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Original Article

Opportunities for the development of seaweed farming as a supplementary income for small-scale fishermen in Nador lagoon: Experimental cultivations of *Gracilaria gracilis* (Stackhouse)

Jawad Kassila[1*], Hassan Nhhala[1], Thierry Givernaud[2], El Mahdi Mansouri[3], Outmane Yazami[4], Azzeddine Abrehouch[1], Abdelhakim Mesfioui[5], Mohamed Idhalla[6]

[1] Centre Spécialisé en Zootechnie et Ingénierie Aquacoles Marines, INRH, BP 32, M'diq, Morocco
[2] STECOF Company, Kenitra, Morocco
[3] Agence Nationale de Développement de l'Aquaculture, Rabat, Morocco
[4] Département des sciences de la vie, Faculté Polydisciplinaire, Larache, Morocco
[5] Centre Régional de Nador, INRH, Nador, Morocco
[6] Département de l'Aquaculture, INRH, Casablanca, Morocco

ABSTRACT: The feasibility of growing red seaweed, *Gracilaria gracilis* (Gigartinales, Rhodophyta) in off-bottom and floating longline systems was investigated in Bouareg location. The weight gains of *G. gracilis* in off-bottom cultures tested in winter were low. The lowest daily growth rate (DGR) was recorded in sheet-lines (1.91 % day^{-1}, $p < 0.01$) while the highest's RGR were observed in net-lines and ropes-lines (2.72 and 2.77 % day^{-1} respectively, $p < 0.01$). Plants of *G. gracilis* grew well in the floating longline culture tested at spring. The weight growth rates ranged between 2.54 and 4.26 % day^{-1}. The highest growth rate in Nador lagoon was observed in treatment stocked with 0.6 kg m^{-2}. The high stocking density (0.8 kg m^{-2}) leaded to low growth most probably due to stress on the seaweed when competing for space and resources. Over a 60-day cycle, the harvest of *G. gracilis* cultivated on floating longline system in Nador lagoon was estimated at about 101 t FWT ha^{-1} $year^{-1}$. With 8:1 as wet to dry ratio, the production yield per cropping was estimated at 3,156 kg (DW) per ha. However, the total sales per year was estimated at about $ 6,564 per ha.

Keywords: *Gracilaria gracilis*, culture, Nador lagoon, income, fishermen
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1. INTRODUCTION

The seaweed farming is often undertaken in locations where coastal communities are in front of few economic alternatives (Valderrama, 2012). Small-scale fishermen and their communities are among the poorest sectors of most economies, despite their social and cultural importance and their contribution to total fish production (Allison and Ellis, 2001). The seaweed farming is often suggested as a way to alleviate poverty and to reduce fisheries exploitation (Hill et al., 2011). Seaweed farming is an extensive practice, where inputs and labour are relatively low, compared to the highly controlled intensive culture (Baluyut and Balnyme, 1995).

Correspondence
Jawad Kassila
Centre Spécialisé en Zootechnie et Ingénierie Aquacoles Marines, INRH, BP 32, M'diq, Morocco
Mail: kassilajawad@yahoo.com

the intensive production systems do not necessarily threaten efforts to reduce poverty while large-scale seaweed culture is attractive due to low cost technologies that have been in operation for decades, and the multiple uses of the product. The introduction of seaweed farming does little to mitigate the effects of fisheries overexploitation, and that rather than replacing fishing; it is utilized as an additional source of income (Sievanen et al., 2005). Valderrama (2012) reported that the socioeconomic impacts of seaweed farming have been positive. He attributed this mainly to small-scale, family operations resulting in the generation of substantial employment as compared to other forms of aquaculture. Farmed seaweed production is expanding rapidly in shallow marine habitats as demand for seaweed products has outstripped supply from wild resources (Hehre and Meeuwig, 2016). In Morocco, the seaweed industry based on the extraction of agar from wild *Gelidium sesquipedale* is well-established. To supplement the natural resources of *Gelidium* for agar production, suitable natural sites have been recently identified for *Gracilaria* farming by the National Agency for Aquaculture Development (ANDA). The genus *Gracilaria* is a most attractive candidate from seaweed species because of its ability to achieve high yields and its commercially valuable extracts (Buschmann et al., 2001). The rising demand for seaweed products and the need for fishermen to develop alternative or supplementary livelihoods are driving seaweed farms to emerge in some locations: Sidi Rahal (NW, Atlantic Ocean), Nador lagoon (NE, Mediterranean Sea), and Dakhla bay (SW, Atlantic Ocean). The Nador lagoon has biological, ecological and economic interests and thus constitutes a major challenge for the development of the region. However, it is subject to pollution by sewage, industrial waste, and agricultural discharges (Matoir et al., 2015). The Nador lagoon is considered as a eutrophic semi-enclosed basin. The disappearance of *Posidonia oceanica*, a sea grass, from the lagoon concerned many fishers because of its importance in primary production (Chuenpagdee, 2011). The restoration of Nador lagoon has become a priority and a prerequisite for the implementation of several projects undertaken in the region. The opening of the new artificial inlet contributed significantly to the reduction of eutrophication by enhancing the water circulation into the lagoon (Aknaf et al. 2015). A series of studies have demonstrated the potential beneficial effects of seaweeds on wastewater treatment and bioremediation (Chung et al. 2002). The recovery of Nador lagoon may also be possible with an effective implementation of coastal management and alternative livelihood programs for coastal communities. In the context of declining fish returns and critical income, there is an urgent need to support the fishermen community. Since 2013, fishermen began exploring, the possibility of seaweed (*G. gracilis*) farming in Nador lagoon, under the supervision of the National Agency for Aquaculture Development (ANDA). Within the context of “Integrated coastal zone management (ICZM)” process, and the “Sustainable Med” program implemented by the Ministry of Environment, the “Marchica” fishermen cooperative, created on October 5th, 2013, has received a grant for *Gracilaria* farming from the Global Environment Fund (GEF) and the World Bank. The designated project plans to reach an annual production of 1,300 tons (dry weight) of *G. gracilis* at Bouareg location in Nador lagoon. The feasibility of growing red seaweed, *Gracilaria gracilis* (Gigartinales, Rhodophyta) in off-bottom and floating longline systems was then investigated in this location. The results of the experimental cultivations were discussed in this paper. In order to find a more efficient technique, different support lines (sheet, net and rope lines) using off-bottom cultures of *G. gracilis* were compared by its daily growth rate. Different stocking densities of *G. gracilis* (0.4, 0.6 and 0.8 kg m^{-2}) in floating longline system were also tested. The return analysis was done for 1 ha *Gracilaria* farming using the floating longline method. This paper presents a case study of the transition of some fishermen at Nador lagoon from an exclusive dependence upon capture fishing to an extensive involvement in seaweed (*Gracilaria gracilis*) farming.

2. Materials and Methods

2.1.Field cultivation area

The experimental cultivations of *Gracilaria gracilis* were conducted on the south-western portion of Nador lagoon, at Bouareg location (35°07’41.8” N, 2°52’13.9” W) (Fig. 1). The farming area has moderate water movement, and sandy mud sediments (Najih et al., 2017). The organic matter in sediment ranged between 0.9 and 1.6 %. The Nador lagoon is situated in the Mediterranean coast of Morocco between ‘Trois-fourches’ cape and ‘Ras-El-Ma’ cape. The lagoon basin has a volume of about 5.4 10^8 m^3 and a surface of about 115 km^2. The lagoon has an oval shape, quite regular. The lengths of major and minor axis of the lagoon are ~ 23 km and ~ 7 km respectively. The width of the new built inlet is about 300 m. The average depth of the lagoon is 4.8 m, with a maximum depth of 8 m. The prevalent wind come from W-NW and E, which is of Biological and Ecological

Interest(SBEI) since 1996 and designated Ramsar site since 2005. about the direction of the major axis of the lagoon.

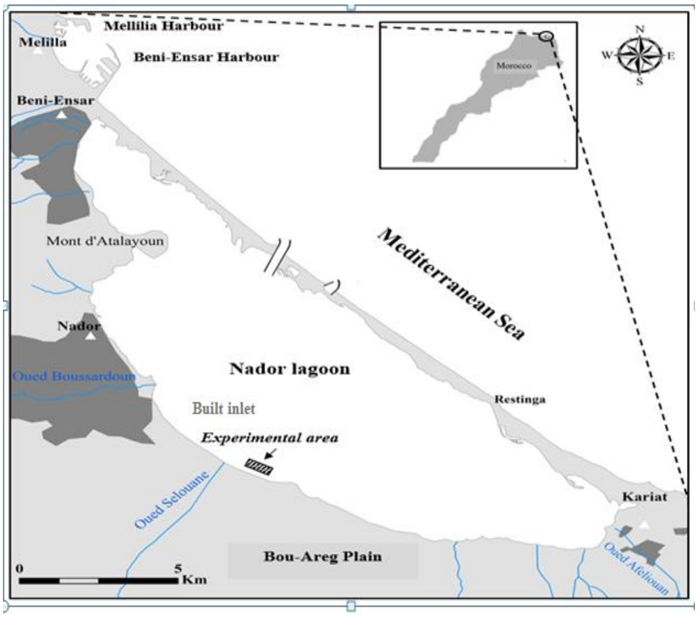

Figure 1. Map showing the experimental location in Nador Lagoon in North-eastern Morocco.

Uncontrolled discharges of domestic wastes, agricultural pollutants, and industrial effluents have caused an imbalance in this ecosystem that tends towards eutrophication. The Nador lagoon is considered as a eutrophic semi-enclosed basin. A management plan was developed to reduce pollution in the lagoon. This will involve the construction of a drainage system and diversion channels, shoreline cleaning, and a program with farmers to reduce agricultural pollutants including pesticides (Chuenpagdee, 2011).

2.2.Small-scale fishermen community

Small-scale fishing is the main socio-economic activity in Nador lagoon. Populated by approximately 800 fishermen, this community has traditionally depended almost exclusively (92 %) upon fishing for its livelihood (Najih et al., 2015). The artisanal fisheries sites that surround the Nador lagoon is 16, including nearly 390 boats. Fishermen explored the waters of Nador lagoon in their motorized boats and used various forms of gear such as trammel nets, the “pallanza” (a form of set net), beach seine and small purse seines. Most boats have small outboard engines between 8 and 20 horse powers. It is a mixed fishery, with eels, anchovies, seabream, cuttlefish and octopus. Fishing in this lagoon is an entirely male activity with women playing no role in the supply chain. The fishermen population is relatively poor and less likely to be literate than the regional average. Fishing in Nador lagoon is almost an exclusive profession (Chuenpagdee, 2011). Only 8% of fishermen combine fishing with subsistence agriculture or small commercial activities. Since the early 1980’s, fishermen have experienced declining catches and incomes.

2.3.Experimental cultivations

From 23 December, 2016 to 23 January, 2017, *Gracilaria gracilis* was cultivated by three off-bottom methods in three rectangular modules (5 m × 25 m). The wooden anchors (Eucalyptus) were staked firmly into the substratum by using heavy ball hammer about 5 meters apart. The stakes were arranged in rows at 1 m intervals. *G. gracilis* was cultivated in off-bottom systems using three different support lines: sheet, net and rope (Fig. 2). The sheet support (1 m wide and 5 m long) was developed by ATSEA Technologies Co. (Belgium) for vegetative growing red seaweeds. The different lines were then stretched tightly between wooden poles. The support lines were hung at about 0.5 m above the bottom. The *Gracilaria* seedlings of 100 g were tied to the lines at 25 cm intervals using soft plastic materials.

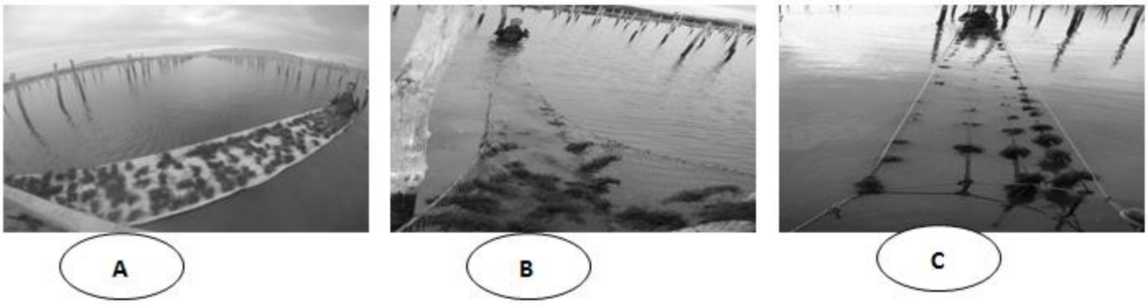

Figure 2. Fixed off-bottom cultures of *Gracilaria gracilis* in Nador lagoon using sheet (A), net (B) and rope (C) lines.

From 17 April to 31 May, 2017, *G. gracilis* was cultivated in floating longline systems under three stocking densities (0.4, 0.6 and 0.8 kg m^{-2}), in three rectangular modules (5 m × 25 m) (Fig. 3). The longlines (soft plastic netting of 5 m length) were attached to the anchored steel piles and suspended about 80-100 cm from the bottom. Each longline was seeded with 200 seedlings of 100 g wet weight, placed at equal intervals of 25 cm. Buoys were used as floats to maintain the seaweed line level. The three stocking densities of *G. gracilis* were tested by using 25, 38 and 50 longlines respectively.

Figure 3. Floating longline culture of *Gracilaria gracilis* in Marchica lagoon.

2.4.Growth measurement

The growth of *G. gracilis* was measured after 15 and 30 days of cultivation in off-bottom cultures, and after 60 days in longline cultures. Thereafter a total sample of 50 plants was taken randomly from each treatment. The plants were left in the air for two minute to remove excess water; after that, the biomass was determined. Each plant was individually weighed with a scale having a precision of 0.01 g. The daily growth rate (DGR) was measured using the formula DGR=100× (ln (W_f /W_i)/t), where W_f = final wet weight; W_i = initial wet weight, and t=cultivation days (Hurtado et al. 2001).

2.5. Abiotic parameters

The environmental parameters (temperature, oxygen concentration, pH, and salinity) were measured weekly over the experimental periods and their min-max ranges are shown in Table 1.

Table 1: Min-Max ranges of temperature, salinity, dissolved O_2 and pH during the both experimental periods.

Experimental periods	Temperature (°C)	Salinity (‰)	Dissolved oxygen (mg l^{-1})	pH
23 December 2016 - 23 January 2017 (Fixed off-bottom cultures)	15.3 - 16.8	37.2 - 38.2	8.3 - 9.2	8.0 - 8.4
17 April 2017 - 31 May 2017 (Floating longline culture)	20.0 - 23.1	36.6 - 38.1	5.9 - 7.8	8.0 - 8.1

2.6.Data analysis

To determine the influence of support line treatment on length and weight growth rates, One-way ANOVAs followed by Tukey test as post-hoc test were performed for both periods (23 December 2016 -07 January 2017 and 23 December 2016 - 23 January 2017). Similarly, the effect of stocking density on final biomass and growth rates was analysed by ANOVA followed by Turkey test during the experimental period (17 April - 31 May 2017). The assumptions of normality and homogeneity of variances were previously tested with Shapiro-Wilk and Levene tests (p value > 0.05) respectively. A value of p < 0.05 was considered to indicate statistical significance. Statistical analyses were performed using the software IBM SPSS Statistics.

3.RESULTS

3.1.Fixed off-bottom cultures

The type of lines has significant effect on growth in length and weight of *Gracilaria gracilis* in fixed off-bottom cultures (Table 2). The length growth rates were ranged between 1.91 and 2.77 % day^{-1} over 30 days (23 December 2016 - 23 January 2017). The lowest daily growth rate (DGR) was recorded in sheet-lines (1.91 % day^{-1}, p < 0.01) while the highest's DGR were observed in net-lines and ropes-lines (2.72 and 2.77 % day^{-1} respectively, p < 0.01). Thalli had low weight gain in all treatments over the experimental period (23 December 2016 - 23 January 2017) (Table 3). The lowest growth rate was recorded in sheet-lines (0.43 % day^{-1}, p < 0.001) while the highest DGR was observed in net-lines (0.97 % day^{-1}, p < 0.01). All three treatments elicited the same pattern of growth response of thalli

(Table 3); growth has been faster up to day 15, but slower between day 16 and day 30. Significant differences in growth rate were found among treatments in both periods (Table 3).

Table 2: One-way ANOVA results testing the influence of line type (sheet, net and rope lines) on the length growth rate (% day^{-1}) and weight growth rate (% day^{-1}) of *Gracilaria gracilis* in off-bottom cultures.

Source of variation	d.f.	S.S.	M.S.	F	P value*
Length					
Line type	2	91,900	45,950	26.35	1.6e-10***
Residuals	147	256,250	1,743.19		
Weight					
Line type	2	5,633.3	2,816.6	126.6	1.0e-32***
Residuals	147	3,270.0	22.24		

$p < 0.05$* $p < 0.01$** $p < 0.001$***

Table 3. Growth rates (% day^{-1}) of length and weight of *Gracilaria gracilis* in off-bottom cultures using sheet, net and rope lines. Different letters significant differences between groups ($p < 0.05$).

	Fixed off-bottom cultures		
	Sheet-lines	Net-lines	Rope-lines
23 December 2016 - 08 January 2017			
Mean Length	3.84[b]	4.33[a]	4.30[a]
SD	0.65	1.14	0.92
Mean Weight	0.51[c]	1.10[a]	0.75[b]
SD	0.24	0.21	0.27
23 December 2016 - 23 January 2017			
Mean Length	1.91[b]	2.72[a]	2.77[a]
SD	0.38	0.42	0.40
Mean Weight	0.43[c]	0.97[a]	0.71[b]
SD	0.15	0.14	0.11

3.2. Shipworms damage

The shipworms caused serious damage to wooden poles used in off-bottom cultures, stacked since October 2016 into the substratum (Figure 4). About 30% of poles were destroyed by these molluscans which are notorious for boring into wood that is immersed in sea water. The destructive ability of shipworms is illustrated in Figure 3. They drilled passages or tunnels which they rasped their way through (Figure 3).

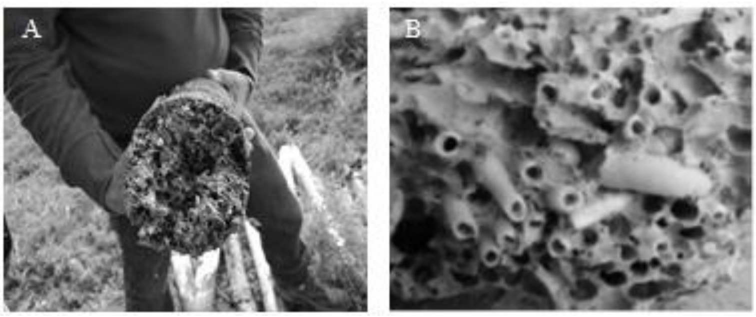

Figure 4: Damage caused by shipworms at wooden poles used in fixed off-bottom cultures of *Gracilaria gracilis* (A) and tunnels occupied by calcareous tubes of shipworms (B).

3.3.Infestation by parasitic epiphytes

Algal epiphytism was the major problem during this study, especially in off-bottom cultures tested in winter when infestations by green algae occurred. The most common epiphytes were *Chaetomorpha aerea* and *Ulva lactuca*. The green algae *Ulva intestinalis* appeared in minor quantities. Heavy loads of epiphytes were observed, particularly on sheet lines. During spring, plants of *G. gracilis* cultivated in a floating longline were free of epiphytes and healthy.

3.4.Floating longline cultures

A two-way ANOVA showed that stocking density significantly affected biomass ($p < 0.001$), and growth rate ($p < 0.001$), but there was no significant difference ($p > 0.05$) between Treatments 1 and 3 (Tables 3 and 4). Maximal growth rate was 4.26 % day^{-1} for the 0.6 kg m^{-2} stocking density; it declined, with stocking density, to only 2.77% day^{-1} at the 0.8 kg m^{-2} density. The lowest growth rates varied not significantly between 2.54 and 2.77 % day^{-1} in T1 and T3 respectively. Changes in biomass production under three experimental treatments are shown in Table 4. Seaweed biomass increased with time. Indeed, biomass increases in the 0.4, 0.6 and 0.8 kg m^{-2} stocking densities represented increases of 214%, 580% and 76% of initial weights, respectively (Table 5). At the end of the experiment, the highest production reached 3,402.2 g m^{-1} (initial biomass 500.0 g m^{-1}) was observed in Treatment 2 with 0.6 kg m^{-2} stocking density. Thalli of *Gracilaria gracilis* has low weight gain in treatments T1 and T3, reaching 1,570.0 and 1,738.0 g m^{-1} respectively with no significant differences among them ($p < 0.05$).

Table 4. One-way ANOVA results testing the influence of stocking density (0.4, 0.6 and 0.8 kg.m^{-2}) on the final biomass (g m^{-1}) and weight growth rate (% day^{-1}) of *Gracilaria gracilis* in floating longline cultures.

Source of variation	d.f.	S.S.	M.S.	F	*P value**
Final biomass					
Stocking density	2	4,549,066.3	2,274,533.1	44.78	6.4e-16***
Residuals	147	7,465,468.5	5,078.5		
Stocking density	2	89.22	44.61	503.0	1.8e-66***
Residuals	147	13.03	0.08		

p < 0.05* *p* < 0.01** *p* < 0.001***

4.DISCUSSION

4.1.Fixed off-bottom cultures

The weight gains of *Gracilaria gracilis* in off-bottom cultures tested in winter, were low. Seaweed growth rate and yield depend on species, the site of cultivation, the season and the cultivation methodology (Titlyanov and Titlyanova, 2010). Water temperature is one of the important factors determining the production of *Gracilaria sp.* Plants of *G. gracilis* did not grew well, because the experimental period had unfavourable temperature range (15.3-16.8°C). Most species in *Gracilaria* grow well when the temperature is 20 °C or higher (Raikar et al. 2001a) while the optimum growth rate of *G. gracilis* was reached at 18°C at Tosa Bay, southern Japan (Rebello et al. 1996).

The off-bottom line method tested in this study is commonly used in *Gracilaria* farming (Rejeki et al., 2018). This is due to lower cost of materials, labour and maintenance compared to the net, raft and floating longline methods (Castaños and Buendia, 1998). However, the shipworms caused serious damage to wooden poles used in the experimental cultivations.

Ever since marine wood borers became a problem to wooden marine installations, there has been a worldwide search for timber naturally impervious to both teredinid and limnorid wood borers under all conditions of temperature and salinity (Quayle, 1992). There is wide variation in susceptibility to attack based partly on wood hardness, content of chemicals such as resin, silicate, and alkaloids (Quayle, 1992). However, woods must be treated with natural products to prevent environmental and health risks. The naturally durable, untreated wood such as redwood cannot be used in off-bottom cultures at Nador lagoon because of its high cost. Given damages caused by shipworms to wooden poles, the experimental cultivations of *Gracilaria* were shifted to the floating longline method by using steel piles for anchoring.

The another serious problem for the off-bottom cultures tested in winter at Nador lagoon was the colonization by the parasitic algae (*Chaetomorpha aerea* and *Ulva lactuca*). Epiphytes can reduce productivity of the farm directly by shading the seaweed and consequently reducing its growth or indirectly by sinking culture lines (Drummond, 2017). Moreover, epiphytes can turn on seedlings causing damage to thalli and reducing production (Hurtado et al., 2008). Buschmann et al. (1994a) also reported that winter favoured epiphytes, which decreased with the approach of spring and renewed growth of *Gracilaria.* Therefore, information on biofouling in commercial cultivation is essential to better management practices to avoid reductions in productivity. Emergence of an epiphytic outbreak is a complex problem, and the extent of the outbreak often depends on the quality of the cultivated strain, abiotic parameters of the culture site, and seasonal weather fluctuations (Borlongan et al., 2011). There are several methods available for minimizing fouling. Indeed, depth can be adjusted to reduce settlement or survival of fouling organisms (Kim et al., 2017). Increasing stocking density will allow the thalli to outcompete the parasitic algae (Carney and Lane, 2014). Timing the seeding of the lines and harvest of the crops can be efficient for avoiding fouling settlement (Kim et al., 2017).

4.2.Floating longline cultures

Plants of *G. gracilis* grew well in floating longline culture tested in spring because the temperatures were ranged between 20.2 and 23.1°C. *Gracilaria sp* has an optimal range of 20-28°C (Kim et al., 2016). The growth rates achieved in Nador lagoon were almost similar to those obtained in experimental cultivation in Namibia where the daily growth rate ranged between 3.2 to 4.5% (Dawes, 1995). Salinity was ranged between 36.6 and 38.1 ‰ during the experimental period (17 April – 31 May 2017). *Gracilaria sp* are euryhaline species, which can tolerate a wide range of salinities, from about 10-40 ‰ (Kim et al., 2017).

The results indicated that the initial stocking density is an important factor in determining the production obtained (Table 5). The highest growth rate in Nador lagoon was observed in treatment stocked with 0.6 kg m^{-2}. The high stocking density (0.8 kg m^{-2}) leaded to low growth most probably due to stress on the seaweed when competing for space and resources. Generally, the lower stocking densities would result in higher growth rates of the seaweeds (Msuya, 2013). However, the lowest initial density (0.4 kg m^{-2}) tested in this study leaded on the contrary to low growth. The macroscopic diagnosis of the thalli revealed the presence of isopods (*Idotea baltica*). The major problems of economically effective seaweed farming are: reduction of fouling alga and epiphyte growth, control of grazing animals, and a low level of planting stock (Titlyanov and Titlyanova, 2010). The role of the floating system is to maintain the culture lines at a level sufficiently high to prevent colonization by fouling and ensure the stability of the longlines in order to allow routine activities to be carried out smoothly. The first-order effect of grazing is to decrease biomass of a preferred seaweed species (Hauxwell et al., 1998). Nevertheless, we did not find any evidence to explain why isopods did not graze the thalli of *G. gracilis* in the other treatments initially stocked with 0.6 and 0.8 kg m^{-2}.

Table 5. Growth of *Gracilaria gracilis* cultivated under different stocking densities (T_1: 0.4 kg.m^{-2}, T_2: 0.6 kg.m^{-2} and T_3: 0.8 kg.m^{-2}) in floating longline cultures. Different letters significant differences between groups ($p < 0.05$).

Treatments	Initial biomass (g m^{1})	Final biomass (g m^{1})	Period of growth (days)	Increase times	Growth rate (% day^{-1})
T_1	500.0 ± 0.0	1,570.0^{b} ± 378.5	45	3.14	2.54^{b} ± 0.54
T_2	500.0 ± 0.0	3,402.2^{a} ± 394.2	45	6.80	4.26^{a} ± 0.27
T_3	500.0 ± 0.0	1,738.0^{b} ± 203.1	45	3.47	2.77^{b} ± 0.26

4.3.Seaweed farming a potent solution against eutrophication

The *G. gracilis* grew well in the eutrophic waters of Nador lagoon by using the floating longline method. The seaweeds are able to absorb large quantities of N and P, and produce large amounts of O_2, and, consequently, reduce eutrophication (Xiao et al., 2017).

Xiao et al., (2017) estimated that one hectare of seaweed aquaculture removes the equivalent nutrient inputs entering 17.8 ha for nitrogen and 126.7 ha for phosphorus of Chinese coastal waters, respectively. They also reported that the magnitude of nutrient removal by seaweed aquaculture is dependent on the yield and the nutrient concentration in the seaweed tissues, which depends, in turn, on the species composition (Xiao et al., 2017). Given the high capacity of seaweeds in bioextraction of nutrients, it is essential that other fishermen in Nador lagoon turn toward seaweed farming. The role of seaweeds in mitigating eutrophication may be significant with a future growth of seaweed aquaculture in Nador lagoon.

4.4.Income diversification by seaweed production

The results show that *G. gracilis* can be grown in Nador lagoon to produce a reasonable harvest weight over a 45-day cycle in floating longline cultures. When *Gracilaria* biomass is high enough, the seaweed to attach the rope can be harvested easily. The outer portion of fronds can be cut and leaving fronds to provide continuous cultivation. About 5,320 kg of seedlings will be needed during each cycle by using the cultivation parameters detailed in Table 6. Over a 60-day cycle, the harvest of *G. gracilis* cultivated on floating longline system in Nador lagoon was estimated at about 101 t FWT ha^{-1} year^{-1}. *Gracilaria* in the tropics and subtropics grows on ropes in Sri Lanka for about two months, constitutes only 35 t (FW: fresh weight) ha$^{–1}$ year$^{–1}$ (in Sri Lanka) (Santelices and Fonck, 1979). In brackish water estuaries in southern Chile, the harvest of *Gracilaria* cultivated on ropes constitutes, however, about 100 t (FW) ha$^{–1}$ per season (Westermeier et al., 1993). In Morocco, the price of seaweeds at farm level is determined by the exclusive buying company (SETEXAM), which in turn depends on prices determined in international markets, their costs and profit margins. In 2017, the price per tonne was $ 520 (Table 6). In terms of local currency, this was equivalent to 5 DH per kg. However, the farmers complained that local market prices were depressed compared with the volume of work required in seaweed production.

Table 6. Cultivation parameters and return analysis for a 1 ha seaweed (*Gracilaria gracilis*) farming using the floating longline method

Cultivation parameters		Return per cropping	
Length of line (m)	100	Initial weight of seedlings (fresh weight in kg)	5,320
Number of monoline	133	Average growth rate (% day^{-1})	3
Number of plants per line	400	Final weight (fresh weight in kg)	32,184
Initial weight per plant (g)	100	Biological loss in kg (5%)	1,609
Distance between tie per plant (m)	0.25	Seedling for next cropping (fresh weight in kg)	5,320
Distance between lines (m)	0.75	Net fresh weight for drying (in kg)	25,255
Culture period (days)	60	Wet to dry ratio	8 : 1
Number of cropping per year	4	Production yield (dried in kg)	3,156
		Price per kilo ($)	0.52
		Total sale ($)	1,641
		Return per year	
		Total sales ($)	6,564

The operating and maintenance expenses were supported by the external donors. Farming materials such as plastic netting, buoys and steel piles for anchoring were provided free of charge to the farmers. The seaweed farming project developed in Nador lagoon is recognized as an 'interventionist' system, in which external donors support the promotion of small-scale subsistence aquaculture systems to alleviate poverty. Reducing the vulnerability of fishers to income volatility is their first priority. It is also well-known that fisher's cooperatives had also multiple benefits, including marketing, access to microloans, and providing a channel for communicating with the authorities (Chuenpagdee, 2011). After harvesting, seaweed was dried in the sun and packed in sacks before being sold. With 8:1 as wet to dry ratio, the production yield per cropping was estimated at 3,156 kg (DW) per ha (Table 6). However, the total sales per year was estimated at about $ 6,564 per ha.

CONCLUSION AND RECOMMENDATIONS

In conclusion, this study demonstrated that the cultivation of *G. gracilis* in floating longline system is a technically viable method, which obtains reasonably good growth and productivity. Suspended cultivation of *Gracilaria* has potential in bioremediation, where the seaweed can be used to absorb some of the excess nutrients discharged from other human activities into the eutrophic waters of Nador lagoon. Moreover, *Gracilaria* cultivation is a promising approach for sustainable resource cycling in a future regenerative economy. Seaweed farming may provide supplementary income to artisanal farmers. The small-scale fishers in Nador lagoon should therefore be encouraged to create new cooperatives, and the cooperative which already exist should be also strengthened. The seaweed farming was met by such a high degree of enthusiasm by the fishers in Nador lagoon. The likely role of cooperatives in promoting education and literacy, access to scientific information and research institutions on fisheries, and helping enforce regulations will also be emphasized.

CONFLICT OF INTERESTS

The authors declare no conflict of interests.

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