

Original Article

Seasonal growth and retention of edible seaweeds and optimizing culture of *Gracilaria corticata* and *Gracilaria salicornia* in Madagascar

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Abstract

Seaweed farming offers a sustainable solution to malnutrition and economic challenges in southwestern Madagascar. This study assessed the seasonal performance of 12 edible seaweed species and optimized cultivation parameters for *Gracilaria corticata* and *Gracilaria salicornia* using long-line aquaculture. Environmental factors, including temperature, light intensity, salinity, and current speed, were monitored across warm and cool seasons. *G. corticata*, *G. salicornia*, and *Hormophysa cuneiformis* exhibited the highest retention rates (>50 %) and growth performance, with *G. corticata* demonstrating significant superior growth in both seasons. Smaller cuttings (0–50 g) achieved higher retention and specific growth rates, particularly in the first 30 days. Growth was significantly influenced by light intensity (4209.35 ± 3274.72 lux in the warm season; 3107.77 ± 3194.22 lux in the cool season) and temperature (30.20 ± 1.26 °C in the warm season; 24.83 ± 0.35 °C in the cool season), with optimal conditions occurring in the warm season. These findings highlight the potential of *G. corticata* and *G. salicornia* for sustainable aquaculture, contributing to species diversification and food security. Optimizing environmental conditions and cutting sizes is crucial for maximizing seaweed productivity in Madagascar.

Keywords: seaweed aquaculture, red algae, retention rates, growth performance, long-line cultivation, southwestern Madagascar.

Introduction

Seaweed farming, particularly mariculture, is one of the fastest-growing industries worldwide. In 2020, global seaweed production reached 35.1 million metric tons (wet weight), generating approximately USD 16.5 billion (FAO, 2022). This represents a

substantial increase from 2.2 million tons in 1969 to over 35 million tons in 2019, with aquaculture contributing nearly 97 % of global output (FAO, 2021). Today, around 130 countries are engaged in seaweed farming or harvesting for industrial and research purposes (Froehlich *et al.*, 2019; FAO, 2021). While

China, Indonesia, and the Republic of Korea lead global exports, primary importers include China, Japan, and the United States (FAO, 2022).

Seaweeds are classified into three major groups: Rhodophyta (red algae), Chlorophyta (green algae), and Ochrophyta (formerly Phaeophyta, brown algae) (Pereira, 2021; Premarathna *et al.*, 2022). Of the approximately 12,000 identified species, around 500 are harvested from the wild, while 33 genera, mainly red and brown algae, are farmed for commercial purposes (McHugh, 2003; Mouritsen, 2013). Global production of seaweed farming is dominated by *Laminaria japonica*, *Eucheuma spp.*, *Gracilaria spp.*, *Undaria pinnatifida*, *Porphyra spp.*, *Kappaphycus alvarezii*, and *Eucheuma denticulatum* (FAO, 2022).

In Africa, seaweed production remains limited despite considerable biophysical potential. Most countries rely heavily on wild harvesting, with only a small proportion coming from aquaculture (Msuya *et al.*, 2022). Strengthening seaweed farming could therefore offer substantial economic opportunities for coastal communities across the continent (Msuya *et al.*, 2022).

In Madagascar, seaweed farming began in 1989 with *K. alvarezii*, cultivated alongside *Eucheuma spp.* for carrageenan extraction, an industrial hydrocolloid widely used as gelling, thickening, and stabilizing agents in food and pharmaceutical applications (Bagal-Kestwal *et al.*, 2019). Farming activities were initiated by the Institut Halieutique et des Sciences Marines (IH. SM) of the University of Toliara in partnership with BIOMAD (Tsiresy, 2016; Todinanahary *et al.*, 2016; MAEP, 2021). In 2017, production reached 2,300 tons of dry algae, dominated by *Kappaphycus alvarezii* “Cotonii” and *Eucheuma denticulatum* “Spinousum”, mainly farmed in the southwestern and northeastern regions of Madagascar (MAEP, 2021). However, outbreaks of epiphytic filamentous algae (EFA) continue to threaten production stability (Tsiresy, 2016).

Recent surveys documented 98 marine macroalgae taxa in the coastal habitats of southwestern Madagascar, including 42 edible species (Rodine *et al.*, 2024b). Despite this diversity, only a small fraction of local households (9 %) report having tried or occasionally consumed seaweeds—mainly as *Kappaphycus alvarezii* and *Hydroclathrus clathratus*—suggesting that many edible species remain underutilized (Rodine *et al.*, 2024a). Evaluating their farming potential is therefore essential.

Southern Madagascar faces chronic food insecurity due to recurrent droughts exacerbated by climate change (Ralaingita *et al.*, 2022). About 90 % of the population in the region lives below the international poverty line of 2.15 U.S. dollars per capita per day (World Bank, 2025), with Integrated Food Security Phase Classification (IPC) analyses indicating acute food crises affecting thousands of people (Harrington *et al.*, 2022). Edible seaweed farming could contribute to nutritional resilience and diversify household incomes. Seaweeds are rich in protein, carbohydrates, minerals, vitamins, and dietary fiber, making them a promising complementary food resource (Peng *et al.*, 2021).

At the national level, the Ministry of Agriculture and Livestock (MAEP) has identified seaweed aquaculture as a priority sector with strong development potential. Strategic plans emphasize increasing production, diversifying export markets, expanding the range of cultivated species, and supporting the emergence of new enterprises (MAEP, 2021). Among candidate species for diversification, *Gracilaria* and *Hypnea* have received particular attention, as they are already cultivated or processed in Tanzania, Mauritius, and Mayotte (MAEP, 2021). Since 2022, IH.SM and Green-Madag have also initiated the testing of *Halymenia durvillei* for cosmetic production, with trial farming in Sarodrano since 2024.

However, despite more than three decades of seaweed farming, Madagascar’s production remains low compared to neighboring countries such as Tanzania, which produces approximately 170,654 tons annually (FAO, 2022). Expanding edible seaweed aquaculture—especially species suitable for long-line systems—could support food security, local value chains, and climate-resilient livelihoods.

In this context, identifying edible species with high farming potential is crucial. The present study aims to: i) assess the farming performance through retention rate, defined as the proportion of fragments remaining attached to the culture line over the observation period, and specific growth rate of a subset of edible seaweeds from southwestern Madagascar; and ii) determine the optimal initial cutting size and cultivation duration for *Gracilaria corticata* and *Gracilaria salicornia*.

Methodology

Study area

The study area is located both in the Baie of Ranobe (BR) and the Baie of Toliara (BT) in the southwest

region of Madagascar (Fig. 1). BR is situated between $23^{\circ}3'0''$ S and $43^{\circ}33'0''$ E and is bounded to the north by the Manombo River and to the south by the Fiherenana River. Adjacent to BR, the BT is a smaller bay positioned between $23^{\circ}25'0''$ S and $43^{\circ}42'0''$ E, with its northern limit marked by the Fiherenana River and its southern limit by the Onilahy River.

Sarodrano Reef is a fringing reef with a width ranging from 450 to 1,000 meters (Ramahatratra, 2014). It is located at the southern end of the Bay of Toliara, approximately 25 km south of Toliara, in the rural commune of Saint-Augustin. A coastal reef runs along the peninsula formed by the Sarodrano sand spit, which is directly connected to the mainland. This area exhibits

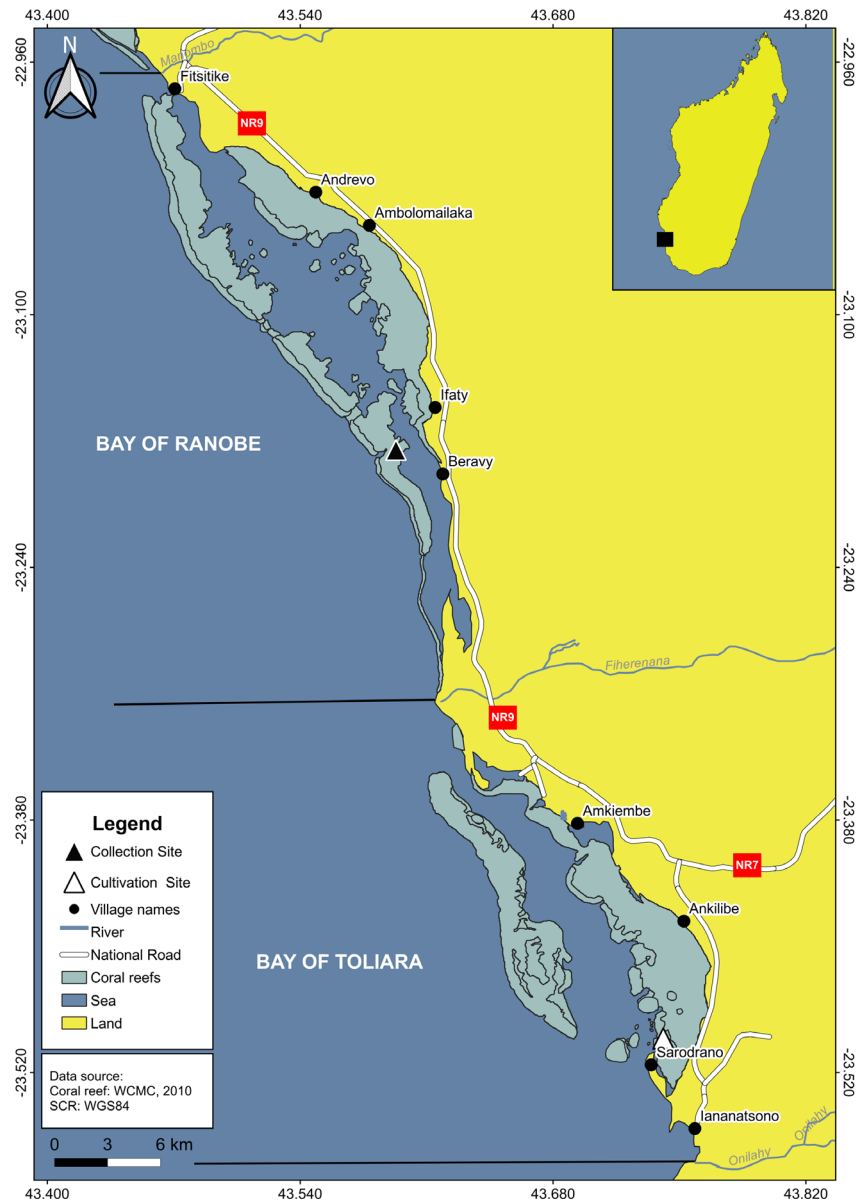


Figure 1. Location of Bay of Ranobe, Bay of Toliara, and the study sites for cutting collection and cultivation.

In BR, seaweed cuttings were collected opposite the villages of Beravy and Ifaty.

The cultivation site was designated at Sarodrano in BT, where the experimental trials were conducted in collaboration with the company GreenMadag.

similar morphological and bionomic characteristics (Clausade *et al.*, 1971). The mouth of the Onilahy River is also nearby, potentially influencing the site through nutrient inputs and variations in salinity, which could affect seaweed growth and productivity.

Collection and handling of seaweed cuttings

The cuttings used for the experiment were collected from wild seaweed species. This collection took place off the coast of Beravy and Ifaty, specifically for this purpose, using an outrigger canoe and free diving with a mask and snorkel. Cuttings were collected by hand through collection nets during low neap tide periods to avoid strong tidal currents and high winds.

Once collected, the seaweed cuttings were placed in coolers, transported directly to the IH.SM laboratory in Toliara, and transferred into outdoor aquariums previously filled with filtered seawater and equipped with an aeration system. The seaweed was kept in these aquariums overnight before being transported and directly planted at the Sarodrano sites. The transport to the cultivation sites was also carried out in coolers to preserve their physiological condition.

Assessment of seaweed retention rate and growth

Twelve seaweed species from the three major taxonomic groups were selected for assessment during warm and cool seasons. However, only eight of these species were actually cultivated during the cool season, as the remaining four (*Acanthophora spicifera*, *Galaxaura rugosa*, *Hypnea musciformis*, and *Turbinaria decurrens*) were either completely unavailable or available in quantities too low to proceed with the cultivation. All 12 species are listed in Table 1.

The long-line cultivation technique, as described by Tsiresy (2016) and Todinanahary *et al.* (2016), was employed. Lines were positioned at an average depth

of 4 m above the seabed, varying between 2.5 and 5.5 m due to tidal fluctuations (~3 m) in the Toliara region. Each cultivation line measured 20 m in length and was designated for 100 cuttings of a single species, with a spacing of 25 cm between cuttings. Cuttings ranged in wet weight from 5 to 40 g, depending on the species. The experiment was conducted twice, once during the warm season (January–March 2024) and once during the cool season (June–August 2024). For each species, 100 cuttings were cultivated per season.

The maintenance of seaweed cultivation lines was carried out daily or every two to three days by pirogue, depending on maintenance requirements, weather conditions—particularly wind intensity—and tide schedules. In general, maintenance lasted three to four hours, usually between 8:00 and 14:00, depending on tide conditions.

The retention rate of seaweed on the lines was monitored weekly by counting the number of remaining cuttings for each farmed species, while the weight of each individual attached cutting was measured only at the beginning and the end of the 60-day cultivation period. A kitchen scale with 1g precision was used for this monitoring, with measurements taken after draining the seaweed.

Optimizing culture parameter of performance for *Gracilaria corticata* and *Gracilaria salicornia*

G. corticata and *G. salicornia* were selected due to their promising potential, exhibiting high retention rates in both warm and cool seasons. Cultivation was

Table 1. Seaweed species collected and used in the cultivation experiment during the warm and cool seasons.

Group	Species	Season	
		Warm	Cool
Red algae	- <i>Acanthophora spicifera</i>	+	-
	- <i>Gracilaria corticata</i>	+	+
	- <i>Gracilaria salicornia</i>	+	+
	- <i>Galaxaura rugosa</i>	+	-
	- <i>Hypnea cervicornis</i>	+	+
	- <i>Hypnea musciformis</i>	+	-
Brown algae	- <i>Dictyota dichotoma</i>	+	+
	- <i>Hormophysa cuneiformis</i>	+	+
	- <i>Padina boryana</i>	+	+
	- <i>Turbinaria decurrens</i>	+	-
	- <i>Turbinaria ornata</i>	+	+
Green	- <i>Ulva lactuca</i>	+	+

“+” indicates that the species was used in the experiment during the given season; “-” indicates that the species was not used.

conducted over a 60-day period from July 17 to September 3, 2024, using the same cultivation method (longline). For each species, four lines containing 100 cuttings were established with size classes]0–25 g[, [25–50 g[, [50–75 g[, and [75–100 g[. Smaller cuttings were used for the lighter and more fragile *Gracilaria* species (Herliany *et al.*, 2016; KouhGardi *et al.*, 2014), compared to ~100 g typically used for *Kappaphycus alvarezii*. (Tsiresy, 2016). Cultures were monitored every 15 days (Raja *et al.*, 2025) at 30, 45, and 60 days - 30 days as an early check, 45 days following Herliany *et al.* (2016), and 60 days corresponding to typical harvest (The Nature Conservancy, 2024) - with retention rates and biomass weight recorded.

For each experiment, the daily growth rate (DGR) was calculated using an exponential growth model with the following formula:

$$DGR = \left(\frac{DGR = \ln W_t - \ln W_0}{t} \right) \times 100$$

where:

DGR = Daily Growth Rate (%·d⁻¹)

W₀ = Initial weight

W_t = Final weight

t = Cultivation duration (days)

This method follows the approach described by Hurtado *et al.* (2001), Kasim and Mustapha 2017, and Susilowati *et al.* (2019).

Monitoring of environmental parameters

During the study period, which encompassed both warm and cool seasons, environmental parameters of the water surface at the cultivation field were measured and recorded. Temperature and light intensity were monitored hourly using a HOBO Pendant Light/Temperature Logger (UA-002-64). Salinity was measured daily (at every 10:00 AM) using a refractometer. Current velocity data were obtained from the Copernicus Marine Environment Monitoring Service (CMEMS) (<https://marine.copernicus.eu/>).

Statistical analysis

Seaweed retention rate was analyzed using a binomial generalized linear model of the form `glm(cbind(-Fixed, Detached) ~ factors)`, followed by Chi-square likelihood ratio tests (`anova(model, test = "Chisq")`). This approach was applied to assess, in the first experiment, the effects of species, season, and their interaction, and in the second experiment, the effects of cutting size, cultivation period, and their interaction

on the retention rate of *Gracilaria corticata* and *Gracilaria salicornia*.

Specific growth rate (SGR) data were first evaluated for normality using the Anderson–Darling test and for homogeneity of variances using Levene’s test. When these assumptions were not satisfied, square-root or logarithmic transformations were applied. As the transformed data still violated parametric assumptions, analyses were conducted using the non-parametric two-factor Scheirer–Ray–Hare test, followed by Dunn’s post-hoc comparisons. The factors considered were species and season in the first experiment, and initial cutting size and cultivation period in the second experiment.

All statistical analyses were performed in R (version 4.2.1, R Core Team, 2022). The *readxl* package was used for data importation, *nortest* for the Anderson–Darling test, and *car* for Levene’s test. The Scheirer–Ray–Hare analyses were conducted using *rstatix*, *coin*, and *rcompanion*, while Dunn’s tests were performed with FSA.

Results

Environmental parameters

The environmental surface water parameters and variability are presented in Figure 2. The mean temperature, light intensity, and current speed were higher during the warm season (30.2 ± 1.3 °C; 4209 ± 3275 lux; 0.34 ± 0.19 m s⁻¹) than in the cool season (24.8 ± 0.35 °C; 3108 ± 3194 lux; 0.16 ± 0.06 m s⁻¹). In contrast, salinity was slightly lower in the warm season (34.82 ± 0.47 ‰), when variability was higher than in the cool season (35.50 ± 0.00 ‰, P < 0.005), when salinity was constant. These environmental conditions help explain the observed seasonal differences in seaweed growth and attachment.

Retention rates

Apart from *H. cuneiformis*, *G. corticata*, *G. salicornia*, *T. ornata*, and *T. decurrens*, all other tested species exhibited low retention rates (<50%) during the first four weeks of cultivation in the warm season (Fig. 3A). Similar observations were made during the cool season, except for *T. decurrens*, which was absent during this period (Fig. 3B).

At the end of the nine-week cultivation period, only *G. corticata*, *G. salicornia*, and *H. cuneiformis* showed high retention rates, with 51 %, 45 %, and 64 % in the warm season and 56 %, 67 %, and 17 % in the cool season, respectively. Statistical analysis revealed a significant

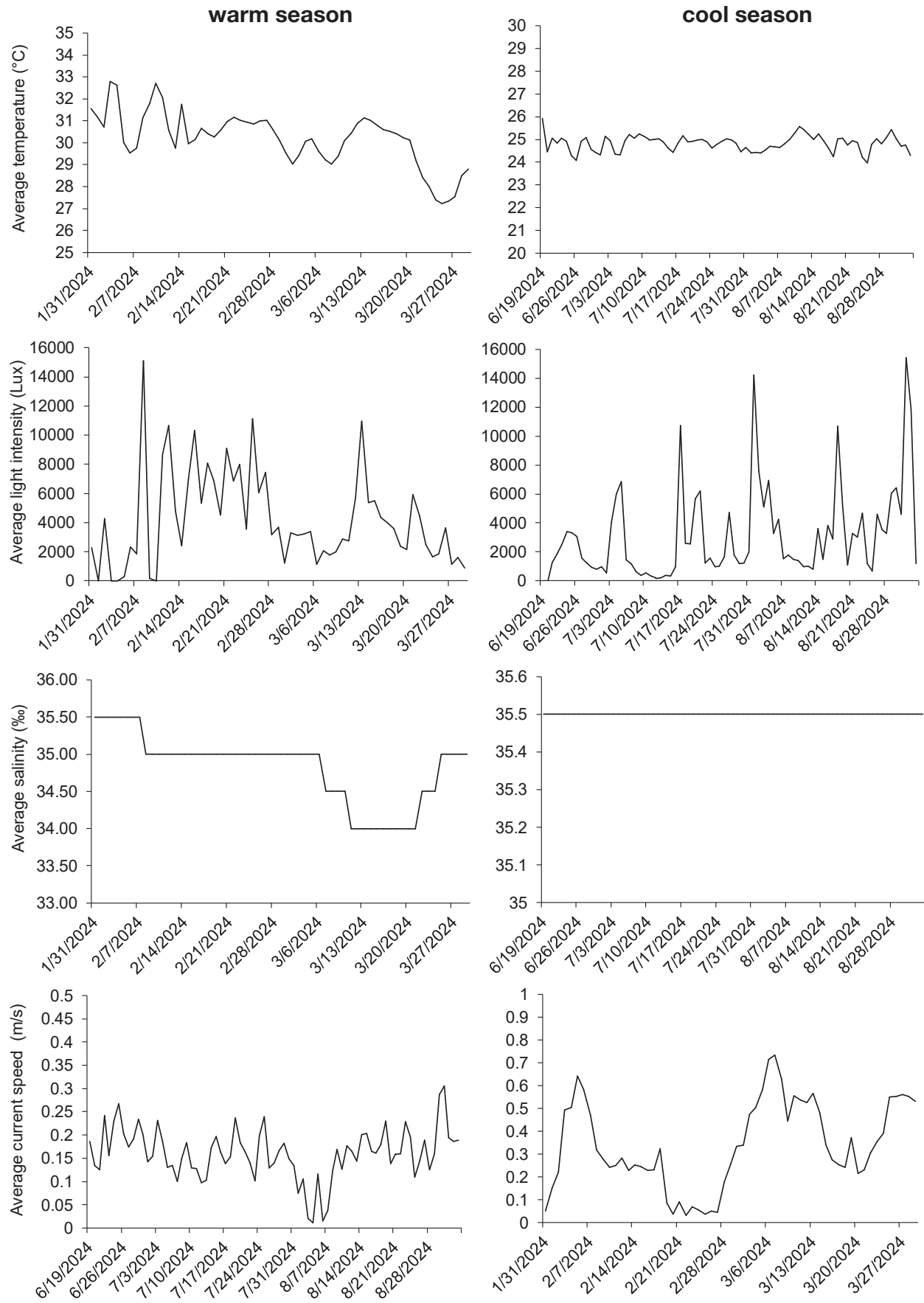


Figure 2. Variation of environmental parameters in the sea surface of the culture site during the warm and cool seasons.

Table 2. Effects of species, season, and their interaction on seaweed retention rates (global tests).

Variable / Response	Factor / Comparison	Test used	df	Test statistic	p-value
Retention rate	Species (global effect)	GLM binomial + ANOVA χ^2	2	11.132	0.0038
Retention rate	Season (global effect)	GLM binomial + ANOVA χ^2	1	2.719	0.099
Retention rate	Species $\times$ Season (interaction)	GLM binomial + ANOVA χ^2	2	55.826	7.54e-13

effect of species on retention rates ($p < 0.05$), whereas the effect of season alone was not significant ($p > 0.05$). Importantly, there was a highly significant interaction between species and season ($p < 0.001$), indicating that the effect of season differed depending on the species

(Table 2). Post-hoc comparisons showed that *H. cuneiformis* differed significantly from *G. corticata* and *G. salicornia* in the cool season ($p < 0.005$), while in the warm season, only the comparison *H. cuneiformis* vs *G. salicornia* was significant ($p = 0.02$).

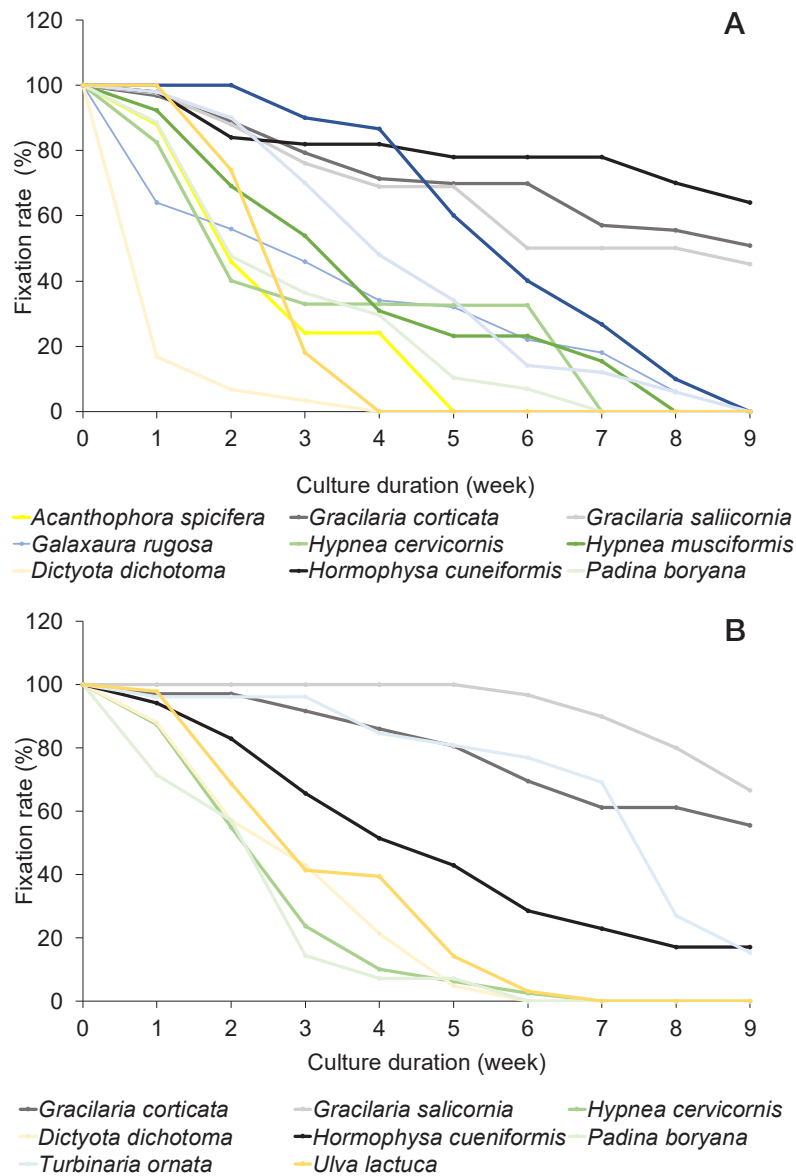


Figure 3. Evolution of seaweed retention rates. A. Warm season; B. Cool season.

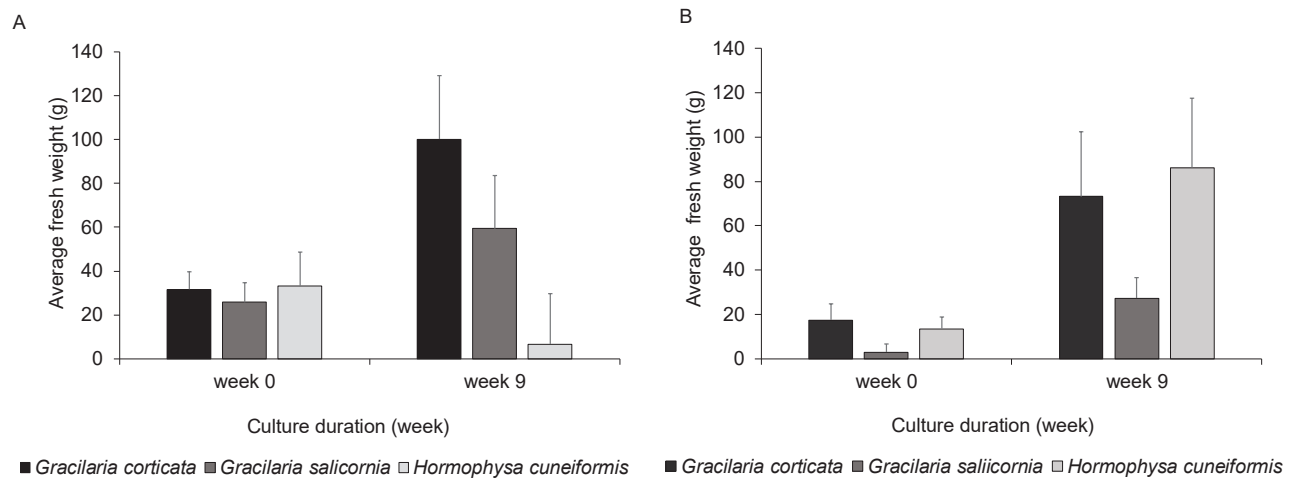


Figure 4. Evolution of seaweed growth: Initial and final weights. A. Cool season and B. Warm season.

Growth and specific rates of seaweed species

Over the nine-week cultivation period, all species showed positive growth except for *H. cuneiformis* during the cool season, where the mean weight decreased from 33.08 ± 15.59 g to 6.67 ± 2.73 g (Fig. 4).

The Specific Growth Rate (SGR), ranged from a minimum of $1.34 \% d^{-1} \pm 1.03$ for *G. salicornia* in the cool season, to a maximum of $4.99 \% d^{-1} \pm 1.34$ for *G. salicornia* in the warm season (Fig. 5), except *H. cuneiformis*, which exhibited negative growth during the cool season. Significant differences were found in the SGR between season ($p < 0.05$) but not between species ($p > 0.05$). However, the interaction between species

and season was highly significant ($p < 0.01$), indicating that seasonal effects differed among species (Table 3).

Effects of cutting size and cultivation period on the retention and growth rates of *G. corticata* and *G. salicornia*

Retention rates were generally high for both species during the first 30 days. For *G. corticata*, rates exceeded 80 % for most cutting sizes, except the largest fragments (75–100 g), which showed lower attachment (56 %), declining to 26–71 % by day 60 (Fig. 6A). *G. salicornia* showed retention rates above 80 % for small and medium cuttings (0–50 g) and above 60 % for larger cuttings after 60 days (Fig. 6B). For both species,

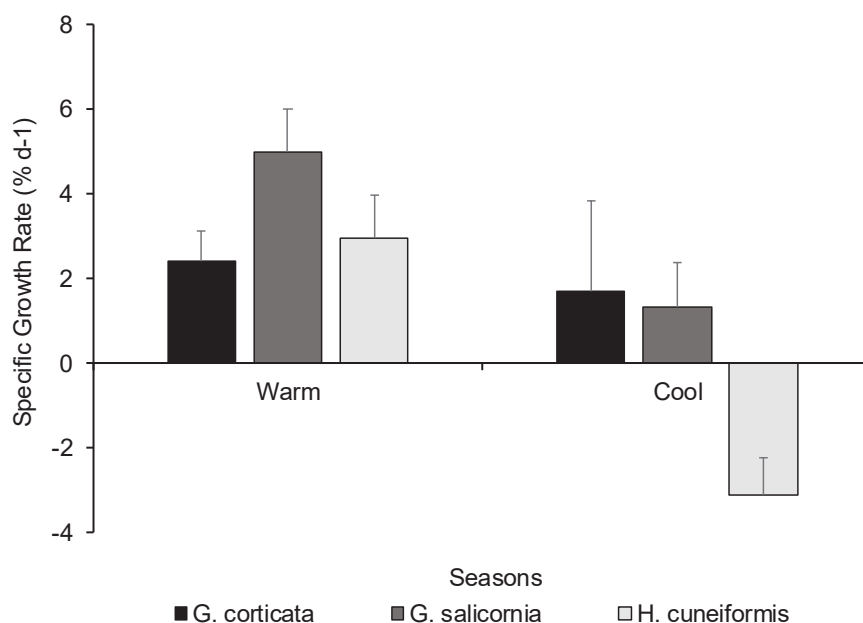


Figure 5. Growth rates of seaweed species during the two seasons.

Table 3. Results of the Scheirer–Ray–Hare test assessing the effects of species, season, and their interaction on Specific Growth Rate (SGR).

Source of variation	Df	Sum Sq	H	p-value
Species	2	7,274	5.205	0.074
Season	1	65,437	46.825	<0.001
Species × Season	2	17,694	12.661	0.0018
Residuals	123	91,554		

cutting size and culture duration significantly affected retention ($p < 0.05$), with no significant interaction ($p > 0.05$) (Tables 4 and 5).

Growth dynamics over the 60-day cultivation period across different initial weight classes for both species *G. Corticata* and *G. Salicornia* are presented in Figures 7 A and B. In *G. corticata*, growth rate was generally positive, peaking at $+3.6 \% d^{-1} \pm 2.7$ for small cuttings (0–25 g) during the first 30 days, while larger cuttings reached about $+1.2 \% d^{-1}$ (Fig. 8A). In *G. salicornia*, growth rate was highest during the first 30 days ($+3.8 \% d^{-1} \pm 5.3$ for 0–25 g cuttings) but declined for larger cuttings, reaching $-7 \% d^{-1}$ for 50–100 g cuttings between days 45–60 (Fig. 8B). Growth rate was significantly affected by cutting size, culture duration, and their interaction in both species ($p < 0.05$; Tables 6–7). Results for post hoc comparisons are detailed in Tables 8–9.

Discussion

Suitability of edible seaweed species for cultivation

Among the edible seaweeds tested, *Gracilaria corticata* and *Gracilaria salicornia* were the only species that maintained retention rates above 50 % across both seasons. All other species—*Acanthophora spicifera*, *Hypnea*

musciformis, *Galaxaura rugosa*, and *Turbinaria decurrens*—either declined sharply or were absent during the cool season. Similar seasonal patterns have been documented for *A. spicifera* and *H. musciformis*, whose biomass peaks in warm months and drops markedly in winter (Kilar and McLachlan, 1986; Tsuda *et al.*, 2008; Aziza *et al.*, 2008; Mtolera and Buriyo, 2004). Their instability, combined with low retention rates, indicates that these species are not suitable for long-line aquaculture in southwestern Madagascar.

Conversely, the strong attachment performance of both *Gracilaria* species reflects their recognized ecological plasticity. *Gracilaria* can tolerate wide temperature ranges—up to 35 °C (Gorman *et al.*, 2017)—broad salinity variability (10–50 ‰; Alvez *et al.*, 2021; Mensi *et al.*, 2020), and diverse irradiance levels (Abreu *et al.*, 2009; Kim and Yarish, 2014; Ak and Yücesan, 2012). These ranges encompass the environmental conditions recorded during this study, explaining their superior performance.

Seasonal environmental effects on growth

Growth rates of *G. corticata* and *G. salicornia* were higher during the warm season. Warmer temperatures and

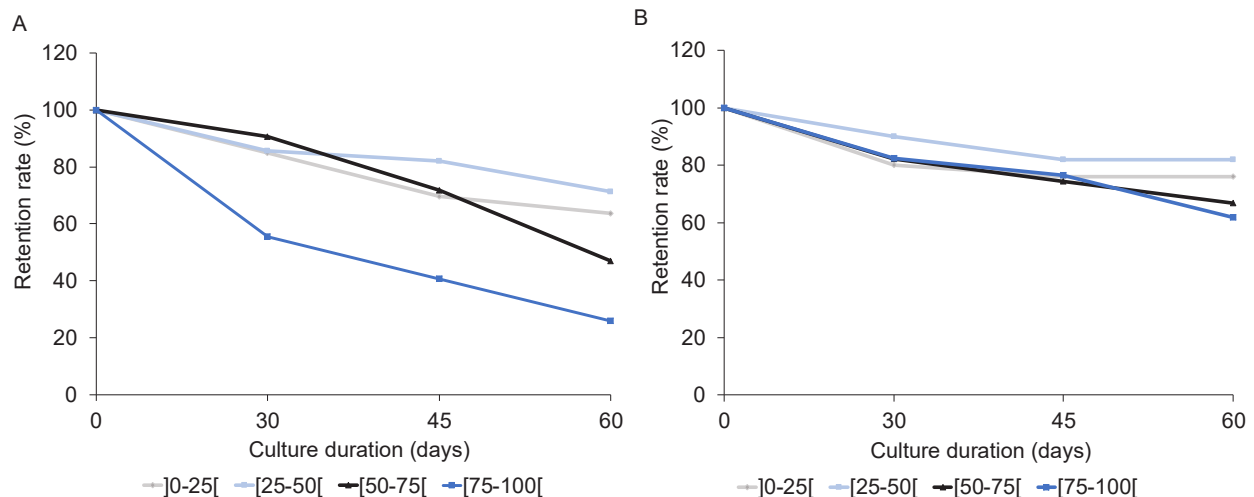
**Figure 6.** Retention rates of cuttings during a 60-Day cultivation period: (A) *G. corticata* and (B) *G. salicornia*.

Table 4. Statistical analysis of the effects of cutting size, cultivation period, and their interaction on retention rates of *Gracilaria corticata*.

Term	Df	Deviance Resid.	Df Resid.	Dev	Pr>Chi)
NULL			11	202.171	
Cutting size	3	114.226	8	87.946	< 2e-16
Cultivation period	2	76.479	6	11.467	< 2e-16
Cutting size: Cultivation period	6	11.467	0	0.000	0.07498

Table 5. Statistical analysis of the effects of cutting size, culture time, and their interaction on retention rates of *Gracilaria salicornia*.

Term	Df	Deviance Resid.	Df Resid.	Dev	Pr>Chi)
NULL			11	34.942	
Cutting size	3	14.189	8	20.753	0.0026588
Cultivation period	2	16.289	6	4.464	0.0002903
Cutting size: Cultivation period	6	4.464	0	0.000	0.6141437

stronger irradiance are known to enhance photosynthesis and biomass production in *Gracilaria* (Wedchaparn *et al.*, 2015; Zou and Gao, 2013). The lower current velocity observed during the cool season may also have limited nutrient renewal, contributing to slower growth.

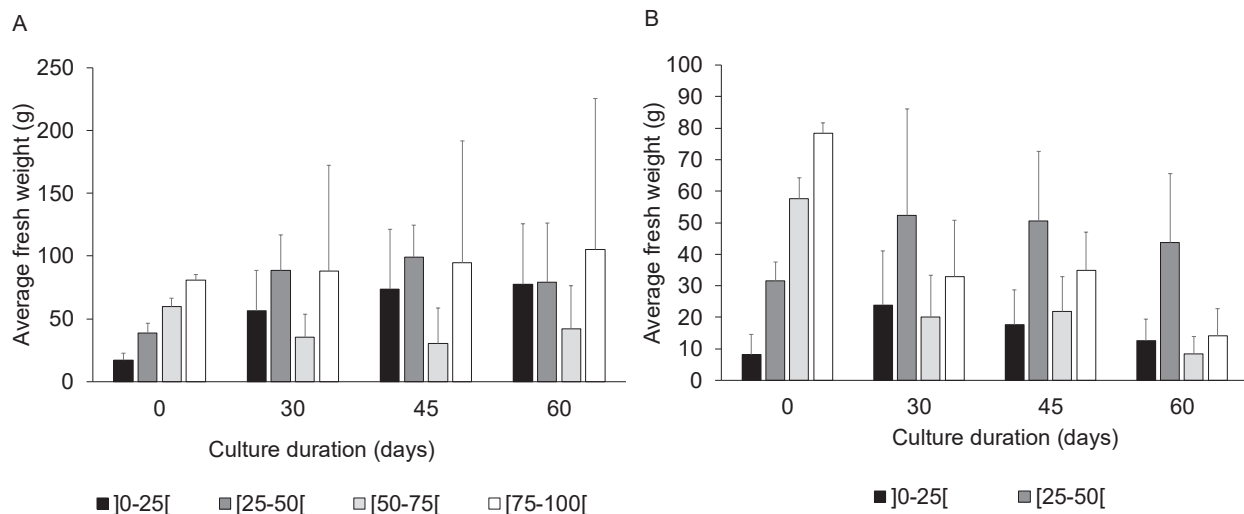
Slightly reduced salinity during the warm season did not inhibit growth, confirming that both species tolerate moderate salinity fluctuations.

Influence of cutting size and cultivation duration

Initial cutting size had a marked effect on growth. The highest growth rates—3.63 % day⁻¹ for *G. corticata* and 3.8 % day⁻¹ for *G. salicornia*—were obtained from small

cuttings (0–25 g) cultivated for 30 days. This pattern mirrors results from *G. verrucosa*, where small cuttings consistently performed best (Susilowati *et al.*, 2019), and aligns with values reported by Choi *et al.* (2006) and López-Campos *et al.* (2022).

In contrast, cuttings larger than 50 g tended to lose biomass. This decline may result from epiphytic overgrowth (Choi *et al.*, 2006) or increased fragmentation susceptibility when thalli reach excessive size (López-Campos *et al.*, 2022). These findings highlight the importance of using small, vigorous cuttings and limiting cultivation cycles to avoid stress, breakage, or epiphyte accumulation.

Figure 7. Growth dynamics of seaweeds across different initial weight classes over a 60-day cultivation period. A. *Gracilaria corticata*; B. *Gracilaria salicornia*.

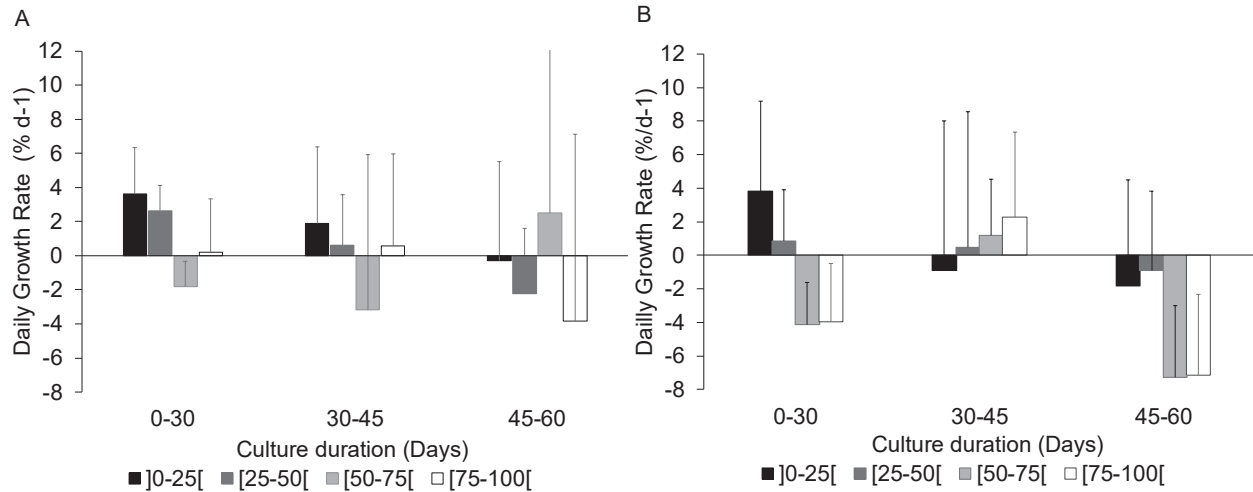


Figure 8. Daily Growth Rate (DGR% d⁻¹) dynamics of seaweeds across different initial weight classes over a 60-day cultivation period. A. *Gracilaria corticata*; B. *Gracilaria salicornia*. Vertical error bars indicate standard deviations.

Implications for optimizing cultivation

Based on retention, growth, and seasonal patterns, *G. corticata* and *G. salicornia* represent the most promising edible seaweeds for long-line cultivation in southwestern Madagascar. Optimal performance is achieved by selecting initial cutting sizes of 0–25 g and applying short cultivation cycles (~30 days). Although growth rates are higher during the warm season, cultivation can be carried out throughout the year, including the cool season, albeit with slower growth.

In conclusion, *G. corticata* and *G. salicornia* emerged as the most suitable species for long-line aquaculture in southwestern Madagascar due to their high retention, strong growth, and adaptability compared to other edible seaweeds. Their successful cultivation can support sustainable seaweed farming, contributing to food security, economic development, and ecological resilience. Long-term monitoring and adaptive management will be essential to ensure the continued expansion and sustainability of Malagasy seaweed aquaculture.

Table 6. Results of the Scheirer–Ray–Hare test assessing the effects of cutting size, cultivation period and their interaction on the Specific Growth Rate (SGR) of *Gracilaria corticata*.

Source of variation	Df	Sum Sq	H	p-value
Cutting size	2	83957	15.802	0.00124488
Cultivation period	3	73815	13.893	0.00096188
Cutting size: Cultivation period	6	123515	23.248	0.00071760
Residuals	240	1052274		

Table 7. Results of the Scheirer–Ray–Hare test assessing the effects of cutting size, cultivation period and their interaction on the Specific Growth Rate (SGR) of *Gracilaria salicornia*.

Source of variation	Df	Sum Sq	H	p-value
Cutting size	3	385113	32.258	4.6169e-07
Cultivation period	2	409408	34.293	3.5750e-08
Cutting size: Cultivation period	6	615611	51.566	2.2800e-09
Residuals	366	3090648		

Table 8. Combined Dunn post hoc comparisons (Bonferroni-adjusted) for the effects of cutting size and culture duration on the Specific Growth Rate (SGR) of *Gracilaria corticata*.

		Comparison	Z	P.unadj	P.adj
Cutting size	1	0-25g - 25-50g	12.2780149	0.0227256905	0.136354143
	2	0-25g - 50-75g	3.6912792	0.0002231291	0.001338774
	3	25-50g - 50-75g	1.4387318	0.1502265176	0.901359106
	4	0-25g - 75-100g	1.6704156	0.0948371579	0.569022947
	5	25-50g - 75-100g	0.1435833	0.8858295201	1.000000000
	6	50-75g - 75-100g	-0.9358310	0.3493602043	1.000000000
Cultivation period	1	30days - 45days	2.048656	0.0404958049	0.1214874148
	2	30days - 60days	3.721027	0.0001984138	0.0005952415
	3	45days - 60days	1.672372	0.0944510080	0.2833530241

Table 9. Combined Dunn post hoc comparisons (Bonferroni-adjusted) for the effects of cutting size and culture duration on the Specific Growth Rate (SGR) of *Gracilaria salicornia*.

		Comparison	Z	P.unadj	P.adj
Cutting size	1	0-25g - 25-50g	-0.09408181	9.250442e-01	1.000000e+00
	2	0-25g - 50-75g	4.28443586	1.832034e-05	1.099221e-04
	3	25-50g - 50-75g	4.43407426	9.246875e-06	5.548125e-05
	4	0-25g - 75-100g	3.52833365	4.181847e-04	2.509108e-03
	5	25-50g - 75-100g	3.65414469	2.580407e-04	1.548244e-03
	6	50-75g - 75-100g	-0.44670393	6.550888e-01	1.000000e+00
Cultivation period	1	30days - 45days	-0.746326	4.554705e-01	1.000000e+00
	2	30days - 60days	4.656971	3.208961e-06	9.626884e-06
	3	45days - 60days	5.403297	6.542710e-08	1.962813e-07

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