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Culture of *Gigartina skottsbergii* (Rhodophyta) in southern Chile. A pilot scale approach

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Abstract

In the last 10 years studies on the management and exploitation of Chilean carrageenophytes have proliferated in response to the increasing development of the local processing industry. One of the most important sources of raw material for Chilean carrageenan, *Gigartina skottsbergii* Setchell et Gardner, was the subject of an intensive study to design a commercial cultivation technique which could be an alternative to wild harvest. In this context this pilot study reports the first successful attempt to culture *G. skottsbergii* from spores to harvestable plants. A three-step farming approach was developed: (i) seeding of spores onto scallop shells followed by a two-month nursery period in a greenhouse (until the development of initial upright thalli from the discoid crust occurred), (ii) outplanting juvenile plants on shells in the sea on a long-line system (until thalli attained 3–4 cm diameter) and (iii) detachment of fronds from the shells, fixing of individuals to vertical ropes and growth until commercial size was reached. Additional experiments to compare bottom and suspended growth, cultivation by fragmentation and whole fronds and meristematic activity of different zones of the fronds were performed. This study shows the technical feasibility of culturing *G. skottsbergii* from spores, complemented with growth of vegetative fragments, in order to optimize the management of the culture. In the future, therefore, it may be possible to replace the heavy exploitation of wild beds in southern Chile with farming activities.

Introduction

Recently, several studies on wild populations of *Gigartina skottsbergii* Setchell et Gardner have been performed in order to acquire a basic knowledge on yearly abundance patterns, reproductive phenology and recruitment of young thalli (Zamorano & Westermeier, 1996; Avila et al., 1997, 1999a; Westermeier et al., 1999; Marín et al., 2002). Buschmann et al. (1999, 2001) suggested that *G. skottsbergii* was being overexploited and consequently that the development of culture technologies was urgently required to support the local carrageenan industry. In fact, Avila et al. (2003) reported that the heavy exploitation of natural beds was reaching as far south as Seno Año Nuevo (55°25′S; 69°00′ W). Such harvest displacement to southerly sites (approximately 1500 km south from traditionally harvested sites in Chiloe during the 1990s) was the logical consequence of an increasing *G. skottsbergii* shortage in previously productive beds of Chiloe. Since 2002 to late 2003, exploited beds have shown serious symptoms of depletion. Consequently, a continued decline in standing stocks could be a serious risk for both local and overseas carrageenan industries.

Preliminary experiments done by Buschmann et al. (1999) recorded that the growth of germlings seeded in the laboratory on Petri dishes and transplanted to outdoor tanks reached 1–2 mm in 3 months. Buschmann et al. (2001) reported that the growth of germlings seeded in the laboratory on ceramic plates and later transplanted to the field reached about 5 mm^2 after 5 months in the sea. Growth during 6 months, of 16 fragments of fronds excised from immature wild fronds

was reported by Buschmann et al. (1999) and growth of 20 whole young fronds during 12 months was reported by Buschmann et al. (2001). Both experiments used the same methods: fastening the fragments and fronds to ropes settled at 20 cm above the bottom. In addition, Correa et al. (1999) suggested from *in vitro* experiments that mass cultures by vegetative propagation techniques could be a promising tool for establishing future farms.

A greenhouse nursery method for *G. skottsbergii* mass culture consisting of: (a) settlement of spores on natural and artificial substrata; (b) survival of germlings under indoor conditions and then outplanting into the sea, was developed by Avila et al. (2003). Germlings of about 60 to 110 mm^2 were obtained in 15 months. The method consisted of seeding of spores on different types of substrata followed by the development of germlings, for two months in a greenhouse. Plants were then transplanted to suspended systems at different depths in the Bay of Hueihue (41°54′S; 73°31′W in Chiloé Island). The best depth for early growth of *G. skottsbergii* in the environmental conditions at the Bay of Hueihue was shown to be 3–6 m (see Zamorano & Westermeier, 1996, for general abiotic conditions of Ancud near the study area).

This paper presents for the first time the results of a pilot study of 31 months on commercial culture techniques of *G. skottsbergii,* to produce kappa-carrageenan gametophytes, at the Bay of Hueihue. The culture was based on a tetraspore-seeding method using scallop shells as substrata (Avila et al., 2003). Cultivation was followed by the growth of thalli on suspended cultures in the sea until plants reached of commercial size, complementing the results of Avila et al. (2003). In addition, growth of germlings on bottom and suspended systems, and both whole thalli and fragments were compared. Finally, meristematic activity on different parts of young plants was assessed.

Material and methods

Mass culture starting from spores

All mature sporophytes used as reproducers were collected at the Bay of Ancud (41°52′S; 73°31′W) and at Calbuco Channel (41°45′S; 73°05′W). The spore-seeding method on scallop shells was used (Avila et al., 2003). Scallop shells were one of the best substrata reported and were easily available from farms of scallops near the site of study. Spore seeding, using only tetraspores to produce kappa-carrageenan gametophytes, was done at the greenhouse facilities of the Maricultural Station at the licensed site of the Instituto de Fomento Pesquero in the Bay of Hueihue (41°54′S; 73°31′W). After two months, once the basal crusts developed their uprights of gametophyte fronds, the germlings were transplanted to the sea.

Variations of the floating structures described in Romo et al. (2001b) were used in this study. Cylindrical floats of PVC which separated the lines of the 100 m double long-line and the small 2 L buoys were replaced by 9 polystyrene 200 L buoys for better flotation. The shells, perforated in the centre, with germlings growing in the upper side of the shells, were arranged in sets of ten shells fixed to 1 m polypropylene ropes of 3 mm diameter (Figure 1A). Knots adjusted on and under each shell secured them to the ropes; shells were separated by 10 cm. A total of 1370 shells disposed in 137 ropes, were placed at 6 m depth, one of the most suitable depths for growth reported by Avila et al. (2003). Three metres depth was also good for germling growth but in the present study this depth was not used due to excessive fouling that developed on shells in previous

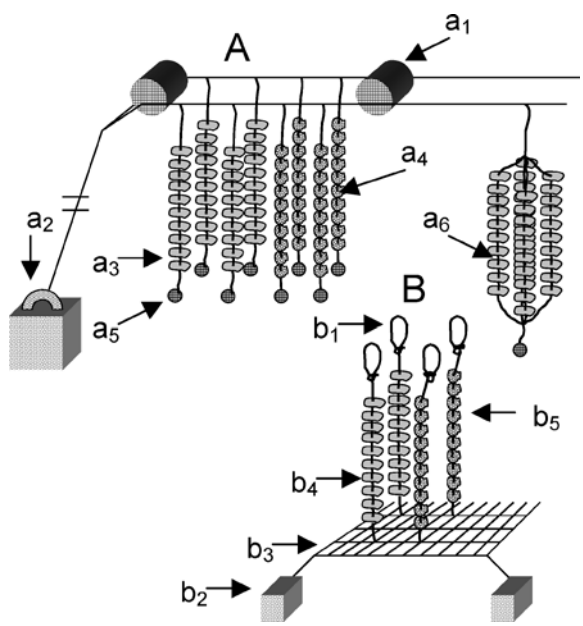

Figure 1. (A) Floating system for *G. skottsbergii* cultivation: a_1 = buoys; a_2 = concrete anchor; a_3 = fronds; a_4 = shells with young thalli; a_5 = sinker; a_6 = four ropes with fronds in a vertical rope. (B) Bottom system, b_1 = buoys; b_2 = concrete anchor; b_3 = net; b_4 = fronds; b_5 = shells with young thalli.