Seedling production technology for gametophytes of the red alga *Asparagopsis taxiformis* utilizing its life cycle

The red alga *Asparagopsis taxiformis* has recently attracted attention as a promising seaweed for reducing methane emissions from ruminant livestock due to its high content of bromoform, a compound known to inhibit microbial methanogenesis. However, the practical implementation of its aquaculture requires the establishment of a stable and efficient seedling supply system.

A. taxiformis has a heteromorphic life cycle that consists of sporophyte (2n) and gametophyte (n) phases. While sporophytes are too small to be cultured in marine environments, gametophytes are applicable to marine farming, which is less costly and suitable for large-scale cultivation. This study focuses on the alternation of generations in *A. taxiformis*, to develop techniques for seedling production suitable for sea-based cultivation by inducing spore release from sporophytes and promoting the growth of gametophytes.

The results demonstrate that sporophytes can be stably maintained at 20°C under a 12 h light: 12 h dark photoperiod, but maturation and tetraspore release are effectively induced under either elevated temperature (25°C) or short-day conditions (8 h light: 16 h dark). These two factors act independently, yet exhibit a synergistic effect when combined, reducing the time required for initial spore release to approximately 11 days. Under other conditions, neither maturation nor spore release was observed, indicating that precise environmental control is essential for reliable seed production.

Furthermore, the growth of gametophytes derived from spores is significantly enhanced under aerated culture conditions. Over a four-week period, the daily growth rate increased from 4.72% under static conditions to 6.86% with aeration. Aerated cultures also showed more pronounced development of upright axes, lateral branches, and basal structures. In addition, the bromoform content per unit dry weight was substantially higher under aeration, indicating improved functional quality.

These findings provide a practical foundation for low-cost, large-scale marine cultivation of *A. taxiformis* by enabling stable gametophyte seedling production independent of land-based systems.

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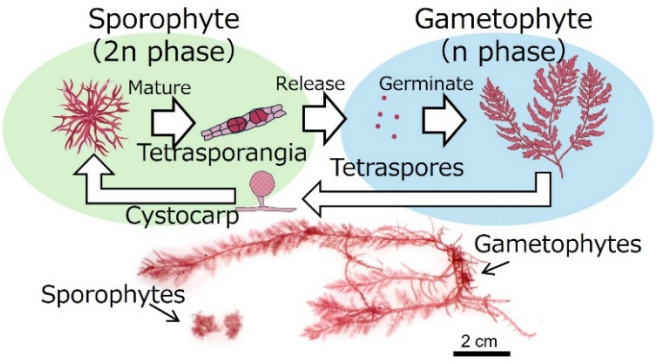

Fig. 1. Life cycle of *Asparagopsis*

The red alga *Asparagopsis taxiformis* has a life cycle in which the sporophyte (2n phase) and gametophyte (n phase) alternate generations. Upon maturation, the sporophyte forms tetrasporangia and releases tetraspores, which upon germination develop into gametophytes. The gametophytes reproduce sexually, forming a cystocarp through fertilization, which then develops into a sporophyte.

Water Temp	Light: Dark cycle	Spore Release
20 °C	L:D 12 h: 12 h	×
25 °C	L:D 12 h: 12 h	○
30 °C	L:D 12 h: 12 h	×
20 °C	L:D 14 h: 10 h	×
20 °C	L:D 12 h: 12 h	×
20 °C	L:D 10 h: 14 h	×
20 °C	L:D 8 h: 16 h	○

Table 1. Conditions for spore release

This table indicates whether spore release occurred (○) or did not occur (×) when *A. taxiformis* sporophytes were cultured for 21 days under different temperature and photoperiod conditions. L:D denotes the light period (L) and dark period (D); for example, L:D 12 h:12 h indicates a photoperiod of 12 hours light and 12 hours dark.

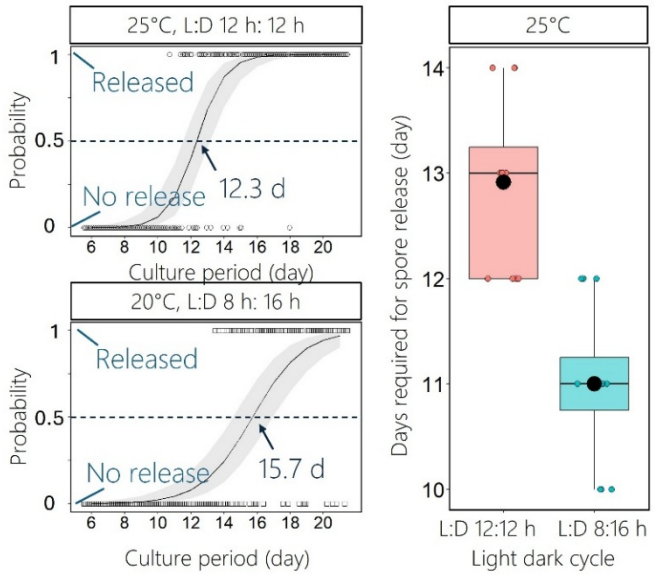

Fig. 2. Effects of temperature and photoperiod on spore release

The left panels show the probability of spore release (1 = occurred, 0 = not occurred) when sporophytes were cultured under a water temperature of 25°C or a photoperiod of 8 h: 16 h L:D. Arrows and shaded areas indicate the 50% spore release day and the 95% confidence interval estimated by binomial logistic regression. The right panel shows box plots of days to first spore release at 25°C under different photoperiods. ● = mean. (n = 12)

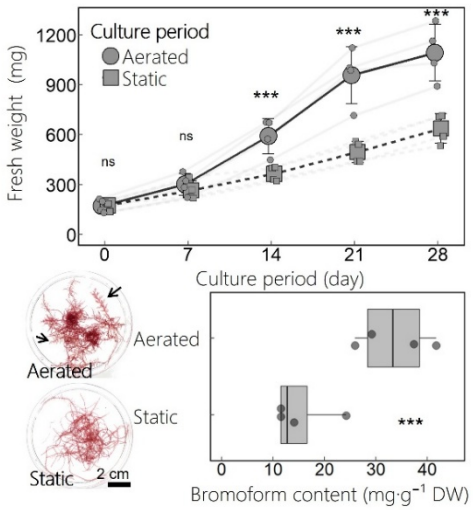

Fig. 3. Efficient cultivation method for gametophytes

Growth curves (upper graphs), morphology at day 28 (lower photos), and bromoform content per dry weight (lower graphs) of gametophytes cultured under aerated or static conditions. Arrows indicate the development of erect thalli with lateral branches. Fresh weight and bromoform content were compared using a generalized linear model. ns: $p > 0.05$; ***: $p < 0.001$ (n = 4)

Reference: Matsuda and Kuwano (2025) *Marine Biotechnol* 27:115.