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Nota Científica

Cultivation of cystocarpic, tetrasporic and vegetative fronds of *Chondracanthus chamissoi* (Rhodophyta, Gigartinales) on ropes at two localities in northern Chile*

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ABSTRACT. *Chondracanthus chamissoi* is a red algae that is highly valuated as a delicacy in Japan bringing a good price. However, this market demands a high quality product that can not be easily harvested from natural populations. Here we present results showing that it is technically feasible to cultivate this species on ropes in the sea. We tested two sites in northern Chile comparing the performance of reproductive and vegetative specimens. The best results were obtained at Calderilla bay using vegetative fronds.

Key words: algae, culture, *Chondracanthus chamissoi*, Rhodophyta, Chile.

Cultivo de frondas cistocárpicas, tetraspóricas y vegetativas de *Chondracanthus chamissoi* (Rhodophyta, Gigartinales) en dos localidades del norte de Chile*

RESUMEN. *Chondracanthus chamissoi* es una macroalga altamente apreciada como alimento natural en países asiáticos, alcanzando buenos precios internacionales. Sin embargo, este mercado demanda un producto de alta calidad, el cual difícilmente puede ser obtenido a partir de poblaciones naturales. En este trabajo, se muestra que es técnicamente posible cultivar esta especie a partir de talos dispuestos en cuerdas. Se realizaron cultivos en dos bahías del norte de Chile y se compararon los desarrollos de talos reproductivos y vegetativos. Los mejores resultados se obtuvieron en bahía Calderilla con talos vegetativos.

Palabras clave: algas, cultivo, *Chondracanthus chamissoi*, Rhodophyta, Chile.

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Chondracanthus chamissoi (C. Agardh) Kützing is a benthic marine red algae that may reach up to 50 cm in length. This species is found from the lower intertidal zone to 15 m depth (Hoffmann & Santelices, 1997). It is distributed from Paita, Peru (5ºS) to Ancud, Chile (42ºS) (Ramírez & Santelices, 1991). In northern Chile, the main harvesting areas are Caldera (27º04'S), La Herradura (29º58'S) and Puerto Aldea (30º15'S).

Chondracanthus chamissoi has commonly been commercialized as a raw product for the extraction of carrageenan (Hoffmann & Santelices, 1997). There is, however, growing interest in the Asian market for acquisition of this product for direct human consumption. Although attractive prices are offered for this alga in world markets, quality standards for the product are strict, with requirements for a clean product, free from epiphytes and impurities, devoid of cystocarps and with specific color and texture. However, *C. chamissoi* may have a broad morphological diversity (Acleto, 1986), various degrees of epiphytism (Vásquez & Vega, 2001) and the typical seasonality of abundance for algae beds in northern Chile (González *et al.,* 1997; Vásquez & Vega, 2001; Macchiavello *et al.*, 2003). This makes difficult to the deliver sufficient amounts of quality

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product on a reliable production schedule.

The objective of the present study is to evaluate a culture technique for the vegetative propagation *C. chamissoi* that would result it a high quality product on a more predictable schedule.

The experiments were carried out between July and October 2003 at two locations in northern Chile: Calderilla bay (27º04'S) and La Herradura bay (29°58'S) (Fig. 1). Fronds of *C. chamissoi* were collected at La Herradura bay at depths of 4 to 6 m, and were transported fresh to the marine botany laboratory of the Universidad Católica del Norte near the sampling site. The plants were sorted into cystocarpic, tetrasporic, and vegetative specimens (putatively infertile female and male gametophytic and tetrasporophytic fronds, and reproductive male which do not present visible structures).

Fronds of *C. chamissoi* 5–10 cm in length were closely inserted among braids of 7 mm diameter polypropylene rope (2 m in length). The main axis of each frond was inserted in the rope, leaving the lateral branches free to grow. Steel stakes were driven into the bottom and the ropes were strung between them,

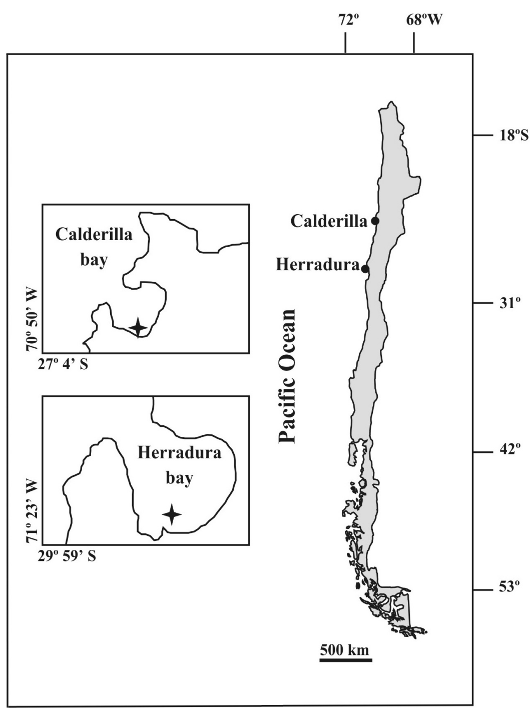

Figure 1. Geographic location of the study area.

Figura 1. Localización geográfica de las áreas de estudio.

at about one meter above the bottom and at 3 m depth. Five replicates of each reproductive stage were made at each location. Each rope was recovered at monthly intervals, drained, weighed and then returned to the sea. The amount of algal biomass was calculated as average wet weight (g) per linear meter of rope.

A two-way analysis of variance (ANOVA) was used to evaluate the differences in biomass among the different reproductive stages and between the two locations studied. Homogeneity of the variances and normality were reviewed for all results. A Tukey test was used when the treatments demonstrated significant differences (Sokal & Rohlf, 1981).

Figure 2a shows that in La Herradura bay there was a slow increase in biomass for all three reproductive stages. Although the plants presented natural coloration, they were fouled by epiphytes (*Polysiphonia sp*) and were variable in size. After 30 days of culture, the maximum accumulated biomass was 44 ± 10, 28 ± 8, and 21 ± 3 $g \cdot m^{-1}$ for vegetative, cystocarpic and tetrasporic fronds, respectively. The biomass recorded for the vegetative fronds (ANOVA, Fc: 3.81; $p < 0.05$) was significantly higher (Tukey, $p < 0.05$).

At Calderilla, the maximum accumulated biomass was reached at 60 days of culture, and showed some significant differences among reproductive stages (ANOVA, Fc: 5.18; $p < 0.05$); the biomass recorded for the vegetative fronds (93 ± 23 $g \cdot m^{-1}$) was significantly higher (Tukey, $p < 0.05$) than reached by the tetrasporic (54 ± 9 $g \cdot m^{-1}$) and cystocarpic (49 ± 13 $g \cdot m^{-1}$) (Fig. 2b). In general, these plants were natural in appearance, had slender thalli with abundant ramifications and were between 10 and 20 cm in length. The vegetative plants did not form visible reproductive structures over the period of the experiment. After 30 days we began to observe some release of the larger plants from the cords due to drag.

The present study showed that the vegetative rope culture of *C. chamissoi* was feasible, without damage occurring to the fronds. The results showed that the biomass accumulation in all the reproductive stages of this algae was greater at the Calderilla site than at La Herradura. The former site typically had calm, clear water with a local temperature pattern that may have been responsible for these results (Zúñiga & Acuña, 2002). Bulboa & Macchiavello (2001) showed *in vitro* that better growth occurred in *C. chamissoi* with an increase in temperature up to 20°C. In the region of Calderilla, Zúñiga & Acuña

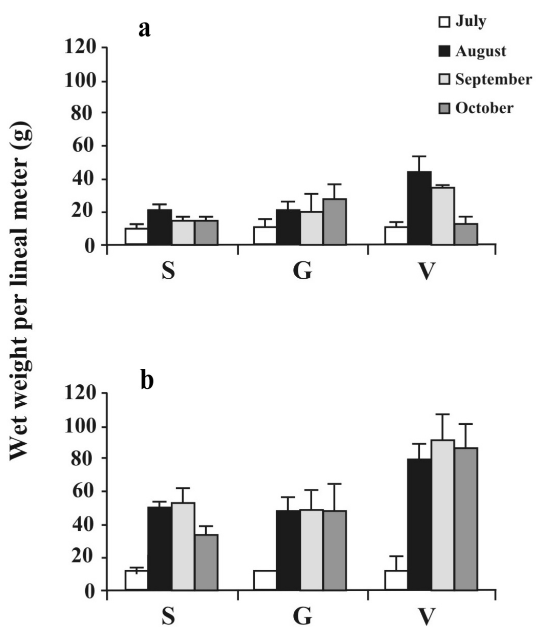

Figure 2. Biomass accumulation (g) and standard deviation of tetrasporophytic (S), female gametophytic (G) and vegetative (V) fronds of *Chondracanthus chamissoi*, cultivated in the sea at two sites: a) La Herradura bay, and b) Calderilla bay.

Figura 2. Acumulación de biomasa (g) y desviación estándar de frondas tetraesporofíticas (S), gametofito femenino (G) y vegetativas (V) de *Chondracanthus chamissoi*, cultivadas en dos localidades: a) bahía La Herradura, y b) bahía Calderilla.

(2002), reported a seasonal temperature range between 14º and 17ºC, with maxima of 20ºC during period in which coastal upwelling was absent.

The rope culture technique presently described would permit the use of the bottom in shallow, soft-bottom coastal areas within the bathymetric limitations of this species (0-15 m). It would be a convenient method for carrying out mixed culture, particularly at Calderilla and nearby areas which host extensive hanging cultures of the scallop *Argopecten purpuratus* (Zúñiga & Acuña, 2002). Use of the bottom in these areas would increase the efficiency of marine concessions, with the advantages recognized for mixed culture technology, where algae use sunlight to extract from the water dissolved inorganic nutrients (Chopin *et al.,* 2001; Troell *et al.*, 2003).

In our experiments, vegetative plants did not develop visible reproductive structures. In addition they produced the highest biomass at both sites. In natural conditions infertile fronds of *C. chamissoi* tend to be abundant, and have been found as an important portion of the population structure of this species in northern Chile (González *et al.*, 1997). The culture of non reproductive plants would be favorable and the higher growth could be certainly related to a reduced energy budget needed for reproduction (Hoyle, 1978).

The present results showed, that *C. chamissoi* could be farmed in Calderilla, yielding products with attractive traits, such as: i) coloration appreciated in the market, ii) plants without cystocarps, which is a favorable condition for commercialization, iii) slim thalli with abundant ramifications, which is sought by buyers, and iv) clean plants with few or no epiphyte attachment.

The present study showed that the vegetative culture of *C. chamissoi* is technically feasible. Production could be improved by making simple modifications, designed to control plant loss and epiphyte accumulation. Determination of the economic feasibility of this activity has yet to be determined, however.

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