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Open sea cultivation of *Palmaria palmata* (Rhodophyta) on the northern Spanish coast

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Abstract

The aim of this study was to adapt the techniques of rope culture to the cultivation of the edible seaweed *Palmaria palmata* on the northern Spanish coast. Vertical rope rafts were installed in two locations. Fronds were attached to 4-mm polyethylene ropes that were suspended from a steel frame secured in position using weights and buoys. In the first two trials (April to August 1999) we investigated the effects of the outplanting season (spring–summer), and length of the cultivation period (number of weeks) on the growth of *P. palmata*. Cultivation in autumn and winter was not performed due to the rough sea conditions. The following three trials (April to August 2000) aimed to test the effects on the growth and quality (i.e. N content) of the fronds of other additional factors: cultivation technique (fronds inside mesh bags versus directly inserted into ropes), use of marginal proliferations as source stock (versus field material), different stocking densities, and addition of nutrients versus no enrichment. Maximum observed growth during the best cultivation season in spring was about 14% of the initial fresh weight per day (about 0.7 g FW). The growth of cultivated fronds was noticeably greater than the growth of field individuals and four weeks was a suitable period for cultivation. The bag method was better than inserting the fronds into ropes due to the avoidance of frond loss, and enhancement of the quality. Appropriate stocking density was very important when using bags since the growth tended to decrease with increasing number of fronds per bag. The artificial nutrient enrichment also enhanced the quality of the fronds in two locations, and the growth in one site (with lower seawater nutrient concentration). Nutrient enhanced fronds grew at a rate similar to that observed one month and a half earlier when nutrient concentration was higher. In Spain the stock of *P. palmata* is limited. However, the marginal proliferations grew at a similar rate than field material partially solving this limitation. Results from these trials suggest the potential to aquaculture *P. palmata* in northern Spain.

Keywords: Bag cultivation; Fertilizer; Mariculture; *Palmaria palmata*; Rope cultivation

1. Introduction

Humans have carried out the culture of seaweeds for hundreds of years and it is well developed in several Asian countries (Perez, 1992; Ohno and Critchley, 1993; Lobban and Harrison, 1997; Neori et al., 2004).

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Nowadays, cultured seaweeds represent most of the seaweed production, which is about 10 million tons fresh weight (FW) worldwide (Lüning and Pang, 2003). However, the use of seaweeds as food and its cultivation in western countries is by far less developed (Browne, 2001). *Palmaria palmata* (Linnaeus) Kuntze is probably the most popular seaweed used as food in North America and Europe, and has been also used for feeding abalone in hatcheries (Morgan et al., 1980a; Irvine and Guiry, 1995; Le Gall et al., 2004). This species, commonly known as "dulse" in the northern Europe, is a good source of dietary requirements, rich in vitamins and minerals, proteins, and fibre (Morgan et al., 1980b; Lahaye et al., 1993). *P. palmata* is commercially harvested and sold in dry form by several food selling companies in Canada, USA, Ireland, and UK (Chopin, 1998; Browne, 2001). The development of the mariculture of this species has been suggested to have high potential in Canada and in the USA (Chopin, 1998; Cheney, 1999). Cultivation in small tanks (8 l) received large attention in the 1980s in Nova Scotia (Morgan et al., 1980a; Morgan and Simpson, 1981a,b,c). Recently, cultivation in larger tanks has been developed with fronds collected from Roscoff (France), and open sea cultivation has been tested in Northern Ireland (Browne, 2001; Pang and Lüning, 2004).

We summarize in this paper the results from the first open sea cultivation of *P. palmata* on the northern Spanish coast. The cultivation technique was modified from rafts culture methods developed for *Laminaria japonica* Areschoug mass cultivation in China, and from *P. palmata* experimental cultivation in Northern Ireland (FAO, 1989, 2001, 2003; Perez, 1992; Ohno and Critchley, 1993; Browne, 2001). The aim of our study was to adapt the known techniques of vertical rope raft culture to suit the local conditions of the coast of Asturias (northern Spain). For this purpose, we investigated the effects of several factors on the growth and quality (i.e. N content) of the fronds during five successive cultivation trials.

The two first trials aimed to test the best outplanting season given that field *P. palmata* showed their highest growth rates during spring (Faes and Viejo, 2003). The optimum length of the cultivation period (number of weeks) was also tested. High growth during the first weeks followed by reduced growth has been observed in cultures of *Gigartina atropurpurea* J. Agardh and other red seaweeds (McNeill et al., 2003).

In the next trial the cultivation of fronds inside mesh bags was compared to the cultivation of fronds directly inserted into ropes following the more traditional vertical rope culture techniques (FAO, 1989, 2001, 2003; Perez, 1992; Ohno and Critchley, 1993). The coast of Asturias is exposed to waves with few moderately sheltered sites. The use of mesh bags in such conditions has been shown to prevent the detachment of algal material (Ask and Azanza, 2002; Reddy et al., 2003).

The efficiency of an alternative method to the collection of field material for culturing was tested in the fourth trial. The ultimate objective was the reduction of harvest pressure on the natural populations. *P. palmata* develops marginal proliferations that were collected from the material harvested in the third trial and used as source stock. Pruning methods are common in algal cultivation procedures to assure the sustainability of the cultivation system (Melo et al., 1991; Perez, 1992; Ohno and Critchley, 1993; Lobban and Harrison, 1997; McNeill et al., 2003).

The third and fourth trials also tested the hypothesis that increasing the density on ropes, or increasing the number of fronds inside mesh bags, would cause a decrease in growth due to the reduction of light and nutrients (Browne, 2001).

Finally, in the fifth trial we tested the effect of an artificial fertilizer on frond growth and quality. In the studied area, the growth of *P. palmata* fronds from the field populations is limited by very low nutrient concentrations in late summer (Martínez and Rico, 2002; Faes and Viejo, 2003). Nutrient enrichment treatments have been shown to prevent growth and quality decay in cultures from other geographic areas (FAO, 1989, 2001, 2003; Ask and Azanza, 2002; Tseng, 2004).

These experiments represented a pioneer activity in Spain since algae are not traditionally consumed nor cultured in this country (Juanes and Sosa, 1998).

2. Material and methods

2.1. Sites

The *P. palmata* culture rafts were placed in two locations along the coast of Asturias (northern Spain): *Ensenada de Arnao* (43°33′ N, 7°01′ W) and *Concha de Artedo* (43°34′ N, 6°12′ W). The *Ensenada de Arnao* (Arnao) is a bay at the eastern side of the mouth of an embayment about 5 km long (*Ría de Ribadeo*). The hydrography and dynamics of the *Ría de Ribadeo* are dominated by tidal and wave forcing. The site where the rafts were set is subjected to a significant outflow current caused by the wave breaking at the west side (Piedracoba et al., in press). The *Concha de Artedo* (Artedo) is a bay dominated by wave forcing due to its