

Comparisons of Germling Growth Abilities under Various Culture Conditions among Two *Sargassum horneri* Populations and *S. filicinum* in Hiroshima Bay

Goro Yoshida*¹, Noboru Murase*², and Toshinobu Terawaki*¹

Abstract The effects of irradiance and temperature on germling growth were studied under laboratory conditions and compared among the Ohno-seto (autumn-fruiting) and Matsugahana (spring-fruiting) *Sargassum horneri* populations and *S. filicinum* in Hiroshima Bay. Relative thallus area (leaves and stipes) and rhizoid area were used as indices of growth.

The relative thallus area increased until saturation at 100 to 200 $\mu\text{Em}^{-2}\text{s}^{-1}$, ranging from 12.5–400 $\mu\text{Em}^{-2}\text{s}^{-1}$ at 20°C for all materials. The relative rhizoid area increased until saturation at about 50 $\mu\text{Em}^{-2}\text{s}^{-1}$ for germlings of the Ohno-seto *S. horneri* population, but no clear relationships between the relative rhizoid area and irradiance gradient were observed for the Matsugahana *S. horneri* population and *S. filicinum*.

In the 5–30°C temperature range, the relative thallus and rhizoid areas of all three materials exhibited the greatest increases at 20 or 25°C under a constant illumination of 100 $\mu\text{Em}^{-2}\text{s}^{-1}$, and at around 15°C under 25 $\mu\text{Em}^{-2}\text{s}^{-1}$.

Although the Ohno-seto *S. horneri* population showed slightly different results from the Matsugahana *S. horneri* population and *S. filicinum*, the relationships between germling growth and culture condition gradients (irradiance and temperature) were very similar among the three materials.

Key words: *Sargassum horneri*, *Sargassum filicinum*, germling growth, irradiance, temperature, physiological disparity between populations

Sargassum horneri (Turner) C. Agardh and *S. filicinum* Harvey belong to a specific group (subdivision *Spongocarpus* in the subgenus *Bactrophyucus*) in the genus *Sargassum*. *S. horneri* is distributed widely along the Japanese coast except for eastern Hokkaido (Yoshida 1983), and is one of the most common and important species contained in *Sargassum* beds. Therefore, it has been the subject of many ecological studies (Marui *et al.* 1981, Umezaki 1984, Terawaki 1986, Taniguchi and Yamada 1988, Yoshida *et al.* 1997b, Yoshida *et al.* 1998). In contrast, *S. filicinum* is restricted to the western part of Japan, exhibiting a more scattered distribution pattern (Okuda 1977, Yoshida 1983). Ecological information on this species is scarce.

Both are annual species and are the exclusive members of the *Spongocarpus*, characterized by their thallus construction in which the stem continues to elongate without producing main branches during the course of

development (Yoshida 1983). Their morphological features are quite similar except for the vesicular form. *S. filicinum* vesicles are spherical to fusiform while *S. horneri* vesicles are cylindrical. Another prominent difference reported between the two species is that *S. horneri* is dioecious while *S. filicinum* is monoecious (Sawada 1955, Yoshida 1983).

Generally, *S. horneri* maturation occurs from winter to spring in the central and western parts of Japan (Umezaki 1984, Terawaki 1986, Okuda 1987). In the Seto Inland Sea, many ecological studies have shown that *S. horneri* matures in spring, generally from March to May (Kohmoto and Tomiyama 1968, Yamauchi 1984, Yoshikawa and Tsukidate 1987). However, autumn-fruiting populations (maturation from October through to December) were also found around Hiroshima Bay in the 1980s (Takaba and Mizokami 1982, Okuda 1987), and physiological and genetic disparities between local popu-

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*¹ 吉田吾郎・寺脇利信: 瀬戸内海区水産研究所 〒739-0452 広島県佐伯郡大野町丸石2-17-5 (G. Yoshida and T. Terawaki: National Research Institute of Fisheries and Environment of Inland Sea, 2-17-5 Maruishi, Ohno, Saeki, Hiroshima 739-0452, Japan)

*² 村瀬昇: 水産大学校 〒759-6595 山口県下関市永田本町2-7-1 (N. Murase: National Fisheries University, 2-7-1 Nagatahonmachi, Shimonoseki, Yamaguchi, 759-6595, Japan)

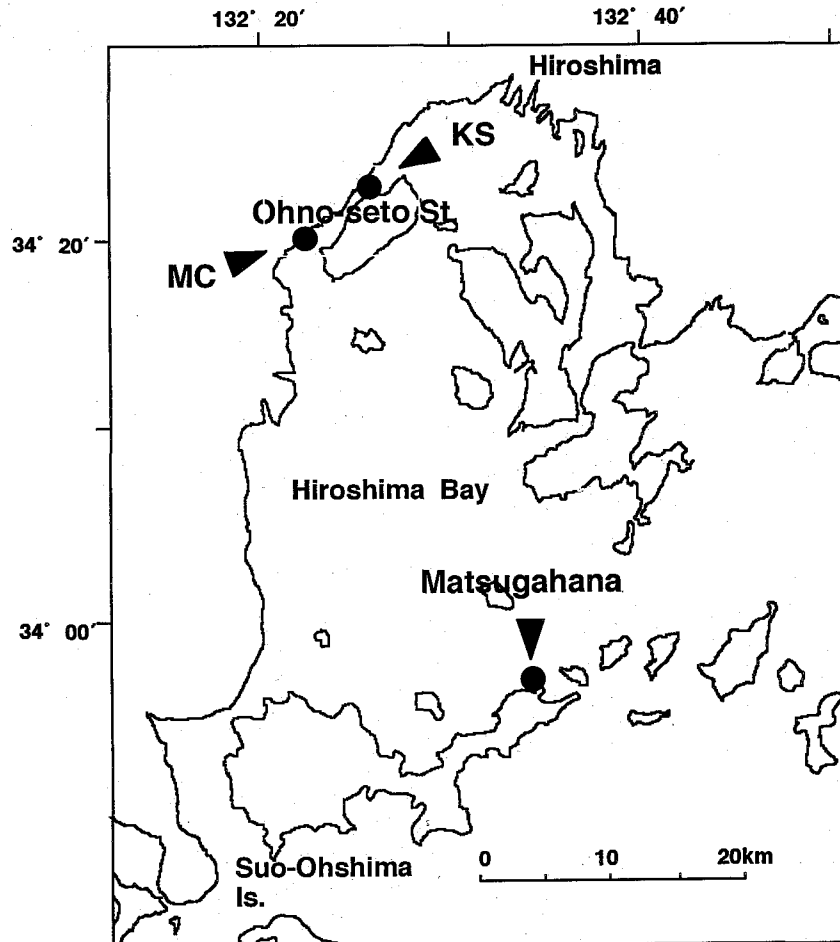


Fig. 1. Sampling sites for culture materials. MC (Maruishi Coast) for Ohno-seto *S. horneri*, KS (Kameno-se Shoal) for *S. filicinum*, Matsugahana for Matsugahana *S. horneri*

lations with different fertility seasons have been subjects of inquiry (Honda and Okuda 1989, Uchida and Arima 1993).

In a previous report, Yoshida *et al.* (1998) compared annual growth and maturation patterns between the autumn- and spring-fruiting types of *S. horneri* in Hiroshima Bay. Germlings of the autumn-fruiting type must grow in winter, when the water temperature is the lowest. In contrast, germlings of the spring-fruiting type can grow under more moderate temperature conditions. Because early life stages are supposed to be more sensitive to environmental fluctuations than adult forms and their survival is important to the subsequent establishment of stands (De Wreede 1978), growth abilities of germlings should be elucidated in relation to various environmental factors. In this study, embryos of two populations of *S. horneri* with different fertile seasons were cultured under various irradiance and temperature conditions, and the development of germling thallus and rhizoids was measured and compared.

Recent research has indicated that the distributional area of *S. filicinum* has spread, especially in the Seto Inland Sea replacing *S. horneri**). Therefore, *S. filicinum*

embryos from Hiroshima Bay were also cultured to elucidate germling growth ability in comparison with *S. horneri*.

Materials and methods

Culture materials Materials for culture were sampled at the Ohno-seto Strait and Matsugahana in Hiroshima Bay, western Seto Inland Sea (Fig. 1). For the Ohno-seto *S. horneri* population (autumn-fruiting population), oospore release was observed from November to February, and for the Matsugahana *S. horneri* population (spring-fruiting population), from April to May in 1995–6 (Yoshida *et al.* 1998). Fertile plants of *S. horneri* were collected at the Maruishi Coast of Ohno-seto in December 1996 and at Matsugahana in May 1996. Collected plants were brought to the National Research Institute of Fisheries and Environment of Inland Sea (formerly Nansei Nat. Fish. Res. Inst.) and female and male plants

*) M. Mizutani and T. Okuda, 1992: Crossing between *Sargassum horneri* and *S. filicinum*. Proceedings of the autumnal meeting of The Japanese Society of Fisheries Science, p. 109.

were cultured together in outdoor tanks until embryos were released. *S. horneri* embryos for culture studies were isolated on 16th Dec. 1996 for the Ohno-seto plants and on 19th May 1996 for the Matsugahana plants (Table 1).

Fertile *S. filicinum* plants were sampled at Kamen-

se Shoal in Ohno-seto in June 1996 (Fig. 1). The plants have fusiform vesicles (Fig. 2a), which are morphologically different from vesicles of *S. horneri* (Fig. 2c). The leaves exhibit a coarser pinnatisected appearance than those of *S. horneri* used in this study (Fig. 2b and d). Although the receptacles were not examined in detail,

Table 1. Profiles of culture materials for *Sargassum horneri* and *S. filicinum*

	<i>S. horneri</i>		<i>S. filicinum</i>
	Ohno-seto	Matsugahana	Ohno-seto
Sampling sites	Ohno-seto	Matsugahana	Ohno-seto
Depth (m)	2.0	2.0	4.0
Water temperature (°C) when oospores were released	13.4	15.0	19.0
Date of isolation	16th Dec. 1996	19th May 1996	14th Jun. 1996
Size of embryos when isolated (μm)	240±25×188±20	284±26×241±26	293±23×219±21
Initial area (mm ²)			
Thallus	0.047±0.006	0.093±0.009	0.064±0.009
Rhizoids	0.006±0.002	0.030±0.006	0.075±0.012

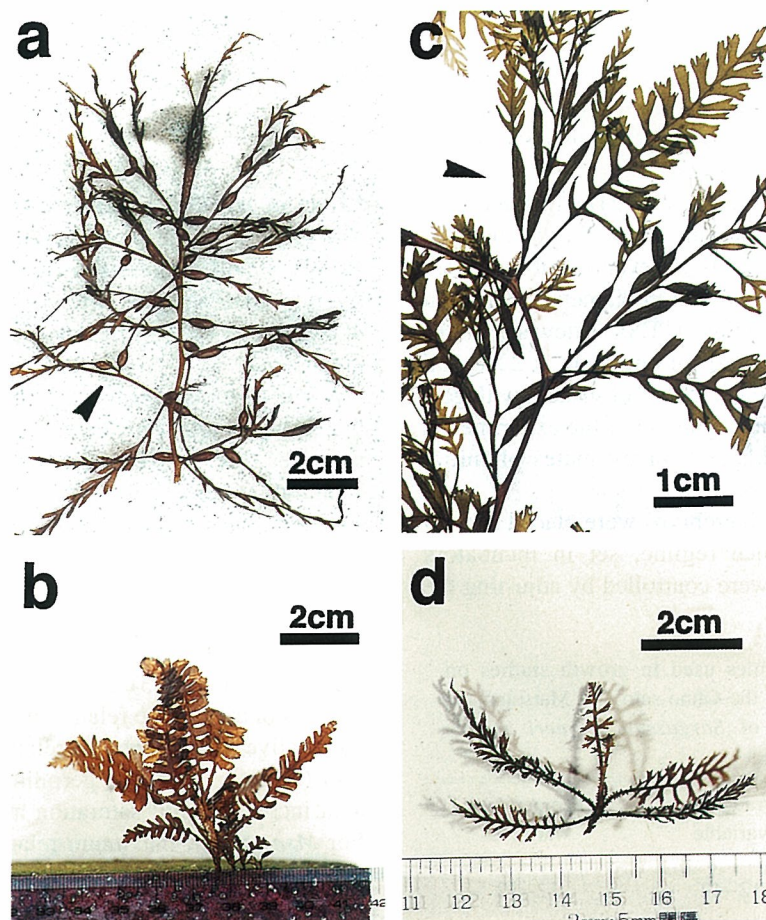


Fig. 2. Morphological differences between *S. filicinum* and *S. horneri* in Hiroshima Bay. Fusiform vesicles on a fertile branch (a) and a young plant of *S. filicinum* (b). Cylindrical vesicles of Ohno-seto *S. horneri* (c) and a young plant of Matsugahana *S. horneri* (d).

self-fertilized embryos were observed on a single plant left in a tank, indicating the plant was monoecious. Embryos for culture were isolated on 14th June 1996 (Table 1).

In this study, we use the abbreviations *Osh* (Ohno-seto population of *S. horneri*), *Msh* (Matsugahana population of *S. horneri*) and *Sf* (*S. filicinum*) for the algal materials. The average embryo size of the two *S. horneri* materials and *S. filicinum* and water temperature when embryos were released are shown in Table 1.

Culture experiments As indices of germling growth, projected areas of the thallus (leaves and stipes) and rhizoids (hereafter, thallus and rhizoid area) were measured instead of thallus and rhizoid length. One reason for this is that when cultured under various conditions, germling leaves exhibit various morphologies (Yoshida *et al.* 1995), and therefore thallus area was believed to be a more suitable growth index than thallus length. A second reason is associated with their ecological functions (Yoshida *et al.* 1997a). During early developmental stages, leaves are continuously produced at the basal part of the thallus (Yoshida 1984), so the growth occurs as horizontal expansion rather than vertical elongation, which is advantageous for efficiency capturing light energy for photosynthesis. Rhizoids are essential organs which ensure germlings attach to the substrata tightly, so their growth as horizontal expansion is also considered important for germling survival.

Culture methods, regimes (Table 2) and the methodology used for growth measurements follow those of Yoshida *et al.* (1997a). Sixty to seventy embryos were dispersed in petri dishes (90 mm in diameter; 15 mm in depth) with 30 ml of medium (PESI, Tatewaki 1966). Petri dishes were shaded, left for one night at 22°C and embryos were made to attach to the substratum with germinated rhizoids. At the beginning of the experiments, germlings were photographed for estimates of initial thallus and rhizoid area.

Two petri dishes with embryos were placed in each temperature or irradiance regime, set in incubators (Table 2). Irradiances were controlled by adjusting the

distance from light sources and by covering dishes with shielding nets, and checked by a LI-COR spherical quantum system. Ten to twenty (or more) plants were picked randomly from each dish and preserved in 5% formalin-seawater solution every 7 days. Media were renewed every 2–3 days.

Ten preserved samples were supplied for measurement in each regime. Thallus and rhizoid areas were photographed separately and each area was measured with a picture-analysis application for Macintosh (NIH-Image). Relative thallus and rhizoid areas were calculated by dividing the areas after 2 and 4 weeks of culture by the initial areas (Table 1).

Temperature and irradiance survey at each habitat

Surface water temperature was measured weekly at Ohno-seto *S. horneri* habitat and monthly at Matsugahana *S. horneri* habitat from May 1996 to May 1997. Irradiance survey was carried out twice or three times a week from January to December in 1995 at Ohno-seto *S. horneri* habitat and a portion of the results is in Yoshida *et al.* (1997b). Irradiance survey at Matsugahana habitat was conducted monthly with the temperature survey. A LI-COR spherical quantum system was also used to elucidate field light conditions. All measurements were carried out in the day time (11:00–14:00).

Results

Effect of irradiance on growth Relative thallus and rhizoid areas of the germlings of *Osh*, *Msh* and *Sf* under various irradiances are shown in Figs. 3 and 4, respectively. *Msh* samples after 4 weeks of culture under 400 $\mu\text{Em}^{-2}\text{s}^{-1}$ were lost due to contamination by blue-green algae.

The patterns of increase in relative thallus area with increasing irradiance were quite similar among the three materials (Fig. 3). Relative thallus area increased until saturation around an irradiance of 100 to 200 $\mu\text{Em}^{-2}\text{s}^{-1}$. The maximum relative thallus areas after 4 weeks were 630.2 (at 200 $\mu\text{Em}^{-2}\text{s}^{-1}$), 348.5 (at 200 $\mu\text{Em}^{-2}\text{s}^{-1}$) and 518.5 (at 400 $\mu\text{Em}^{-2}\text{s}^{-1}$) for *Osh*, *Msh* and *Sf*, respectively. Thallus areas at those irradiances after 4 weeks were 29.8, 32.3 and 33.0 mm² for *Osh*, *Msh* and *Sf*, respectively (Table 3).

In contrast to the relative thallus area, the results of the relative rhizoid area are relatively unclear except for *Osh* (Fig. 4). For *Osh* germlings, the relative rhizoid area increased until saturation at around 50 $\mu\text{Em}^{-2}\text{s}^{-1}$. For *Msh* and *Sf*, maximum relative rhizoid areas were observed at relatively lower irradiances (at 25 $\mu\text{Em}^{-2}\text{s}^{-1}$ for *Msh* and at 50 $\mu\text{Em}^{-2}\text{s}^{-1}$ for *Sf*) and relative areas at higher irradiances were smaller for both materials. The maximum relative rhizoid areas after 4 weeks for *Osh*, *Msh* and *Sf* were 107.0 (at 400 $\mu\text{Em}^{-2}\text{s}^{-1}$), 25.1 (at 25 $\mu\text{Em}^{-2}\text{s}^{-1}$) and 12.3 (at 50 $\mu\text{Em}^{-2}\text{s}^{-1}$), respectively. The

Table 2. Culture regimes used in growth studies on germlings of the Ohno-seto and Matsugahana populations of *Sargassum horneri* and *S. filicinum*

	Irradiance variable	Temperature variable
Photoperiod (hrs) (light-dark)	12–12	12–12
Irradiance ($\mu\text{Em}^{-2}\text{s}^{-1}$)	12.5, 25, 50, 100, 200, 400	25, 100
Temperature (°C)	20	5, 10, 15, 20, 25, 30

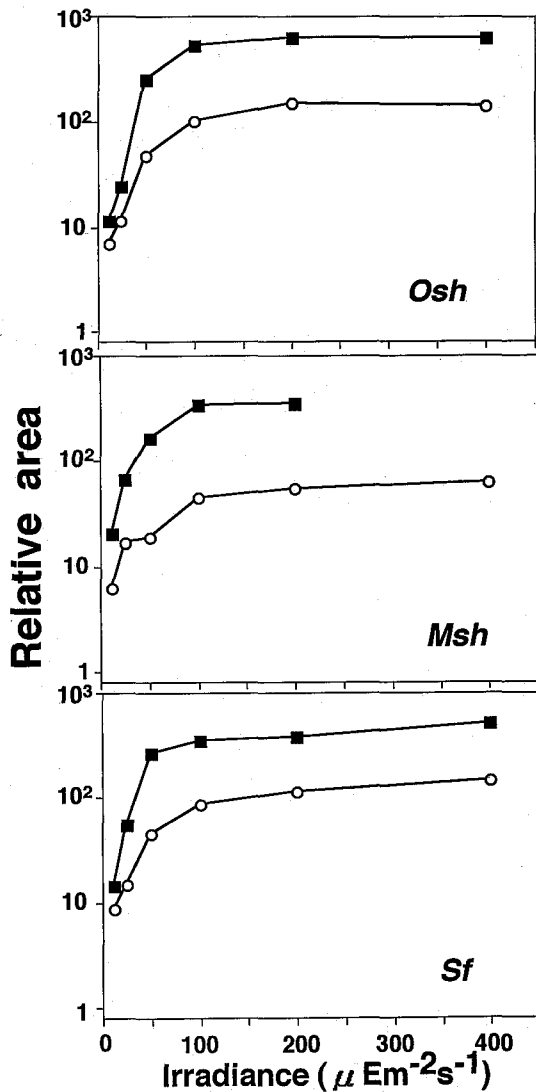


Fig. 3. Relative thallus areas of germlings from the Ohno-seto (*Osh*) and Matsugahana (*Msh*) populations of *S. horneri* and *S. filicinum* (*Sf*) under various irradiances. Initial area=1
After 2 (—○—) and 4 (—■—) weeks of culture.

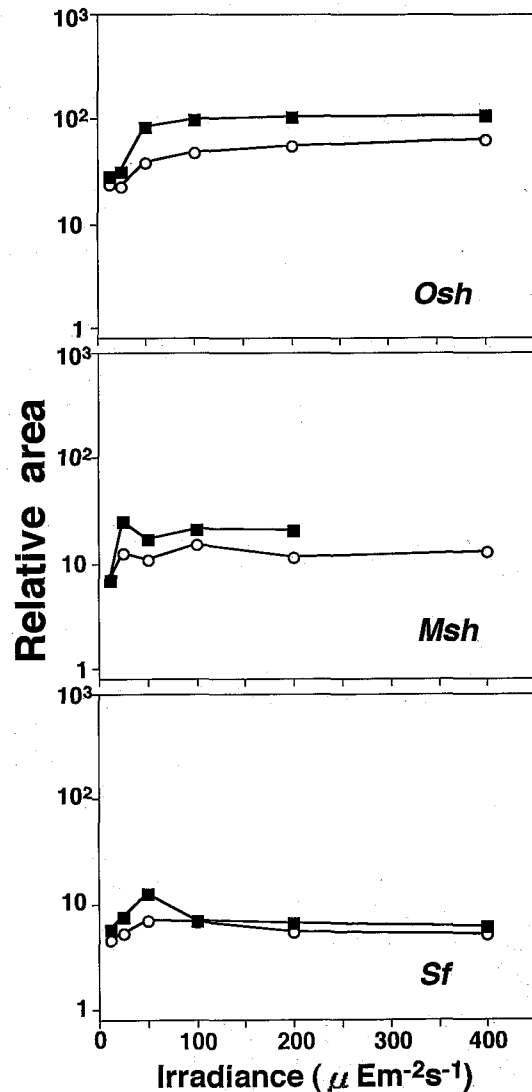


Fig. 4. Relative rhizoid areas of germlings from the Ohno-seto (*Osh*) and Matsugahana (*Msh*) populations of *S. horneri* and *S. filicinum* (*Sf*) under various irradiances. Initial area=1
After 2 (—○—) and 4 (—■—) weeks of culture.

large increase observed in *Osh* was due to the low initial value at the start of culture (Table 1). The average rhizoid areas after 4 weeks of culture for *Osh*, *Msh* and *Sf* were 0.64, 0.76 and 0.92 mm², respectively (Table 4).

Effect of temperature on growth Relative thallus and rhizoid areas for *Osh*, *Msh* and *Sf* after 4 weeks of culture under various temperature conditions at irradiances of 25 and 100 μEm⁻²s⁻¹ are shown in Figs. 5 and 6, respectively. The patterns of relative thallus and rhizoid area increase along the temperature gradient are similar among the three materials, especially between *Msh* and *Sf*.

In terms of relative thallus area (Fig. 5), *Osh* germlings achieved the greatest growth at 25°C under

Table 3. Maximum thallus area of *Sargassum horneri* and *S. filicinum* achieved after 4 weeks of culture in the irradiance experiment and conditions

Condition (μEm ⁻² s ⁻¹)	<i>S. horneri</i>		<i>S. filicinum</i>
	Ohno-seto	Matsugahana	
Average thallus area (mm ²)	29.8±2.9	32.3±1.8	33.0±4.5
Average length of thallus (mm)	7.8±0.5	8.4±0.7	8.7±0.8
Average number of leaves	7.8	6.7	6.8

Table 4. Maximum rhizoid area of *Sargassum horneri* and *S. filicinum* achieved after 4 weeks of culture in the irradiance experiment and conditions

condition ($\mu\text{Em}^{-2}\text{s}^{-1}$)	<i>S. horneri</i>		<i>S. filicinum</i>
	Ohno-seto	Matsugahana	
	200	25	50
Average rhizoid area (mm^2) at the maximum	0.64 ± 0.14	0.76 ± 0.28	0.92 ± 0.12
Average length of rhizoids (mm)	1.1 ± 0.2	1.5 ± 0.3	1.8 ± 0.2

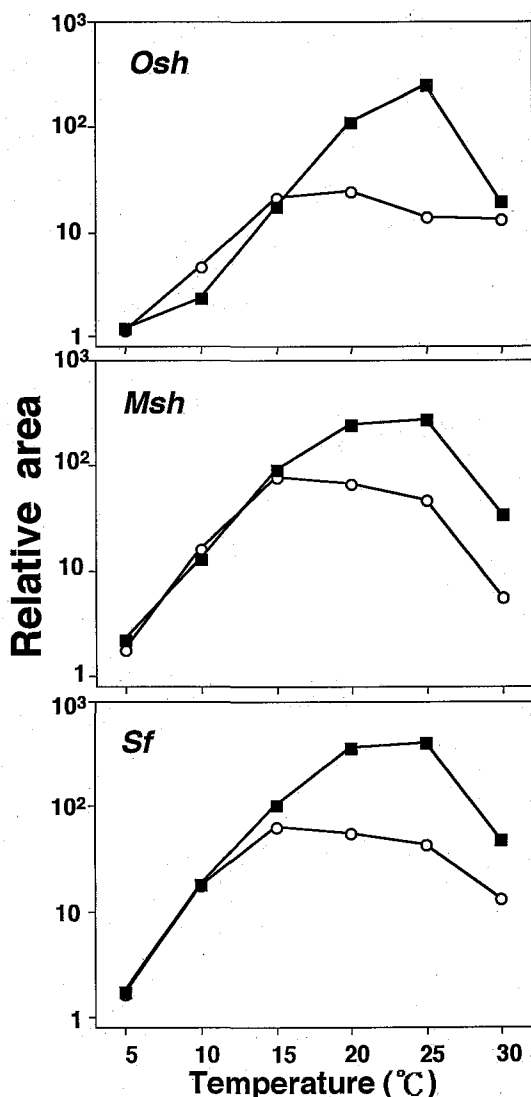


Fig. 5. Relative rhizoid areas of germlings from the Ohno-seto (*Osh*) and Matsugahana (*Msh*) populations of *S. horneri* and *S. filicinum* (*Sf*) under various temperatures after 4 weeks of culture. Initial area=1 Under 25 (\circ) and 100 (\blacksquare) $\mu\text{Em}^{-2}\text{s}^{-1}$.

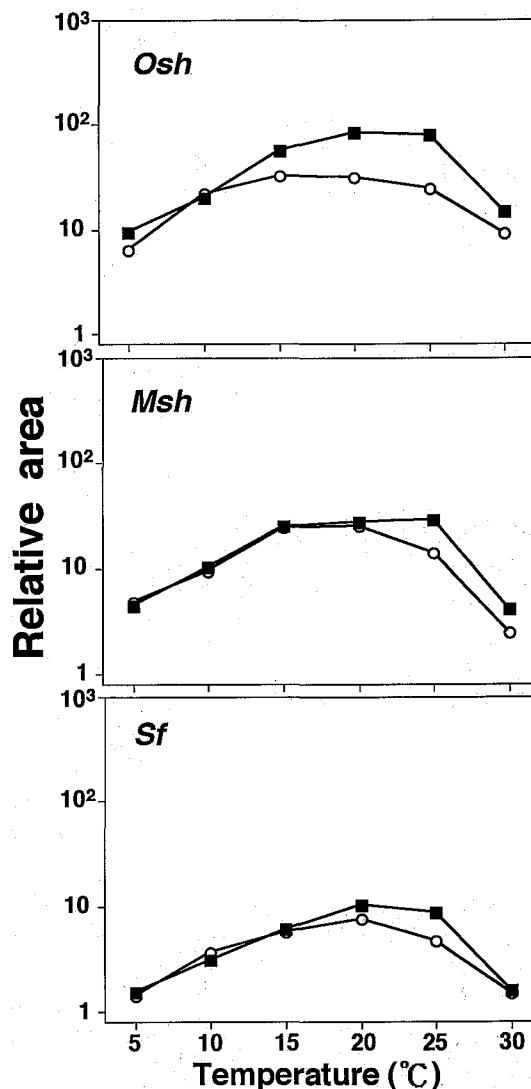


Fig. 6. Relative rhizoid areas of germlings from the Ohno-seto (*Osh*) and Matsugahana (*Msh*) populations of *S. horneri* and *S. filicinum* (*Sf*) under various temperatures after 4 weeks of culture. Initial area=1 Under 25 (\circ) and 100 (\blacksquare) $\mu\text{Em}^{-2}\text{s}^{-1}$.

$100 \mu\text{Em}^{-2}\text{s}^{-1}$ and at 15 or 20°C under 25 $\mu\text{Em}^{-2}\text{s}^{-1}$. At 10°C, thallus area increased more at 25 $\mu\text{Em}^{-2}\text{s}^{-1}$ than at 100 $\mu\text{Em}^{-2}\text{s}^{-1}$. For *Msh* and *Sf*, the maximum thallus area was also observed between 20 and 25°C under 100 $\mu\text{Em}^{-2}\text{s}^{-1}$, and at around 15°C under 25 $\mu\text{Em}^{-2}\text{s}^{-1}$. Under temperature conditions below 15°C, the relative thallus area did not differ markedly between 25 and 100 $\mu\text{Em}^{-2}\text{s}^{-1}$. Thallus of germlings in all algal samples raised at 30°C failed to grow prominently. Instead they exhibited abnormal development, taking on a clump-like appearance.

In terms of relative rhizoid area (Fig. 6), temperature conditions under which the greatest increase was observed were around 20–25°C under 100 $\mu\text{Em}^{-2}\text{s}^{-1}$ for all three materials. Under 25 $\mu\text{Em}^{-2}\text{s}^{-1}$, the optimum temperatures for rhizoid increase became lower, as

observed for the relative thallus area. For *Msh* and *Sf*, no considerable difference in the relative rhizoid area between 25 and 100 $\mu\text{Em}^{-2}\text{s}^{-1}$ was observed below 15°C. Rhizoid development was also inhibited at 30°C for all three materials under both irradiances.

Temperature and irradiance conditions at each habitat Water temperature fluctuation in the Ohno-seto and Matsugahana *S. horneri* habitats is in Fig. 7. The lowest temperature was observed in February at both habitats, 10.1°C at Ohno-seto and 10.4°C at Matsugahana. Maturation period of both *S. horneri* populations indicated in Yoshida *et al.* (1998) is also in Fig. 7.

The average irradiance at the open seafloor (2 m in depth, where *S. horneri* plants mainly distribute) during the survey was about 30% that at the surface and about 300 $\mu\text{Em}^{-2}\text{s}^{-1}$ in the day time (11:00–14:00).

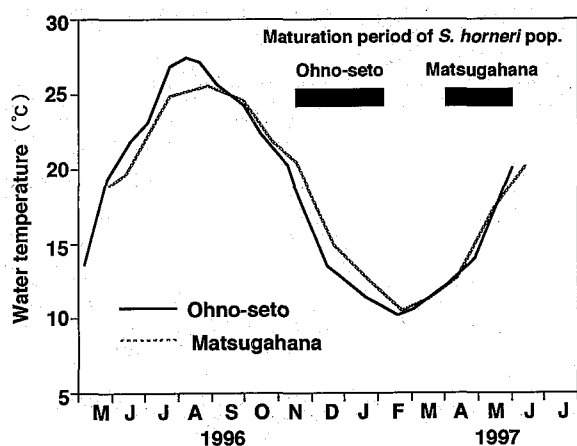


Fig. 7. Water temperatures at Ohno-seto and Matsugahana habitats and maturation period of both populations of *S. horneri*.

Discussion

In the irradiance experiments, patterns of the increase in relative thallus area under various irradiances were quite similar among the three materials. Saturation occurred at around 100 to 200 $\mu\text{Em}^{-2}\text{s}^{-1}$. Relative rhizoid area increase occurred until saturation was observed around 50 $\mu\text{Em}^{-2}\text{s}^{-1}$ for *Osh*, but the results for *Msh* and *Sf* were relatively unclear. Relative rhizoid areas of *Msh* and *Sf* exhibited peaks at relatively lower irradiances (at 25 $\mu\text{Em}^{-2}\text{s}^{-1}$ for *Msh* and at 50 $\mu\text{Em}^{-2}\text{s}^{-1}$ for *Sf*) and decreased under higher irradiances. It is possible that rhizoid growth of *Msh* and *Sf* was promoted more under lower irradiances, or that irradiance level had little effect. The results of the temperature experiments indicate that the relative rhizoid areas of *Msh* and *Sf* did not differ considerably between 25 and 100 $\mu\text{Em}^{-2}\text{s}^{-1}$ at 20°C (the temperature condition set in the irradiance experiment). Therefore, it appears reasonable to conclude that irradiance had little effect on *Msh* and *Sf*

rhizoid growth. If so, the peaks in rhizoid area for *Msh* and *Sf* at lower irradiances in the irradiance experiment were due to other factors.

The present results for the germling growth of *S. horneri* and *S. filicinum* under various irradiances were quite different from the results of *S. macrocarpum*, which is a perennial species with a supposed longevity of 8 or 9 years (Yoshida 1983, Murase and Kito 1998). The relative thallus area of *S. macrocarpum* increased until saturation at an irradiance of 50 $\mu\text{Em}^{-2}\text{s}^{-1}$, with saturation for rhizoid area (as 'attachment' area in Yoshida *et al.* 1997a) occurring at 200 $\mu\text{Em}^{-2}\text{s}^{-1}$, indicating that allocation of assimilatory products to the attachment organs is more important than allocation to the thallus when surplus products are produced by photosynthesis. In contrast, it seems that allocation to the thallus is more important than to the rhizoids in *S. horneri* and *S. filicinum*. This difference between species can be explained in terms of differing survival and population maintenance strategies for annual and perennial species. In annual species such as *S. horneri* and *S. filicinum*, germlings have to compete with other algal species for light and achieve rapid thallus growth. In perennial species such as *S. macrocarpum*, germlings have to spend a certain period under the canopy of adult plants, where shady conditions prevail and other competitive algae are rare. Germling growth tends to be slow until the canopy opens due to the death of adult plants. In addition, the survival of individuals is more important in maintaining *S. macrocarpum* populations, whereas annual species maintain populations by producing a large number of gametes alone. Assimilatory energy in perennial species might be allocated more into the development of the holdfast, which sustains the plant for several years.

In the temperature experiment, the results for all three materials were similar, although *Osh* differed slightly from *Msh* and *Sf*. For all three materials, the greatest increases in both the relative thallus and relative rhizoid areas were obtained at 20 or 25°C under 100 $\mu\text{Em}^{-2}\text{s}^{-1}$, and at around 15°C under 25 $\mu\text{Em}^{-2}\text{s}^{-1}$. Similar phenomena have been observed in the photosynthetic reactions of other seaweeds. In several Laminariales species, the optimum temperatures for net-photosynthesis rates shift lower as the available light decreases (Sakanishi and Iizumi 1998). As the materials for plant growth are based upon photosynthetic activity, it is possible that similar trends could be observed in the growth studies.

At temperatures below 15°C in our studies, the difference in growth of both the thallus and rhizoids achieved under 25 and 100 $\mu\text{Em}^{-2}\text{s}^{-1}$ lessened. As there was a prominent difference in growth between 25 and 100 $\mu\text{Em}^{-2}\text{s}^{-1}$ over 15°C, increased irradiance promotes germling growth at temperatures over 15°C. In contrast below 15°C, germling growth is suppressed even though

irradiance is sufficient, which indicates that water temperature limits growth below 15°C.

The *Osh* and *Msh* populations release embryos from November to February and from April to May, respectively (Yoshida *et al.* 1998). *Osh* germlings have to spend 2 or 3 months at the lowest water temperature (10 to 12°C, from January to March at Ohno-seto, Fig. 7), although germlings of *Msh* can grow under more moderate temperatures (13 to 17°C, in April and May at Matsugahana, Fig. 7). The growth of *Osh* germlings in the natural habitat during winter and early spring is very slow (daily increase in thallus length: $< 0.1 \text{ mm d}^{-1}$, Yoshida *et al.* 1998), and after May when the water temperature rises, the growth rate increases ($> 0.3 \text{ mm d}^{-1}$, Yoshida *et al.* 1998). As the present results indicate, *Osh* growth during winter and early spring was suppressed by low water temperature. In contrast, *Msh* germling growth was steadier (increase in thallus length: $0.1\text{--}0.3 \text{ mm d}^{-1}$, Yoshida *et al.* 1998) due to moderate water temperature conditions. However, when temperature conditions are suitable, light conditions are likely to be the key for germlings to achieve smooth growth, as indicated in the present results. The average irradiance at the open seafloor at both *S. horneri* habitats is about $300 \mu \text{Em}^{-2}\text{s}^{-1}$ in the day time. However, microhabitat conditions for germlings are often shaded by the canopy of other algae, especially in the Ohno-seto habitat. There is a luxuriant cover of *Ulva pertusa* and some red algae, such as *Gelidium elegans*, on the substrata during winter and early spring at Ohno-seto (Terawaki *et al.* 1998), and it is impossible to find germlings growing on the natural substrata during these seasons (Yoshida *et al.* 1997b). If germling shading continues beyond May when the temperature increases, it is possible that young plants could not grow sufficiently to develop a stand. This is a possible reason to explain the lower population density of adult *S. horneri* plants in the Ohno-seto habitat ($0.4 / \text{m}^2$, estimated from the result of Yoshida *et al.* 1997b) compared to the Matsugahana habitat (about $30 / \text{m}^2$, Nakamura and Miyago 1982), where a lower cover of other algae competitive with *S. horneri* germlings occurs.

Considering the results of a previous field survey (Yoshida *et al.* 1998) and the present culture studies, in which the physiological features of germlings of both populations were elucidated, the Ohno-seto population spends winter as germlings, although the growth rate is low, and the Matsugahana population spends winter as adults preparing for gamete release in spring. We suggest that there is an ecological reason behind the differences in maturation season and winter life history stage, which has resulted in both populations having the most suitable annual growth patterns for survival in each habitat. Slight differences between *Osh* and *Msh* were observed in the present results, and more research will be needed to elucidate the physiological features of the early

developmental stages of each population.

Similar results were obtained for all samples, particularly between Matsugahana *S. horneri* and *S. filicinum* in the present study. The *S. filicinum* embryos used in this study were isolated in June, but the appearance of the mother plants indicated that oospores were released prior to this. As Sawada (1955) also reported that the maturation season of *S. filicinum* occurs in late spring, the maturation seasons of *S. filicinum* and spring-fruiting *S. horneri* appear to overlap. Based on the present results, at least under laboratory conditions, the physiological features of germlings relating to irradiance and temperature exhibited no prominent difference between Matsugahana (spring-fruiting) *S. horneri* and *S. filicinum* in Hiroshima Bay.

A monoecious nature is considered to be advantageous for invading new areas by detachment and release of floating fertile branches (Paula and Eston 1987). Therefore, *S. filicinum* might have more potential to spread than *S. horneri*, even though the distribution of *S. filicinum* is currently more restricted than *S. horneri*. However, recent research indicates that *S. filicinum* is spreading, especially in the Seto Inland Sea^{*)}.

Some taxonomic problems remain unresolved for *S. horneri* and *S. filicinum*. First, although *S. horneri* had been reported to be strictly dioecious, some individuals with androgynous receptacles were found in recent studies (Okuda 1982, 1987). Therefore, *S. horneri* sexuality could be more complicated. Secondly, a crossing experiment between male gametes of *S. filicinum* and oospores of *S. horneri* succeeded, resulting in fertile offspring^{*)}. Thirdly, vesicular form, which is the only prominent difference in morphology between both species, is a quite ambiguous feature. The vesicular form has been reported to be spherical to fusiform for *S. filicinum*, and to be cylindrical for *S. horneri*. However, vesicular form has been found to vary between individuals in a series^{*)} (Sawada 1956). Given this, it may be difficult to discriminate between the two species with morphology alone. New techniques such as gene analysis should be introduced to discriminate between local populations of *S. horneri* and *S. filicinum*, in addition to detailed morphological analysis and comparisons of ecological and physiological features.

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広島湾の2つのアカモク個体群及びシダモクの初期成長特性の比較

吉田 吾郎・村瀬 昇・寺脇 利信

広島湾のアカモクの大野瀬戸個体群（秋季成熟）と松が鼻個体群（春季成熟）及びシダモクの幼胚を様々な光量子量及び水温下で培養し、その初期成長特性を比較した。葉状部と仮根部の投影面積を成長の指標として用いた。

12.5~400 $\mu\text{Em}^{-2}\text{s}^{-1}$ （水温 20°C）の光量子量の範囲では、3株の全てにおいて葉状部の面積の増加は100~200 $\mu\text{Em}^{-2}\text{s}^{-1}$ で飽和した。仮根部面積の増加は大野瀬戸のアカモクでは50 $\mu\text{Em}^{-2}\text{s}^{-1}$ でほぼ飽和したが、松が鼻のアカモクとシダモクでは仮根部の発達と光量子量の間には明確な関係は見られなかった。5~30°Cの水温の範囲においては、3株全てにおいて葉状部・仮根部面積ともに100 $\mu\text{Em}^{-2}\text{s}^{-1}$ 下では20~25°Cで最大の増加が見られたが、25 $\mu\text{Em}^{-2}\text{s}^{-1}$ 下では低温側にシフトし、15°Cで最大の増加が見られた。これらの結果をそれぞれの生育現場における生態特性と関連づけて論じた。