An Investigation of the Potential for Commercial Mariculture of Seamoss (Gracilaria spp., Rhodophycophyta) in St. Lucia

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ABSTRACT

The Caribbean Sea has a rich marine flora which includes over 700 species of macroscopic algae. Few of the larger algal species (seaweeds) have been exploited by man, but some are in great demand. The most widely used seaweed is known locally as seamoss, which is a collective term for any of four species of *Gracilaria* that are used to thicken drinks and puddings. The species are widespread, but not abundant. There is a small inter-island trade in bleached, dried seamoss, but limited wild stocks have restricted the development of this resource, and demand exceeds the supply.

The potential for commercial mariculture of *Gracilaria crassissima*, *G. domingensis*, *G. debilis* and a fourth, terete *Gracilaria* sp. has been investigated in St. Lucia. There is as yet no commercial cultivation of seaweeds in the Atlantic Ocean or Caribbean Sea and initial work was based on methods developed in the Philippines and elsewhere in the Indo-Pacific. Cultivation methods included spore recruitment or vegetative propagation on monolines or on solid substrates. The vegetative propagation and cultivation of *Gracilaria* 'terete,' using the stake-and-monoline method, is described. A plot has been established in shallow water over a seagrass community, containing 650 m of lines, using innoculum from a single population of relatively fast-growing plants. The system is labor-intensive and operating costs are low.

INTRODUCTION

In most of the Caribbean countries where marine algae have been studied, the studies have been primarily taxonomic, such as those of Børgesen (1913-1920), Taylor (1960) and Chapman (1961, 1963). Some information is available on seaweeds as a resource from the work of Diaz-Piferrer and others in Puerto Rico (Diaz-Piferrer and Caballer de Perez, 1964), Cuba (Diaz-Piferrer, 1961) and Venezuela (Diaz-Piferrer, 1967) and the reviews of Richardson (1958, 1959), but for many countries there are no published data available (Michanek, 1975). This is particularly true of the Lesser Antilles, although certain species of seaweeds are well-known and highly prized commodities in the area. One of these is the carrageenophyte *Eucheuma isiforme*, which is collected for food in Antigua and Barbuda. The most widely used species, however, are a group of agarophytes in the genus *Gracilaria*, which are known collectively as seamoss and are used as a thickener in flavoured drinks and puddings.

Seamoss is in great demand in a number of islands, mostly because of its reputation as an aphrodisiac and general tonic. Of the 19 species of *Gracilaria* that have been reported from the Caribbean, four have so far been identified from collections of seamoss in the Lesser Antilles. These are *G. debilis*, *G. crassissima*, *G. domingensis* and a terete species that is possibly *G. armata*. The species of *Gracilaria* are notoriously difficult in a taxonomic sense and a number of the Caribbean species, including *G. debilis*, will be renamed when the genus is revised. Meanwhile, the four species mentioned above are readily distinguishable from their external morphology. It is worth noting that species of *Gracilaria* from the Pacific are a major source of industrial grade agar which is used in many processed foods and as a thickener and emulsifier in a variety of products including medicines and cosmetics.

The use of seamoss for food in the Caribbean region appears to be limited to the English-speaking islands but not all species are used on each island. For example, only *G. debilis* is used in Barbados; *G. domingensis* and *G.* 'terete' in St. Vincent and the Grenadines; *G. debilis*, *G. crassissima* and occasionally *G.* 'terete' in St. Lucia.

In St. Lucia the wild plants are collected by hand in shallow water. *G. crassissima* is often found in calm areas and can be collected while wading but *G. debilis* is most prolific in areas of moderate to severe wave action where it can only be collected by competent swimmers. After harvesting, the plants are cleaned, rinsed with fresh water and spread in the sun to dry. To hasten the bleaching process during drying, the plants are given further fresh water rinses and may also be covered with a sheet of polythene before final drying. After three to four days the seamoss is ready to be sold locally or to be bagged for shipment. The ratio of drained fresh weight to sun-dry weight is approximately 8:1. The local harvest is estimated to be 32 t yr^{-1} (dry weight), and fetches approximately EC$20 - 22 kg^{-1}. As prices are considerably higher in Barbados and Trinidad, much of the harvest is exported, but the development of trade in seamoss has been restricted by the limited availability of wild stocks.

The species are widespread in the eastern Caribbean but are seldom abundant in any one area. In Barbados and St. Lucia, populations that are readily accessible are generally overharvested and the plants are small. In addition, plants are usually pulled from the substrate together with their holdfasts, thus preventing the regeneration of fronds for subsequent harvests. Natural populations of *G. debilis* contain a high number of plants that arise from large coalesced holdfasts, which indicates that regeneration of established plants may be more important than the recruitment of sporelings in the accumulation of biomass between harvests. Plants of *G. crassissima* produce secondary holdfasts from the decumbent fronds and complete removal of the plant is less common. Further work is needed on G. domingensis and G. 'terete' in the islands where they are used, to determine their regenerative ability in wild, harvested populations.

MARICULTURE

Since 1980, the International Development Research Centre of Canada (IDRC) has funded a seamoss mariculture program in St. Lucia, in collaboration with the Ministry of Agriculture, Lands, Fisheries, Labour and Co-operatives. The aim of the program has been the development of methods for commercial farming of seamoss, suitable for coastal communities. Commercial seaweed cultivation is well established in a number of Pacific countries but has never been achieved in the Atlantic or Caribbean. Experimental work in the Atlantic has generally involved intensive production in artificial systems such as raceways and tanks, using methods that are not practicable in smaller Caribbean islands.

The recent development of Eucheuma farming in the Phillipines (Doty, 1980) is the first example of commercial seaweed cultivation in the tropics. Eucheuma is used directly for food in the Philippines but the incentive for mariculture development is the fact that Eucheuma spp. are important sources of carrageenans that are widely used in the food industry. Using the labor-intensive stake-and-line method that has proved so successful with Eucheuma, as well as methods developed in St. Lucia, the response to cultivation of four seamoss species has been investigated. Much of the experimental work has been conducted on the south-east coast of St. Lucia, over extensive seagrass (Thalassia testudinum and Syringodium filiforme) beds that are protected from the Atlantic wave-action by an off-shore reef.

PROPAGATION

Two approaches to propagation are possible, based on the biology of the algae. First, the triphasic life history includes the production and release of two types of spores. After release, the spores settle and germinate, the haploid tetraspores give rise to male and female gametophytes and the diploid carpospores give rise to tetrasporophytes. Second, the algae may be propagated vegetatively, by subdividing the plants into propagules, each of which develops into a new plant. The algae do not possess roots and as the holdfast serves only to anchor the plant to the substrate, the propagules need only be firmly attached to an artificial substrate for cultivation. The function of nutrient uptake is carried out over the entire plant surface.

Successful spore recruitment can be achieved in the field by anchoring suitable substrates within populations that include reproductive plants. All reproductive phases of the four seamoss species were found throughout the year and a variety of substrates have been tested. Wild G. crassissima and G. debilis have been found only on rock and coral rubble and recruitment of spores of these species has not been successful. As they are both robust species they are considered better suited to vegetative methods of propagation. The terete species in the wild is seldom found attached to anything but rock and coral rubble but as sporelings occasionally appear on culture lines further work on the recruitment of this species may be fruitful.

The greatest success with spore recruitment has been obtained with G. domingensis, which is fortunate as this is the only species tested that has been found to be too fragile for vegetative propagation. Wild plants are found growing on a variety of natural and synthetic substrates including rock, metal, cloth, polythene sheet and woven plastic sacking. Polypropylene rope and woven sacking have both been used to recruit spores, most successfully near shore in calm protected bays. Sporelings are recognisable after 7-10 days of growth. Recruitment areas are usually unsuitable for large scale mariculture and inoculated substrates must be outplanted to culture sites. Monolines with attached sporelings are transferred directly, while sacking is torn into strips and woven into the monolines before outplanting.

Early attempts at vegetative propagation, with G. debilis, were hampered by the accumulation of sediment on plants and lines. Co-cultivation with G. domingensis, which was tied to the 8 mm Ø polypropylene line between G. debilis fronds, resulted in the G. debilis being swept clean by the more flexuous fronds of G. domingensis. For large scale cultivation it would be preferable to recruit G. domingensis sporelings onto monolines to which G. debilis fronds could then be added by insertion between the strands.

The fronds of G. 'terete' are smaller and more delicate than those of G. debilis and are best inserted into the rope in bunches. The process takes 35 to 45 minutes per 3.5 m line and requires careful handling of the plants. However, lines that are seeded successfully will retain the innoculum for at least 12-16 weeks. The first harvest can be made after 6-8 weeks and involves cutting the fronds 50 mm above the point of attachment to the rope, leaving the bases of the plants intact to regenerate new fronds for further harvests.

One other method of vegetative propagation deserves mention as it is applicable to the high-energy rocky coastlines where G. debilis is generally found and harvested, but which are unsuitable for the stake-and-line method. Propagules of G. debilis are held in place on the rock by a covering of 10 mm mesh nylon netting, which is laced firmly over the rock. The method was first tested in the mariculture sites located on the sheltered seagrass beds, using rocks up to 50 kg in weight. The rocks were seeded on shore and transferred to the site by boat. The propagules grew readily, proliferating through the netting. Maintenance requirements were minimal if the plants were securely anchored to the rock.

The method was then tested *in situ*, on large boulders, on the southwest coast where wave action precludes the installation of high-profile artificial substrates. The plants again proliferated readily and further investigation of this method is needed to find a simple method of installing pegs in the rock to which the netting can be tied. The boulders on this coast supported dense populations of *G. debilis* prior to the hurricanes of 1979 and 1980. These beds have not recovered, probably because the layer of algal turf and trapped sediment prevents the attachment of *G. debilis* spores on the underlying rock.

GROWTH RATES

The growth rates of three *Gracilaria* spp. were determined. Fronds of *G. crassissima* and *G. debilis* were tagged, weighed after shaking off excess surface water and tied to monolines in the mariculture sites. Each week the fronds were removed from the sites, weighed and returned. Bunches of *G.* 'terete' fronds were inserted into the strands of 50-70 mm segments of monoline, tagged and weighed as above. The results are given in Table 1.

Table 1. Specific growth rate, μ, of three seamoss species, incubated at a depth of 0.5 m; overall water depth 1.0 m.

G. crassissima	*G. debilis*	*G.* 'terete'
0.84	1.07	2.83
n = 7, t = 12	n = 39, t = 49	n = 72, t = 36

Specific growth rate, $\mu = 100(\log_n w/w_o)t^{-1}$

The growth of *G. domingensis* on monolines seeded with spores has been determined from earlier work (Smith *et al.*, 1984). This was not repeated using vegetative methods as these are not applicable to large scale cultivation.

The results shown in Table 1 represent net growth after losses due to fragmentation and herbivory. The most important herbivores were fish, particularly members of the families Scaridae and Acanthuridae. Herbivory in the mariculture sites increased from May to September, was most evident in the shallower parts of the site, and affected *G.* 'terete' more than the other species. As all lines were installed approximately 0.5 m below the surface, herbivory appeared to be a function of proximity to the seagrass, which was later demonstrated by growing plants a different depths in deeper water, as shown in Table 2. The growth of G. 'terete', enclosed in a cage of 10 mm nylon net to exclude fish, exceeded 6% but the rate of 5% obtained by installing the plants in deeper water is considered satisfactory for mariculture.

Table 2. Specific growth rate of Gracilaria 'terete' at different depths and in cage enclosure; overall water depth 1.7 m.

Line depth (m)			
0.5	4.95	n=10	t=31
1.0	4.65	"	"
1.5	-4.20	"	"
1.0 (enclosed)	6.29	n=20	t=14

MARICULTURE OF Gracilaria 'terete'

G. 'terete' has so far proved to be the most successful candidate for commercial mariculture in St. Lucia, using vegetative methods of propagation. Accordingly, a plot containing 200 monolines, each 3.5 m long, has been established on the south-east coast, using the stake-and-line method over seagrass. Various sources of stakes have been tested, the most successful to date being the white mangrove, Laguncularia racemosa. As there is little mangrove in St. Lucia, alternatives are still being sought, the ideal being a species that could be cultivated for the purpose. To reduce the number of stakes needed, the lines may be installed between horizontal bamboo poles tied to pairs of mangrove stakes.

Not all wild populations of G 'terete' have proved to be suitable sources of innoculum. For example, plants from Vieux Fort Bay and Laborie Bay tended to fragment in culture and much of the innoculum was lost within a week of outplanting. One east coast population has proved successful but because the population is small, most of the innoculum for the large plot has been cultivated from an initial collection of approximately 5.0 kg of wild material.

Once a source of innoculum and a suitable mariculture site have been found, successful cultivation depends largely on the care with which the lines are seeded at the outset. Well seeded lines yield 1.5-2.0 kg fresh weight after approximately 8 weeks and will yield at least one further harvest before spaces on the lines require re-seeding. The mean yield from three representative lines is shown in Table 3.

Table 3. Vegetative propagation of Gracilaria 'terete' and cultivation on 3.5 m monolines at 0.5 m depth; overall water depth 1.0 m.

Initial frond weight (g)	Interval (days)	Harvest (g)	
		($\bar{x}$) frond wt line^{-1}	($\bar{x}$) dry wt m^{-1}
200	58	1578	56
			($\bar{x}$) = 1.g m^{-1}d^{-1}

The significant problems encountered in cutivation of G. 'terete' have been the accumulation of sediment on plants and lines, entanglement by drift algae, and the loss of biomass to herbivores.

Plants cannot be kept free of sediment by water motion alone, even when installed near the surface on high-energy coastlines. Physical contact between the plants is necessary and thus the more flexuous species are affected least by sediment deposition. The terete species in cultivation remains remarkably free of sediment and epiphytes and requires little cleaning after harvest. The only contaminants are drift algae, which may be present in the mariculture sites in large amounts at certain times of the year. The most abundant species are Chaetomorpha linum and C. gracilis. The species of Chaetomorpha readily become entangled with the rigid fronds of G. debilis but this is less common on the lines of G. 'terete.' In addition, the drift algae can be excluded to a large extent by surrounding the site with one or two horizontal lines of nylon monofilament, which trap the plants. This is only necessary between September and January when the species of Chaetomorpha are most abundant.

The problem of herbivory appears to have been reduced significantly by keeping the culture lines approximately 1.0 m above the seagrass, apparently out of the normal range of the herbivorous fish.

In conclusion, it appears that G. 'terete' can be cultivated on a large scale, using the methods described. The species is capable of high yields under the right conditions and as a commodity the demand greatly exceeds the supply. There seems to be no reason why the commercial production of seamoss should not become a reality in the Caribbean.

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