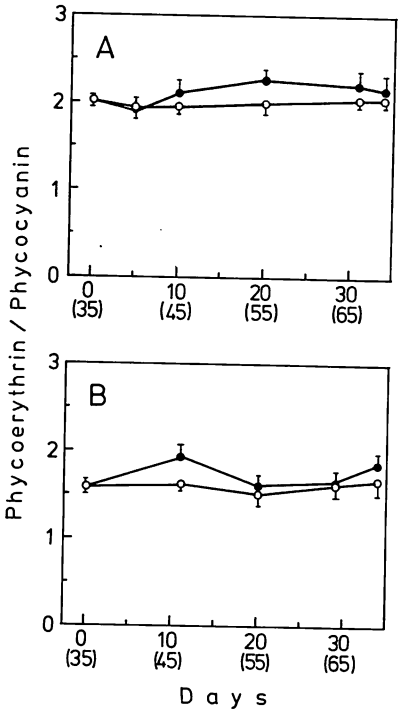

Fig. 10. Changes in the ratio of phycoerythrin to phycocyanin content ($\pm\frac{1}{2}$ S. D.) of *P. yezoensis* thalli cultured with periodical emersion (●) and without emersion (○) under laboratory conditions. Abscissae; days of culture (days after conchospore attachment in parentheses). A: light period emersion (Exp. 1). B: dark period emersion (Exp. 4).

phycocyanin to chlorophyll *a* content showed little variation (Fig. 9). No correlation was observed between phycoerythrin and chlorophyll *a* contents, and between phycocyanin and chlorophyll *a* contents. The ratio of phycoerythrin to phycocyanin content was higher in thalli with periodical emersion than in those without emersion both in light period emersion and dark period emersion (Fig. 10).

The ratios of phycoerythrin to phycocyanin and of phycoerythrin to chlorophyll *a* were also compared by using the results of *in vivo* absorption measurements of *P. yezoensis* thalli (Table 1). The ratios of phycoerythrin to phycocyanin (A_{567}/A_{620}) and of phycoerythrin to chlorophyll *a* (A_{567}/A_{676}) of thalli with periodical emersion were higher than those of thalli without emersion. The difference in the ratio of phycocyanin to chlorophyll *a* (A_{620}/A_{676}) of thalli with periodical emersion from thalli without emersion was small.

Fig. 11 shows the after-effects of 23 hr desiccation on photosynthetic and respiratory rates of *P. yezoensis* thalli following re-transfer to seawater. After re-transfer to seawater, the photosynthesis of thalli with periodical emersion recovered within an hour to the previous level, but that of thalli grown totally submerged recovered only to 2/3 of the previous level even 2 hrs after re-transfer

Table 1. Phycoerythrin/chlorophyll *a*, phycocyanin/chlorophyll *a* and phycoerythrin/phycocyanin ratios deduced from the absorbance ratios of A_{567}/A_{676}, A_{620}/A_{676} and A_{567}/A_{620}, respectively, in *in vivo* absorption spectra of *P. yezoensis* thalli cultured for 21 days of light period emersion treatment under laboratory conditions (Exp. 2).

Thallus number	With periodical emersion			Without emersion		
	A_{567}/A_{676}	A_{620}/A_{676}	A_{567}/A_{620}	A_{567}/A_{676}	A_{620}/A_{676}	A_{567}/A_{620}
1	0.89	0.61	1.46	0.87	0.64	1.36
2	0.88	0.65	1.35	0.87	0.63	1.38
3	0.92	0.64	1.45	0.87	0.64	1.36
4	0.97	0.60	1.60	0.88	0.65	1.35
5	0.92	0.60	1.52	0.83	0.62	1.34
6	0.88	0.61	1.43	0.84	0.63	1.33
Mean	0.91	0.62	1.47	0.86	0.64	1.35
S. D.	±0.03	±0.02	±0.08	±0.02	±0.01	±0.02

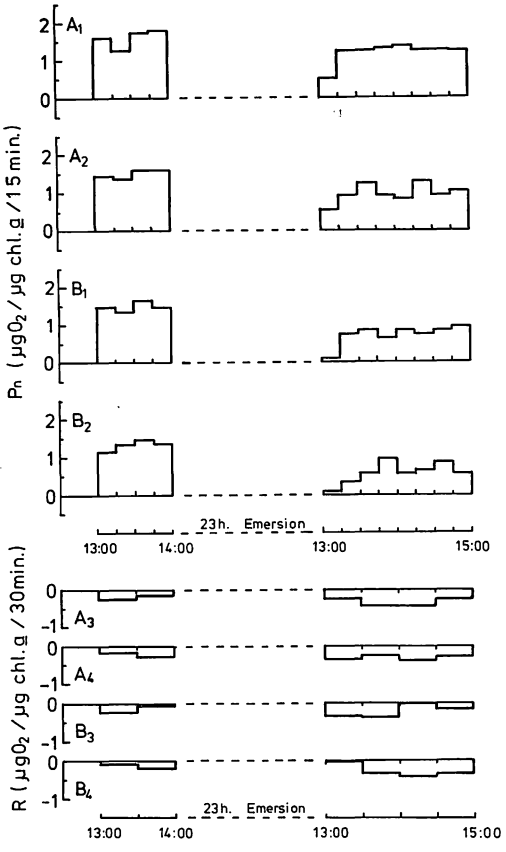

Fig. 11. Changes of net photosynthesis (Pn) and respiratory rates (R) of *P. yezoensis* thalli cultured for 24 days with periodical emersion (A) and without emersion (B) under laboratory conditions following re-transfer to seawater after 23 hr emersion.

to seawater. Especially 15-30 min after re-transfer to seawater, the photosynthetic rates of the thalli grown totally submerged were small. Since the rates were small, the difference in respiration between the two types of thalli with different treatments was not clear. After 23 hrs of emersion followed by retransfer to seawater, the respiratory rates of thalli with either treatment were slightly higher than those before the emersion. The water content (D) after 23 hrs of emersion ranged from 4 to 38. No correlation was observed between the photosynthetic and respiratory rates and the water content (D). The same holds true for the results obtained with 13 and 32 days old thalli (data not shown).

Discussion

In the present culture experiments, the *P. yezoensis* thalli exposed to air for 3 hrs daily were compared with those cultured in continuous submersion. Fig. 12 shows the time course of water loss from thalli in emersion. The water content (D) of thalli in Exp. 1 was observed to be much higher than that in Exp. 4 when both were measured at the beginning of emersion treatment. This difference might be due to residual water trapped between thalli when they overlapped on the net in Exp. 1. In Exp. 4, therefore, care was taken so that the thalli did not overlap as they dried. However, after 1.5 hrs the water content of thalli in both experiments was almost equal. After 3 hrs thalli lost about half the water content of wet weight in both experiments.

The growth rates in terms of length and width of thalli were measured and it was found that growth of thalli with periodical emersion was very much slower than that of thalli without emersion (Fig. 3). This is similar to the results reported by IMADA *et al.* (1970) and OGATA and SCHRAMM (1971). The difference in growth may be attributed to the slowing down of physiological activi-

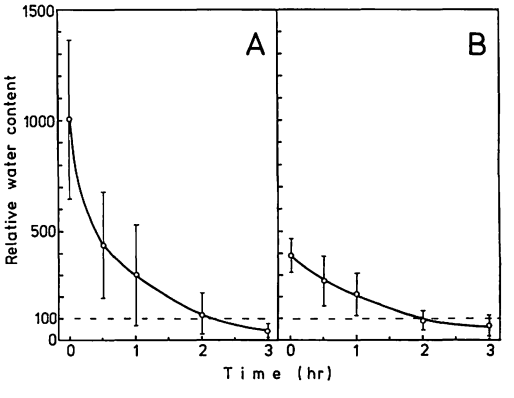

Fig. 12. Time course of water loss from *P. yezoensis* thalli in emersion. Ordinate: water content (D) with S. D.; D of 100 is equivalent to wet weight. A: light period emersion (Exp. 1). B: dark period emersion (Exp. 4).

ties, such as photosynthesis and nutrient uptake, which were caused by the emersion of thalli. IMADA *et al.* (1970) reported, however, that about 50% of the original activity of photosynthesis remained until the water content decreased to 20-25% in *Porphyra tenera*. Furthermore, JOHNSON *et al.* (1974) reported that photosynthetic rates of *Porphyra perforata* can be 2.84 times greater in air than in water. Therefore, it is thought in the present experiments that the difference in growth may be attributed to the lack of nutrient when thalli were exposed to air.

LIDDLE (1975) reported that comparisons of cell sizes in *Padina sanctae-crucis* showed differences between intertidal and subtidal populations, and that the cells from the intertidal populations were significantly smaller than those of cells from the subtidal populations. He assumed that the cells of the intertidal plants do not undergo as much enlargement after mitosis as the cells of subtidal plants. Similar results were obtained in the present study (Fig. 4). Whether the difference is due to cell enlargement after mitosis or not was not investigated. The dry weight per unit thallus area, an index of the frond thickness, was greater in thalli with periodical emersion than in thalli without emersion (Fig. 5). OGATA and SCHRAMM (1971) noted that the influence of salinity was more important than the influence of emersion on the dry weight per unit thallus area. They reported that the dry weight per unit thallus area is higher in hypertonic conditions than in normal and hypotonic conditions. Therefore, the increase of dry weight per thallus area may not only be due to desiccation but also to some other stimulation. In the present culture experiment, thalli with periodical emersion were thinner than those without emersion, but the dry weight per unit thallus area was greater in thalli with periodical emersion than in those without emersin. This indicates that the thalli with periodical emersion had higher cell content than those without emersion.

Comparisons of photosynthesis-light curves of thalli with periodical emersion with thalli without emersion were reported by OGATA and SCHRAMM (1971) using *Porphyra umbilicalis* and OOHUSA *et al.* (1978) using *P. yezoensis* f. *narawaensis*. OGATA and SCHRAMM (1971) reported that rates of O_2 output on a thallus area basis were in general slightly higher in the algae desiccated every day than in those continuously submerged. OOHUSA *et al.* (1978) reported that photosynthesis on a dry weight basis of thalli with periodical emersion was lower than that of thalli without emersion. In the present work, photosynthesis on a thallus area basis was higher in thalli with periodical emersion than in thalli without emersion. When the same value was expressed on a dry weight basis, photosynthesis of thalli with periodical emersion was lower than that of thalli without emersion. Furthermore, when the same value was expressed on a chlorophyll *a* basis, the difference in photosynthesis between the two types of thalli was very small (Fig. 6). It seems that photosynthetic activity per chlorophyll *a* is not changed by emersion treatment. The difference of photosynthesis-light curves on a dry weight basis from those on a thallus area basis depends on the change in chlorophyll *a* content (Fig. 8). After 29 days of daily emersion in dark, photosynthesis-light curves on a chlorophyll *a* basis differed only slightly (Fig. 7). It is not known whether this difference resulted from the difference among individual thalli or from some other factors.

The respiration rates of thalli under periodical emersion and submersion conditions were low and the differences were negligible.

The color of thalli with periodical emersion was observed to be more reddish than that of thalli without emersion. The result of quantitative measurements of phycoerythrin and phycocyanin indicated that the ratio of phycoerythrin to phycocyanin content was higher in thalli with periodical emersion than in thalli without emersion (Fig. 10).

The after-effects of dehydration on photosynthesis were studied by KALTWASSER (1938), SCHRAMM (1968) and SCHONBECK and NORTON (1978). SCHONBECK and NORTON

(1978) reported that the ability to resume photosynthesis and growth when re-submerged was greatest in the species found highest on the shore, and was progressively less in species inhabiting successively lower tidal levels. IWASAKI and MATSUDAIRA (1956) reported that the exposure had no significant effect on the photosynthetic activity of the *Porphyra* thallus during a period of less than 9 days. WATANABE *et al.* (1971) determined the after-effects of desiccation using the peroxidase activity of thalli that had been emerged for 8 hrs in the light period. They noted that those thalli recovered fully 5 hrs after re-transferred to seawater, and that the peroxidase activity of thalli which had been emerged for 8 hrs in the dark period fully recovered 3 hrs after re-transferred to seawater. In the present work, the thalli in both treatments were emerged for 23 hrs. The ability to resume photosynthetic activity when re-submerged was greater in the thalli cultured with periodical emersion than in the thalli cultured without emersion (Fig. 11). In other words, the emersion-treated thalli had greater emersion tolerance.

The present experimental result on the effects of emersion on *Porphyra yezoensis* shows that the cell contents of thalli with periodical emersion were still complete within 2 weeks and that the emersion tolerance developed.

Observations of *Porphyra yezoensis* f. *narawaensis* thalli cultivated on a fixed pole system and on a floating system under field conditions were also conducted. These observations were discontinued, however, only after one week due to a disease in the thalli. During this period there was no change observed in the photosynthesis-light curves and thalli color, but the dry weight per unit thallus area and the after-effects of desiccation on photosynthesis as well as the variation of chlorophyll *a* content had the same tendency as those of laboratory experiments.

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田尻純仁・有賀祐勝： スサビノリ葉状体の生長および光合成に及ぼす干出の影響

ノリ葉状体の生長および光合成に及ぼす干出の影響を調べるため，室内培養したノリを用いて実験を行った。10時間明期（10 klux）・14時間暗期，15°C で培養したスサビノリに葉齢約35日から1日3時間の干出を与え，数日間隔で葉長，葉幅，光合成，呼吸，光合成色素含量などを測定し，無干出のものと比較した。干出を与えた葉状体では，厚さが薄くなり，葉長の生長速度は低下するが，干出処理開始後 1～2 週間で細胞内容物が無干出のものより充実し，また干出後海水中にもどしたときの光合成活性回復の速さからみて干出に対する耐性を得たと判断される。葉面積あたりの光合成活性は干出を与えた葉状体の方が無干出の葉状体より高かったが，Chl. *a* 量あたりの光合成活性は干出を与えた葉状体でも無干出の葉状体でも変らなかった。これは葉面積あたりの Chl. *a* 含量が干出を与えたものの方が無干出のものより高いことと関連しており，葉重あたりの Chl. *a* 含量は干出を与えたものの方が無干出のものより低かった。(108 東京都港区港南 4-5-7　東京水産大学水産植物学研究室)