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Effects of Light, Desiccation and Salinity for the Spore Discharge of *Gracilaria verrucosa* (Rhodophyta) in Korea

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The effects of light, desiccation and salinity on the discharge of spores in Korean agarophyte, *Gracilaria verrucosa* were studied. Among the examined factors, light after darkness was the most effective for spore discharge. The maximum release of tetraspores was induced at 24 h after the treatment. Desiccation also seems to be conductive to the release of tetraspores. However, its effect, as in treatment of distilled water for salinity, was hardly found in induction of carpospore discharge. This may suggest that spore discharge in this alga is primarily related with photoperiodic rhythm. Also it appears that the amount of light energy received by fertile thalli also significantly affects to the spore release, considering relationship between the amount of the discharged spores and the elapsed time after treatment.

Key words: Korean agarophyte, *Gracilaria verrucosa* (Rhodophyta), Spore discharge, Tetrasporore, Carpospore

Introduction

The red algal genus *Gracilaria* is of considerable economic importance as an algal source for agar production in Asia, South America and southern Africa (Santelices and Doty, 1989). Moreover, *Gracilaria* is used as food for both human (Abbott, 1988) and shellfish (abalone) (Critchley, 1993) and as chemical agarose for research (Renn, 1990). Also the genus has been now recognized as a potential source of pharmaceuticals such as antiviral compounds (Neushul, 1990) and anti-tumour compounds (Noda et al., 1990). This useful seaweed has been harvested from naturally occurring stocks in a number of countries. However, its natural production is not enough to offer raw material for the agar industry, because of declining populations due to over-harvesting. Hence, commercial cultivation has been practised in various places of several countries (Tseng, 1981).

In Korea, this agarophyte, *G. verrucosa* (Hudson) Papenfuss, grows on rocks, stones, gravels, which are in the littoral zone (Kang, 1968). In spite of its economical importance, this Korean alga has been little studied on its physiology, taxonomy and distribution. Only some studies have been undertaken by Koh (1969), Kim et al. (1993) and Lee et al. (1995).

In the course of the ecophysiological study on reproduction and growth of the Korean *G. verrucosa*, this study was attempted to examine the correlation between the spore liberation and environmental factors. Particularly, effects of light, desiccation and salinity on the spore discharge and the optimal condition including peak time for maximum spore liberation, which are potentially important in planning and executing *Gracilaria* cultivation, are examined in this study.

Materials and Methods

Fertile tetrasporophytes and carposporophytes of *G. verrucosa* were collected at the intertidal region

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of Chongsapo near Pusan, Korea, from August to October 1995. The plants were separately put into plastic bottles with seawater and transported to the laboratory. Fertile branches bearing many cystocarps or tetrasporangia were carefully excised to 10 mm in length and 10 fragments were placed in a petri dish containing 30 mL of sterilized seawater (35 ‰).

To examine the effects of light, desiccation and salinity on the discharge of carpo- and tetraspores, the excised fragments were treated with light after darkness and desiccation. Also cystocarps and tetrasporangia in the fertile fragments were stimulated with distilled water to determine the effects of salinity on the spore discharge.

In light experiments, the petri dishes with 10 fragments and seawater were wrapped using aluminum foil, kept for different dark periods (0.5, 1, 2, 4, 8, 12, 24, 48 h) and then placed under a 100 μmol photons $m^{-2}s^{-1}$ of irradiance. For desiccation experiments, fertile fragments were blotted with blotting paper to remove the moisture and exposed to air with the same intervals of light after darkness in the laboratory.

To count discharged spores, the spore suspension of each treatment was transferred to a test tube with a pipette, diluted with sterilized seawater in treatments that the concentration of spore suspensions was high, and then spore suspension of 1 mL was subsampled. Count of released spores was made under a microscope using a Sedwick Rafter counting chamber. So the spore liberation per a fragment (10 mm) was estimated by the mean values of three replicates.

Results and Discussion

The effects of light, desiccation and salinity on the release of tetraspores varied and the elapsed times also affected the tetra-spore discharge (Fig. 1). Light after darkness was the most effective method for induction of tetraspore release. Amount of tetraspore release was low at 1 and 2 h after the treatment, and then was gradually increased with the elapsed time. The peak of tetraspore discharge was found at 24 hours as about 80 cells/mL of spore suspension (Fig. 1).

In desiccation treatments, maximal tetraspore discharge occurred at 2 h as about 65 cells/mL, after that decreased rapidly with the elapsed time (Fig. 1). In experiment of the distilled water, gradual increasing of spore liberation was observed, attaining to the peak at 48 h as about 70 cells/mL (Fig. 1). However, most tetraspores discharged showed abnormal shapes (e.g. bleaching and small size, etc.) in the distilled water treatments.

For the liberation of carpospores, light after darkness was also very effective. However, unlike the case of tetraspore, amount of the spore liberation decreased gradually with the elapsed time after the treatment (Fig. 2). Carpospore discharge was not enhanced by desiccation and by distilled water treatments (Fig. 2).

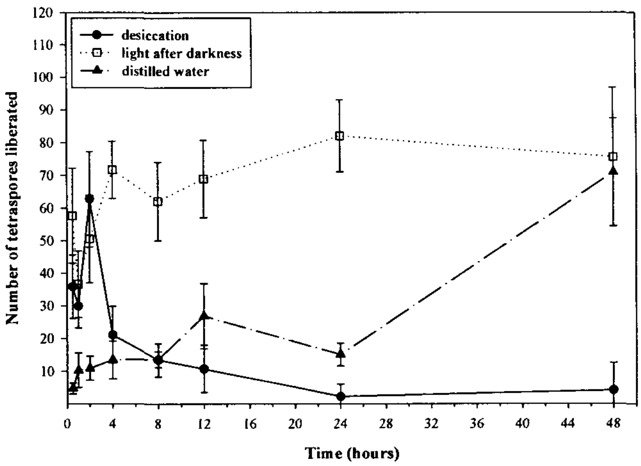

Fig. 1. **Effects of light, desiccation and salinity on the liberation of tetraspores from *Gracilaria verrucosa*.**

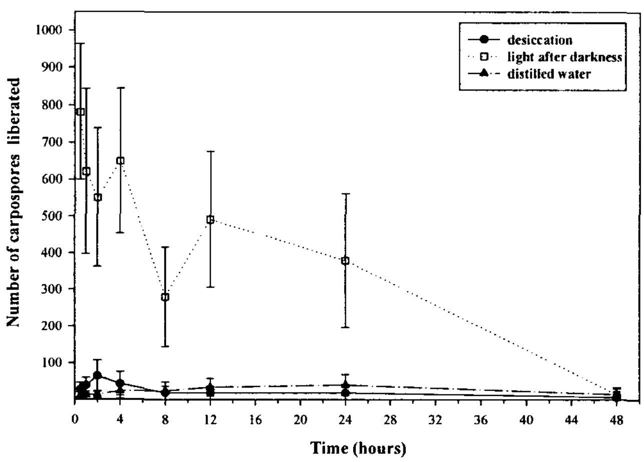

Fig. 2. **Effects of light, desiccation and salinity on the liberation of carpospores from *Gracilaria verrucosa*.**

Since the work of Suto (1950), some factors influencing spore discharge in red algae have been studied (Segawa et al., 1955; Umamaheswara Rao and Kaliaperumal, 1983). These limiting factors for spore discharge have been basically associated with fluctuating conditions of the environment, in which the algae grow.

As noted above, the maximum tetraspore release in the Korean *G. verrucosa* was induced at 24 h under light after darkness treatment. This may suggest that tetraspore discharge in this alga is closely related with photoperiodic rhythm due to alternation between darkness and daylight. Also it appears that the amount of light energy that fertile thalli received also significantly affected the spore release, considering relationship between the number of the discharged spores and the elapsed time, although Dixon (1970) pointed out that there were not clear cut examples in red algae showing the influence of the amount of light energy on the formation and release of spores.

It has been known that desiccation caused by tidal cycle is conductive to spore release in marine macroalgae (Segawa et al., 1955), with exception of some red algae, *Gelidium, Pterocladia* and *Gelidiopsis* (Umamaheswara Rao and Kaliaperumal, 1983). In Korean *G. verrucosa,* its distinctive effect for the induction of tetraspore discharge was also observed, even though it was not recognized for carpospores.

Spore discharge of macroalgae is occasionally related to lunar and tidal rhythms (Dring, 1982; Ngan and Price, 1983). Ngan and Price (1983) commented that tidal rhythms might be related to the physiological activities of the parent plants as well as of the developing spores. The pattern of spore discharge in relation to tidal oscillations may be also thought as an adaptation to reduce desiccation of recently settled spores, as well as to promote spore dispersal in water column. As spores are most commonly liberated around the times of high tides, the released spores are probably more readily dispersed by water movements. Moreover, spore liberation during spring tide periods, could give more room for settlement because of long dispersal distance.

In this viewpoint, desiccation together with photoperiodic rhythm also appears to play a significant role in rhythm of spore release in Korean *G. verrucosa.* However, further study is needed for desiccation to apply to artificial spore settling, considering vitality of the released spores, as commented by Koh (1969).

Acknowledgements

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