International Journal of Sciences

Research Article Volume 3 - January 2014 (1)

Study of the Red Algae Growth Gelidium Sesquipedale Turner) Thuret (Rhodophyceae, Gelidiales) of Moroccan Atlantic Coast

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Summary: The red algae *Gelidium sesquipedale* is the main source of agar; 44% of world production. This natural resource is subject to intensive exploitation and has significant signs of deterioration. To enable the local industry to continue its development, it was necessary to find new sources of raw material. In this regard, we conducted this study to show the best time of collection of this species. The pursuit of growth parameters (the length of the thallus, the mass of the fronds and the total number of branches) of *Gelidium sesquipedale* in the three stations (Lahdida (North of Azemmour), Moulay Abdellah and Sidi Abed) in the Moroccan Atlantic coast has identified the best period for collection from July to September each year.

Keywords: red algae, *Gelidium sesquipedale*, production, resource, collection, agar, growth

I. Introduction

The interest in marine plants and in particular seaweed is rising steadily around the world and for different reasons, including their wealth protein, carbohydrates, fats, minerals, etc. This is why these plants are used in several areas such as agriculture, food and feed, agro- industries food, thalasso-therapy, in cosmetics, medicine, pharmacy, etc.

Algae belonging to the genus *Gelidium* constitute the main raw material for the preparation of the agar or agar-agar; 44% of world production after *Gracilaria* which contribute 53% of world production (Marinho-Soriano E. and Bourret E., 2003). In this context, different species of *Gelidium* such as *G. sesquipedale* (in the Iberian Peninsula and Morocco), *G. pristoides* in South Africa, *G. robustum* in Mexico, *G. amansii* in Japan, and other species living in Chile are subject of natural collections and some cultivation trials at sea, such as in Spain, the tonnages collected are very different depending on the country (Melo R., 1998).

Morocco is the second largest producer of Agar. This phycocolloïd is used for its gelling properties both in the industry food and in pharmaceutical or in biotechnology. In Morocco, it is extracted almost exclusively from *Gelidium sesquipedale* (Turner) Thuret (Rhodophyceae, Gelidiale). This seaweed is collected by diving on natural deposits. This natural resource is subject to intensive exploitation and significant signs of degradation (Givernaud Th. and al., 2003), (Givernaud Th. and al., 2005) and (Perez R., 1997). To enable the local industry to continue its development, it was necessary to find new sources of raw material supply. The biology of this species and changes in the chemical composition of thalli was followed in natural environment (Givernaud Th. and al., 1999) and (El Gourji A. 1999). This study has allowed to determine the best harvest period. So, we will achieve a study of the evolution of the growth parameters of *Gelidium sesquipedale* in the three stations (Lahdida (North of Azemmour), Moulay Abdellah and Sidi Abed) in the Moroccan Atlantic coast.

II. Materials and methods

II.1. Collection stations

The study area is located along the Moroccan Atlantic coast, it is located between the coordinates 33 ° 25' N and 32 ° 50' S. We selected three stations in this part of research: Lahdida North of Azemmour, Moulay Abdellah and Sidi Abed (Figure 1).

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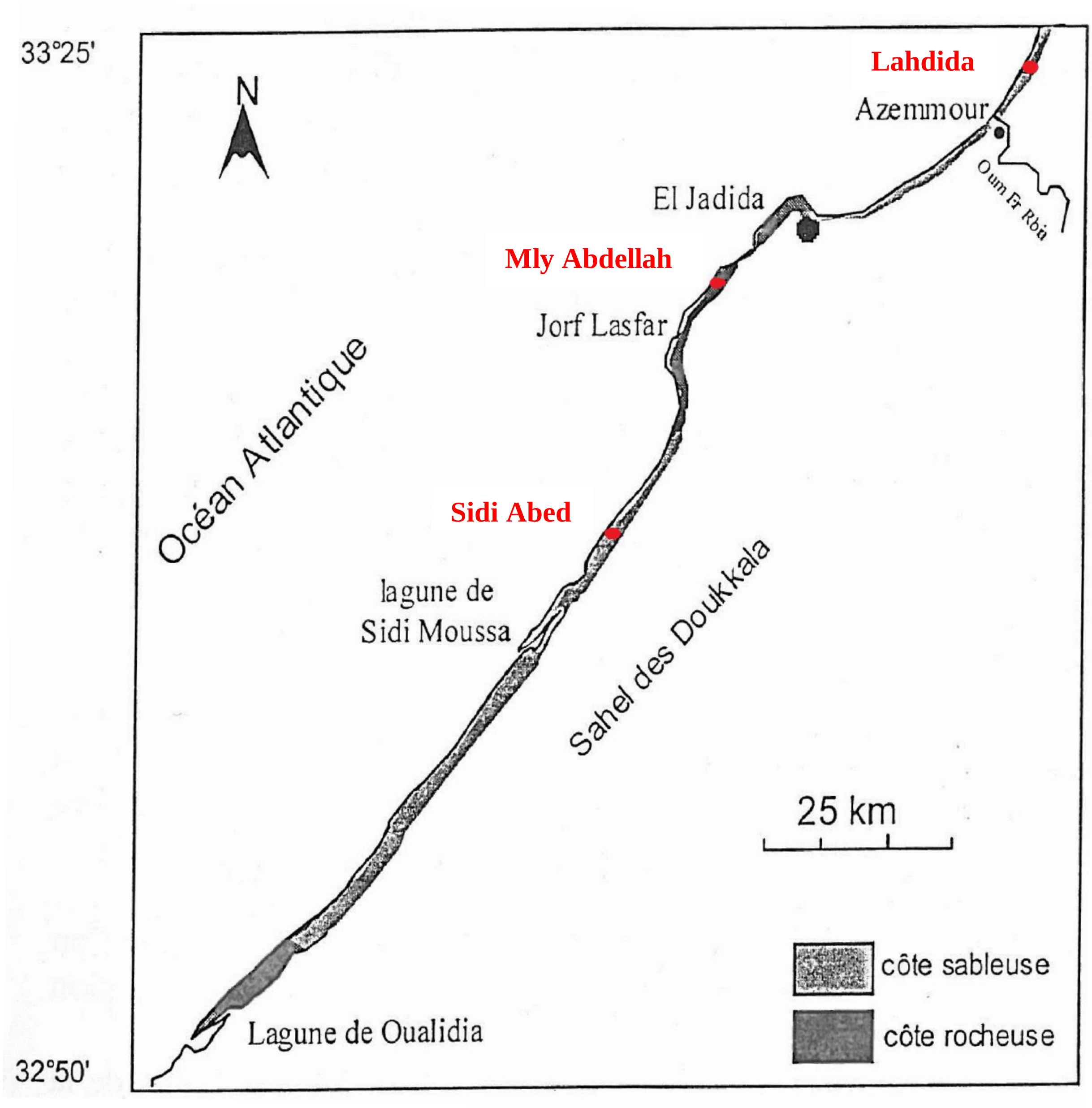


Figure 1: Geographical aspects of the three study sites.

We chose these three stations among others for the following reasons:

- The number of stations was limited to three for reasons of difficulties of sampling.
- Stations were too separated to cover the entire coastline Doukkala-Abda.
- The Lahdida Station was chosen to evaluate the effect of silting caused by the mouth of Om Er Rbie River.
- The Mly Abdellah Station was chosen to evaluate the effect of pollution by discharges of the Jorf Lasfar phosphate complex and the effect of overexploitation.
- The Sidi Abed Station was chosen as reference station by its distance from the pollution source and algae raising activities intensively.

II.2. Materials used

The species of red algae concerned by biological study is *Gelidium sesquipedale*. The thallus of this agarophyte is red to red-brown has a rugged look and a cartilaginous consistency. It consists of fronds erect, grouped in clumps of variable size from 10 to 40 cm, rising from crawling filaments (stolons or rhizoids) which ensure fixing to the substrate of the algae. The frond is made of a set of principal axes of unlimited growth holders of limited lateral growth ramifications, giving to the thallus a pyramidal shape. This species forms dense stands on all rocky wrought fashion from the low-water level of bright waters to a depth of 20 m (Goff L. J and al., 1994) and (Kabbaj I., 1994).

II.3. Methods

The harvest of *Gelidium sesquipedale* was conducted monthly in three geographically separated stations: Lahdida (North of Azemmour), Moulay Abdellah and Sidi Abed. The measurement of parameters considered in the evolution of the biology of this species was made on 100 thallus collected at random from natural deposits, and is:

- The length of the thallus (L in cm), it was determined by measuring the length of the frond.
- The mass of the frond (P in g) was determined by weighing each frond using a balance with a precision milligram.
- The total number of branches (RT) is counted for each frond.

III. Results

III.1. Growth analysis of *Gelidium sesquipedale*

III.1.1. Qualitative analysis of growth

Knowing that the samples collected in the lower shore show no great variation, which explains the decrease of total ramification number and the size of the fronds which vary only slowly during the study period. We will focus on the samples obtained by underwater diving of the subtidal part. Seeing that our study, for the evaluation of the monthly change in the growth of *Gelidium sesquipedale* fronds, started from June 2012, so we begin our descriptions from this month.

- **June-July 2012:** From the start of June, the apical growth of axes is very important and gives axes increasingly thin and clear.
- **August-September 2012:** Fronds size is maximal; the color is variable depending on exposure. The reproductive organs begin to develop. The species is characterized by a hail and branched form. In September, the size and the total number of branches of the thalli are highest.
- **October-December 2012:** During this period, the axis endpoints are slightly colored, particularly in the month of October, new thalli from the detached fragments of old fronds and which are refixed appear. The regenerative power reaches its maximum during this period.
- **January-February 2013:** The fronds grow longer, the ends of the axes begin to flatten, and have blanks ramifications with unlimited growth. In February, the two lobes are well developed. At this period, destructions occurring at the frond axes are observed frequently. From place to place on the frond, depigmentations and necrosis appear. It seems that these thalli disorganized are fragmenting easily when the sea is rough.
- **March-April 2013:** The ramifications flatten and reach a maximum width. The ends are rounded. The thalli are dark red.
- **May 2013**: From the start of this month, the apical growth of the axes is changed. It is maximal and gives cylindrical axes increasingly thin and clear. The ends become pointed.

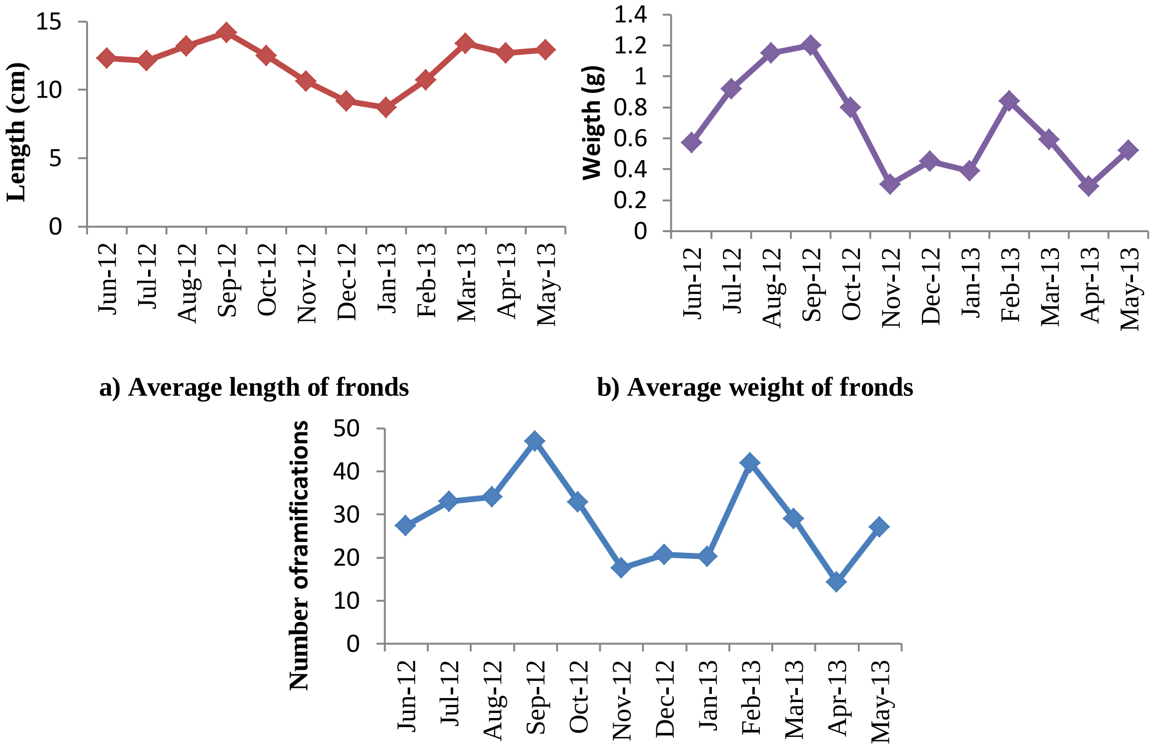
According to the work carried out by (Mouradi A., and al., 2007), seasonal variations in *G. sesquipedale* are not very marked. However, the appearance of the apex of the axes changes with the seasons indicating a significant change in the apical growth:

-In winter, the apical axis endpoints are, for the majority of thalli, broad and rounded. The two lobes are well developed. The first branches appear near the apex of the axis that gave them birth. The branches are wide at their insertion point on the axis which carries them.

-In summer, the apical axis endpoints are for the most thin and slender. In this case, the two lobes are less developed. The first branches appear further away from the apex of the axis that gave them birth. The ramifications have a slight constriction at their base; they appear to develop in a plane slightly inclined relative to the plane of flattening of the main axis.

III.1.2. Quantitative analysis of growth

III.1.2.1. In Moulay Abdellah station



a) Average length of fronds **b) Average weight of fronds**

c) Average number of branches

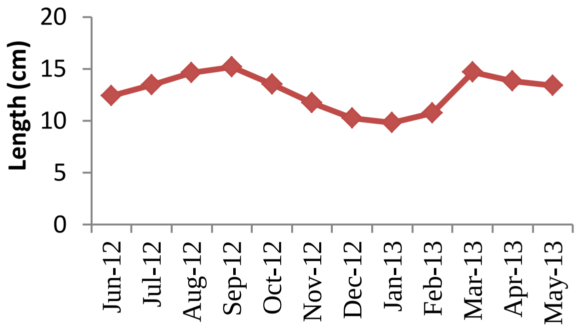
Figure 3: Seasonal variation in the average length, the average weight of thalli and the average in total number of branches of *G. sesquipedale* harvested at Moulay Abdellah during an annual cycle.

-Average length of fronds: The average length of fronds (Figure 3a) decreases from June to July 2012 then increases again to reach its maximum in September (14.2 cm). Then it notes a reduction in the length of the fronds in winter to reach a minimum in January 2013 (8.7 cm). A second peak of growth in length was observed in March 2013 (13.4 cm).

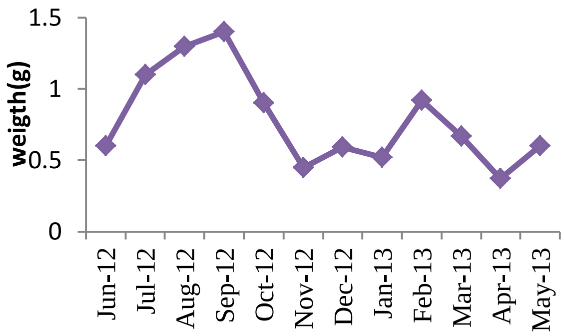
- Average weight of fronds: The average weight of fronds is defined as the fresh weights of individual frond. The evolution curve of average weight (Figure 3b) according to the seasons shows an increase in weight from June to the maximum values in September 2012 (1.2 g), then brutally decreases to the minimum value of 0.3 g noted in November. Then, an increase in the average weight of thalli until reaching a second peak (0.84 g) in February 2013. Then decreases until April and increases in May 2013.

- Analysis of the average number of branches: The total number of branching fronds of *G. sesquipedale* increased significantly from May to September, with a maximum of 47 branches per thallus in September 2012 (Figure 3c). A decrease in the total number of branches is recorded in September to November and January; 20 branches per individual are recorded in the month of January 2013. A further increase is noted in February 2013. Then a decrease in the total number of branching frond is noticed in April 2013. The formation of new secondary axes resumes from these dates.

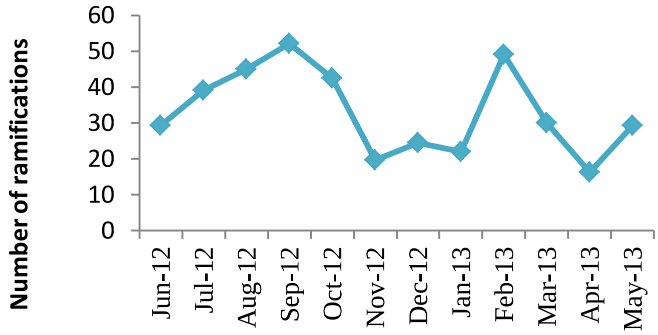
III.1.2.2. In Lahdida station



a) Average length of fronds



b) Average weight of fronds



c) Average number of branches

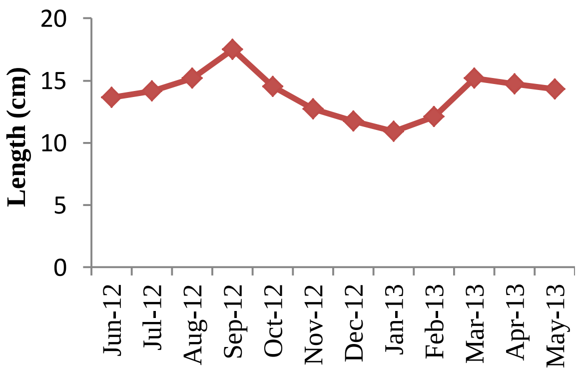
Figure 4: Seasonal variation in the average length, the average weight of thalli and the average in total number of branches of *G. sesquipedale* harvested at Lahdida during an annual cycle.

-Average length of fronds: The average length of fronds (Figure 4a) gradually increases between June and September, with a maximum of 15.2 cm in September, and decreases in October to its lowest in January 2013 (9.8 cm). Then growth resumes from January to March to reach a second maximum of 14.7 cm in March. Thereafter, the growth in length decreases to a minimum in December about 7 cm.

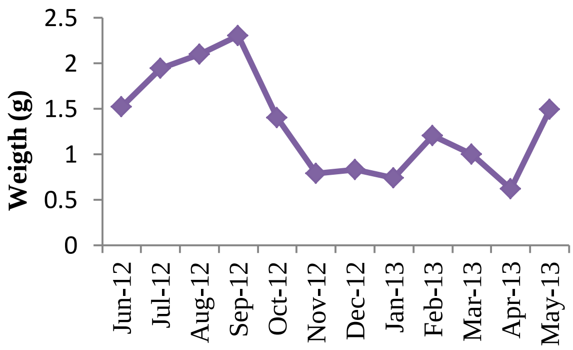
-Average weight of fronds: The curve of the average weight of thalli (Figure 4b) has a maximum value reached in September 2012 (1.4 g) and a second noticed in February 2013 (0.92 g).

-Analysis of the average number of branches: The evolution of the total number of individual branches (Figure 4c) showed a maximum average number was reached in September 2012 (52 branches per individual), and a second peak was recognized in February 2013 (49 branches per individual).

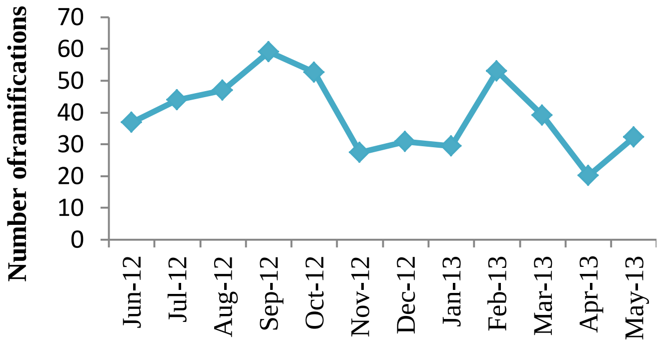
III.1.2.3. In Sidi Abed station



a) Average length of fronds



b) Average weight of fronds



c) Average number of branches

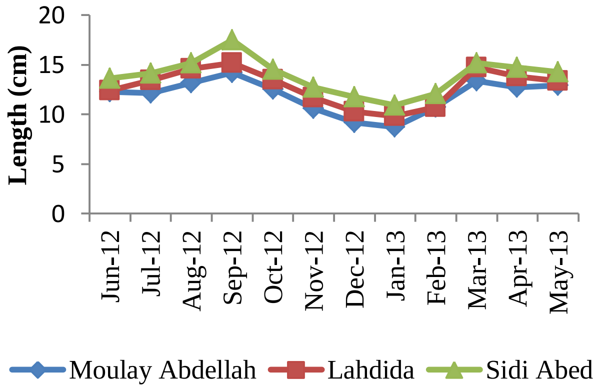
Figure 4: Seasonal variation in the average length, the average weight of thalli and the average in total number of branches of *G. sesquipedale* harvested at Sidi Abed during an annual cycle.

-Average length of fronds: The average length of fronds of *G. sesquipedale* (Figure 5a) increases from June 2012 to September when it reaches the maximum size in September (17.5 cm), then it decreases to a minimum value in January 2013 (10.9 cm). It is noted, a re-increase of the length of fronds to achieve a second peak in March 2013 lower than in September 2012 (15.2 cm). A decrease is noticed from March to May 2013.

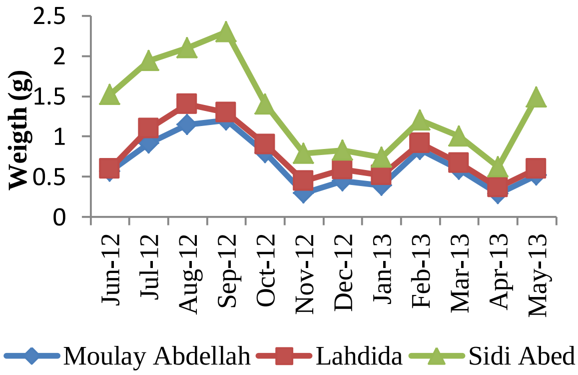
-Average weight of fronds: The evolution curve of the average weight of the frond according to the seasons (figure 5b) showed an evolution from June 2012 until reaching a maximum value in September 2012 (2.3 g), then decreases to a minimum value in January 2013 (0.74 g). Then a slight increase in February 2013 (1.2 g) is noted. Then decreased until April 2013 (0.62 g) and increases again in May 2013.

-Analysis of the average number of branches: Starting from June 2012 (Figure 5c), there is an increase in the average total number of branches until reaching a maximum in September 2012 (59 branches per individual), then decreases until November 2012 (27 branches per individual). Then, it increases to a second peak in February 2013 (53 branches per individual), then decreases to a minimum value in April 2013(20 branches per individual) and increases slightly in May 2013.

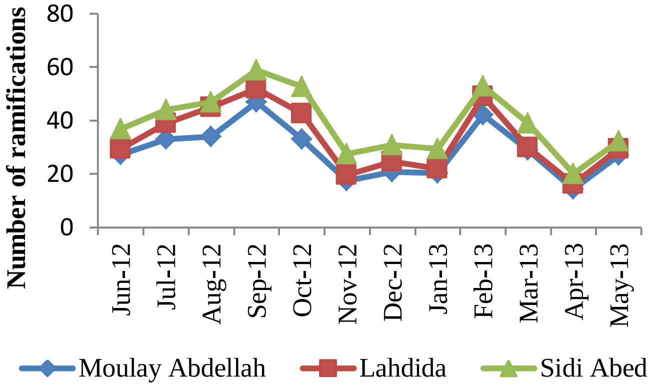
III.1.2.4. Comparisons between the three stations



a) Average length of fronds



b) Average weight of fronds



c) Average number of branches

Figure 4: Seasonal variation in the average length, the average weight of thalli and the average in total number of branches of *G. sesquipedale* harvested at Sidi Abed during an annual cycle.

-Average length of fronds: The evolution curves of the fronds length (Figure 6a) according to the season in three study sites look the same evolution. The maximum lengths are noted in September 2012 in the three stations (Moulay Abdellah, Lahdida and Sidi Abed) followed by a decrease until January 2013, then a slight increase until March followed by a decrease in May 2013. We also note that the variation of the monthly growth of the frond length is influenced by the study site; where the values of the length growth are recorded in Moulay Abdellah, followed by Lahdida and Sidi Abed.

-Average weight of fronds: The evolution of the average weight of the fronds of *G. sesquipedale* (Figure 6b) shows the same appearance in the three stations. Thalli reach a maximum weight in September 2012 then decreases to a minimum value in November, then slightly increases and decreases in April 2013 and increased again in May 2013. The recognized difference between stations is linked to the growth rate between the three stations; Sidi Abed station characterized by a very high rate of growth in weight compared to the two other stations.

-Analysis of the average number of branches: Regarding the seasonal variation of the average total number of branches (Figure 6c), there is also the same appearance of evolution recognized in the three study sites. Always the Sidi Abed station is the most important of viewpoint growth in total number of branches of *G. sesquipedale* compared to the other stations.

IV. Discussion

The monitoring of the evolution of the growth parameters of *G. sesquipedale* has demonstrated the heterogeneity of the populations of this algae even in less exploited areas (North of Azemmour) and distinguish periods of growth and regeneration in the thalli development.

Thus, from April to September growth is active; the weight gain is first due to the increase of the total number of branching and also to the frond elongation. From September seaweed is degraded of its fronds suite, either to the liberation of reproductive cells or to the natural fronds fragmentation by waves. Indeed, during this period, the number of fronds harvested with grounding is important. The same result was reported by (Kaas R. and Barabaroux O., 1998) in *G. sesquipedale* populations in south of France, and by (Mouradi A., and al., 2007) in the Mehdia site. The period from September to January is a phase of fronds aging which ends in January with a deterioration of the fronds ends. From January to April, corresponds to the period of rapid regeneration of *G. sesquipedal* (Mouradi A., et al., 2007).

The monitoring of seasonal changes in morphology showed that *G. sesquipedale*, harvested in the subtidal part, did not significantly change during the year, the thalli are always pyramidal with an apical dominance, as has been shown by (Seoane-Camba J. A., 1969) and (Mouradi A., and al., 2007).

The comparison of the evolution of the three parameters of growth of red algae *G. sesquipedale* shows a significant difference; where we note that the Sidi Abed station recognized a very important development of biological parameters (thallus length, weight and total number of branches) compared to other stations. This result seems to be related to the remoteness of the site of the pollution sources and of human exploitation. The Lahdida station in the North of Azemmour is characterized by biological parameters well advanced; but less than Sidi Abed station because of a siltation in the site recognized by the profligate Om Er rbie which covers the substrate while avoiding hooking algal fragments during regeneration and also gene to the natural increased of biological parameters of *G. sesquipedale*. However, this site is still a very rich site with algal biomass because it is less exploited and away from intense human activities. Moulay Abdellah station is the most affected by the pollution of the Jorf Lasfar phosphate complex and also by human exploitation during the collection of seaweed. It's also recognized the substitution phenomenon of *G.sesquipedale* by *Halopithys incurvus* because poaching and failure to respect for the biological period of the species studied.

The slow growth of *G.sesquipedale* biological parameters is related to intrinsic factors rather than a trait which can be changed by external factors (Mouradi A., 1992) and (Luning K., 1990). Light acts particular on polarity, differentiation of reproductive organs and on photoreceptors (Santelices B., 1988). The temperature is considered the main factor controlling the geographical distribution of algae (Seoane-Camba J. A., 1969), and the dominant factor in seasonal phenomena of growth and reproduction (Barilotti DC and Silverhorne W., 1972) (DeBoer JA, 1981). Phosphorus, especially nitrogen; are normally present in sea water at such low concentrations that they sometimes become limiting nutrient factors (Lobban C. S., Harrison P. J., 1994) and (Seoane-Comba J. A., 1966). If the action of these factors is generally known, each species responds differently to changes in these factors and each species has a typical development cycle (Mouradi A. and al., 2007).

The study conducted by Mouradi and al., (2006) did not notice a large morphological variation of this species collected at the infralittoral. However the works of Givernaud et al. (2003) have shown that external factors may change the morphology of *G.sesquipedale*; Indeed, the culture of this species without substrate or under heat stress gives frond slightly branched, slender recalling the stolons morphology of the species. In the end of September, the fronds deteriorate following the liberation of reproductive cells or to the natural fragmentation of the fronds by waves. During this period, the number of fronds harvested grounding is very important.

The period corresponding to a weight gain spreads out from May to September and is linked to an increase in length and ramification number. If the period from September to January is a phase of aging fronds which ends in January with a deterioration of the ends of the thalli, spring period corresponds to the periods of high regeneration of *G. sesquipedale*. Fragments, which are detached from the thallus, attach to the substrate and give new growth which form new fronds. This phenomenon of high regeneration ability of the algae has been used by several authors (Silva J. and Santos R., 2003), (Givernaud Th. and al., 2003), (Salinas J. M., 1991) and (Borja A., 1994) to try to cultivate or reseed the fields of *G. sesquipedale*.

Conclusion

At the end of this study, it seems there is a difference between the growth rates of *G. sesquipedale* in the three sites studied. Therefore, these variations are related to adaptations of the species to the influence of environmental factors.

The growth cycle of this species shows that there are two periods of active growth: the first recognized from April to September for the three growth parameters (length, weight, and total number of branches), and the second from January to March for both growth parameters (weight and total number of branches) and from January to February for the length.

The period from April to September acknowledged an active growth; the weight gain is primarily due to the increase of the branching total number and also of the thalli elongation. From September seaweed undergoes degradation of its fronds suite, either the liberation of the reproductive cells or to the natural fragmentation of the fronds by wave.

The period from September to January is a phase of aging fronds which ends in January with a deterioration of the fronds ends. January to March corresponds to the period of rapid regeneration of *G. sesquipedale*. Fragments, which are detached from the thallus attach to the substrate and give new growths which form new fronds.

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