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A *Eucheuma* (Solieriaceae, rhodophyta) cultivation test on the south-west coast of Madagascar

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Abstract

Well established populations of *Eucheuma denticulatum* and *E. striatum* exist on the coral reef of the south west coast of Madagascar but natural beds are not dense enough to support high harvest pressure. A cultivation test was conducted on a 250 m^2 module using the monoline method with 1560 seedlings of both species for over one year (weighings at 15 day intervals). *E. denticulatum* and *E. striatum* showed similar maximum growth rates (2.8% d^{-1}) occurring respectively in fall and in summer. For both species, minimum growth was observed during the warmest months (February–March). Mean growth rates, although relatively low, showed a high standard deviation, suggesting wide possibilities of strain selection. The preliminary selection experiment led to strains more resistant to breakage and having a growth rate up to 3.3% d^{-1}. The 'ice-ice' disease is also present in this area and affects the algae mainly from January to March. Mean carrageenan yield for *E. denticulatum* was 42.5% ± 2.3 and rheological properties were above industrial standards, with a highly elastic gel and were thus suitable for commercial applications.

Introduction

The genus *Eucheuma* is currently farmed, mainly in the Far East (Philippines, Indonesia), as raw material for carrageenan extraction. For the African continent, the genus *Eucheuma* is reported from Tanzania (Msigheni, 1973), Kenya (Yarish & Wamukoya, 1990) and Mauritius (Børgesen, 1943). Andriamampandry (1976) reviewed the historical records for Madagascar which were limited to the observation of only a few specimens. Rabesandratana (1988) listed 3 *Eucheuma* species in her study of the Tuléar reef and we observed wild populations of *Eucheuma denticulatum* (Burman) Collins et Hervey and *E. striatum* Schmitz on the Songoritelo reef (Mollion *et al.*, 1990). A preliminary survey indicated that the two species are widespread along 300 km of coastline between Tuléar and Morondava but do not form dense beds, restricting harvesting to a few hundred tons dry weight per year. The possibility of cultivating these two species was tested in order to estimate growth rate as well as carrageenan content and rheological properties.

Materials and methods

Cultivation test

Experiments were conducted on the Songoritelo reef (23° 15′ S–43° 40′ E) with the monoline method. A test module of 250 m^2 was established

(40 polypropylene lines of 3 mm diameter with an individual length of 10 m and a spacing of 0.65 m) bearing 1560 seedlings. A mix of *E. denticulatum* and *E. striatum*, collected from the natural beds, was tied with plastic ribbons to the lines. Forty randomly sorted thalli for *E. denticulatum* and 30 thalli for *E. striatum* were tagged and weighings performed at 15 days intervals. All the cultivated *E. denticulatum* was collected from the same location within a population growing on the seaward platform of the reef whereas *E. striatum* was collected from the reef rim. In order to insure the same history for the weighed algae, the lost thalli were replaced by untagged seedlings from the test module. Starting weight of seedlings was in the range 50–100 g f. wt. When the thalli reached a final weight of 300 to 700 g, according to the season, they were trimmed back to the initial seeding weight in order to avoid excessive breakage. Three indices were calculated for both species: specific growth rate (SGR), losses (LO) and breakage ratio (BR):

$$SGR = [W2/W1 - 1]^{1/T} * 100\,,$$

where $W1$ is the initial weight, $W2$ the final weight and T the time in days ellapsed between two weighings. The mean specific growth rate is calculated in the same manner as above by replacing $W1$ and $W2$ by the sum of the individual weights.

LO: Sum of initial weights of lost thalli divided by the total initial weight of seedlings.

BR: Sum of lost tissue (final wt – initial wt for broken thalli) divided by total initial weight of seedlings.

Strain selection

Twenty thalli of *E. denticulatum* were selected for their longevity and resistance to breakage. A genetically well defined population was obtained by isolating clones for each cultivated strain and using the same plant or its genetic replica (obtained by dividing the thalli) during the entire experiment. Spare genetic replica, cultivated apart, were used to replace the experimental plants whenever lost accidentally. Fifteen of the 20 selected strains were chosen among the sorted plants participating in the general cultivation test, the rest were untagged plants which had been cultivated on the module for at least 2 months.

Chemical analysis

At nearly each weighing, 1 kg fw was randomly collected on the test module, washed with seawater and sun dried to about 10–15% residual moisture. Carrageenans were extracted by the standard alkaline method in use in the laboratory of Sanofi (Fostier, 1989). Gel strength was measured with an Instron penetrometer as previously described (Cosson *et al.*, 1990). Total nitrogen and phosphorus internal pools of the seaweeds were determined spectrophotometrically, after Kjeldahl digestion, according to the methods described by Strickland & Parsons (1972).

Results and discussion

Observations of natural beds

No cystocarps were observed on *E. denticulatum* growing in nature. An increase in the size and number of plants occurred between April and February, with a peak in November–December. In March, plants gradually became lighter in color. At this time infection by 'ice-ice' disease (Doty, 1973), although occurring all year, became much more frequent. The population disappeared almost completely at the end of March, some plants remaining as fragments attached to the sides of little crevices.

Numerous cystocarps were found all year on the thalli of *E. striatum*. No significant seasonal variations could be observed in the population biomass or the size of individual plants. Infection by 'ice-ice', although found occasionally in all seasons, was more frequent in October –November.

Growth rate

The growth rate of *E. denticulatum* was followed from June 1990 to April 1992 (Fig. 1B). Despite

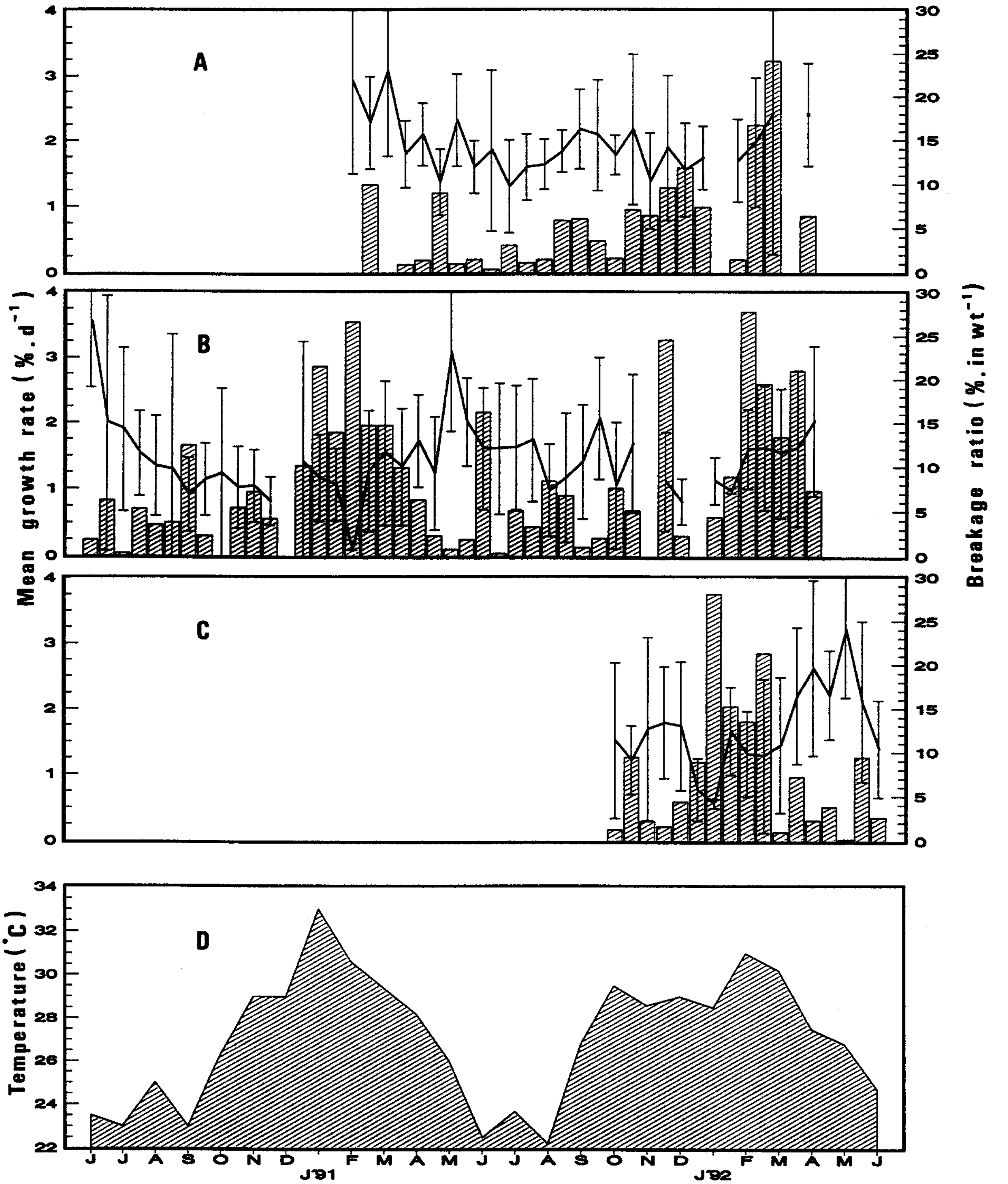

Fig. 1. Seasonal changes of growth rates (solid line) and breakage ratios (histograms) for *Eucheuma striatum* [A], *E. denticulatum* (cultivation test) [B], *E. denticulatum* (strain selection) [C]. Vertical bars represent standard deviation ($n = 40$ for *E. denticulatum* and $n = 30$ for *E. striatum*). Seasonal variation of seawater temperature [D].

high standard deviations, mean maximum SGR calculated by averaging all the results obtained for each season, showed a significant maximum of 2.2% d^{-1} in fall (Table 1). For the rest of the year, the mean growth rate was 1.4% d^{-1}. These results are lower than those measured in the Bali area (Adnan & Porse, 1987) or in Djibouti waters (Braud & Perez, 1978). This could be because the seaweeds were collected directly from the wild instead of using preselected thalli. Another cause could be the site, which was close to the algal ridge and had insufficient protection against waves. The period of minimal growth is similar to that observed by Luxton *et al.* (1987) and corresponds, for Madagascar, to the highest water temperatures (30–33 °C; Fig. 1D). The growth rate peak is concomitant with the regeneration of plants in natural beds.

The breakage ratio shows a conspicuous seasonal variation with a maximum in winter, especially in February and March, the period of 'ice-ice'.

The phenomenon of 'ice-ice' seems to be related to the high seawater temperature (Fig. 1D) as salinity remained fairly stable throughout the year contrary to what occurs in Asia. The other times breakage reached more than 10% were during periods of windy weather.

The seasonal growth rate of *E. striatum* was of the same order of magnitude as *E. denticulatum* but the maximum occurred in summer instead of fall (Fig. 1A; Table 1). The highest growth rate occurred when water temperature was about 30 °C (Fig. 1D) but the correlation between the two parameters is not significant ($r = 0.470$). The mean breakage ratios, calculated between Feb. 1991 and Feb. 1992, are 5.3% ± 5.9 and 7.9% ± 6.6 for *E. denticulatum* and *E. striatum*, respectively, but the difference is not significant. The same conclusion prevails for the losses ratio (not shown on the figure) with respectively 8.2% ± 8.8 and 8.2% ± 8.1.

The breakage peaks appear to be related to 'ice-ice' and to the size of the thalli and roughness of the sea. During the winter calm period, thalli could reach a weight of more than 700 g fw. However, they were pruned back to their starting weight after reaching 300 g fw.

The effect of seedling initial weight on growth rate was studied with clones of strain N 56 of *E. denticulatum* divided into 2 lots of 6 thalli weighing 142 ± 35 g ('heavy') and 79 ± 12 g ('light'). The mean growth rate was respectively 1.45 and 2.79% d^{-1} but tissue production was higher for the 'heavy' lot (Fig. 1C).

Strain selection

The high standard deviation of mean growth rate (cf. Fig. 1A and B) reflects the heterogeneity of the studied population and indicates a possibility of strain selection. An experiment was conducted for 7 months, including the 'ice-ice' period, on 20 thalli having at least 2 months of cultivation. Compared to the standard population (Fig. 2), 2 strains showed growth reaching 3.5% d^{-1} during May and a marked resistance to the disease

Table 1. Statistical analysis of the seasonal variation of mean specific growth rate (MSGR expressed in % d^{-1}) for cultivated *E. denticulatum* and *E. striatum*

	E. denticulatum				*E. striatum*			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
MSGR	1.43	1.40	1.35	2.22	1.48	1.22	1.90	1.18
SD	1.13	1.03	0.88	1.34	0.98	1.29	1.53	1.04
n	374	159	124	302	106	82	81	74
ANOVA (F)	34.1 ($p < 0.001$)				5.9 ($p < 0.001$)			

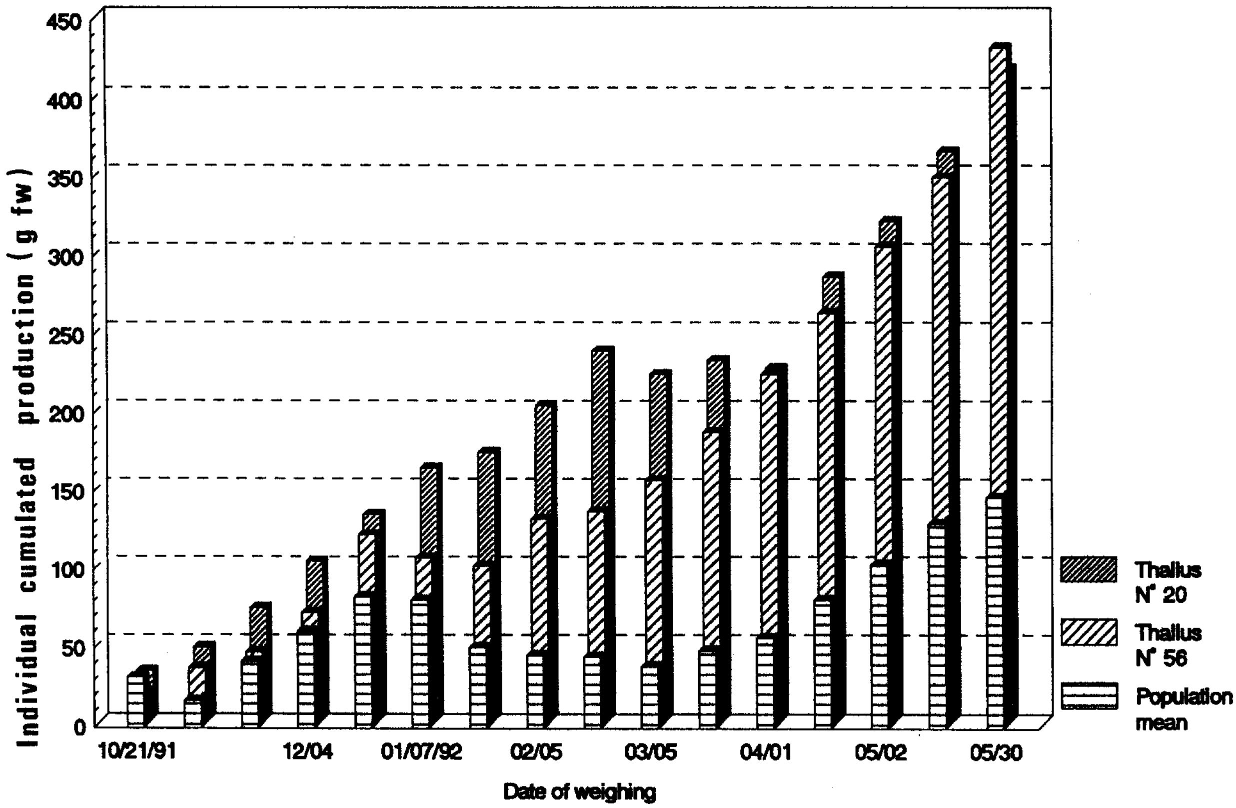

Fig. 2. Comparison of cumulated production of 2 selected strains with reference population average.

(January–March). Cumulated production obtained with strains N° 20 and 56 were respectively 415 and 431 g fw as compared to 147 g (average result of reference population). These preliminary results are to be confirmed but the resistance to diseases is of prime importance to insure the reliability of a large scale culture.

Chemical analysis

No seasonal variation in carrageenan yield was evident for *E. denticulatum* with a mean of 42.2 ± 2.4 (Table 1). As the standard error of the method is 2.4% we have not encountered, thus far, a problem of poor yields as reported by Adnan & Porse (1987) in Bali where farmed *E. denticu-*

Table 2. Statistical parameters for carrageenan yields, gel strengths (expressed in Newton) and internal N and P pools for cultivated *Eucheuma denticulatum*. Sampling period: every 15 days between 24/06/1990 and 08/09/1991

	Carrageenan yield (% dw^{-1})	Gel strength		Seaweed internal pools	
		In milk (N)	In water (N)	Nitrogen (% dw^{-1})	Phosphorus (% dw − 1)
Maximum value	45.6	4.31	2.06	1.50	0.117
Minimum value	38.1	0.61	0.24	0.75	0.074
Mean	42.2	2.38	1.09	1.10	0.092
SD	2.4	1.05	0.64	0.23	0.011
n	22	22	21	20	20

latum had a carrageenan content below 30%. Only two samples of *E. striatum* have been analyzed so far, with an average yield of 41.7%.

The gel strengths of carrageenans from *E. denticulatum*, in milk or water, were above the Sanofi standard (0.60 and 0.25 N respectively). The milk gels were highly elastic, an important factor for iota-carrageenan applications. Milk gel strengths increased during the experiment to reach a plateau of about 3–4 N but did not correlate with any of the studied parameters.

The internal phosphorus pool fluctuated while the nitrogen pool showed a seasonal variation with a maximum in winter ($1.35 \pm 0.15\%$ d.w.$^{-1}$) and a minimum during summer ($0.88 \pm 0.17\%$ d.w.$^{-1}$). The mean minimal values were significantly different from the year averages ($t = 2.79$ for $p < 0.02$) and coincided with the period of 'ice-ice' supporting the explanation that the disease is a consequence of physiological stress of the alga (Uyenco *et al.*, 1981).

Conclusions

Although the growth rates of *E. denticulatum* and *E. striatum* were lower that reported for traditional cultivation areas, the possibilities of strain selection and use of more sheltered zones on the Madagascar reef should improve production. The period of maximum growth did not occur in the same season for the two species, which is an advantage for stabilizing the income in large scale mixed cultures. The 'ice-ice' disease may be associated with a seasonal lack in nitrogen, although some plants showed a semi-resistance to the phenomenon with significant growth rates during the illness period. The carrageenan yields and rheological properties of the extract from farmed seaweeds are in the range of industrial standards. Thus, these preliminary experiments suggest that farming of either *E. denticulatum* or *E. striatum* is feasible on the south-west reefs of Madagascar.

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